Ministry for the Environment
Manatū Mō Te Taiao

New Zealand's Greenhouse Gas Inventory 1990–2012

New Zealand Government

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Executive summary

Key points

- New Zealand's total greenhouse gas emissions were 76,048 Gg CO_2 equivalent (CO_2-e) in 2012, showing a 2 per cent increase since 2011.
- The Energy and Agriculture sectors are the two largest contributors to New Zealand's emissions profile (approximately 90 per cent of total emissions in 2012).
- Since 1990, New Zealand's total emissions have increased by 25 per cent. The four emission sources that contributed the most to this increase were:
  - carbon dioxide from road transport
  - nitrous oxide from agricultural soils
  - emissions from the consumption of fluorinated compounds (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride)
  - methane emissions from enteric fermentation.
- Emissions from the Industrial Process and Waste sectors and emissions from the road transportation category in the Energy sector showed a slight reduction from 2011.
- New Zealand's net emissions were 49,450 Gg CO_2-e in 2012.
- Due to the contribution of carbon dioxide removals from forests in the LULUCF sector, New Zealand's net emissions are strongly influenced by cycles of harvesting of plantation forests and changes in land use.

ES.1 Background

New Zealand's Greenhouse Gas Inventory (the 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 2012 (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.

For Annex I Parties, 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. 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 elected to 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 emissions from the LULUCF sector. Reporting of total emissions excluding the LULUCF sector is consistent with the reporting requirements of the Climate Change Convention.[1]

1990–2012

In 1990, New Zealand's total greenhouse gas emissions were 60,641.4 Gg carbon dioxide equivalent (CO_2-e). In 2012, total greenhouse gas emissions had increased by 15,406.5 Gg CO_2-e (25.4 per cent) to 76,048.0 Gg CO_2-e (figure ES 2.1.1). From 1990 to 2012, the average annual growth in total emissions was 1.03 per cent per year.

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

2011–2012

Since 2011, New Zealand's total greenhouse gas emissions increased by 1,654.5 Gg CO_2-e (2.2 per cent). The size of the overall increase is small because, although emissions from the Energy and Agriculture sectors rose, there was a decrease in emissions from the Industrial Processes and Waste sectors.

The increase in energy emissions is primarily due to an increase in emissions from electricity generation. This was due to abnormally low hydro inflows in 2012 that led to a decrease in the share of electricity generated from renewable energy sources. A lower contribution from renewable energy in the national grid resulted in a higher proportion of fossil-fuel based electricity generation over the year.

The increase in agricultural emissions is attributable to the favourable weather and good grass growth. There was an increase in the population of dairy cattle and amount of nitrogen fertiliser used in 2012. This increase in dairy and fertiliser emissions outweighed emission reductions from decreases in non-dairy cattle and deer. The increase in dairy cattle numbers and the reduction in non-dairy cattle and deer are primarily due to higher relative returns being achieved

[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 inventories (following incorporation of the provisions of decision 13/CP.9).*

[2] Methane emissions produced by livestock digestive processes.

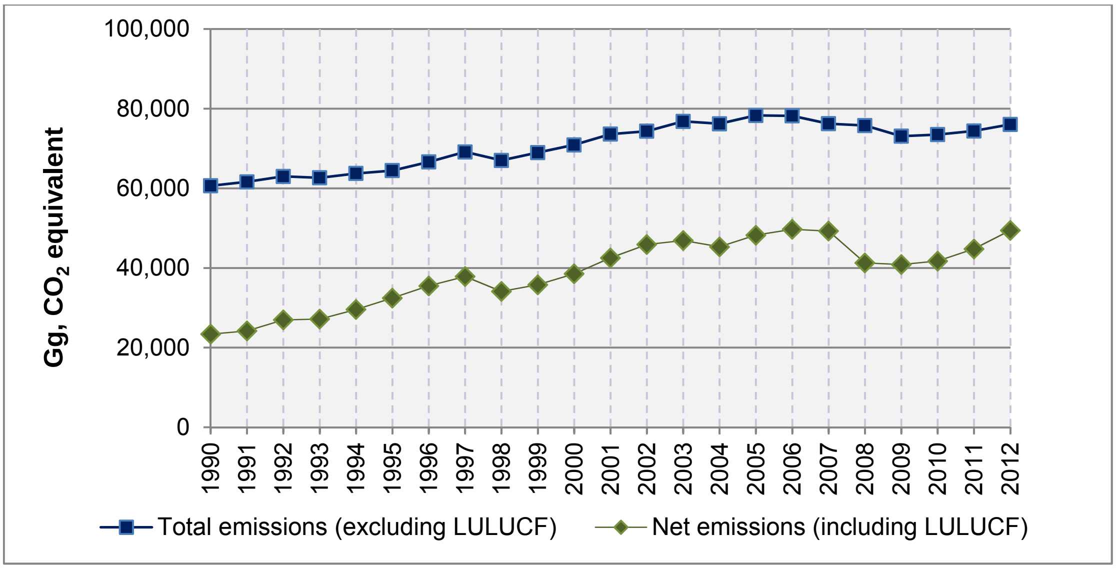
in the dairy sector. The dairy industry is the main user of nitrogen fertiliser in New Zealand, and this increased the sale and use of nitrogen fertiliser.

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 23,391.1 Gg CO_2-e. In 2012, net greenhouse gas emissions had increased by 26,058.6 Gg CO_2-e (111.4 per cent) to 49,449.7 Gg CO_2-e (figure ES 2.1.1).

Figure ES 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2012



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 2.1 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 2012, net removals were 14,968.6 Gg CO_2-e from land subject to afforestation, reforestation and deforestation (see section 2.5 for further detail). The accounting quantity for 2012 was 15,149.5 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.

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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.

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 2012, 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.

Table ES 3.1.1 New Zealand's total (gross) emissions by gas in 1990 and 2012

Direct greenhouse gas emissions	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2012	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
CO_2	24,915.9	34,258.2	+9,342.3	+37.5
CH_4	26,834.7	29,038.5	+2,203.8	+8.2
N_2O	8,245.8	10,885.7	+2,639.9	+32.0
HFCs	NO	1,804.7	+1,804.7	NA
PFCs	629.9	40.8	–589.1	–93.5
SF_6	15.2	20.2	+5.0	+32.8
Total	**60,641.4**	**76,048.0**	**+15,406.5**	**+25.4**

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 1990 (table ES.4.1.1 and figure ES.4.1.1). The proportion of emissions from the Agriculture sector has generally been decreasing between 1990 and 2008. Emissions from agriculture have increased from 2009 to 2012 due to favourable growing weather and a 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 CH_4 and N_2O emissions from the sector.

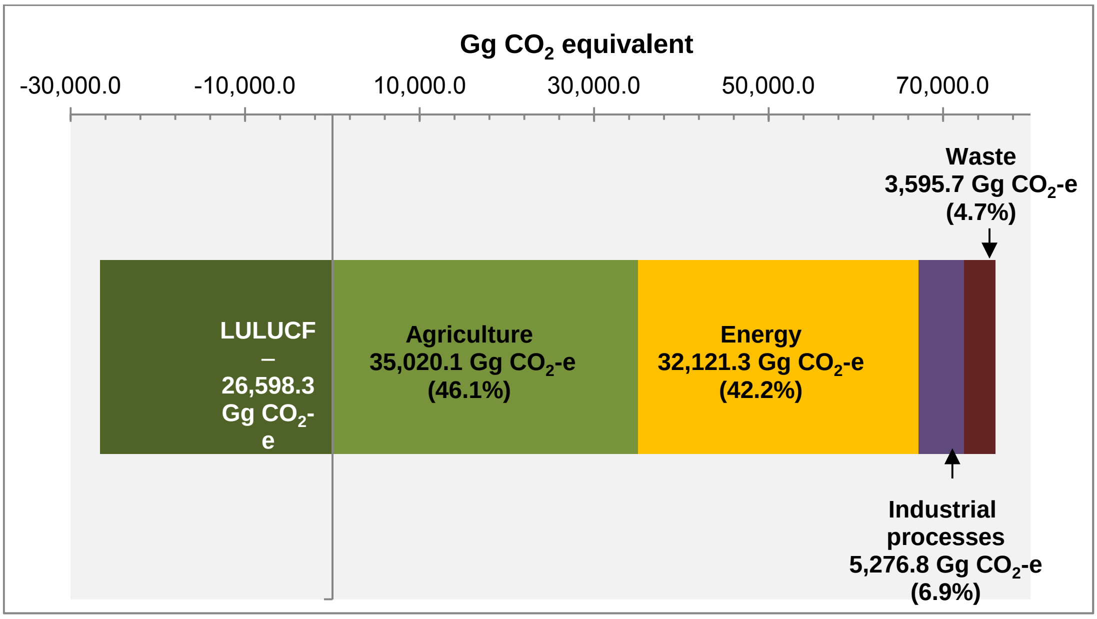
The Energy sector experienced the greatest increase over the period 1990–2008 (figure ES.4.1.2). Energy emissions have increased approximately two-and-a-half times as much as those from the Agriculture sector. The Energy sector had the most influence on the trend in total emissions between 1990 and 2008 becoming the largest contributing sector to total emissions in 2008 (figure ES.4.1.2). In 2009–11 emissions from the Energy sector showed a decrease resulting from the 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. A slight increase of emissions from the sector in 2012 (2.9 per cent) was mostly due to low hydro inflows and a subsequent reduction in the share of electricity production generated from renewable sources in the national energy grid.

Table ES 4.1.1 New Zealand's emissions by sector in 1990 and 2012

Sector	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2012	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
Energy	23,560.4	32,121.3	+8,560.9	+36.3
Industrial processes	3,303.6	5,310.9	+2,014.7	+61.8
Solvent and other product use	41.5	34.1	–7.4	–17.9
Agriculture	30,471.0	35,020.1	+4,549.2	+14.9
Waste	3,303.5	3,595.7	+289.2	+8.8
Total (excluding LULUCF)	**60,641.4**	**76,048.0**	**+15,406.5**	**+25.4**
LULUCF	–37,250.4	–26,598.3	+10,652.0	+28.6
Net total (including LULUCF)	**23,391.1**	**49,449.7**	**+26,058.6**	**+111.4**

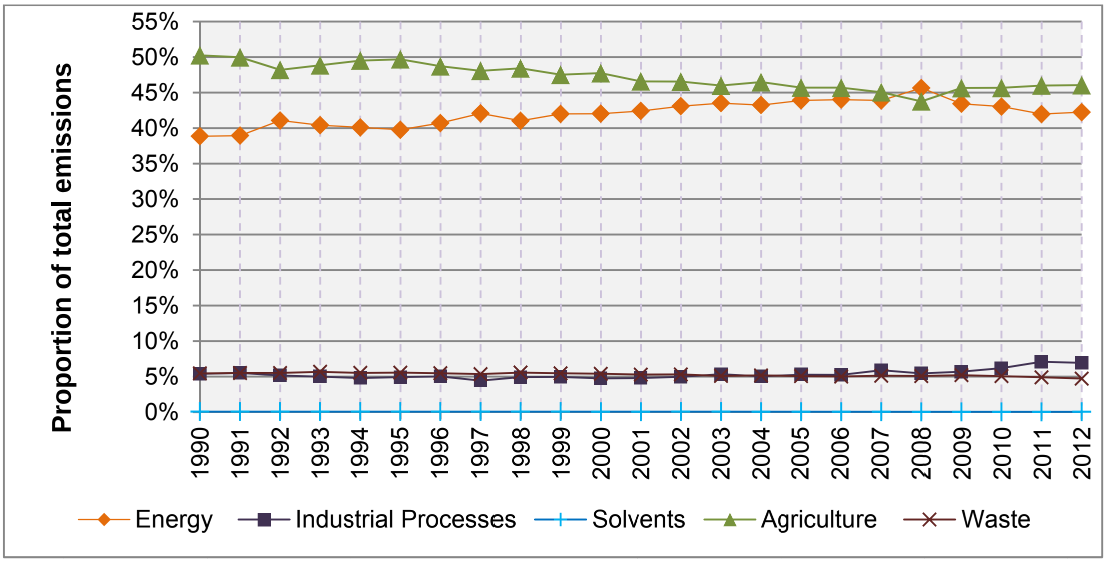
Note: Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Columns may not total due to rounding. In this table Solvent and other product use line is included in Industrial Processes and should not be figured in the total emission value.

Figure ES 4.1.1 New Zealand's emissions by sector in 2012



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 2012



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 2012

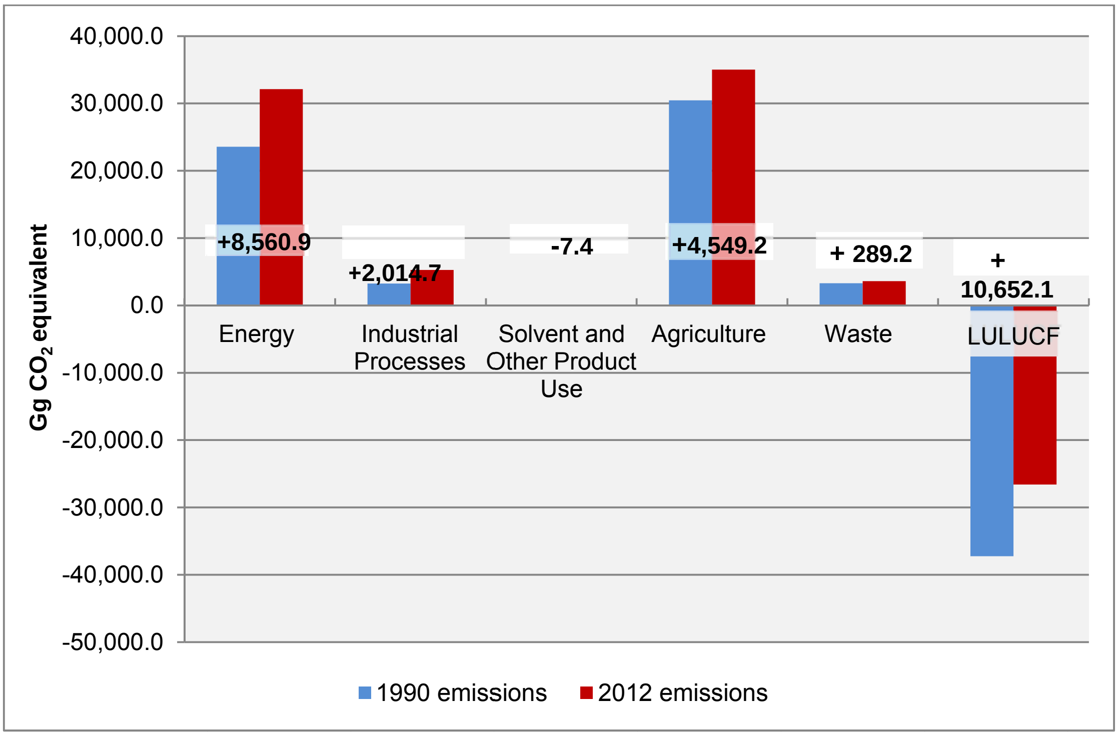
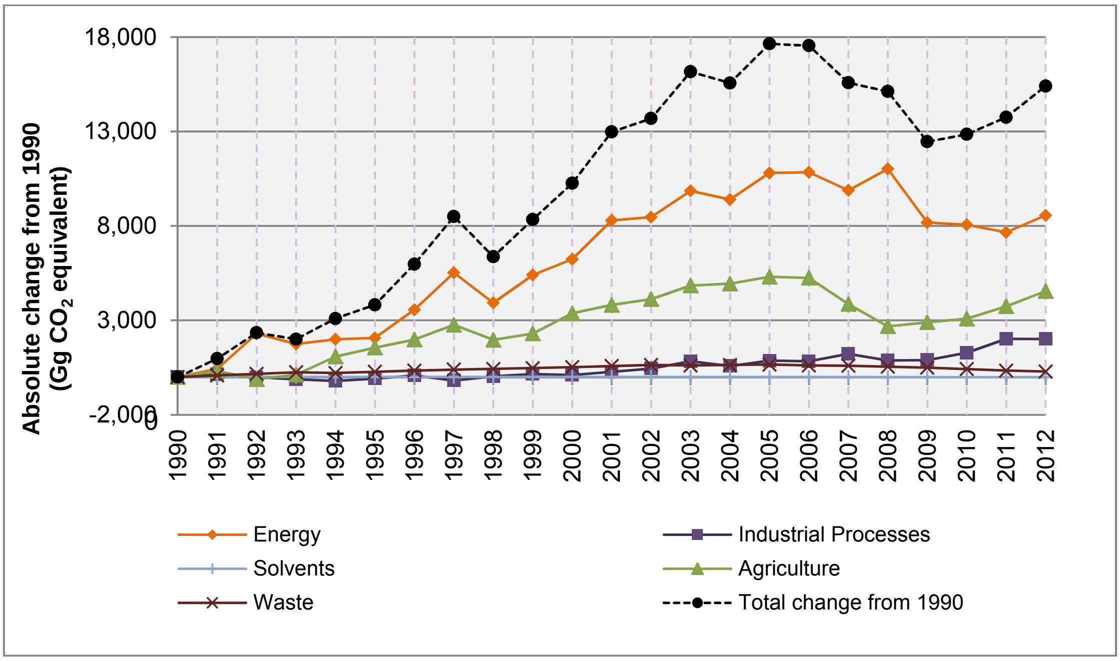


Figure ES 4.1.4 Absolute change in New Zealand's total emissions by sector from 1990 to 2012



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

Energy (chapter 3)

2012

The Energy sector was the source of 32,121.3 Gg CO_2-e (42.2 per cent) of total emissions in 2012. The largest sources of emissions in the Energy sector were road transportation, contributing 12,439.9 Gg CO_2-e (38.7 per cent), and public electricity and heat production, contributing 6,299.9 Gg CO_2-e (19.6 per cent) to energy emissions.

1990–2012

In 2012, emissions from the Energy sector increased by 36.3 per cent (8,560.9 Gg) above the 1990 level of 23,560.4 Gg CO_2-e. This growth in emissions is primarily from road transportation, which increased by 5,033 Gg CO_2-e (68.0 per cent), and public electricity and heat production, which increased by 2,834 Gg CO_2-e (81.8 per cent).

2011–2012

Since 2011, emissions from the Energy sector increased by 899.5 Gg CO_2-e (2.9 per cent). This is primarily due to an increase of 1,222.1 Gg CO_2-e (24.1 per cent) in emissions from electricity generation. This resulted from an increase in the proportion of electricity generated from renewable sources in New Zealand's national grid. Due to abnormally low hydro inflows, the share of electricity generated from renewable energy sources in the national energy grid dropped from 77 per cent in 2011 to 73 per cent in 2012. This resulted in increased fossil fuel based electricity generation over the year. Electricity generation from coal increased 63.7 per cent from 2011.

There was also a 312 Gg CO_2-e (12.5 per cent) decrease in fugitive emissions between 2011 and 2012. This resulted from reduced coal mining and handling activities in New Zealand's underground mines and the Spring Creek Mine suspending coal production in 2012. There were small reductions in emissions from exploration of natural gas and from flaring.

here was also a 288 Gg CO_2-e (2.0 per cent) decrease in emissions from road transportation that may be attributed to several factors, such as the increasing efficiency of road vehicles, changes in driving habits due to increases in petrol prices, as well as some residual effects of the economic recession.

Industrial Processes (chapter 4)

2012

The Industrial Processes sector contributed 5,276.8 Gg CO_2-e (6.9 per cent) of total emissions in 2011. The largest source of industrial process emissions is the metal production category (CO_2 and a small amount of PFCs), contributing 43.2 per cent of Industrial Processes sector emissions in 2012. Consumption of halocarbons and SF_6 is also a large source with 34.2 per cent of industrial processes emissions, due to the prevalence of halocarbons in air conditioning and refrigeration equipment.

1990–2012

Emissions from the Industrial Processes sector in 2012 increased by 2,014.7 Gg CO_2-e (61.8 per cent) above the 1990 level of 3,262.1 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 1,812.5 Gg CO_2-e. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol. Also, CO_2 emissions from mineral, chemical and metals production have gradually increased due to increasing product outputs. These increases have been partially offset by a reduction in emissions of PFCs from aluminium production, due to improved control of anode effects in aluminium smelting.

2011–2012

Since 2011, emissions from the Industrial Processes sector decreased by 7.3 Gg CO_2-e (less than 1 per cent). Emissions of CO_2 from minerals increased by 38.9 Gg due to increased cement production. Emissions of CO_2 from the chemical industry increased by 20.8 Gg due to re-opening of the urea production plant in the end of 2011. Meanwhile, the emissions from metal production have decreased by 56.9 Gg due to fluctuations in output for these products. Emissions from the use of halocarbons and SF_6 decreased by 10.1 Gg, which may be associated with the introduction of obligations under the New Zealand Emissions Trading Scheme (NZ ETS) for these gases.

Solvent and Other Product Use (chapter 5)

In 2012, the Solvent and Other Product Use sector was responsible for 34.1 Gg CO_2-e (0.04 per cent) of total emissions. The emission levels from the Solvent and Other Product Use sector are negligible compared with other sectors.

Agriculture (chapter 6)

2012

New Zealand has an unusual emissions profile amongst developed countries with the Agriculture sector being the largest source of emissions. In 2012, this sector contributed 35,020.1 Gg CO_2-e (46.1 per cent of total emissions). In Annex I countries, the Agriculture sector emissions average around 12 per cent of total emissions.

The largest sources of emissions from the Agriculture sector in 2012 were from enteric fermentation (CH_4 emissions) and agricultural soils (N_2O emissions).

1990–2012

In 2012, New Zealand's agricultural emissions increased by 4,549.2 Gg CO_2-e (14.9 per cent) from the 1990 level of 30,471.0 Gg CO_2-e. This increase is largely due to the increase of CH_4

emissions from enteric fermentation from dairy cattle and N_2O emissions from agricultural soils.

2011–2012

Since 2011, emissions from the Agriculture sector increased 806.6 Gg CO_2-e (2.4 per cent). This is caused by an increase in the dairy cattle population and, as the dairy industry is the main user of nitrogen fertiliser in New Zealand, the amount of nitrogen applied as fertiliser.

LULUCF under the Climate Change Convention (chapter 7)

2012

In 2012, net emissions from the LULUCF sector under the Climate Change Convention were –26,598.3 Gg CO_2-e (figure ES 4.1.5). The highest contribution to removals in 2012 (25,206.0 Gg CO_2-e) was from land converted to forest land. This is largely due to the removals from the growth of first rotation forests.

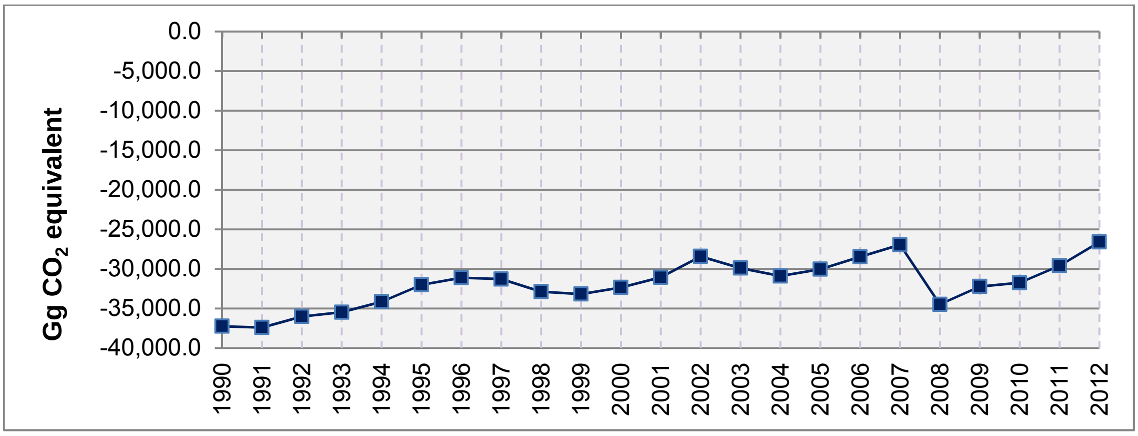
The largest source of emissions in LULUCF is from land converted to grassland. In 2012, net emissions for land converted to grassland contributed 3,940.4 Gg CO_2-e. This is largely due to the emissions from loss of living biomass on land conversion.

1990–2012

From 1990 to 2012, net emissions from LULUCF increased by 10,652.0 Gg CO_2-e (28.6 per cent) from the 1990 level of –37,250.4 Gg CO_2-e. This increase in net emissions is largely the result of increased harvesting as a larger proportion of the production forest estate reaches harvest age.

The fluctuations in net emissions 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 increase in net emissions 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 NZ ETS.[4]

Figure ES 4.1.5 New Zealand's LULUCF sector net removals from 1990 to 2012



2011–2012

Since 2011, net emissions from LULUCF increased by 2,996.5 Gg CO_2-e (10.1 per cent). This increase in net emissions is largely the result of a greater proportion of forest land reaching either harvest or thinning age in 2012, compared with 2011. This is influenced by the age-class

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

profile of New Zealand's production forests. Emissions have also increased in the grassland category due to larger areas of forest land being converted to grassland in 2012, than in 2011.

Waste (chapter 8)

The Waste sector contributed 3,595.7 Gg CO_2-e (4.7 per cent) to total emissions in 2012.

Emissions from the Waste sector have increased by 289.2 Gg CO_2-e (8.8 per cent) from the 1990 level of 3,306.4 Gg CO_2-e. This growth in emissions can generally be attributed to the growth in New Zealand's population and gross domestic product. The increase in population resulted in an increase in the total volume of wastewater processed and the amount of organic matter in the wastewater.

The other source of increase in emissions from the Waste sector is an increasing amount of solid waste disposal on land, specifically, in non-municipal and on-site farm landfills.

Meanwhile, there has been a decrease in waste placement at municipal landfills.

ES.5 Activities under Article 3.3 of the Kyoto Protocol

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

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2012 was 654,354 hectares. The net area is the total area of post-1989 forest (674,945 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (20,591 hectares). Net removals from this land in 2012 were 18,965.1 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2012 was 151,544 hectares. The area subject to deforestation in 2012 was 6,762 hectares. In 2012, deforestation emissions were 3,996.5 Gg CO_2-e, compared with 3,376.0 Gg CO_2-e in 2011 (an increase of 18.4 per cent). Deforestation emissions include non-CO_2 emissions and lagged CO_2 emissions that occurred in 2012 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 2008–12

Source	2008	2009	2010	2011	2012
Afforestation/reforestation (AR)					
Net cumulative area since 1990 (ha)	621,401	623,924	629,782	642,382	654,354
Area in calendar year (ha)	2,324	5,024	6,940	13,692	12,539
Emissions from AR land not harvested in CP1 (Gg CO_2-e)	–17,405.4	–17,957.2	–18,458.1	–18,828.8	–19,145.9
Emissions from AR land harvested in CP1 (Gg CO_2-e)	41.9	121.1	265.0	253.1	180.8

Emissions in calendar year (Gg CO_2-e)	–17,363.5	–17,836.0	–18,193.1	–18,575.7	–18,965.1
Deforestation					
Net cumulative area since 1990 (ha)	121,030	131,434	138,656	144,783	151,544
Area in calendar year (ha)	5,984	10,405	7,222	6,127	6,762
Emissions in calendar year (Gg CO_2-e)	3,166.9	5,616.0	4,087.2	3,376.0	3,996.5
Total area subject to afforestation, reforestation and deforestation	742,431	755,359	768,438	787,165	805,898
Net emissions (Gg CO_2-e)	**–14,196.6**	**–12,220.0**	**–14,105.9**	**–15,199.7**	**–14,968.6**
Accounting quantity (Gg CO_2-e)	**–14,238.5**	**–12,341.2**	**–14,370.9**	**–15,452.8**	**–15,149.5**

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. CP1 refers to the first commitment period under the Kyoto Protocol and the period 2008-12. Columns may not total due to rounding.

ES.6 Improvements introduced

Following the 2013 submission and its review in September 2013, improvements in the accuracy of emissions and removals were made in the LULUCF, Energy, Agriculture, Industrial Processes and Waste 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)

The main differences between this submission and previous estimates of New Zealand's LULUCF net removals reported in the 2013 Inventory submission are the result of (in decreasing order of magnitude):

- the inclusion for the first time of estimates of carbon stock change for natural forests. This addresses recommendations of previous expert review teams to report on carbon stock change within natural forests. This has accounted for a decrease in emissions of at least –16,000 Gg CO2-e annually for every year of the Inventory
- the completion of the 2012 land-use map and continued improvements to the 1990 and 2008 land-use maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest
- the net planted forest area for pre-1990 and post-1989 planted forest being identified and modelled separately for this submission. This ensures the harvesting and planting activity data obtained from the Ministry for Primary Industries is consistent with the planted forest area modelled for Climate Change Convention reporting
- a return to a Tier 2 methodology for estimating mineral soil organic carbon
- the post-1989 planted forest carbon stock yield table being revised based on the full re-measurement of the plot network that was completed in 2012. The inclusion of additional sample plots addresses a bias in the earlier estimates caused by incomplete sampling of the forest area

- post-1989 natural forest being identified, measured and category-specific carbon stock yield tables applied for the first time in the 2012 Inventory (2014 submission).

Energy (section 3.3.1)

A number of changes have been made since the 2013 Inventory submission to improve the accuracy, completeness and transparency of the Inventory. The most significant changes are outlined below.

- The natural gas used for production of methanol has been split into fuel gas and feedstock gas. The emissions from the fuel portion are shown in the Energy sector, and the emissions from the feedstock portion are described in the Industrial Processes sector.

- Natural gas used for production of ammonia and urea has been split into feedstock gas, which is included in the Industrial Processes sector, and energy-use gas, which is included in the Energy sector.

- Venting of natural gas has been separated from flaring.

- Emissions of N2O as a result of flaring have been included in the Energy sector.

- The emission factors for solid fuels have been revised for the time series 1990–2007. Values are now calculated by interpolation between 1990 and 2008.

- An improvement has been made in the oil data system so that annual gross calorific values are used for performing conversion calculations. This applies to all liquid fuels produced by New Zealand’s sole oil refinery. Previously a static gross calorific value was used.

- A reallocation of fuel data has been made in the oil data system to reallocate all aviation fuel consumption data to the transport sector.

- Fugitive emissions resulting from oil and gas exploration have been estimated for this submission.

- The 2013 Inventory submission included all feedstocks and flared gas under 1.AB as carbon stored. This was done as an attempt to balance the reference and sectoral approaches. This submission only reports carbon that is stored in products under 1.AB as carbon stored.

- Fugitive emissions from industrial plants have been revised to include both energy-use and non-energy-use gas.

- Activity data for international bunkers have been aligned to a more consistent data source. The change is summarised in the table 3.2.1.

Agriculture (sections 6.1.4 – 6.1.6)

Two changes to the Inventory methodology in the Agriculture sector are included in the 2014 Inventory submission:

- A revised equation for partitioning of nitrogen in excreta between dung and urine.

- Inclusion of the mitigation technology, urease inhibitors, in the calculation of the fraction of nitrogen in fertiliser that is volatilised. This is to reflect that urease inhibitors are already in use in New Zealand.

Industrial Processes (section 4.1.5)

Major improvements in the Industrial Processes sector are focused on improving transparency in reporting emissions of fluorine-containing gases, mineral products and resolving previously noted cross-sectoral issues. These improvements cover:

- the recalculation of HFC imports, since some double counting of HFC-134a imports that occurred in 2011 was identified
- the other SF6 applications subcategory, where some uncertainty remains on medical and scientific uses of SF6
- the natural gas inputs used for production of methanol and ammonia for urea production, which have been split into fuel gas and feedstock gas. The emissions from the fuel portion are shown in the energy sector, and the emissions from the feedstock portion are described in the industrial processes sector
- reporting of dolomite and other carbonates to address the expert review team (ERT) comments during the Centralised review 2013 (September 2013).
- ongoing verifications with the NZ ETS to ensure that no discrepancies occur between the NZ ETS and Ministry of Business, Innovation and Employment data.

Waste (section 8.1.6)

The estimates for the Waste sector have been recalculated. Several improvements have been made to the calculation of emission estimates in the Waste sector including:

- inclusion of estimates from non-municipal landfills and on-site farm fills
- incorporation of waste placement data collected under the Waste Minimisation Act 2008
- revision of historic waste placement estimates
- revision of historic waste methane correction and oxidation factors
- minor amendments to waste composition values prior to 1980
- incorporation of a 2012 waste composition estimate and a revision of the 2008 estimate
- inclusion of estimates of emissions from the wool scouring industry
- inclusion of activity data and revised parameters for the wine industry
- inclusion of activity data and revised parameters for the pulp and paper industry (sludge treatment).

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 CO_2-e. At the end of 2013, there were 305,777,516 assigned amount units. During 2013, no Kyoto Protocol units expired, or were replaced or cancelled.

Contents

Tables

Figures

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, 2013). This increase is attributed to human activity, particularly the burning of fossil fuels and land-use change. It is extremely likely that most of the global warming since the mid-20th century was caused by the increase in greenhouse gas concentrations and other human activities (IPCC, 2013). Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system.

1.1.1 United Nations Framework Convention on Climate Change

The science of climate change is assessed by the Intergovernmental Panel on Climate Change (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 (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[5] to the Climate Change Convention commit to providing financial assistance to non-Annex I Parties (developing countries).

Annex I[6] 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

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5 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.

6 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'.

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 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[7] 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 (or AAUs)[8] 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 AAUs, removal units from land use, land-use change and forestry (LULUCF) activities under Article 3.3 or 3.4 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 AAUs 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.

7 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.

8 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 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 (RMUs) 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).

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.

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 had been converted to non-forested land. For the first commitment period, reforestation activities are limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.

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). As per the UNFCCC reporting guidelines, New Zealand followed the IPCC 1996 good practice guidance and the revised IPCC 1996 guidelines in preparation of the 2014 Inventory submission.

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 CO_2, CH_4, 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 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:

- estimate annually New Zealand's anthropogenic emissions by sources and removals by sinks, of greenhouse gases
- 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:

- identify source categories
- 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)

- estimate the emissions and removals by sinks for each source category
- undertake assessments on uncertainties
- undertake procedures to verify the data
- 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 National system

New Zealand is required under Article 5.1 of the Kyoto Protocol to have a national system in place for its 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 as well as information on data archiving, security and recovery are documented in chapter 13 of this submission.

The Ministry for the Environment is New Zealand's single national entity for the 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 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 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.

1.3 Inventory preparation processes

Consistent with the Climate Change Convention reporting guidelines, each Inventory is submitted 15 months after the 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 occurs.

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 Inventory. 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 good 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:

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

- Tier 2 methods apply country-specific emission factors and use IPCC default models for emissions and/or removals calculations
- 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 emission estimates 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 (CRL Energy Ltd., 2013). 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 are 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 from Statistics New Zealand and independent organisations 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, with country-specific emission factors for swine and poultry. Activity data on burning of savanna are obtained from Statistics New Zealand. A Tier 2 (model) approach is used to calculate emissions from burning of agricultural residues. There is no rice cultivation in New Zealand.

Land Use, Land-Use Change and Forestry (LULUCF, 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
- use of allometric equations and models to estimate carbon stock and carbon-stock change in natural and planted forests respectively (Holdaway et al, 2013; Beets et al, 2012; 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 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 2012 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 21.8 per cent
- CH_4 emissions from dairy cattle enteric fermentation; a contribution of 9.3 per cent
- CO_2 emissions from forest land remaining forest land; a contribution of 6.9 per cent
- CH_4 emissions from sheep enteric fermentation; a contribution of 6.9 per cent.

The key categories that were identified as having the largest relative influence on the trend including LULUCF from 1990 to 2012, compared with the average change in net emissions from 1990 to 2012 (table 1.5.3(a)), were:

- CO_2 emissions from forest land remaining forest land; a contribution of 28.5 per cent

- CH_4 emissions from sheep enteric fermentation; contributed 9.6 per cent to the net emissions trend through a decrease
- CH_4 emissions from dairy cattle enteric fermentation; contributed 9.1 per cent to the net emissions trend through an increase
- CO_2 emissions from conversion to forest land; contributed 8.3 per cent to the net emissions trend through an increase.

Table 1.5.1 Summary of New Zealand's key categories for the 2012 level assessment and the trend assessment for 1990 to 2012 (including and excluding LULUCF activities)

Quantitative method used: IPCC Tier 1		
IPCC categories	**Gas**	**Criteria for identification**
Energy		
Transport – civil aviation – jet kerosene	CO_2	level, trend
Transport – navigation – residual oil	CO_2	level
Transport – road transport – diesel oil	CO_2	level, trend
Transport – road transport – gasoline	CO_2	level, trend
Transport – road transport – gaseous fuels	CO_2	trend
Transport – road transport – liquefied petroleum gases	CO_2	trend
Energy industries – Manufacture of solid fuels and other energy industries – 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 – public electricity and heat production – gaseous fuels	CO_2	level, trend
Energy industries – public electricity and heat production – solid fuels	CO_2	level, trend
Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	level, trend
Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Liquid Fuels	CO_2	level, trend
Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Solid Fuels	CO_2	level, trend
Manufacturing industries and construction – food processing, beverages and tobacco – gaseous fuels	CO_2	level
Manufacturing industries and construction – other – mining and construction – liquid fuels	CO_2	level, trend
Manufacturing industries and construction – other – other non-specified – liquid fuels	CO_2	trend
Manufacturing industries and construction – other – other non-specified – solid fuels	CO_2	trend
Manufacturing industries and construction – other – non–metallic minerals – solid fuels	CO_2	level
Manufacturing industries and construction – pulp, paper and print – gaseous fuels	CO_2	level, trend
Other sectors – agriculture/forestry/fisheries – liquid fuels	CO_2	level, trend
Other sectors – agriculture/forestry/fisheries – solid fuels	CO_2	level, trend
Other sectors – commercial/institutional – gaseous fuels	CO_2	level, trend
Other sectors – commercial/institutional – liquid fuels	CO_2	level, trend
Other sectors – residential – gaseous fuels	CO_2	level, trend
Other sectors – residential – solid fuels	CO_2	trend
Fugitive – coal mining and handling – underground mines	CH_4	trend
Fugitive – flaring – combined	CO_2	trend
Fugitive – natural gas – distribution	CH_4	trend
Fugitive – natural gas – other leakage	CH_4	level, trend
Fugitive – natural gas – production/processing	CO_2	level, trend
Fugitive – other – geothermal	CO_2	level, trend
Agriculture		
Agricultural soils – indirect emissions	N_2O	level, trend

Quantitative method used: IPCC Tier 1		
IPCC categories	**Gas**	**Criteria for identification**
Agricultural soils – pasture, range and paddock	N_2O	level, trend
Agricultural soils – direct emissions	N_2O	level, trend
Enteric fermentation – dairy cattle	CH_4	level, trend
Enteric fermentation – non-dairy cattle	CH_4	level, trend
Enteric fermentation – deer	CH_4	level
Enteric fermentation – other	CH_4	trend
Enteric fermentation – sheep	CH_4	level, trend
Manure management	CH_4	level, trend
Industrial processes		
Mineral products – cement production	CO_2	level
Metal production – iron and steel production	CO_2	level
Metal production – aluminium production	CO_2	level
Metal production – aluminium production	PFCs	trend
Chemical industry – hydrogen production	CO_2	level
Chemical industry – ammonia production	CO_2	qualitative
Consumption of halocarbons and SF_6 – foam blowing	HFCs & PFCs	trend
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	level, trend
LULUCF		
Conversion to forest land	CO_2	level, trend
Forest land remaining forest land	CO_2	level, trend
Conversion to grassland	CO_2	level, trend
Grassland remaining grassland	CO_2	level, trend
Conversion to wetland	CO_2	trend
Waste		
Solid waste disposal on land	CH_4	level, trend
Wastewater 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) 2012 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): 2012				
IPCC categories	**Gas**	**2012 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	25,210.1	21.8	21.8
Enteric fermentation – dairy cattle	CH_4	10,807.7	9.3	31.1
Forest land remaining forest land	CO_2	7,954.6	6.9	38.0
Enteric fermentation – sheep	CH_4	7,948.1	6.9	44.9
Transport – road transport – gasoline	CO_2	6,884.8	5.9	50.8
Agricultural soils – pasture, range and paddock	N_2O	5,817.6	5.0	55.8
Transport – road transport – diesel oil	CO_2	5,372.8	4.6	60.5
Enteric fermentation – non-dairy cattle	CH_4	4,648.0	4.0	64.5
Conversion to grassland	CO_2	3,914.2	3.4	67.9
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,631.7	3.1	71.0
Solid waste disposal on land	CH_4	3,120.5	2.7	73.7
Energy industries – public electricity and heat production – solid fuels	CO_2	2,643.8	2.3	76.0
Agricultural soils – indirect emissions	N_2O	2,621.7	2.3	78.2
Grassland remaining grassland	CO_2	2,013.9	1.7	80.0
Agricultural soils – direct emissions	N_2O	1,901.5	1.6	81.6
Metal production – iron and steel production	CO_2	1,718.9	1.5	83.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,717.6	1.5	84.6
Other sectors – agriculture/forestry/fisheries – liquid fuels	CO_2	1,344.9	1.2	85.8
Manufacturing industries and construction – food processing, beverages and tobacco – solid fuels	CO_2	1,304.5	1.1	86.9
Manufacturing industries and construction – chemicals – gaseous fuels	CO_2	1,045.0	0.9	87.8
Transport – civil aviation – jet kerosene	CO_2	826.7	0.7	88.5
Energy industries – petroleum refining – liquid fuels	CO_2	779.2	0.7	89.2
Manure management	CH_4	672.1	0.6	89.8
Fugitive – other – geothermal	CO_2	629.6	0.5	90.3
Manufacturing industries and construction – food processing, beverages and tobacco – gaseous fuels	CO_2	599.8	0.5	90.8
Mineral products – cement production	CO_2	568.6	0.5	91.3
Manufacturing industries and construction – other – mining and construction – liquid fuels	CO_2	535.5	0.5	91.8
Metal production – aluminium production	CO_2	521.0	0.5	92.2
Enteric fermentation – deer	CH_4	485.4	0.4	92.6
Fugitive – natural gas – production/processing	CO_2	419.4	0.4	93.0
Other sectors – commercial/institutional – gaseous fuels	CO_2	417.9	0.4	93.4
Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	397.0	0.3	93.7
Cropland remaining cropland	CO_2	383.4	0.3	94.0
Other sectors – commercial/institutional – liquid fuels	CO_2	355.8	0.3	94.3
Manufacturing industries and construction – pulp, paper and print – gaseous fuels	CO_2	346.0	0.3	94.6
Other sectors – agriculture/forestry/fisheries – solid fuels	CO_2	332.2	0.3	94.9
Other sectors – residential – gaseous fuels	CO_2	331.2	0.3	95.2

(b) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2012				
IPCC categories	**Gas**	**2012 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Enteric fermentation – dairy cattle	CH_4	10,807.7	14.2	14.2
Enteric fermentation – sheep	CH_4	7,948.1	10.5	24.7
Transport – road transport – gasoline	CO_2	6,884.8	9.1	33.7
Agricultural soils – pasture, range and paddock	N_2O	5,817.6	7.6	41.4
Transport – road transport – diesel oil	CO_2	5,372.8	7.1	48.4
Enteric fermentation – non-dairy cattle	CH_4	4,648.0	6.1	54.5
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,631.7	4.8	59.3
Solid waste disposal on land	CH_4	3,120.5	4.1	63.4
Energy industries – public electricity and heat production – solid fuels	CO_2	2,643.8	3.5	66.9
Agricultural soils – indirect emissions	N_2O	2,621.7	3.4	70.3
Agricultural soils – direct emissions	N_2O	1,901.5	2.5	72.8
Metal production – iron and steel production	CO_2	1,718.9	2.3	75.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,717.6	2.3	77.4
Other sectors – agriculture/forestry/fisheries – liquid fuels	CO_2	1,344.9	1.8	79.1
Manufacturing industries and construction – food processing, beverages and tobacco – solid fuels	CO_2	1,304.5	1.7	80.8
Manufacturing industries and construction – chemicals – gaseous fuels	CO_2	1,045.0	1.4	82.2
Transport – civil aviation – jet kerosene	CO_2	826.7	1.1	83.3
Energy industries – petroleum refining – liquid fuels	CO_2	779.2	1.0	84.3
Manure management	CH_4	672.1	0.9	85.2
Fugitive – other – geothermal	CO_2	629.6	0.8	86.0
Manufacturing industries and construction – food processing, beverages and tobacco – gaseous fuels	CO_2	599.8	0.8	86.8
Mineral products – cement production	CO_2	568.6	0.7	87.6
Manufacturing industries and construction – other – mining and construction – liquid fuels	CO_2	535.5	0.7	88.3
Metal production – aluminium production	CO_2	521.0	0.7	89.0
Enteric fermentation – deer	CH_4	485.4	0.6	89.6
Fugitive – natural gas – production/processing	CO_2	419.4	0.6	90.2
Other sectors – commercial/institutional – gaseous fuels	CO_2	417.9	0.5	90.7
Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	397.0	0.5	91.2
Other sectors – commercial/institutional – liquid fuels	CO_2	355.8	0.5	91.7
Manufacturing industries and construction – pulp, paper and print – gaseous fuels	CO_2	346.0	0.5	92.2
Other sectors – agriculture/forestry/fisheries – solid fuels	CO_2	332.2	0.4	92.6
Other sectors – residential – gaseous fuels	CO_2	331.2	0.4	93.0
Manufacturing industries and construction – other – non-metallic minerals – solid fuels	CO_2	313.8	0.4	93.4
Wastewater handling	CH_4	289.5	0.4	93.8
Transport – navigation – residual oil	CO_2	289.2	0.4	94.2
Manufacturing industries and construction – food processing, beverages and tobacco – liquid fuels	CO_2	269.4	0.4	94.6
Fugitive – natural gas – other leakage	CH_4	261.3	0.3	94.9
Chemical industry – hydrogen production	CO_2	251.4	0.3	95.2

Table 1.5.3 (a & b) **1990–2012 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)**	**2012 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Forest land remaining forest land	CO_2	21,108.3	7,954.6	0.122	28.5	28.5
Enteric fermentation – sheep	CH_4	11,723.0	7,948.1	0.041	9.6	38.0
Enteric fermentation – dairy cattle	CH_4	4,999.3	10,807.7	0.039	9.1	47.1
Conversion to forest land	CO_2	18,045.9	25,210.1	0.035	8.3	55.4
Transport – road transport – diesel oil	CO_2	1,409.5	5,372.8	0.029	6.7	62.0
Conversion to grassland	CO_2	238.5	3,914.2	0.028	6.5	68.5
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	2,643.8	0.016	3.7	72.2
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,717.6	0.013	3.0	75.3
Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.2	397.0	0.012	2.8	78.0
Agricultural soils – direct emissions	N_2O	460.5	1,901.5	0.010	2.4	80.5
Grassland remaining grassland	CO_2	875.1	2,013.9	0.008	1.8	82.3
Enteric fermentation – non-dairy cattle	CH_4	4,820.2	4,648.0	0.006	1.5	83.8
Metal production – aluminium production	PFCs	629.9	40.8	0.005	1.2	84.9
Transport – road transport – gasoline	CO_2	5,582.2	6,884.8	0.004	0.9	85.9
Manufacturing industries and construction – other – other non-specified – solid fuels	CO_2	464.9	34.0	0.004	0.9	86.8
Manufacturing industries and construction – chemicals – gaseous fuels	CO_2	526.4	1,045.0	0.003	0.8	87.6
Fugitive – other – geothermal	CO2	228.6	629.6	0.003	0.7	88.2
Other sectors – residential – solid fuels	CO_2	338.0	39.5	0.003	0.6	88.8
Agricultural soils – indirect emissions	N_2O	2,039.6	2,621.7	0.002	0.5	89.4
Fugitive – natural gas – production/processing	CO_2	109.3	419.4	0.002	0.5	89.9
Other sectors – agriculture/forestry/fisheries – solid fuels	CO_2	34.4	332.2	0.002	0.5	90.4
Agricultural soils – pasture, range and paddock	N_2O	5,330.4	5,817.6	0.002	0.4	90.8
Manufacturing industries and construction – food processing, beverages and tobacco – solid fuels	CO_2	1,353.9	1,304.5	0.002	0.4	91.3
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	3,631.7	0.002	0.4	91.7
Metal production – iron and steel production	CO_2	1,306.7	1,718.9	0.002	0.4	92.1
Other sectors – commercial/institutional – liquid fuels	CO_2	495.5	355.8	0.002	0.4	92.5
Conversion to wetland	CO_2	218.1	43.4	0.002	0.4	92.8
Solid waste disposal on land	CH_4	2,912.4	3,120.5	0.001	0.3	93.2
Enteric fermentation – other	CH_4	209.6	46.7	0.001	0.3	93.5
Transport – civil aviation – jet kerosene	CO_2	883.7	826.7	0.001	0.3	93.8
Manufacturing industries and construction – other – mining and construction – liquid fuels	CO_2	328.1	535.5	0.001	0.3	94.1
Transport – road transport – gaseous fuels	CO_2	139.6	1.8	0.001	0.3	94.4
Other sectors – commercial/institutional – gaseous fuels	CO_2	234.0	417.9	0.001	0.3	94.6
Manure management	CH_4	459.1	672.1	0.001	0.3	94.9

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)						
IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2012 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Other sectors – agriculture/forestry/ fisheries – liquid fuels	CO_2	1,060.7	1,344.9	0.001	0.2	95.2

(b) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)						
IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2012 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation – sheep	CH_4	11,723.0	7,948.1	0.071	20.9	20.9
Enteric fermentation – dairy cattle	CH_4	4,999.3	10,807.7	0.048	14.0	34.9
Transport – road transport – diesel oil	CO_2	1,409.5	5,372.8	0.038	11.2	46.1
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	2,643.8	0.022	6.4	52.5
Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.2	397.0	0.018	5.4	57.9
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,717.6	0.018	5.3	63.2
Enteric fermentation – non-dairy cattle	CH_4	4,820.2	4,648.0	0.015	4.3	67.5
Agricultural soils – direct emissions	N_2O	460.5	1,901.5	0.014	4.1	71.6
Agricultural soils – pasture, range and paddock	N_2O	5,330.4	5,817.6	0.009	2.7	74.3
Metal production – aluminium production	PFCs	629.9	40.8	0.008	2.3	76.6
Manufacturing industries and construction – other – other non-specified – solid fuels	CO_2	464.9077145	34.0	0.006	1.7	78.3
Solid waste disposal on land	CH_4	2,912.4	3,120.5	0.006	1.6	80.0
Manufacturing industries and construction – food processing, beverages and tobacco – solid fuels	CO_2	1353.935893	1,304.5	0.004	1.2	81.2
Manufacturing industries and construction – chemicals – gaseous fuels	CO_2	526.3860711	1,045.0	0.004	1.2	82.4
Other sectors – residential – solid fuels	CO_2	338.0300759	39.5	0.004	1.2	83.6
Fugitive – other – geothermal	CO_2	228.57616	629.6	0.004	1.1	84.6
Other sectors – agriculture/forestry/ fisheries – solid fuels	CO_2	34.43865968	332.2	0.003	0.9	85.5
Fugitive – natural gas – production/ processing	CO_2	109.297	419.4	0.003	0.9	86.4
Transport – civil aviation – jet kerosene	CO_2	883.7	826.7	0.003	0.9	87.3
Other sectors – commercial/institutional – liquid fuels	CO_2	495.546226	355.8	0.003	0.8	88.1
Enteric fermentation – other	CH_4	209.6	46.7	0.002	0.7	88.8
Energy industries – petroleum refining – liquid fuels	CO_2	773.9	779.2	0.002	0.6	89.3
Transport – road transport – gaseous fuels	CO_2	139.6	1.8	0.002	0.5	89.9
Energy industries – petroleum refining – gaseous fuels	CO_2	0.0	136.68	0.001	0.4	90.3
Fugitive – natural gas – distribution	CH_4	233.0875479	156.9	0.001	0.4	90.7
Other sectors – commercial/institutional – gaseous fuels	CO_2	234.0254374	417.9	0.001	0.4	91.1
Manufacturing industries and construction – other – mining and construction – liquid fuels	CO_2	328.1388304	535.5	0.001	0.4	91.5
Transport – road transport – gasoline	CO_2	5,582.2	6,884.8	0.001	0.4	91.8
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	3,631.7	0.001	0.3	92.2

(b) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)						
IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2012 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Fugitive – coal mining and handling – underground mines	CH_4	243.2	195.4	0.001	0.3	92.5
Transport – road transport – liquefied petroleum gases	CO_2	101.0	21.6	0.001	0.3	92.9
Other sectors – residential – gaseous fuels	CO_2	183.9924513	331.2	0.001	0.3	93.2
Fugitive – natural gas – other leakage	CH_4	286.2910967	261.3	0.001	0.3	93.5
Manure management	CH_4	459.1	672.1	0.001	0.3	93.8
Fugitive – flaring – combined	CO2	113.5127719	235.8	0.001	0.3	94.1
Manufacturing industries and construction – food processing, beverages and tobacco – liquid fuels	CO_2	289.208961	269.4	0.001	0.3	94.3
Manufacturing industries and construction – other – other non-specified – liquid fuels	CO_2	51.44824483	156.5	0.001	0.3	94.6
Manufacturing industries and construction – pulp, paper and print – gaseous fuels	CO_2	345.5405672	346.0	0.001	0.3	94.9
Consumption of halocarbons and SF_6 – foam blowing	HFCs & PFCs	0.0	85.2	0.001	0.3	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 2012 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 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 2014 Inventory submission are discussed in sections 1.6.1 and 1.6.2 below. Examples of quality-control checks are provided in the MS 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 2012 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 Inventory, 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 in 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 6.1.4 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, three Energy reviewers, one Industrial Processes reviewer, two Agriculture reviewers, three 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 Agriculture and Energy sector compilers is well documented within respective manuals. There is also documentation for compiling the Industrial Processes, LULUCF and Waste sectors. These 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 New Zealand Emissions Trading Scheme (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 2007–09 and 2011–13 Inventory submissions were reviewed during centralised reviews (UNFCCC, 2009; 2010; 2012; 2013 and UNFCCC, 2014). The 2010 Inventory submission was subject to an in-country review in August–September 2010 (UNFCCC, 2011). 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 latest published expert review report (UNFCCC, 2014, p.26-27) concluded that:

- *The inventory submission of New Zealand is complete (categories, gases, years and geographical boundaries and contains both an NIR and CRF tables for 1990–2011)*
- *The inventory submission of New Zealand has been prepared and reported in accordance with the UNFCCC reporting guidelines.*
- *The Party's inventory is in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories and the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry*
- *The ERT concluded that the Party's national system continues to be in accordance with the requirements of national systems outlined in decision 19/CMP.1.*
- *New Zealand's 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 decisions of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP).*

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 Inventory 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 2012 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 2012

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) is ±13.3 per cent. This is a 13.1 per cent decrease from 2011. Similar to 2011, the uncertainty in a given year is dominated by emissions of N_2O from agricultural soils (section 6.5), N_2O from wastewater handling and CH_4 from enteric fermentation (section 6.2). These categories comprised ±10.1 per cent, ±6.3 per cent and ±5.0 per cent respectively of New Zealand's total emissions uncertainty in 2012. 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 2012 is ±11.1 per cent. This is an increase in the trend uncertainty compared with the value reported for 2011 (±2.3 per cent) due to revised activity data uncertainties in the solid waste disposal category of the Waste sector.

Net emissions

Uncertainty in 2012

The calculated uncertainty for New Zealand's Inventory, including emissions and removals from the LULUCF sector in 2012 is ±17.8 per cent. Removals of CO_2 from forest land were a major contribution to the uncertainty for 2012 at ±15.5 per cent of New Zealand's net emissions.

The overall uncertainty of the national net emissions for the 2012 year has increased 16.3 per cent compared with the estimate provided for the 2011 year in the 2013 Inventory submission (±15.3 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 2012 is ±9.0 per cent. This is an increase of 4.7 per cent from the uncertainty estimates in the trend compared with 2011. 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 2012 was 10.2 per cent. The uncertainty introduced into net emissions from deforestation in 2012 was 3.8 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 Inventory for the period 1990–2012 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 2013, New Zealand's national registry held 306,041,662 AAUs, 16,153,534 emissions reduction units, 8,680,399 certified emission reduction units and 9,050,000 removal units (table 1 in table 12.2.2).

At the end of 2013, there were 305,777,516 AAUs, 79,861,097 emission reduction units, 10,864,195 certified emission reduction units and 9,050,000 removal units held in the New Zealand registry (table 4 in table 12.2.2). A detailed account of the transactions made to New Zealand's national registry during 2013 is presented in section 12.2 of the inventory (table 2 (a), (b) and (c) in table 12.2.2).

New Zealand's national registry did not hold any temporary certified emission reduction units or long-term certified emissions reduction units during 2013 (table 4 in section 12.2.2).

During 2013, 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 climate change. The following sections explain how the domestic New Zealand Unit (NZU) relates to international units and how the data collected for the NZ ETS has been used to verify CO_2 emissions in the Energy and Industrial Processes sectors.

1.10.1 The New Zealand Unit

In 2008, New Zealand established the NZ ETS. The NZ ETS places 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 to surrender emission units. The NZ ETS is based around a trade in units that represent a tonne of CO_2-e. The primary unit of trade is the NZU, which is the unit created and distributed by the New Zealand Government.

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 or by awarding them to individuals or firms conducting approved removal activities (such as the establishment of forests). The Government also has the ability to auction NZUs, but has not yet done so. 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 able to surrender NZUs or approved Kyoto units 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, 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.

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

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

(c) 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 chapters 3 and 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 or other Kyoto units to cover their emissions annually. How participants estimate their emissions is set out in the regulations prescribed under the Climate Change Response Act 2002 (amended in 2012). 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	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 submission 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 were 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 emissions and removals made to the Inventory following the 2013 Inventory submission and the Centralised Inventory review in September 2013, were made in the LULUCF, Energy, Agriculture, Industrial Processes and Waste 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)

The main differences between this submission and previous estimates of New Zealand's LULUCF net removals reported in the 2013 Inventory submission are the result of (in decreasing order of magnitude):

- the inclusion for the first time of estimates of carbon stock change for natural forests. This addresses recommendations of previous expert review teams to report on carbon stock change within natural forests. This has accounted for a decrease in emissions of at least –16,000 Gg CO_2-e annually for every year of the Inventory
- completion of the 2012 land-use map and continued improvements to the 1990 and 2008 land-use maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest
- the net planted forest area for pre-1990 and post-1989 planted forest has been identified and modelled separately for this submission. This ensures the harvesting and planting activity data obtained from the Ministry for Primary Industries are consistent with the planted forest area modelled for Convention on Climate Change reporting
- returning to a Tier 2 methodology for estimating mineral soil organic carbon
- the post-1989 planted forest carbon stock yield table has been revised based on the full re-measurement of the plot network that was completed in 2012. The inclusion of additional sample plots addresses a bias in the earlier estimates caused by incomplete sampling of the forest area
- post-1989 natural forest has been identified, measured and category-specific carbon stock yield tables applied for the first time in the 2012 Inventory (2014 submission).

Energy (section 3.3.1)

A number of changes have been made since the 2013 Inventory submission to improve the accuracy, completeness and transparency of the Inventory. The most significant changes are:

- following the 2013 ERT recommendation, the natural gas used for production of methanol has been split into fuel gas and feedstock gas. The emissions from the fuel portion are shown in the CRF category 1.AA.2.C Chemicals in the Energy sector, and the emissions from the feedstock portion are described in chapter 4 (Industrial processes), section 4.3.2. The IPCC default emission factors were used for estimating emissions that resulted from combustion of gas for energy.
- natural gas used for production of ammonia/urea has been split into feedstock gas which is included in 2.B.5.5 Ammonia, and energy-use gas which is included in 1.AA.2.C Chemicals. Further details are included chapter 4 (Industrial Processes). The calculation of emissions resulting from combustion of the energy use gas uses default emission factors
- venting of natural gas has been separated from flaring and included in 1.B.2.C.1 Venting. This is in response to the 2013 ERT recommendation
- emissions of N_2O as a result of flaring have been included and are now aligned with the IPCC 1996 reporting methodology. This is in response to the 2013 ERT recommendation

- the emission factors for solid fuels have been revised for the time series 1990–2007. This is in response to the 2013 ERT recommendation. Values are now calculated by interpolation between 1990 and 2008

- an improvement has been made in the oil data system so that annual gross calorific values are used for performing conversion calculations. This applies to all liquid fuels produced by New Zealand's sole oil refinery. Previously a static gross calorific value was used

- a reallocation of fuel data has been made in the oil data system to reallocate all aviation fuel consumption data to the transport sector

- fugitive emissions resulting from oil and gas exploration have been estimated for this submission. A time series of the number of wells drilled published in Energy in New Zealand (2013) was used as activity data. Since no data was available prior to 2001, these were estimated using linear regression. Default emission factors from the IPCC Good Practice Guidance (2000) were then used to calculate emissions estimates

- the previous submission included all feedstocks and flared gas under 1.AB as carbon stored. This was done as an attempt to balance the reference and sectoral approaches. This submission only reports carbon that is stored in products under 1.AB as carbon stored

- fugitive emissions from industrial plants have been revised to include both energy use and non-energy use gas. This is in response to the 2013 ERT recommendation.

- activity data for international bunkers have been aligned to a more consistent data source. The change is summarised in the table 3.2.1. See section 3.2.2 for an explanation regarding the *Delivery of Petroleum Fuels by Industry Survey* (DPFI) and *Monthly Oil Supply Survey* (MOS). Note that the other fuels category is not covered in the DPFI so data must come from the MOS.

Agriculture (sections 6.1.4 – 6.1.6)

Two major changes to the inventory methodology in the Agriculture sector are included in the 2014 Inventory submission:

- a revised equation for partitioning of nitrogen in excreta between dung and urine

- inclusion of the mitigation technology, urease inhibitors, in the calculation of the fraction of nitrogen in fertiliser that is volatilised. This is to reflect that urease inhibitors are already in use in New Zealand

Industrial Processes (section 4.1.5)

Major improvements in the Industrial Processes sector were focussing on improving transparency in reporting emissions of fluorine containing gases, mineral products, and resolving previously noted cross-sectoral issues:

- recalculation of HFC imports since some double counting of HFC-134a imports that occurred in 2011 was identified

- other SF_6 applications subcategory where some uncertainty remains on medical and scientific uses of SF_6

- the natural gas inputs used for production of methanol and ammonia for urea production have been split into fuel gas and feedstock gas. The emissions from the fuel portion are shown in the energy sector, and the emissions from the feedstock portion are described in the industrial processes sector

- reporting of dolomite and other carbonates to address the ERT comments during the Centralised review 2013 (September 2013)
- ongoing verifications with the NZ ETS to ensure that no discrepancies occur between the NZ ETS and the Ministry of Business, Innovation and Employment (MBIE) data.

Waste (section 8.1.6)

The estimates for the Waste sector have been recalculated. Several improvements have been made to the calculation of emission estimates in the waste sector including:

- inclusion of estimates from non-municipal landfills and on-site farm fills
- incorporation of waste placement data collected under the Waste Minimisation Act 2008
- revision of historic waste placement estimates
- revision of historic waste methane correction and oxidation factors
- minor amendments to waste composition values prior to 1980
- incorporation of a 2012 waste composition estimate and a revision of the 2008 estimate
- inclusion of estimates of emissions from the wool scouring industry
- inclusion of activity data and revised parameters for the wine industry
- inclusion of activity data and revised parameters for the pulp and paper industry (sludge treatment).

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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).

1990–2012

In 1990, New Zealand's total greenhouse gas emissions were 60,641.4 Gg carbon dioxide equivalent (CO_2-e). In 2012, total greenhouse gas emissions had increased by 15,406.5 Gg CO_2-e (25.4 per cent) to 76,048.0 Gg CO_2-e (figure 2.1.1). From 1990 to 2012, the average annual growth in total emissions was 1.03 per cent per year.

The four emission sources that contributed the most to this increase in total emissions were: road transportation, agricultural soils, consumption of halocarbons and sulphur hexafluoride (SF_6), and enteric fermentation.[9]

2011–2012

Since 2011, New Zealand's total greenhouse gas emissions have increased by 1,654.5 Gg CO_2-e (2.2 per cent). The size of the overall increase is small because, although emissions from the Energy and Agriculture sectors rose, there was a decrease in emissions from the Industrial Processes and Waste sectors.

The increase in energy emissions is primarily due to an increase in emissions from electricity generation. This was largely driven by the abnormally low hydro inflows in 2012 that led to a decrease in share of electricity generated from renewable energy sources. A lower contribution from renewable energy in the national grid resulted in a higher proportion of fossil fuels based electricity generation over the year.

Total agricultural emissions in 2012 were higher than the 2011 level, which is attributable to the favourable weather and good grass growth. There was an increase in the population of dairy cattle and amount of nitrogen fertiliser used in 2012. This increase in dairy and fertiliser emissions outweighed emission reductions from decreases in non-dairy cattle and deer. The increase in dairy cattle numbers and the reduction in non-dairy cattle 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, and this increased the sale and use of nitrogen fertiliser.

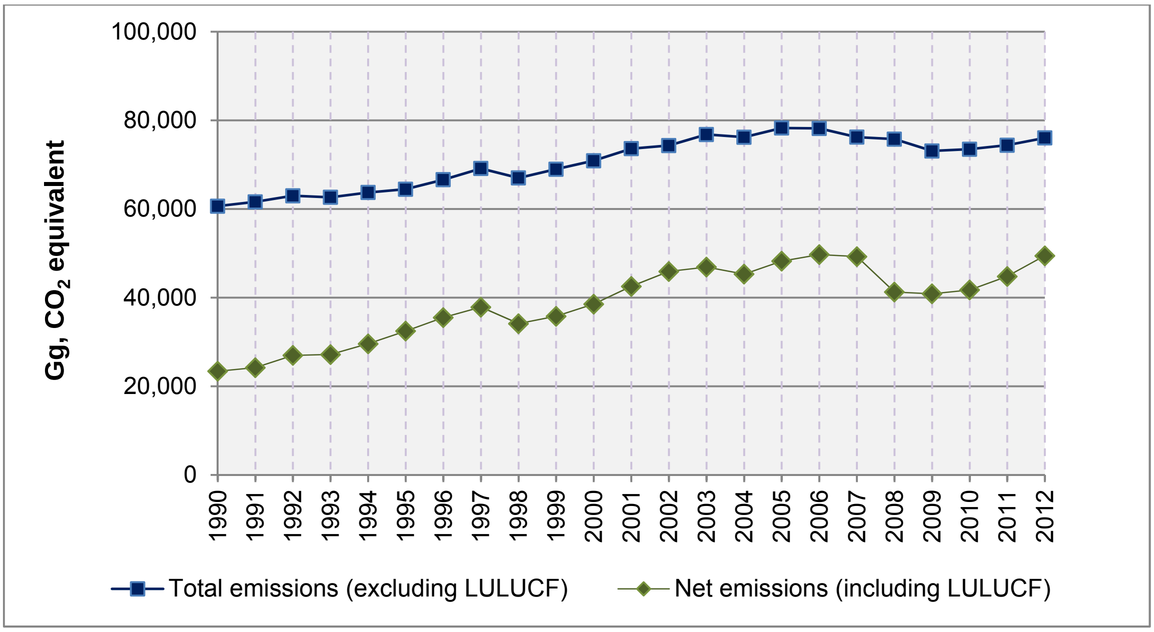
[9] Methane emissions produced from ruminant livestock.

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 23,391.1 Gg CO_2-e. In 2012, net greenhouse gas emissions had increased by 26,058.6 Gg CO_2-e (111.4 per cent) to 49,449.7 Gg CO_2-e (figure 2.1.1). The four categories that contributed the most to the increase in net emissions between 1990 and 2012 were forest land remaining forest land, dairy cattle 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 2012



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-e (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 (2008–12) 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 2012, net removals were 14,968.6 Gg CO_2-e from land subject to afforestation, reforestation and deforestation (see section 2.5 for further detail). The accounting quantity for 2012 was 15,149.5 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), SF_6, perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). Table 2.2.1 provides the change in each gas from 1990 to 2012. In 2012, 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 93 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 2012 (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

2012

Carbon dioxide contributed the largest proportion of total emissions in 2012 at 34,258.2 Gg (45.0 per cent). The largest sources of total CO_2 emissions are from road transportation and public electricity and heat production. In 2012, road transportation contributed 12,281.0 Gg (36.9 per cent) to total CO_2 emissions and public electricity and heat production contributed 6,278.3 Gg (18.9 per cent).

In 2012, net emissions of CO_2 from the LULUCF sector (as reported under the Climate Change Convention) were –26,684.1 Gg.[10] The forest land category is the biggest contributor to the sector, with net emissions of –33,164.7 Gg in 2012. Carbon dioxide emissions from afforestation and reforestation activities (as reported under Article 3.3 of the Kyoto Protocol) were –18,970.2 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 2012, CO_2 emissions from deforestation of all forests (6,762 hectares) contributed 3,969.9 Gg to net emissions. The deforestation was mainly for conversion into grassland, largely due to the relative profitability of other land uses, compared with forestry.

1990–2012

Total CO_2 emissions have increased by 9,342.3 Gg (37.5 per cent) from the 1990 level of 24,915.9 Gg. The two largest sources of this growth were the increased emissions from road transportation and public electricity and heat production.

Between 1990 and 2012, the net CO_2 removals from LULUCF have decreased by 10,630.4 Gg CO_2 (28.5 per cent) from the 1990 level of –37,314.6 Gg. This decrease is largely the result of increased harvesting and deforestation since 1990.

2011–2012

Between 2011 and 2012, total CO_2 emissions increased 999.7 Gg (3 per cent). The increase in CO_2 emissions from the Energy sector is primarily due to an increase in emissions from electricity generation. The main driver that led to the increase in emissions from electricity generation was abnormally low hydro inflows in 2012 that led to a decrease in share of electricity generated from renewable energy sources. A lower contribution from renewable

[10] In climate change literature, negative emissions are often referred to as 'removals' because they indicate removing carbon dioxide from the atmosphere as a net result. This report uses the term 'removal' or 'net removal' when it makes the relevant sections easier to understand.

energy in the national energy grid resulted in a higher proportion of fossil fuel based electricity generation over the year.

Between 2011 and 2012, net emissions from the LULUCF sector increased by 2,980.5 Gg (10.0 per cent). The main contributor to the change occurred within the forest land category as a greater proportion of forest reached either harvest or thinning age in 2012 due to the age class profile of New Zealand's production forests. Emissions have also increased in the grassland category due to larger areas of forest land being converted to grassland in 2012, than in 2011.

Between 2011 and 2012, CO_2 emissions from the deforestation of all forests increased by 615.6 Gg (18.4 per cent) as there was a larger area deforested in 2012, than in 2011.

Methane

2012

Methane contributed 29,038.5 Gg CO_2-e (38.2 per cent) to total emissions in 2012. 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, and also goats. In 2012, enteric fermentation CH_4 from all livestock contributed 23,935.9 Gg CO_2-e (83.6 per cent) to total CH_4 emissions.

1990–2012

In 2012, CH_4 emissions increased by 2,203.8 Gg CO_2-e (8.2 per cent) from the 1990 level of 26,834.7 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 2012 has led to a decrease in CH_4 from enteric fermentation from sheep by 3,769.9.6 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 5,808.4 Gg CO_2-e.

2011–2012

Between 2011 and 2012, CH_4 emissions increased 412.9 by Gg CO_2-e (1.4 per cent) primarily due to the increase in emissions from dairy cattle enteric fermentation.

Nitrous oxide

2012

Nitrous oxide contributed 10,885.7 Gg CO_2-e (14.3 per cent) to total emissions in 2012. The largest source of N_2O emissions is from agricultural soils. In 2012, the agricultural soils category contributed 10,340.8 Gg CO_2-e (97.1 per cent) to New Zealand's total N_2O emissions.

1990–2012

In 2012, N_2O emissions increased by 2,639.9 Gg CO_2-e (32.0 per cent) from the 1990 level of 8,245.8 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 a six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2012 period, which has resulted in an increase of direct N_2O emissions from synthetic fertiliser use from 259.8 Gg CO_2-e in 1990 to 1,594.1 Gg CO_2-e in 2012.

2011–2012

Between 2011 and 2012, emissions of N_2O increased by 241.5 Gg CO_2-e (2.3 per cent). This was largely due to an increase in the amount of nitrogen fertiliser applied to agricultural soils under pasture. The dairy industry is the main user of nitrogen fertiliser in New Zealand.

Hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride

In 2012, HFCs, PFCs and SF_6 contributed the remaining 1,1865.6 Gg CO_2-e (2.5 per cent) to total emissions.

In 1990, no HFCs were used in New Zealand and, therefore, no percentage is shown in table 2.2.1. In 2012, 1,804.7 Gg CO_2-e of HFC emissions occurred. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons, which were phased out under the Montreal Protocol.

Emissions of PFCs have decreased by 589.1 Gg CO_2-e (93.5 per cent) from the 629.9 Gg CO_2-e in 1990 to 40.8 Gg CO_2-e in 2012. This decrease is the result of improvements in the aluminium smelting process.

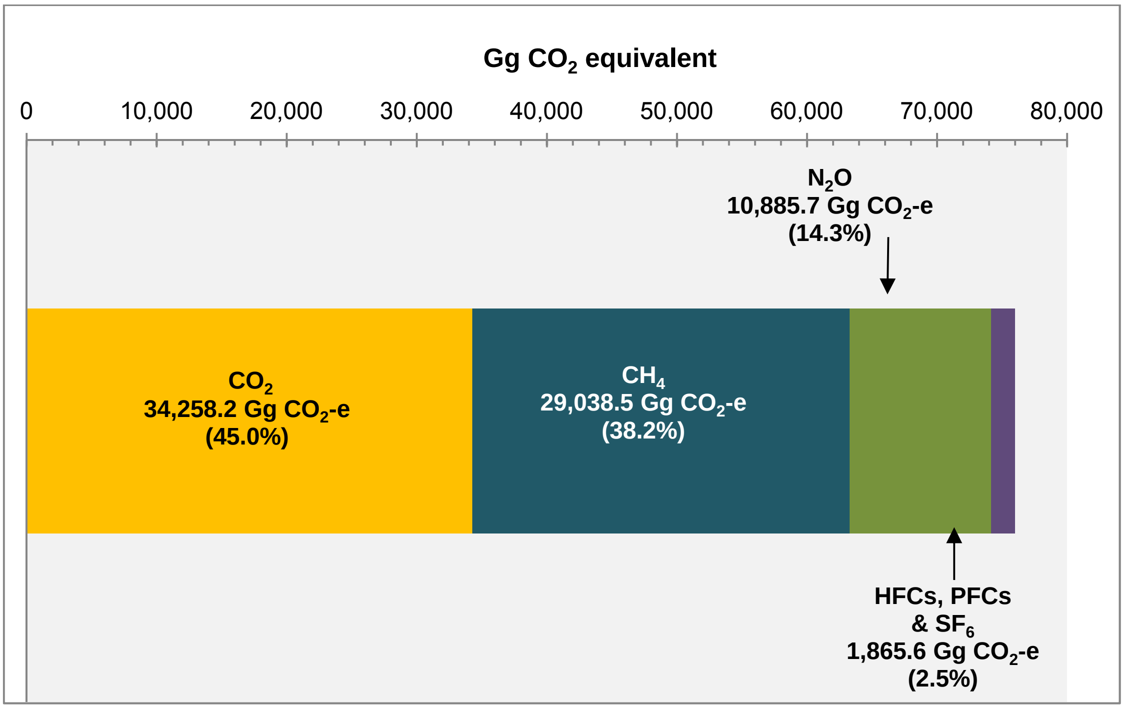
Emissions of SF_6 have increased by 5.0 Gg CO_2-e (32.8 per cent) from the 1990 level of 15.2 Gg CO_2-e. The majority of SF_6 emissions are from use in electrical equipment.

Table 2.2.1 New Zealand's total (gross) emissions by gas in 1990 and 2012

Direct greenhouse gas emissions	Gg CO_2 equivalent 1990	2012	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
CO_2	24,915.9	34,258.2	+9,342.3	+37.5
CH_4	26,834.7	29,038.5	+2,203.8	+8.2
N_2O	8,245.8	10,885.7	+2,639.9	+32.0
HFCs	NO	1,804.7	+1,804.7	NA
PFCs	629.9	40.8	–589.1	–93.5
SF_6	15.2	20.2	+5.0	+32.8
Total	**60,641.4**	**76,048.0**	**+15,406.5**	**+25.4**

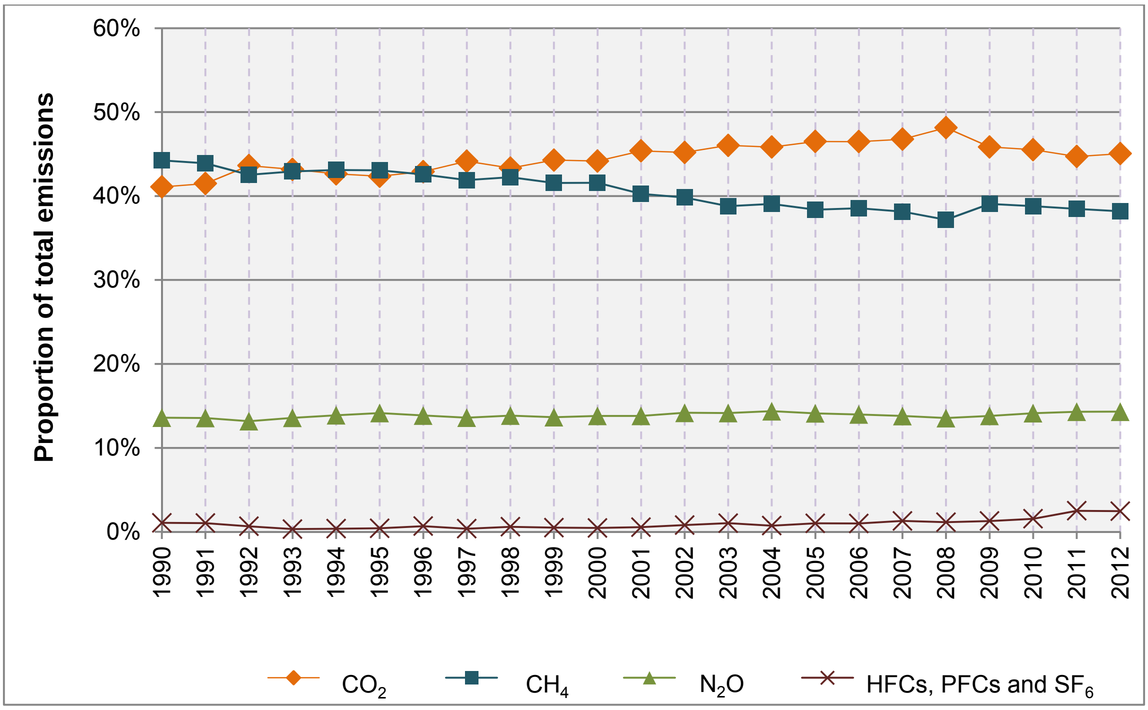
Note: Total emissions exclude net removals from the LULUCF sector. The per cent change for hydrofluorocarbons is not applicable (NA) as production of hydrofluorocarbons in 1990 was not occurring (NO). Columns may not total due to rounding.

Figure 2.2.1 **New Zealand's total emissions by gas in 2012**



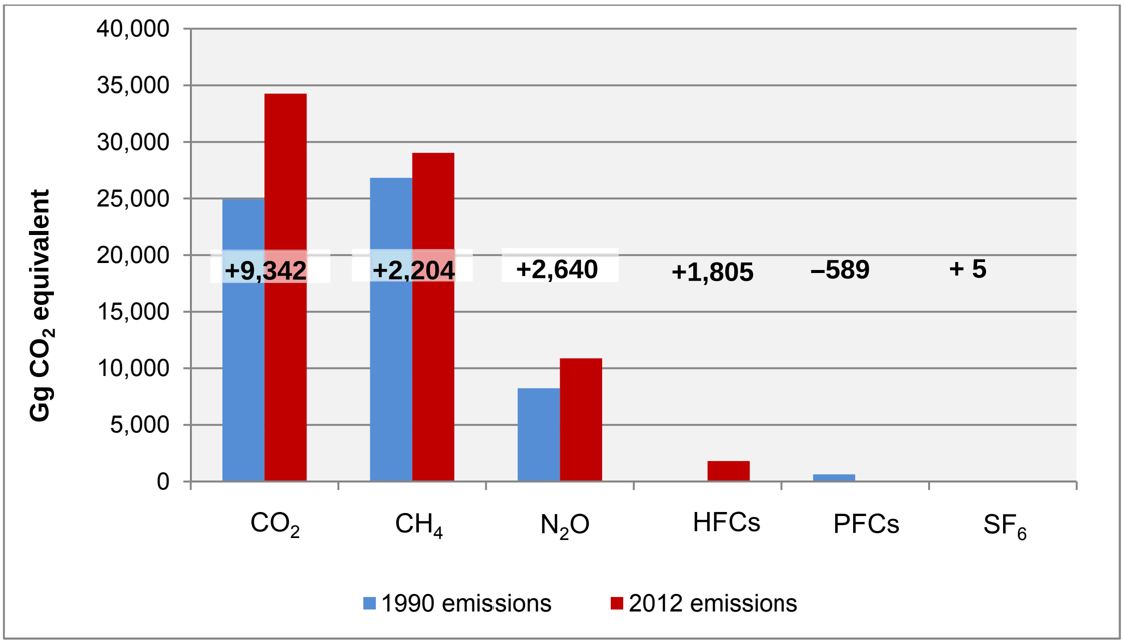
Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.2.2 **Proportion that gases contributed to New Zealand's total emissions from 1990 to 2012**



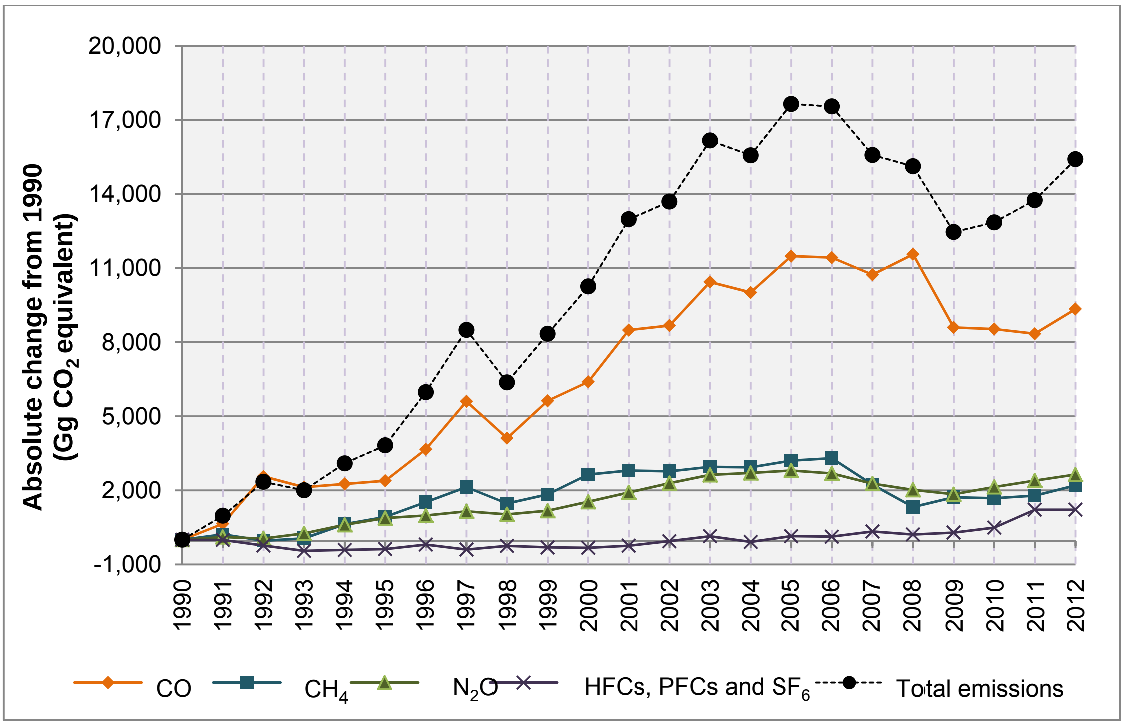
Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.2.3 Change in New Zealand's total emissions by gas in 1990 and 2012



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

Figure 2.2.4 Change in New Zealand's total emissions by gas from 1990 to 2012



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 2012 (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 2012 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)

2012

The Energy sector was the source of 32,121.3 Gg CO_2-e (42.2 per cent) of total emissions in 2012. The largest sources of emissions in the Energy sector were road transportation, contributing 12,439.9 Gg CO_2-e (38.7 per cent), and public electricity and heat production, contributing 6,299.9 Gg CO_2-e (19.6 per cent).

1990–2012

In 2012, emissions from the Energy sector had increased by 36.3 per cent (8,560.9 Gg) above the 1990 level of 23,560.4 Gg CO_2-e. This growth in emissions is primarily from road transportation, which increased by 5,033 Gg CO_2-e (68.0 per cent), and public electricity and heat production, which increased by 2,834 Gg CO_2-e (81.8 per cent).

2011–2012

Between 2011 and 2012, emissions from the Energy sector increased by 899.5 Gg CO2-e (2.9 per cent). This increase is primarily due to an increase in emissions from public electricity and heat production. This resulted from a change of proportion between different sources of electricity generation in New Zealand's national grid. Due to abnormally low hydro inflows, the share of electricity generated from renewable energy sources in the national energy grid dropped from 77 per cent in 2011 to 73 per cent in 2012. This resulted in increased gas and coal based electricity generation over the year. Electricity generation from coal increased 63.7 per cent from 2011.

Industrial processes (chapter 4)

2012

In 2012, New Zealand's Industrial Processes sector produced 5,276.8 Gg CO_2-e, contributing 6.9 per cent of New Zealand's total greenhouse gas emissions. The largest source of industrial processes emissions is the metal production category (CO_2 and a small amount of PFCs), contributing 43.2 per cent of Industrial Processes sector emissions in 2012.

1990–2012

In 2012, emissions from the Industrial Processes sector increased by 2,014.7 Gg CO_2-e (61.8 per cent) above the 1990 level of 3,262.1 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 1,812.5 Gg CO_2-e. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons, which were phased out under the Montreal Protocol. Also, CO_2 emissions from mineral, chemical and metals production have gradually increased due to increasing product outputs. These increases have been partially offset by a reduction in emissions of PFCs from aluminium production, due to improved control of anode effects in aluminium smelting.

2011–2012

Since 2011, emissions from the Industrial Processes sector decreased by 7.3 Gg CO_2-e (less than 1 per cent). The change was a result of a combination of several factors: emissions of CO_2 showed a slight increase because of increased cement production (38.9 Gg, 0.7 per cent) and the re-opening of the urea production plant at the end of 2011 (20.8 Gg, 0.4 per cent). Meanwhile, the emissions from metal production have decreased by 56.9 Gg (1.1 per cent) due to fluctuations in output for these products. Emissions from the use of halocarbons and SF_6 decreased by 10.1 Gg CO_2-e (0.2 per cent). This may be associated with the introduction of obligations under the New Zealand Emissions Trading Scheme (NZ ETS) for these gases.

Solvent and other product use (chapter 5)

In 2012, the Solvent and Other Product Use sector was responsible for 34.1 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)

2012

New Zealand has an unusual emissions profile amongst developed countries with the Agriculture sector being the largest source of emissions. In 2012 this sector contributed 35,020.1 Gg CO_2-e (46.1 per cent of total emissions). In Annex I countries, agricultural emissions average around 12 per cent of total emissions.

The largest sources of emissions from the Agriculture sector in 2012 were from enteric fermentation (CH_4 emissions) and from agricultural soils (N_2O emissions).

1990–2012

In 2012, New Zealand's Agriculture sector emissions increased by 4,549.2 Gg CO_2-e (14.9 per cent) from the 1990 level of 30,471.0 Gg CO_2-e. This increase is largely due to the increase of CH_4 emissions from the enteric fermentation from dairy cattle and N_2O emissions from agricultural soils.

2011–2012

Since 2011, emissions from the Agriculture sector increased by 806.6 Gg CO_2-e (2.4 per cent). This is caused by an increase in the dairy cattle population and the amount of nitrogen applied as fertiliser, since the dairy industry is the main user of nitrogen fertiliser in New Zealand.

The increase in dairy cattle and fertiliser emissions outweighed emission reductions from decreases in the population of non-dairy cattle and deer. The increase in dairy cattle numbers and the reduction in non-dairy cattle and deer populations 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 on Article 3.3 activities under the Kyoto Protocol see section 2.5.

2012

In 2012, net emissions from the LULUCF sector under the Climate Change Convention were –26,598.3 Gg CO_2-e. The highest contribution to the removals in 2012 was from land converted to forest land.

The largest source of emissions in LULUCF is from land converted to grassland. In 2012, net emissions for land converted to grassland contributed 3,940.4 Gg CO_2-e to the sector total. This is largely due to biomass loss on land-use conversion.

1990–2012

Between 1990 and 2012, net emissions from LULUCF increased by 10,652.0 Gg CO_2-e (28.6 per cent) from the 1990 level of –37,250.4 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 emissions from LULUCF across the time series (figure 2.3.5) are influenced by the age class profile of New Zealand's production forests particularly in regard to 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 NZ ETS.[11] The decrease in net removals since 2008 is due to the increase in harvesting that has been occurring in New Zealand's production forests.

2011–2012

Between 2011 and 2012, net emissions from LULUCF increased by 2,996.5 Gg CO_2-e (10.1 per cent). The main contributor to the change was a greater proportion of forest land reaching either harvest or thinning age in 2012, compared with 2011, due to the age-class profile of New Zealand's production forests.

Waste (chapter 8)

The Waste sector contributed 3,595.7 Gg CO_2-e (4.7 per cent) to total emissions in 2012.

Emissions from the Waste sector have increased by 289.2 Gg CO_2-e (8.8 per cent) from the 1990 level of 3,306.4 Gg CO_2-e. This growth in emissions can generally be attributed to the growth in New Zealand's population and gross domestic product. The increase in population resulted in an increase in the total volume of wastewater processed and the amount of organic matter in the wastewater.

The other source of increase in emissions from the Waste sector is an increasing amount of solid waste disposal on land, specifically, in non-municipal and on-site farm landfills.

Meanwhile, there has been a decrease in waste placement at municipal landfills.

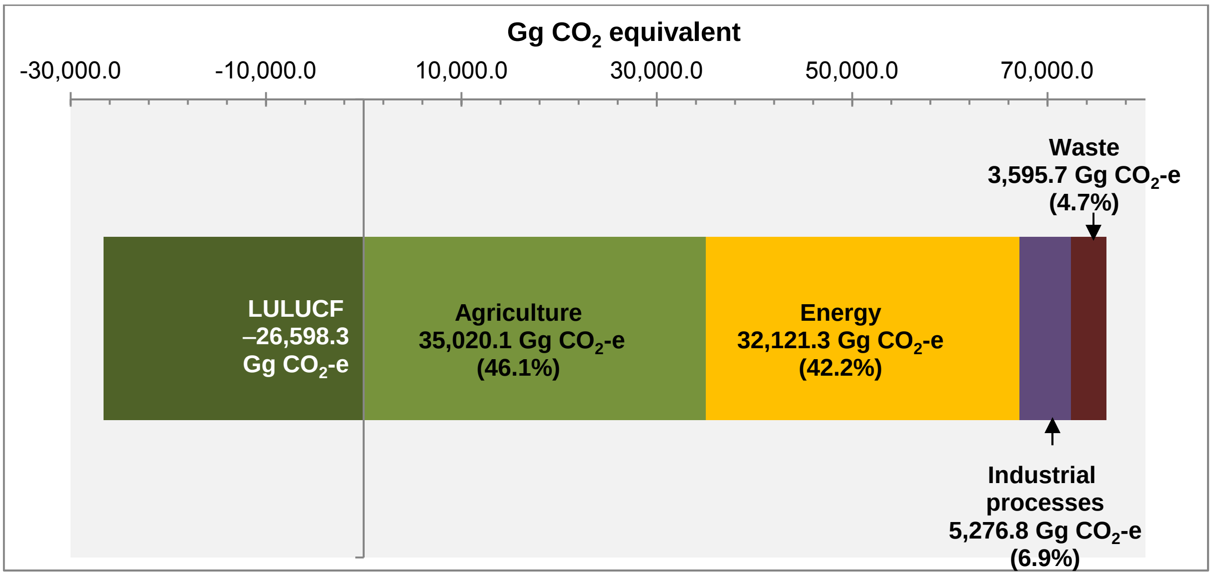
[11] The New Zealand Emissions Trading Scheme included the forestry sector as of 1 January 2008.

Table 2.3.1 New Zealand's emissions by sector in 1990 and 2012

Sector	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2012	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
Energy	23,560.4	32,121.3	+8,560.9	+36.3
Industrial processes	3,262.1	5,276.8	+2,014.7	+61.8
Solvent and other product use	41.5	34.1	–7.4	–17.9
Agriculture	30,471.0	35,020.1	+4,549.2	+14.9
Waste	3,303.6	3,595.7	+289.2	+ 8.8
Total (excluding LULUCF)[12]	**60,641.4**	**76,048.0**	**+15,406.5**	**+25.4**
LULUCF	–37,250.4	–26,598.3	+10,652.0	+28.6
Net Total (including LULUCF)	**23,391.1**	**49,449.7**	**+26,058.6**	**+111.4**

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

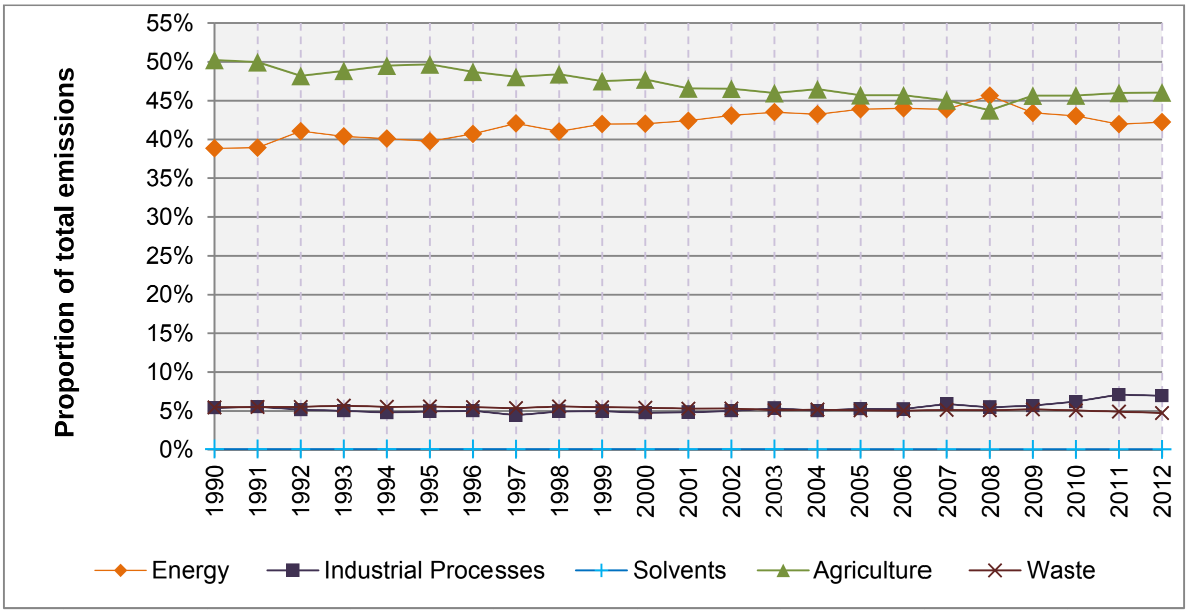
Figure 2.3.1 New Zealand's emissions by sector in 2012



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).

[12] The totals may not add up with the 1 decimal point precision due to rounding

Figure 2.3.2 Proportion that sectors contributed to New Zealand's total emissions from 1990 to 2012



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 2012

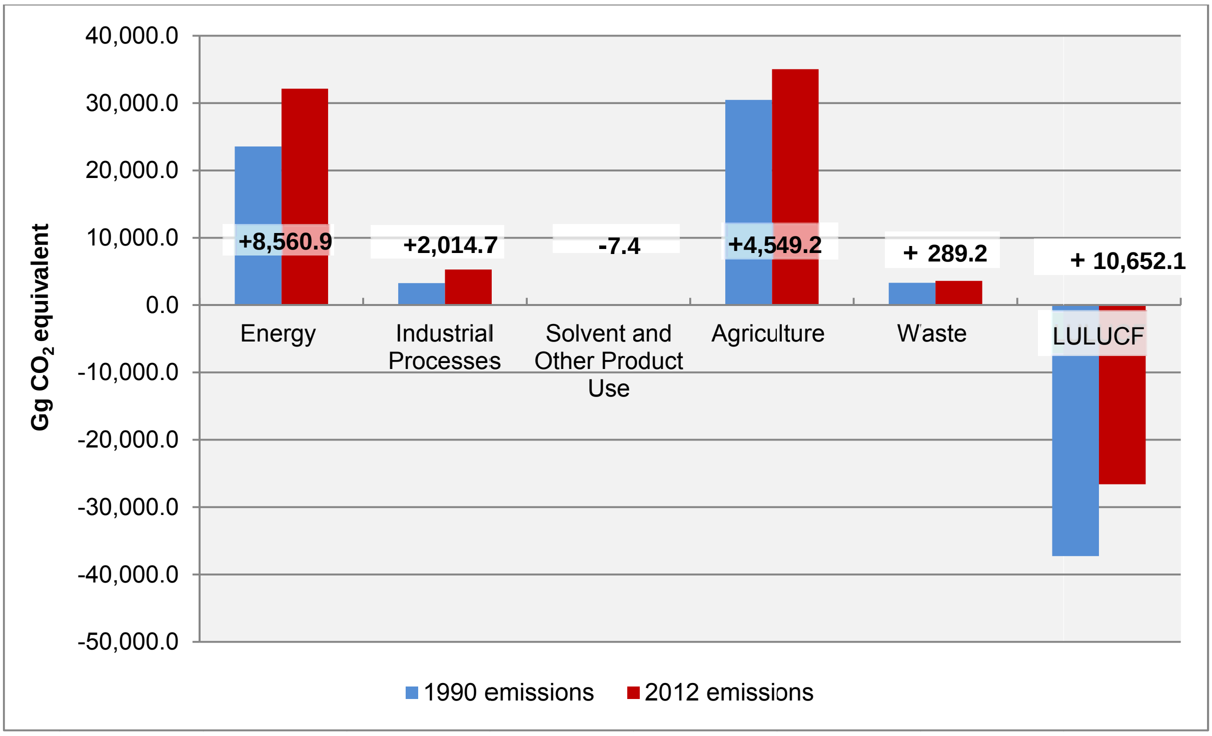
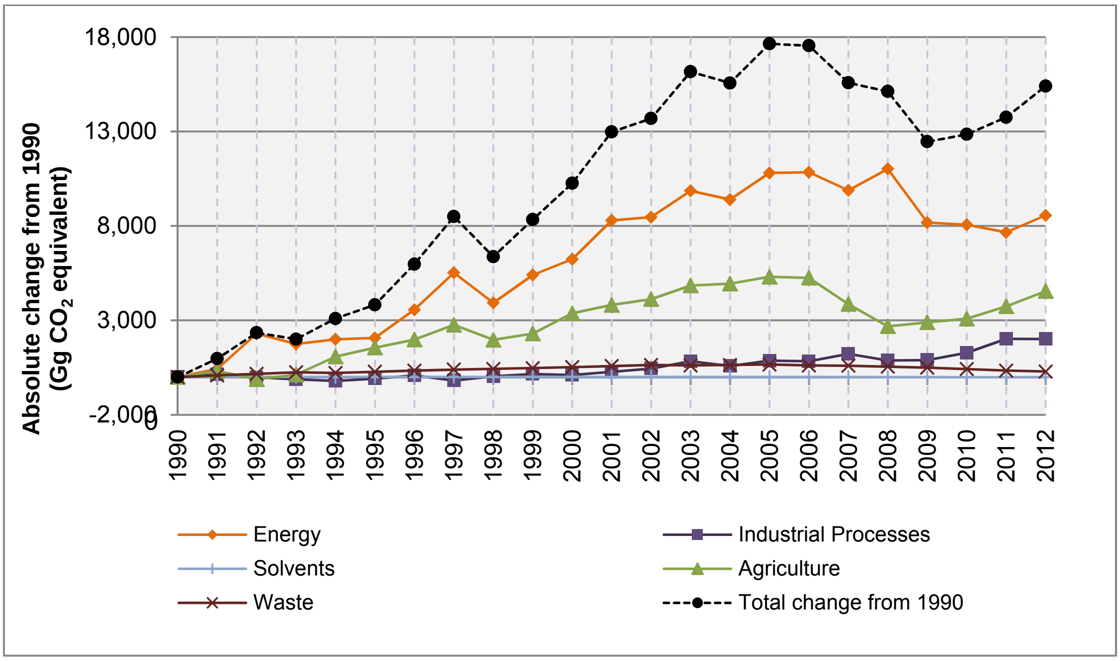
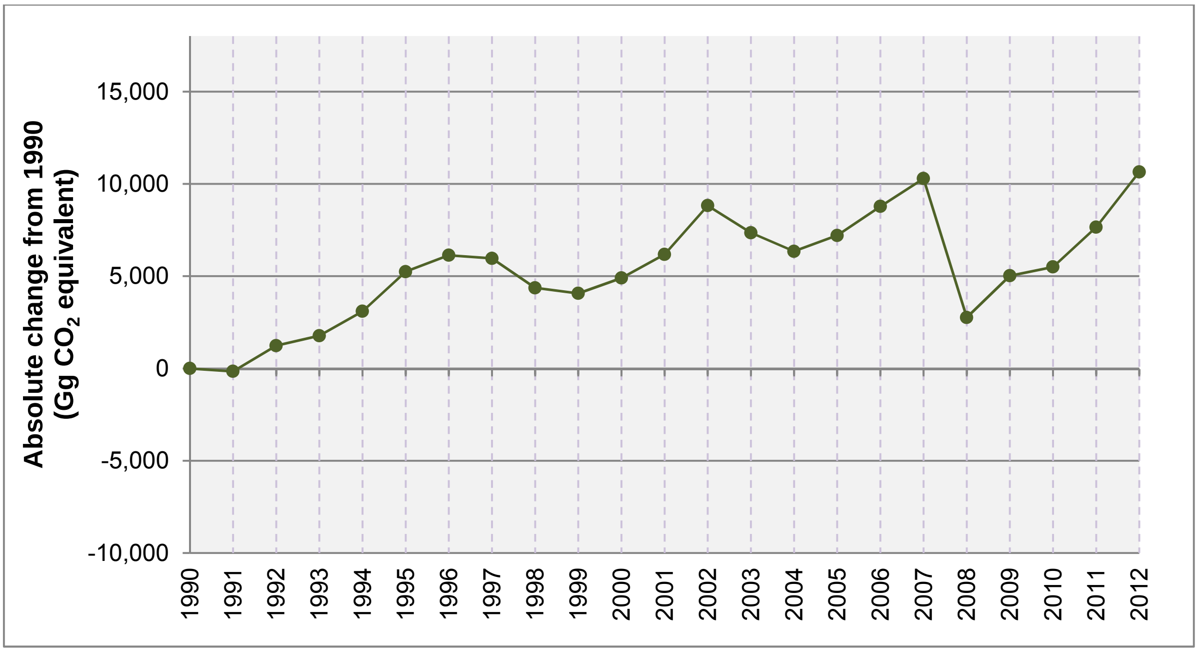


Figure 2.3.4 Absolute change from 1990 in New Zealand's total emissions by sector from 1990 to 2012



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

Figure 2.3.5 Absolute change from 1990 in New Zealand's net emissions from the LULUCF sector from 1990 to 2012 (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 2012 are shown in table 2.4.1. Consistent with the 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 2012

Indirect gas	Gg of gas(es) 1990	2012	Change from 1990 (Gg)	Change from 1990 (%)
NO_x	100.5	158.5	+58.0	+57.7
CO	644.9	714.2	+69.32	+10.7
NMVOCs	132.9	169.9	+37.0	+27.8
SO_2	58.4	78.2	+19.76	+33.8
Total	**936.7**	**1,120.7**	**+184.0**	**+19.6**

Note: Columns may not total due to rounding.

Emissions of CO and NO_x are largely from the Energy sector. The Energy sector produced 88.8 per cent of total CO emissions in 2012. 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 (98.1 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 71.6 per cent of NMVOC emissions in 2012. Emissions from road transportation comprised 59.3 per cent of total NMVOC emissions. Other major sources of NMVOCs were in the Solvent and Other Product Use sector (21.0 per cent) and the Industrial Processes sector (7.4 per cent).

In 2012, emissions of SO_2 from the Energy sector comprised 86.0 per cent of total SO_2 emissions. The energy industries category contributed 18.2 per cent, manufacturing industries and construction category 35.6 per cent and the transport category 15.5 per cent of total SO_2 emissions. The industrial processes sector contributed 14.0 per cent of total SO_2 emissions. Aluminium production accounted for 8.3 per cent of SO_2 emissions.

2.5 Article 3.3 activities under the Kyoto Protocol

In 2012, net removals from land subject to afforestation, reforestation and deforestation (Article 3.3 activities under the Kyoto Protocol) were 14,968.6 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
- emissions associated with nitrogen fertiliser use on afforested and reforested land because these are reported and accounted for in the Agriculture sector. The notation key IE (included elsewhere) is reported in the common reporting format tables for direct N2O emissions from nitrogen fertilisation associated with afforestation and reforestation.

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2012 was 654,354 hectares. The net area is the total area of post-1989 forest (674,945 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (20,591 hectares). Net removals for land included under afforestation and reforestation in 2012 were 18,965.1 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2012 was 151,544 hectares.[13] The area subject to deforestation in 2012 was 6,762 hectares. In 2012, deforestation emissions were 3,996.5 Gg CO_2-e, compared with 3,376.0 Gg CO_2-e in 2011 (an 18.4 per cent increase). Deforestation emissions include non-carbon emissions and lagged CO_2 emissions that occurred in 2012 as a result of deforestation since 1990. Lagged emissions include the liming of forest land converted to grassland and cropland, biomass burning associated with deforestation and 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 for the period 2008–12

	2008	2009	2010	2011	2012
Afforestation/reforestation (AR)					
Net cumulative area since 1990 (ha)	621,401	623,924	629,782	642,382	654,354
Area in calendar year (ha)	2,324	5,024	6,940	13,692	12,539
Emissions from AR land not harvested in CP1 (Gg CO_2-e)	–17,405.4	–17,957.2	–18,458.1	–18,828.8	–19,145.9
Emissions from AR land harvested in CP1 (Gg CO_2-e)	41.9	121.1	265.0	253.1	180.8
Emissions in calendar year (Gg CO_2-e)	–17,363.5	–17,836.0	–18,193.1	–18,575.7	–18,965.1
Deforestation					
Net cumulative area since 1990 (ha)	121,030	131,434	138,656	144,783	151,544
Area in calendar year (ha)	5,984	10,405	7,222	6,127	6,762
Emissions in calendar year (Gg CO_2-e)	3,166.9	5,616.0	4,087.2	3,376.0	3,996.5

13 Deforestation includes deforestation of natural forest, pre-1990 planted forest and post-1989 forest.

Total area subject to afforestation, reforestation and deforestation	742,431	755,359	768,438	787,165	805,898
Net emissions (Gg CO_2-e)	**–14,196.6**	**–12,220.0**	**–14,105.9**	**–15,199.7**	**–14,968.6**
Accounting quantity (Gg CO_2-e)	**–14,238.5**	**–12,341.2**	**–14,370.9**	**–15,452.8**	**–15,149.5**

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

3.1.1 Introduction

In New Zealand, the Energy sector covers both combustion emissions resulting from fuel being burnt to produce useful energy and fugitive emissions resulting from production, transmission and storage of fuels, and from non-productive combustion that includes venting of carbon dioxide (CO_2) at gas treatment plants, gas flaring at oil production facilities and emissions from geothermal fields.

Historically, combustion emissions from road transport and public electricity and heat production constituted the largest share of domestic emissions from the Energy sector in New Zealand. New Zealand has one of the highest rates of car ownership among members of the Organisation for Economic Co-operation and Development (OECD) and a relatively old vehicle fleet. Like many other countries, the majority of freight is transported by emission-intensive trucks rather than by train or coastal shipping, which are less emission-intensive.

Due to New Zealand's sparse population and rural-based economy, New Zealand's domestic transport emissions per capita are high when compared with many other Annex 1 countries.

Electricity generation from the combustion of coal, oil and gas supports New Zealand's highly renewable electricity system. In 2012, fossil fuel thermal plants provided 28 per cent of New Zealand's total electricity supply, which is low by international standards due to the high proportion of demand met by hydro generation as well as other renewable sources (eg, wind). While this provides a strong base in good hydro years, electricity emissions remain sensitive to rainfall in the key catchment areas.

Fugitive emissions present a relatively minor portion in New Zealand's energy emissions profile. The main sources of New Zealand's fugitive emissions include coal mining operations, production and processing of natural gas (largely venting and flaring) and geothermal operations (largely for electricity generation).

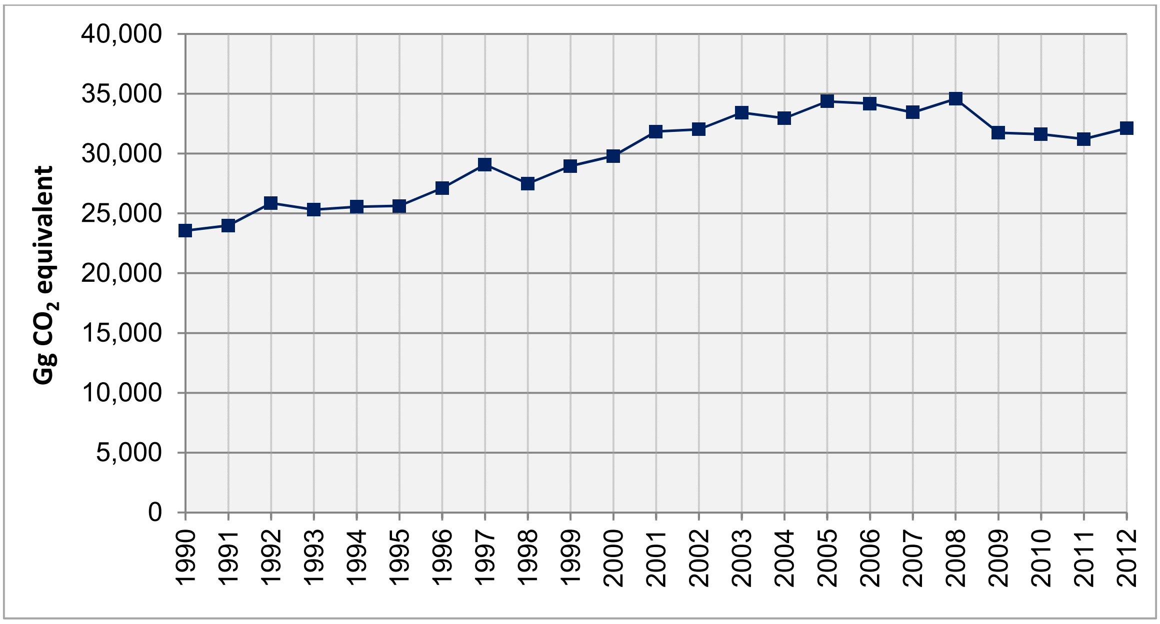
2012

In 2012, the Energy sector produced 32,121 Gg carbon dioxide equivalent (CO_2-e), representing 42.4 per cent of New Zealand's total greenhouse gas emissions. The largest sources of emissions in the Energy sector were road transportation, contributing 12,439 Gg CO_2-e (38.7 per cent), and public electricity and heat production, contributing 6,299.94 Gg CO_2-e (19.6 per cent) to energy emissions.

1990–2012

In 2012, emissions from the Energy sector had increased by 36.3 per cent (8,561 Gg) above the 1990 level of 23,560 Gg CO_2-e. Figure 3.1.1 shows the time series from 1990 to 2012. This growth in emissions is primarily from road transportation, which increased by 5,033 Gg CO_2-e (68.0 per cent), and public electricity and heat production, which increased by 2,834 Gg CO_2-e (81.8 per cent). Emissions from the subcategory 1.A.1.c manufacture of solid fuels and other energy industries have decreased by 1,320 Gg CO_2-e (76.8 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997.

Figure 0.1 New Zealand's Energy sector emissions (1990–2012)



2011–2012

Between 2011 and 2012, emissions from the Energy sector increased by 899.5 Gg CO_2-e (2.9 per cent). This is primarily due to a 1,222 Gg CO_2-e (24.1 per cent) increase in emissions from subcategory 1.AA.1.A Public electricity and heat production as a result of the following.

- The share of electricity generated from renewable energy sources was 73 per cent in 2012. This was lower than in 2011 (77 per cent) due to abnormally low hydro inflows.
- This resulted in increased gas and coal-based electricity generation over the year. Electricity generation from coal increased 63.7 per cent from 2011.

There was also a 312 Gg CO_2-e (12.5 per cent) decrease in sector 1.B Fugitive emissions. This was due to reduced activity in subcategory 1.B.1.A Coal mining and handling, as well as reductions in the subcategories 1.B.2.B Natural gas and 1.B.2.C Venting and flaring.

There was also a 288 Gg CO_2-e (2.0 per cent) decrease in emissions from sector 1.AA.3 Transport.

3.1 Key categories in the Energy sector

Full details of New Zealand's key category analysis are presented in section 1.5. Table 3.1.1 presents the key source categories of 1.A fuel combustion activities and 1.B Fugitive emissions from fuels.

Table 3.1.1 Key sources of 1.A fuel combustion activities including LULUCF

IPCC category	Category name	Greenhouse gas	Key source assessment
1.A.3.a	Transport – civil aviation – jet kerosene	CO_2	LA, TA
1.A.3.d	Transport – navigation – residual oil	CO_2	LA
1.A.3.b	Transport – road transport – diesel oil	CO_2	LA, TA
1.A.3.b	Transport – road transport – gasoline	CO_2	LA, TA
1.A.3.b	Transport – road transport – gaseous fuels	CO_2	TA
1.A.3.b	Transport – road transport – liquefied petroleum gases	CO_2	TA
1.A.1.c	Energy industries – manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	LA, TA
1.A.1.b	Energy industries – petroleum refining – liquid fuels	CO_2	LA, TA
1.A.1.b	Energy industries – petroleum refining – gaseous fuels	CO_2	TA
1.A.1.a	Energy industries – public electricity and heat production – gaseous fuels	CO_2	LA, TA
1.A.1.a	Energy industries – public electricity and heat production – solid fuels	CO_2	LA, TA
1.A.2.c	Manufacturing industries and construction – chemicals – gaseous fuels	CO_2	LA, TA
1.A.2.e	Manufacturing industries and construction – food processing, beverages and tobacco – liquid fuels	CO_2	LA, TA
1.A.2.e	Manufacturing industries and construction – food processing, beverages and tobacco – solid fuels	CO_2	LA, TA
1.A.2.e	Manufacturing industries and construction – food processing, beverages and tobacco – gaseous fuels	CO_2	LA
1.A.2.f	Manufacturing industries and construction – other – mining and construction – liquid fuels	CO_2	LA, TA
1.A.2.f	Manufacturing industries and construction – other – other non-specified – liquid fuels	CO_2	TA
1.A.2.f	Manufacturing industries and construction – other – other non-specified – solid fuels	CO_2	TA
1.A.2.f	Manufacturing industries and construction – other – non-metallic minerals – solid fuels	CO_2	LA
1.A.2.d	Manufacturing industries and construction – pulp, paper and print – gaseous fuels	CO_2	LA, TA
1.A.4.c	Other sectors – agriculture/forestry/fisheries – liquid fuels	CO_2	LA, TA
1.A.4.c	Other sectors – agriculture/forestry/fisheries – solid fuels	CO_2	LA, TA
1.A.4.a	Other sectors – commercial/institutional – gaseous fuels	CO_2	LA, TA
1.A.4.a	Other sectors – commercial/institutional – liquid fuels	CO_2	LA, TA
1.A.4.b	Other sectors – residential – gaseous fuels	CO_2	LA, TA
1.A.4.b	Other sectors – residential – solid fuels	CO_2	TA
1.B.1.a.1	Fugitive – coal mining and handling – underground mines	CH_4	TA
1.B.2.c.3	Fugitive – flaring – combined	CO_2	TA
1.B.2.b.4	Fugitive – natural gas – distribution	CH_4	TA
1.B.2.b.5	Fugitive – natural gas – other leakage	CH_4	LA, TA
1.B.2.b.2	Fugitive – natural gas – production/processing	CO_2	LA, TA
1.B.2.d	Fugitive – other – geothermal	CO_2	LA, TA

Note: LA = level assessment (if not further specified – for the years 1990 and 2012); TA = trend assessment 2012.

3.1.1 Energy flows

This inventory 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 2012 calendar year.

3.1.2 Ministry nomenclature

In July 2012, the Ministry of Economic Development was merged with the Ministry of Science and Innovation, the Department of Labour and the Department of Building and Housing to become the Ministry of Business, Innovation and Employment. For this submission, historical references to the Ministry of Economic Development have been changed to the Ministry of Business, Innovation and Employment.

3.1 Background information

3.1.1 Reference approach versus sectoral 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 on a regular basis through various surveys. For verification, New Zealand has also applied a reference approach to estimate CO_2 emissions from fuel combustion for the time series 1990–2012.

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 the Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1996).

$$Apparent\ consumption = Production + Imports - Exports$$
$$- International\ bunkers - Stock\ change$$

Each *apparent consumption* is then multiplied by a carbon emission factor to obtain an estimate of carbon emissions from combustion. The quantity of carbon stored through industrial processes such as 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 carbon dioxide/carbon ratio (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 emission factors for liquid fuels are based on annual carbon content and the gross calorific value data provided by New Zealand's only oil refinery, Refining New Zealand. Where this data is not available, an IPCC 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 2014 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 3.3.2.

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 released along with *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2013).

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 Business, Innovation and Employment, 2013) 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 Business, Innovation and Employment. Before 2008, various energy statistics were collected by Statistics New Zealand or the Ministry of Business, Innovation and Employment. The change resulted in a more consistent and transparent approach to energy data collection as one agency collected data across the supply chain.

3.1.2 International bunker fuels

The data on fuel use by international transportation is collected and published online by the Ministry of Business, Innovation and Employment (2013a). This data release 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* (DPFI) survey conducted by the Ministry of Business, Innovation and Employment.

Some of the international bunkers data in common reporting format (CRF) table 1.A.b is from the *Monthly Oil Supply* (MOS) survey, whereas the international bunkers data in CRF table 1.C is from the DPFI survey. See section 3.2.7 for a description of changes since the previous submission. The DPFI survey is a quarterly sectoral breakdown of observed demand (ie, actual sales figures to different industries, one of which is international bunkers). The MOS survey is collected monthly and is a liquid fuels supply balance provided by companies selling fuels, of which one category is 'international bunkers'. Companies who respond to the DPFI survey are requested to reconcile their figures with respect to their figures in the MOS survey. Discrepancies between the surveys are usually very small, and the companies explain differences between the two data-sets as the MOS survey following a top-down approach and the DPFI following a bottom-up approach. Furthermore, the MOS and DPFI surveys are usually reported by different sections within the oil companies.

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 3.3.8.

International bunker fuel is not subject to goods and services tax (GST) in New Zealand, whereas fuel sold for fishing vessels and so on is subject to GST. The liquid fuel retailers are able to accurately eliminate international bunker sales because of the fact that GST is not charged on these sales.

3.1.3 Feedstock and non-energy use of fuels

For some industrial companies, the fuels supplied are used both as a fuel and 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 CRF table 1.A.d.

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

- Much of the carbon in natural gas used to produce methanol is stored in the product and therefore has no associated emissions. The balance of the carbon is oxidised and results in CO2 emissions reported under the associated sector.
- Emissions from the use of natural gas used in urea production (feedstock) are reported under the industrial processes sector.
- Bitumen produced in New Zealand is not used as a fuel but rather by the companies Fulton Hogan and Downer EDi as a road construction material (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.

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.

3.1.4 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 2012.

3.1.5 Country-specific issues

Reporting of the Energy sector has few areas of divergence from the IPCC guidelines (IPCC, 1996 and 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 to the IPCC guidelines (IPCC, 1996). This creates inconsistent boundaries for table 1.AC difference – reference and sectoral approach; emissions from coal use in iron and steel production appear in the reference approach but not in the sectoral approach.

Reference approach – Natural gas flaring

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, CRF 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 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 CO_2 emissions from flared gas have therefore been added to the sectoral approach to reconcile differences with the reference approach for comparison purposes in section 3.3.1.

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 were previously reported under 1.AA.2.C chemicals rather than 2. industrial processes. For this submission, only energy-use emissions are included in 1.AA.2.C. See section 3.1.7 for further explanation.

3.1.6 Energy balance

Energy in New Zealand (Ministry of Business, Innovation and Employment, 2013) is an annual publication from the Ministry of Business, Innovation and Employment. 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-in-new-zealand-2013. Annex 2, section A2.4 provides an overview of the 2012 energy supply and demand balance for New Zealand.

3.1.7 Improvements since the previous submission

A number of changes have been made since the 2013 submission to improve the accuracy, completeness and transparency of the inventory. The most significant changes are outlined below.

- Following the 2013 expert review team (ERT) recommendation, the natural gas used for production of methanol has been split into fuel gas and feedstock gas. The emissions from the fuel portion are shown in the CRF category 1.AA.2.C chemicals in the Energy sector, and the emissions from the feedstock portion are described in chapter 4 (Industrial processes), section 4.3.2. The IPCC default emission factors were used for estimating emissions that resulted from combustion of gas for energy.

- Natural gas used for production of ammonia and urea has been split into feedstock gas, which is included in 2.B.5.5 ammonia, and energy-use gas, which is included in 1.AA.2.C chemicals. Further details are included chapter 4 (Industrial processes). The calculation of emissions resulting from combustion of the energy-use gas uses default emission factors.

- Venting of natural gas has been separated from flaring and included in 1.B.2.C.1 venting. This is in response to the 2013 ERT recommendation.

- Emissions of N2O as a result of flaring have been included and are now aligned with the IPCC 1996 reporting methodology. This is in response to the 2013 ERT recommendation.

- The emission factors for solid fuels have been revised for the time series 1990–2007. This is in response to the 2013 ERT recommendation. Values are now calculated by interpolation between 1990 and 2008.

- An improvement has been made in the oil data system so that annual gross calorific values are used for performing conversion calculations. This applies to all liquid fuels produced by New Zealand's sole oil refinery. Previously, a static gross calorific value was used.

- A reallocation of fuel data has been made in the oil data system to reallocate all aviation fuel consumption data to the transport sector.

- Fugitive emissions resulting from oil and gas exploration have been estimated for this submission. A time series of the number of wells drilled published in Energy in New Zealand (Ministry of Business, Innovation and Employment, 2013) was used as activity data. Since no data was available before 2001, these were estimated using linear regression. Default emission factors from the IPCC good practice guidance (IPCC, 2000) were then used to calculate emissions estimates.

- The previous submission included all feedstocks and flared gas under 1.AB as carbon stored. This was done as an attempt to balance the reference and sectoral approaches. This submission only reports carbon that is stored in products under 1.AB as carbon stored.

- Fugitive emissions from industrial plants have been revised to include both energy-use and non-energy-use gas. This is in response to the 2013 ERT recommendation.

- Activity data for international bunkers have been aligned to a more consistent data source. The change is summarised in the table 3.2.1. See section 3.1.2 for an explanation regarding the DPFI and MOS surveys. Note that the 'other fuels' category is not covered in the DPFI, so data must come from the MOS survey.

Table 3.2.1 Change in data source for international bunkers

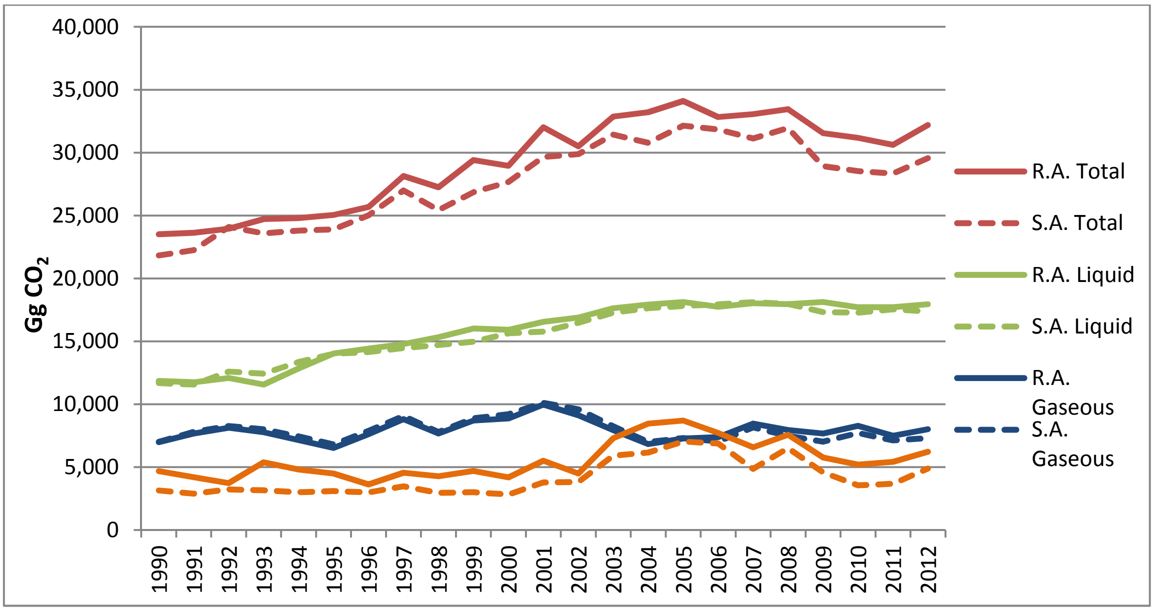
Fuel	Previous data source: international bunkers	Current data source: international bunkers
Gasoline	DPFI	DPFI
Diesel	MOS	DPFI
Fuel Oil	MOS	DPFI
Aviation fuels	DPFI	DPFI
Other fuels	MOS	MOS

3.2 Fuel combustion (CRF 1.A)

3.2.1 Comparison of the sectoral approach with the reference approach

In 2012, CO_2 emissions estimated in the sectoral approach were 8.2 per cent lower than those estimated in the reference approach. The following figure and table show the results for the two approaches for the period 1990–2012.

Figure 3.2.1 Reference and sectoral approach carbon dioxide



Note: R.A. = reference approach; S.A. = sectoral approach.

Table 3.3.1 Carbon dioxide emissions of the reference and sectoral approach (Gg CO_2)

Year	Reference approach				Sectoral approach 1.A Fuel combustion			
	Liquid	Solid	Gaseous	Total	Liquid	Solid	Gaseous	Total
1990	11,844	4,681	6,987	23,512	11,678	3,147	7,005	21,830
1991	11,746	4,202	7,672	23,620	11,564	2,883	7,799	22,246
1992	12,086	3,730	8,130	23,946	12,597	3,229	8,270	24,095
1993	11,561	5,380	7,770	24,711	12,428	3,150	8,004	23,581
1994	12,841	4,808	7,145	24,793	13,361	3,003	7,439	23,803
1995	14,033	4,489	6,520	25,042	14,009	3,087	6,802	23,897
1996	14,426	3,626	7,624	25,676	14,149	2,988	7,882	25,019
1997	14,779	4,552	8,812	28,143	14,463	3,471	9,057	26,991
1998	15,321	4,267	7,664	27,252	14,701	2,945	7,786	25,432
1999	16,015	4,689	8,705	29,409	14,973	2,995	8,883	26,850
2000	15,909	4,183	8,863	28,955	15,636	2,819	9,212	27,667
2001	16,547	5,510	9,966	32,023	15,771	3,778	10,108	29,657
2002	16,898	4,487	9,120	30,505	16,470	3,813	9,595	29,878
2003	17,632	7,306	7,930	32,868	17,276	5,908	8,245	31,428
2004	17,924	8,457	6,826	33,208	17,635	6,152	6,993	30,780
2005	18,126	8,698	7,276	34,099	17,803	7,027	7,313	32,143
2006	17,742	7,714	7,380	32,836	17,934	6,881	7,242	32,056
2007	18,028	6,571	8,464	33,063	18,113	4,859	8,151	31,123
2008	17,945	7,564	7,948	33,458	17,976	6,507	7,475	31,958
2009	18,121	5,757	7,672	31,550	17,320	4,582	7,025	28,927
2010	17,701	5,196	8,277	31,174	17,277	3,551	7,704	28,532
2011	17,705	5,415	7,494	30,615	17,539	3,680	7,125	28,343
2012	17,949	6,222	8,018	32,189	17,373	4,878	7,306	29,557

Explanation of differences

- Solid fuels: The reference approach includes process emissions from blast furnaces and steel production, which are included in category 2.C metal production.
- Gaseous fuels: The reference approach includes emissions from flaring and venting of natural gas, while the sectoral approach includes these under 1.B fugitive emissions.
- Gaseous fuels: Process emissions from ammonia and urea production are included in category 2.B.1 ammonia production.
- Gaseous fuels: Field-specific emission factors are used for natural gas supplied for industrial processes, while the reference approach uses an average emission factor.
- Solid fuels: Stock change data for coal is not available for 1990 and 1991 resulting in a large statistical difference in 1992.
- Liquid fuels: The energy balance is mass balanced but not carbon balanced. Fuel category 'other oil' is an aggregation of several fuel types and therefore it is difficult to quantify a reliable carbon emission factor for the reference approach. The reference approach takes a share of feedstocks used for plastics and solvent production as non-carbon stored. In the sectoral approach, emissions from plastics waste incineration are reported as 'other fuels' but in the reference approach it is included in 'liquid fuels'. Emissions from solvent use are included in category 3 solvent and other products use.
- Diesel and gasoline: In the reference approach CO2 emissions from diesel and gasoline are fully accounted for as fossil emissions while in the sectoral the share of mixed biofuels is accounted for as biogenic.
- In the sectoral approach, sector- or even plant-specific net calorific values are taken to calculate the energy consumption, whereas, in the reference approach, average (country-specific) calorific values are applied.

Sources of differences that can be easily quantified are given in the table 3.3.2.

Table 3.3.2 Sources of differences between reference and sectoral approaches (Gg CO_2)

Year	1.B Fugitive	2. Industrial processes		Total
	Gaseous[1]	Gaseous[2]	Solid[3]	
1990	114	22	1,295	1,430
1991	127	25	1,409	1,561
1992	97	30	1,486	1,614
1993	82	27	1,518	1,627
1994	96	28	1,399	1,523
1995	63	48	1,478	1,589
1996	126	48	1,441	1,615
1997	203	43	1,282	1,528
1998	157	43	1,350	1,551
1999	99	44	1,425	1,568
2000	83	31	1,409	1,523
2001	133	48	1,478	1,659
2002	82	30	1,446	1,559

2003	55	31	1,642	1,727
2004	46	33	1,649	1,728
2005	40	33	1,603	1,676
2006	45	32	1,603	1,680
2007	208	41	1,622	1,870
2008	359	34	1,517	1,909
2009	336	32	1,498	1,865
2010	376	34	1,677	2,087
2011	361	40	1,664	2,065
2012	236	40	1,642	1,917

Notes:

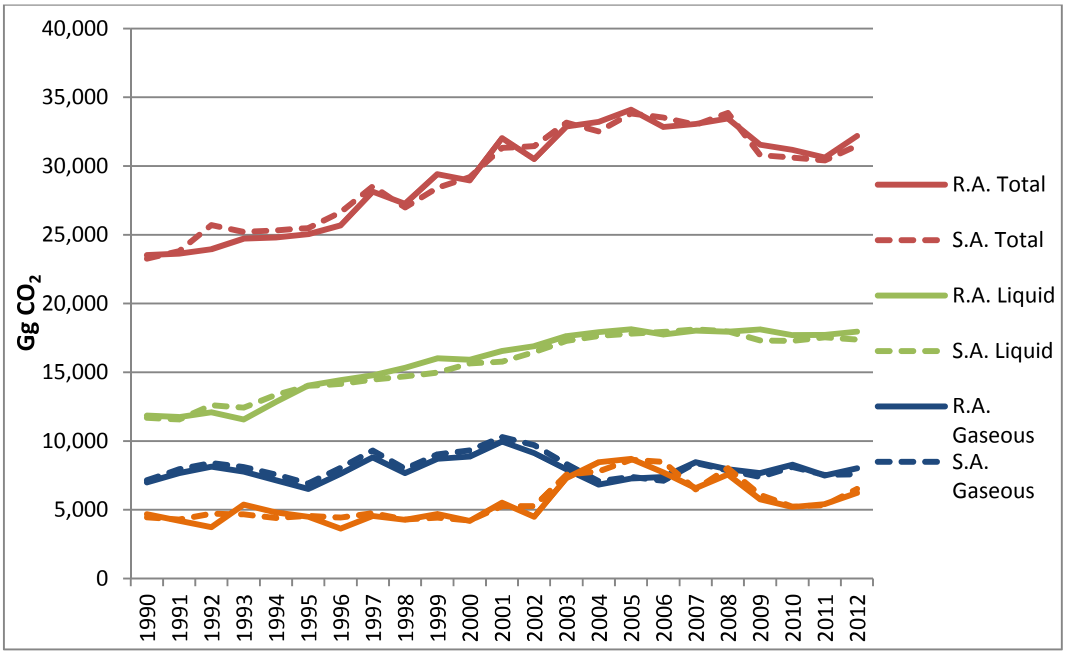
1. CO_2 emissions from flaring of natural gas reported under category 1.B.

2. CO_2 emissions from non-energy use of natural gas reported under category 2.B.1.

3. CO_2 emissions from non-energy use of coal reported under category 2.C.1.

The emissions from table 3.3.2 can then be hypothetically added to the sectoral approach for a more accurate and useful comparison with the reference approach. The result is shown in figure 3.3.2, and the residual differences are given in table 3.3.3. The remaining difference for 2012 is 2.3 per cent. This is within the accepted tolerance threshold of 5 per cent difference between the two approaches.

Figure 3.2.2 Reference and sectoral approach including emissions from table 3.3.2



Note: R.A. = reference approach; S.A. = sectoral approach.

Table 3.3.3 Sectoral approach including emissions from table 3.3.2 (Gg CO_2)

Year	Remaining difference			
	Liquid (%)	Solid (%)	Gaseous (%)	Total (%)
1990	1.4	5.4	–2.1	1.1
1991	1.6	–2.1	–3.5	–0.8
1992	–4.1	–20.9	–3.2	–6.9
1993	–7.0	15.3	–4.2	–2.0
1994	–3.9	9.2	–5.5	–2.1
1995	0.2	–1.6	–5.7	–1.7
1996	2.0	–18.1	–5.4	–3.6
1997	2.2	–4.2	–5.3	–1.3
1998	4.2	–0.6	–4.0	1.0
1999	7.0	6.1	–3.5	3.5
2000	1.7	–1.0	–5.0	–0.8
2001	4.9	4.8	–3.1	2.3
2002	2.6	–14.7	–6.1	–3.0
2003	2.1	–3.2	–4.8	–0.9
2004	1.6	8.4	–3.5	2.2
2005	1.8	0.8	–1.5	0.8
2006	–1.1	–9.1	0.8	–2.7
2007	–0.5	1.4	0.8	0.2
2008	–0.2	–5.7	1.0	–1.2
2009	4.6	–5.3	3.8	2.5
2010	2.5	–0.6	2.0	1.8
2011	1.0	1.3	–0.4	0.7
2012	3.3	–4.6	5.8	2.3

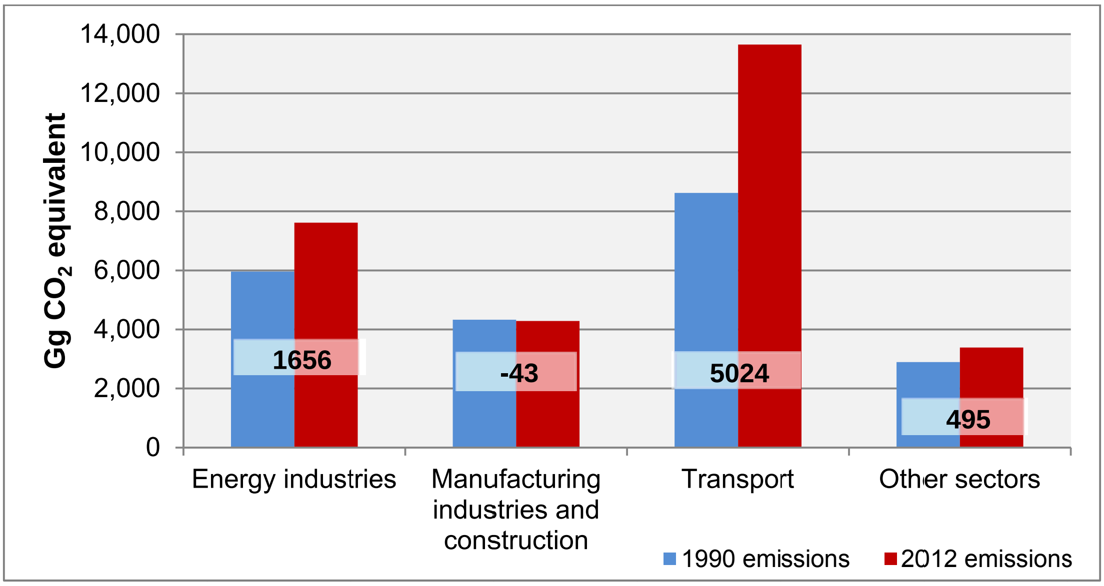
3.2.2 Sector-wide information

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 3.3.3). 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 3.3.3 Change in New Zealand's emissions from the fuel combustion categories (1990–2012)



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 DPFI. The Ministry of Business, Innovation and Employment began conducting the DPFI 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). Before 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.

Changes to note since the previous submission are listed below.

- An improvement has been made in the oil data system so that annual gross calorific values are used for performing conversion calculations. This applies to all liquid fuels produced by New Zealand's sole oil refinery. Previously, a static gross calorific value was used.
- A reallocation of fuel data has been made in the oil data system to reallocate all aviation fuel consumption data to the transport sector.

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 Business, Innovation and Employment commissioned survey in 2008 on liquid fuel use (see Ministry of Business, Innovation and Employment, 2008) found that there were 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 as the majority of fuel purchased from the distribution companies was used by the agriculture, forestry and fisheries 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 Business, Innovation and Employment, 2010) outlines in further detail the methodology employed to perform this calculation.

Solid fuels

Since 2009, the Ministry of Business, Innovation and Employment 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 Industrial Classification (Australian Bureau of Statistics and Statistics New Zealand, 2006). Before 2009, when Statistics New Zealand ran the survey, coal sold was attributed to seven sectors.

All solid fuel used for iron and steel manufacture is reported under 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 ERT 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.

- New Zealand reports biogas emissions from landfill gas, sewage waste gas and cattle effluent (the Tirau dairy processing facility) and commercial biogas use. Before 2013, New Zealand only reported emissions from landfill gas, sewage waste gas and commercial biogas use.
- New Zealand's biogas emissions are estimates based on electricity generation data (some of which is itself estimated). No direct data is available on biogas emissions from landfills or sewage treatment facilities. See the below for details of the estimation methodology of landfill gas and sewage gas.
- Biogas is also thought to be used by some local government councils; however, we have no information on this use. At some point, information was collected, however, the small quantities and materially insignificant emissions mean we have put no focus on collecting this data for many years. A standing estimate (unchanged) has been included since 2006. The source for this number is unknown. Emissions continue to be reported under this category to ensure there is no under reporting, given it is known at least anecdotally that some use outside of electricity generation and industry takes place.
- No information is collected on flared biogas.
- The only biogas direct-use that data has been collected for is the Tirau dairy processing facility (and only one data point, which has been used for all years where it is believed the plant has emitted).

Information on how biogas emissions are estimated based on electricity generation data.

- Electricity generation data is collected for 15 individual plants. At 31 December 2012, New Zealand biogas generation is currently known to include the following.
  - Eleven landfill facilities, totalling 29.4 megawatts (MW). These facilities are electricity only (some landfill gas was used to heat a swimming pool in Christchurch before the Christchurch earthquake of February 2011, but that facility suffered major earthquake damage and has been removed).
  - Four wastewater treatment facilities, totalling 11.3 MW. These are all co-generation facilities, which provide heat and electricity for the processing of sewage.
  - Accurate information is not available on the exact type of generation plant used at these individual facilities, although it is known to be a combination of gas turbines, internal combustion engines and some steam turbine facilities.
- Generation data is collected for years ending 31 March, with generation assumed to be distributed equally across quarters to estimate December year end generation.
  - Generation data is usually collected from all 15 plants. However, in some years, estimates are made based on the previous year's generation.
- Fuel input information for generation is not collected for small generators (those less than 10 MW) to minimise respondent burden and ensure we get some information rather than nothing. Estimates of fuel input are made on the assumption of 30 per cent efficiency based on gross generation.

– All generation data collected is assumed to be net generation – that is, parasitic load has already been taken off. It is then scaled up using default net to gross generation factors sourced from the International Energy Agency. For all thermal generation, the net to gross factor is assumed to be 1.07 (ie, an additional 7 per cent of generation is generated but used by the plant to generate more electricity). Fuel input estimates are then calculated based on the gross generation using a default electrical efficiency factor of 30 per cent. This estimated quantity of biogas is used as total biogas for energy purposes. Biogas use estimates for landfill gas and sewage gas are summed up and reported in petajoules (PJ).

– Energy quantities of biogas are then converted into greenhouse gas emissions using default IPCC emissions factors. These factors are as follows:

  - CO_2 – 27.5 kt C/PJ or 100.98 kt CO_2/PJ (before and after oxidation). This is derived from the IPCC default net emission factor (it is assumed that the net emission factor is 10 per cent less than the gross emission factor)
  - methane (CH_4) – 1.080 t/PJ
  - nitrous oxide (N_20) – 2.070 t/PJ.

- Emissions from biogas are a very small part of New Zealand's emissions inventory. Given this is the case, we believe the current process is sufficient for estimating emissions from biogas. Efforts to improve emissions quality would be better focused on other areas.

Residential biomass data is estimated based on information on the proportion of households with wood burner heaters (census, see below) and data from the Building Research Association of New Zealand (2002), on the average amount of energy used by households that use wood for heating. Finally, industrial biomass data is based on the report *Heat Plant in New Zealand* (Bioenergy Association of New Zealand, 2010).

The Census is the official count of how many people and dwellings there are in New Zealand. It takes a snapshot of the people in New Zealand and the places where people live. Up until 2006, the census was undertaken every five years (since after World War 2). In 2011, the national census was cancelled due to the Christchurch earthquakes, which caused major disruption. In March 2013, a new census was held (after seven years). The next census is scheduled for 2018.

At the time of preparing this inventory, only data from the 2006 census was available (see www.stats.govt.nz/Census/2006CensusHomePage.aspx). The census collects information on the heating fuels used for housing in New Zealand. For the latest data, see www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/quickstats-about-a-subject/housing/heating-fuels.aspx.

In 2006, 40.9 per cent of households used wood at some stage as a heating fuel. Based on 2006 Census population figures, this equates to 574,482 households in 2006. The Building Research Association of New Zealand Household Energy End-use Project (HEEP) (2002) (study found that, on average, households using wood used nearly 13.7 gigajoules (GJ) per annum. For the wood-use numbers, we have multiplied the estimated number of households using wood by the estimated use of wood per household. So, in 2006: 574,482*13.7 GJ = nearly 7.8 PJ in 2006.

Since 2006, the trends have been extrapolated (declining per cent of households using wood). When new census data becomes available from the 2013 Census, numbers from 2007 will need to be revised. Calorific values used in the HEEP study are not available.

Liquid biofuel activity data is based on information collected under the *Petroleum or Engine Fuel Monitoring Levy* as reported in the Ministry of Business Innovation and Employment quarterly online data releases.

Electricity auto-production

In response to ERT 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, CH_4 and 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 OECD 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

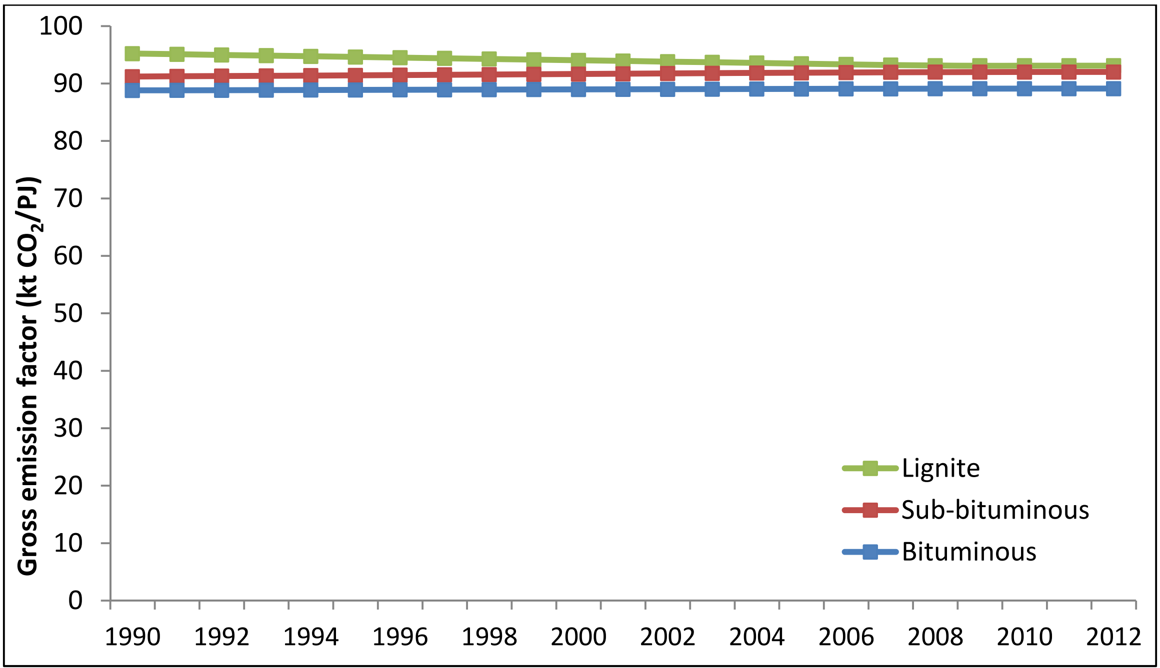
Liquid fuels

Where possible, CO_2 emission factors for liquid fuels are calculated on an annual basis. Carbon dioxide emission factors are calculated from Refining New Zealand 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 2008 in response to a 2013 ERT recommendation. A comprehensive list of carbon content by coal mining is not currently available. A review of New Zealand's coal emission factors in preparation for the NZ ETS (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). However, following review of our 2013 submission, the ERT recommended interpolating the emission factors between 1990 and 2008. The updated emission factors are shown in figure 3.3.4.

Figure 3.3.4 Gross carbon dioxide emission factors for solid fuels



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's 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 2012 from all fields, along with the production weighted average are included in annex 2 (section A2.1).

The annual 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, Pohokura) coming on stream. This emission factor fluctuates slightly from year to year, mainly due to the relative production volume 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 is removed at the Kapuni gas treatment plant. Consequently, separate emission factors were used to calculate emissions from Kapuni treated and un-treated 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.B.2 production/processing.

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 (1996) default emission factors.

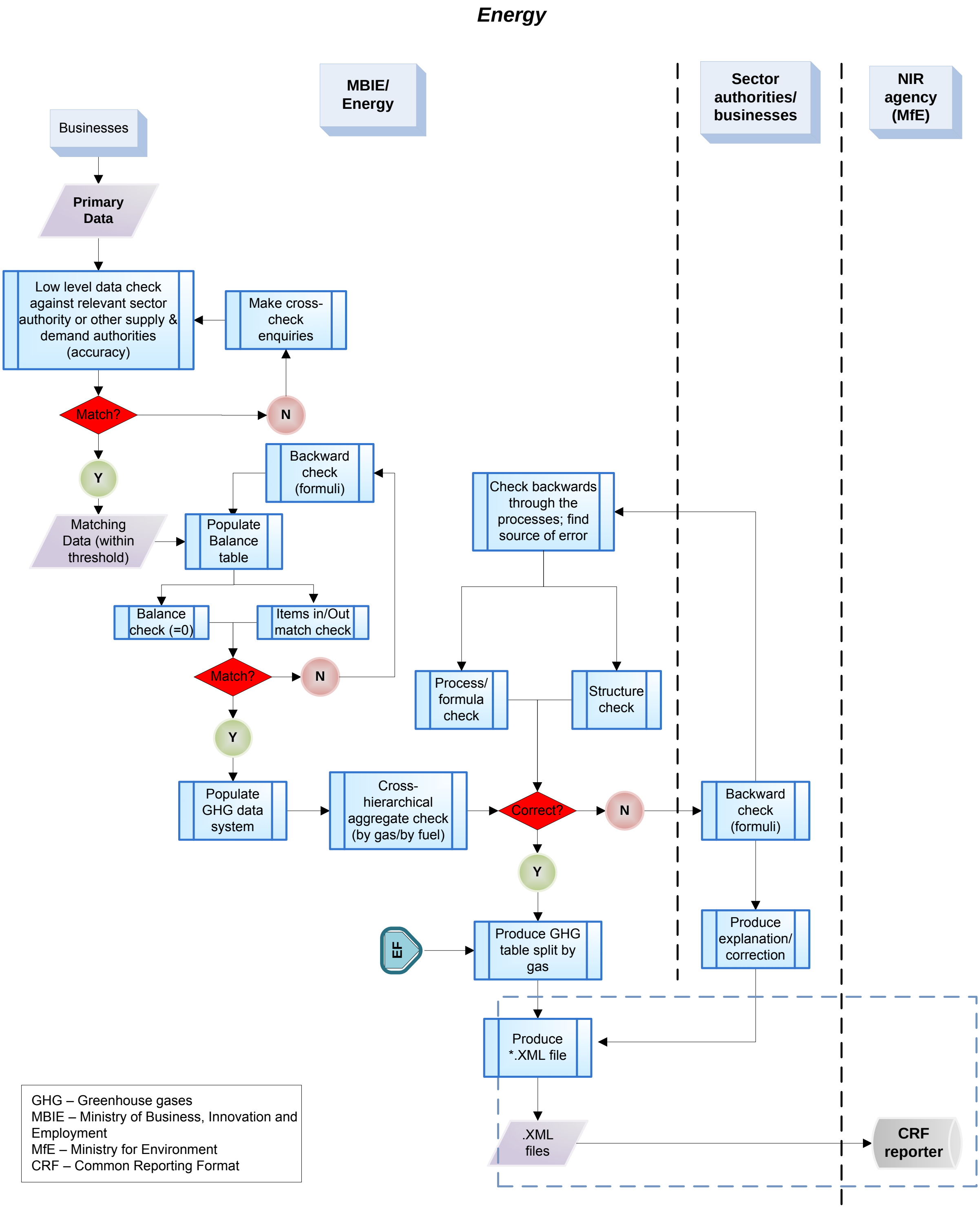
3.2.3 Sector-wide planned improvements

- All source-specific planned improvements are 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.

3.2.4 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 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular control sums throughout systems to verify system integrity, time-series consistency checks on activity data and consistency checks on implied emission factors at the industry–plant level where possible. Figure 3.3.5 describes the quality control process map for the Energy sector.

Figure 3.3.5 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 (2012) and converted to gross values for comparability with the New Zealand energy system.

Figures 3.3.6, 3.3.7 and 3.3.8 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 top of the IPCC range 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 (as discussed in section 3.3.2), each fuel type falls within the IPCC default range.

Figure 3.3.6 Carbon dioxide implied emission factor (IEF) – Liquid fuel combustion (1990–2012)

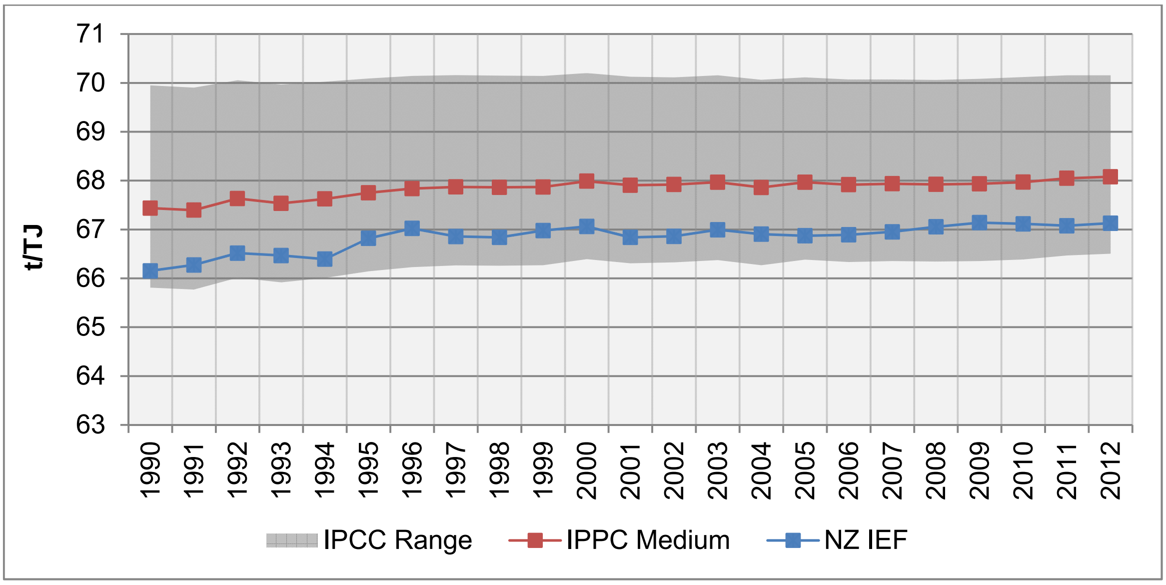


Figure 3.3.7 Carbon dioxide implied emission factor (IEF) – Solid fuel combustion (1990–2012)

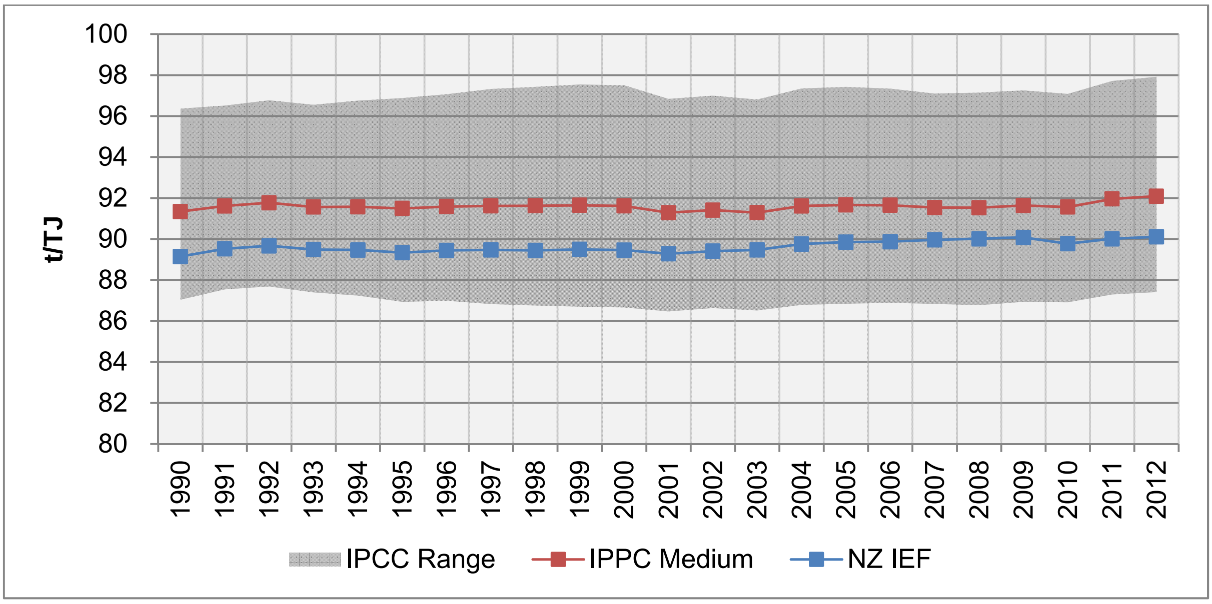
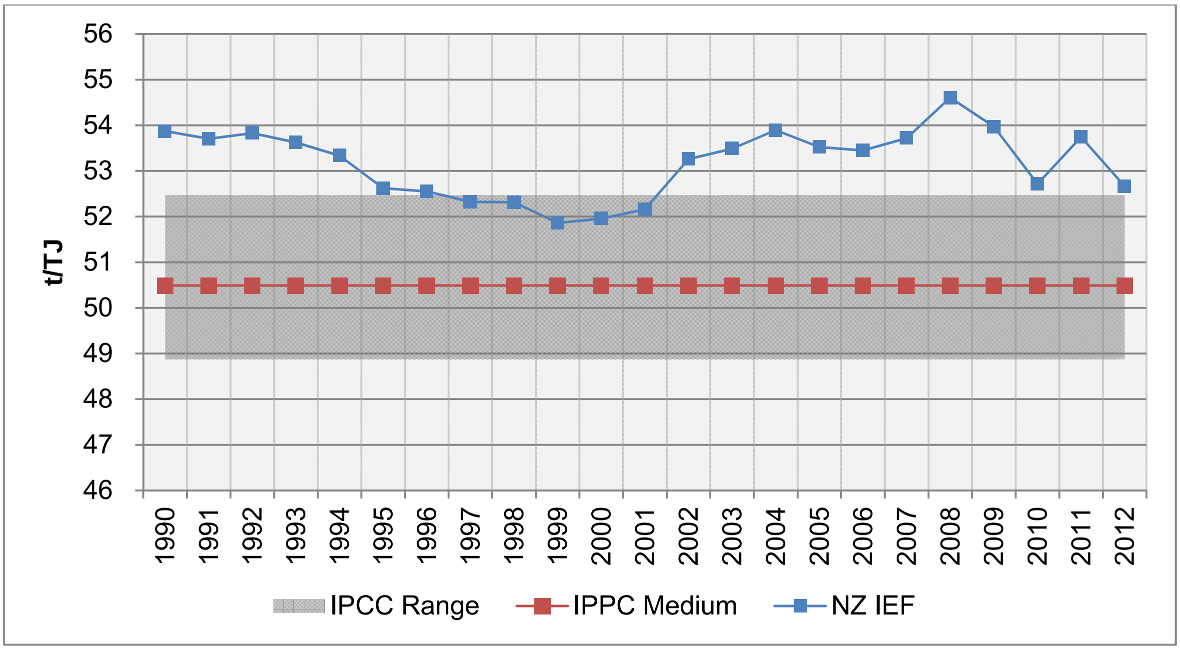


Figure 3.3.8 **Carbon dioxide implied emission factor (IEF) – Gaseous fuel combustion (1990–2012)**



Note: As discussed in section 3.3.2 under 'Emission factors', carbon dioxide emission factors for New Zealand gas fields are established through gas composition analysis and are known to be high by international standards.

3.2.5 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 over 92 per cent of CO_2-e emissions from fuel combustion in New Zealand in 2012. By comparison, emissions of the non-CO_2 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 3.3.4. Many of the non-CO_2 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 3.3.4 Uncertainty for New Zealand's Energy sector emission estimates

		Activity data uncertainty (%)	Emission factor uncertainty (%)
CO_2	Liquid fuels	3.23	±0.5
	Solid fuels	13.30	±3.5
	Gaseous fuels	8.54	±2.4
	Fugitive – geothermal	5.00	±5.0
	Fugitive – venting/flaring	8.54	±2.4
	Fugitive – oil transport	5.00	±50.0
	Fugitive – transmission and distribution	8.54	±5.0
CH_4	Liquid fuels	3.23	±50.0
	Solid fuels	13.30	±50.0
	Gaseous fuels	8.54	±50.0
	Biomass	5.00	±50.0
	Fugitive – geothermal	5.00	±5.0
	Fugitive – venting/flaring	8.54	±50.0
	Fugitive – coal mining	13.30	±50.0
	Fugitive – transmission and distribution	8.54	±5.0
	Fugitive – other leakages	5.00	±50.0
	Fugitive – oil transportation	5.00	±50.0
N_2O	Liquid fuels	3.23	±50.0
	Solid fuels	13.30	±50.0
	Gaseous fuels	8.54	±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 to estimate activity data uncertainty. As a result, activity data uncertainty can vary significantly from year to year.

3.2.6 Fuel combustion: Energy industries (CRF 1.A.1)

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 2012, emissions in category 1.AA.1 energy industries totalled 7,615 Gg CO_2-e (23.7 per cent of the Energy sector emissions). Emissions from energy industries have increased 1,654 Gg CO_2-e (28 per cent) since the 1990 level of 5,962 Gg CO_2-e. Subcategory 1.AA.1.A public electricity and heat production accounted for 6,301 Gg CO_2-e (83 per cent) of the emissions from the energy industries category in 2011. This is an increase of 2,834 Gg CO_2-e (82 per cent) from the 1990 level of 3,467 Gg CO_2-e.

Changes in emissions between 2011 and 2012

Between 2011 and 2012, there was an increase of 1,222 Gg CO_2-e (24.1 per cent) in emissions from 1.AA.1.A public electricity and heat production. This was due to a combination of the following.

- The share of electricity generated from renewable energy sources was 73 per cent in 2012. This was lower than in 2011 (77 per cent) due to abnormally low hydro inflows.
- This resulted in increased gas and coal generation over the year. Generation from coal increased 63.7 per cent from 2011.

Key categories identified in the 2012 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
- manufacture of solid fuels and other energy industries – gaseous fuels
- petroleum refining – liquid fuels.

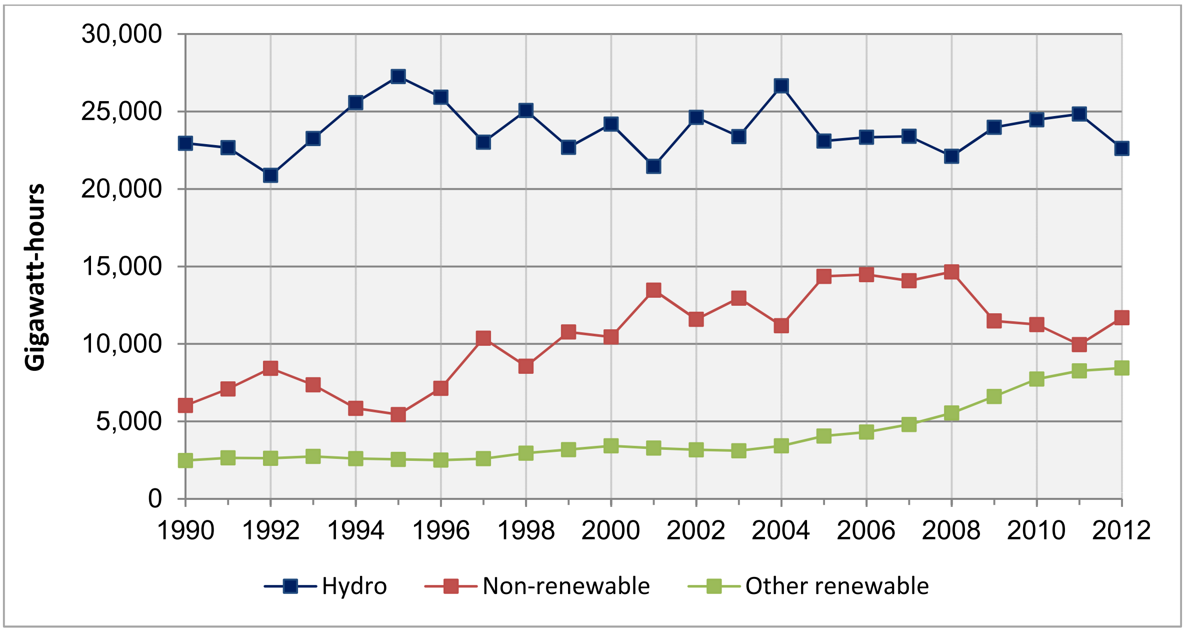
Key categories identified in the 2012 trend assessment from the energy industry category include CO_2 emissions from:

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

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2012 calendar year, hydro generation provided 53 per cent of New Zealand's electricity generation. A further 14 per cent came from geothermal, 5 per cent from wind and 1 per cent from biomass. The remaining 28 per cent was provided by fossil fuel thermal generation plants using gas, coal and oil (Ministry of Business, Innovation and Employment, 2013).

Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990 and 2012. 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 3.3.9). 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, 2009; Ministry of Business, Innovation and Employment, 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 3.3.9 New Zealand's electricity generation by source (1990–2012)



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

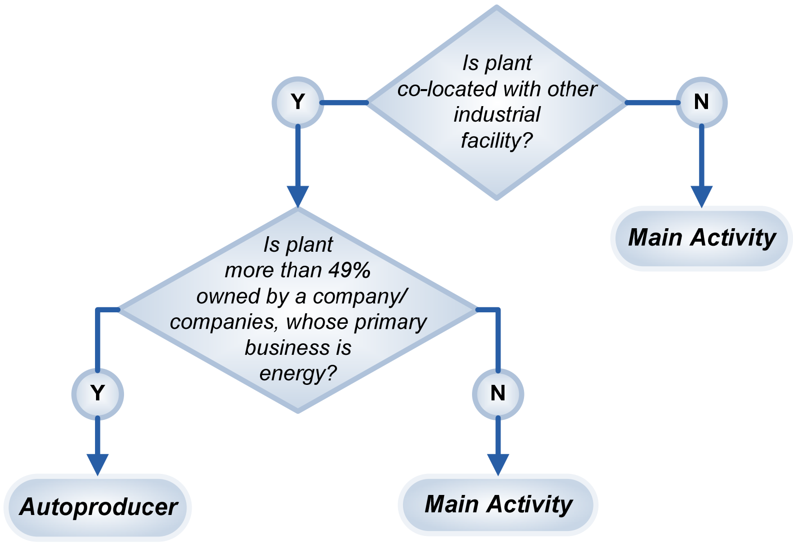
All thermal electricity generators provide figures for the amount of coal, gas and oil used for electricity generation to the Ministry of Business, Innovation and Employment. Greenhouse gas emissions from geothermal electricity generation are reported under 1.B.2.D.

Around 6 per cent of New Zealand's electricity is supplied by co-generation (also known as combined heat and power) (Ministry of Business, Innovation and Employment, 2013). 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 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 3.3.10).

Figure 3.3.10 Decision tree to identify an autoproducer



1.AA.1.B Petroleum refining

Refining New Zealand 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-CO_2 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 is 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 3.3.2, 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 CO_2 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 3.3.4).

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 control sums throughout systems to verify system integrity, and consistency checks on implied emission factors.

Source-specific recalculations

As discussed in section 3.3.2, emission factors for solid fuels have been updated for this submission in response to a 2013 ERT recommendation. 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 coal-fired electricity generation.

The net effect is a decrease 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).

3.2.7 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 2012, emissions from 1.AA.2 manufacturing industries and construction subcategory accounted for 5,273 Gg CO_2-e (16.7 per cent) emissions from the Energy sector. Emissions were 678 Gg CO_2-e (14.4 per cent) above the 1990 level of 4,695 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 2011 and 2012

Between 2011 and 2012, emissions from the manufacturing industries and construction sector increased by 179 Gg CO_2-e (3.4 per cent). This is primarily due to a 98 Gg CO_2-e (9.5 per cent) increase in emissions from liquid fuels in the sector as a result of the increased economic activity and the restart of the second methanol production facility at Motunui.

Key categories identified in the 2012 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 2012 trend assessment from the manufacturing industries and construction category include CO_2 emissions from:

- gaseous fuels
- liquid fuels
- 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 reducing agent 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 submission further disaggregates emissions previously reported under 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 released with *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2013) split out industrial uses of energy using the Australia New Zealand Standard Industrial Classification 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

In 2010, the Ministry of Business, Innovation and Employment 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, the coal sales survey conducted by the Ministry of Business, Innovation and Employment provides data at a more disaggregated level. As more disaggregated data becomes available, these splits will be reviewed and revised as necessary.

Table 3.3.5 Solid fuel splits for 2009 used to disaggregate the manufacturing industries and construction category between 1990 and 2008

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: NO stands for 'not occurring'. Survey data indicates that coal combustion does not occur in these sectors. IE stands for 'included elsewhere'. In the case of solid fuels used for iron and steel production, emissions are reported under 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 3.3.6). 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 3.3.6 Solid biomass splits for 2006 that were used to disaggregate the manufacturing industries and construction category between 1990 and 2012

Manufacturing industries and construction subcategory	Per cent
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 stands for '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. See section 3.3.2 (Biomass) for further information.

Biogas is not metered or analysed at the site, but estimates of flow rate and CH_4 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 3.3.2 (Liquid fuels), 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 the 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 and fisheries increase significantly.

Following ERT 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 (PJ per unit of 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 3.3.11 Splits used for manufacturing industries and construction category – Gasoline (1990–2012)

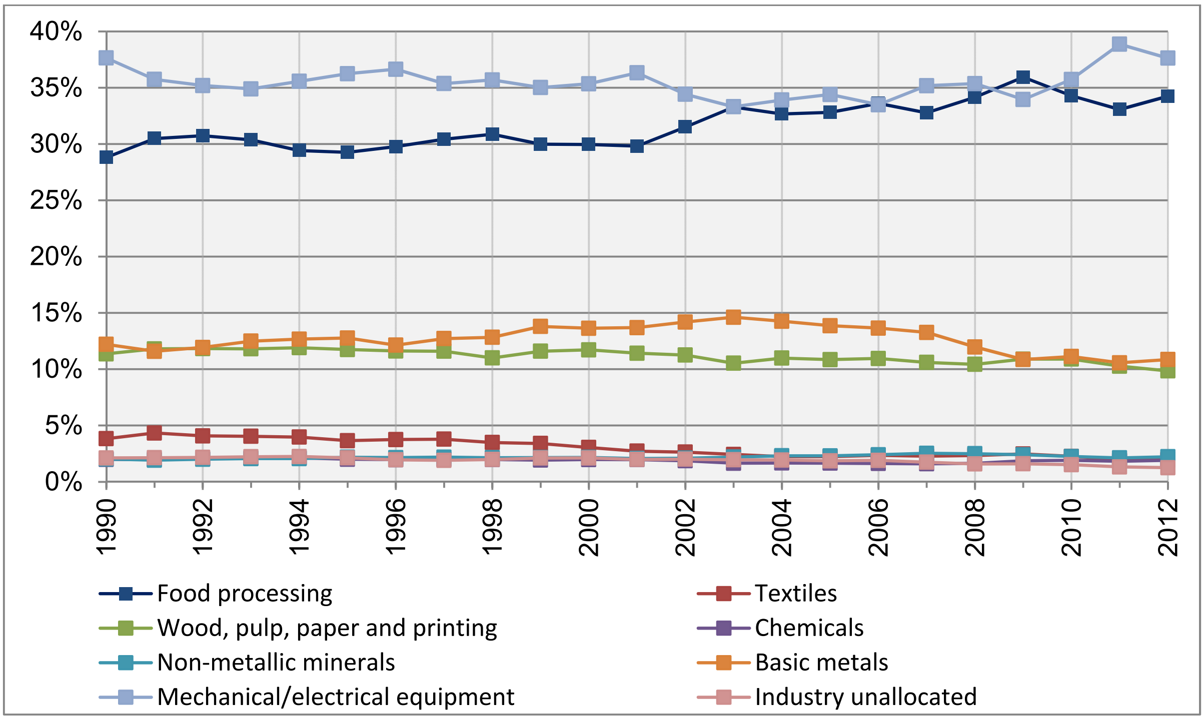


Figure 3.3.12 Splits used for manufacturing industries and construction category – Diesel (1990–2012)

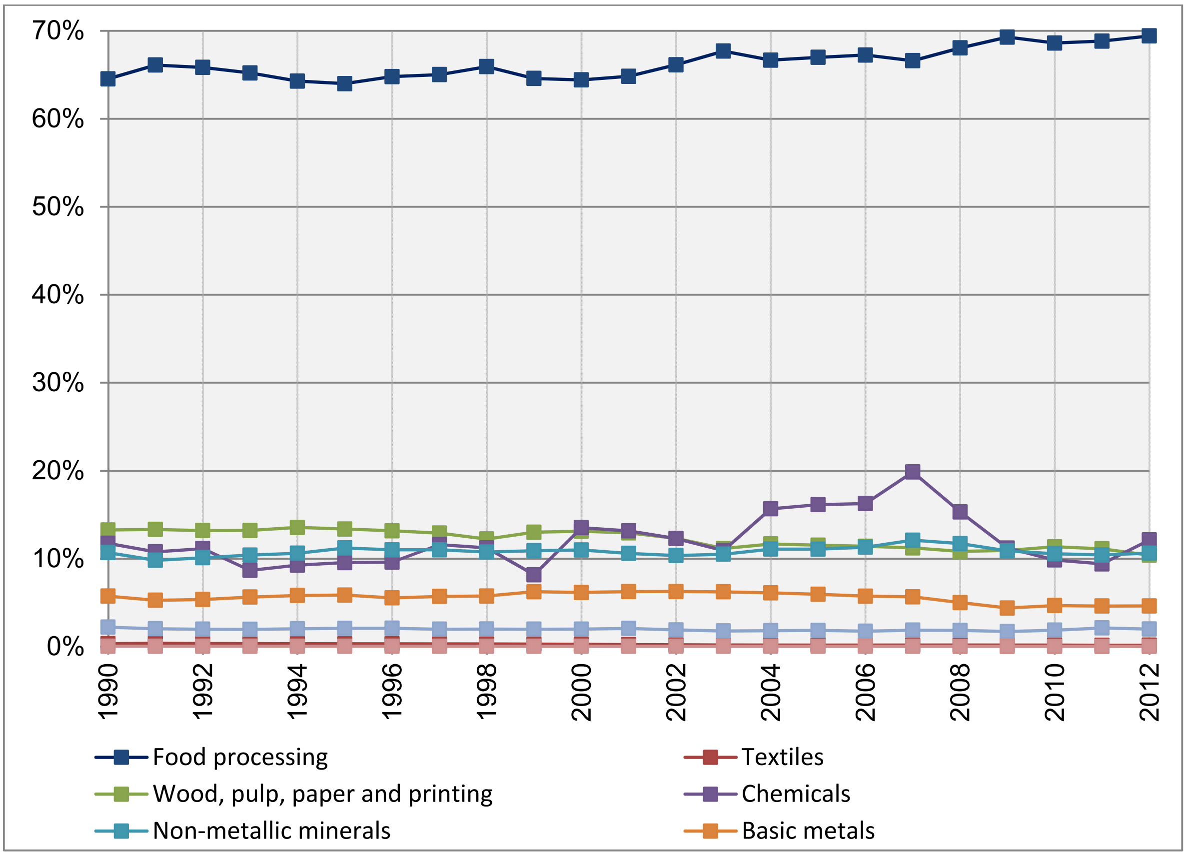
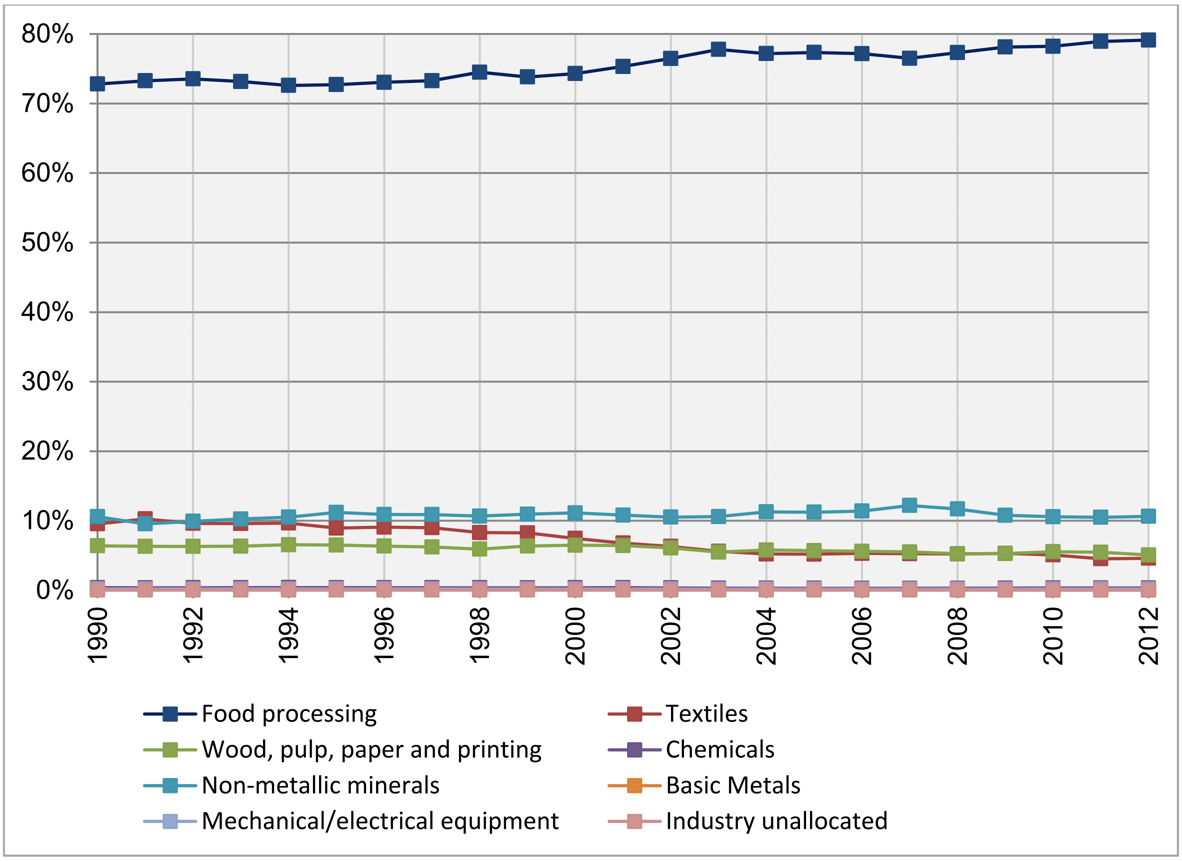


Figure 3.3.13 Splits used for manufacturing industries and construction category – Fuel oil (1990–2012)



Gaseous fuels

A review 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 based on 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 iron-sand. 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 under 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.

Two important improvements since the previous submission should be noted.

- Production of methanol has been moved from 1.AA.2.C chemicals to 2. Industrial processes. This is in response to the 2013 ERT recommendation. Natural gas used for production of methanol has been split into feedstock gas, which is included in 2.B.5.5 (methanol), and energy-use gas, which is included in 1.AA.2.C chemicals. Further details are included chapter 4 (Industrial processes). The calculation of emissions resulting from combustion of the energy-use gas uses default emission factors.
- Natural gas used for production of ammonia and urea has been split into feedstock gas, which is included in 2.B.5.5 ammonia, and energy-use gas, which is included in 1.AA.2.C chemicals. Further details are included chapter 4 (Industrial processes). The calculation of emissions resulting from combustion of the energy-use gas uses default emission factors.

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 re-opened in late 2008. Methanex New Zealand exports the majority of this methanol.

Methanex is the sole methanol producer in New Zealand and considers its gas consumption to be commercially sensitive information. 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.

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 3.3.2, 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 3.3.10.

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 control sums throughout systems to verify system integrity, and time-series consistency checks.

Source-specific recalculations

As mentioned under methodological issues, 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 the Statistics New Zealand energy-use surveys.

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 3.3.11, 3.3.12 and 3.3.13.

Fuel used in the auto-production on 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.

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.

3.2.8 Fuel combustion: Transport (CRF 1.A.3)

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 2012, category 1.AA.3 transport was responsible for 13,755 Gg CO_2-e (42.8 per cent of emissions from the Energy sector), or 18.1 per cent of total emissions. Emissions increased 5,077 Gg CO_2-e (58.5 per cent) from the 8,677 Gg CO_2-e emitted in 1990. The transport emissions profile in 2012 was dominated by emissions from subcategory 1.AA.3.B road transportation. In 2012, road transport accounted for 12,439 Gg CO_2-e (90.4 per cent) of total transport emissions. This was an increase of 5,033 Gg CO_2-e (68.0 per cent) from the 1990 level of 7,406 Gg CO_2-e.

Changes in emissions between 2011 and 2012

Between 2011 and 2012, emissions from transport decreased by 287.8 Gg CO_2-e (2.0 per cent).

Key categories identified in the 2012 level assessment from the transport category include CO_2 emissions from:

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

Key categories identified in the 2012 trend assessment from the transport category include CO_2 emissions from:

- road transport – gasoline
- road transport – diesel oil
- civil aviation – jet kerosene
- road transport – liquefied petroleum gases
- 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 2001–10. Before 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 Zealand14 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 seven 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).

[14] As at 2014, New Zealand only manufactures a small number of buses and heavy trucks.

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 the 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 before 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 Business, Innovation and Employment and Ministry for the Environment met with the Australian inventory reporting team in July 2011 to conduct a review of proposed 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 3.3.14 and 3.3.15 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 submission.

Figure 3.3.14 Methane emissions from road transport from 2001 to 2012 – Gasoline

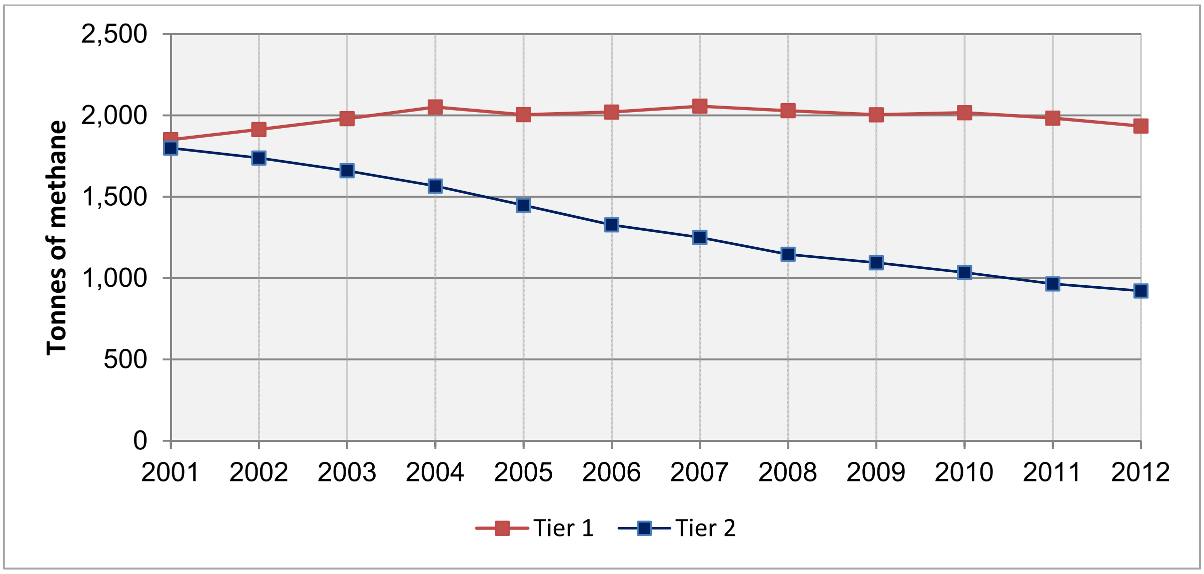
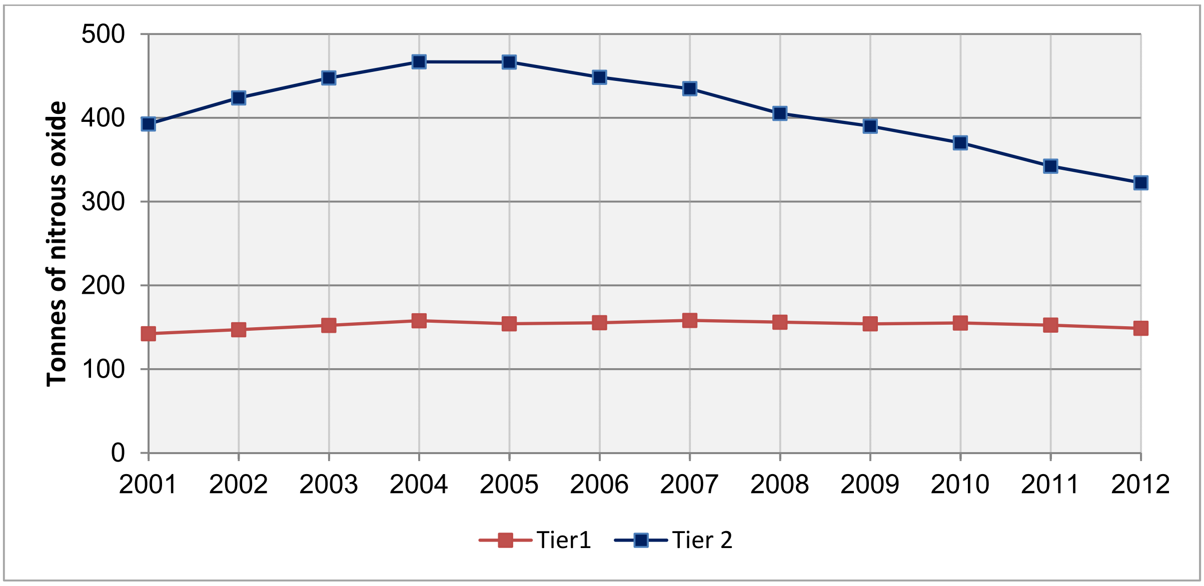


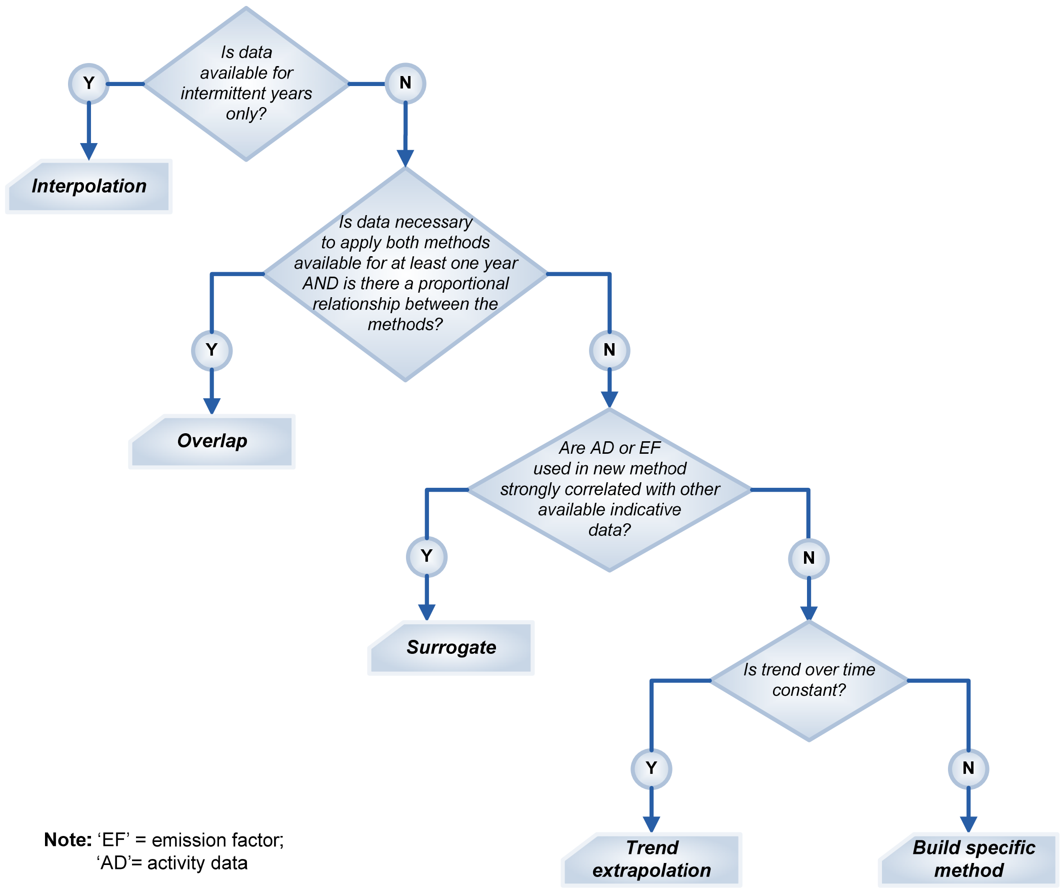
Figure 3.3.15 Nitrous oxide emissions from road transport from 2001 to 2012 – Gasoline



Time-series consistency

The data available for applying the Tier 2 methodology between 1990 and 2000 was 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 of the relationship between the Tier 1 and Tier 2 methods was used (see figure 3.3.16). The process was developed on a basis of the IPCC good practice guidance (IPCC, 2000).

Figure 3.3.16 Splicing method decision tree for gasoline emissions



Note: 'EF' = emission factor; 'AD'= activity data

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:

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

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 (2001–10), 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 Emission Factor Database (2012). For the purposes of this calculation, all countries using default emission factors – including New Zealand – were removed from the calculation.

Figures 3.3.17 and 3.3.18 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 the 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 emissions 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 overestimate rather than underestimate N_2O emissions.

Figure 3.3.17 Nitrous oxide implied emission factors from 1990 to 2011 – Gasoline road transport

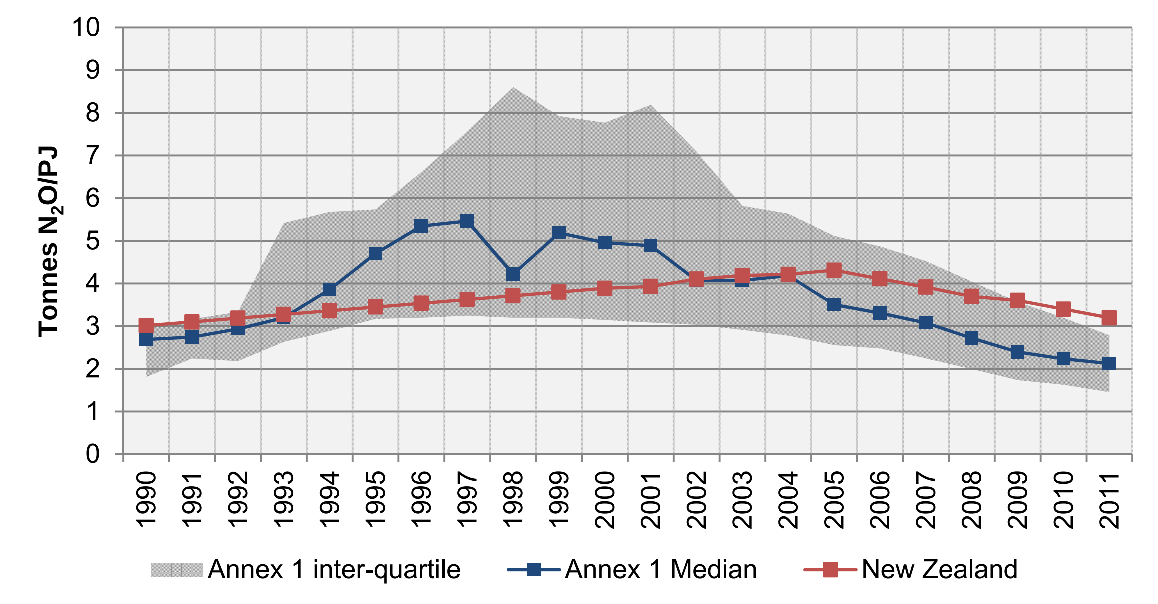
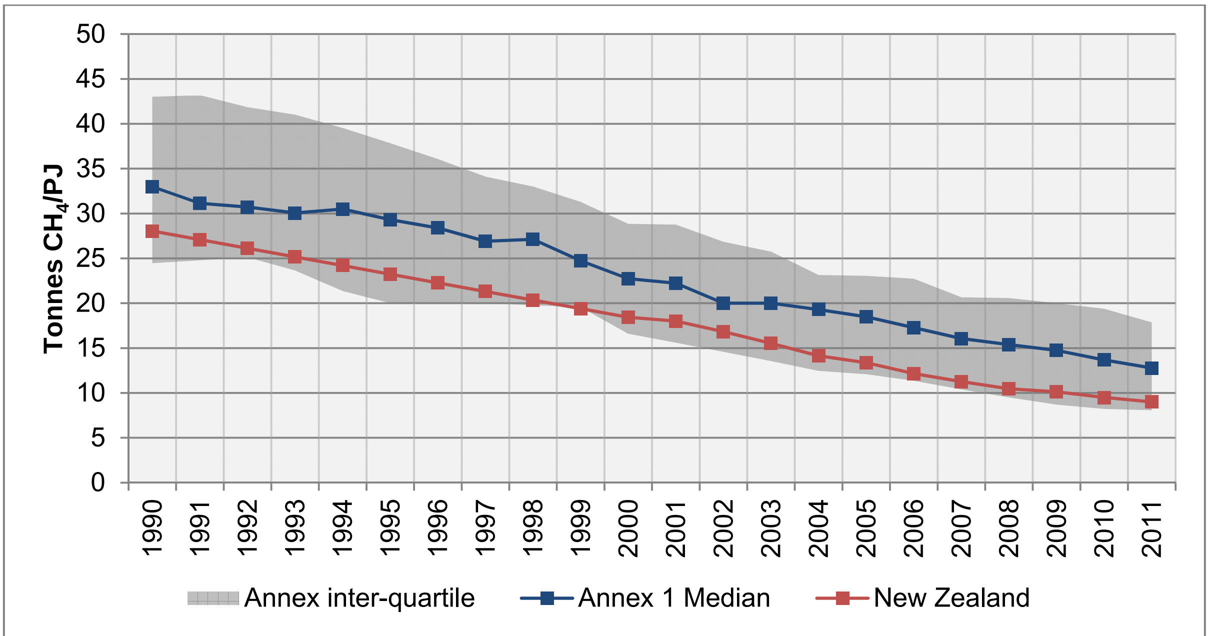


Figure 3.3.18 Methane implied emission factors from 1990 to 2011 – Gasoline road transport



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 2012, 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 a share of combined gasoline and bio-gasoline or mineral diesel as a 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.

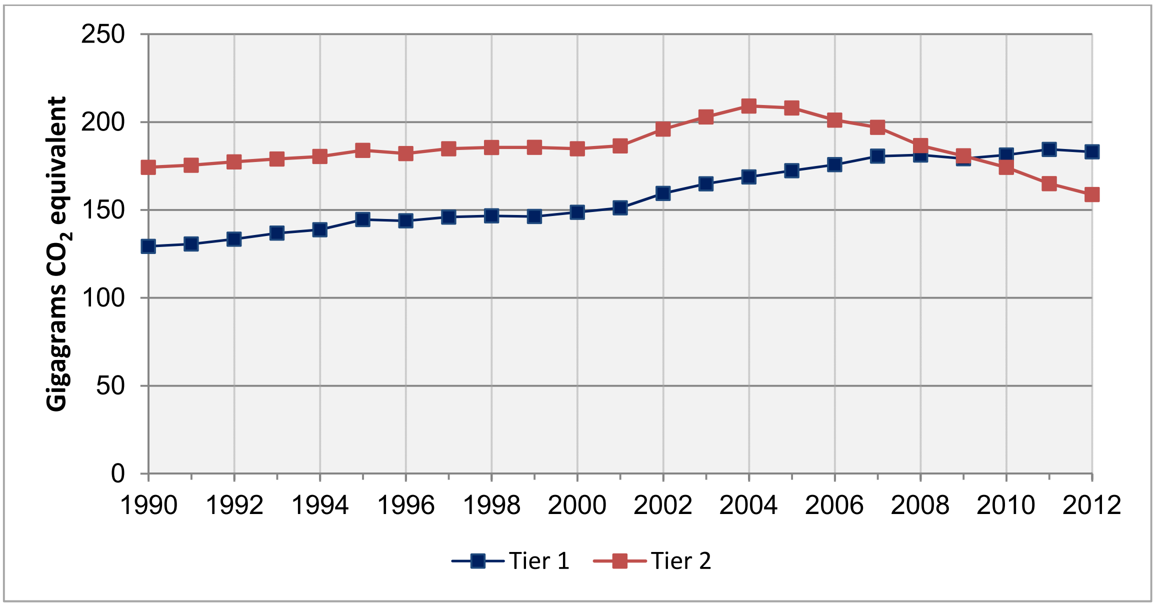
Overall effect of moving to Tier 2 methodology

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-e 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-e emissions from N_2O and CH_4 in road transport are lower under the Tier 2 methodology than under the previous Tier 1 methodology, reflecting continued improvements in emission control technology entering the fleet (see figure 3.3.19).

Figure 3.3.19 Total methane and nitrous oxide road transport emissions from 1990 to 2012



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 currently collects aviation fuels used for international and domestic aviation through the DPFI. 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 ERT. The latest centralised review stated (UNFCCC, 2013):

> *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 the 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 DPFI, 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 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. Based on the above findings, the Ministry of Business, Innovation and Employment believes that the 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.

1.AA.3.B Road transportation

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 DPFI conducted by the Ministry of Business, Innovation and Employment. Liquefied petroleum gas and compressed natural gas consumption figures are reported online by the Ministry of Business, Innovation and Employment.

As mentioned in section 3.3.2, 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 nearly 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 under subcategory 1.AA.3.B road transportation are allocated to the correct (sub)category.

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

The diesel activity data for the 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 DPFI conducted by the Ministry of Business, Innovation and Employment. The DPFI provides 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 GST on the fuel sold – GST is not charged when the destination of a voyage is outside of New Zealand.

Historically, the Marsden Point oil refinery produced marine diesel oil (MDO). Production of MDO at the refinery stopped in late 2006. Data collected from the operators of the Interislander Ferry service (KiwiRail) has not included MDO use since 2006. This coincided with this operator ceasing a 'fast ferry' service between the North Island and South Island – this ferry ran on MDO – whereas the remainder of its fleet runs on fuel oil. There is no significant quantity of diesel used for commercial domestic navigation in New Zealand. There may be smaller quantities of diesel used in private and/or recreational vessels; however, this is difficult to measure. The DPFI would capture these sales as road transport.

Uncertainties and time-series consistency

Uncertainties in emission estimates from the transport category are relevant to the entire fuel combustion sector (table 3.3.4).

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 control sums throughout systems to verify system integrity, and time-series consistency checks.

Comparison of international implied emission factors across the time series (1990–2011), 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 transportation 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.

3.2.9 Fuel combustion: Other sectors (CRF 1.A.4)

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 2012, fuel combustion of the other sectors category accounted for 3,294 Gg CO_2-e (10.3 per cent of the emissions from the Energy sector). This is an increase of 435 Gg CO_2-e (15.2 per cent) from the 1990 value of 2,858 Gg CO_2-e.

Emissions from subcategory 1.AA.4.A commercial/institutional were 905.7 Gg CO_2-e (27.5 per cent of the other sectors category) in 2012. This is an increase of 29.5 Gg CO_2-e (3.4 per cent) from the 1990 level of 876.2 Gg CO_2-e.

Emissions from subcategory 1.AA.4.B residential were 606.0 Gg CO_2-e (18.4 per cent) of the other sectors category in 2012. This is a decrease of 165.3 Gg CO_2-e (21.4 per cent) from the 1990 level of 771.2 Gg CO_2-e.

Emissions from subcategory 1.AA.4.C agriculture, forestry and fisheries were 1,781.1 Gg CO_2-e (54.1 per cent) of the other sectors category in 2012. This is an increase of 568.8 Gg CO_2-e (46.9 per cent) from the 1990 level of 1,212.3 Gg CO_2-e.

Changes in emissions between 2011 and 2012

Between 2011 and 2012, emissions from 1.AA.4 other sectors increased by 220.4 Gg CO_2-e (7.2 per cent).

Key categories identified in the 2012 level assessment from the other sectors category include CO_2 emissions from:

- liquid fuels
- gaseous fuels
- solid fuels.

Key categories identified in the 2012 trend assessment from the other sectors category include CO_2 emissions from:

- liquid fuels
- gaseous fuels
- solid fuels.

Methodological issues

There are no notable methodological issues in this category.

Activity data

Liquid fuels

As mentioned in section 3.3.2, 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. In 2012, these independent resellers accounted for nearly 25 per cent of national diesel deliveries and 7 per cent of national gasoline deliveries.

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

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

As mentioned in section 3.3.7, historical national energy sales surveys captured fuel use by mining operations under 'other primary industry'. For consistency with IPCC (1996) guidelines, this inventory uses the Statistics New Zealand *Energy Use Survey: Primary Industries 2008* (Statistics New Zealand, 2008) to estimate the split of historical other primary industry between forestry and logging and mining (see table 3.3.7).

Table 3.3.7 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

In 2010, in was discovered that some coal reported as sold to the commercial sector was in fact being on-sold. As a result, some activity previously reported under the commercial sector has been reallocated to the agriculture sector. This on-selling 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 review 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 based on 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 3.3.4).

Source-specific QA/QC and verification

In the preparation of this inventory, the other sectors 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 control 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 transportation 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.

3.3 Fugitive emissions from fuels (CRF 1.B)

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 2012, fugitive emissions from fuels accounted for 2,183 Gg CO_2-e (6.8 per cent) of emissions from the Energy sector. This is an increase of 816.7 Gg CO_2-e (59.7 per cent) from the 1990 level of 1,367 Gg CO_2-e.

Changes in emissions between 2011 and 2012

Between 2011 and 2012, fugitive emissions from fuels decreased by 312.6 Gg CO_2-e (12.5 per cent). This was primarily the result of decreased activity in subcategory 1.AA.1.A coal mining and handling and due to Spring Creek Mine suspending coal production in 2012 (Solid Energy New Zealand Ltd, 2012).

Key categories identified in the 2012 level assessment from fugitive emissions include CO_2 emissions from:

- natural gas production/processing
- geothermal electricity generation.

Key categories identified in the 2012 trend assessment from fugitive emissions include CO_2 emissions from:

- flaring combined
- natural gas production/processing
- geothermal electricity generation.

No key categories were identified in the 2012 level assessment from fugitive emissions that include CH_4 emissions.

- natural gas other leakage.

Key categories identified in the 2012 trend assessment from fugitive emissions include CH_4 emissions from:

- natural gas distribution
- coal mining and handling
- natural gas other leakage.

3.3.1 Fugitive emissions from fuels: Solid fuels (CRF 1.B.1)

Description

In 2012, fugitive emissions from the solid fuels subcategory produced 292.9 Gg CO_2-e (13.4 per cent) of emissions from the fugitive emissions category. This is an increase of 9.7 Gg CO_2-e (3.4 per cent) from the 283.2 Gg CO_2-e reported in 1990.

Between 2011 and 2012, fugitive emissions from solid fuels decreased by 117.6 Gg CO_2-e (28.7 per cent) as a result of decreased production from underground mines. Production at Spring Creek Mine was suspended in 2012 pending a business review. As a result, 2012 production from underground mines in New Zealand was 35 per cent lower than in 2011, 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, 66.7 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 2012, New Zealand coal production was 4.9 million tonnes, a 0.4 per cent decrease from the 2011 production level.

At the end of 2012, 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, however, these projects have not progressed further.

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 and/or 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 3.3.4).

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 control 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.

3.3.2 Fugitive emissions from fuels: Oil and natural gas (CRF 1.B.2)

Description

In 2012, fugitive emissions from the oil and natural gas subcategory contributed 1,891 Gg CO_2-e (86.6 per cent) to emissions from the fugitive emissions category. This is an increase of 807 Gg CO_2-e (74.5 per cent) from 1,083 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 CH_4 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 under 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 2012, emissions from geothermal operations were 738.6 Gg CO_2-e, an increase of 464 Gg CO_2-e (169 per cent) since the 1990 level of 274.6 Gg CO_2-e.

Between 2011 and 2012, emissions from geothermal have decreased by 0.1 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

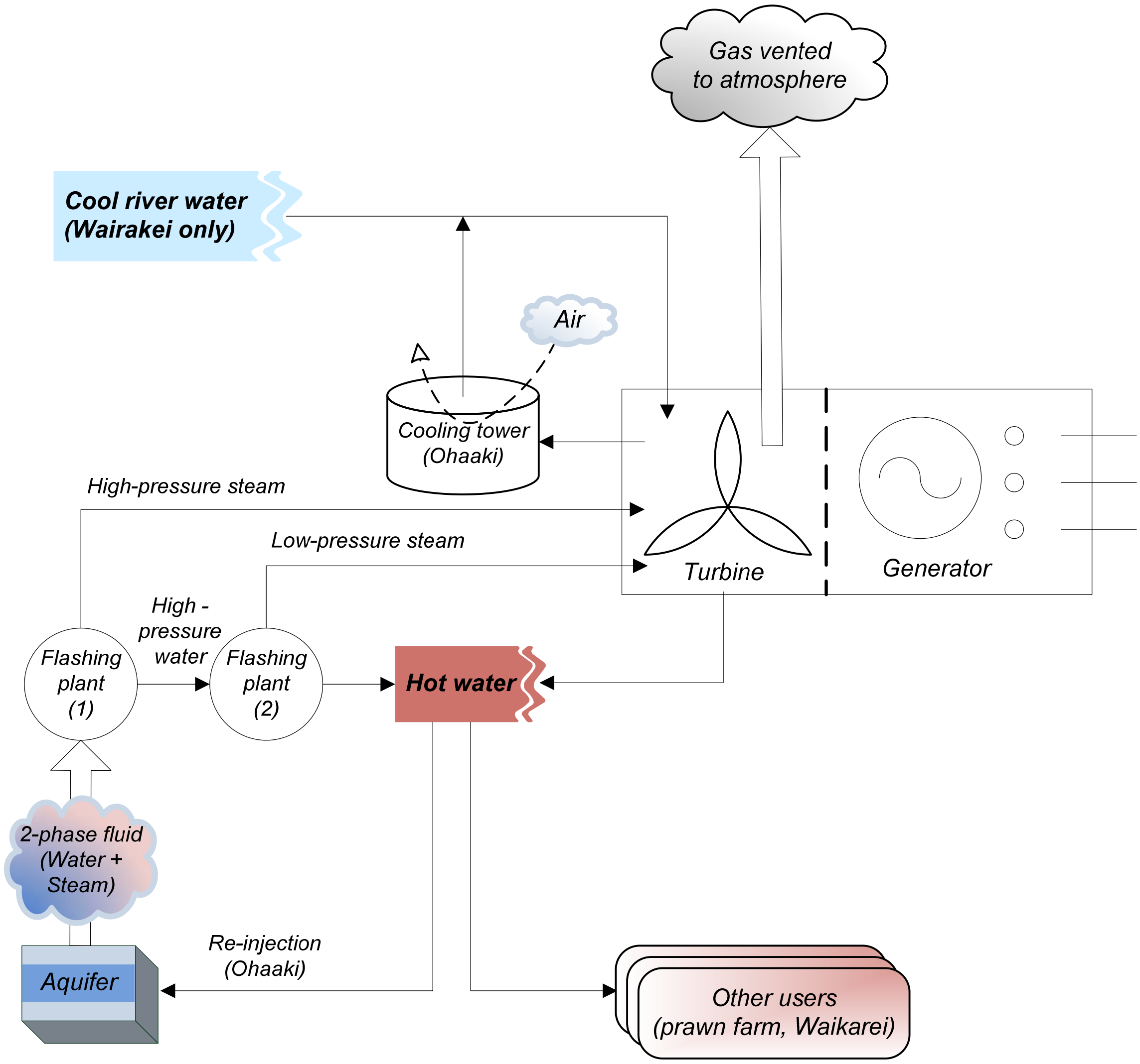
Emissions for other leakages of natural gas are estimated using a Tier 1 method. Methane emissions are estimated for leakages at both ‘industrial plants and power stations’ and ‘residential and commercial sectors’. For this Inventory, all gas supplied to industrial plants, including both energy-use gas and feedstock gas, has been included in the estimation calculations.

1.B.2.D Geothermal

When geothermal fluid is discharged, some CO_2 and small amounts of CH_4 are also released. 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 13 geothermal power stations – most of these are owned (or partly 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 MW Kawerau geothermal plant being online since late 2008 and Nga Awa Purua and Tauhara plant being online since 2010.

The schedules to the Climate Change Response Act 2002 create obligations for people carrying out certain activities 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 – CH4 and N2O
- 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 Business, Innovation and Employment received five applications relating to the use of UEFs 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 Business, Innovation and Employment 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 from 2010 onwards are calculated using UEFs where available and field-specific DEFs otherwise.

When several years of UEF data are 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 CO_2 and CH_4 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 (wastewater).

The concentration of CO_2 (eg, 0.612 per cent) and CH_4 (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 CO_2 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:

$$3.565 \frac{tonnes\ of\ CO_2}{hour} x 8760 \frac{hours}{year} = 31{,}230 \text{ tonnes of } CO_2.$$

Using the same methodology above will yield 149 tonnes of CH_4. The overall emission for Company A is therefore 34,359 tonnes of CO_2-e emissions.

Geothermal methodology for Company B

At Company B, spot measurements of both CO_2 and CH_4 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 CO_2 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 has improved the data split between natural gas flaring and venting since its 2013 submission in response to previous ERT recommendations. These items are now disaggregated and reported separately.

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. Gas transmission losses included both direct leakage of CH_4 and CO_2 as well as gas lost and/or used when starting lines compressors. This information is provided by Vector. Data is provided for GJ of CH_4 and tonnes of CO_2. Gigajoules of CH_4 are converted to tonnes of CH_4 using the Ministry for the Environment's standard conversion factor for CH_4 of 55.60 tonnes/GJ. New Zealand has a high-pressure transmission network nearly 3,500 kilometres in length. It joins most North Island cities (natural gas is only available in New Zealand's North Island). No time series of transmission lines length is available.

New Zealand bases distribution loss emissions off information on gas entering the distribution network, which is administrative data collected at the 'gas gate' by the gas industry regulator (the Gas Industry Company), rather than the alternative of using survey information collected from gas retailers on the amount of gas sold and metered at the individual customer (household, small business) level.

Of the gas entering the low-pressure distribution system, 1.75 per cent (which is based on consultation between the Government and the Gas Association of New Zealand (an industry group)) is assumed to be lost through leakage. 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 Ministry of Business, Innovation and Employment's online energy data tables (2013a). 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. A different source was chosen for the CO_2 fugitive emissions because the IPCC good practice guidance (2000) has an emissions factor that more closely aligns to the way oil is transported in New Zealand. The specific factor chosen was for oil transport in 'tanker trucks and rail cars' (table 2, page 112, IPCC (2000)).

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, and the fugitive CH_4 emission factor for oil refining is 0.745 tonnes of CH_4/PJ. These emission factors are the mid-point of the IPCC default range from the IPCC guidelines (1996), for Western Europe (table 1-58, page 1.121). 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’.

Natural gas storage occurs at the Ahuroa gas storage facility. Ahuroa is a depleted field that can hold nearly 5–10 PJ of natural gas at any one point. This gas is used to run Contact Energy’s Stratford gas peaking plant, which consists of two 100 MW open cycle gas turbine units. As the Ahuroa gas storage facility is a depleted gas field, where gas is re-injected for storage, leakage emissions from this facility are no different than from any other industrial plant or power station. Therefore, leakage emissions from this facility are included under the category other leakage from industrial plants and power stations.

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 control 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 grows, 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

The emissions reported under the Industrial Processes sector are from the chemical transformation of materials from one substance to another and from the consumption of halocarbons and sulphur hexafluoride (SF_6). Although fuel is also often combusted in the manufacturing process, emissions arising from combustion are reported under the Energy sector. Carbon dioxide (CO_2) emissions related to the production of synthetic petrol from natural gas, which occurred between 1990 and 1997, are also reported under 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 seven 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 methanol
- production of hydrogen.

Table 4.1.1 lists greenhouse gas emissions by the key categories in the Industrial Processes sector.

Table 4.1.1: Emissions by key categories in the Industrial Processes sector

Category name	IPCC code (1996)	Gas	Assessment type
Mineral products – cement production	2.A.1	CO_2	LA
Metal production – iron and steel production	2.C.1	CO_2	LA
Metal production – aluminium production	2.C.3	CO_2	LA
Metal production – aluminium production	2.C.3	PFCs	TA
Chemical industry – hydrogen production	2.B.5	CO_2	LA
Chemical industry – ammonia production	2.B.1	CO_2	qualitative
Consumption of halocarbons and SF_6 – foam blowing	2.F(a).2	HFCs, PFCs & SF_6	TA
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	2.F(a).1	HFCs, PFCs & SF_6	LA, TA

Note: IPCC = Intergovernmental Panel on Climate Change; HFCs = hydrofluorocarbons; PFCs = perfluorocarbons; LA = level assessment; TA = trend assessment

Emissions in 2012

In 2012, New Zealand's Industrial Processes sector produced 5,276.8 Gg of carbon dioxide equivalent (CO_2-e), contributing 6.9 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 43.2 per cent of sector emissions in 2012.

Changes in emissions 1990–2012

Emissions from industrial processes in 2012 had increased by 2014.7 Gg CO_2-e (61.8 per cent) above the 1990 level of 3,262.1 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 1,812.5 Gg CO_2-e (figure 4.1.2). Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons, and CO_2 emissions from mineral, chemical and metals production have gradually increased due to increasing product outputs. Emissions of perfluorocarbons from aluminium production have decreased, due to improved control of anode effects in aluminium smelting.

Figure 4.1.1 New Zealand's Industrial Processes sector emissions from 1990 to 2012

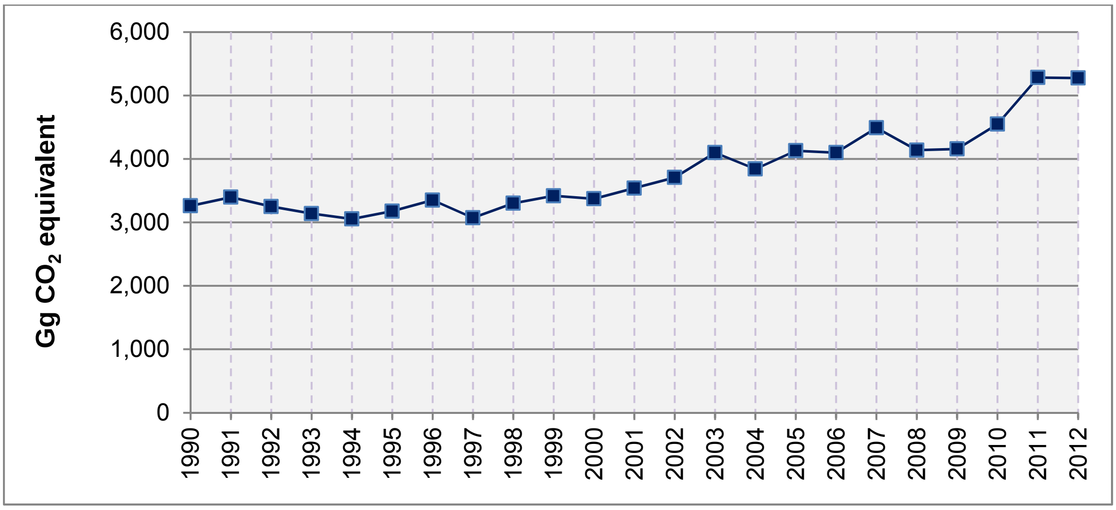
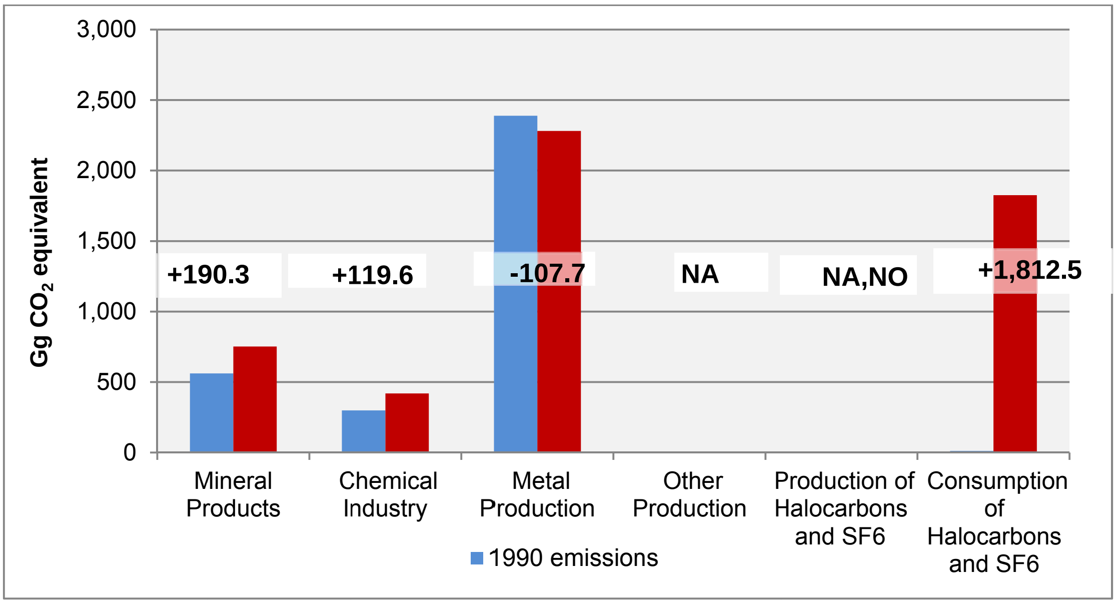


Figure 4.1.2 Change in New Zealand's Industrial Processes sector emissions from 1990 to 2012



Note: Other production and the production of halocarbons and 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.

Changes in emissions 2011–2012

Since 2011, emissions from the Industrial Processes sector decreased by 7.3 Gg CO_2-e (0.1 per cent). Carbon dioxide emissions decreased by 7.8 Gg (0.2 per cent). Emissions from the consumption of hydrofluorocarbons (HFCs) had increased, by 807.4 Gg CO_2-e, between 2010 and 2011 and remained at this higher level in 2012.

4.1.1 Methodological issues

Emissions of CO_2 from industrial processes are compiled by the Ministry of Business, Innovation and Employment (formerly 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 2012, the only known methane (CH_4) emissions from the Industrial Processes sector came from methanol production. However, as discussed below, CH_4 emissions from methanol production are considered to be related to the distribution and use of gas, and are reported under the Energy sector (section 3.3.7).

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

4.1.4 Recalculations

Previous submissions reported quantities of urea manufactured as the activity data for New Zealand's ammonia–urea plant. The activity data series for ammonia production has been revised so that the activity data reported is now the quantity of ammonia manufactured. Also, emissions related to the combustion of gas at this plant have been moved from the Industrial Processes sector to the Energy sector.

Activity data on methanol production, which was previously regarded as confidential, is reported in CRF 2B.

Errors in data supplied by industry in the metals and halocarbons categories have been corrected. Emissions data for the use of SF_6 in electrical equipment has been revised to account for improved estimation of the capacity of equipment.

4.2 Mineral products (CRF 2A)

4.2.1 Description

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 2012, the mineral products category accounted for 752.1 Gg CO_2 (14.3 per cent) of total emissions from the Industrial Processes sector. Emissions in this category have increased by 190.3 Gg CO_2 (33.9 per cent) from the 1990 level of 561.9 Gg CO_2. The increase has been driven mainly by increasing cement production.

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 under the Energy sector.

In 2012, cement production accounted for 568.63 Gg CO_2 (75.6 per cent) of emissions from the mineral products category. In the same year, lime production accounted for 112.0 Gg CO_2 (14.9 per cent), limestone use 63.0 Gg CO_2 (8.4 per cent) and soda ash use 8.5 Gg CO_2 (1.1 per cent). Emissions from the minerals category increased by 38.9 Gg (5.5 per cent) between 2011 and 2012, due to increased cement production.

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

The only key category identified in the 2012 level assessment from the minerals category is CO_2 emissions from cement production. There were no sources identified in the 1990–2012 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 to 2012 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 2012, 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 under 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 have been 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 calculation of CO_2 emissions from raw meal converted to clinker from 1990 to 2009 to obtain its final process CO_2 emissions. From 2010, 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 to 2012, 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 1990–2012 time series. In general, the figure shows clinker and cement production increasing over the time series 1990–2012. 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).

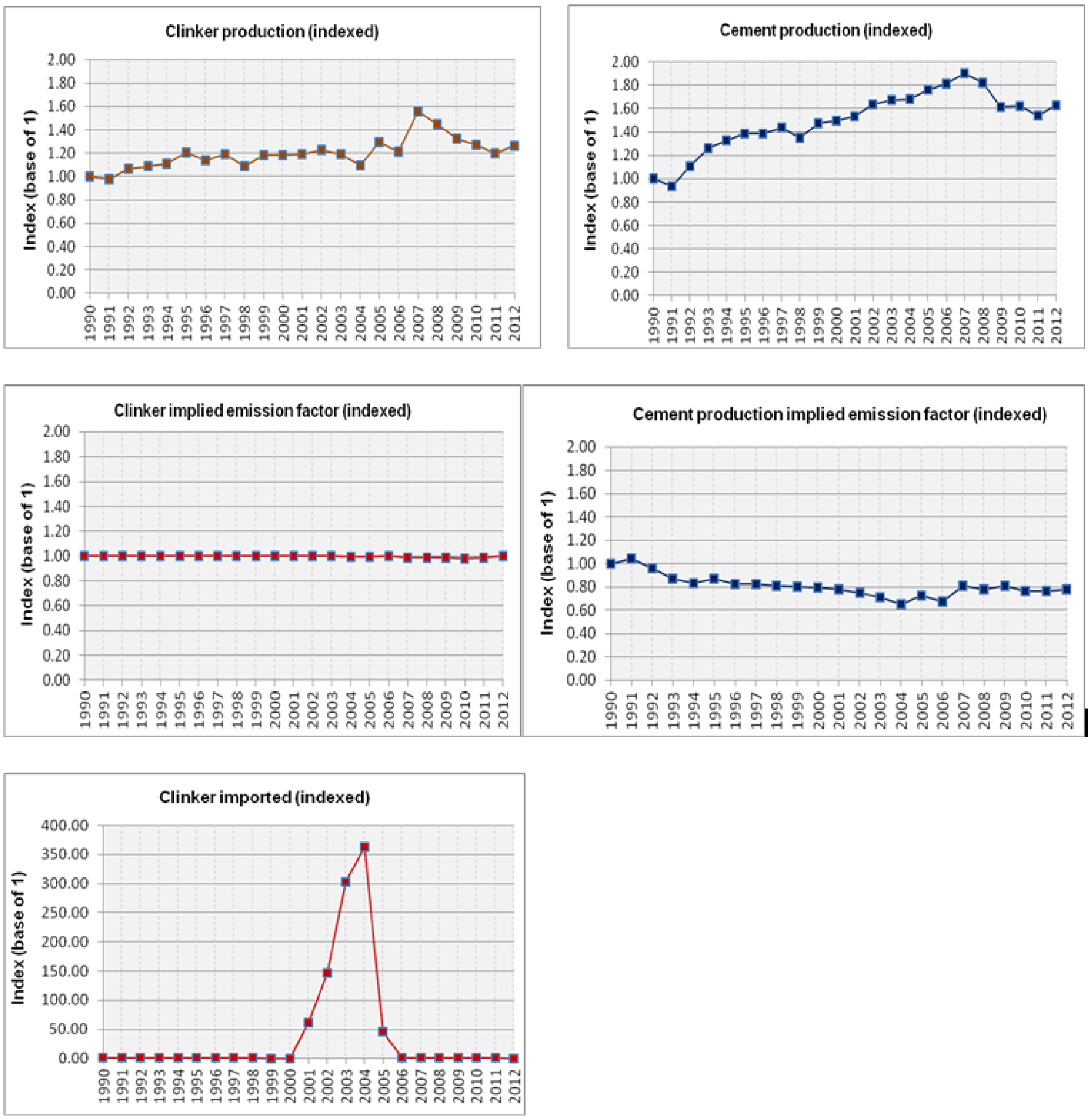
The cement implied emission factor decreased between 2000 and 2006 with the increasing use of imported clinker. Meanwhile, the implied emission factor for clinker remained relatively unchanged. In September 2006, Golden Bay Cement completed an expansion of its Northland facility, resulting in an increase 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 returning 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), also resulted in lower 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 was 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 proportion of 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 to 2012**



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 under 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 have been 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, 2011 and 2012 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 data set. 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, which 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 monoxide (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 under 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 to 2012 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 three 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 to 2012, 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. 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 to 2012 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 to 2012.

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 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 from 2007 (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 to 2012 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 2006–2012.

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 (NO_x), 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 2006–2012.

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

NMVOC emitted = A × B × C × 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 2010–2012, 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 2012, CO_2 emissions from cement production were a key category (level assessment). In the preparation of this inventory, the data for these emissions underwent IPCC Tier 1 quality checks.

4.2.5 Source-specific recalculations

There were no recalculations for this category.

4.2.6 Source-specific planned improvements

The inventory agency will continue to work closely with glass producers and New Zealand Steel Ltd 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 data set, and to determine whether any unreported, non-market production of burnt lime exists in New Zealand. 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 major chemical processes occurring in New Zealand that fall into the chemical industry category are the production of ammonia (for processing into urea fertiliser), 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 2012, emissions from the chemical industry category comprised 419.1 Gg CO_2-e (7.9 per cent) of total emissions from the Industrial Processes sector. Emissions have increased by 119.7 Gg CO_2-e (40.0 per cent) from the 1990 level of 299.4 Gg CO_2-e.

In 2012, CO_2 emissions from ammonia production accounted for 167.7 Gg CO_2-e (40.0 per cent) of emissions in the chemical industry category. CO_2 from hydrogen production, nearly all as part of an oil refining process, contributed the remaining 251.4 Gg CO_2-e (60.0 per cent) of emissions from the chemical industry in 2012. These emissions have shown an increasing trend since 1990, driven by increasing capacity for both oil refining and urea production.

Emissions from the chemical industry category increased by 20.8 Gg (5.2 per cent) between 2011 and 2012. A fire and consequent shutdown of the ammonia–urea plant in August 2011 meant that ammonia and urea production was lower than normal in 2011, and recovered in 2012 (Ballance, 2012).

A key category identified in the 2012 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 at one plant in New Zealand by the catalytic steam reforming of natural gas. Liquid ammonia and CO_2 are reacted together to produce urea. All of the ammonia produced is used for urea production, and essentially all of the urea produced is used as a fertiliser in New Zealand. Emissions are calculated using a Tier 2 methodology, i.e. a carbon balance based on the natural gas feedstock used. Data on the natural gas supplied to the plant is provided to the Ministry of Business, Innovation and Employment by Ballance Agri-Nutrients Ltd, which operates the ammonia–urea production plant.

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 feedstock gas (from different gas fields) by their respective emission factors. The CO_2 implied emission factor has been consistent since 1998, apart from a peak in 2011 and 2012 which appears to be related to a plant shutdown caused by a fire in August 2011 (Ballance, 2012).

Non-carbon dioxide emissions are considered to arise from fuel distribution and combustion rather than from the process of making ammonia and are therefore reported under the Energy sector.

Methanol

Methanol is manufactured from natural gas feedstock, at two production sites in the Taranaki region. When built, one of these plants processed methanol to make synthetic gasoline for transport use in New Zealand. Synthetic gasoline production stopped in 1997, and from that time both sites have made only methanol for export.

Emissions from the chemical transformation of materials into methanol would normally be reported under the Industrial Processes sector, using a Tier 2 methodology to determine any CO_2 emissions from a carbon balance. However, the available data on gas supplied to the methanol plants does not allow feedstock to be clearly distinguished from gas for combustion. Also, the conversion of feedstock gas to methanol is believed to be close to 100 per cent, so that any process CO_2 emissions are likely to be small. Therefore, any process CO_2 emissions are included in the Energy sector, manufacturing industries and construction (section 3.3.7) for all years.

Methane emissions related to the methanol plants are reported under the Energy sector, because they relate to the distribution and use of gas and to avoid any double counting. This means there are no emissions reported under methanol production in the Industrial Processes sector, although the activity data is reported.

Hydrogen

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. In both cases the hydrogen is produced from CH_4 and steam. Carbon dioxide is a by-product of the reaction and is vented to the atmosphere.

Emissions of CO_2 from hydrogen production are calculated using a Tier 2 methodology. The required data is supplied directly to the Ministry of Business, Innovation and Employment by the two production companies. Field-specific emission factors are used to determine the CO_2 emissions from the feedstock gas used in the production of hydrogen. In 2012, 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 reported under 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 2006–2012. Plant-specific emission factors used in previous years were applied to the 2012 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 (CRL Energy, 2006a) 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. 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 manufacturer in New Zealand that provides data to 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 ±10 superphosphate	±15 sulphuric acid ±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. This has resulted in a recalculation as described below.

4.3.5 Source-specific recalculations

Ammonia and urea

In previous submissions the quantity of urea manufactured has been reported as the activity data for the ammonia–urea plant. For this submission, the time series has been corrected to ensure that the activity data reported is the quantity of ammonia produced in each year.

Also, to avoid any double counting, previous submissions have reported all emissions at the production site, including emissions associated with the combustion of fuel for energy, as industrial process emissions. For this submission, emissions related to the combustion of natural gas at the ammonia–urea plant have been separated and are now reported under the Energy sector (section 3.3.7). This means that a Tier 2 methodology is applied, in line with IPCC Guidelines, and that the implied emission factors are comparable with those given in the Guidelines (IPCC, 1996). Data to separately report the quantities of natural gas used for combustion, for the entire time series, has been provided to the Ministry of Business, Innovation and Employment by the plant operator.

Methanol

For all submissions up to 2013, all CO_2 and non-CO_2 emissions from methanol production for all years were reported under the energy subcategory, manufacturing industries and construction (section 3.3.2). This was done because of confidentiality concerns, given that one firm owns and operates both methanol production sites in New Zealand. As a result, no activity data or emissions were reported under methanol production in the Industrial Processes sector.

Data on the number of tonnes of methanol produced each year is now published and made publicly available. For this submission, activity data on methanol production is reported under the Industrial Processes sector. However, CO_2 emissions from gas used for combustion are reported under the Energy sector in accordance with IPCC Guidelines.

The available data on gas supplied to the methanol plants does not allow feedstock to be clearly distinguished from gas for combustion. Also, it is believed that, to a good approximation, there is 100 per cent conversion of feedstock gas to methanol and therefore no significant CO_2 emissions related to the process. Therefore, any small amount of process CO_2 emissions is still included in the Energy sector.

Non-carbon dioxide emissions are considered to arise from fuel distribution and combustion rather than from the process of making ammonia and are therefore also reported under the Energy sector.

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 the fact that up to the 2013 Inventory submission all data related to these emissions has been reported under the Energy sector because of confidentiality concerns. New Zealand plans to work with the industry to attempt to further 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 2012, emissions from the metal production category were 2,280.7 Gg CO_2-e, 43.2 per cent of emissions from the Industrial Processes sector. Emissions from this category decreased 107.7 Gg CO_2-e (4.5 per cent) from the 1990 level of 2,388.5 Gg CO_2-e. The decrease has been driven by a substantial reduction in emissions of perfluorocarbons from aluminium smelting, which has offset an increase in CO_2 emissions driven mainly by increasing steel production:

- Carbon dioxide emissions accounted for 98.2 per cent of emissions in this category, with the other 1.8 per cent from PFCs. In 2012, the level of CO_2 emissions had increased by 484.9 Gg CO_2 (27.6 per cent) above the 1990 level.
- Perfluorocarbon emissions have decreased from the 629.9 Gg CO_2-e in 1990 to 40.8 Gg CO_2-e in 2012, a decrease of 589.1 Gg CO_2-e (93.5 per cent). This decrease is due to improvements made by the aluminium smelter. These improvements are discussed further in the following section.

In 2012, emissions from iron and steel production contributed 1,718.9 Gg CO_2-e (75.4 per cent) and aluminium production contributed 561.8 Gg CO_2-e (24.6 per cent) to the metal production category.

Total emissions from metal production decreased by 56.9 Gg (2.4 per cent) between 2011 and 2012. This decrease is the result of lower CO_2 emissions due to fluctuation in product outputs.

The key categories identified in the 2012 level assessment from the metal production category are CO_2 emissions from:

- iron and steel production
- aluminium production.

In the metal production category, the emission of PFCs from aluminium production was identified as a key category in the 1990–2012 trend assessment.

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 the Ministry of Business, Innovation and Employment (formerly the Ministry of Economic Development) 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 of primary concentrate (provided by New Zealand Steel Ltd)

Component	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 as 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 under 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 that 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 C to obtain the CO_2 emissions.

Table 4.4.2 Approximate 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	Up to 30.00
Diajetta	99.90
Recarburiser	98.00

Reported emissions exclude the minor carbon component of the vanadium, manganese or silicon additives that are subsequently added to the ladle. These additives are excluded because the amount of carbon is considered negligible and is likely to be sequestered 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 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, operated by New Zealand Aluminium Smelters Ltd. The smelter produces aluminium by smelting imported raw material using centre-worked prebake 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 under 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 the Ministry of Business, Innovation and Employment until 2010. For 2011 and 2012, 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 6,500 and 9,200 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 fluctuated over the time series between 1990 and 1998. These fluctuations are identified and explained in table 4.4.3. Since 1998, emissions have been lower than previously and relatively stable, due to much better control of anode effects.

Figure 4.4.1 New Zealand's implied emission factors for aluminium production from 1990 to 2012

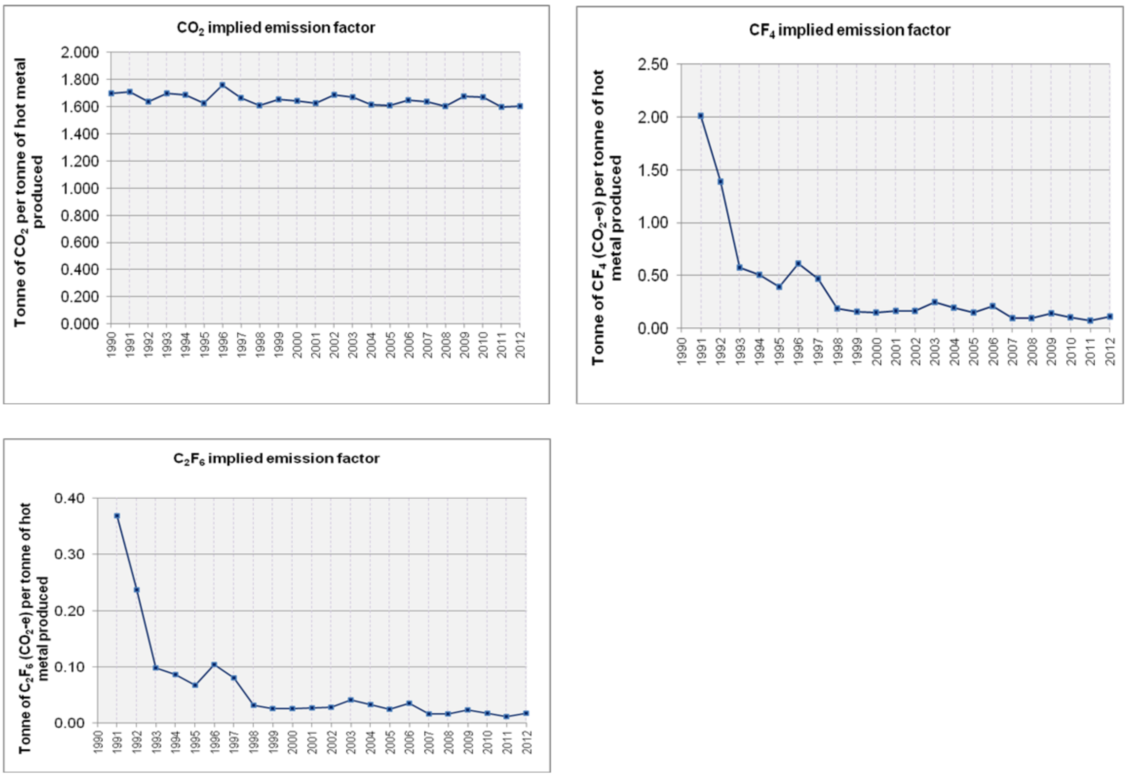


Table 4.4.3 Explanation of variations in New Zealand's aluminium emissions

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 so that 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 both for iron and steel and for 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 (2012 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 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, 2011 and 2012 calendar years.

The verification process concluded that there were no significant discrepancies between the datasets for emissions from Pacific Steel Ltd.

New Zealand Steel Ltd reports emissions from all carbon-containing inputs under the NZ ETS. The total emissions from carbon-containing inputs should be comparable with the emissions from limestone, coke and electrodes as reported by the company to the Ministry of Business, Innovation and Employment for the compilation of the national inventory using a mass-balance approach (see section 4.2.2).

Verification in 2013 showed apparent discrepancies between these datasets, with two possible causes. First, New Zealand Steel Ltd reports emissions from uncalcined dolomite under the NZ ETS, whereas it was unclear whether these emissions were captured in the national inventory. Second, New Zealand Steel reports data to the NZ ETS on the basis of limestone and other materials at the time they are purchased, while it reports inventory data at the time they are consumed. As a result, stock changes may cause discrepancies.

Following clarification and some corrected data provided by New Zealand Steel Ltd, the apparent discrepancy related to dolomite use has been resolved. The inventory agency is actively monitoring the remaining apparent discrepancies, which appear to be due to stock changes and are therefore expected to average out over time. The inventory agency will work with New Zealand Steel Ltd to work through the differences in reporting methodologies. The inventory agency is expecting to fully resolve these discrepancies in future Inventory submissions.

4.4.5 Source-specific recalculations

Iron and steel production

Errors have been corrected in the data provided by New Zealand Steel Ltd, which affects emission estimates for 2009, 2010 and 2011. 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.

Pacific Steel identified in 2013 that the carbon content of an additive used in the electric arc furnace from 2009 had been over-estimated, based on data from the supplier of the additive. This has been corrected by the company for this submission.

4.4.6 Source-specific planned improvements

The inventory agency is actively monitoring the apparent discrepancies explained in section 4.4.4 and will continue to work 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 2012, emissions from this category totalled 7.9 Gg NMVOC. This was an increase of 2.0 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, they are reported under the Energy sector.

Pulp and paper

There is 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 under 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 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) ±20 (wine) ±40 (spirits)	±80 (beer and wine) ±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

Hydrofluorocarbons and perfluorocarbons

In 2012, emissions from the consumption of HFCs and PFCs totalled 1,804.7 Gg CO_2-e, 34.2 per cent of emissions from the Industrial Processes sector. This is a decrease of 12.7 Gg CO_2-e (0.7 per cent) from the 2011 level of 1,817.4 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 2012 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.

Sulphur hexafluoride

The emissions inventory for SF_6 is broken down into two subcategories: electrical equipment and other. The majority of SF_6 emissions are from use in electrical equipment. In New Zealand, the main electricity distribution company accounts for 70 per cent of total SF_6 used in electrical equipment.

In 2012, SF_6 emissions were 20.2 Gg CO_2-e. This is an increase of 7.9 Gg CO_2-e (63.7 per cent) from the 1990 level of 12.3 Gg CO_2-e, and an increase of 2.6 Gg CO_2-e (14.6 per cent) from 2011.

4.7.2 Methodological issues

Hydrofluorocarbons and perfluorocarbons

Activity data on the bulk imports and end use of HFCs and PFCs in New Zealand is 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 United Nations Framework Convention on Climate Change 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 dataset (CRL Energy, 2013).

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.

A Tier 2a method has been applied to metered dose inhalers and the emission factor is 50 per cent of the initial charge per year. The default emission factor of 50 per cent of the initial charge per year (IPCC, 2006) is applied to the sales of aerosols.

Aerosols

Emissions from aerosols contributed 22.5 Gg CO_2-e in 2012, an increase of 20.8 Gg CO_2-e from the 1996 level of 1.6 Gg CO_2-e. Aerosols containing HFCs were not widely used in New Zealand until 1996, 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 and 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 2012, emissions from metered dose inhalers contributed 62.7 Gg CO_2-e, an increase of 62.2 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 2012 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, 2013).

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, 2013).

Foam

In New Zealand, emissions from closed-cell foam (hard foam) only are known to have occurred between 2000 and 2012. In 2012, emissions from the use of HFCs in hard foam blowing were 0.4 Gg CO_2-e, an increase of 0.3 Gg CO_2-e from the 2000 level of 0.1 Gg CO_2-e.

For 2010, 2011 and 2012, 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 2012. These emissions are estimated to have increased from 0.1 tonnes in 2004 to 1.5 tonnes in 2012. 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 2012, activity data was provided by the sole supplier of HFCs for foam blowing (CRL Energy, 2013). 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 1a 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 1,542.0 Gg CO_2-e in 2012. This is an increase of 1,540.7 Gg CO_2-e from the 1992 level of 1.3 Gg CO_2-e. In 2012, stationary refrigeration and air conditioning made up 84.5 per cent of the emissions from the halocarbon and SF_6 consumption category. In 1992, only HFC-134a was used, while in 2012, HFCs -32, -134a, -125 and -143a were consumed. There was no use of HFCs and PFCs before 1992. A small amount of C_2F_6 (in the form of a mix) was used in 2010 only.

The increase in emissions from 1992 to 2012 is due to HFCs and PFCs being 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 decreased from 1,564.0 Gg CO_2-e in 2011to 1,542.0 Gg CO_2-e in 2012. These emissions had increased from 2010 to 2011, due to increased imports which may have been associated with the introduction of NZ ETS obligations. This increased level of emissions has decreased slightly for 2012.

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 1990–2012. Table 4.7.3 provides a breakdown of the annual sales of new refrigerant in New Zealand for 1990–2012. 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 from 1990 to 2012 (CRL Energy, 2013)

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	1033.2	245.5	45.9	0	833.6
2012	842.6	264.2	43.0	0	621.4

[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 from 1990 to 2012 (CRL Energy, 2013)

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

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)
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	930.5	23.6	207.2	80.9	1033.2
2012	0	741.0	31.8	219.2	85.8	842.6

Table 4.7.4 Total charge of new equipment sold in New Zealand from 1990 to 2012 (CRL Energy, 2013)

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
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

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)
2010	66.6	188.8	255.4
2011	38.3	207.2	245.5
2012	45.0	219.2	264.2

1 It is not possible to differentiate between the chemical to charge domestically manufactured and imported non-factory-charged equipment.

To estimate HFC and PFC 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, 2013) 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 2012, HFC-134a emissions from mobile air conditioning were 175.6 Gg CO_2-e, an increase of 174.4 Gg CO_2-e from the 1994 level of 1.3 Gg CO_2-e. Emissions from mobile air conditioning made up 9.6 per cent of total emissions from the halocarbon and SF_6 consumption category in 2012. 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 the year 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 1994–2012.

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 from 1994 to 2012 (CRL Energy, 2013)

Year	First-fill emissions	Operation emissions	Disposal emissions	Intentional destruction	Annual emissions of HFC-134a
1994	0.000	1.0	0.0	0	1.0
1995	0.003	2.6	0.3	0	2.9
1996	0.016	2.7	0.9	0	3.6
1997	0.012	5.4	2.9	0	8.3
1998	0.008	8.8	2.7	0	11.5
1999	0.005	13.4	3.0	0	16.4
2000	0.005	17.7	5.0	0	22.6
2001	0.007	23.6	7.4	0	31.0
2002	0.010	30.1	10.2	0	40.3
2003	0.015	37.4	11.4	0	48.8
2004	0.003	47.6	14.8	0	62.4
2005	0.001	55.7	21.5	0	77.2
2006	0.001	61.1	29.1	0	90.2
2007	0.001	66.7	35.0	0	101.8
2008	0.002	59.6	40.2	0	99.8
2009	0.001	72.2	41.8	0	114.0
2010	0.001	75.4	42.2	0	117.6
2011	0.001	77.8	50.3	0	128.1
2012	0.001	80.2	54.9	0	135.2

First-fill emissions are calculated from imported vehicle fleet numbers provided by Statistics New Zealand and the New Zealand Transport Registry Centre. Assumptions are made about the percentage of mobile air-conditioning installations. Operation and disposal data is 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, 2013).

Fire protection

In 2012, HFC-227ea emissions from fire protection were 1.5 Gg CO_2-e, an increase of 1.4 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.

For the first time, another major importer of fire protection equipment was identified and was able to provide detailed HFC-227ea import figures from 2009 when they commenced imports.

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.

The high ratio of potential to actual emissions for fire protection systems containing HFC-227ea is a result of both the long lifespan of these systems (IPCC 2006: 15 to 35 years) and slowly expanding use.

Electrical equipment

In 2012, SF_6 emissions from electrical equipment were 17.3 Gg CO_2-e, an increase of 7.9 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, 2013).

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, 2013).

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. The decrease in potential emissions between 2011 and 2012 was due to one supplier exiting the market and exporting remaining stocks. Potential SF_6 emissions are usually two to three times greater than actual emissions in a given year (CRL Energy, 2013). The high ratio of potential to actual emissions for SF_6 is a result of the long lifespan of electrical equipment (IPCC 2006: more than 30 to 40 years) and the expansion of the electricity transmission system.

Other SF_6 applications

Emissions from other SF_6 applications in 1990 and 2012 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 1 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 2012 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.

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, 2013)

HFC source	Uncertainty estimates (%)
Aerosols	Combined uncertainty ±47
Metered dose inhalers	Combined uncertainty ±10
Solvents	Not occurring
Foam	Combined uncertainty ±49
Stationary refrigeration/air conditioning	Combined uncertainty ±18
Mobile air conditioning	Combined uncertainty ±33
Fire protection	Combined uncertainty ±32
SF_6 source	**Uncertainty estimates (%)**
Electrical equipment	Combined uncertainty ±28
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

There have been several improvements for this submission in the estimation of emissions from stationary refrigeration and air conditioning. Some double counting of HFC-134a imports (and consequent calculated emissions) was discovered for 2011 and corrected in this report. The reduction in the imported bulk chemical amount means that the corrected 2011 emissions of HFC-134a in the stationary refrigeration and air conditioning sector was reduced by 50.64 tonnes from the record level of calculated emissions in that year.

Improved information was provided by Fisher and Paykel on its HFC-134a purchases and exports for 2011. For the previous report, detailed figures have been unavailable so an average of 2008 to 2010 figures (7.0 tonnes) had been used for the amount of chemical used to fill equipment manufactured for use in New Zealand – instead the figure appears to be closer to 8.5 tonnes of HFC and this has been amended with the consequence that calculated 2011 emissions were reduced by 1.5 tonnes.

There was a much more significant difference in the correction to the assumed figure for the amount of chemical used to fill equipment manufactured for export. Because Fisher and Paykel's production was shifting overseas, the assumption of 15.9 tonnes HFC-134a exported in equipment in 2011 proved to be just 7.0 tonnes, so the amended calculated emissions have been increased by 8.9 tonnes.

HFC-134a imports in household refrigerators, freezers and refrigerator/freezers were each reduced by 1 per cent in 2011 as an assumption of the transition from <1 per cent hydrocarbon refrigerants in 2010 to 3 per cent in 2012.

The combined effect of the four changes described above was to increase HFC-134a emissions for the stationary refrigeration and air conditioning sector by 7.4 tonnes in 2011.

Fire protection

The identification of a third major importer of fire protection equipment has resulted in increases in HFC-227ea import figures from 2009 to 2011 and consequent emissions. The increase in total imports over the three years to the end of 2011 increased calculated emissions by 0.012 tonne for that year (21 per cent higher than the previous calculation).

Electrical equipment

Improved information was provided by several utilities which resulted in changes to the total SF_6 nameplate capacity for 2000 to 2011. A smaller but significant reduction in one company's nameplate capacity resulted from an improved inventory that better identified bulk gas stocks. The records were sufficiently detailed to enable recalculations back to 2000.

Associated with these reductions in total nameplate capacity were small reductions in actual emissions from stocks and amended equipment import assumptions in some years to build up the equipment stocks.

These changes had a relatively small impact on the calculation of actual emissions for 2000 to 2011. Figures for 2000 to 2007 were 0 to 4 kg lower for the revised calculation while for 2008 to 2011, they were 17 to 19 kg lower compared with the previous study.

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 2012 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 2012 level assessment or the trend assessment.

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Chapter 5: Solvent and Other Product Use

5.1 Sector overview

In 2012, New Zealand's Solvent and Other Product Use sector produced 34.1 Gg carbon dioxide equivalent (CO_2-e) emissions, contributing 0.04 per cent of New Zealand's total greenhouse gas emissions.

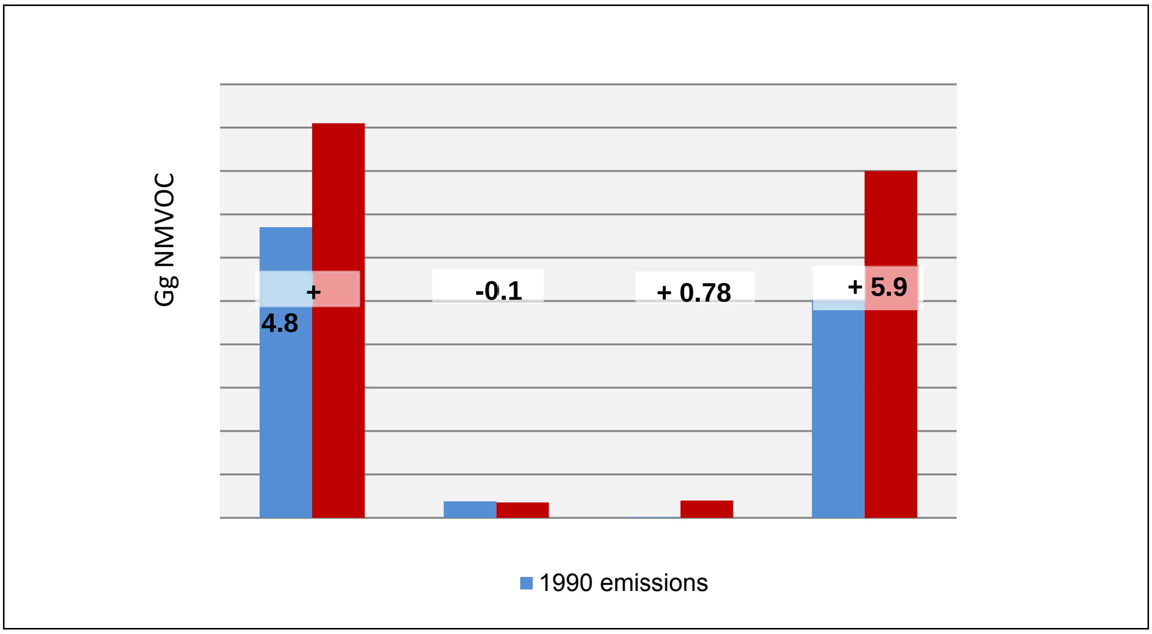
The only direct greenhouse gas reported in this category is nitrous oxide (N_2O) emissions from anaesthesia and other uses. In 2012, N_2O emissions from anaesthesia and other uses totalled 34.1 Gg CO_2-e. This was a decrease of 7.4 Gg CO_2-e (17.8 per cent) from the 1990 level of 41.5 Gg CO_2-e.

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 2012, non-methane volatile organic compound (NMVOC) emissions from the Solvent and Other Product Use sector were 35.7 Gg, or 21.0 per cent of total NMVOC emissions. This was an increase of 11.4 Gg (46.9 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 2012 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 2012



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 2012 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 2012 calendar year (CRL Energy, 2013). 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 N_2O 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 2012 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 2012 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 is 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 per capita per 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 Product Use 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

The Agriculture sector is a main component of the greenhouse gas inventory of New Zealand. In 2012, the Agriculture sector contributed 35,020.1 Gg carbon dioxide equivalent (Gg CO_2-e) emissions (46.1 per cent) to New Zealand's total emissions. Since 1990, emissions have increased by 4,549.2 Gg CO_2-e (14.9 per cent) from the 1990 level of 30,471.0 Gg CO_2-e (figure 6.1.1).

The increase since 1990 is primarily due to a 1,834.6 Gg CO_2-e (8.3 per cent) increase in methane (CH_4) emissions from the enteric fermentation category and a 2,510.2 Gg CO_2-e (32.0 per cent) increase in nitrous oxide (N_2O) emissions from the agricultural soils category (figure 6.1.2). The main drivers for this change in emissions are an increase of 26.7 per cent in total cattle population and 512 per cent in nitrogen fertiliser use, while a decrease of 46.0 per cent in sheep populations offset these increases.

In 2012, 68.3 per cent (23,935.9 Gg CO_2-e) of the emissions were from enteric fermentation, followed by 29.5 per cent (10,340.8 Gg CO_2-e) from agricultural soils, 2.0 per cent from manure management, 0.1 per cent from field burning of agricultural residues and 0.02 per cent from prescribed burning of savannas. Methane emissions from enteric fermentation were 83.6 per cent of New Zealand's total emissions, and N_2O emissions from the agricultural soils category were 97.1 per cent of New Zealand's total emissions.

New Zealand has made a number of improvements in its 2014 submission, specifically the inclusion of a new equation for partitioning nitrogen in excreta between dung and urine, incorporating mitigation by including urease inhibitor, improved data on monthly milk production and regional milk production, and a number of corrections and improvements to its emission model: the animal population dynamics model. Planned improvements are summarised in section 6.1.6 and described in detail in category-specific sections.

Figure 6.1.1 New Zealand Agriculture sector emissions from 1990 to 2012

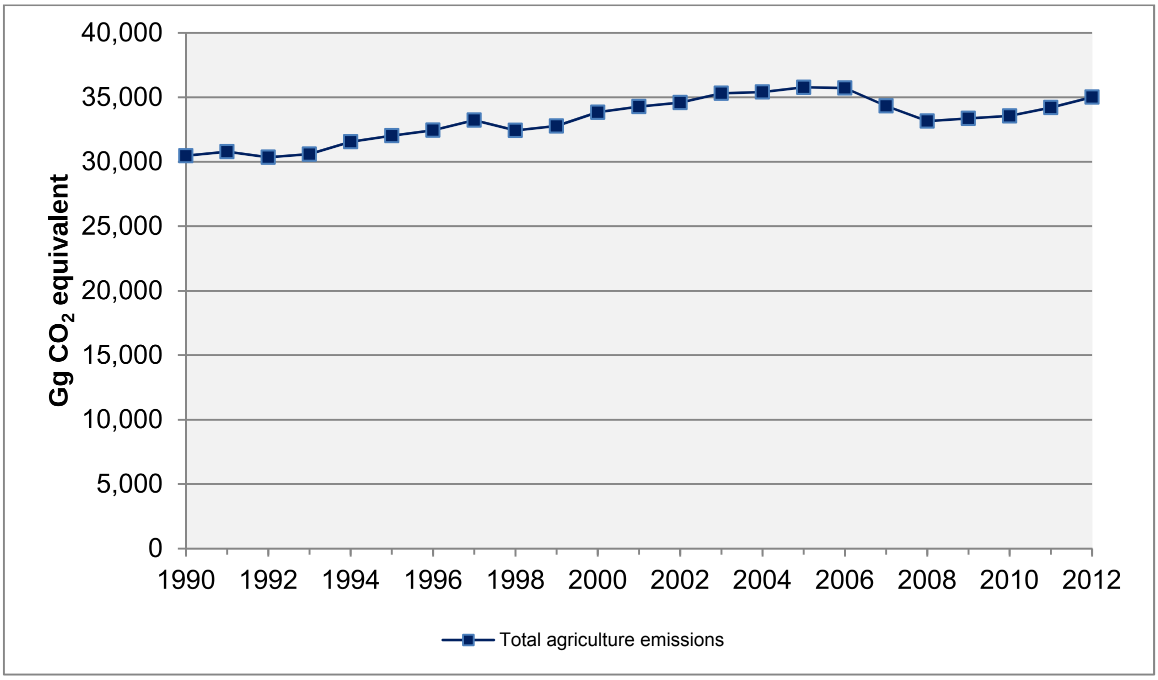
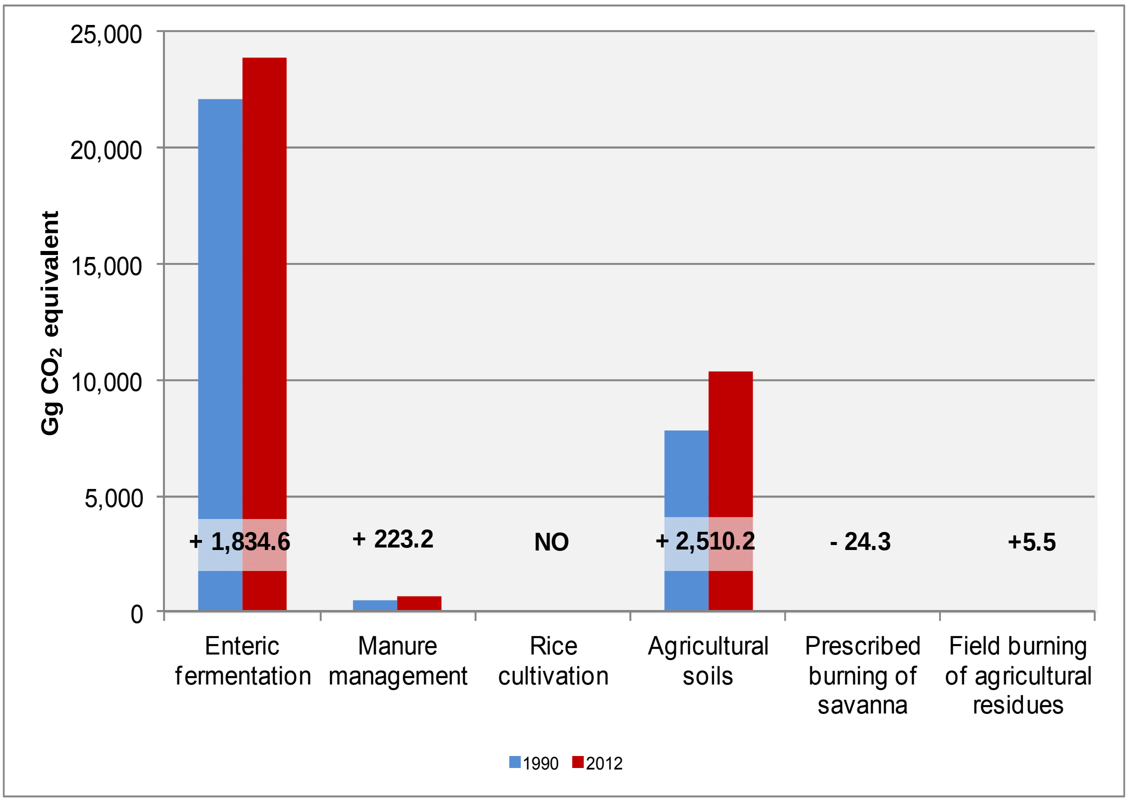


Figure 6.1.2 Change in New Zealand's emissions from the Agriculture sector from 1990 to 2012



Note: Rice cultivation does not occur (NO) in New Zealand.

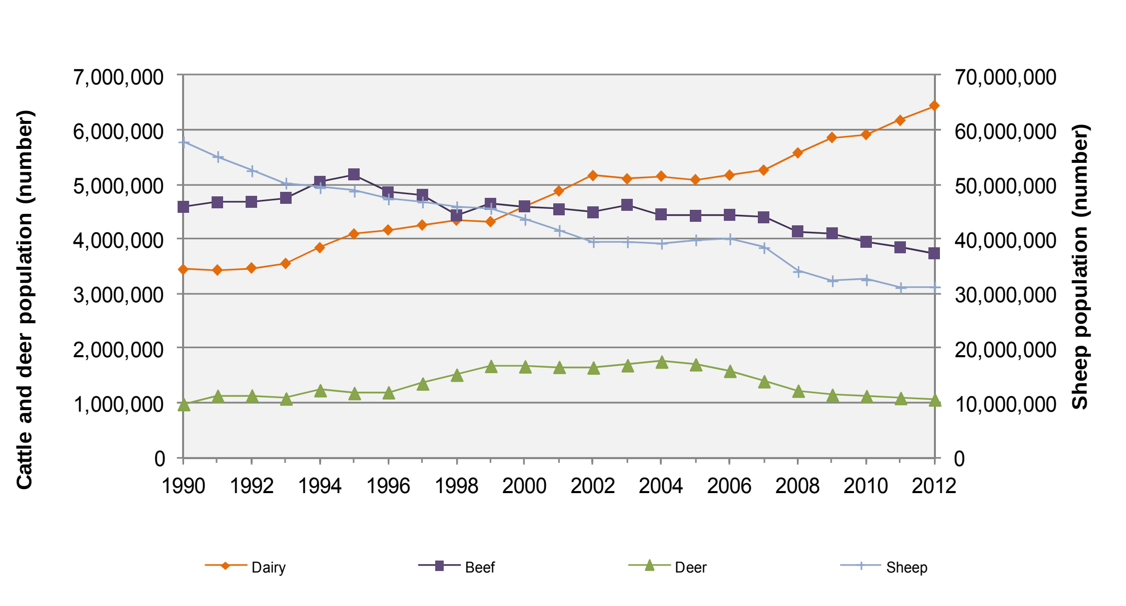
Agriculture is a major component of the New Zealand economy and agricultural products comprise 60 per cent of the total value of merchandise exports (Ministry for Primary Industries, 2013). This is helped by the favourable temperate climate, the abundance of agricultural land and the unique farming practices used in New Zealand. These practices include the use of year-round extensive outdoor pastoral grazing systems and a greater 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 species is not practised in New Zealand. For further information about New Zealand's favourable agricultural growing conditions see chapters 1 and 2 (Executive Summary and National Circumstances) of New Zealand's sixth national communication (www.mfe.govt.nz/publications/climate/nz-sixth-national-communication/index.html). These chapters provide evidence of New Zealand's climate conditions, rainfall and temperature by region and season and explain 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 that for 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 (inferred from livestock numbers, figure 6.1.3, and Statistics New Zealand land-use data). Since 1990, there has also been more forestry planted on areas that were previously in pasture (see chapter 7).

Figure 6.1.3 **Population of New Zealand's major ruminant livestock from 1990 to 2012 – 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 2012. 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 overall livestock emissions. The implied emission factors have started to increase again now that seasonal growing conditions have improved.

The land area used for cropland has increased since 1990 and the types of produce grown have changed (Statistics New Zealand table builder and Infoshare database, 2013). Overall, there is now less cultivated land area for crops such as oats, fruit and vegetables and more for wheat and grapes (for wine production) than in 1990, and productivity per hectare has increased during this time (Coriolis, 2014). There has also been a net increase in land planted in forestry, reducing the land available for agricultural production (chapter 7).

Changes in emissions between 2011 and 2012

Total agricultural emissions in 2012 were 806.6 Gg CO_2-e (2.4 per cent) higher than the 2011 level, which is attributable to the favourable growing weather and good grass growth. There was an increase in emissions due to increases in the population of dairy cattle (271,178 or 4.4 per cent), sheep (130,386 or 0.4 per cent) and amount of nitrogen fertiliser used (2,224 tonnes or 0.6 per cent) in 2012 compared with 2011. This increase in dairy, sheep and fertiliser emissions outweighed emission reductions from decreases in the non-dairy cattle (112,003 or 2.9 per cent) and deer (27,839 or 2.6 per cent). The increase in dairy cattle numbers and the reduction in non-dairy cattle 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, 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 2012 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 2012 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 uses a range of models and tiers appropriate to the size of the emission category. Approximately 93.1 per cent of New Zealand's current 2012 agriculture emissions are due to four major grazed livestock categories: dairy cattle, non-dairy cattle, sheep, and deer. New Zealand uses a detailed livestock population characterisation and a complex nutritional and energy model structure to calculate emissions from these livestock. Other minor livestock species account for approximately0.5 per cent of New Zealand agriculture emissions and these are estimated using Tier 1 methods. Wherever possible, New Zealand has used country-specific emission methods and factors to estimate emissions for minor livestock species. Direct emissions from synthetic fertiliser account for 5.9 per cent of New Zealand's agricultural emissions and are calculated using a Tier 1 method with a country-specific emission factor. The remaining 0.4 per cent of New Zealand agriculture emissions is due to crop residues, nitrogen-fixing crops, crop burning and savanna burning. Emissions from crop residues and nitrogen-fixing crops, including burning of some agriculture residues, are calculated using a Tier 2 method. Emissions from prescribed burning of savanna use a Tier 1 method from the revised 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines with some country-specific emission factors (IPCC, 1996).

New Zealand Tier 2 model for determining energy requirements for major 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. The inventory model was developed to conform to the revised 1996 IPCC guidelines and the IPCC good practice guidance (IPCC, 1996; 2000) and is constantly under improvement.

New Zealand's Tier 2 modelling for key livestock categories could be considered as approaching Tier 3, as it uses country-specific data and monthly data intervals for livestock population, productivity and pasture quality.

New Zealand uses a different characterisation for pasture-based livestock compared with that recommended in the revised 1996 IPCC guidelines, the IPCC good practice guidance and the 2006 IPCC guidelines (IPCC 1996; 2000; 2006). With respect to cattle 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, 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/greenhouse-gas/agricultural-greenhouse-gas-inventory).

Activity data: major species

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, Deer Industry 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 these data are 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 livestock 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), the calculated emission data from the last six months of a July–June year are 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 other countries.

Livestock population data

The detailed livestock population characterisation for each livestock type (dairy, beef, sheep and deer) 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 (2008a). 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 livestock population numbers present and recorded 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/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory).

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, 2008b).

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 was 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 New Zealand Dairy Statistics published by the Livestock Improvement Corporation Ltd (LIC) (2013), Beef and Lamb New Zealand (2013, table 8), Deer Industry New Zealand and slaughter statistics collected by the Ministry for Primary Industries (www.mpi.govt.nz/news-resources/statistics-forecasting/livestock-slaughter-statistics). 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 is summarised in the time-series tables in the MS Excel worksheets available for download with this report from the Ministry for the Environment website (www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2014/index.html). The data include 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).

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.

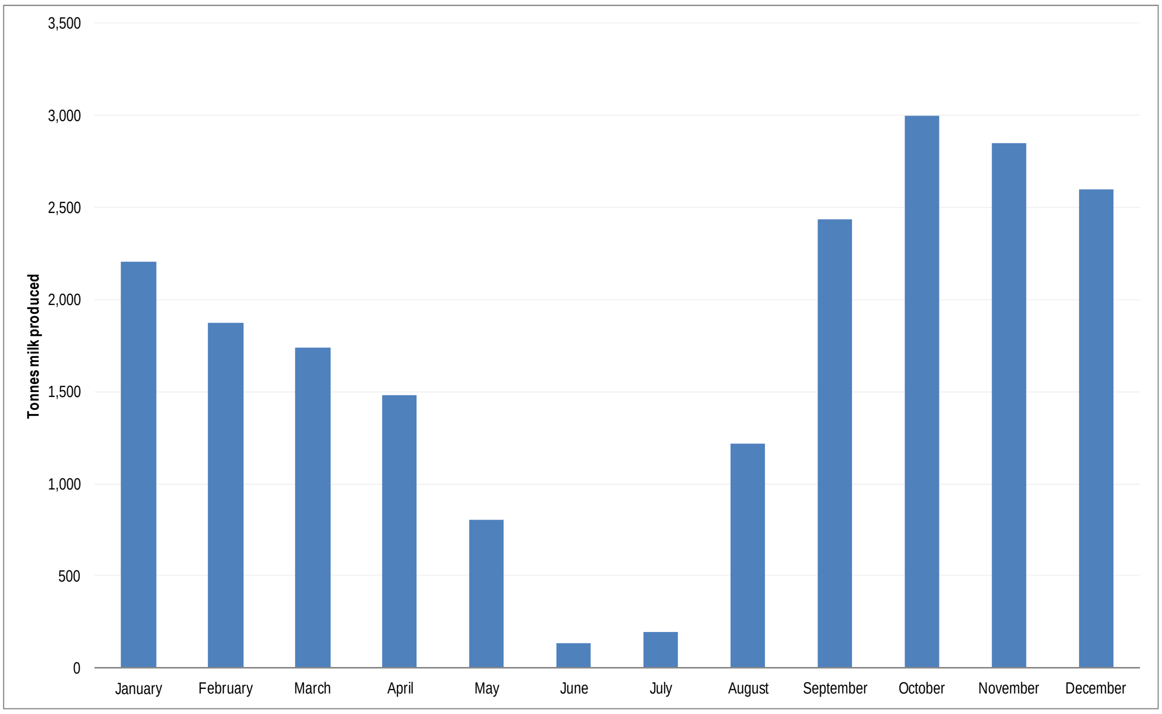
Dairy cattle: Dairy farmers are paid on the basis of milk solids collected (and not on a volume basis), so there would be an incentive regardless to be as accurate as possible with milk production data. Tankers that collect the milk also meter the milk collected from farms, and these meters are regularly calibrated and audited. Milk samples from farms are also independently tested when collected for milk solids including milk fat and protein content.

New Zealand has developed a Jersey–Friesian cross breed specific to New Zealand's pasture-based systems. This cow is a lot lighter than a Friesian with less maintenance feed requirements and does less damage to pasture. The Jersey–Friesian cross also has higher milk volumes than the Jersey while maintaining a good percentage of milk solids. As a pasture-based system, production will be lower when compared against intensive housed and grain-fed dairy cattle in some other parts of the world.

New Zealand dairy production statistics are collectively compiled and published annually by DairyNZ (a non-government, industry-good organisation funded through a compulsory levy on milk solids) and the LIC (a dairy herd improvement company owned by New Zealand dairy farmers). Data on New Zealand's total milk production is the amount of milk processed through New Zealand dairy factories for both the export and domestic markets, which is made available for DairyNZ through its collection of the levy on milk solids. Data on individual animal production are sourced from the Dairy Core Database, the regulated portion of the LIC's database that holds core production data from cows herd tested in New Zealand. Approximately 70 percent of all cattle (LIC Statistics 2012/2013) are tested by the LIC for liveweight, milk production, milk fat and milk protein. The LIC also does genetic testing to identify key breeding stock and their genetic background. Genetic improvement has contributed significantly to the productivity improvements in the New Zealand dairy cattle herd. Herd testing is a regulated activity, and the LIC and other herd testers are audited by a government-approved auditor. Under the Commodity Levies Act 1990, the affairs of DairyNZ may be subject to an audit if the Minister for Primary Industries is sufficiently concerned about the organisation's performance.

The LIC provides annual milk production data (milk yield and composition), but the Tier 2 livestock model operates on a monthly time step. Monthly milk production is therefore determined by multiplying the total annual milk production by the proportion of annual milk yield each month (annex 3, table A3.1.9). Milk production starts in late July to early August every year, peaking around October–November and drying-off during autumn (April, May and June in the southern hemisphere). The production in June and July is low and primarily for domestic milk consumption. Monthly milk production for the calendar year 2012 is shown in figure 6.1.3.

Figure 6.1.3: National monthly milk production for 2012



Source: Dairy Companies Association of New Zealand (www.DCANZ.com/statistics)

From 2004 onwards, the productivity data was collected by the LIC at a similar territorial authority level as the livestock population data is collected by Statistics New Zealand. Ministry for Primary Industries officials aggregate these territorial data up into the regional council boundaries used for the population data.

From 2004, annual milk yields per animal have been obtained and reported as additional data in the common reporting format (CRF) tables by dividing the total milk produced by the total number of milking dairy cows and heifers. In addition, New Zealand assumes an additional 107 litres of milk is added to the first half of the annual lactation of each cow to allow for the milk fed to calves; this assumption was based on a review of the model and a survey of farmers by Thomson et al (2010). This additional milk is included in the first six months of lactation.

Before 2004, not all productivity data required could be collected from the LIC at a territorial authority level. Therefore, some extrapolations of data were required to obtain the required values. From 1993–2003, annual milk yield per cow was determined by the following equation.

$$Litres\ milk\ per\ cow = \frac{Average\ kg\ milk\ fat\ per\ cow \times 100}{per\ cent\ milk\ fat}$$

Before 1993, no productivity data were 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 are obtained by taking into account the proportion of each breed in the national herd and its age structure based on data from the LIC. Dairy cow liveweights are only available from the LIC from 1996 onwards for six livestock improvement regions that have the largest number of dairy animals; each region comprises several territorial local authorities. 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 before 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 in the model 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 are available on the liveweights and performance of most breeding dairy 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 1 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 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 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 in the model: 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[15] are made to estimate the liveweights of breeding beef 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 percentages[16] 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 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 2012 from which the individual fleece weight is estimated.

Deer: Liveweights of growing hinds and stags are estimated from Deer Industry New Zealand 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 a report by Suttie (2012). 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

Monthly 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 monthly 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, which is 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.

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15 The number of beef cows slaughtered is assumed to be 17 per cent of the total beef cow herd with other adult cows slaughtered 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).

16 Percentage of carcass weight in relation to liveweight.

$$ME_m = \frac{K \times S \times M \times (0.28W^{0.75} \times \exp(-0.03A)}{k_m} + 0.1ME_p + \frac{E_{GRAZE}}{k_m}$$

Where:

ME_m = metabolisable energy (MJ ME/day)

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 from 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, up to a maximum value of 6

k_m = net efficiency of use of ME for maintenance, equal to: 0.02 × ME + 0.5 where ME is the metabolisable energy (MJ ME/kg dry matter) of pasture that has a gross energy content of 18.4 MJ/kg dry matter

ME_p = the amount of dietary ME being used directly for production (MJ ME/day). $0.1ME_p$ accounts for the accepted effect of feed intake level on the maintenance metabolism of ruminants (CSIRO, 2007)

E_{GRAZE} = additional energy expenditure of grazing compared with similar housed animals (MJ ME/day).

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 Pickering and Wear (2013) available on the Ministry for Primary Industries website (http://www.mpi.govt.nz/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory).

Monthly diet energy concentrations

A single data-set of monthly energy concentrations of the diets consumed by beef cattle, dairy cattle, sheep and deer is used for all years in the time series. These data are reported in annex 3, tables A3.1.7 to A3.1.9. This is because there is no comprehensive published data available that allow 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.

Activity data: minor species

The revised 1996 IPCC guidelines Tier 1 methodology is used for goats, horses, swine, poultry and alpaca, with a combination of default and country-specific emission factors. The country-specific emission factors are detailed in the relevant sections and summarised in annex 3, table A3.1.5.

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 Henderson and Cameron (2010) based on the Alpaca Association New Zealand and, when available, Statistics New Zealand data on alpaca are used from 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. 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 Agricultural Production Census (or survey).

The average annual flock size is determined by the following equation:

$$Average\ annual\ flock\ size = \frac{days\ alive}{365} \times \frac{annual\ number\ of\ birds\ processed}{(1 - rate\ of\ mortality)}$$

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 over 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 sector of the inventory are shown in figure 6.1.4.

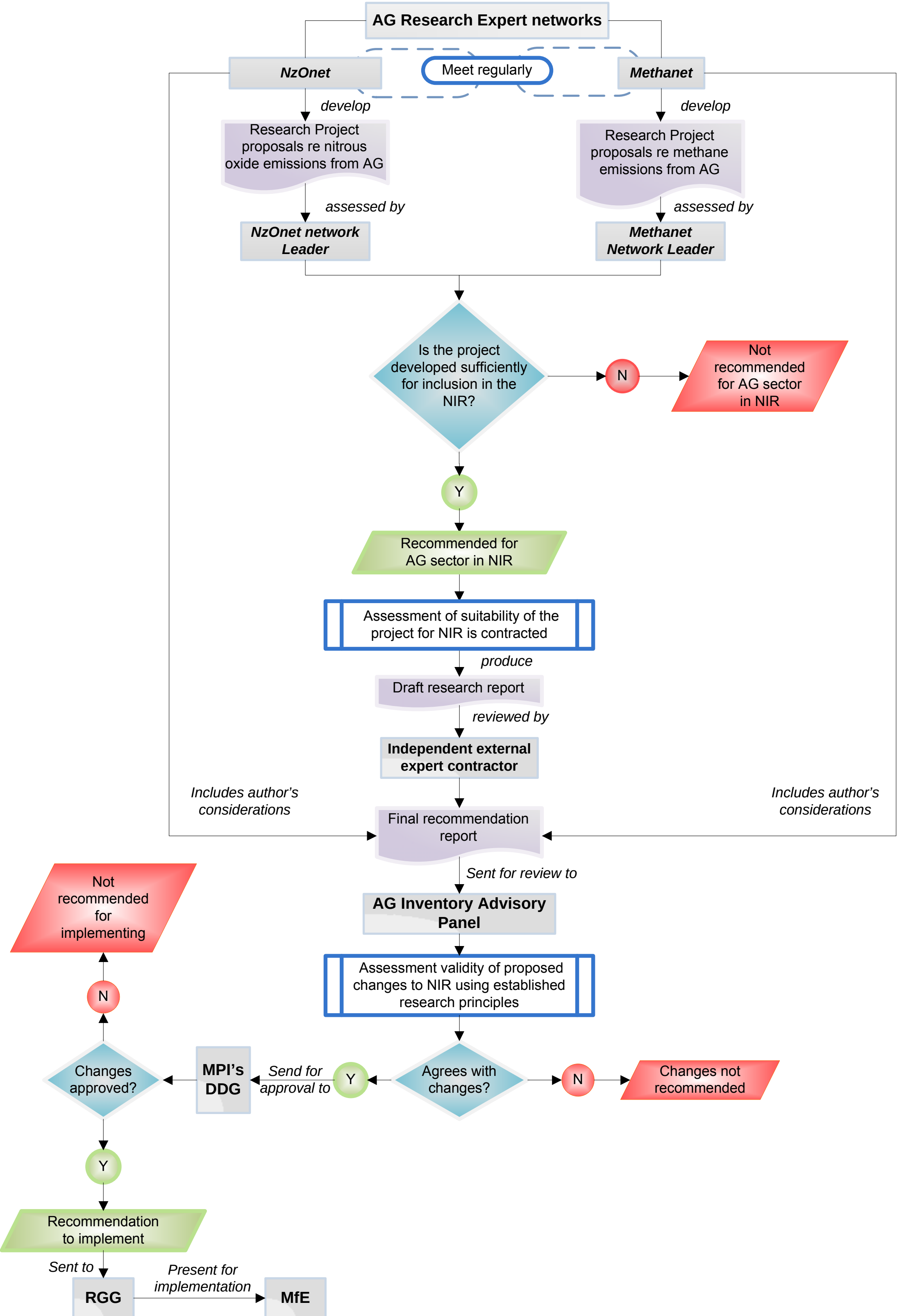
The New Zealand Methanet and New Zealand NzOnet networks meet regularly during the year and present their research findings. When research projects are sufficiently developed they are assessed by the leaders of each network to choose those projects considered suitably developed to be included in the Agriculture sector of the inventory. The research is contracted to address specific questions related to gaps in New Zealand's 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 principles and if there is sufficient scientific evidence to support the change(s). The 2013 meeting of the Panel was held on 12 November 2013 where an update to the equation for partitioning nitrogen in excreta between urine and dung for key species categories was recommended for inclusion in the 2014 submission, as well as incorporation of the nitrous oxide mitigation technology, urease inhibitor. The briefs, reports and minutes of the Panel meeting have been placed on the Ministry for Primary Industries website (see www.mpi.govt.nz/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory-panel).

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 into the annual inventory. During the course of the year, recalculations being considered by all sectors are proposed to the Reporting Governance Group, which is chaired by the Ministry for the Environment and leads the reporting, modelling and projections of greenhouse gas emissions and removals across government. Further details of the Reporting Governance Group are provided in section 1.2.2.

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 2014 Inventory submission in the Agriculture sector

The 2013 Agriculture Inventory Advisory Panel agreed on two changes to the inventory methodology for the 2014 annual submission.

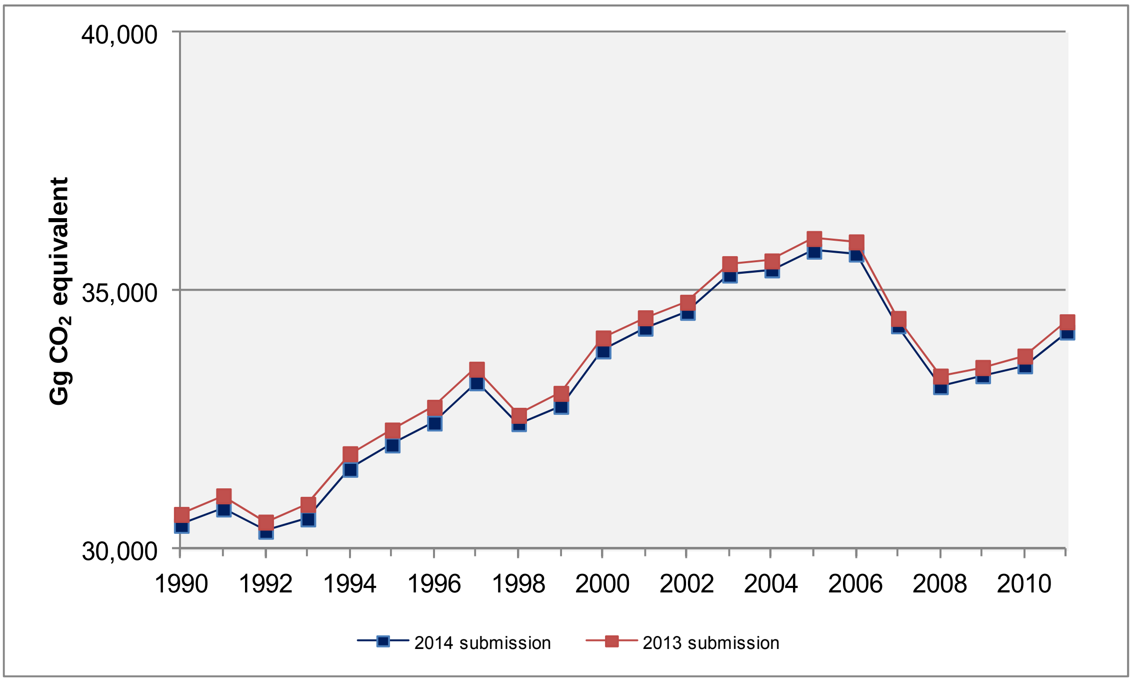
- The equations to partition nitrogen in excreta between dung and urine from dairy, beef, sheep and deer in the Tier 2 models have been updated.
- The fraction of nitrogen from fertiliser that volatilises as nitrogen oxide (NOx) and ammonia (NH3) is reduced where urease inhibitor is used.

A small change made to the method to allocate milk production to two small regions was introduced, and activity data for herbage seeds were revised for 2004–2011. New data for the proportion of annual milk produced in each month have been used. The provisional data from the 2012 agriculture production survey (December 2012) were also updated with the release of the final 2012 agriculture production census (May 2013).

The recalculation for these activities will result in recalculations in enteric fermentation, manure management and agricultural 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 also provided in section 10.1.4.

The improvements made in the agriculture sector have resulted in a 0.7 per cent (212.6 Gg CO_2-e) decrease in agricultural emissions in 1990, and a 0.6 per cent (198.4 Gg CO_2-e) decrease in agricultural emissions in 2011. Figure 6.1.5 shows a comparison of emission estimates for 1990 to 2011 from the 2012 submission with this submission.

Figure 6.1.5 Effect of recalculations on New Zealand's Agriculture sector from 1990 to 2011



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 agricultural 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 LIC, Deer Industry New Zealand and the Fertiliser Association of New Zealand.

The draft national inventory report is reviewed by Ministry for Primary Industries personnel 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 QA/QC processes. New Zealand has used this feedback to update and improve the QA/QC methodology.

The scope of the Deloitte review included:

- 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 are 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 reflect the domestic situation.
- Where practical, key historical data are 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 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 starts.
- 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 completed on different aspects of the inventory. In recent years, the population models and animal productivity parameters have been reviewed (eg, Thomson et al, 2010) and used to update and improve the Tier 2 model. During 2013, the nitrogen retention rates in liveweight gains, milk protein and fibre, and pasture quality were reviewed; however, the reviews were not completed in time to be submitted to the 2013 Agriculture Inventory Advisory Panel meeting for approval. The results are expected to be incorporated in the 2015 annual submission.

- 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, was hired to review the workbooks, check the formulae and model parameters.

Model improvements

- The original model for calculating Tier 2 livestock emissions in the Agriculture sector dates back to 2003. It had been developed using the computer language Delphi, which is not in common use. During 2011 and 2012, the model for calculating Tier 2 livestock 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 completed, 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 was tested with proprietary diagnostic tools to test formulae consistency across time periods.

- An issues register was maintained throughout the QA/QC review process by Deloitte 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 CRF reporter are signed off by the compiler, people involved in data checking and the manager responsible for the staff.

Documentation

- Internal working instructions are maintained to allow for changes in staff.

- 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 GHG Inventory are encouraged to complete the UNFCCC and Kyoto Protocol national system training and to 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:

- incorporating results from a meta-analysis of N2O emissions by source, in particular using more trials from urea fertiliser
- a review of the partitioning of nitrogen in excreta between dung and urine in grazing livestock
- a review of research specific to New Zealand of indirect emissions of N2O from leaching and run-off (EF5)
- a review of nitrogen retention rates in liveweight gain, milk protein and fibre for Tier 2 livestock
- the effect of land slope on N2O emissions from excreta (beef, sheep and deer) deposited on grazed hill country
- updated estimates on metabolisable energy and nitrogen content for pasture
- changes as required to meet the revised reporting guidelines (Decision 15/CP.17) including the use of the 2006 IPCC guidelines
- a review of the treatment of uncertainty and including an update to the uncertainty analysis for agricultural soils.

It had been anticipated that a few of these short-term improvements could have been included in the 2014 submission, however, most were still under review at the time of inventory compilation and are now expected to be included in the 2015 submission.

The review of the leaching and run-off (EF_5) was delayed due to a national drought, but is expected to be completed before the 2015 submission.

A report on pasture quality, collating data of approximately 19,300 samples collected from 1996 to 2011 from dairy, sheep and beef farms all over New Zealand was completed late in 2013. The report could not be peer-reviewed and assessed by the Agriculture Inventory Advisory Panel for the 2014 submission.

The report, subject to the peer review and Panel approval, may be used to update some estimates of metabolisable energy and nitrogen in pasture for some livestock, especially dairy. The report also identified sampling gaps in some regions and land types and has recommended more pasture sampling across New Zealand to eliminate these gaps. This research has been added to the long-term improvement plan.

Longer term trials are also being completed to improve the estimates of:

- the relationship between DMI and CH4 emissions from lactating dairy cattle
- the direct N2O emissions factor (EF1) and ammonium emissions for urea nitrogen fertiliser and dairy shed effluent under a range and combination of treatments with nitrogen inhibitors, including urease inhibitors
- methane emissions from anaerobic dairy effluent ponds
- trials on N2O emissions from very steep slopes (greater than 25 degrees)
- trials on N2O emissions under different environmental conditions
- updating national estimates of pasture quality especially for metabolisable energy, nitrogen and dry-matter digestibility
- revisiting enteric emissions factors for sheep including the results of recent trials using new calorimeters based at New Zealand's Agriculture Greenhouse Gas Research Centre.

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)).

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 2011 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 used by New Zealand for estimating CH_4 emissions from enteric fermentation in domestic livestock is a Tier 2 modelling approach.

In 2012, enteric fermentation contributed 23,935.9 Gg CO_2-e. This represented 31.5 per cent of New Zealand's total CO_2-e emissions and 68.3 per cent of agricultural emissions. Dairy and beef cattle contributed 15,455.7 Gg CO_2-e (64.6 per cent) of emissions from the enteric fermentation category, and sheep contributed 7,948.1 Gg CO_2-e (33.2 per cent) of emissions from this category. Emissions from the enteric fermentation category in 2012 were 1,834.6 Gg CO_2-e (8.3 per cent) above the 1990 level of 22,101.3 Gg CO_2-e.

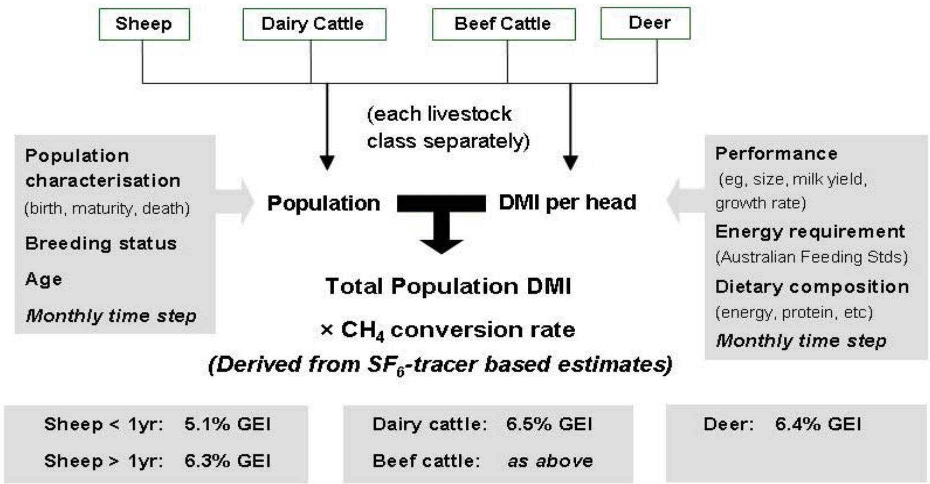
Since 1990, there have been changes in the relative sources of emissions within the enteric fermentation category. The largest increase came from emissions from dairy cattle. In 2012, dairy cattle were responsible for 10,807.7 Gg CO_2-e, an increase of 5,808.4 Gg CO_2-e (116.2 per cent) from the 1990 level of 4,999.3 Gg CO_2-e. Meanwhile, there have been decreases in emissions from sheep and minor livestock populations, such as goats, horses and swine. In 2012, emissions from sheep were 7,948.1 Gg CO_2-e, a decrease of 3,774.9 Gg CO_2-e (32.2 per cent) from the 1990 level of 11,723.0 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[17] 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,

[17] 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).

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 (Clark et al, 2003). 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 2012

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	69.2	50.0	9.6	17.0
1991	72.2	51.4	9.9	17.6
1992	72.7	52.2	9.9	18.4
1993	73.7	53.0	10.1	18.8
1994	72.3	53.4	10.2	18.3
1995	72.0	52.9	10.0	19.2
1996	74.3	54.7	10.5	19.6
1997	75.2	55.6	10.9	19.8
1998	73.1	55.7	10.9	19.8
1999	74.6	54.4	10.9	19.9
2000	76.2	56.4	11.3	20.2
2001	77.1	57.4	11.3	20.2
2002	76.6	57.2	11.4	20.3
2003	79.4	56.8	11.5	20.1
2004	78.3	57.8	11.8	20.6
2005	78.8	58.4	11.9	20.9
2006	78.6	59.5	11.7	21.2
2007	77.6	58.1	11.3	21.2
2008	76.5	57.4	11.5	21.4
2009	77.0	57.8	11.9	21.6

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)
2010	78.9	57.6	11.5	21.6
2011	80.0	58.5	11.9	21.7
2012	79.8	59.3	12.1	21.8

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 2012.

Livestock population data

The populations of goats, horses, pigs and alpacas are reported using statistical data as noted 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 2012, 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.

Swine: New Zealand uses a country-specific emission factor of 1.06 kg CH_4/head/year (Hill, 2012), which was calculated using the IPCC (1996) Tier 2 methodology using a country-specific value for gross energy intake of 26.9 MJ per animal per day (Hill 2012). The value of gross energy intake and the composition of swine diet are based on a survey of 56 farms accounting for 59 per cent of New Zealand pork production. Swine feed formulation is similar across farms, as swine diets are controlled in New Zealand and limited ingredients are available for feed (Hill, 2012). Nutritional information was available for different age classes and categories, and the average value of gross energy intake was adjusted for population and further verified against national animal welfare standards. The New Zealand value is lower than the IPCC (1996) default, which is based on average values derived from 1980s Western German production and population statistics. This is not representative of New Zealand systems and changes in production due to: improvements in genetic selection, reproductive cycle performance, housing and feed, animal husbandry and herd management (Hill, 2012).

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.

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 agricultural production 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 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 (then the Ministry of Agriculture and Forestry) 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 2012, 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	1,052.4	884.1	1,220.8
2012	1,139.8	957.4	1,322.2

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. 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 2000 IPCC good practice guidance, the 2003 IPCC good practice guidance for land use, land-use change and forestry (LULUCF), and the 2006 IPCC guidelines (IPCC 1996; 2000; 2003; 2006).

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 dairy 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 the implied emission factor for Australia 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[18] (kg CH_4/head/year)
IPCC (1996) Oceania default value	68	53	8
Australian-specific IEF 2011 value	114	72	7
United Kingdom-specific IEF 2011 value	111	43	5
New Zealand-specific 2011 value[19]	80	60	12

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 4 December 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.

Bown et al (2013) were commissioned by the Ministry for Primary Industries to review and collate data held around New Zealand on metabolisable energy and nitrogen content of pasture. Pasture ME and nitrogen values from eight research studies and a commercial testing laboratory were collated, analysed and compared with the national monthly average values used in the current model.

The collated database (defined in the figures as the global database) was collected from 1996 to 2011 from dairy, sheep and beef farms all over New Zealand. Figure 6.2.2 shows how the current New Zealand inventory (see annex 3, table A3.1.6) values for metabolisable energy compare with 2,371 dairy samples from the global database. The dairy metabolisable energy values from the database analysis are in reasonable agreement with those of the current inventory model.

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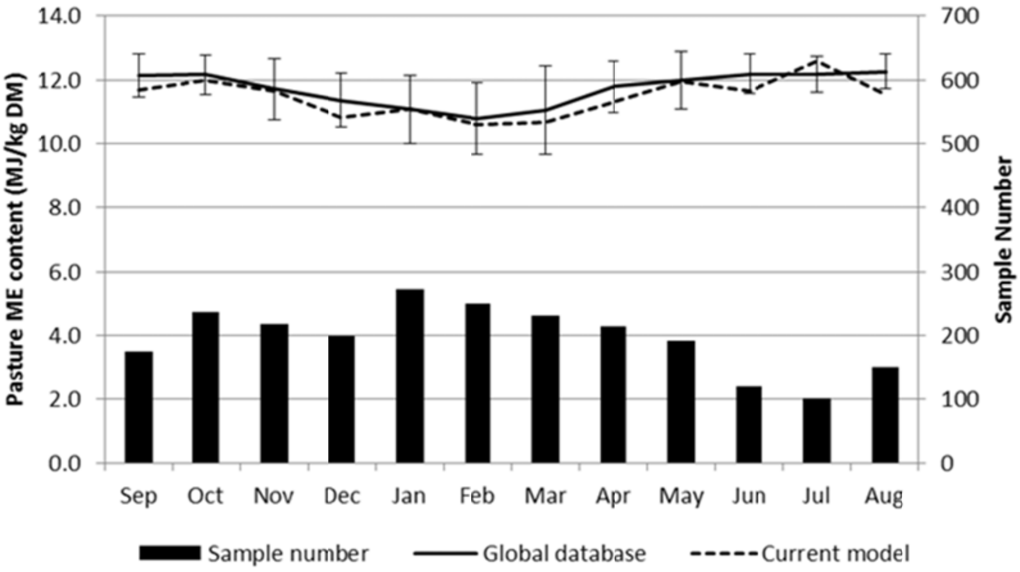
18 All values except for New Zealand include lambs in the implied emission factor calculation.

19 As reported in New Zealand's *Greenhouse Gas Inventory 1990–2011* (Ministry for the Environment, 2013).

Figure 6.2.2 **Mean ME content (+/–standard deviation) of dairy pastures compared**



Source: Bown et al (2013)

6.2.5 Source-specific recalculations

All activity data were updated with the latest available data: Statistics New Zealand table builder and Infoshare database (2013) and LIC statistics (2013).

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 recode has improved the usability of the model as well as increased its transparency and accuracy. During the 2013 annual review, small errors were found and corrected in the population models for deer and non-dairy cattle. The correction increased emissions from deer and was included in the re-submission of 7 September 2013. The correction to non-dairy cattle and sheep reduced emissions and has been implemented in the 2014 submission.

Dairy milk yields were revised in two small dairy regions: Gisborne (adjoining Hawke's Bay) and Nelson (adjoining Tasman). Production data for Nelson has been included with Tasman since 2002, and production data for Wairoa, which were previously included with Hawke's Bay, was recently included with Gisborne. The data for Nelson was previously disaggregated from Tasman by extrapolating the relationship between milk production in Tasman and Nelson between 1990 and 2002. The variations in milk yield appeared implausible for Gisborne and Nelson and therefore the milk yields in each region were revised by calculating the average milk yield when aggregated with their adjoining regions. Total national milk production was not changed; milk production was simply reallocated between the adjoining regions. The recalculation affected all years from 1990 to 2011.

New data became available from the Dairy Companies Association of New Zealand on monthly national milk production, which updated the values used for the average monthly apportioning of annual milk production (figure 6.1.3, annex 3, table A3.1.9). Total annual national milk production is not changed.

The method to interpolate the emission factor for enteric fermentation from goats was corrected. There was no change to emissions in 1990; however, emissions in 2011 were reduced by 0.3 Gg CO_2-e. The revision was applied for all years except for the years when data on milking goats was available (1990 and 2009).

Recalculations to the Tier 2 model will also affect emissions from manure management (N_2O and CH_4) and agricultural soils due to changes in animal livestock excretion levels.

6.2.6 Source-specific planned improvements

Pasture quality (metabolisable energy and nitrogen) revisions

A review by Bown et al (2013) of values of the pasture metabolisable energy (ME) concentration and nitrogen content provided updated national estimates for metabolisable energy and nitrogen content of pasture, but was not ready in time to be independently peer reviewed and considered by the Agriculture Inventory Advisory Panel for the 2014 submission. The results from this report should be included in the 2015 submission. Section 6.2.4 (Enteric Fermentation: Source-specific QA/QC and verification) compares the current ME assumptions of dairy pasture every month, with the Bown et al (2013) results taken from New Zealand-wide sampling.

New Zealand-wide pasture sampling

Bown et al (2013) also identified further improvements that could be made to sampling pasture quality, particularly of hill country pasture grazed by non-dairy cattle, sheep and deer, and further work to support regional disaggregation of pasture quality data. New Zealand plans to organise a workshop later in 2014, to bring together industry associations and researchers, and to commission a multi-year study to improve the sampling especially where gaps were identified by Bown et al (2013).

Emission factor – lactating cattle

A three-year project to update the current estimate of the relationship between DMI and CH_4 emissions in lactating cattle started in early 2013. The research will use the New Zealand Agriculture Greenhouse Gas Centre ruminant CH_4 measurement facility's purpose-built calorimeter chambers to measure the relationship between enteric fermentation emissions and DMI. As part of the study, milk yields and nitrogen content and partitioning of the feed will be conducted. The results will be used to improve the estimates of CH_4 and nitrous emissions from dairy cattle.

Emission factor – sheep

Enteric emission factors for sheep will be reviewed, and will include the results of recent trials using new calorimeters based at New Zealand's Agriculture Greenhouse Gas Research Centre. Results from these trials are undergoing detailed statistical analysis for future inclusion in the national inventory.

2006 IPCC guidelines

Other improvements include changes required to meet the revised reporting guidelines (Decision 15/CP.17) including the use of the 2006 IPCC guidelines.

6.3 Manure management (CRF 4B)

6.3.1 Description

In 2012, emissions from the manure management category comprised 708.0 Gg CO_2-e (2.0 per cent) of emissions from the Agriculture sector. Emissions from manure management had increased by 223.2 Gg CO_2-e (46.0 per cent) from the 1990 level of 484.8 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 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 (36.0 Gg CO_2-e) in 2012. In comparison, N_2O emissions from the agricultural soils category totalled 10,340.8 Gg CO_2-e in 2012.

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, deer, goats, alpaca and horses) graze outdoors all year and deposit all of their faecal material (dung and urine) directly onto pastures. 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.

Nitrous oxide 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[20] (%)	Pasture, range and paddock[21] (%)	Solid storage and dry-lot (%)	Other (%)
Non-dairy cattle	–	–	100	–	–
Dairy cattle	5	–	95	–	–
Sheep	–	–	100	–	–
Deer	–	–	100	–	–
Goats	–	–	100	–	–
Horses	–	–	100	–	–
Swine[22]	21	26	9	42	2
Poultry – Broilers[23]	0	–	4.9	–	95.1
Poultry – Layers[9]	–	–	5.8	–	94.2
Poultry – Other[24]	–	–	3	–	97
Alpaca	–	–	100	–	–
Mules and asses	–	–	100	–	–

20 Reported under 'agricultural soils' under direct soil emissions from agricultural fields (Direct Soil Emissions (CRF 4D1)).

21 Reported under 'agricultural soils' under direct soil emissions from animal production (Pasture, Range and Paddock Manure (CRF 4D2)).

22 Hill (2012).

23 Fick et al (2011) and pers. comm.; 2010 estimates shown.

24 IPCC (1996) default waste management proportions for Oceania.

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 (IPCC 1996; 2000). 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 following equation:

$$FDM = DMI \times (1\text{-}DMD)$$

where:

FDM = faecal dry-matter output (kg/head/month)

DMI = dry-matter intake (kg/head/month)

DMD = dry-matter digestibility (decimal kg/kg).

The dry matter intake (DMI) and dry-matter digestibility (DMD) estimates here are the same as are used to estimate enteric fermentation CH_4 and to estimate nitrogen in excreta. These 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 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	95	0.98[25]	5	90[26]	4.6[27]	3.27[28]
Beef cattle	100	0.98[29]	0	–	–	–
Sheep	100	0.69[30]	0	–	–	–
Deer	100	0.92[31]	0	–	–	–

25 Saggar et al (2003) and Sherlock et al (2003).

26 Heatley (2001).

27 McGrath and Mason (2004).

28 McGrath and Mason (2004).

29 Saggar et al (2003) and Sherlock et al (2003).

30 Carran et al (2003).

31 Average of sheep and cattle values. See text for details.

Using the above values, CH_4 from pasture is therefore determined using the following equation.

$$M = (FDM \times MMS) \times Y_m$$

Where: M = methane from manure management (kg/head/month)

FDM = faecal dry-matter output (kg/head/month)

MMS = proportion of faecal material deposited on pasture

Y_m = country-specific methane yield (g CH_4/year).

And for anaerobic lagoons, the following equation is used:

$$M = (FDM \times MMS) \times W/1000/d \times Y_m$$

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)

Y_m = methane yield (g CH_4/m^2/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).

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 2.08 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 derived from Fick et al (2011). 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 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 nitrogen excretion rates (N_{ex}) 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 LIC. 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 nitrogen excretion rates increasing over time, reflecting the increases in animal productivity in New Zealand since 1990. For full details of how nitrogen excretion rates are derived for each species, see the inventory methodology document on the Ministry for Primary Industries website (www.mpi.govt.nz/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory).

Table 6.3.3 Values of nitrogen excretion rates (N_{ex}) values for New Zealand's main livestock classes from 1990 to 2012

Year	Dairy cattle N_{ex} (kg N/head/year)	Non-dairy cattle N_{ex} (kg N/head/year)	Sheep N_{ex} (kg N/head/year)	Deer N_{ex} (kg N/head/year)
1990	104.1	64.3	13.2	25.2
1991	108.1	66.1	13.7	26.0
1992	108.8	67.2	13.7	27.1
1993	110.1	68.3	13.9	27.6
1994	108.0	68.9	14.0	26.8
1995	107.6	68.3	13.9	28.1
1996	110.7	70.8	14.4	28.6
1997	111.7	72.1	15.0	28.8
1998	109.2	72.2	14.9	28.8
1999	111.1	70.3	15.0	28.9
2000	112.7	72.8	15.6	29.4
2001	113.8	74.1	15.5	29.4
2002	113.1	73.7	15.7	29.5
2003	117.2	73.2	15.8	28.9
2004	115.7	74.5	16.1	29.4
2005	116.3	75.4	16.4	29.6
2006	115.5	76.9	16.1	29.8
2007	114.2	74.9	15.6	29.4
2008	112.5	73.9	15.8	29.4
2009	113.3	74.5	16.3	29.5
2010	115.9	74.3	15.8	29.4
2011	116.9	75.4	16.2	29.6
2012	116.9	76.5	16.6	29.7

Nitrous oxide from other minor livestock categories

Goats: New Zealand uses country-specific nitrogen excretion rates for goats to estimate N_2O emissions of 10.6 kg N/head/year for 1990 and 12.1 kg 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 nitrogen excretion rates are not available for horses. Horses are in the minor livestock category in New Zealand and the 1996 IPCC default emission factor (25.0 kg 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 nitrogen excretion rate of 10.8 kg 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 nitrogen excretion rates for all other years are indexed relative to 2009 for the average pig kill weights for each year.

Poultry: New Zealand-specific and IPCC default nitrogen excretion rates are used for poultry (Fick et al, 2011). These are the country-specific values of 0.39 kg N/head/year for broiler birds and 0.42 kg N/head/year for layer hens. The default value of 0.60 kg 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 nitrogen excretion rate for alpacas. Therefore, this was calculated by assuming a default nitrogen excretion rate 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 nitrogen excretion rate for other livestock from the revised 1996 IPCC guidelines was used (25.0 kg 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 2011 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 2011 value	8.65	0.04	0.00
United Kingdom-specific IEF 2011 value	31.83	2.67	0.12
New Zealand-specific 2011 value[32]	3.43	0.80	0.12

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 18 December 2013.

Note: IEF = implied emission factor.

6.3.5 Source-specific recalculations

All activity data were updated with the latest available data: Statistics New Zealand table builder and Infoshare database (2013) and LIC statistics (2013).

Changes to the Tier 2 model for livestock population, productivity and energy equations explained in section 6.2.5 will flow through to the emissions from manure management and result in recalculations.

During the 2013 annual review under the United Nations Framework Convention on Climate Change, the Ministry for Primary Industries became aware of an updated paper by Luo and Kelliher (2010). The inventory has adopted the following equation to partition excreted nitrogen into nitrogen from urine and nitrogen from dung (from Luo and Kelliher, 2010).

$$\%N_u = (10.5 \times N_{\%d}) + 34.4$$

32 As reported in *New Zealand's Greenhouse Gas Inventory 1990–2011* (Ministry for the Environment, 2013).

Where: $\%N_u$ is the percentage of excretal N in the form of urine

$N_{\%d}$ is percentage of nitrogen in the diet

And:

$$\%N_f = 100 - \%N_u$$

Where: $\%N_f$ is the percentage of nitrogen excreted in faeces.

These equations replace the calculation to partition excreted nitrogen between dung and urine in the 2013 Inventory and earlier submissions equation 33 (Pickering and Wear 2013):

$$\%N_u = (10.7 \times N_{\%d}) + 34$$

Table 6.3.5 compares nitrogen partitioning in urine using the current and proposed methodology. With the recalculation, a lower proportion of nitrogen goes into urine, resulting in a small reduction in estimated emissions due to urine having a higher emission factor than dung. The recalculation is applied to all years from 1990 to 2011. The change was approved by the Agriculture Inventory Advisory Panel and further details are on the Ministry for Primary Industries website (www.mpi.govt.nz/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory-panel).

Table 6.3.5 Comparison of revised nitrogen in excreta as dung and urine

	Percentage of N in diet	Percentage of N in excreta as urine	Percentage of N in excreta as urine
		Previous	Recalculated
Dairy	3.7	73.6	73.3
Beef	3.0	66.1	65.9
Sheep	3.0	66.1	65.9
Deer 1990	3.32	69.5	69.3
Deer 2011	3.07	66.8	66.6

Note: The percentage of N in pasture for deer is estimated using the share of the deer population grazed on dairy and sheep/beef pasture each year.

6.3.6 Source-specific planned improvements

Improved manure management methodology

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.

Revised nitrogen retention rates in livestock

A report was commissioned and completed during 2013 to review nitrogen retention rates in wool, milk, deer velvet and animal liveweight gain. The report was not completed in sufficient time to allow peer review and to be considered by the Agriculture Inventory Advisory Panel for the 2014 submission. The results are expected to be included in the 2015 submission, subject to peer review and acceptance by the Agriculture Inventory Advisory Panel.

Partitioning nitrogen in excreta between dung and urine

A new analysis is under way to assess the portioning of nitrogen in excreta between dung and urine, which includes an updated data-set including additional data for sheep and a comparison of cattle and sheep results with international findings. In this paper, further refinement to the calculation is likely, and estimates may then be available for the individual livestock categories.

2006 IPCC guidelines

Other improvements include changes as required to meet the revised reporting guidelines (Decision 15/CP.17) including the use of the 2006 IPCC guidelines

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 2012, the agricultural soils category contributed 10,340.8 Gg CO_2-e (13.6 per cent) to New Zealand's total emissions and 97.1 per cent to total N_2O emissions. Emissions were 2,510.2 CO_2-e (32.1 per cent) above the 1990 level of 7,830.5 Gg CO_2-e. The subcategories are as follows:

- Direct N_2O emissions from animal production (pasture, range and paddock). In 2012, N_2O emissions from animal production contributed 5,817.6 Gg CO_2-e (56.3 per cent) to emissions from the agricultural soils category. This is an increase of 487.2 Gg CO_2-e (9.1 per cent) from the 1990 level of 5,330.4 Gg CO_2-e. Direct N_2O emissions from animal production were identified as a key category (trend and level assessment).

- Other 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. Other direct N_2O soil emissions contributed 1,901.5 Gg CO_2-e (18.4 per cent) to emissions from the agricultural soils category in 2012. This was an increase of 1,441.0 Gg CO_2-e (312.9 per cent) from the 1990 level of 460.5 Gg CO_2-e. Other direct N_2O emissions from agricultural soils were identified as a key category (level and trend assessment).

- Indirect N_2O emissions are due to nitrogen lost from the field as nitrate (NO_3), ammonia (NH_3) or nitrogen oxides (NO_x) through volatilisation and leaching. In 2012, indirect N_2O

emissions from nitrogen used in agriculture contributed 2,621.7 Gg CO_2-e (25.4 per cent) to emissions from the agricultural soils category. This was an increase of 582.1 Gg CO_2-e (28.5 per cent) from the 1990 level of 2,039.6 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, $EF_{3(PR\&P)}$, $EF_{3(PR\&P\ DUNG)}$, $Frac_{LEACH}$, $Frac_{GASM}$ and $Frac_{GASF}$ (annex 3, tables A3.1.2 and A3.1.4). 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; Muller et al, 1995; de Klein et al, 2003; 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 pasture, range and paddock manure section below. 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 soil emissions (nitrous oxide)

The N_2O emissions from the direct soil 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 nitrogen (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/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory).

Synthetic nitrogen fertiliser

Anthropogenic N_2O emissions from nitrogen from 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 2012. 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 362,508 tonnes in 2012. This has resulted in an increase of direct N_2O emissions from nitrogen-based fertiliser, from 259.8 Gg CO_2-e in 1990 (0.8 per cent of agricultural emissions) to 1,594.1 Gg CO_2-e (4.6 per cent of agricultural emissions) in 2012.

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 (kg N)

N_{fert} = amount of nitrogen fertiliser applied to soils (kg N)

$Frac_{GASF}$ = 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 109.0 Gg CO_2-e (0.4 per cent of agricultural emissions) and, in 2012, this had increased to 204.0 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.

$$F_{AM} = N_{AW} \times (1\text{-}Frac_{GASM})$$

$$N_2O_{direct\ from\ AW}\text{-}N = F_{AM} \times EF_1$$

Where:

F_{AM} = 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* and census. 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 2012, N_2O emissions from this subcategory totalled 10.5 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 Statistics* and census. 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 2012, 61.7 Gg CO_2-e (0.2 per cent of agricultural emissions).

For the 2012 submission onwards, 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 histosols

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, section 5.4, table 3). This area includes the proportion of organic agricultural soil as reported within the LULUCF sector that has been cultivated (Dresser et al, 2011 section 5.4 table 3, 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 sector 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 of the inventory 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 and has remained at 31.3 Gg CO_2-e (0.1 per cent of agricultural emissions) since 1990.

Pasture, range and paddock manure (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 on the Ministry for Primary Industries website (www.mpi.govt.nz/news-resources/statistics-forecasting/greenhouse-gas/agricultural-greenhouse-gas-inventory). In accordance with IPCC good practice guidance (IPCC, 2000), the following equation is used to determine direct N_2O emissions from animal production:

$$(N_2O - N) = N \times N_{ex} \times MS \times EF_{3(PR\&P)}$$

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 (ie, 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 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 EF3(PR&P). Field studies have been performed as part of a collaborative research effort called NzOnet. The EF3(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). These regional data are 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 EF3(PR&P) data and their distribution to pastoral soil drainage class, to determine an appropriately weighted (using proportions of land area by soil drainage class) national annual mean value. The complete EF3(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 N2O emissions using the methodology in the revised 1996 IPCC guidelines (IPCC, 1996)
- the N2O 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, $EF_{3(PR\&P\ DUNG)}$. This included field studies ranging over eight years being performed in regions across New Zealand (Waikato, Southern Hawke's Bay, Manawatu, Canterbury and Otago) on free and poorly drained soils in the spring, summer, autumn and winter. These field studies used the 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 their distribution to the pastoral soil drainage class, and carried out a further trial to confirm data during the spring, to determine an appropriately weighted national annual mean value. This review found that:

- results confirm a disaggregation of EF3(PR&P) between dung and urine is warranted
- EF3 decreases as follows: cow urine > cow or cattle dung > sheep dung
- however, when seasonal data were 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 0.25 per cent.

Incorporation of nitrous oxide mitigation technologies into the Agriculture inventory

Nitrification inhibitor dicyandiamide

A methodology to incorporate an N_2O mitigation technology, the nitrification inhibitor dicyandiamide (DCD),[33] into the Agriculture 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). Mitigation estimates for calendar years 2007 to 2012 are shown in table 6.5.1

Dicyandiamide has been well researched, and research to date has shown it 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 using this inhibitor.

The method to incorporate inhibitor mitigation of N_2O emissions into New Zealand's Agriculture 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 inhibitor 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, applied twice per year in autumn and early spring within seven days of the application of excreta. 'Good practice' application methods of the inhibitor can be by slurry or granule.

Changes to the emission factors $EF_{3PR\&P}$ and parameter $Frac_{LEACH}$ were established for use with inhibitor 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 the inhibitor was applied.

The literature on inhibitor use in grazed pasture systems has been extensively peer reviewed, and it was determined that, on a national basis, reductions in $EF_{3PR\&P}$ and $Frac_{LEACH}$ of 67 per cent and 53 per cent could be made respectively (Clough et al, 2008). There has been some research into the effect of the inhibitor 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 Agriculture sector of the inventory.

The reductions in the emission factors and parameters are used along with the fraction of dairy land treated with the inhibitor 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

[33] DCD (Dicyandiamide) has been voluntarily withdrawn from the market in New Zealand due to customer concern over low residue levels in milk products. There is no risk to humans from these levels of inhibitor in milk products. A Technical Working Group, led by MPI, is still gathering data before submitting it to the relevant international food standards organisation, Codex Alimentarius. Further details about DCD can be found at http://www.mpi.govt.nz/news-resources/news/dcd-suspension-supported.

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 the inhibitor is applied (May to September). The modified emission factors (table 6.5.1) are based on information from the Statistics New Zealand *Agricultural Production Statistics* and census that 2.9 per cent of the effective dairying area in New Zealand received inhibitor in 2012.

Table 6.5.1 Emission factors, parameters and mitigation for New Zealand's DCD inhibitor calculations (2007–2012)

	2007	2008	2009	2010	2011	2012
Percentage of dairy area applied by area with inhibitor	3.5	4.5	3.1	2.2	3.0	2.9
Final modified emission factor or parameter, $EF_{3PR\&P}$ (kg N_2O-N/kg N)	0.00992	0.00990	0.00993	0.00995	0.00993	0.00994
Final modified emission factor or parameter, $Frac_{LEACH}$ (kg N_2O-N/kg N)	0.06957	0.06944	0.06962	0.06973	0.06963	0.06964
Mitigation (Gg CO_2-e)	18.7	25.4	18.3	13.7	19.5	19.6

Note: $EF_{3PR\&P}$ = 0.01 and $FRAC_{LEACH}$ = 0.07 when inhibitor is not applied

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 the inhibitor is used as an N_2O mitigation technology.

The inhibitor was found to have no effect on ammonia volatilisation during May to September when the inhibitor 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 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.

Urease inhibitor

A methodology to include a greenhouse gas mitigation technology, urease inhibitor (UI), into the Agriculture sector of the inventory has been developed, based on research by Saggar et al (2013). Urea is the key nitrogen fertiliser for grazed pastures, as well as being excreted in urine. Urease inhibitors restrict the action of an enzyme, urease, which is a catalyst for the volatilisation of the nitrogen contained in urea fertiliser and urine into ammonia gas, which can act as a secondary source of N_2O.

Urease inhibitor mitigation is included in New Zealand's Agriculture sector of the inventory by amendment to the value of the existing country-specific N_2O parameter: $Frac_{GASF}$. In particular, Saggar et al (2013) considered the mitigating effect of a UI, nBTPT (sold as 'Agrotain'), as it is the most widely used product. Based on field and laboratory studies conducted in New Zealand and worldwide, Saggar et al (2013) showed that the presently recommended country-specific value of $Frac_{GASF}$ = 0.1 (Sherlock et al, 2009) can be reduced to 0.055 where urea containing urease inhibitors is applied at a rate of 0.025% w/w, which is equivalent to a scaling factor for $Frac_{GASF}$ of 0.55.

Indirect N_2O emissions from atmospheric deposition with and without urease inhibitors applied are calculated below:

$$N_2O(G)\text{-}N = [(N_{FERT\text{-}UI} \text{ x } Frac_{GASF\text{-}UI}) + (N_{FERT} \text{ x } Frac_{GASF})] \text{ x } EF_4$$

Where:

$Frac_{GASF\text{-}UI}$ is the fraction of gas that volatilises with UI applied (0.045)

$Frac_{GASF}$ is the fraction of gas that volatilises when UI is not applied (0.1)

$N_{FERT\text{-}UI}$ is quantity of nitrogen contained in urea fertiliser that is treated with UI (kilograms)

N_{FERT} is quantity of nitrogen contained in fertiliser that is not treated with UI (kilograms).

Activity data on urease inhibitor usage are provided by Ballance AgriNutrients New Zealand from sales records for 2001 to 2012. Data provided is the tonnes nitrogen contained in urea treated with urease inhibitors.

The N_2O emissions reported in the Agricultural Soils category (Direct Soil Emissions, Synthetic Fertilisers) take into account the use of urease inhibitors. Estimates of mitigation from nitrous oxide emissions from volatilisation for the calendar years 2001 to 2012 are shown in table 6.5.2.

Table 6.5.2 Mitigation of Atmospheric Deposition Emissions for New Zealand's Urease Inhibitor (2001–2012)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Mitigation ($GgCO_2$-e)	2.3	2.0	2.7	5.0	1.0	4.9	3.1	3.1	4.9	4.2	3.6	4.7
Percentage inhibitor applied (% urea treated/total urea)	4.2	3.0	3.7	6.6	1.3	6.7	4.5	4.3	7.9	5.8	4.6	6.0

All other emission factors and parameters relating to animal excreta and fertiliser use ($Frac_{GASM}$, $Frac_{LEACH}$ and EF_1) do not change as a result of including urease inhibitors in the calculations. An adjustment for $Frac_{GASM}$ was not recommended as the effect of urease inhibitors on reducing NH_3 volatilisation from animal urine nitrogen could not be assessed accurately (Saggar et al, 2013).

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 website (www.mfe.govt.nz/publications/climate).

The method will be refined over time to reflect any updated data and information that may arise from ongoing research into this area.

Indirect emissions (nitrous oxide)

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 2012, N_2O emissions from leaching made up 4.8 per cent (1,670.2 Gg CO_2-e) of agricultural emissions, an increase of 28.7 per cent from the 1990 value of 1,297.9 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 2012, N_2O emissions from volatilisation made up 2.7 per cent (951.5 Gg CO_2-e) of agricultural emissions, an increase of 28.3 per cent from the 1990 value of 741.7 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 6.5.3). The distribution of the emission factors is skewed, reflecting pastoral soil drainage classes whereby 74 per cent of soils are classified as well-drained soils, 17 per cent are imperfectly drained soils and 9 per cent are classified as poorly drained soils. For the 2012 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the 2002 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 6.5.3 New Zealand's uncertainties in nitrous oxide emissions from agricultural soils for 1990, 2002 and 2012 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2012)

Year	N_2O emissions from agricultural soils (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	25.3	14.7	44.0
2002	32.2	18.7	56.0
2012	33.4	19.3	58.0

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 6.5.4, together with their percentage contributions to the uncertainty. There was no recalculation of the influence of parameters for the 2012 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 due to weather and soil type (by drainage classification); however, there have been no trials or uncertainty analysis on the effects of weather.

Table 6.5.4 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
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

Source: Kelliher et al, 2003, table 16

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; Thomas 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 2012) 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 91,000 tonnes lower (approximately 25 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 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. Some farmers use contract fertiliser spreading companies (including aerial spreading), and may not have an accurate estimate of the tonnes of fertiliser applied.

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 6.5.5 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 6.5.5 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 2011 value	0.0058	0.004	NA
United Kingdom-specific IEF 2011 value	0.0125	0.02	NA
New Zealand-specific 2011 value	0.01	0.01	0.0025

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) retrieved 3 January 2014 and UNFCCC (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/ items/7383.php) retrieved 14 January 2014

Note: IEF = implied emission factor.

Table 6.5.6 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 $Frac_{LEACH}$ value. 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 6.5.6 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 2011 value	0.1	0.0	0.3
United Kingdom-specific IEF 2011 value	0.1	0.20	0.3
New Zealand-specific 2011 value	0.1	0.1	0.07

Source: UNFCCC (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php) retrieved 14 January 2014

Note: IEF = implied emission factor.

6.5.5 Source-specific recalculations

All activity data were updated with the latest available data: Statistics New Zealand table builder and Infoshare database (2013) and LIC statistics (2013).

Updated data on the cultivation of herbage seeds for 2004 to 2011 have become available from Plant and Food Research.

Enhancements, described in sections 6.2.5 and 6.3.5, 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.

Urease inhibitors have been used in New Zealand since 2001. These reduce the fraction of nitrogen that volatilises into ammonia, and therefore reduce indirect emissions from atmospheric deposition. The effect of using urease inhibitors was included in the inventory, and recalculations of emissions from atmospheric deposition were made for every year from 2001 to 2011. Applying the revised 1996 IPCC guidelines and the IPCC good practice guidance direct N_2O emissions from nitrogen in synthetic fertiliser increases because the guidelines erroneously require an adjustment for volatilisation (IPCC 1996; 2000). Therefore, there is an increase in direct N_2O emissions from synthetic fertiliser (2001 to 2011) equal to the reduction in emissions from atmospheric deposition because both sources of N_2O emissions have the same value for the emission factor. The 2006 IPCC guidelines correct this error and will be applied from the 2015 submission, after which the use of urease inhibitors will result in an estimated net reduction in emissions.

Changes to the partitioning of nitrogen in excreta between urine and dung (see section 6.3.5) resulted in recalculations for emissions in each year 1990 to 2011 because different emission factors are applied to dung and urine.

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 nitrification inhibitors.

Tier 2 inventory model

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 inhibitor 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.

Nitrous oxide leaching and run-off (EF_5)

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 are 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}).

Nitrous oxide emissions on hill country (EF_3) implementation

New Zealand has completed research and published papers on the effects of medium hill slope on N_2O emissions, which confirmed that emissions of N_2O from excreta on sloping hill pastoral land are less than those from 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, and this recalculation is expected to be included in the 2015 submission.

Additionally, new research and a field-based methodology has started to determine N_2O emissions from dung and urine from New Zealand beef cattle and sheep (and deer, if possible) on steeply sloping (more than 25 degrees) pastoral land under New Zealand environmental conditions. The trials will be conducted over the next three-to-four years.

Nitrous oxide emissions on steep hill country (EF_3) field trials

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 inhibitor, and combinations on these nitrogen treatments, to derive acceptable emissions factors and methodologies specific for New Zealand conditions.

Nitrous oxide emissions and environmental factors

This project aims to improve New Zealand's understanding of N_2O emissions from animal excreta on pastoral land (emission factor EF_3) for cattle and sheep (and deer, if possible). Expert advice is required to define options for, and the benefit of, research frameworks to better constrain the seasonal and regional climatic influences on EF_3. Once a future long-term strategy for improving EF_3 has been agreed, a gap analysis of existing data will be performed and further field trials done to support the improvement of the certainty of the country-specific EF_3. The trials will be conducted over the next three-to-four years.

Nitrous oxide uncertainty analysis

The uncertainty analysis for N_2O from agricultural soils was based on 44 trials. Since the original uncertainty analysis was conducted there have been more trials and $EF_{3(PR\&P)}$ has been disaggregated for urine and dung. There have now been 185 N_2O trials between 2000 and 2013, and further field measurements are planned. Therefore, the uncertainty analysis will be updated to include updated emission factors and more trials.

2006 IPCC guidelines

Other improvements include changes as required to meet the revised reporting guidelines (Decision 15/CP.17) including the use of the 2006 IPCC guidelines.

6.6 Prescribed burning of savanna (CRF 4E)

6.6.1 Description

In 2012, 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 decreasing steadily over the past 50 years as a result of changes in lease tenure and a reduction in grazing pressure. In 2012, prescribed burning emissions accounted for 6.1 Gg CO_2-e, a 24.3 Gg CO_2-e (80.1 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 (Thomas 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 (Thomas et al, 2011).

Thomas 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 (dry matter, dm). Most of the composition and burning ratios used in calculations are from New Zealand-specific research and have been updated (Payton and Pearce, 2009). Thomas 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 dm) = area of tussock burned annually × above-ground biomass density (t dm/ha) × fraction actually burned/1,000

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	Thomas et al, 2011
Fraction oxidised	1	Thomas et al, 2011
Ratio of N:C loss	0.015	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, 2001; Payton and Pearce, 2009; and IPCC, 1996 – all cited in Thomas 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 changeover. 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 have 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

There were no recalculations for this source in 2013.

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 29.4 Gg CO_2-e in 2012. This was an increase of 5.5 Gg CO_2-e (22.8 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 2013.

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 (Thomas 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. 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/1,000

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 before 2005. Therefore, there was no annual data series for crop residue previously, and other methods for obtaining this 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 (Thomas 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 this 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 (Thomas 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: Thomas 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 is 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/1,000

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[34]
United Kingdom-specific IEF 2010 value	0
New Zealand-specific 2010 value	0.49

Source: UNFCCC (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php) retrieved 14 January 2014

Note: IEF = implied emission factor.

6.7.5 Source-specific recalculations

There were no recalculations for this source in 2013.

6.7.6 Source-specific planned improvements

No improvements are currently planned.

[34] Australia reports that there is no field residue burning and therefore it does not use $Frac_{BURN}$.

Chapter 6: References

Some references may be downloaded directly from the following webpage:

www.mpi.govt.nz/environment-natural-resources/climate-change/research-and-funded-projects/greenhouse-gas-inventory-projects-table.aspx

The Ministry for Primary Industries is progressively making reports used for the inventory available on this page provided copyright permits.

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Chapter 7: Land Use, Land-Use Change and Forestry (LULUCF)

7.1 Sector overview

Emissions summary

2012

In 2012, net emissions by the Land Use, Land-Use Change and Forestry (LULUCF) sector were –26,598.3 Gg carbon dioxide equivalents (CO_2-e). This comprises net removals of –26,684.1 Gg carbon dioxide (CO_2), emissions of 64.95 Gg CO_2-e of methane (CH_4) and 20.85 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 land converted to grassland subcategory.

1990–2012

Net emissions in 2012 have increased by 10,652.0 Gg CO_2-e (28.6 per cent) from the 1990 level of –37,250.4 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 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 are estimated as occurring over 20 years.

Table 7.1.1 New Zealand's greenhouse gas emissions for the LULUCF sector by land-use category, as well as their share and trend, in 1990 and 2012

	Emissions (Gg CO_2-e)		Difference	% Change	Share (%)	
Land-use category	**1990**	**2012**	**1990–2012**	**1990–2012**	**1990**	**2012**
Forest land	–39,138.4	–33,149.9	5,988.5	–15.3	+105.1	+124.6
Cropland	502.9	507.2	4.3	0.9	–1.4	–1.9
Grassland	1,154.4	5,985.1	4,830.8	418.5	–3.1	–22.5
Wetlands	218.1	44.4	–173.7	–79.6	–0.6	–0.2
Settlements	6.3	–3.0	–9.3	–147.2	–0.0	+0.0
Other land	6.2	17.8	11.5	185.5	–0.0	–0.1
Total LULUCF	**–37,250.4**	**–26,598.3**	**10,652.0**	**–28.6**	**+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 total due to rounding.

Emissions in the LULUCF sector are primarily caused by harvesting production forests, deforestation and the decomposition of organic material following these activities, whereas removals are primarily because of the sequestration 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 methane (CH_4), carbon monoxide (CO), other oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs).

2011–2012

Between 2011 and 2012, net emissions from the LULUCF sector increased by 2,996.5 Gg CO_2-e (10.1 per cent). The main contributor to the change occurred within the forest land category as a greater proportion of forest land reached either harvest or thinning age in 2012 compared with 2011 due to the age-class profile of New Zealand's production forests. Emissions have also increased in the grassland category due to larger areas of forest land being converted to grassland in 2012 than in 2011.

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, grassland remaining grassland, conversion to grassland and conversion to wetlands are key categories for New Zealand in 2012.

Figure 7.1.1 New Zealand's annual emissions from the LULUCF sector from 1990 to 2012

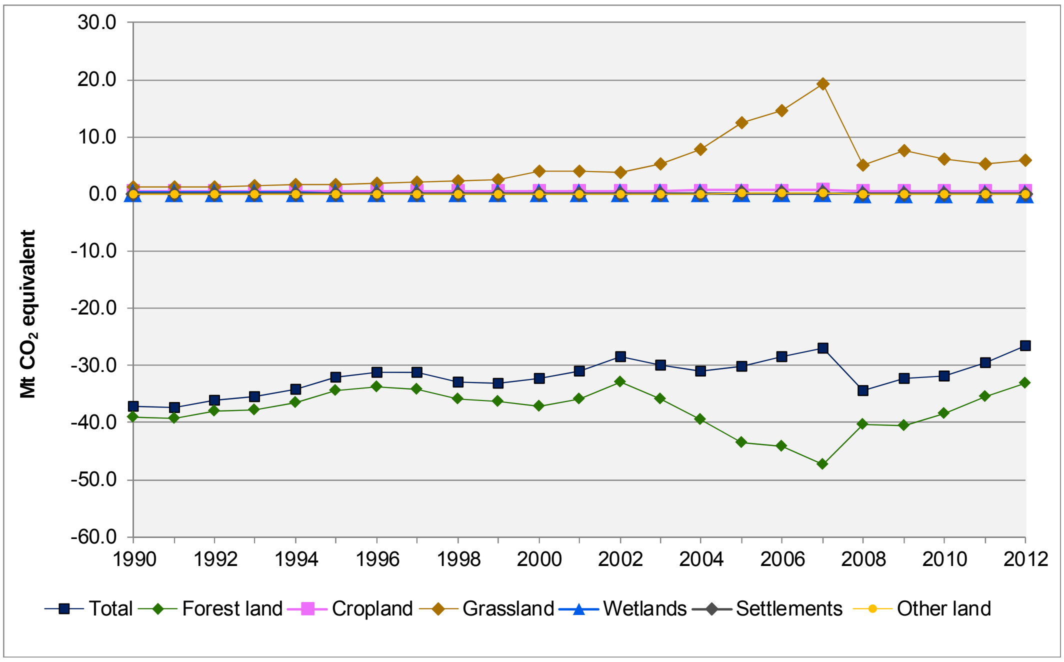
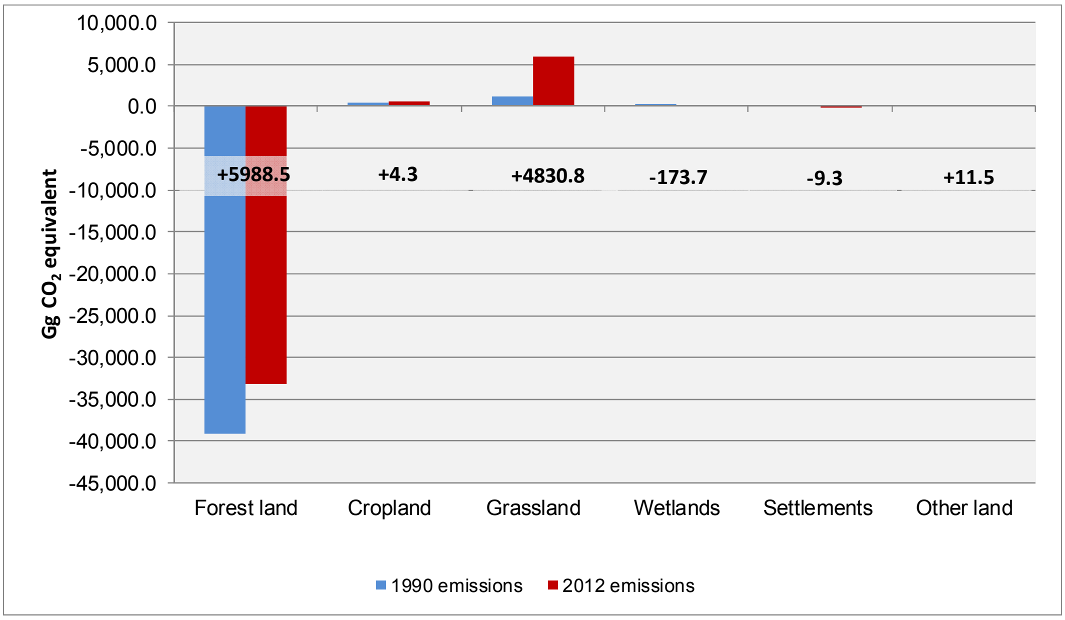


Figure 7.1.2 Change in New Zealand's emissions from the LULUCF sector from 1990 to 2012



Recalculations since 2013 submission

Since the 2013 submission there have been major recalculations in LULUCF sector emissions. These recalculations have resulted in a change in emissions at 1990 of –9,137.7 Gg CO_2-e (32.5 per cent) and –16,054.7 Gg CO_2-e at 2011 (118.6 per cent). The largest recalculations were due to the inclusion for the first time of estimates of carbon stock change for natural forests, and recalculations to activity data following completion of the 2012 land-use map. As part of producing the 2012 land-use map, previous maps were revised to correct errors and maintain time series consistency. Further details on these recalculations are provided in section 7.1.4 below, and in chapter 10.

7.1.1 Land use, land-use change and forestry in New Zealand

New Zealand has a land area of approximately 270,000 square kilometres 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.

Since 1990, approximately 4.0 per cent of New Zealand's total land area has undergone land-use change.

Before human settlement, natural forests were New Zealand's predominant land cover, estimated at 85 per cent of total land area (McGlone, 2009). Today, natural forest covers around 29 per cent of the total land area of New Zealand (see table 7.1.2). Nearly all lowland areas have been cleared of indigenous vegetation for agriculture, horticulture, plantation forestry and urban development. Much of the remaining indigenous vegetation, however, is now legally protected, whether in private ownership or within the conservation estate.

Forestry and agriculture are core to the New Zealand economy and are 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 one of 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 2012, plantation forests covered approximately 2.1 million hectares – around 7.8 per cent of New Zealand's total land area. This also includes areas not managed for timber supply; for instance, areas planted for erosion control.

Table 7.1.2 Land use in New Zealand in 2012

Land-use category	Subcategory	Area (hectares)	Proportion of total area (%)
Forest land	Natural forest	7,840,853	29.1
	Pre-1990 planted forest	1,457,173	5.4
	Post-1989 forest	654,354	2.4
	Subtotal	*9,952,380*	*37.0*
Cropland	Annual	371,808	1.4
	Perennial	104,290	0.4
	Subtotal	*476,098*	*1.8*
Grassland	High producing	5,806,973	21.6
	Low producing	7,538,391	28.0
	With woody biomass	1,353,943	5.0
	Subtotal	*14,699,307*	*54.6*
Wetlands		678,722	2.5
Settlements		224,415	0.8
Other land		894,173	3.3
Total		**26,925,094**	**100.0**

Note: Areas as at 31 December 2012. Columns may not total due to rounding.

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 7.1.4 and 7.1.5). A Tier 1 approach has been used to estimate carbon stock change in the four biomass pools for all land-use categories except for forest land, perennial cropland and grassland with woody biomass, which use Tier 2 approaches.

For all land-use categories, Tier 1 modelling approaches have been used to estimate carbon stock changes in organic soils and a Tier 2 modelling approach has been used to estimate soil organic carbon changes for mineral soils.

New Zealand applies different methods to obtain separate emission factors for estimating emissions for post-1989 forest made up of natural species and post-1989 forest planted for timber production. This is to ensure the different growth characteristics are reflected in the estimates. For reporting of emissions in the common reporting format (CRF) tables, these divisions are combined into a single subcategory of post-1989 forest.

To distinguish descriptions of the methodologies used for post-1989 and pre-1990 forests, the prefix pre-1990 is used within the national inventory report (NIR) to describe areas where forest existed at 1990. In the CRF tables, pre-1990 natural forest is described as natural forest as shown in the mapping of categories in table 7.1.3.

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. Grassland with woody biomass is therefore a diverse category. To account for these differences, grassland with woody biomass is split into 'permanent' and 'transitional' subcategories for modelling of land-use change. Separate emission factors for each type of grassland with woody biomass are derived from the Land Use and Carbon Analysis System (LUCAS) plot network (Wakelin and Beets, 2013). Within the CRF tables, grassland with woody biomass is reported at the aggregate level.

Table 7.1.3 Mapping of forest and grassland with woody biomass categories between the NIR and CRF tables

NIR	CRF tables
Pre-1990 natural forest	Natural forest
Pre-1990 planted forest	Pre-1990 planted forest
Post-1989 natural forest	Post-1989 forest
Post-1989 planted forest	
Grassland with woody biomass – transitional	Grassland with woody biomass
Grassland with woody biomass – permanent	

Emission factors

The emission factors required to estimate carbon stock changes using the tier 1 and tier 2 equations are provided in tables 7.1.4 and 7.1.5. Table 7.1.4 contains biomass carbon stocks in each land-use subcategory prior to conversion and table 7.1.5 contains the annual growth in carbon stocks after land-use change.

Table 7.1.4 New Zealand's biomass carbon stock emission factors in land use before conversion

Land-use category	Land-use subcategory	2014 submission emission factors (t C ha^{-1})	Carbon pools	Reference
Forest land	Pre-1990 natural forest: shrub	84.88*	All biomass pools	LUCAS plot-based estimate
	Pre-1990 natural forest: tall forest	253.14*	All biomass pools	LUCAS plot-based estimate
	Pre-1990 planted forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot-based estimate
	Post-1989 natural forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot-based estimate
	Post-1989 planted 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 – transitional	11.99	All biomass pools	LUCAS plot-based estimate
	With woody biomass – permanent	59.96	All biomass pools	LUCAS plot-based estimate
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. * For conversions from natural forest, the indicated carbon stock is emitted instantaneously depending on the vegetation type present (tall forest or shrub) immediately before conversion. 'All biomass pools' includes above- and below-ground biomass, litter and dead organic matter. See below in section 7.3 and under Methodological issues in each category-specific section for further details on how emissions are estimated.

Table 7.1.5 New Zealand's emission factors for annual growth in biomass in land after conversion

Land-use category	Land-use subcategory	2014 submission emission factor (t C ha^{-1})	Carbon stock maturity cycle	Carbon pools	Reference
Forest land	Pre-1990 natural forest	Based on net annual growth increment	NA	All biomass pools	LUCAS plot-based estimate
	Pre-1990 planted forest	Based on an age-based carbon yield table	NA	All biomass pools	LUCAS plot-based estimate
	Post-1989 natural forest	Based on an age-based carbon yield table	NA	All biomass pools	LUCAS plot-based estimate
	Post-1989 planted forest	Based on an age-based carbon yield table	NA	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 – transitional	0.43	28	All biomass pools	LUCAS plot-based estimate
	With woody biomass – permanent	NO	NA	NA	NA
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. 'All biomass pools' includes above- and below-ground biomass, litter and dead organic matter.

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 pools used for reporting under the United Nations Framework Convention on Climate

Change (Climate Change Convention). Table 7.1.6 summarises the methods being used to estimate carbon by pool for each land use.

Table 7.1.6 Relationships between land-use category, carbon pool, and method of calculation 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	Pre-1990 natural forest	Allometric equations	Per cent of above-ground biomass	Allometric equations	Lab analysis	Tier 2, country-specific data and model	Not applicable
	Pre-1990 natural forest [D]	Emission factor based on the vegetation type present (tall forest or shrub) before deforestation occurring since 1 January 1990					
	Pre-1990 planted forest	Age-based carbon yield table by biomass pool derived from the LUCAS plot network and the Forest Carbon Predictor model				Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Pre-1990 planted forest [D]	Age-based carbon yield table by biomass pool derived from the LUCAS plot network and the Forest Carbon Predictor model					
	Post-1989 natural forest [AR]	Allometric model	Per cent of above ground biomass	Allometric model	Allometric model	Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Post-1989 natural forest[D]	Allometric model	Per cent of above ground biomass	Allometric model	Allometric model	Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Post-1989 planted forest [AR]	Age-based carbon yield table by biomass pool derived from the LUCAS plot network and the Forest Carbon Predictor model				Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Post-1989 planted forest [D]	Age-based carbon yield table by biomass 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	Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Cropland – perennial	Country-specific emission factor	Not estimated	Not estimated	Not estimated	Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Grassland (high and low producing)	IPCC tier 1 default parameters	IPCC tier 1 default parameters	Not estimated	Not estimated	Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Grassland with woody biomass – transitional and permanent	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	Tier 2, country-specific data and model	IPCC tier 1 default parameters
	Wetlands	IPCC tier 1	IPCC tier 1	Not	Not	Tier 2,	Not

		default parameters (NE)	default parameter (NE)	estimated	estimated	country-specific data and model	estimated
	Settlements	IPCC tier 1 default parameter (NE)	IPCC tier 1 default parameter (NE)	Not estimated	Not estimated	Tier 2, country-specific data and model	Not estimated
	Other land	IPCC tier 1 default parameter (NE)	IPCC tier 1 default parameter (NE)	Not estimated	Not estimated	Tier 2, country-specific data and model	Not estimated

Note: AR = afforestation/reforestation; D = deforestation; NE = not estimated. See the methodology sections for an explanation of soil carbon calculations (section 7.3) and forest models, C_Change and Forest Carbon Predictor (section 7.4.2).

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 provide 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 2012 (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 7.1.4 and 7.1.5)
- age-based biomass carbon yield tables for pre-1990 planted forests and post-1989 forests (see section 7.4.2)
- growth increment for pre-1990 natural forest (see section 7.4.2)
- emission factors and country-level activity data on biomass burning and liming (section 7.10)
- Intergovernmental Panel on Climate Change (IPCC) default conversion factors.

The formula used to calculate emissions from biomass changes is:

$$\left(\textit{Loss of biomass present in previous crop} \times \textit{Activity data (Area)}\right) + \left(\textit{Annual growth in biomass carbon stocks in new land use} \times \textit{Activity data (Area)}\right) \quad (1)$$

The formula used to calculate emissions from soil changes is:

$$\frac{\textit{Soil carbon at steady state in the new land use} - \textit{Soil carbon at steady state in the previous land use}}{\textit{20 years (transition period)}} \times \left(\textit{Activity data (Area)}\right) \quad (2)$$

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 × 100) + (0.67 × 100) = –238 t C (1)

Soil change = (((113.67– 133.12) / 20) × 100) = –97.25 t C (2)

Total carbon stock change = –335.25 t C

Total emissions = (carbon stock change / 1,000 × –1) × (44/12)

Total emissions = 1.229 Gg CO_2

These calculations have been 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. 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 3.2.2.

7.1.3 Uncertainties in LULUCF

Table 7.1.7 shows the four land-use subcategories within the LULUCF sector that make the greatest contribution to uncertainty in the net carbon emissions for the sector. These are given in descending order.

Table 7.1.7 Land-use subcategories making the greatest contribution to uncertainty in the LULUCF sector

Land-use subcategory	Absolute emissions by subcategory (Gg CO_2)	Uncertainty introduced into emissions for LULUCF (%)
Pre-1990 natural forest remaining pre-1990 natural forest	16,078.3	43.7
Pre-1990 planted forest remaining pre-1990 planted forest	8,805.1	30.3
Low-producing grassland converted to post-1989 forest	11,152.8	5.0
High-producing grassland remaining high-producing grassland	1,114.87	3.7

A Monte Carlo simulation approach was used to assess the main sources of uncertainty on carbon stock and carbon stock change in pre-1990 natural forest. Pre-1990 natural forest was found to be a statistically significant sink of carbon, sequestering 0.56 (95 per cent confidence interval 0.07–1.05) tonnes C $ha^{-1}yr^{-1}$ (Holdaway et al, 2013a). However, the variation between individual plot estimates of carbon change and the relatively low sequestration in old growth forest results in an uncertainty of 87.5 per cent for change in the category. This coupled with high removals, as the area of pre-1990 natural forest is large, results in the largest contributor to uncertainty in the LULUCF sector.

Pre-1990 planted forest remaining pre-1990 planted forest contributed the second-greatest level of uncertainty to the sector. The age structure of the pre-1990 planted forest estate results in high removals from growth and high emissions from harvesting, leaving a relatively small net change. Therefore, its uncertainty is high despite relatively low uncertainty in carbon stocks (12.4 per cent).

Low-producing grassland converted to post-1989 forest contributes the third-greatest level of uncertainty due to high removals from forest growth despite the low biomass uncertainty for both components of this land use (8.5 per cent).

High-producing grassland remaining high-producing grassland provides the fourth-greatest level of uncertainty in the sector. Emissions in this category originate mostly from organic soils.

The uncertainties were recalculated and independently reviewed for the 2014 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. Further detailed analysis of LULUCF uncertainties is presented in annex 3.2.1.

7.1.4 Recalculations in LULUCF

For the 2014 submission, New Zealand has recalculated its emission estimates for the LULUCF sector from 1990 to 2011 to incorporate new activity data, New Zealand-specific emission factors and improved methodology for the entire time series.

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 32.5 per cent and to decrease emissions in 2011 by 118.6 per cent (table 7.1.8).

Table 7.1.8 Recalculations to New Zealand's total net LULUCF emissions for 1990 and 2011

	Reported net emissions		Change in estimate	
	2013 submission (Gg CO_2-e)	2014 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	–28,112.7	–37,250.4	–9,137.7	+32.5
2011	–13,540.2	–29,594.9	–16,054.7	+118.6

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions reported in the 2013 submission are the result of (in decreasing order of magnitude):

- the inclusion for the first time of estimates of carbon stock change for natural forests. This addresses recommendations of previous expert review teams to report on carbon stock change within natural forests. Annual carbon stock changes are based on results of analyses presented in Holdaway et al (2013a). This has accounted for a decrease in emissions of at least –16,000 Gg CO2-e annually for every year of the inventory
- completion of the 2012 land-use map
- 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

- the separate identification and modelling of the net planted forest area for pre-1990 and post-1989 planted forest in this submission. This ensures the harvesting and planting activity data obtained from the Ministry for Primary Industries is consistent with the planted forest area modelled for Convention on Climate Change reporting. The planted forest yield tables and emission factors have been revised accordingly
- returning to a tier 2 methodology for estimating mineral soil organic carbon
- the revision of the post-1989 planted forest carbon stock yield table based on the full re-measurement of the plot network that was completed in 2012. The inclusion of additional sample plots addresses a bias in the earlier estimates caused by incomplete sampling of the forest area
- the identification, measurement and application of category-specific carbon stock yield tables for post-1989 natural forest for the first time in the 2012 inventory. A growth model specific to Douglas fir has been incorporated into the Forest Carbon Predictor model used to develop planted forest yield tables for Convention on Climate Change reporting
- new plot-based emission factors for the grassland with woody biomass subcategory
- reporting emissions for controlled burning following deforestation for the first time in the 2012 inventory. Estimates are provided for the burning of post-harvest slash prior to conversion.

The impact of these recalculations on net CO_2-e emissions in each land-use category is provided in table 7.1.9. This table includes recalculated values for 1990 and 2011, to enable a comparison of the two approaches.

Table 7.1.9 Recalculations to New Zealand's net LULUCF emissions for 1990 and 2011

Land-use category	Net emissions (Gg CO_2-e) 2013 submission: 1990 estimate	2014 submission: 1990 estimate	2013 submission: 2011 estimate	2014 submission: 2011 estimate	Change in 1990 estimate (%)	Change in 2011 estimate (%)
Forest land	–27,717.3	–39,138.4	–17,741.2	–35,518.5	+41.2	+100.2
Cropland	568.3	502.9	390.8	516.2	–11.5	+32.1
Grassland	–1,233.1	1,154.4	3,753.3	5,343.4	–193.6	+42.4
Wetlands	167.3	218.2	20.9	45.5	+30.4	+118.4
Settlements	97.6	6.3	34.7	–3.5	–93.5	–110.2
Other land	4.5	6.2	1.3	22.0	+37.3	+1,566.1
Total	**–28,112.7**	**–37,250.4**	**–13,540.2**	**–29,594.9**	**+32.5**	**+118.6**

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.

7.1.5 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-based pre-1990 natural forest carbon stock inventory
- completion of natural forest carbon stock and change assessment
- method development to enable implementation of the 2006 IPCC guidelines
- estimating non-carbon emissions from wildfires in converted forest land back to 1990
- improvements to mapping as further data becomes available
- improvements to mineral soil organic carbon assessment.

7.2 Representation of land areas

The total land area of New Zealand is 26,925.1 kilohectares. This 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 2012 (IPCC, 2003, chapter 2.3.2.3). The total land-use areas as at 1 January 1990, 1 January 2008 and 31 December 2012 are based on wall-to-wall mapping of satellite and aircraft remotely sensed imagery taken in, or close to the start of, 1990, 2008 and 2012 respectively, as described in section 7.2.2. The mapping of forest areas includes improvements made up to August 2013 using aerial photography and data from the NZ ETS. Deforestation occurring between 2008 and 2012 has been mapped by year using ancillary satellite imagery and oblique aerial photography. All other land-use changes occurring between 1990 and 2012 have been interpolated from other sources. This is described in further detail in section 7.2.3.

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 2013 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[(2)]
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'. (2) Mapped as a single land-use subcategory but stratified into 'post-1989 natural forest' and 'post-1989 planted forest' for calculating carbon based on the plot network.

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 (IPCC, 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'. These subcategories are then aggregated for reporting in the CRF tables. See section 7.7 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 *Land Use and Carbon Analysis System: Satellite imagery interpretation guide for land-use classes* (2nd edition) (Ministry for the Environment, 2012b).

Table 7.2.2 New Zealand's mapping definitions for land-use subcategories

Land-use subcategory	Definition
Pre-1990 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, mānuka–kānuka 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.
Pre-1990 planted forest	Areas that, on 1 January 1990, were and presently include: • 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 less than 30 metres in width 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	Includes post-1989 planted forest, which consists of: • 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)

Land-use subcategory	Definition
	• riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989 • harvested areas within post-1989 forest land (assuming these will be replanted, unless deforestation is later detected). Includes post-1989 natural forest, which consists of: • 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. Includes areas within post-1989 natural forest or post-1989 planted forest that are: • 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	Includes: • all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland.
Cropland – perennial	Includes: • all orchards and vineyards • linear shelterbelts associated with perennial cropland.
Grassland – high producing	Includes: • 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	Includes: • low-fertility grassland and tussock grasslands (eg, *Chionochloa* and *Festuca* spp.) • mostly hill country • montane herbfields either at 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	Includes: • grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (eg, māhoe – *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 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) • 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	Includes: • areas classified and mapped separately as ‘wetlands – open water’ and ‘wetlands – vegetated’ • open water comprising lakes, rivers, dams and reservoirs • vegetated wetlands comprising 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.

Land-use subcategory	Definition
Settlements	Includes: • 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	Includes: • 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 in section 7.2.7. 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 methodology

Areas of land use and land-use change between 1990 and 2012 are based on three wall-to-wall land-use maps derived from satellite imagery at nominal mapping dates of 1 January 1990, 1 January 2008 and 31 December 2012. Area information from these maps is interpolated and extrapolated to obtain a complete time series of land-use change occurring between 1990 and 2012 (section 7.2.3).

Satellite image acquisition and pre-processing

Each of the national land-use maps is based on a collection of either Landsat or SPOT satellite imagery acquired over the summer periods (October to March) as described in table 7.2.3. This type of satellite imagery is only acquired over New Zealand during the summer months because a high sun angle is required to reduce shadowing and increase the dynamic range of the signal received from the ground.

Table 7.2.3 Satellite imagery used for land-use mapping in 1990, 2008 and 2012

Land-use map	Satellite imagery	Resolution (metres)	Acquisition period
1990	Landsat 4 and Landsat 5	30	November 1988 – February 1993
2008	SPOT 5	10	November 2006 – April 2008
2012	SPOT 5	10	October 2011 – March 2013

All the imagery was orthorectified and atmospherically corrected, then 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). This standardisation process removes the effect of terrain slope from the imagery and effectively 'flattens' the imagery so that individual land cover types are a more consistent colour across the whole image. By minimising the effects of terrain, a more accurate and consistent classification of land use is possible. This is particularly important in New Zealand due to the extensive areas of steep terrain.

The final step in image preparation was the mosaicing of the satellite image scenes into a seamless national image. To minimise the effect of cloud and cloud shadows in the mosaic, cloud masks were digitised for each scene. These masks were then used to prioritise the order of inclusion of each scene in the mosaic to obtain near cloud-free image of New Zealand at each mapping date.

1990 and 2008 land-use maps

Mapping approach

The 1990 and 2008 land-use maps were created using a common mapping approach based on difference detection from an intermediate reference land-cover layer which was derived from Landsat 7 ETM+ imagery acquired in 2000–2001. A semi-automated approach was used to classify woody land cover[35] in the 1990 and 2008 image mosaics. These layers were then differenced from the 2001 reference layer to create a 1990–2001 potential woody change layer and a 2001–2008 potential woody change layer.

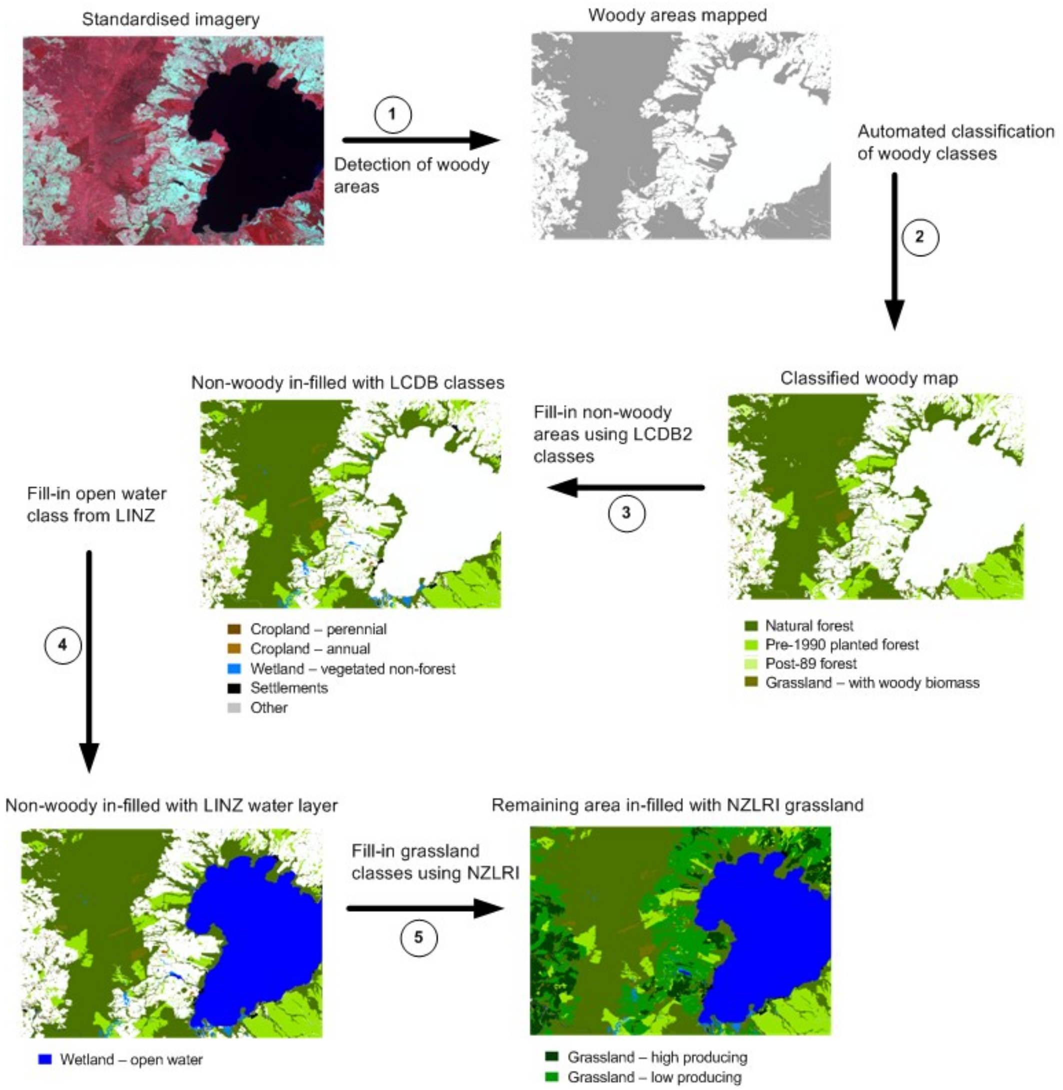
The potential woody change layers were visually checked to confirm change and then the changes were combined with the 2001 reference layer to create the 1990 and 2008 woody land cover layers. Area and proximity rules were used to convert these layers from woody land cover to woody land-use, making allowances for unstocked areas within forest extents and areas of regenerating shrubland in a forest context. This process is described in Shepherd and Newsome (2009a).

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), hydrological data from Land Information New Zealand (a government agency) and the New Zealand Land Resource Inventory (NZLRI) (Eyles, 1977) was used (Shepherd and Newsome, 2009b).

The NZLRI database defined 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.

[35] Land cover consistent with pre-1990 natural forest, pre-1990 planted forest, post-1989 forest and grassland with woody biomass land-use subcategories.

Figure 7.2.1 New Zealand's land-use mapping process

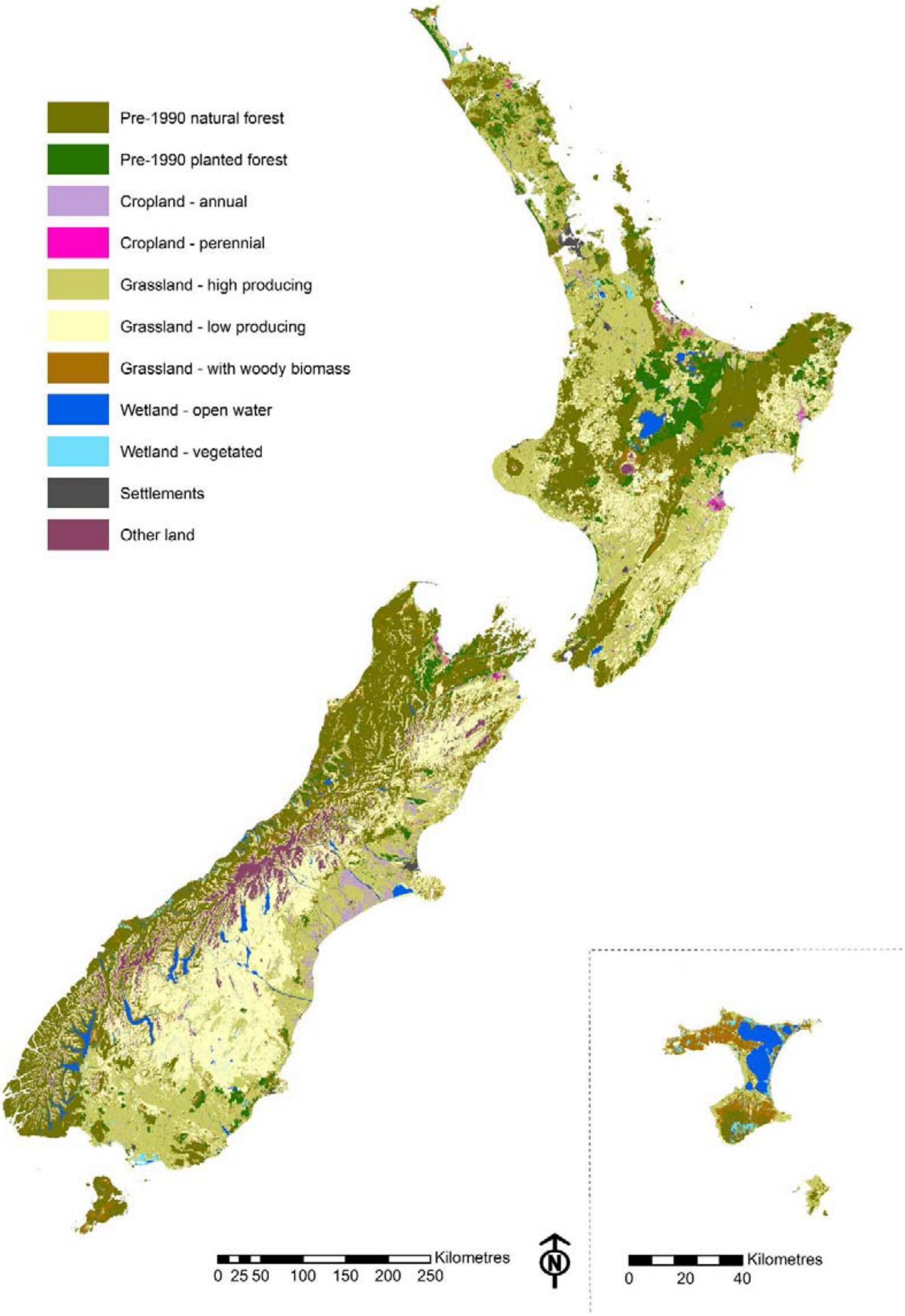


Note: LINZ = Land Information New Zealand.

An interpretation guide for automated and visual interpretation of satellite imagery was prepared and used to ensure a consistent basis for all mapping processes (Ministry for the Environment, 2012b). 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).

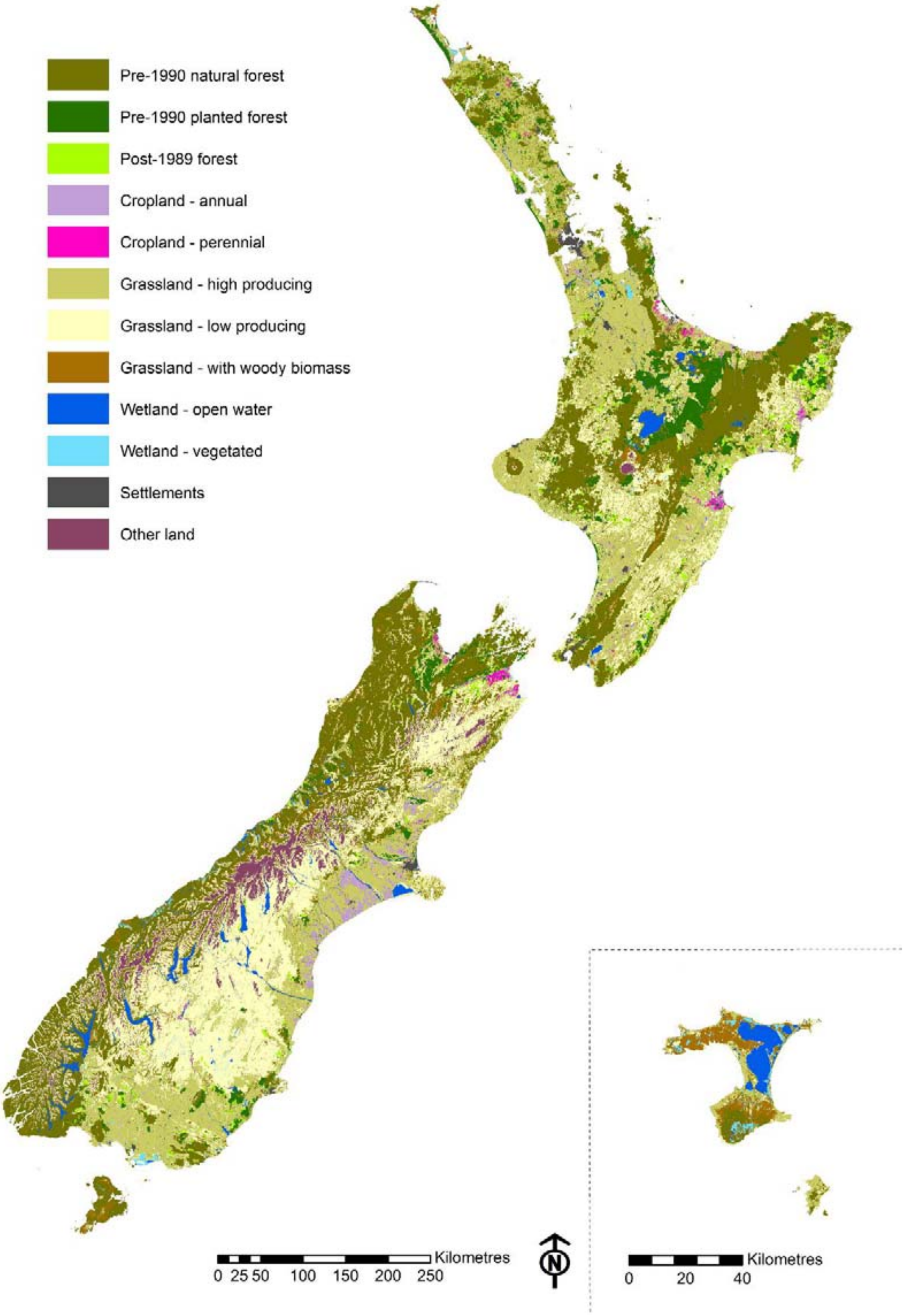
Figures 7.2.2 and 7.2.3 show the land-use map of New Zealand as at 1 January 1990 and 1 January 2008 respectively.

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.

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.

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, since 2009 the NZ ETS has provided valuable spatial information that has been used to confirm 1990 forest land-use classifications.

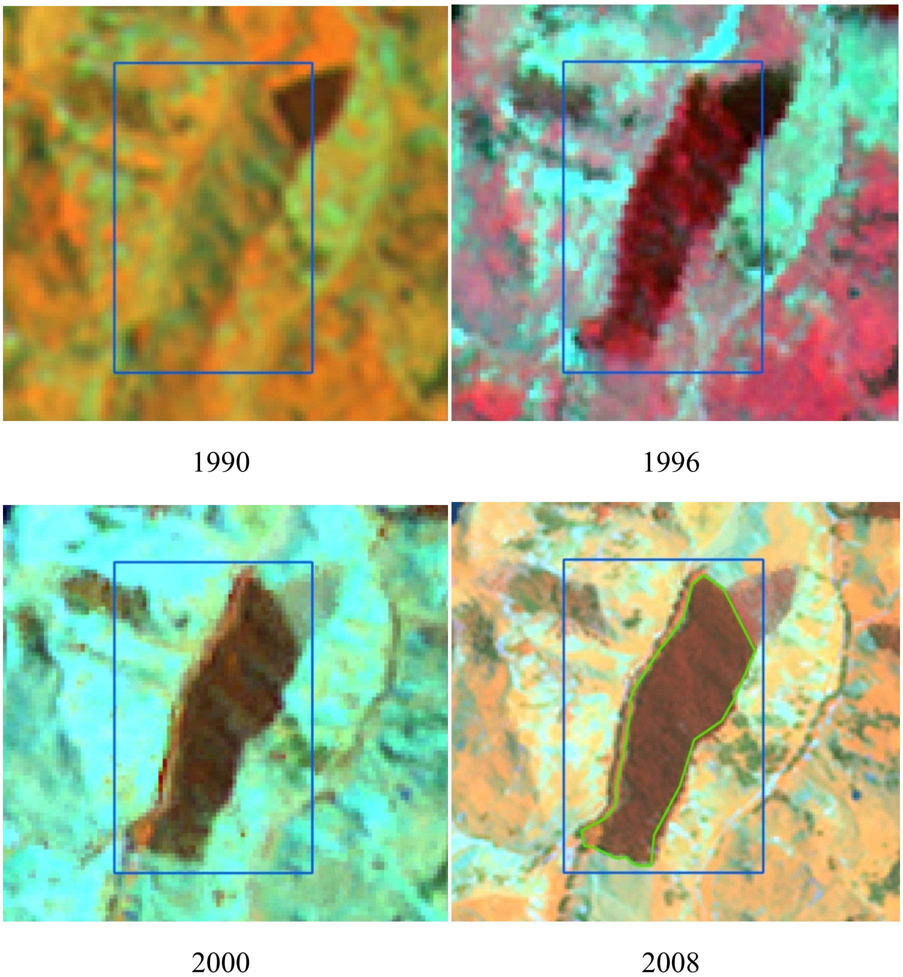
Owners of post-1989 forest are able to lodge their forests with the NZ ETS to obtain credit for increases in carbon stock since 1 January 2008. Mapping received by the Ministry for Primary Industries for these applications is used to improve LUCAS land-use maps.

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 1987 and 1993. Figure 7.2.4 illustrates how mapping operators determined the status of an area of planted forest established between 1987 and 1993.

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.

2012 land-use mapping

The 2012 land-use map was created by detecting change between 2008 and 2012 and updating these areas in the 2008 land-use map to create a 2012 version. A multi-date image segmentation process was used to identify areas of possible change between the 2008 and 2012 SPOT satellite imagery datasets. This process is described in Shepherd et al (2013).

These areas of potential change were confirmed using two separate approaches: one for areas mapped as non-forest at 2008 and one for areas mapped as forest at 2008.

Mapping approach: non-forest areas

Potential change in areas mapped as non-forest subcategories at 2008 were manually checked in the satellite imagery to determine whether a land-use change had occurred between 2008 and 2012. Operators used the 2008 and 2012 SPOT imagery along with other imagery datasets as listed in table 7.2.4 to establish whether land-use change had occurred.

Table 7.2.4 Ancillary imagery datasets used in land-use mapping

Satellite imagery	Resolution (metres)	Coverage	Acquisition period
SPOT Maps product	2.5	North Island, South Island and Stewart Island	2008–2009
Disaster Monitoring Constellation (DMC)	22	North Island, South Island and Stewart Island	November 2009 – March 2010
SPOT 5	10	4 priority areas: Northland, Waikato, Marlborough and Southland	October 2010 – March 2011
Aerial photography	variable	All of North Island and Stewart Island and most of South Island	various

Once change was confirmed, the area of change was delineated in the 2012 land-use map.

Mapping approach: forest areas

Areas of possible change within the forest extent were considered to be potential destocking. The areas of potential destocking were first checked in aerial photography to determine whether replanting had occurred. Cases of replanting were then removed from the destocking layer.

All remaining areas were field checked with oblique aerial photography taken over each site to determine the current land use. Previous deforestation mapping experience has highlighted that it is not possible to make this destock classification using currently available satellite imagery; however, efficient flight planning made oblique over-flight of all areas of destocking a realistic and cost-effective alternative.

Based on the oblique aerial photographic evidence and supporting evidence from the NZ ETS, each area was given one of the following destock classifications:

- Harvested: The area shows evidence of ongoing forestry land use such as replanting, preparation for planting or a context consistent with replanting, such as being surrounded by plantation forestry.
- Deforested: The area shows evidence of land-use change such as the removal of stumps, pasture establishment, fencing and stock or the area has been destocked and lying fallow for four or more years.36
- Awaiting: The area has been destocked for less than four years and there is no evidence of land-use change. That is, the area is lying fallow or, in the case of natural forest areas, the vegetation has been sprayed but not cleared.37

[36] New Zealand uses a 'four-year rule' for the confirmation of deforestation. Any area not replanted or regenerating after four years is deemed to be deforested even when there is no evidence of active land-use change.

- No change: The area has not been destocked and was incorrectly identified as change.
- Not forest: The area was not forested at the beginning of the change period. These areas required correction to a non-forest land use in the 2008 land-use map.
- Non-anthropogenic change: Destocking was not human induced – for example, erosion.

Deforested areas were then attributed with further information such as the year in which the deforestation occurred. This was determined by examining the ancillary imagery datasets listed in table 7.2.4 as well as a national time series of Landsat 7 satellite imagery acquired between 2007 and 2012. Figure 7.2.5 shows the process of confirming deforestation and establishing the year in which it occurred. Further information on the mapping of forest change can be found in Indufor Asia-Pacific (2013).

The final step in the 2012 land-use mapping process was to add the confirmed areas of deforestation into the 2012 map. Figure 7.2.6 shows the land-use map of New Zealand as at 31 December 2012.

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[37] Often regenerating shrubland areas are sprayed but land-use conversion is not completed by clearing the area. In these instances the vegetation regenerates and recovers, therefore land-use change has not occurred.

Figure 7.2.5 New Zealand's identification of deforestation

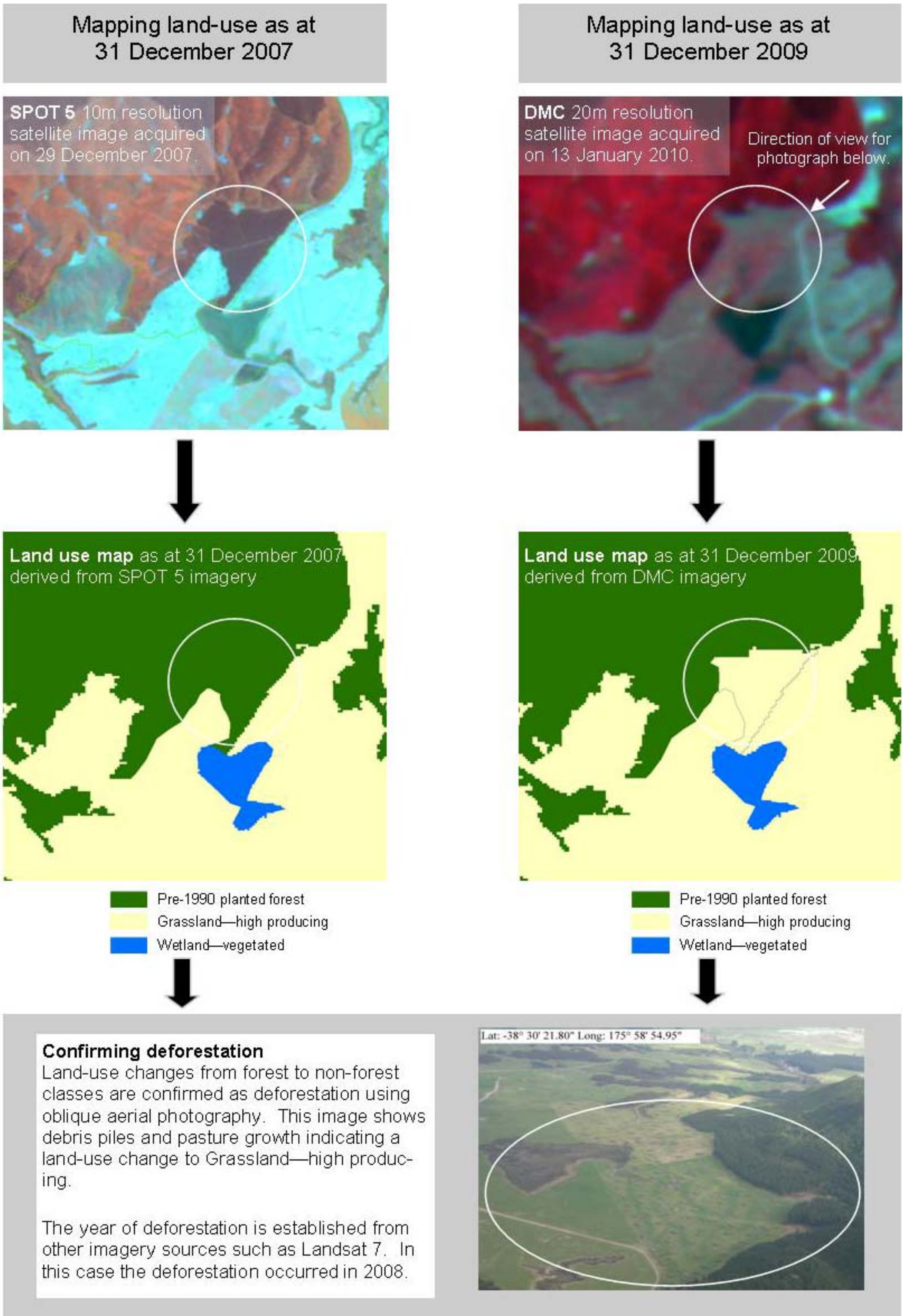
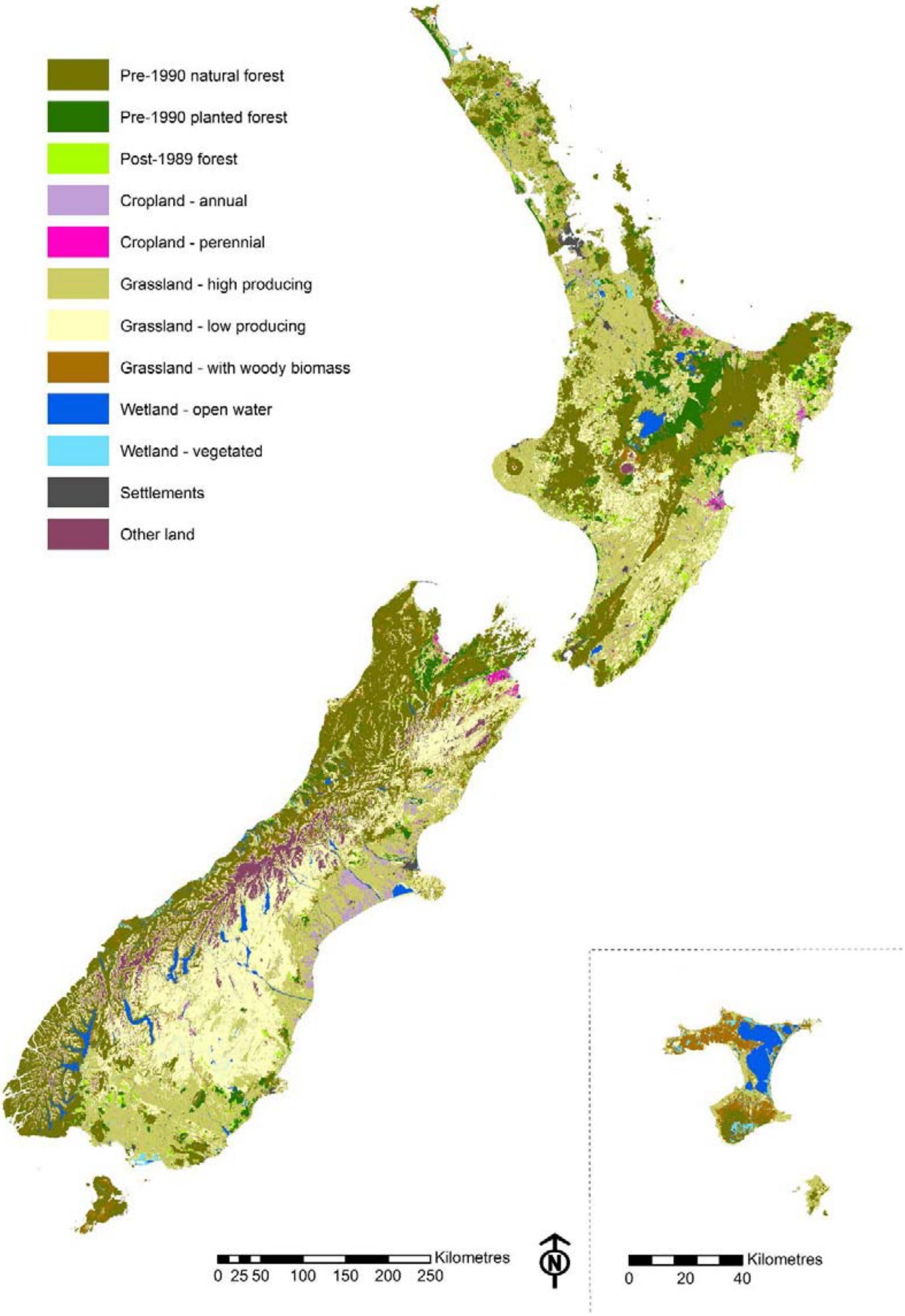


Figure 7.2.6 Land-use map of New Zealand as at 31 December 2012



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.

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 2014 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 7.2.5.

Land-use change from 1990 to 2012

Annual land-use changes from 1990 to 2012 are interpolated from the 1990, 2008 and 2012 land-use maps. Two separate interpolations are calculated. The first covers the period between 1990 and 2007 and the second covers the period between 2008 and 2012. Most of the land-use changes are interpolated linearly between mapping dates; however, some of the land-use changes make use of surrogate datasets to better reflect the trends of land-use change within these periods. This approach follows methodology outlined in section 5.6.2 of GPG-LULUCF.

The surrogate datasets used between 1 January 1990 and 31 December 2007 are as follows.

- Deforestation trends between 1990 and 1 January 2008 for pre-1990 planted forest and post-1989 forest are based on 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).
- Afforestation trends for post-1989 planted forest are based on estimates from the National Exotic Forest Description (Ministry for Primary Industries, 2013a).
- Afforestation trends for post-1989 natural forest are based on plot analysis as described in Beets et al (2013).

Surrogate datasets used between 1 January 2008 to 31 December 2012 are as follows:

- Total afforestation for 2008 to 2012 is estimated from the National Exotic Forest Description (Ministry for Primary Industries, 2013a). This dataset is used to provide a trend extrapolation for afforestation occurring between 2008 and 2012. The National Exotic Forest Description dataset is used to provide the total afforestation up to 2012 in preference to the total 2012 mapped afforestation because not all new planting will have been detected in satellite imagery. Further details on the use of the National Exotic Forest Description data for estimating total afforestation can be found in section 7.4.1.
- Deforestation occurring between 2008 and 2012 has been mapped by year for most of the country. Some extrapolation was required to complete the estimate of deforestation in 2012. This was necessary to account for the portion of New Zealand that was imaged for mapping in the summer of 2011/12 as opposed to the summer of 2012/13. The average deforestation occurring in these regions for 2008 to 2011 was used to provide the 2012 estimate. This proved to be the most robust method for completing the estimate of 2012

deforestation and was tested by comparing the deforestation totals for regions where 2012 data was available with estimates based on the same extrapolation methodology.

Table 7.2.6 shows a land-use change matrix for the years 1990 to 2012 based on these inputs.

Prominent land-use changes between 1 January 1990 and 31 December 2012 include:

- forest establishment of 674,945 hectares (classified as post-1989 forest) that has occurred mostly on land that was previously grassland, primarily low-producing grassland. Approximately 20,591 hectares of this post-1989 forest has subsequently been deforested
- deforestation of 151,544 hectares. This includes the 20,591 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 7.2.7 shows a land-use change matrix for the period 31 December 2011 to 31 December 2012.

Table 7.2.5 New Zealand’s land-use change matrix from 1962 to 1989

1989 \ 1962		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 1989 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	7,852.4							45.8				7,898.2
	Pre-1990 planted	274.4	450.5					372.7	432.9				1,530.5
	Post-1989												-
Cropland	Annual				323.9	1.4	21.2	8.2					354.7
	Perennial				0.9	59.2	5.1	4.1					69.2
Grassland	High producing	76.2			70.1	17.8	4,867.9	451.8	378.2	50.7			5,912.7
	Low producing	409.7						7,441.6	40.0				7,891.2
	With woody biomass	56.0						426.8	1,003.6				1,486.4
Wetlands	Wetlands	14.4								663.4			677.8
Settlements	Settlements	5.1			7.6		6.7	3.6	0.3		182.8		206.1
Other land	Other land											898.2	898.2
Net area as at 31 Dec 1962 (kha)		8,688.2	450.5	-	402.5	78.4	4,900.9	8,708.7	1,900.7	714.2	182.8	898.2	26,925.1
Net change 1962–1989		–790.0	1,080.1	0.0	–47.7	–9.2	1,011.7	–817.5	–414.4	–36.4	23.3	0.0	0.0
Net change 1962–1989 (%)		–9.1	239.8	NA	–11.9	–11.7	20.6	–9.4	–21.8	–5.1	12.7	NA	NA

Note: Units in 000’s hectares; NA = not applicable. Shaded cells indicate land remaining in each category.

Table 7.2.6 New Zealand's land-use change matrix from 1990 to 2012

2012 \ 1990		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2012 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	7,840.9											7,840.9
	Pre-1990 planted	18.3	1,438.7				0.1	0.1	0.0				1,457.2
	Post-1989				0.3	0.0	109.9	387.7	152.0	0.3	0.0	4.2	654.4
Cropland	Annual	0.0	0.3		345.4	2.4	22.8	0.7	0.1		0.0	0.1	371.8
	Perennial	0.1	0.3		6.6	61.2	32.6	3.1	0.4	0.0	0.0	0.1	104.3
Grassland	High producing	8.7	49.4		1.9	4.5	5,718.3	2.1	21.8	0.1	0.0	0.2	5,807.0
	Low producing	25.5	35.3		0.0	0.1	0.1	7,432.1	44.6	0.3		0.5	7,538.4
	With woody biomass	4.3	5.5		0.1	0.1	14.3	61.9	1,266.2	0.3	0.0	1.3	1,353.9
Wetlands	Wetlands	0.0	0.0		0.025	0.0	0.4	1.4	0.2	676.6	0.0	0.0	678.7
Settlements	Settlements	0.3	0.5		0.5	0.8	13.5	1.9	0.7	0.0	206.1	0.1	224.4
Other land	Other land	0.208	0.512		0.0	0.0	0.662	0.393	0.455	0.2	0.0	891.7	894.2
Area as at 1 Jan 1990 (kha)		7,898.2	1,530.5	-	354.7	69.2	5,912.7	7,891.2	1,486.4	677.8	206.1	898.2	26,925.1
Net change 1 Jan 1990–31 Dec 2012		–57.4	–73.4	654.4	17.0	35.1	–105.7	–352.8	–132.4	0.9	18.2	–4.0	-
Net change 1990–2012 (%)		–0.7	–4.8	N/A	4.8	50.7	–1.8	–4.5	–8.9	0.1	8.9	–0.4	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 greater than 100 hectares during the period. Land-use change areas do not include deforestation of post-1989 forest since 1990 (20,591 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 2012 and 1 January for 1990). Columns and rows may not total due to rounding.

Table 7.2.7 New Zealand's land-use change matrix from 2011 to 2012

2012 \ 2011		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2012 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	7,840.9											7,840.9
	Pre-1990 planted		1,457.1				0.0	0.0	0.0				1,457.2
	Post-1989			641.8	0.0	0.0	1.8	7.6	3.1	0.0		0.0	654.4
Cropland	Annual				371.6	0.2	0.0	0.0	0.0				371.8
	Perennial				0.1	103.7	0.4	0.1	0.0				104.3
Grassland	High producing	0.0	0.3	0.0	0.0	0.2	5,805.8	0.0	0.6	0.0		0.0	5,807.0
	Low producing	0.8	5.1	0.5		0.0	0.0	7,529.4	2.5	0.0		0.0	7,538.4
	With woody biomass			0.0	0.0	0.0	0.2	0.9	1,352.8	0.0		0.0	1,353.9
Wetlands	Wetlands			0.0	0.0	0.0	0.0	0.0	0.0	678.7	0.0	0.0	678.7
Settlements	Settlements		0.0		0.0	0.0	0.1	0.0	0.0		224.3	0.0	224.4
Other land	Other land	0.0				0.0	0.0	0.0	0.0	0.0		894.1	894.2
Net area as at 31 Dec 2011 (kha)		7,841.7	1,462.5	642.4	371.7	104.1	5,808.4	7,538.2	1,359.0	678.7	224.3	894.1	26,925.1
Net change 31 Dec 2011 – 31 Dec 2012		–0.8	–5.3	12.0	0.1	0.2	–1.4	0.2	–5.1	0.0	0.2	0.0	0.0
Net change 2011–2012 (%)		0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	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 (20,591 ha), 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 2012.) Columns and rows may not total due to rounding.

7.2.4 Methodological change

The 2012 land-use map was created using a similar methodology to the earlier 1990 and 2008 land-use maps. The process for detecting change in satellite imagery between 2008 and 2012 used an enhanced multi-date segmentation approach described in Shepherd et al (2013).

Previous submissions included a range of approaches to annual deforestation mapping. 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.

Following completion of the 2012 land-use map using 10-metre resolution SPOT satellite imagery, deforestation mapping for 2008 to 2011 was updated. The method used to map deforestation between 2008 and 2012 built on techniques developed for earlier deforestation mapping projects. The improved resolution of the SPOT satellite imagery, when compared with the last national coverage of DMC 22-metre resolution data, allowed more deforestation to be identified in 2008 and 2009. It has also completed the coverage of 2010 deforestation mapping, which had only partial coverage of New Zealand, and provided mapping for 2011 and 2012.

The introduction of a third mapping date has added complexity to the interpolation process that is used to derive annual land-use change estimates. Previous submissions were based on interpolations between the activity data derived from the 1990 and 2008 mapping, and an extrapolation for the reporting years after 2007. Now that activity data from the 2012 land-use map is available, a second interpolation process is used to derive annual land-use change estimates for the years 2008 to 2012.

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 2012 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 with 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 has been used to improve the accuracy of areas mapped as grassland with 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 Quality assurance/quality control (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, 2008 and 2012 land-use mapping data has been checked to determine the level of consistency in satellite image classification with the requirements set out in *Land Use and*

Carbon Analysis System: Satellite imagery interpretation guide for land-use classes (Ministry for the Environment, 2012b).

The quality-control checks performed on the 1990 and 2008 land-use maps included checking approximately 28,000 randomly selected points in the 1990 and 2008 woody classes. These were evaluated by independent assessors. In 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 was used to plan improvements to the 1990 and 2008 land-use maps. These improvements have now been completed.

Two distinct quality-control checks were performed on the 2012 land-use map. The first of these checked every polygon where land-use change had occurred from a non-forest land use between 2008 and 2012. The acceptance criterion for this check was that the land-use classification had to be correct at both mapping dates at least 90 per cent of the time. The second quality-control check was to check the accuracy of destock detection in areas that were in a forest land-use at 2008. Sampling for this check was designed to test that at least 90 per cent of the destocking had been detected at the 95 per cent confidence level. Checks were completed on each of the 16 regions of New Zealand individually and all regions passed. A total of 14,443 points were checked during this process.

These quality-control checks do not determine errors of omission and/or commission that would provide an accuracy assessment and definitive level of uncertainty.[38] An accuracy assessment is planned for mid-2014.

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.

As part of the 2012 land-use mapping process, data from the NZ ETS was reconciled with the 1990, 2008 and 2012 land-use maps. 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 land-use maps. Where mapping differences were identified, these areas were assessed against satellite imagery and the LUCAS forest land-use definitions to determine whether the 1990, 2008 and/or 2012 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 2008–2012 deforestation mapping activity was a multi-stage process. The contractor undertook initial quality assurance by cross-checking operator interpretation of oblique aerial photography acquired from light aircraft (figure 7.2.5). All areas of mapped deforestation were then 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).

[38] 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.

7.2.7 Planned improvements

The NZ ETS provides an ongoing source of mapping information on forest extent and age along with limited information on deforestation activity. This will be used as part of a continuous improvement programme to update the 1990, 2008 and 2012 land-use maps.

The land-use maps will also be improved by cross-checking the mapping against a new land cover map of New Zealand which has been independently created from the same 2008 SPOT satellite imagery used to map the 2008 land-use map. Land Cover Database 3 (LCDB3) will be compared with the LUCAS 2008 land-use map to identify class inconsistencies, establish which map is incorrect, and complete corrections as required.

LCDB3 will also provide useful forest-type information which could be used to provide a mapped sub-classification of pre-1990 natural and planted forest. Research into methods to achieve this will be undertaken in 2014.

7.3 Soils

In this submission, New Zealand uses a tier 2 method to estimate soil carbon changes in mineral soils and follows the tier 1 approach for organic soils.

7.3.1 Mineral soils

New Zealand's tier 2 method for mineral soils involves estimating steady state soil organic carbon (SOC) stocks for each land use based on New Zealand soil data (described in more detail below) and calculating changes in soil carbon stocks associated with land-use change according to the IPCC default method (IPCC, 2003) using the equation:

$$\Delta C = [(SOC_0 - SOC_{(0\text{-}T)})/20] * A \qquad (3)$$

Where:

ΔC = change in carbon stocks (tonnes (t))

SOC_0= Stable SOC stock in the inventory year (tonnes C ha^{-1})

$SOC_{(0\text{-}T)}$= Stable SOC stock T years prior to the inventory year (tonnes C ha^{-1})

A = land area of parcels with these SOC terms (hectare)

20 = default SOC stock transition period (year)

The SOC stock for each land use is characterised with country-specific data via the Soil Carbon Monitoring System (Soil CMS) model **(**McNeill et al, 2013, 2014**)**. The correct operation of the Soil CMS model involves fitting the model to the soil carbon dataset and then using the coefficients for the different land-use classes for each land-use transition (equation 3). The interpretation of the different land-use effects is informed by multi-comparison significance.

Characterising SOC stocks: New Zealand's Soil Carbon Monitoring System

Unbiased estimates of SOC stocks associated with each land use in New Zealand are calculated by using country-specific data in the Soil CMS model. The operation of the Soil CMS model to produce SOC pool estimates involves applying a linear statistical model to key factors of land use, climate, and soil class, which together regulate net SOC storage. The model also includes an additional environmental factor consisting of the product of slope and rainfall (hereafter, slope × rainfall) – a term used as a proxy for erosivity, the potential for surface soil erosion to occur (Giltrap et al, 2001).

The key concept in the operation of the Soil CMS model is the premise that land use affects SOC on decadal time scales (Baisden et al, 2006b), and so estimates must be reported grouped by specified land-use classes. The model allows for an explanatory effect by land-use class, so that estimates grouped by land use are unbiased where a specific land-use class has an effect significantly different from the pooled soil carbon value from all land-use classes. In addition, where some land-use classes have such an effect, incorporating land use as an explanatory variable reduces the overall residual standard error in soil carbon (McNeill et al, 2014).

Soil C linear parametric model

The general least squares (GLS) model used for the Soil CMS is a minimum variance unbiased estimator (Draper and Smith, 1998) so the soil C values, and the soil C changes as a result of a land-use transition, are unbiased if the coefficients are used in this manner. This approach is consistent with the physically based soil C model outlined in the literature (Baisden et al, 2006b; Kirschbaum et al, 2009; Scott et al, 2002; Tate et al, 2005).

The GLS regression model for soil C in the 0–30cm layer uses explanatory variables of the soil–climate factor, the land-use class, and slope × rainfall. This model is represented as an equation for the soil carbon $C_{i,j}^{0-30cm}$ in land use class i and soil-climate class j as

$$C_{i,j}^{0-30cm} = M + L_i + S_j + b.SR + \varepsilon \quad (4)$$

In equation (4), $C_{i,j}^{0-30cm}$ is the mean soil carbon in the 0–30-centimetre layer for the combination of the reference level of land use (low-producing grassland), the reference level for soil–climate (moist temperate – high activity clay), and level ground. L_i is the effect of the *i*-th land use, specifying the difference in soil carbon relative to the reference land use (low-producing grassland), in tonnes per hectare (t/ha). S_j is the effect of the *j*-th soil–climate class relative to the reference level, and b is the additional soil carbon for each unit of erosivity (slope × rainfall), or SR (millidegree $\times\ 10^{-1}$). The model uncertainty is encapsulated in ε.

The quantities M, L_i, S_j, as well as the slope × rainfall coefficient b, are obtained by fitting a statistical model to the Soil CMS calibration dataset; all other quantities are obtained from other datasets or from separate analyses (McNeill et al, 2013). For example, the mean value of the slope × rainfall must be obtained from national statistics of rainfall and a terrain slope map, which has been calculated from geographic information system (GIS) layers (Giltrap et al, 2001).

Soil data sets

Soil data for the Soil CMS inventory model comes from four sources.

Historic Soils: The Historic Soils dataset is derived primarily from the National Soils Database (NSD), with a small number of samples from various supplementary datasets; data were collected between 1935 and 2005. The NSD represents soil profile data for over 1,500 soil pits scattered throughout New Zealand. These data contain the soil description following either the *Soil Survey Method* (Taylor and Pohlen, 1962) or *Soil Description Handbook* (Milne et al, 1995), as well as physical and chemical analyses from either the Landcare Research Environmental Chemistry Laboratory or the Department of Scientific and Industrial Research (DSIR) Soil Bureau Laboratory. This dataset was collated as the first stocktake of available soil data for national greenhouse gas reporting and, as such, underwent substantial quality-assurance and quality-control checks (Baisden et al, 2006b; Scott et al, 2002; Tate et al, 2005).

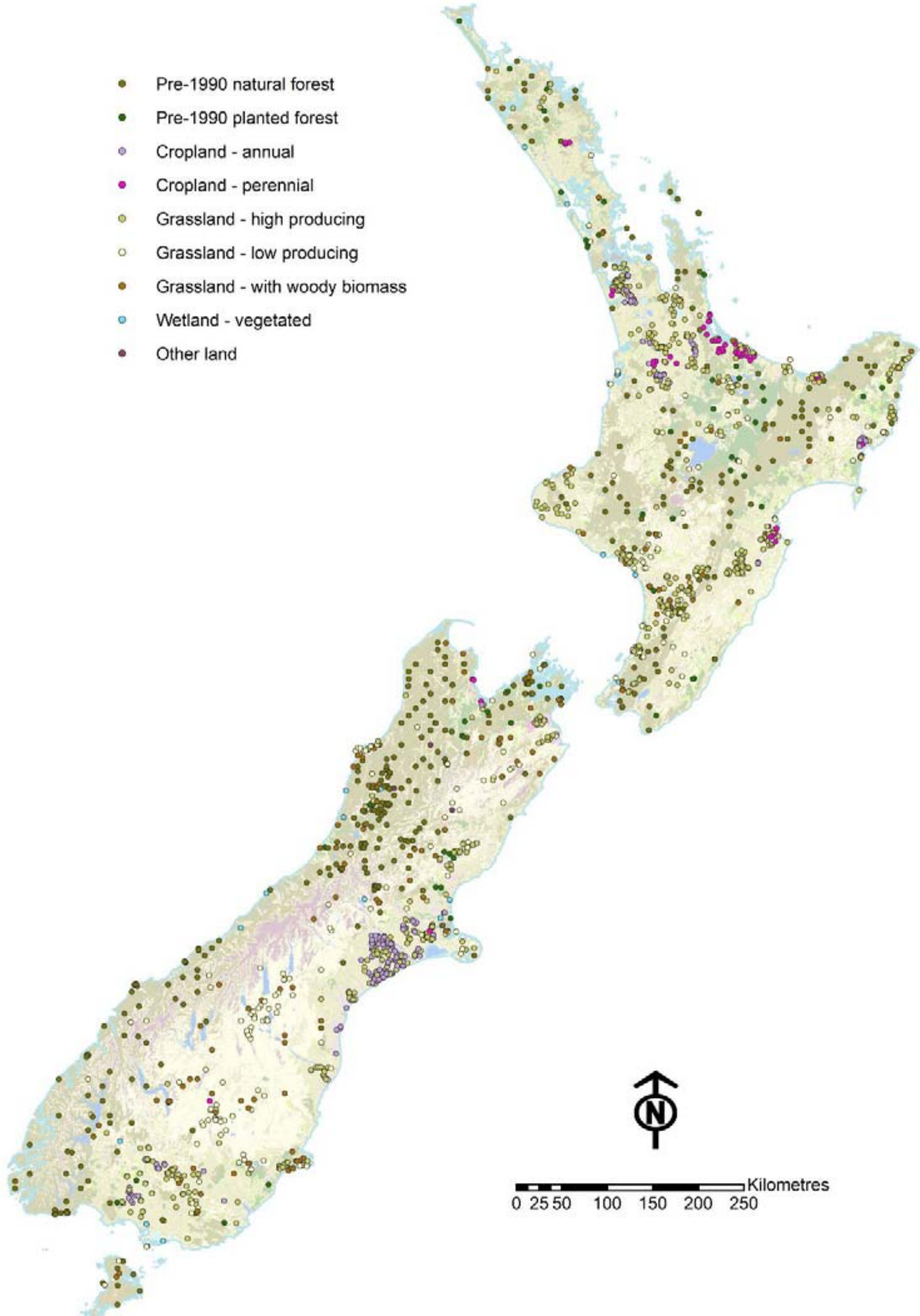
Natural Forest Soils: These data were gathered between 2001 and 2007 as part of the Natural Forest Survey, with soil subsampled on a regular 8-kilometre grid across the country (Garrett, 2009). The Natural Forest Soils were important in the development of the Soil CMS model as they provide spatial balancing in areas of New Zealand not adequately covered by the historic soils dataset.

Cropland dataset: The third source of data originated as a set of intensively spatially-sampled high-producing grassland, annual cropland, and perennial cropland records collected for other purposes, referred to as the Cropland dataset (Lawrence-Smith et al, 2010).

Wetland: The fourth source of data comprises wetland soil data from a recent research effort to combine field data with analysis of the spatial distribution of current wetlands in New Zealand (Ausseil et al, 2013). This resulted in the addition of 21 wetland mineral soil samples to the Soil CMS dataset (McNeill et al, 2014).

Together, the four combined datasets cover most of New Zealand (figure 7.3.1), including Stewart Island, although coverage does not extend to the Chatham Islands and other offshore islands.

Figure 7.3.1 Soil samples in Soil CMS model calibration dataset



Due to reliance on available data, coverage is dense in areas of agricultural activity, and the density of points varies widely between different regions (figure 7.3.1). In addition, types of land use vary geographically: some are widespread (eg, high-producing grassland), whereas others are spatially constrained (eg, cropland), so that the number of soil samples needed varies according to land-use category (McNeill et al, 2013).

There is a wide variation in the number of records associated with the different land-use classes and soil orders, with the largest land use (high-producing grassland) having 783 samples and the smallest (other land) only three samples. Thus, it would be reasonable to expect that there will also be considerable variability in the uncertainty of the estimated land-use effect for each of the different land-use classes, assuming all other things are equal.

Two of the twelve land-use categories were not used in the model due to lack of soil carbon data: open water (assumed 0, by definition) and settlements (assumed to be the same as the low-producing grassland as no data was available for this land use category).

Currently, a SOC estimate for post-1989 forests is not specifically calculated in the model; the pre-1990 planted forest SOC figure serves as a substitute. Since the Soil CMS model was built on the IPCC default assumption that SOC stocks in various land-use classes reach steady state after 20 years (IPCC, 2003), soil data from newly planted forests that had not yet reached steady state were not appropriate to include in the Soil CMS data set. Note that a post-1989 forest soil data collection programme is being implemented during 2013/2014 so that post-1989 forest soil carbon can be characterised directly in the model for the next submission.

Ancillary data

S-map: S-map is a contemporary digital soil spatial information system for New Zealand (Lilburne et al, 2012), which provides the best-available knowledge of the classification of the soil order consistent with the *New Zealand Soil Classification* (Hewitt, 1998). S-map coverage is not available for all the land area, as its focus is on regions of intensive agricultural use.

Fundamental Soils Layer: Where S-map was unavailable, data from the Fundamental Soils Layer (FSL) was used instead. FSL provides GIS information on the classification of soil order and other soil or landscape attributes over New Zealand. It is generated from the NZLRI and NSD. FSL provides GIS information of the expert-assessed classification of soil order and other soil or landscape attributes over New Zealand.

Topographic information: Topographic slope information was estimated from a digital elevation model generated from Land Information New Zealand 1:50,000 scale topographic data layers, including 20-metre contours, spot heights, lake shorelines and coastline (McNeill et al, 2013).

2013 Soil CMS model

Land-use effects: characterising soil carbon stocks

The 2013 version of the Soil CMS model used in this report builds on previous model versions. There has been additional statistical development work, which incorporates new data for previously under-represented land-use categories, and further investigates significant land-use transitions with robust statistical techniques (McNeill et al, 2013).

The ‘land-use effect’ (LUE) denotes the influence of land use on soil carbon stocks, and corresponds to the model coefficients calculated for each land-use category. The land-use effect for a transition from low-producing grassland to one of the other land-use classes can be obtained by using the coefficients of the soil C model (table 7.3.1). SOC stocks for each land use are derived from the land-use effect coefficient in relation to the intercept (the reference of low-producing grassland on high activity soils in a moist temperate climate (table 7.3.1)). These values are used in equation (3) (as SOC_0 and $SOC_{(0-T)}$) to calculate soil carbon changes due to land-use change.

Table 7.3.1 Land-use effect coefficients with standard errors, *t*-values, and corresponding *p*-value significance estimates, extracted from full model results

Subcategory	Value	Standard error	*t*-value	*P*-value
Intercept: Grassland – low producing	133.1	11.1	12.0	0.000
Grassland – high producing	–0.216	3.16	–0.068	0.946
Grassland – with woody biomass	–7.72	3.74	–2.06	0.039
Cropland – perennial	–19.5	6.31	–3.08	0.002
Cropland – annual	–15.1	4.52	–3.3	0.001
Wetlands – vegetated	38.9	9.02	4.3	0.000
Pre-1990 planted forest	–17.7	5.67	–3.1	0.002
Natural forest	–13.9	3.74	–3.7	0.000
Other land	–39.4	21.5	–1.8	0.067

Source: McNeill et al, 2013.

Note: The grassland – low producing estimate is also used for settlements; the pre-1990 planted forest estimate is also used for post-1989 forest.

Table 7.3.2 Soil organic carbon stocks, with 95 per cent confidence intervals, calculated from Soil CMS model (v. 2013)

Subcategory	Steady state carbon SOC stock (t)	95% confidence intervals (CI) 2.5% CI SOC stock (t)	97.5% CI SOC stock (t)
Natural forest	119.22	111.92	126.56
Pre-1990 planted forest	115.46	104.32	126.58
Post-1989 forest	115.46	104.32	126.58
Grassland – with woody biomass	125.41	118.12	132.73
Grassland – high producing	132.91	126.70	139.11
Grassland – low producing	133.12	111.00	155.00
Cropland – perennial	113.67	101.32	126.03
Cropland – annual	118.01	109.12	126.87
Wetlands – open water	0.00	NA	NA
Wetlands – vegetative non-forest	172.06	154.42	189.72
Settlements	133.12	111.00	155.00
Other land	93.71	51.52	135.93

Note: NA = not applicable.

The residual standard error (RSE) for the model is 42.1 t/ha, and the corrected Akaike information criterion value (AICc) is 20,519.7. The spatial autocorrelation scale distance is 19.3 kilometres, with a nugget of 0.46. A correction for spatial correlation is necessary as the samples are located close to one another rather than evenly spread throughout New Zealand (as land use is not even throughout New Zealand). These are values consistent with earlier analyses (McNeill et al, 2009; McNeill, 2010, 2012). The use of the AICc as a model selection and comparison mechanism is widely supported in the literature in general, and soil modelling specifically (Burnham and Anderson, 2002; Elsgaard et al, 2012; Ogle et al, 2007).

Measures of statistical validity: Assessing significant differences among SOC stocks

As noted in the model results, all but one of the main land-use effect coefficients are significant (table 7.3.1). The land-use effect of high-producing grassland has not been detected as significantly different from the reference low-producing grassland. The land-use effect for the other land category may be considered marginal, as it also does not reach the standard threshold level of statistical significance (p-value < 0.05).

The uncertainty of the land-use effect (the change in soil C assuming the transition is stable) between two land-use classes in isolation is conceptually straightforward: two estimates of land-use effect are more likely to be significantly separated if their point estimates are farther apart after taking account of the covariance between the two land-use effects. The standard error $\sigma_{i,j}$ of the LUE change for a transition between two land-use classes with effects L_i and L_j is then estimated from:

$$\sigma_{i,j} = \sqrt{Var\ (L_i) + Var\ (L_j) - 2. Cov\ (L, L_j)} \qquad (5)$$

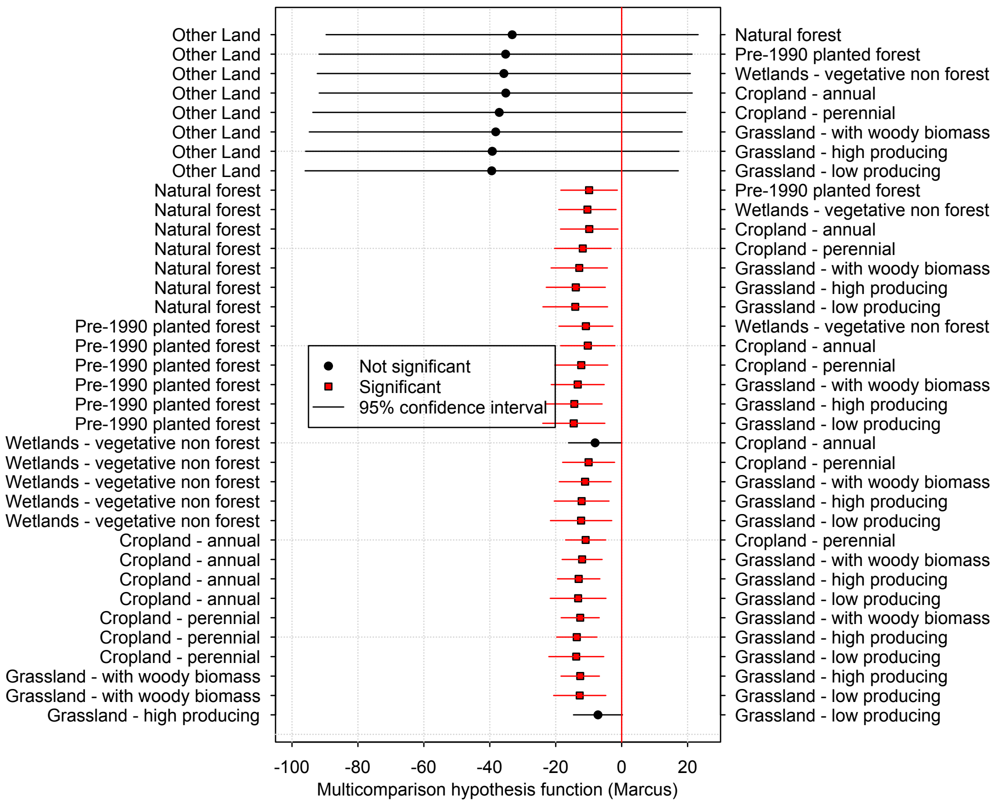
where $Var(L_i)$ is the variance of land-use effect i, and $Cov(L_i, L_j)$ is the covariance between land-use effects L_i and L_j (McNeill et al, 2013, 2014).

Although equation (5) provides a mathematically straightforward way to estimate the significance of a single transition from one land-use class to another (a comparison-wise significance), it is often desirableto be able to determine whether a number of land-use classes are likely to be significantly different or essentially the same as an ensemble. As more comparisons are made between many different land-use types, it becomes more and more likely that at least one of the land-use effect changes will appear to be different as a result of random chance alone, resulting in an increase in the Type 1 error. Thus, the significance of all possible land-use transitions must be calculated as a family of simultaneous comparisons (multiple comparison significance), rather than calculated one at a time (McNeill et al, 2014).

In order to control the Type 1 error rate in multiple comparison significance testing for the soil C change model, the simultaneous testing of all possible combinations of the land-use classes for equality (a two-sided test) is required, where the number of cases in each category is markedly different. For the Soil CMS model (v. 2013) (McNeill et al, 2014), a closed testing procedure test described by Marcus et al (1976) was used, which is a general method for performing a number of hypothesis tests simultaneously implemented in the multi-comparison package in R (Bretz et al, 2010).

The closed testing procedure described by Marcus et al (1976) yielded point estimates and confidence intervals of a test statistic for each distinct combination of land-use transitions, and the critical test is whether the confidence intervals brace zero. All land-use transition pairs were significant, except those noted earlier: the high-producing grassland to/from low-producing grassland pair; transitions involving other land (figure 7.3.2); a third, but not occurring, transition was also non-significant: vegetated wetland to/from annual cropland.

Figure 7.3.2 Result of applying Marcus' multi-comparison test to the adopted model



Note: The marker is the estimated value for the specified transition to indicate significance, and the error bars represent the 95 per cent confidence interval of the test statistic. Land-use transitions with point estimates and confidence intervals marked in red are considered highly significant differences within the set of all possible land-use transitions.

These land-use transition pairs contribute relatively little to land-use induced carbon change calculations. The transitions involving high-producing grassland to/from low-producing grassland comprise approximately 0.2 per cent of all land-use change detected between 1990 and 2012. All land-use transitions involving other land make up approximately 0.9 per cent of all land-use change detected between 1990 and 2012, but it should be noted that this category is used both to classify marginal land and to allow mapped areas to reconcile with national area, so carbon pools would not need to be assessed for the category except for checking for overall consistency (IPCC, 2003). The third non-significant land-use transition, between vegetated wetland and annual cropland, did not occur between 1990 and 2012. Note this would be expected from an ecological and land management perspective as well as statistically. Given the quite different carbon stocks of these two categories and the distribution of the dataset, it is likely the lack of significance is an artefact.

It is important to note that this interpretation of significance does not alter the method of calculation of the soil C change as a result of land-use transition. In particular, it would not be correct to substitute a value of zero for the effect of a land-use transition where the transition itself is not significant in the multi-comparison sense, since if such a substitution were to be carried out, the calculation of the soil C would no longer be unbiased. Avoiding the bias in this manner also reduces the residual uncertainty of the soil C estimates. For this reason, the effect of all land-use transitions ought to be included in calculations of soil C change (McNeill et al, 2014).

7.3.2 Organic soils

Organic soils occupy a 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 centimetres 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 are based on the temperature data layer of the Land Environments New Zealand (LENZ) classification (Leathwick et al, 2002). Soil-type data are 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 climatic zones. These areas are compared with the land use to determine the area of organic soils in each land-use category.

The LULUCF organic soils definition is the same as that used for reporting under the Agriculture sector (Dresser et al, 2011).

New Zealand has used IPCC default emission factors for organic soils under forest land, grassland and cropland (IPCC, 2003) to estimate organic soil emissions (table 7.3.3). 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 7.3.3 New Zealand emission factors for organic soils

Land use	Climatic temperature regime	IPCC tier 1 default emission factor applied and 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.

7.3.3 Uncertainties and time-series consistency

Mineral soils

For the most part, uncertainties associated with the model coefficients (table 7.3.2) are substantially reduced from the tier 1 default value of 95 per cent. Those land-use categories with higher uncertainties are those with few data points, such as other land, or are dominant land uses in the country, thus occurring across a wide range of environmental factors, such as high-producing grassland.

Uncertainties also arise from lack of soil carbon data for some soil, climate and land-use combinations (Scott et al, 2002), and from variations in site selection, sample collection and laboratory analysis with data from different sources and time periods (Baisden et al, 2006b). Other uncertainties in the Soil CMS include: the assumption that soil carbon reaches steady state in all land uses and the 20-year linear transition period to reach it; lack of soil carbon data and soil carbon changes estimates below 0.3 metres; potential carbon losses from mass-movement erosion; and a possible interaction between land use and the soil–climate classification (Tate et al, 2004, 2005).

Organic soils

New Zealand uses the IPCC tier 1 default value for uncertainty of organic soils under forest, grassland and cropland as given in IPCC (2003, tables 3.3.5 and 3.4.6). This value is 90 per cent.

Further detail on uncertainty for each land-use category is discussed in the appropriate category sections.

The same method is used for all years of reporting to ensure time-series consistency.

7.3.4 Source-specific QA/QC and verification

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, to be consistent with GPG-LULUCF and New Zealand's inventory quality-control and quality-assurance plan.

- Details of the quality-management system for data collection, laboratory analyses and database management of the National Soils Database are given in Wilde (2003).
- Recent data collection, analyses and management methods are subject to the soils quality-control and quality-assurance plan.
- The consolidated soils dataset used within the Soil CMS has been subject to further quality-assurance procedures (Fraser et al, 2009).

The Soil CMS model has been subject to various forms of testing, validation and recalibration (Baisden et al, 2006b; McNeill et al, 2009; McNeill, 2010, 2012; Scott et al, 2002; Tate et al, 2005).

Testing of the Soil CMS was completed to evaluate its ability to predict soil carbon stocks at regional and local scales. The results from the Soil CMS have been compared against independent, stratified soil sampling for South Island low-producing grassland (Scott et al, 2002) and for an area of the South Island containing a range of land-cover and soil-climate categories (Tate et al, 2003a, 2003b). A regional-scale validation exercise has also been performed using the largest climate–soil–land-use combination cell (moist temperate – volcanic × high-producing grassland), within dependent random sampling of 12 profiles taken on a fixed grid over a large area (2,000 square kilometres). Mean values derived from the random sampling were well within the 95 per cent confidence limits of the database values (Tate et al, 2005; Wilde et al, 2004). A second study validated the Soil CMS model for a different cell, dry temperate – high-activity clay – low-producing grassland, finding no significant differences among field data, calibration data, and model estimates (Hedley et al, 2012). Overall, tests have indicated that the Soil CMS estimates soil carbon stocks reasonably well at a range of scales (Tate et al, 2005).

The system has also been validated for its ability to predict soil carbon changes between land uses at steady state for New Zealand's main land-use change, grassland converted to planted forest. This was done by comparing the Soil CMS results with estimates based on paired sites (Baisden et al, 2006a; Tate et al, 2003b). This validation approach compares two nearby sites that have reasonably uniform morphological properties and were previously under a single land use, for which one site has changed to a different land use and sufficient time has elapsed for it to reach steady state values for soil carbon (Baisden et al, 2006a, 2006b). This removes the influence that differing soil types, climatic conditions and previous land-use regimes may have on soil carbon, and any resulting changes in soil carbon can be attributed to the most recent change in land use. In one study, results indicated that, once a weighting for forest species type was applied to the paired-site dataset (to remove potential bias as *Pinus radiata* was under-represented in the analysis), the predictions of mean soil carbon from the Soil CMS model and paired sites were in agreement within 95 per cent confidence intervals (Baisden et al, 2006a, 2006b). In a more recent study comparing low-producing grassland and pre-1990 planted forests (Hewitt et al, 2012), the measured decrease in SOC under pre-1990 planted forest (–17.4 t ha^{-1}) matched that determined by the Soil CMS model (table 7.3.1) (McNeill et al, 2013). This supported the Soil CMS model estimate (both in magnitude and direction) that forests planted pre-1990 have significantly lower soil carbon stocks than the low-producing grassland and that the sampling depth of 0.3 metres was adequate for the estimation of soil carbon stock change.

7.3.5 Source-specific planned improvements

New Zealand continues to pursue increasing the accuracy and reducing the uncertainty of the soil carbon stock estimates produced by the Soil CMS model. Improvement activities include data collection for under-represented land-use categories (eg, post-1989 planted forests during the 2013/2014 field season), further recalibration and development of the Soil CMS model, and investigation of other modelling options.

7.4 Forest land (CRF 5A)

7.4.1 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 as they are not on land managed as forest. 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. In 2012, forests covered 37 per cent (just under 10 million hectares) of New Zealand's total land area. In 2012, forest land contributed –33,149.9 Gg CO_2-e of net emissions. This value includes removals from the growth of pre-1990 forests and post-1989 forests, and emissions from the conversion of land to forest, harvesting and fire. Net emissions from forest land have increased by 5,988.5 Gg CO_2-e (15.3 per cent) on the 1990 level of –39,138.4 Gg CO_2-e (table 7.4.1).

In 2012, forest land remaining forest land and conversion to forest land were key categories (trend and level assessment).

Table 7.4.1 New Zealand's land-use change for the forest land category, and associated CO_2-equivalent emissions, in 1990 and 2012

Forest land land-use category	Net area in 1990 (ha)	Net area in 2012 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2-e)		Change from 1990 (%)
				1990	2012	
Forest land remaining forest land	8,577,872	9,096,314	+6.0	–21,093.8	–7,944.0	–62.3
Land converted to forest land	863,746	856,066	–0.9	–18,044.6	–25,206.0	+39.7
Total	**9,441,618**	**9,952,380**	**+5.4**	**–39,138.4**	**–33,149.9**	**–15.3**

Note: 1990 and 2012 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 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 for forest land, New Zealand uses three forest land subcategories: pre-1990 natural forest (predominantly native forest, labelled natural forest within CRF Reporter, see table 7.1.3 for mapping between the NIR and CRF tables), pre-1990 planted forest (predominantly *Pinus radiata*) and post-1989 forest (natural and planted forests established after 31 December 1989). The definitions used for mapping these land-use subcategories are given in table 7.2.2.

Table 7.4.2 shows land-use change by forest subcategory since 1990 and the associated CO_2 emissions from carbon stock change only (excludes emissions from liming and non-carbon emissions).

Table 7.4.2 New Zealand's land-use change for the forest land subcategories, and associated CO_2 emissions from carbon stock change, in 1990 to 2012

Forest land land-use category	Net area in 1990 (ha)	Net area in 2012 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2 only) 1990	2012	Change from 1990 (%)
Pre-1990 natural forest	7,895,436	7,840,853	–0.7	–16,162.9	–19,028.2	+17.7
Pre-1990 planted forest	1,531,540	1,457,173	–4.9	–23,087.9	+1,963.4	–108.5
Post-1989 forest	14,641	654,354	+4,369.2	96.7	–19,028.2	–19,784.0
Total	**9,441,618**	**9,952,380**	**+5.4**	**–39,154.1**	**–36,092.9**	**–7.8**

Note: 1990 and 2012 areas are as at 31 December. Net area values include land in a state of conversion to forest (due to land-use change prior to 1990) and afforestation since 1990. Net emission estimates are for the whole year indicated. Columns may not total due to rounding. Emissions associated with the conversion of forest to other land uses are reported in the land-use category the land is converted to.

Table 7.4.3 shows New Zealand's carbon stock change by carbon pool within the forest land category from 1990 to 2012. From 1990 to 2012, the total carbon stock stored in forest land had increased by 231,999.0 Gg C, equivalent to emissions of –850,662.9 Gg CO_2 since 1990.

Table 7.4.3 New Zealand's net carbon stock change by carbon pool for the forest land category from 1990 to 2012

Forest land subcategory	Net carbon stock change 1990–2012 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2012 (Gg CO_2)
Pre-1990 natural forest	76,845.1	19,267.0	–146.8	95,965.2	–351,872.6
Pre-1990 planted forest	64,781.8	16,824.6	–6,154.0	75,452.4	–276,658.7
Post-1989 forest	58,824.6	9,757.1	–8,000.4	60,581.3	–222,131.6
Total	**200,451.5**	**45,848.7**	**–14,301.2**	**231,999.0**	**–850,662.9**

Note: Emissions associated with the conversion of forest are reported in the land-use category the land is converted to. Columns may not total due to rounding.

Pre-1990 natural forest

Pre-1990 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. Pre-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 7.9 million hectares of pre-1990 natural forest (including these successional communities).

Pre-1990 planted forest

New Zealand has a substantial estate of planted forests created specifically for timber-supply purposes. In 2012, pre-1990 planted forests covered an estimated 1.46 million hectares of New Zealand (5.4 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 pre-1990 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

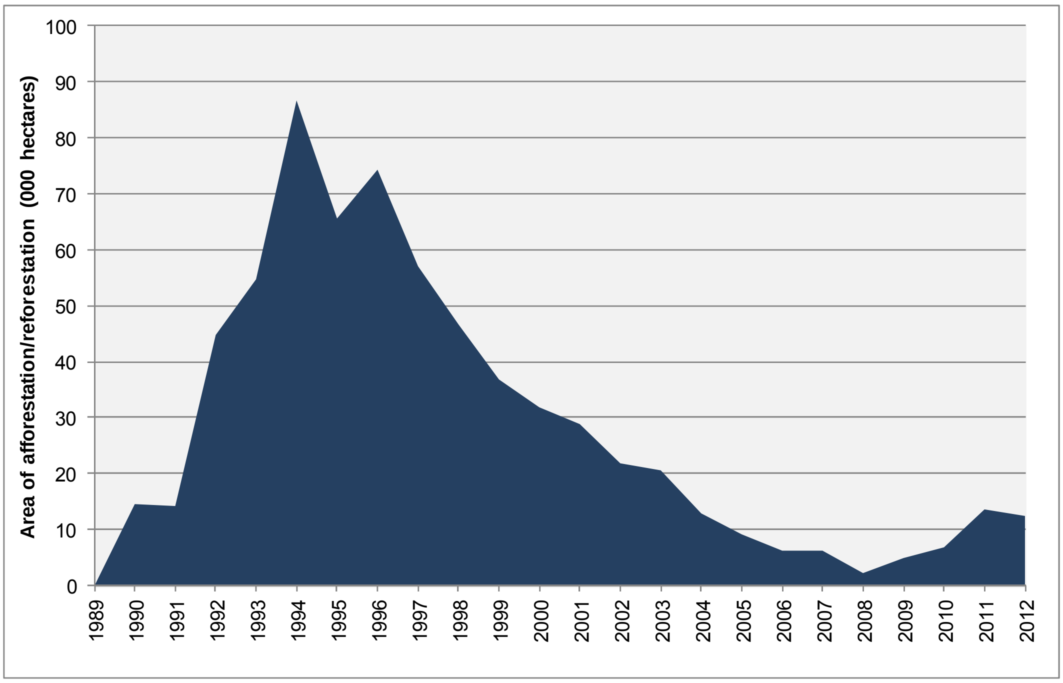
Between 1 January 1990 and 31 December 2012, the net area of forest established as a result of reforestation activities was 654,354 hectares (taking into account deforestation of post-1989 forests). It is estimated that 93 per cent of this forest subcategory is planted forest, with the remaining area comprising natural forest. *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 for Primary Industries, 2013a).

The new forest planting rate (land reforested) between 1990 and 2012 was, on average, 29,000 hectares per year (figure 7.4.1). 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. 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 2012, the Ministry for Primary Industries provisionally estimated that 11,000 hectares of new plantation forest were established (Ministry for Primary Industries, 2013a). This compares with 6,000 hectares of new planting in 2010 (Ministry of Agriculture and Forestry, 2012) and 12,000 hectares in 2011 (Ministry of Agriculture and Forestry, 2012). The increase in planting between 2008 and 2012 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 ecosystems (Ministry of Agriculture and Forestry, 2009).

There are differences in the area defined and reported as planted forest for Convention on Climate Change reporting and the area captured by the *National Exotic Forest Description* (Ministry for Primary Industries, 2013a) from which the new planting 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* reports to a net stocked area standard. To account for these area differences, the net productive forest area has been identified and modelled separately. An unstocked area component is added to the new planting statistic between 2008 and 2012 to maintain consistency with the mapped area used prior to 2008. This ensures the planted forest areas used for Convention on Climate Change reporting are consistent with those reported by the Ministry for Primary Industries and time-series consistency is maintained for Convention on Climate Change reporting. The individual emission factors for the productive and unstocked areas are derived from appropriate plots in the national plot network as described below in section 7.4.2.

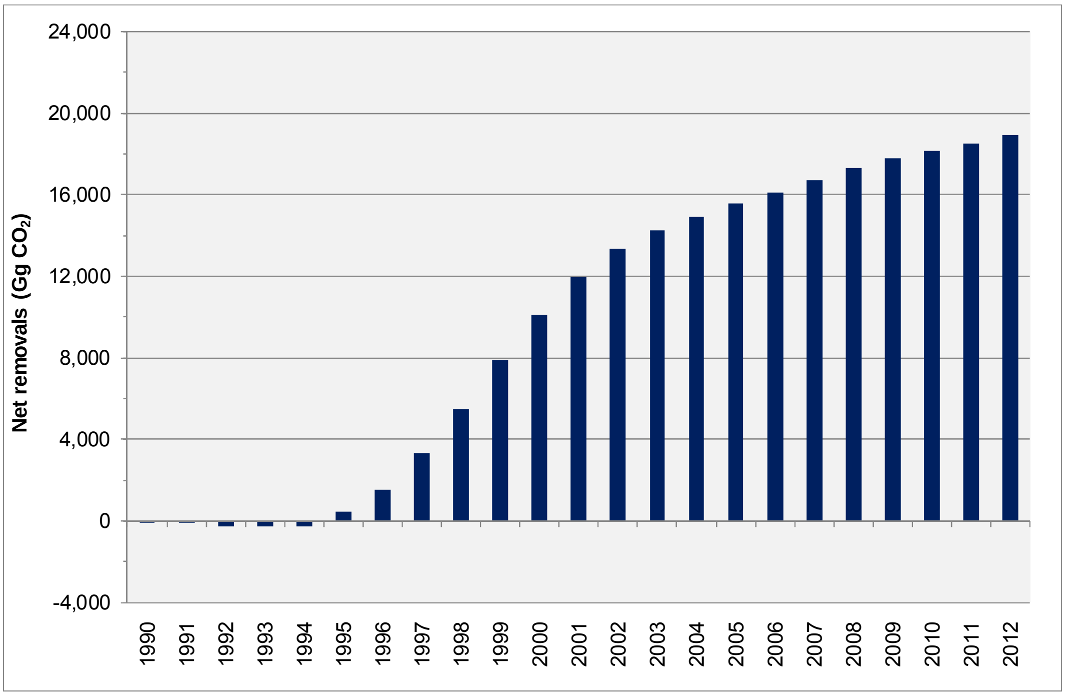
Figure 7.4.1 Annual areas of afforestation/reforestation in New Zealand from 1990 to 2012



Note: Annual planting estimates are derived from annual surveys of forest nurseries, as published in the *National Exotic Forest Description* (Ministry for Primary Industries, 2013a) and have been scaled 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 7.4.2). 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 7.4.2 New Zealand's net carbon dioxide removals by post-1989 forests from 1990 to 2012



Deforestation

In 2012, an estimated 6,762 hectares of forest land were converted to other land uses, primarily grassland. Table 7.4.4 shows the areas of forest land subject to deforestation in 2012 and since 1990. The land uses that forest land has been converted to following deforestation are shown in tables 7.2.6 and 7.2.7.

Table 7.4.4 New Zealand's forest land subject to deforestation

Forest land subcategory	Area of forest in 1990 (hectares)	Deforestation since 1990		Deforestation in 2012	
		Area (hectares)	Proportion of 1990 area (%)	Area (hectares)	Proportion of 1990 area (%)
Pre-1990 natural forest	7,898,244	39,098	0.50	811	0.01
Pre-1990 planted forest	1,530,549	91,855	6.00	5,384	0.35
Post-1989 forest	0	20,591	NA	567	NA
Total	**9,428,792**	**151,544**	**1.61**	**6,762**	**0.07**

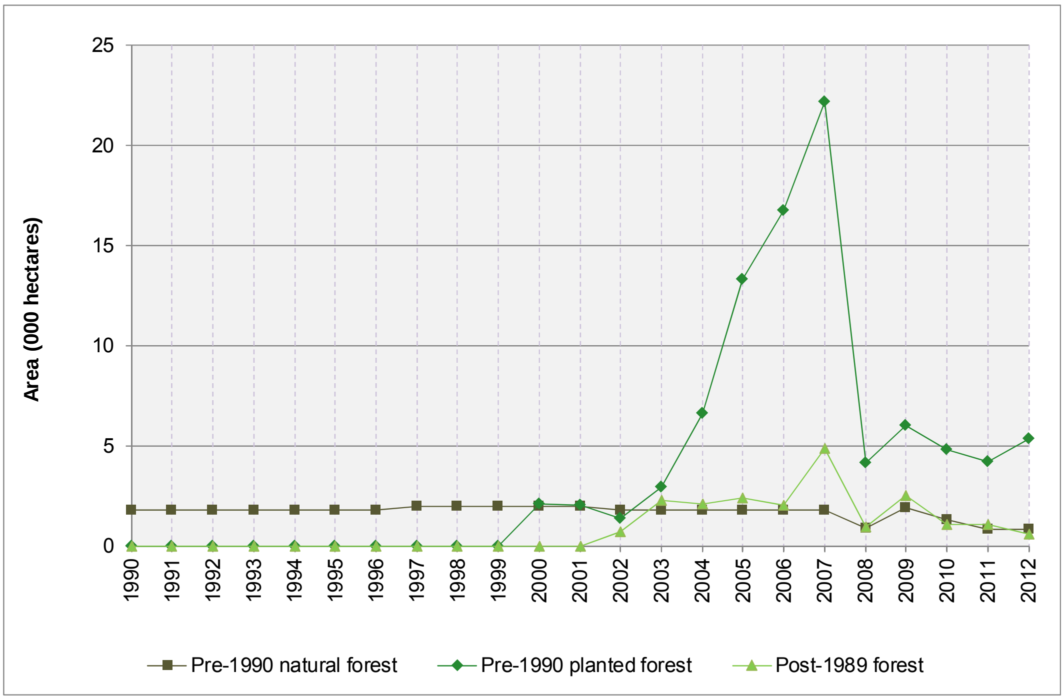
Note: NA = not applicable. 2012 areas are as at 31 December 2012; 1990 areas are as at 1 January 1990 and, therefore, differ from 1990 area values in the common reporting format tables, which are as at 31 December 1990. Columns may not total due to rounding.

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 7.4.3 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 first Kyoto Protocol commitment period (2008–2012), it was expected that the level of 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. The low carbon price has reduced the liability on forest owners for deforestation. Consequently more deforestation has occurred since 2008 than previously expected.

Figure 7.4.3 New Zealand's area of deforestation since 1990, by forest subcategory



The rate of pre-1990 natural forest deforestation has decreased since 2007. A number of factors suggest that the rate of pre-1990 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 pre-1990 natural forest deforestation since 2002.

As there is no data on the deforestation profile for pre-1990 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 pre-1990 natural forest deforestation has been confirmed from 2008 to 2012 through satellite image mapping of deforestation (see figure 7.2.5).

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 grassland, leading to the rapid removal of all biomass as the land is prepared for farming.
- It is not practical to estimate the emission of residues following the deforestation activity, given the rapid conversion from one land use to another and multiple methods of deposing of residues. Further estimating residue biomass and decay rates for multiple deposal methods is difficult and costly.
- However, estimates of biomass burning emissions associated with deforestation are provided for the first time in this submission (see section 7.10.5).

Soil carbon changes associated with deforestation are modelled over a 20-year period using a linear decay profile (section 7.3).

These deforestation emissions are reported in the relevant ‘land converted to’ category, as are all emissions from land-use change. See sections 7.2.2 and 11.1 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 for Primary Industries, 2013a). Roundwood statistics (Ministry for Primary Industries, 2013b) 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 2011) and where published area data are not yet available (as in 2012). 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, 2011 and 2012 from the volume of roundwood removals reported.

There are differences in the area defined and reported as planted forest for 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. To account for these area differences, the net planted forest area for Convention on Climate Change reporting has been identified and modelled separately. This ensures the harvesting data used for Convention on Climate Change reporting are consistent with those reported by the Ministry for Primary Industries.

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. For the 2012 inventory, post-1989 forest harvesting is estimated from the harvested area mapped between 2008 and 2012.

In 2012, it is estimated that 0.05 per cent of New Zealand's total forest timber production was from the harvesting of natural forests (Ministry for Primary Industries, 2013b).

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.

Any harvesting that occurs in natural forests is captured within the natural forest carbon stock and stock change estimates.

7.4.2 Methodological issues

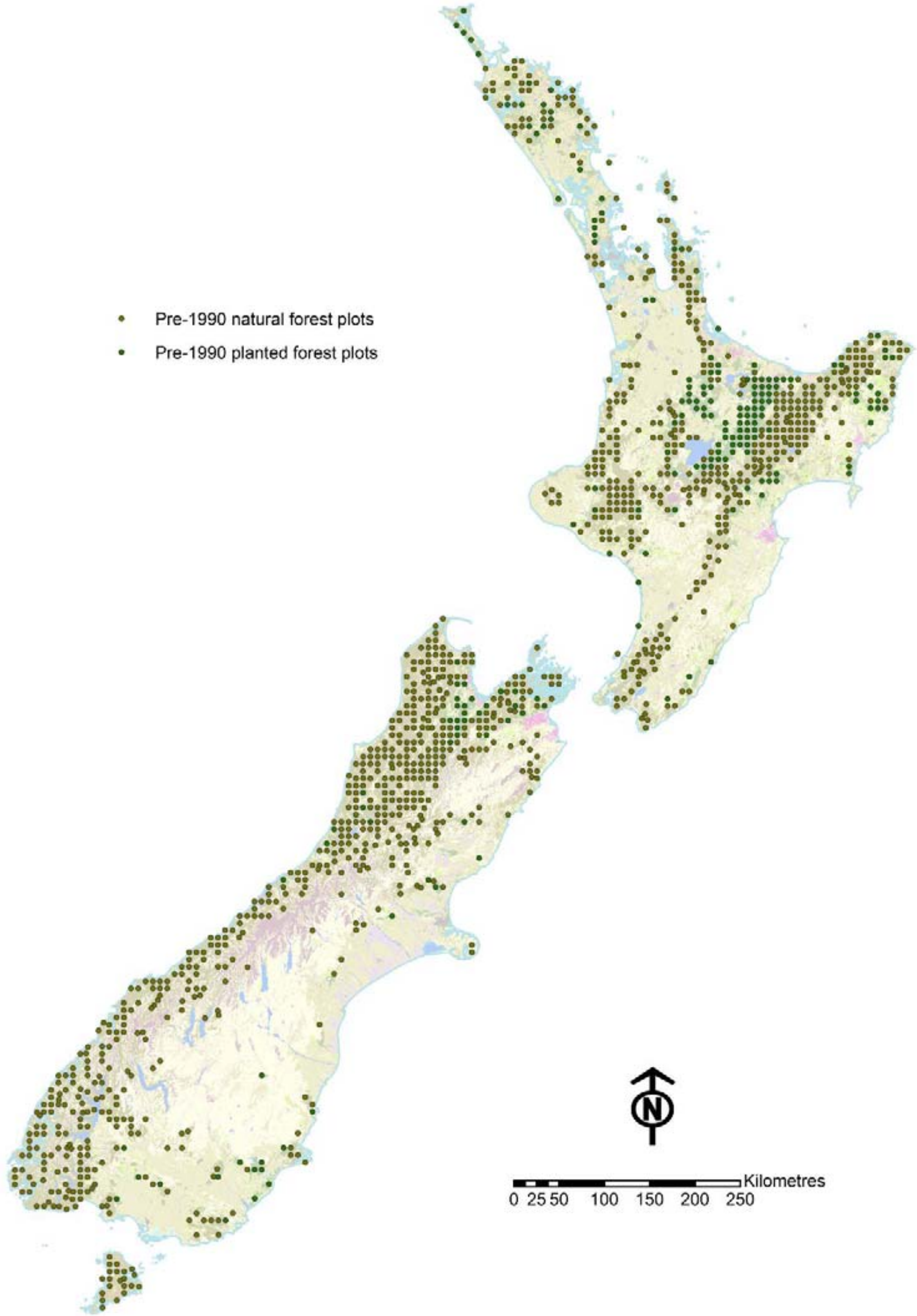
Forest land remaining forest land

Only pre-1990 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 22 years in 2012 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 planted forest, the associated carbon changes are reported under forest land remaining forest land.

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 radiata pine forests are harvested (Ministry for Primary Industries, 2013a).

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 pre-1990 planted forest. Figure 7.4.4 shows the distribution of the pre-1990 natural and planted forest carbon monitoring plots throughout New Zealand.

Figure 7.4.4 Location of New Zealand's pre-1990 forest carbon monitoring plots



Pre-1990 natural forest

A national monitoring programme designed 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). One thousand, two hundred and fifty-six permanent sample plots of 0.04 ha were installed systematically on the 8-kilometre grid across New Zealand's natural forests (see figure 7.4.4) 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 et al, 2004a).

Re-measurement of the national plot network is under way. The re-measurement programme will run until 2014 following methodology revised for this purpose (Ministry for the Environment, 2013a). The re-measurement provides repeat measures data suitable for calculating carbon stock change in natural forest.

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 7.4.5 summarises the method used to calculate the carbon stock in each biomass pool from the information collected at each plot.

Table 7.4.5 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	Holdaway et al, 2013a
	Below-ground biomass	Estimated at 20 per cent of total biomass	Coomes et al, 2002
Dead organic matter	Dead wood	Plot measurements; Allometric equations	Holdaway et al, 2013a
	Litter	Plot samples; Laboratory analysis of samples collected at plots	Holdaway et al, 2013a; Garrett, 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).

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.

Carbon stock change

Re-measurement of the plot network is near completion, with one data collection season remaining. There is sufficient data collected to date to estimate carbon stock change in natural forest. Analysis of the re-measurement and original data sets indicates that pre-1990 natural forest is a slight sink of carbon. Carbon stock change in natural forest is calculated as the difference in carbon stock at time 2 minus time 1. This is calculated for each plot and the mean change across all plots is used as the national average (Holdaway et al, 2013a)

Previous analysis undertaken using historic plots that were incorporated into the national network also indicates New Zealand's natural forests are a sink of carbon. 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).

The re-measurement of the national plot network will be completed in 2014. At this point the data will be re-analysed to include data collected in the final year of the plot re-measurement. While it is not expected that results will change appreciably with this additional data, the re-analysis will give greater confidence that the change in carbon stock is representative of the entire area of natural forest.

Soil organic carbon

Mineral soil organic carbon stocks in natural forest land remaining natural forest land are estimated using a tier 2 method. The steady state mineral soil carbon stock in natural forest is estimated to be 119.22 tonnes C ha^{-1} (table 7.3.2).

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.

Non-CO_2 emissions for pre-1990 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 soil emissions.

Pre-1990 planted forest

All planted forest land established prior to 1990, whether established for wood production or ecosystem services, is included in the pre-1990 planted forest subcategory. This subcategory also includes areas that were natural forest in 1990 but have since been planted with exotic forest. The emissions associated with this area are calculated as the removal of biomass associated with pre-1990 natural forest and the subsequent growth of pre-1990 planted forest. The pre-1990 planted forest yield table best represents the growth on ex-natural forest land because it remains in the forest land category. It has been demonstrated in the development of the post-1989 forest yield table that forests planted onto grassland are more productive than those planted on to forest land (Paul et al, 2013).

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 (Beets et al, 2012a). The pre-1990 planted forest inventory is closely linked, in terms of design and methodology, with the post-1989 planted forest inventory described later in this section.

For the pre-1990 planted forest inventory, 192 circular 0.06 hectare plots (see figure 7.4.4) 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 global positioning system (GPS) for accurate LiDAR co-location and relocation for future measurements (Beets et al, 2012a).

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). LiDAR data from pre-1990 planted forests are not included in this submission but it is expected to be incorporated at a later date to improve the precision of the estimates.

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, the Forest Carbon Predictor, version 4.1 (Beets and Kimberley, 2011), that was developed for the two most common plantation tree species in New Zealand. To enable predictions of carbon stocks and changes in New Zealand's planted forests, this system integrates:

- the 300 Index growth model (Kimberley and Dean, 2006) for Pinus radiata
- the 500 Index growth model for Douglas-fir (Knowles, 2005)
- a wood density model (Beets et al, 2007)
- a stand tending model (Beets and Kimberley, 2011)
- the C_Change carbon allocation model (Beets et al, 1999).

The individual components of the Forest Carbon Predictor are explained below.

The 300 Index and 500 Index growth models produce a productivity index for forest plots derived from stand parameters. These stand parameters include: stand age, mean top height, basal area, stocking and stand silvicultural history. Plot latitude and altitude are also required to run the models. The growth models use these parameters to predict stem volume under bark over a full rotation (planting to harvest). A specific productivity index is produced for each plot, which is then used to estimate the total live and dead stem volume by annual increment. The growth models account 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 (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 combined result of these individual effects can be large, as shown in table 7.4.6 (Beets et al, 2007).

Table 7.4.6 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})	(% 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

The stand tending model: New Zealand's plantation forests are intensively managed and therefore pruning and thinning provide 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 Forest Carbon Predictor 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.

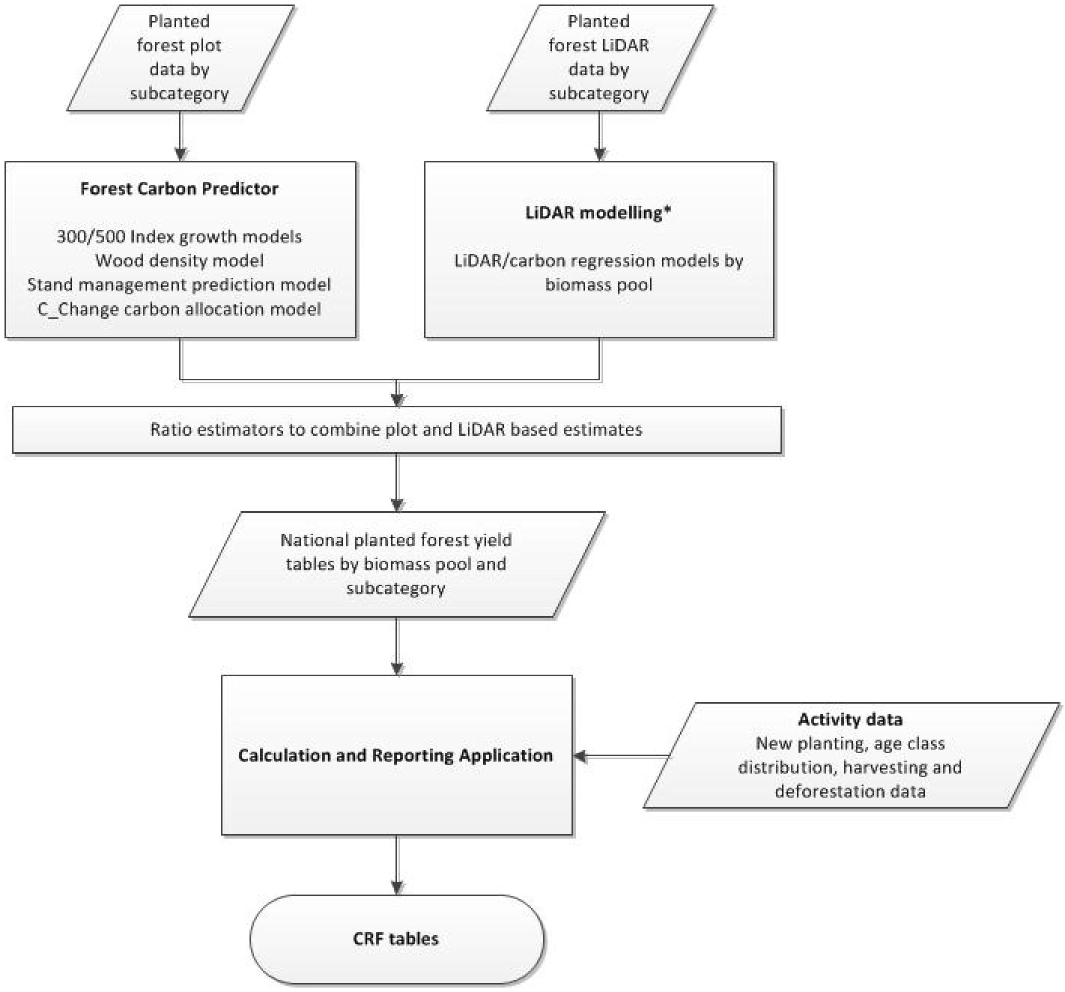
The C_Change carbon allocation model is integrated into the Forest Carbon Predictor and is designed to apportion carbon to needles, branches, stems, roots and reproductive parts via growth partitioning functions. Dead wood and litter pools are estimated by accounting for losses to the live pools from 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.

The individual plot yield curves generated by the Forest Carbon Predictor are combined into estimates of above-ground live biomass, below-ground live biomass, dead wood and litter in an area-weighted and age-based carbon yield table for the productive area of each planted forest subcategory. Plots that are located outside the productive area within the mapped forest boundary are used to provide emission factors for unstocked areas in the post-1989 and pre-1990 planted forest categories (Paul et al, 2013).

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, 1999). 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 Forest Carbon Predictor model as described above. Immediately following harvesting, 30 per cent of the above-ground biomass pool is transferred to the dead wood pool; the other 70 per cent is instantaneously emitted. All material in the dead wood and litter pools is decayed using an empirically derived, temperature-dependent decay profile as described in Garrett et al (2010).

Figure 7.4.5 New Zealand's planted forest inventory modelling process



Note: *LiDAR used only in post-1989 planted forests for this submission.

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, 2012a).

The carbon stock in pre-1990 planted forest as at 31 December 2012, estimated directly from the national plot network, is 154.95 ± 15.72 tonnes C ha^{-1} (at the 95 per cent confidence interval).

Soil organic carbon

Soil carbon stocks in pre-1990 planted forest land remaining pre-1990 planted forest land are estimated using a tier 2 method for mineral soils and a tier 1 method for organic soils (section 7.3). The steady state mineral soil carbon stock in pre-1990 planted forest is estimated to be 115.46 tonnes C ha^{-1} (table 7.3.2).

The IPCC default emission factor for organic soils under planted forest is 0.68 tonnes C ha^{-1} per annum (table 7.3.3). 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.

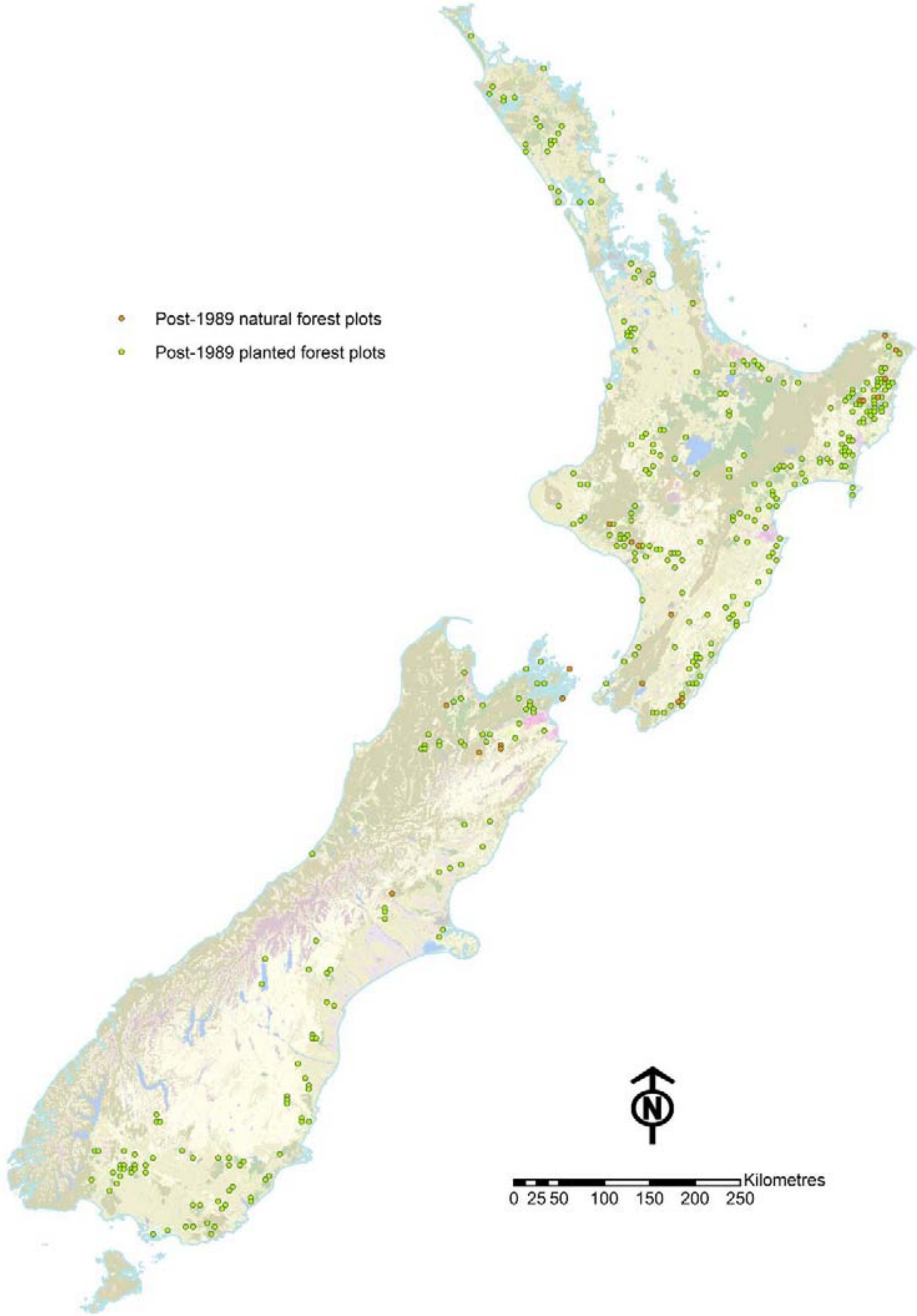
Land converted to forest land

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. The post-1989 forest subcategory is split into two divisions for calculating emissions and removals: post-1989 natural forest and post-1989 planted forest. Reporting is at the aggregate level of post-1989 forest for this submission.

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 2012, approximately 23 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 forest.

New Zealand's post-1989 forests have been sampled on a systematic 4-kilometre grid-based plot network consistent with that used for all forest subcategories, as shown in figure 7.4.6. Sampling includes both post-1989 planted forests and post-1989 natural forest and the method is described below.

Figure 7.4.6 Location of New Zealand's post-1989 forest plots



Post-1989 planted forests

All forest land planted since 1 January 1990, whether established for wood production or soil control purposes, is included in the post-1989 planted forest subcategory.

Living biomass and dead organic matter

A plot-based forest inventory system has been developed for carbon estimation in New Zealand's post-1989 planted forest and is described in detail in Beets et al (2011b). The majority of post-1989 forests in New Zealand are privately owned and access could not be guaranteed at the beginning of the inventory. Initially a double-sampling approach involving LiDAR was employed to reduce the possibility of sampling bias arising from unmeasured plots (Stephens et al, 2012). In practice, access to privately owned forests was generally unrestricted so LiDAR was then used to improve the precision of the carbon stock estimates using a ratio estimator procedure (Paul et al, 2013).

In the post-1989 planted forest inventory, circular 0.06 hectares of permanent sample plots have been established within forests on a systematic 4-kilometre grid coincident with that used for the pre-1990 natural forest and pre-1990 planted forest inventories (Moore and Goulding, 2005). Permanent sample plots were selected over temporary sample plots because change over time is more easily analysed when there are multiple measurements of the same plot set (Beets et al, 2011b).

The initial post-1989 planted forest inventory was carried out during the winters of 2007 and 2008 with 246 plots ground sampled using methodology as described in Payton et al (2008). A second inventory was carried out during the winters of 2011 and 2012 where the earlier established plots were re-measured and additional plots were established. In total, 342 plots were ground measured from the mapped area of post-1989 planted forest in the second inventory. Importantly, the additional plots in the later inventory addressed a bias in the earlier estimates caused by incomplete sampling of the forest area. This was due to the initial field inventory beginning prior to the completion of the 2008 land-use map.

The ground measurements in the post-1989 planted forest inventory include: 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, 2011b). Silvicultural information, including tree age, stocking (stems per hectare) and timing of pruning and thinning activities, was gathered from forest owners and estimated by field teams on site. Ground plot centres were located using a 12-channel differential GPS for sub-meter LiDAR co-location and for relocation in future inventories (Beets et al, 2011b).

LiDAR data was captured for 25 plots in addition to those that were ground measured in the mapped post-1989 planted forest area (Paul et al, 2013). 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.

Stock change in the productive area of post-1989 planted forests is estimated using a subcategory-specific national yield table approach similar to that described above under 'Living biomass and dead organic matter' within pre-1990 planted forest. Plots that are located outside the productive area within the mapped forest boundary are used to provide emission factors for unstocked area of post-1989 planted forests (Paul et al, 2013).

Specific to post-1989 planted forest are plot measurements at two points in time and the use of LiDAR data in the 2012 estimates. To utilise both plot measurements, a single yield table per plot was developed using:

- the earlier measurement for ages below the first measurement age
- the later measurement for ages above the later measurement age
- an interpolated estimate for the ages between the earlier and later measurements.

For plots that were measured once, a ratio estimator derived from the plots that were twice measured was applied to the earlier ages in the yield tables. A LiDAR-based yield table was developed using a regression model developed for predicting 2008–2012 carbon sequestration from LiDAR metrics. A ratio estimator derived from LiDAR sequestration and the plots that were twice measured was developed and applied to the LiDAR-based yield table. Individual yield tables were combined as weighted means in a national yield table for the productive area of post-1989 planted forest (Paul et al, 2013).

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 years. 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 when pruning and thinning cease 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.

The carbon stock estimate for the productive area of post-1989 planted forest is 135.4 ± 6.6 tonnes C ha^{-1} (at the 95 per cent confidence interval) as at 31 December 2012 (Paul et al, 2013). This carbon stock estimate, while high, is consistent with the international comparisons provided in table 3A.1.4 (IPCC, 2003) and reflects that the composition of this forest subcategory is made up of fast-growing and actively managed production forestry.

Post-1989 natural forests

Post-1989 natural forest is forest land established since 1 January 1990 resulting from direct human-induced changes in land-management practice. For example, because people have removed grazing stock and actively facilitated the regeneration of tree species, the land use has changed from grassland to forest land. The resulting forest is comprised of a mix of native and introduced species, especially in early successional stages. As this forest matures, it generally becomes increasingly dominated by native species and in most cases will become native forest. Forest carbon stocks and stock change in post-1989 natural forest are reported for the first time in 2012.

Estimates of carbon stock and stock change in post-1989 natural forest are calculated based on measurements taken in a field inventory. The inventory samples post-1989 natural forest using permanent sample plots on a systematic 4-kilometre grid (consistent with the post-1989 planted forest inventory). Plots in post-1989 natural forest were established and measured for the first time in 2012. The plot network design is described in Beets et al (2012a), and detailed methods for plot measurement are given in the data collection manual (Ministry for the Environment, 2012a).

Living biomass and dead organic matter

At permanent sample plots within post-1989 natural forest, measurements are taken of standing and fallen, live and dead plants. Destructive biomass samples taken outside of the plots are used to create plot-specific allometric equations which are applied to these measurements to calculate above-ground live biomass.

Biomass of standing dead wood (woody debris with a diameter greater than 10 centimetres) and litter (woody debris with a diameter of less than 10 centimetres) is calculated as for living biomass, but is then adjusted for decay using decay functions. Biomass of fallen dead wood is calculated from plot measurements of volume in combination with species-specific wood densities and then also adjusted for decay in the same way.

Biomass sampling on post-1989 natural forest plots includes the determination of plant age, which enables the backcasting of biomass through time. Backcast estimates of biomass are used to calculate carbon stock change. The method used to do this was developed and validated using plots for which multiple measurements in time had been obtained and for which carbon stock change was able to be measured directly (Beets et al, 2012b). Full methods for the calculation of carbon stock and stock change in post-1989 natural forest are described in Beets et al (2013).

The carbon stock estimate for post-1989 natural forest is 26.92 ± 7.05 tonnes C ha^{-1} (at the 95 per cent confidence interval) as at 31 December 2012 (Beets et al, 2013). The average rate of carbon sequestration in post-1989 natural forest over the first Commitment Period is 2.2 tonnes C ha^{-1} yr^{-1} (Beets et al, 2013). This rate is similar to previously reported rates of carbon sequestration in regenerating shrubland in New Zealand (Carswell et al, 2012; Trotter et al, 2005).

Soil organic carbon

Soil carbon stocks in land converted to post-1989 forest are estimated using a tier 2 method for mineral soils and a tier 1 method for organic soils, as described in section 7.3. The steady state mineral soil carbon stock in post-1989 forest is estimated to be 115.46 tonnes C ha^{-1} (table 7.3.2).

In the absence of country- and land-use specific data on the 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 133.12 tonnes C ha^{-1}) to planted forest (soil carbon stock 115.46 tonnes C ha^{-1}) would be a loss of 17.66 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 (table 7.3.3). This is also applied to organic soils on land converted to post-1989 forest.

Quality assurance and quality control

Quality-assurance and quality-control activities were conducted throughout the post-1989 planted forest data capture and processing steps. These activities were associated with the following: inventory design (Brack, 2009; Moore and Goulding, 2005); 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 along with those undertaken within the post-1989 natural forest are described in more detail in section 7.4.4.

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.

7.4.3 Uncertainties and time-series consistency

Emissions from forest land are 15.5 per cent of New Zealand's net emissions uncertainty in 2012 (annex 7). Forest land introduces 6.0 per cent uncertainty into the trend in the national total from 1990 to 2012.

Pre-1990 natural forest

The uncertainty in mapping pre-1990 natural forest is ± 4 per cent (table 7.4.7). Further details are given in section 7.2.5.

The pre-1990 natural forest plot network provides biomass carbon stock estimates that are within 95 per cent confidence intervals of 7.87 per cent of the mean (253.14 ± 19.92) for tall natural forest and 14.48 per cent of the mean (84.88 ± 12.29 tonnes C ha^{-1}) in regenerating natural forest (Holdaway et al, 2013a). Estimates of carbon stock change are within 95 per cent confidence intervals of 87.5 per cent of the mean (+0.56± 0.49). Further details are given in Holdaway et al (2013a).

Table 7.4.7 Uncertainty in New Zealand's 2012 estimates from pre-1990 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	9.0
Uncertainty in biomass carbon change	87.5
Uncertainty in soil carbon stocks	6.1
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**44.3**

Note: NO = not occurring. A Monte Carlo simulation approach is used to assess uncertainty in carbon stock and carbon stock change in pre-1990 natural forest. Pre-1990 natural forest was found to be a statistically significant sink of carbon, sequestering 0.56 (95% CI 0.07–1.05) tonnes C $ha^{-1}yr^{-1}$ (Holdaway et al, 2013b). However the variation between individual plot estimates of change and the relatively low sequestration in old growth forest results in an uncertainty of 87.5 per cent for change in the category. Land area includes land in transition in 2012. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equations 5.2.1 and 5.2.2 from GPG-LULUCF (IPCC, 2003).

Pre-1990 planted forest

A national plot-based inventory system in conjunction with a suite of models is used to estimate carbon stock and change within New Zealand's planted forest. The inventory and modelling system is described and published in Beets et al (2012a). The models are collectively called the Forest Carbon Predictor version 4.1 (Beets and Kimberley, 2011) and are described in further detail in section 7.4.2 under 'Living biomass and dead organic matter' for pre-1990 planted forest. 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.

A paper has been published on the validation of the Forest Carbon Predictor model (Beets et al, 2011a) used to produce carbon yield tables for the LULUCF sector. For the plots in this study, they found that estimates of total carbon stock per plot made using the Forest Carbon Predictor were within 5 per cent of measured values. When just above-ground biomass per plot was considered, accuracy was within 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).

New Zealand's pre-1990 planted forests were sampled in 2010 and the analysis of the data collected has provided an unbiased plot-based estimate of carbon stock and change 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 for Primary Industries, 2013a). The uncertainty of the pre-1990 planted forest biomass estimate at the 95 per cent confidence interval is 12.4 per cent.

The uncertainty in the estimates of pre-1990 planted forest for the 2014 submission is provided in table 7.4.8.

Table 7.4.8 Uncertainty in New Zealand's 2012 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	12.4
Uncertainty in soil carbon stocks	9.6
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**30.3**

Note: The biomass uncertainties are low for pre-1990 planted forest (12.4 per cent). However, the total uncertainty for the subcategory is calculated on the net change. The age structure of the estate in 2012 results in high removals from growth and high emissions from harvesting, leaving a relatively small net change. Therefore uncertainty is high in this subcategory. Land area includes land in transition in 2012. Lime application to pre-1990 planted forest does not occur (NO) in New Zealand. The activity data and combined emission 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

As described in section 7.4.2, post-1989 forest is split into post-1989 natural and post-1989 planted forest. The modelling process for post-1989 planted forest is similar 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 (2011a) and New Zealand's inventory approach is described in Beets et al (2011b).

New Zealand's post-1989 planted forests were first sampled in 2007 and 2008, and were re-measured in 2011 and 2012. The inventory provides a plot-based estimate of carbon stock within this forest subcategory. LiDAR and ground-based measurements have been employed to reduce the possibility of sampling bias arising from unmeasured plots due to access restrictions. The uncertainty of the post-1989 planted forest biomass estimate at the 95 per cent confidence interval is 8.6 per cent.

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 additional plots were measured in 2011 and 2012. The inclusion of these plots in the analysis has provided an unbiased and representative sample of post-1989 planted and natural forests. The re-measurement data and the additional plot data have been introduced for the first time in this submission.

The inventory of post-1989 natural forest provides estimates of carbon stock that are within 26.2 per cent of the mean at the 95 per cent confidence level as at 2012.

Table 7.4.9 Uncertainty in New Zealand's 2012 estimates from post-1989 forest (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	6.0
Emission factors	
Uncertainty in biomass carbon stocks	8.5
Uncertainty in soil carbon stocks	9.6
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**5.6**

Note: Land area includes land in transition in 2012. The biomass carbon stocks value is the weighted value for post-1989 natural and post-1989 planted forests. Lime application to post-1989 forest does not occur (NO) in New Zealand. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF (IPCC, 2003).

7.4.4 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.

Pre-1990 natural forest

Quality control and assurance are undertaken at the data collection, data entry and data analysis stages for 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, 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 randomly selected plots, and the assessment of measurements against data quality standards as described in Ministry for the Environment (2013a). Data entry of all data is subject to quality assurance by the Ministry for the Environment for 10 per cent of plots. The data is also subject to further checking for measurement and data entry errors prior to analysis (Holdaway et al, 2013b).

Pre-1990 planted forest and post-1989 planted 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 quality control had to be re-measured (Beets et al, 2011b, 2012a). 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 Scion'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 (2011a).

Quality-assurance and quality-control procedures for LiDAR data 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, which 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, 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).

The carbon stock estimate for the productive area of post-1989 planted forest has also been verified by comparing it with table 3A.1.6 (IPCC, 2003). The New Zealand estimate is 135.4 ± 6.6 tonnes C ha^{-1} (at the 95 per cent confidence interval) as at 31 December 2012 (Paul et al, 2013). This carbon stock estimate (135.4 ± 6.6 tonnes C ha^{-1}), while high, is consistent with the international comparisons provided in table 3A.1.6 (IPCC, 2003) and reflects that this forest subcategory is made up of fast-growing and actively managed production forestry.

Post-1989 natural forest

As for pre-1990 natural forest, quality control and assurance are undertaken at the data collection, entry and analysis stages for post-1989 natural forest.

During field data collection, 10 per cent of plots were subject to an independent field audit. The audit involved randomly selected sites being re-measured by an audit field team, and the assessment of differences between inventory and audit measurements against set data quality standards as set out in Ministry for the Environment (2012a). Audit results are described in Beets and Holt (2013). Further checks for data entry and measurement were also undertaken prior to data analysis stage as described in Beets et al (2013).

7.4.5 Category-specific recalculations

In this submission, New Zealand has recalculated its emission 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 emission estimates for the forest land category is provided in table 7.4.10. 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 7.4.10 Recalculations of New Zealand's estimates for the forest land category in 1990 and 2011

Net emissions (Gg CO2-e)	2013 submission	2014 submission	Change from the 2013 submission	% change
1990	–27,717.3	–39,138.4	–11,421.1	+41.2
2011	–17,741.2	–35,518.5	–17,777.3	+100.2
Area (hectares)				
1990	9,652,056	9,441,618	–210,438	–2.2
2011	10,152,478	9,946,566	–205,912	–2.0

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

Carbon stock change in pre-1990 natural forest is reported for the first time in this submission. In previous submissions New Zealand has reported carbon stock change being as at steady state, until sufficient data was available to determine whether this was the case. The re-measurement of the plot network is now almost complete and we have sufficient data to calculate carbon stock change. Analysis of the re-measurement data shows that pre-1990 natural forest is a sink of carbon.

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 and new planting in planted forests is obtained from a national survey of forest owners (Ministry for Primary Industries, 2013a). The survey respondents report areas as net stocked area rather than gross stocked area as reported in the inventory. To account for these area differences, the net planted forest area in the inventory has been identified and modelled separately in this submission. This ensures the harvesting and new planting data used in the inventory is consistent with that reported by the Ministry for Primary Industries.

Removal of land-use area threshold for calculating emissions

Previously New Zealand did not report on land-use change where the total area of change between categories was less than 100 hectares between 1990 and 2007. This constraint has now been removed from the calculation process which has resulted in an increase in the area of change to and from forest.

Emission factors

Pre-1990 natural forest carbon stock and stock change

There is now sufficient data collected in the re-measurement of the pre-1990 natural forest plot network to calculate carbon stock change. In this submission, New Zealand reports carbon stock change in pre-1990 natural forest for the first time. Carbon in pre-1990 natural forest was previously reported as being in a steady state.

The estimate of carbon stock in pre-1990 natural forest is also updated. This is due to a number of improvements to the source data. The current stock estimate is based on the more recent re-measurement data as opposed to data collected during the first round of measurement during 2002–2007. Improvements to the mapped area of pre-1990 natural forest have resulted in some plots that are now not within the area mapped as pre-1990 natural forest being excluded from analysis, as they are no longer representative of it. Extensive data checking has also been undertaken. A number of data validations that are possible when using re-measurement plot data are not possible with data from a single measurement. Data checks undertaken prior to data analysis are described in Holdaway et al (2013a, 2013b).

Post-1989 forest carbon stock change

When post-1989 forests were initially inventoried in 2007 and 2008, mapping of the forest extent had yet to be completed. Consequently, the post-1989 forest sample for this time period was incomplete. The national forest map has now been completed, and additional plots measured in the post-1989 planted and natural forest. The inclusion of these plots in the analysis has provided an unbiased and representative sample of post-1989 forests. The re-measurement data and the additional plot data have been introduced for the first time in this submission.

7.4.6 Category-specific planned improvements

Re-measurement of the natural forest permanent sample plot network is still under way, with around 130 plots yet to be re-measured. This work will be complete by July 2014. Following re-measurement of these remaining plots, New Zealand will re-analyse the natural forest plot network data. It is not expected that estimates of carbon stock and stock change will change appreciably in the re-analysis. However, additional data will enable results to be reported with greater certainty.

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.

7.5 Cropland (CRF 5B)

7.5.1 Description

Cropland in New Zealand is separated into two subcategories: annual and perennial. In 2012, there were 371,808 hectares of annual cropland in New Zealand (1.4 per cent of total land area) and 104,290 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, 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 2012, the net emissions from cropland were 507.2 Gg CO_2-e, comprising 452.1 Gg CO_2 from carbon stock change, 0.05 Gg N_2O (14.0 Gg CO_2-e) from the cultivation of land converted to cropland and 41.1 Gg CO_2 from liming. Net emissions from cropland have increased by 4.3 Gg CO_2-e (0.9 per cent) from the 1990 level when net emissions were 502.9 Gg CO_2-e (table 7.5.1).

Table 7.5.1 New Zealand's land-use change by cropland category, and associated CO_2-equivalent emissions, from 1990 to 2012

Cropland land-use category	Net area in 1990 (ha)	Net area in 2012 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2-e) 1990	2012	Change from 1990 (%)
Cropland remaining cropland	386,391	408,976	+5.8	379.1	383.4	+1.2
Land in conversion to cropland	40,356	67,121	+66.3	123.8	123.8	–0.0
Total	**426,747**	**476,098**	**+11.6**	**502.9**	**507.2**	**+0.9**

Note: 1990 and 2012 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. Values include CO_2 equivalent emissions from N_2O from cultivation of land and CO_2 from liming.

The cropland remaining cropland category is responsible for the majority of cropland emissions. This category comprised 75.6 per cent of all cropland area in 2012.

From 1990 to 2012, the total carbon stock stored in cropland decreased by 3,220.2 Gg C, equivalent to emissions of 11,807.4 Gg CO_2 from cropland since 1990 (table 7.5.2). The majority of the emissions due to carbon stock change are in the soil organic carbon pool (3,229.7 Gg C or 11,842.2 Gg CO_2).

Table 7.5.2 New Zealand's carbon stock change by carbon pool for the cropland category from 1990 to 2012

Cropland subcategory	Net carbon stock change 1990–2012 (Gg C): Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2012 (Gg CO_2)
Annual cropland	–130.2	–4.8	–2,119.9	–2,254.9	8,268.1
Perennial cropland	150.0	–5.5	–1,109.8	–965.3	3,539.4
Total	**19.8**	**–10.3**	**–3,229.7**	**–3,220.2**	**11,807.4**

Note: This table includes CO_2 emissions from carbon stock change only (emissions from N_2O disturbance and liming are not included in this table). The reported dead organic matter losses result from the loss of dead organic matter of woody land-use classes on conversion to cropland.

Table 7.5.3 shows land-use change by cropland subcategory since 1990, and the associated CO_2 emissions from carbon stock change.

Table 7.5.3 New Zealand's land-use change by cropland subcategories, and associated CO_2 emissions from carbon stock change, from 1990 to 2012

Cropland land-use subcategory	Net area in 1990 (ha)	Net area in 2012 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2 only) 1990	Net emissions (Gg CO_2 only) 2012	Change from 1990 (%)
Annual cropland	355,659	371,808	+4.5	338.4	341.5	+0.9
Perennial cropland	71,088	104,290	+46.7	133.8	110.6	–17.3
Total	**426,747**	**476,098**	**+11.6**	**472.2**	**452.1**	**–4.3**

Note: 1990 and 2012 areas are as at 31 December. This table includes CO_2 emissions from carbon stock change only. 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 7.5.4. This shows that land-use change within the cropland category has been dominated by conversions to perennial cropland, both from within the cropland category and from other land-use categories. This conversion has predominantly been for the establishment of vineyards (Davis and Wakelin, 2010).

Table 7.5.4 New Zealand's land-use change for the cropland category from 1990 to 2012

Cropland category	Subcategory	Net area in 1990 (ha)	Net area in 2012 (ha)	Change from 1990 (%)
Cropland remaining cropland	Annual remaining annual	324,536	340,117	4.8
	Perennial remaining perennial	59,197	59,560	0.6
	Annual to perennial	1,197	6,686	458.4
	Perennial to annual	1,461	2,612	78.8
	Subtotal	386,391	408,976	5.8
Land in conversion to cropland	Annual cropland	29,662	29,078	–2.0
	Perennial cropland	10,694	38,043	+255.8
	Subtotal	40,356	67,121	+66.3
Total		**426,747**	**476,098**	**+11.6**

Note: This table shows the change between 31 December 1990 and 31 December 2012. Columns may not total due to rounding.

7.5.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter pools 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 a tier 2 method for mineral soils and IPCC tier 1 defaults for organic soils (section 7.3).

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for cropland is provided in table 7.5.5.

Table 7.5.5 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	118.01	*	20	Soil CMS model (v.2013) LUE coefficient
	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	113.67	[*]	20	Soil CMS model (v.2013) LUE coefficient
	Organic	NE	–1.0 / 10.0		IPCC tier 1 default parameters

Note: EF = emission factor; NA = not applicable; NE = not estimated. * 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; see section 7.3.

The New Zealand-specific emission factor for the living biomass pool for perennial cropland is lower than the default value for temperate ecozones provided in GPG-LULUCF. The IPCC default value is based on a single study of an agroforestry system where crops are grown in rotation with trees, whereas the New Zealand specific emission factor takes into account that New Zealand's main perennial crops are not grown in rotation with trees (ie, are not part of an agroforestry system). New Zealand's main perennial crops are also vine fruit (ie, kiwifruit and grapes) so have a lower carbon content per area in living biomass at maturity than the cropland types included in the IPCC default value.

Cropland remaining cropland

For cropland remaining cropland, the tier 1 assumption is that for annual cropland there is no change in biomass 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 2012, there were 9,041 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 7.5.5). 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 does 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 2 method for mineral soils and a tier 1 method for organic soils, as described in section 7.3. The steady state mineral soil carbon stock for annual cropland is estimated to be 118.01 tonnes C ha^{-1} with an uncertainty of 59 per cent; for perennial cropland it is estimated to be 113.67 tonnes C ha^{-1} with an uncertainty of 64 per cent (table 7.3.2).

Mineral soil carbon change for annual cropland converted to perennial cropland is estimated using the IPCC default method of applying a linear rate of change over 20 years (equation (3) in section 7.3).

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 7.3.3).

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 7.10.4 of this submission. The total amount of agricultural lime (limestone) applied 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 2008 *Agricultural Production Survey* and 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 7.1.4 and 7.1.5.

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 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.

Soil organic carbon

Soil carbon stocks in land converted to annual and perennial cropland are estimated using a tier 2 method for mineral soils and a tier 1 method for organic soils, as described in section 7.3. In the absence of country- and land-use specific data on the 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 uses.

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 7.10.3.

7.5.3 Uncertainties and time-series consistency

The uncertainty in mapping cropland is ± 6 per cent. Further details 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 emission factor (Davis and Wakelin, 2010). As the perennial and annual cropland emission factors are based on only a limited number of biomass studies, the uncertainty in these figures is estimated as ± 75 per cent.

For mineral soils, the uncertainty is ± 7.5 per cent for SOC in annual cropland and ± 10.9 per cent for SOC in perennial cropland, as calculated from the tier 2 method estimates of SOC. For organic 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 and the uncertainty in the emission factor. The activity data uncertainty is estimated as ± 3 per cent for limestone and ± 24 per cent for dolomite. These values are then weighted to give overall uncertainty for liming emissions of ± 3.4 per cent. The emission factor is an IPCC default and its uncertainty is 95 per cent.

As shown in table 7.5.6, 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 7.5.6 Uncertainty in New Zealand's 2012 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	7.5	10.9
Uncertainty in liming emissions	95.1	95.1
Uncertainty introduced into net emissions for LULUCF	**0.9**	**0.3**

7.5.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for CO_2 emissions from the conversion to cropland category underwent tier 1 quality checks.

As part of verification of the New Zealand-specific above-ground biomass emission factor for perennial cropland, this factor has been compared with the IPCC default for temperate perennial cropland (table 3.3.2 of GPG-LULUCF, IPCC, 2003). The New Zealand value for above-ground biomass of 18.76 tonnes C ha^{-1} is much lower than the default value of 63 tonnes C ha^{-1} provided in GPG-LULUCF. Further research into the differences between the values has shown the IPCC default value is based on just four studies of agroforestry systems where crops are grown in rotation with trees, and none of these studies are New Zealand specific. While the country-specific emission factor used is based on a New Zealand study, it takes into account that New Zealand's main perennial crops are not grown in rotation with trees (ie, are not part of an agroforestry system) and that a proportion of New Zealand's main perennial crops is vine fruit (ie, kiwifruit and grapes). This means it has lower carbon content per area in living biomass at maturity than the cropland types included in the study on which the IPCC default value is based.

7.5.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the cropland category is shown in table 7.5.7. Recalculations of the entire time series were carried out for this category as a result of:

- a return to tier 2 modelling for mineral soils. This means the emission factors are now based on country-specific data
- updated activity data on the land area of cropland as part of the 2012 land-use mapping process. New data from LCDB3 was incorporated into the 1990, 2008 and 2012 land-use maps. This resulted in an increase in the areas of both annual and perennial cropland at 1990 and 2008
- updated liming activity data following the release of the final results from the 2012 Agricultural *Production Survey* and census.

Table 7.5.7 Recalculations of New Zealand's net emissions from the cropland category in 1990 and 2011

Year	Net emissions (Gg CO_2-e)		Change from the 2013 submission	
	2013 submission	2014 submission	(Gg CO_2-e)	(%)
1990	568.3	502.9	-65.4	-11.5
2011	390.8	516.2	125.4	32.1

7.5.6 Category-specific planned improvements

During the coming year the focus of planned improvements in this category will be on ensuring the data inputs and modelling are consistent with the 2006 IPCC Guidelines.

7.6 Grassland (CRF 5C)

7.6.1 Description

In New Zealand, grassland is used to describe 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), characteristics of the vegetation, or environmental constraints (eg, alpine shrubland). Grassland with woody biomass is therefore a diverse category. To account for these differences, grassland with woody biomass is split into permanent and transitional subcategories for modelling of land-use change effects on carbon. Separate emission factors for each type of grassland with woody biomass are derived from the LUCAS plot network (Wakelin and Beets, 2013). Within CRF Reporter, reporting on grassland with woody biomass is at the aggregate level.

Land-use research indicates that, under business-as-usual grassland farming operations, areas of woody shrublands (grassland with woody biomass – transitional) 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 or planting, 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, 2012b).

In 2012, there were 5,806,793 hectares of high-producing grassland (21.6 per cent of total land area), 7,538,391 hectares of low-producing grassland (28.0 per cent of total land area) and 1,353,943 hectares of grassland with woody biomass (5.0 per cent of total land area).

The net emissions from grassland were 5,985.14 Gg CO_2-e in 2012 (table 7.6.1). These emissions comprise 5,928.12 Gg CO_2 emissions from carbon stock change and agricultural lime application, and 2.46 Gg CH_4 (51.58 Gg CO_2-e) emissions and 0.02 Gg N_2O (5.44 Gg CO_2-e) 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 2012.

Net emissions from grassland have increased by 4,830.8 Gg CO_2-e (418.5 per cent) from the 1990 level of 1,154.4 Gg CO_2-e. The majority of this change is in the subcategory pre-1990 planted forest converted to low-producing grassland and is the effect of deforestation which involves large losses in the living biomass pool.

Table 7.6.1 New Zealand's land-use change for the grassland category, and associated CO_2-equivalent emissions, from 1990 to 2012

Grassland land-use category	Area in 1990 (ha)	Area in 2012 (ha)	Change from 1990 (%)	Net emissions ($Gg CO_2$-e) 1990	2012	Change from 1990 (%)
Grassland remaining grassland	14,619,064	14,502,351	-0.8	915.9	2,044.8	+123.3
Land in conversion to grassland	654,753	196,955	-69.9	238.5	3,940.4	+1,552.2
Total	**15,273,817**	**14,699,307**	**-3.8**	**1,154.4**	**5,985.1**	**+418.5**

Note: 1990 and 2012 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.

From 1990 to 2012, the net carbon stock change attributed to grassland was a decrease of 28,414.2 Gg C, equivalent to emissions of 104,185.3 Gg CO_2 from grassland since 1990 (table 7.6.2). The majority of these emissions are due to the loss of living biomass carbon stock associated with forest land conversion to grassland (deforestation).

Table 7.6.2 New Zealand's carbon stock change by carbon pool for the grassland category from 1990 to 2012

Grassland subcategory	Net carbon stock change 1990–2012 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2012 (Gg CO_2)
Grassland – high producing	–10,581.0	–953.7	–5,059.7	–16,594.3	60,845.8
Grassland – low producing	–9,848.5	–1,070.3	–92.8	–11,011.6	40,375.7
Grassland – with woody biomass	110.6	–69.4	–849.4	–808.3	2,963.7
Total	**–20,318.9**	**–2,093.4**	**–6,001.9**	**–28,414.2**	**104,185.3**

Note: Columns may not total due to rounding.

Non-CO_2 emissions from grassland in 2012 comprised 2.5 Gg CH_4 (51.6 Gg CO_2-e) and 0.02 Gg N_2O (5.4 Gg CO_2-e) from biomass burning, while emissions from liming of grassland accounted for 626.0 Gg CO_2-e of net grassland emissions in 2012 (11 per cent).

Grassland remaining grassland

There were 14,502,351 hectares of grassland remaining grassland in 2012, equivalent to 53.9 per cent of New Zealand's total land area. For estimating carbon stock change with land-use change, this category has been split into three subcategories (see table 7.6.2).

Land converted to grassland

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).

Between 2011 and 2012, 7,022 hectares of land were converted to grassland, while 13,292 hectares of grassland were converted to other land-use categories.

The majority (95.1 per cent) of land converted to grassland since 1990 is land that was previously forest land. The 128,683 hectares of forest land converted to grassland since 1990 comprises an estimated 38,504 hectares of natural forest deforestation and 90,179 hectares of pre-1990 planted forest deforestation. A further 20,591 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 7.4 and chapter 11). Land-use change of forest land to grassland between 1990 and 2012 resulted in net emissions of 79,977.9 Gg CO_2.

7.6.2 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 7.6.3). Emissions and removals from mineral soils are estimated using a tier 2 method, whereas organic soils are estimated using a tier 1 method (section 7.3).

Table 7.6.3 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 emission factor
	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 emission factor
	AGB	0.8	0.8	1	
	BGB	2.25	2.25	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
With woody biomass – transitional	*Biomass*	11.99	0.43	28	Plot network derived emission factor
	AGB	9.07	0.32	28	
	BGB	2.27	0.08	28	
	Dead organic matter	0.65	0.02	28	
	Deadwood	0.1	0.0	28	
	Litter	0.55	0.02	28	
With woody biomass – permanent	*Biomass*	59.96	NA	NA	Plot network derived emission factor
	AGB	45.02	NA	NA	
	BGB	11.26	NA	NA	
	Dead organic matter	3.68	NA	NA	
	Deadwood	3.68	NA	NA	
	Litter	0.0	NA	NA	

Note: AGB = above-ground biomass; BGB = below-ground biomass; 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 (313,816 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 7.1.5 representing the annual growth in biomass for land converted to another land use. The values given in table 7.1.5 for high-producing and low-producing grassland are tier 1 defaults. The values given for grassland with woody biomass are country-specific factors based on the LUCAS national plot network (Wakelin and Beets, 2013).

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 derived from the LUCAS national plot network (Wakelin and Beets, 2013), 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 2 method for mineral soils (table 7.6.4) and a tier 1 method for organic soils (section 7.3). The IPCC default emission factors for organic soils under grassland are 0.25 and 2.5 tonnes C ha^{-1} per annum for cold temperate and warm temperate regimes, respectively (IPCC, 2003).

Table 7.6.4 New Zealand's soil carbon stock values for the grassland subcategories

Land-use	Soil carbon stock density (t C ha^{-1})
High-producing grassland	132.91
Low-producing grassland	133.12
Grassland with woody biomass	125.41

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 7.10.4 of this submission. 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 Production Survey* and 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 7.1.4. 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).

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.

Where land is converted to grassland with woody biomass, dead organic matter accumulates to 0.65 tonnes C ha^{-1} over 28 years (the maturity period New Zealand has chosen for land to reach steady state).

Soil organic carbon

Soil carbon stocks in land converted to grassland are estimated using a tier 2 method for mineral soils and a tier 1 method for organic soils (section 7.3). In the absence of country- and land-use-specific data on the 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 does not distinguish between grassland remaining grassland and land converted to grassland. The activity data is 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 under 'Liming' in section 7.10.4 and under 'Liming' in 'Grassland remaining grassland' above.

7.6.3 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 7.6.5).

The uncertainty in mapping grassland is ± 6 per cent. Further details 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. A New Zealand-specific value derived from the LUCAS national plot network is used for biomass accumulation in grassland with woody biomass. Grassland with woody biomass is a diverse category; therefore the IPCC default uncertainty value is used (Wakelin and Beets, 2013).

Uncertainty in liming emissions is based on activity data uncertainty (amount of lime applied) from Statistics New Zealand and the uncertainty in the emission factor. The activity data uncertainty is estimated as ± 3 per cent for limestone and ± 24 per cent for dolomite (A Chou, Statistics New Zealand, pers comm 21 August 2009). These values are then weighted to give overall uncertainty for liming emissions of ± 3.4 per cent. The emission factor is an IPCC default and its uncertainty is 95 per cent.

Of the grassland subcategories, low-producing grassland has the greatest uncertainty in soil carbon stocks. Soil carbon stocks for low-producing grassland are variable as this land use covers a wide range of environmental factors due to its geographic extent.

Table 7.6.5 Uncertainty in New Zealand's 2012 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	4.7	16.5	5.8
Uncertainty in liming emissions	95.1	95.1	95.1
Uncertainty introduced into net emissions for LULUCF	**3.7**	**2.0**	**2.5×10^{-9}**

Note: Uncertainty in biomass carbon stocks for grassland with woody biomass is estimated using the IPCC default uncertainty value because an independent estimate of uncertainty for this subcategory is not available.

7.6.4 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.

7.6.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the grassland category is shown in table 7.6.6 below.

Table 7.6.6 Recalculations of New Zealand's net emissions from the grassland category in 1990 and 2011

	Net emissions (Gg CO_2-e)		**Change from the 2013 submission**	
Year	2013 submission	2014 submission	(Gg CO_2-e)	(%)
1990	–1,233.1	+1,154.4	+2,387.5	–193.6
2011	+3,753.3	+5,343.4	+1,590.1	+42.4

These recalculations are due to the change in emission factors and methodology used for calculating carbon stock change for soils, a new emission factor for the grassland with woody biomass subcategory and updated activity data as discussed in section 7.1.4.

7.6.6 Category-specific planned improvements

During the coming year, the focus of planned improvements in this category will be to ensure the data inputs and modelling are consistent with the 2006 IPCC Guidelines.

7.7 Wetlands (CRF 5D)

7.7.1 Description

New Zealand has 425,000 kilometres of rivers and streams, and almost 4,000 lakes that are larger than a 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 hydroelectric 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.[39] 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, which includes herbaceous vegetation that is periodically flooded, and estuarine and tidal areas. New Zealand has mapped its vegetated wetlands using existing 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.

There were 533,766 hectares of open-water wetlands in 2012 and 144,956 hectares of vegetated wetlands. These two subcategories combined make up 2.5 per cent of the total New Zealand land area.

In 2012, there were 44.4 Gg CO_2-e emissions from wetlands, compared with emissions of 218.2 Gg CO_2-e from wetlands in 1990. This declining trend is due to the area of land converted to wetlands transitioning to wetlands remaining wetlands.

Conversion to wetlands was a key category in 2012 in the trend assessment. Conversion to wetlands shows up as a key category because the trend analysis compares 1990 emissions of 218.2 Gg CO_2-e with the 2012 emissions of 44.4 Gg CO_2-e and a small absolute change is significant in relative terms.

[39] An exception 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.

As at 2012, there were 4,733 hectares in a state of conversion to wetlands (table 7.7.1). 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.

Table 7.7.1 New Zealand's land-use change for the wetlands category, and associated CO_2-equivalent emissions, in 1990 and 2012

Wetlands land-use category	Net area (ha)		Change from 1990 (%)	Net emissions (Gg CO_2-e)		Change from 1990 (%)
	1990	2012		1990	2012	
Wetlands remaining wetlands	663,887	673,988	+1.5	0.1	1.1	2,052.0
Land in conversion to wetlands	13,975	4,733	–66.1	218.1	43.4	–80.1
Total	**677,863**	**678,722**	**+0.13**	**218.2**	**44.4**	**–80.1**

Note: 1990 and 2012 area values are as at 31 December. Net emission values are for the whole year indicated. 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 2012, the net carbon stock change for wetlands decreased by 775.7 Gg C, equivalent to emissions of 2,844.3 Gg CO_2 in total since 1990 (table 7.7.2). 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 hydroelectric dams, which continues to have a lagged effect on soil organic carbon in the inventory period.

Table 7.7.2 New Zealand's carbon stock change by carbon pool for the wetlands category from 1990 to 2012

Wetlands subcategory	Net carbon stock change 1990–2012 (Gg C)				Emissions 1990–2012 (Gg CO_2)
	Living biomass	Dead organic matter	Soils	Total	
Wetlands – vegetated	–3.5	–0.4	2.2	–1.7	6.2
Wetlands – open water	–18.0	–1.2	–754.8	–774.0	2,838.1
Total	**–21.5**	**–1.7**	**–752.6**	**–775.7**	**2,844.3**

7.7.2 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 2 method for mineral soils (section 7.3). The mineral soil steady state carbon stock for vegetated wetlands is estimated to be 172.06 tonnes C ha^{-1}, with an uncertainty of 45.3 per cent. For open-water wetlands, the soil carbon stock at equilibrium is assumed 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 2012, 1,248 hectares of land were converted to wetlands, while 2,145 hectares of wetlands were converted to other land uses, mainly grassland (2,002 hectares). This resulted in a net decrease in total wetland area of 897 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 open-water wetlands, the carbon stocks in living biomass and dead organic matter following conversions are equal to zero. For vegetated wetlands, the carbon stocks 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 2 method, as described in section 7.3. In the absence of data on the rate of change specific to country and land-use, 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 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.

7.7.3 Uncertainties and time-series consistency

The uncertainty in mapping wetlands is ± 6.0 per cent (table 7.7.3). Further details are given in section 7.2.5.

The uncertainty for soil carbon stocks in vegetated wetlands is ± 10.3 per cent. No uncertainty is associated with the assumed value of zero for SOC in open-water wetlands.

Table 7.7.3 Uncertainty in New Zealand's 2012 estimates for the wetlands category (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	6.0
Emission factors	
Uncertainty in biomass carbon stocks	NE
Uncertainty in soil carbon stocks	10.3
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**1.4×10^{-4}**

Note: NE = not estimated, NO = not occurring. The activity data and combined emission 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 and emission factor for carbon change underwent tier 1 quality checks.

7.7.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the wetlands land-use category is shown in table 7.7.4. 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 7.3.

Table 7.7.4 Recalculations for New Zealand's net emissions from the wetlands category in 1990 and 2011

	Net emissions (Gg CO_2-e)		**Change from the 2013 submission**	
Year	2013 submission	2014 submission	(Gg CO_2-e)	(%)
1990	+167.3	+218.2	+50.9	+30.4
2011	+20.9	+45.5	+24.7	+118.4

7.7.6 Category-specific planned improvements

During the coming year, the focus of planned improvements in this category will be to ensure the data inputs and modelling are consistent with the 2006 IPCC Guidelines.

7.8 Settlements (CRF 5E)

7.8.1 Description

The settlements land-use category, as described in chapter 3.6 of GPG-LULUCF, 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 224,415 hectares of settlements in 2012 in New Zealand, an increase of 18,250 hectares since 1990. This category comprised 0.8 per cent of New Zealand's total land area in 2012. The largest area of change to settlements between 1990 and 2012 was from high-producing grassland, with 13,455 hectares of high-producing grassland converted to settlements between 1990 and 2012.

In 2012, the net emissions from settlements were –3.0 Gg CO_2-e. These emissions are entirely from the subcategory of land converted to settlements.

Settlements were not a key category in 2012.

Table 7.8.1 New Zealand's land-use change for the settlements category, and associated CO_2-equivalent emissions, from 1990 to 2012

Settlements land-use category	Net area (ha)		Change from 1990 (%)	Net emissions (Gg CO_2-e)		Change from 1990 (%)
	1990	2012		1990	2012	
Settlements remaining settlements	183,641	202,097	+10.1	NE	NE	NA
Land converted to settlements	23,383	22,318	–4.6	6.3	–3.0	–147.2
Total	**207,024**	**224,415**	**+8.4**	**6.3**	**–3.0**	**–147.2**

Note: NA = not applicable. 1990 and 2012 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 no tier 1 default emission factor is provided in GPG-LULUCF for this subcategory; see section 7.8.2 for details. Columns may not total due to rounding.

In 2012, there were 202,097 hectares of settlements remaining settlements (table 7.8.1). 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.

From 1990 to 2012, the net carbon stock change for settlements decreased by 180.5 Gg C, equivalent to emissions of 662.0 Gg CO_2 in total since 1990 (table 7.8.2). These carbon stock losses are predominantly due to the loss of living biomass on land conversion to settlements.

Table 7.8.2 New Zealand's carbon stock change by carbon pool for the settlements category from 1990 to 2012

Land-use category	Net carbon stock change 1990–2012 (Gg C)				Emissions 1990–2012 (Gg CO_2)
	Living biomass	Dead organic matter	Soils	Total	
Settlements	–255.4	–13.9	88.7	–180.5	662.0

7.8.2 Methodological issues

Greenhouse gas emissions within the settlements land-use category derive principally from carbon stock changes within the living biomass pool. GPG-LULUCF (IPCC, 2003, section 3.6) 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.

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 in living biomass (table 7.8.3).

Table 7.8.3 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	133.12	20	Linear change over the conversion period between new and previous stock values	Assumed the same as low-producing grassland (section 7.3.1)
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. 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 (GPG-LULUCF). 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).

Soil carbon

In the absence of country-specific data for this land use, the SOC stock estimate for low-producing grassland is used (section 7.3). Soil carbon stock in low-producing grassland is estimated using a tier 2 method (section 7.3). The steady state mineral soil carbon stock in low-producing grassland and therefore settlements is estimated to be 133.12 tonnes C ha^{-1} (table 7.3.2).

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). 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).

Soil carbon

Soil carbon stocks in land converted to settlements are estimated using a tier 2 method (section 7.3). In the absence of either country- or land-use specific data on the 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.

7.8.3 Uncertainties and time-series consistency

The uncertainty in mapping settlements is ± 6 per cent (table 7.8.4). Further details 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, the uncertainty calculated for low-producing grassland, ± 16.5 per cent, is applied here.

Table 7.8.4 Uncertainty in New Zealand's 2012 estimates for the settlements category (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	6.0
Emission factors	
Uncertainty in biomass carbon stocks	75.0
Uncertainty in soil carbon stocks	16.5
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**1.3×10^{-2}**

Note: NO = not occurring. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF.

7.8.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data for these emissions underwent tier 1 quality checks.

7.8.5 Category-specific recalculations

Recalculations were carried out for this category as a result of changes in activity data due to incorporation of new data from the LCDB3 project; this has enabled New Zealand to more accurately reflect changes in the extent of settlements over the period (table 7.8.5). New Zealand has also returned to using tier 2 methods and New Zealand-specific data for estimating change in soil organic carbon for the 2014 submission.

Table 7.8.5 Recalculations for New Zealand's net emissions from the settlements category in 1990 and 2011

Year	Net emissions (Gg CO_2-e)		Change from the 2013 submission	
	2013 submission	2014 submission	(Gg CO_2-e)	(%)
1990	+97.6	+6.3	–91.2	–93.5
2011	+34.7	–3.5	–38.2	–110.2

7.8.6 Category-specific planned improvements

During the coming year, the focus of planned improvements in this category will be to ensure the data inputs and modelling are consistent with the 2006 IPCC Guidelines.

7.9 Other land (CRF 5F)

7.9.1 Description

Other land is defined in section 3.7 of GPG-LULUCF as including bare soil, rock, ice and all unmanaged land areas that do not fall into any of the other five land-use categories. 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 2012, the net emissions from other land were 17.8 Gg CO_2-e. These emissions occur in the land converted to other land category and are 11.6 Gg CO_2-e (185.5 per cent) higher than the 1990 level of 6.2 Gg CO_2-e. This is primarily because the area of land estimated as having been converted to other land has been steadily increasing since 1990.

An analysis of change in area shows that of the 6,476 hectares converted from other land to different land-use categories, 4,247 hectares were converted to post-1989 forest and 1,253 hectares were converted to grassland with woody biomass.

Between 1 January 1990 and 31 December 2012, there were 2,491 hectares of land converted to other land; most (1,511 hectares) of this was from the grassland category (table 7.2.4). This is likely to be mainly due to conversion of grassland to roads, mines and quarries.

Other land was not a key category in 2012.

Table 7.9.1 New Zealand's land-use change for the land-use category of other land from 1990 to 2012

Land-use category – other land	Net area as at 1990 (ha)	Net area as at 2012 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2-e)		Change from 1990 (%)
				1990	2012	
Other land remaining other land	897,950	891,655	–0.7	NE	NE	NA
Land in conversion to other land	77	2,518	+3,186.8	6.2	17.8	+185.5
Total	**898,026**	**894,173**	**–0.4**	**6.2**	**17.8**	**+185.5**

Note: 1990 and 2012 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 estimated (NE) for this category; see section 7.9.2 for details. Columns may not total due to rounding.

7.9.2 Methodological issues

Other land remaining other land

The area of other land has been estimated based on LCDB2. The method used is described in more detail 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 7.9.2.

Table 7.9.2 Summary of New Zealand emission factors for the land-use category of other land

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)
Soils (mineral)	93.71	20	Linear change over the conversion period between new and previous stock values	Section 7.3 of this submission
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; therefore the change in carbon stocks and non-CO_2 emissions is not estimated for this category.

Soil carbon

Soil carbon stocks in other land remaining other land are estimated using a tier 2 method for mineral soils (section 7.3). The steady state mineral soil carbon stock in other land is estimated to be 93.71 tonnes C ha^{-1}, with an associated uncertainty of 107.1 per cent (McNeill et al, 2013).

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). 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 2 method (section 7.3). 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.

7.9.3 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 0.01 per cent uncertainty into the LULUCF net carbon emissions (table 7.9.3). This is low because the change in other land and the emissions from other land are low.

Table 7.9.3 Uncertainty in New Zealand's 2012 estimates for the land-use category of other land (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	45.0
Uncertainty in liming emissions	NO
Uncertainty introduced into net emissions for LULUCF	**0.01**

Note: NO = not occurring. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF.

7.9.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for these emissions underwent tier 1 quality checks.

7.9.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the other land category is shown in table 7.9.4. Recalculations were carried out for this category as a result of new activity data as explained in section 7.2.4, and changes to the data and method used to estimate carbon stock change in soil organic matter as explained in section 7.3.

Table 7.9.4 Recalculations for New Zealand's net emissions from the other land land-use category in 1990 and 2011

	Net emissions (Gg CO_2-e)		Change from the 2013 submission	
Year	2013 submission	2014 submission	(Gg CO_2-e)	(%)
1990	+4.5	+6.2	+1.7	+37.3
2011	+1.3	+22.0	+20.7	+1,566.1

7.9.6 Category-specific planned improvements

During the coming year, the focus of planned improvements in this category will be to ensure the data inputs and modelling are consistent with the 2006 IPCC Guidelines.

7.10 Non-CO_2 emissions (CRF 5(I-V))

7.10.1 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.

7.10.2 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 GPG-LULUCF (chapter 1.7). The notation key NE (not estimated) is reported in the CRF tables for the LULUCF sector.

7.10.3 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).

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland are minor in New Zealand, estimated at 0.05 Gg N_2O in 2012 (table 7.10.1). This reflects the relatively small area of land converted to cropland since 1990.

Table 7.10.1 N_2O emissions from disturbance associated with land-use conversion to cropland

Area and associated emissions	1990	2012	Change since 1990 (%)
Area of land in conversion to cropland (ha)	40,356	67,121	66.3
Emissions from disturbance (Gg N_2O)	0.02	0.05	83.0

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. 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 N2O from nitrogen in the soil. New Zealand uses a country-specific value of 0.01 kg N2O – 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 7.3.1). 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 (table 7.10.2).

New Zealand uses the IPCC default values for carbon accumulation in soils. The uncertainty in this figure is given as 97 per cent.

Table 7.10.2 Uncertainty in New Zealand's 2012 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

During the coming year, the focus of planned improvements in this category will be to ensure the data inputs and modelling are consistent with the 2006 IPCC Guidelines.

7.10.4 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 2012 were 667.1 Gg CO_2, up 1.5 per cent from emissions of 657.5 Gg CO_2 in 2011 and up 78.5 per cent from 373.8 Gg CO_2 in 1990.

Methodological issues

Information on agricultural lime (limestone and dolomite) application is collected by Statistics New Zealand as part of its annual *Agricultural Production Survey* and census. The *Agricultural Production Survey* and census 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* and census 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) 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 uses, namely cropland and grassland (sections 7.5 and 7.6 respectively).

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* and census carried out each year.

Source-specific recalculations

Emissions from liming in 2011 have been updated as a result of the activity data from the *Agricultural Production Survey* and census having been 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. Improvements will also be made to data inputs and modelling to ensure reporting for liming is consistent with the 2006 IPCC Guidelines.

7.10.5 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) (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 2012 were 3.1 Gg CH_4 (64.9 Gg CO_2-e) and 0.02 Gg N_2O (6.8 Gg CO_2-e) (table 7.10.3).

Table 7.10.3 Non-CO_2 emissions from biomass burning

Emissions	1990	2012	Change since 1990 (%)
CH_4 emissions (Gg CH_4)	2.4	3.1	27.3
N_2O emissions (Gg N_2O)	0.02	0.02	24.1

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, the clearing of vegetation (natural forest) prior to the establishment of exotic planted forest and the burning of post-harvest slash prior to restocking are also included. For the first time in 2012, estimates are provided for controlled burning associated with deforestation. Emissions from the burning of crop stubble and controlled burning of savanna are reported under 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, GPG-LULUCF). 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 1991/92 onwards. In this submission there have been minor revisions to the activity data for several years in the time series. The main change is the use of estimates from the database for all years in the time series, replacing the previous approach of using averages where no data was available. The April year data from the database is converted to calendar years for use in the inventory (Wakelin and Clifford, 2013).

There has not been a significant change in wildfire activity since 1990. Wildfires induced by natural disturbances (lightning) are estimated to account for only 0.1 per cent of burning in grassland and forest land in New Zealand (Doherty et al, 2008; Wakelin, 2006). 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 included in the general stock change calculation as allowed for in GPG-LULUCF (section 3.2.1.4.2). 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 unburnt stand). 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, 2011). 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 7.4.

A survey of controlled burning in planted forest 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, 2012).

Activity data is combined with an emission factor derived from the natural forest national plot network (see table 7.1.3) to estimate non-CO_2 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, 2012).

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 (Forest Industry Training and Education Council, 2005; Robertson, 1998) to provide activity data throughout the time series. It is assumed that 1.6 per cent of restocked area was burnt from 1990 to 1997. From 1997, the area burnt declines linearly to 0.8 per cent, which is used from 2005 onwards (Wakelin, 2012).

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 the age of 28 years (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, 2012).

An estimate is provided for burning of post-harvest residues associated with deforestation for the first time in this submission. No information is available on the extent of burning associated with deforestation in New Zealand. Therefore it is assumed that 30 per cent of conversions involve burning to clear residues. The IPCC default combustion proportion for the burning of harvest residue in non-eucalypt temperate forest (0.62) is applied to subcategory-specific emission factors to estimate emissions from this activity. The emission factor excludes the proportion of logs taken off site (70 per cent of above ground biomass) and is taken from the plot-network-derived yield tables by forest subclass at the average age of harvest in New Zealand.

Carbon dioxide emissions from controlled burning in planted forests in the inventory are captured at the time of conversion or harvest.

Different emission factors derived from the LUCAS plot network are used for wildfire and controlled burning on grassland with woody biomass 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 and Beets, 2013). Controlled burning of grassland with woody biomass for the establishment or re-establishment of pasture has not been included in the inventory.

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 activity data, emission factors and burning fractions where insufficient data exists.

Table 7.10.4 Uncertainty in New Zealand's 2012 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	41.9
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. The biomass burning parameters (emission factors, burning and emission factors), assumptions and dataset are reviewed and updated (Wakelin et al, 2009; Wakelin, 2011, 2012).

Source-specific recalculations

An estimate is provided for burning of post-harvest residues associated with deforestation for the first time in this submission.

The emission factors for forest land and grassland with woody biomass have been updated for the 2014 submission and this has changed the amount of dry matter lost on burning.

Activity data has also been updated between the 2013 and 2014 submissions.

Source-specific planned improvements

Data inputs and modelling will also be reviewed to ensure they are consistent with the 2006 IPCC Guidelines.

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Chapter 8: Waste

8.1 Sector overview

Waste sector emissions cover greenhouse gas emissions resulting from the processing and disposal of solid waste and wastewater treatment. Emissions from the Waste sector include predominantly methane (CH_4) emissions (94.8 per cent), followed by nitrous oxide (N_2O) emissions (5.1 per cent) and then carbon dioxide (CO_2) emissions (0.03 per cent).

2012

In 2012, the Waste sector contributed 3,595.7 Gg carbon dioxide equivalent (CO_2-e) (4.7 per cent) of New Zealand's total greenhouse gas emissions. The largest source of Waste sector emissions in 2012 was the solid waste disposal on land category, which contributed 3,120.5 Gg CO_2-e (or 86.8 per cent of Waste sector emissions). The wastewater handling category contributed 473.0 Gg CO_2-e (13.2 per cent) of the Waste sector emissions, and the waste incineration category contributed the remaining 2.2 Gg CO_2-e (0.06 per cent).

1990–2012

Emissions from the Waste sector were 289.2 Gg CO_2-e (8.7 per cent) above the 1990 baseline value of 3,306.5 Gg CO_2-e (figure 8.1.1). The emissions peaked in 2005 and have gradually decreased since then.

The overall increase was due to an increase in emissions from non-municipal and farm fills and the wastewater sector. The decrease in recent years is due to a decrease in emissions from municipal fills, which is the result of an increase in emission recovery and a decrease in waste placement. Emissions from municipal solid waste disposal on land increased by 208.1 Gg CO_2-e (7.1 per cent) between 1990 (2,912.4 Gg CO_2-e) and 2012 (3,120.5 Gg CO_2-e) (figure 8.1.2). These emissions decreased by 55.9 Gg CO_2-e (1.8 per cent) between 2011 and 2012.

Figure 8.1.1 New Zealand's Waste sector emissions from 1990 to 2012

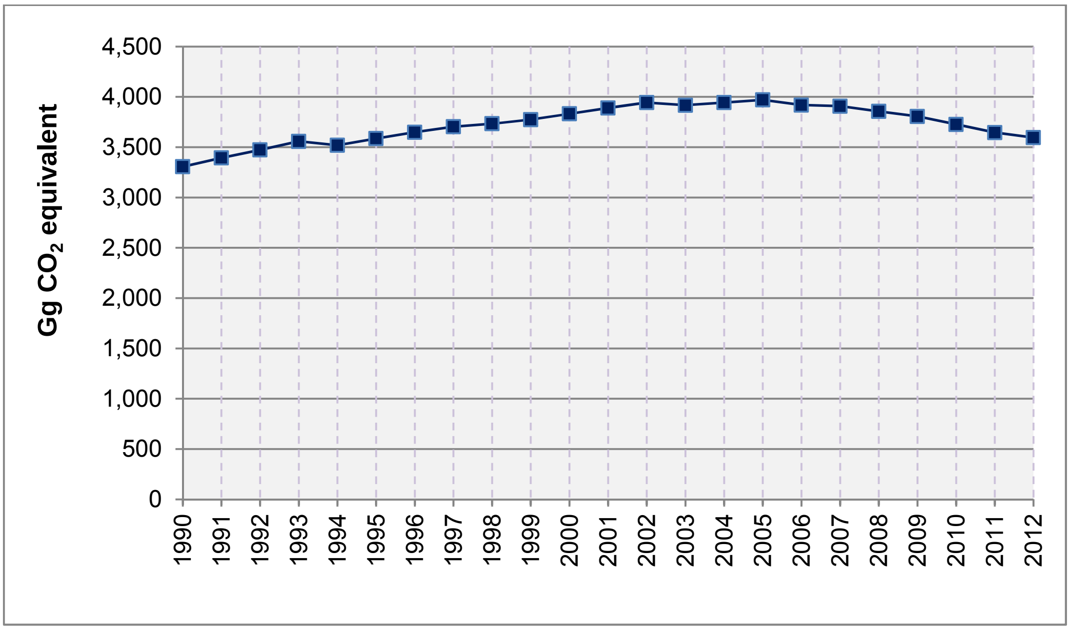
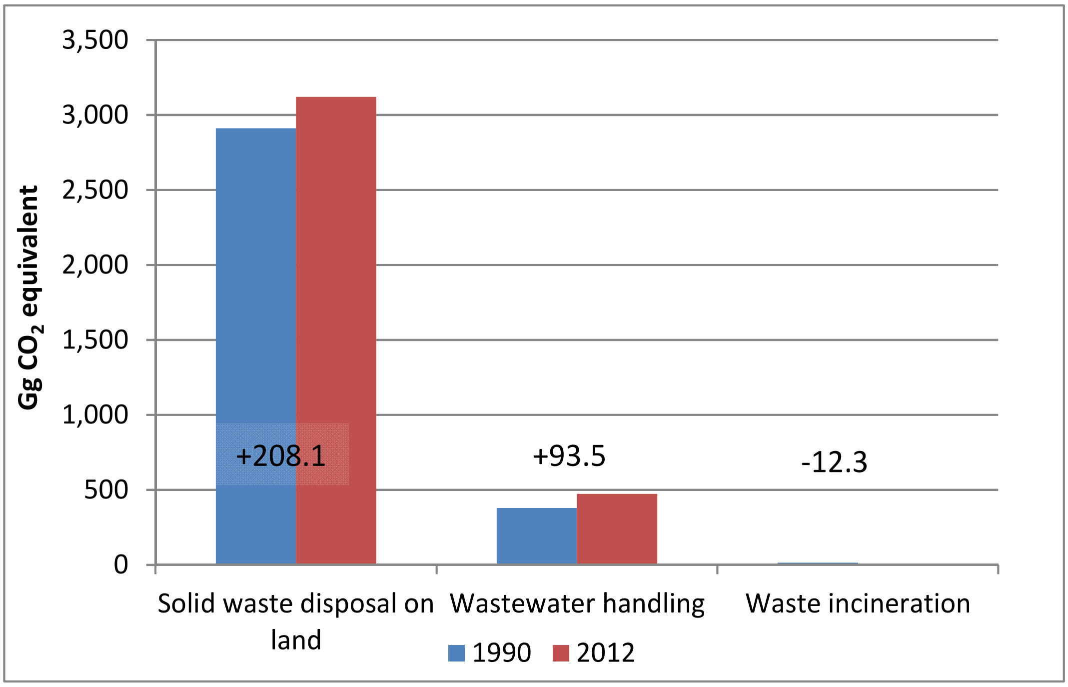


Figure 8.1.2 Change in New Zealand's emissions from the Waste sector from 1990 to 2012



Changes to emissions between 2011 and 2012

Total waste emissions in 2012 were 50.5 Gg CO_2-e (1.4 per cent) lower than the 2011 level. This was largely due to the increase in the recovery of emissions from municipal landfills and the decrease in waste placement to these landfills.

8.1.1 Key categories in the Waste sector

Full details of New Zealand's key category analysis are presented in section 1.5. Key Waste sector categories identified in the 2012 level assessment include:

- solid waste disposal on land (CH4) – (2Fa)
- wastewater handling (CH_4) – (2C1).

Key Waste sector categories identified in the 2012 trend assessment include:

- solid waste disposal on land (CH4).

8.1.2 Methodological issues

Please refer to the relevant sections in this chapter for information on the methodological issues.

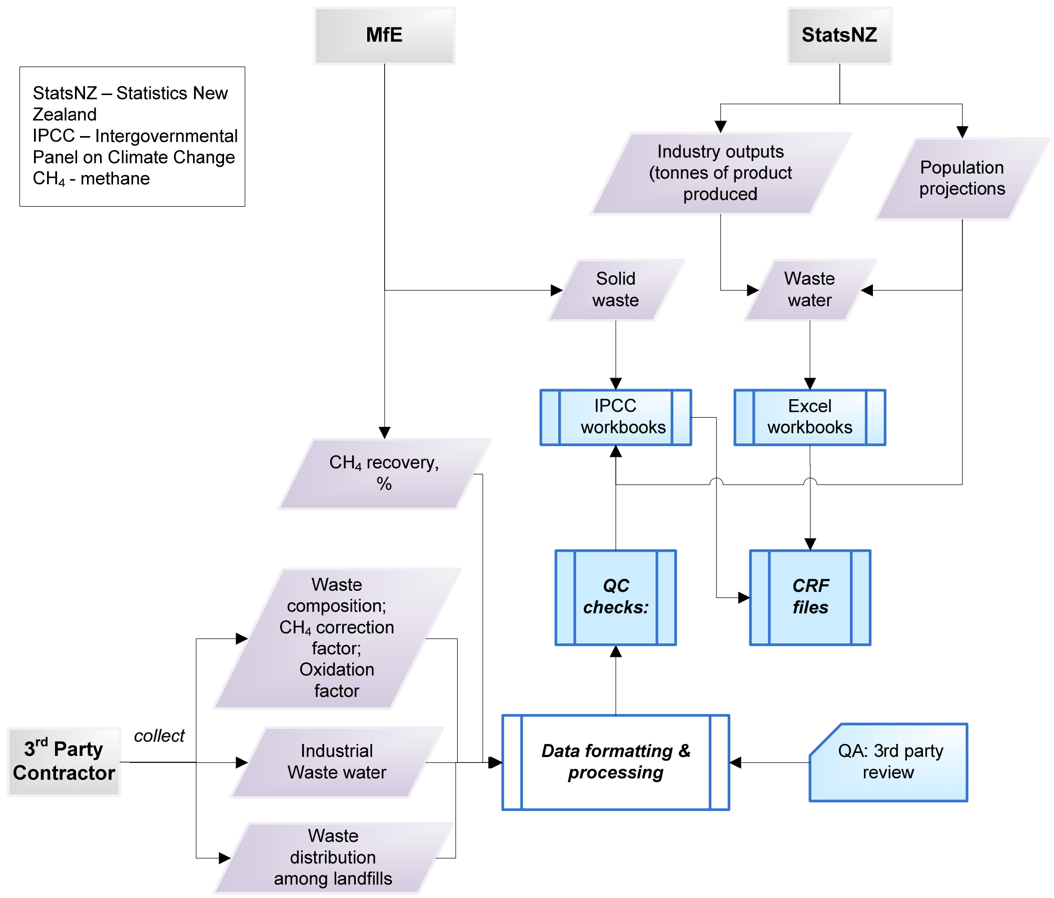
8.1.3 Uncertainties

The uncertainties for emission estimates are discussed under each category in this chapter.

8.1.5 Quality assurance/quality control (QA/QC) processes

In the preparation for this inventory submission, the data for this category underwent Tier 1 quality checks as outlined in figure 8.1.3.

Figure 8.1.3 Tier 1 quality checks for the Waste sector



Notes: CH_4 = methane; CRF = common reporting format; IPCC = Intergovernmental Panel on Climate Change; MfE = Ministry for the Environment; Stats NZ = Statistics New Zealand; QC = quality control; QA = quality assurance.

8.1.6 Sectoral improvements

The estimates for the Waste sector have been recalculated. There have been a number of improvements to the calculation of emission estimates in the Waste sector including:

- the inclusion of estimates from non-municipal landfills
- the inclusion of estimates from on-site farm fills
- the incorporation of waste placement data collected under the Waste Minimisation Act 2008
- the revision of historic waste placement estimates
- the revision of historic waste methane correction and oxidation factors
- minor amendments to composition values before 1980

- the incorporation of a 2012 waste composition estimate and a revision of the 2008 estimate
- estimates of emissions from the wool scouring industry
- activity data and revised parameters for the wine industry
- activity data and revised parameters for the pulp and paper industry (sludge treatment).

8.2 Solid waste disposal on land (CRF 6A)

8.2.1 Description

In 2012, solid waste disposal on land contributed 3,120.5 Gg CO_2-e (86.8 per cent) of total emissions from the Waste sector. Solid waste disposal emissions in 2012 were 208.1 Gg CO_2-e (7.1 per cent) below the 1990 level of 2,912.4 Gg CO_2-e.

This increase was due to an increase in emissions from non-municipal and farm fills. This increase was partially offset by a decrease in emissions from municipal fills, due to an increase in emission recovery and a decrease in waste placement in recent years.

In 2012, the amount of CH_4 recovered from solid waste disposal to municipal landfills was 1,017.5 Gg CO_2-e. Methane recovered in 2012 was 1,018.9 Gg CO_2-e above the 1990 level of 143.5 Gg CO_2-e and 52.0 Gg CO_2-e (5.4 per cent) above the 2011 level.

Methane emissions from solid waste disposal were identified as a key category in the 2012 level assessment and in the 1990–2012 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 CO_2 and CH_4. The CO_2 from aerobic decomposition is not required to be reported in the Waste sector of the inventory because of its biogenic origin. The amount of CH_4 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 CH_4 produced can go directly into the atmosphere via venting or leakage, or it can be flared off and converted to CO_2.

Solid waste management in New Zealand

In New Zealand, managing solid wastes has traditionally meant disposing of solid waste in landfills.

For the purposes of this inventory, landfills have been split into three categories:

1. municipal landfills – landfills that accept some domestic waste
2. non-municipal landfills – landfills that do not accept domestic waste (these include cleanfills –fills that accept largely inert waste – industrial fills, construction and demolition fills, and others)
3. farm fills – fills that receive on-site waste (note that farm fills do accept some domestic waste but are private landfills so are not considered municipal fills).

Since 1990, 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. In 2012, there were 49 municipal landfills compared with 327 in 1995. In 2012, nearly 2.5 million tonnes of solid waste disposed was disposed of to municipal landfills compared with nearly 3.2 million tonnes in 1995.

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 NZD$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. Information from the Act has been incorporated into this inventory submission for the first time.

These initiatives would have also impacted on the management of and waste placement at non-municipal landfills and, to a lesser extent, farm fills.

8.2.2 Methodological issues

Each type of landfill (ie, municipal landfills, non-municipal landfills and farm fills) is discussed in separate sections below. The municipal landfills are split into two types (landfills with CH_4 recovery systems and those without CH_4 recovery systems) and the common parameters used for both types of landfills and where they differ are discussed.

Municipal landfills

Municipal landfills with methane recovery systems

In 2012, 23 landfills had operational CH_4 recovery systems; with one closed landfill with a CH_4 recovery system that is no longer operating. For each of these 24 landfills, a landfill-specific first order decay model, based on the model contained within the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines (IPCC, 2006a), was used to develop estimates of net CH_4 emissions from waste disposal. In 2012, these 24 landfills accepted nearly 80 per cent of waste disposed to municipal landfills in New Zealand.

Activity data

Waste placement

Landfill-specific information on annual solid waste placement was determined for the 24 landfills with CH_4 recovery systems (or with plans to install CH_4 recovery systems by 2012) through direct contact with landfill operators (SKM, Unpublished (a)).

Methane generation rate/half-life

The CH_4 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 CH_4 recovery systems (or with plans to install CH_4 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 23 landfills identified as having CH_4 recovery systems in 2012, estimates of CH_4 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 very slight tendency to underestimate recovery efficiency (by nearly 3 per cent).

Efficiencies ranged from 42 per cent to 90 per cent, with an average efficiency of 56.5 per cent.

All landfills that recover CH_4 for energy generation, and therefore the emissions associated with the electricity generation in the CH_4 recovery process, are included in the Energy sector's estimates. There are some variances between the Waste sector and Energy sector estimates of the amount of CH_4 recovered at some individual landfills. However, the total CH_4 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).

Municipal landfills without methane recovery systems

In 2012, landfills without CH_4 recovery systems accepted nearly 20 per cent of waste disposed to municipal landfills in New Zealand. A first order decay model was used to estimate net CH_4 emissions from this waste.

Waste placement

Annual total waste placement to all landfills has been estimated based on national surveys for the years 1982, 1995, 1998, 2002 and 2006. From 2010, information collected annually under the requirements of the Waste Minimisation Act 2008 has been used. For the years between surveys, solid waste placement is estimated by interpolation. For the years before the 1982 survey, back casting using real gross domestic product (GDP) (ie, adjusted for inflation) has been used. A regression analysis established that there was a relationship between real GDP and the amount of waste landfilled between 1967 and 2002 (Eunomia Research and Consulting and Waste Not Consulting, Unpublished).

The transition from the use of national surveys to using the information collected from the Waste Minimisation Act 2008 uses a linear interpolation (Eunomia Research and Consulting and Waste Not Consulting, Unpublished). Other methods were explored, but this approach provided the most robust estimate.

The annual solid waste placement for landfills without CH_4 recovery systems is the difference between the sum of the estimated annual solid waste placement for the 23 landfills with CH_4 recovery systems and the one closed landfill that historically operated a CH_4 recovery system (SKM, Unpublished (a)) and the total annual solid waste placement discussed above.

Methane generation rate/half-life

New Zealand applies the IPCC default CH_4 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.[40]

Municipal landfills with and without methane recovery systems

The following parameters are applied to both landfills with and without CH_4 recovery systems.

Waste class

New Zealand has insufficient data to categorise solid waste disposed of to municipal fills as either municipal solid waste or industrial solid waste, because many municipal landfills accept industrial waste. All data is therefore reported in the municipal solid waste class and industrial waste is included in the composition estimates for this class.

Methane correction factor

Based on results from a 1971 survey, it has been estimated that at that time all of New Zealand's landfills were not managed and should be classified as uncategorised. From a 1982 survey, it has been estimated that 55 per cent of New Zealand's landfills were managed. In 1995 the proportion of managed landfills was 90 per cent and in 2010 the proportion was 100 per cent. For the years when less than 100 per cent of New Zealand's landfills were managed, the remaining proportion of landfills was considered to be uncategorised (Eunomia Research and Consulting and Waste Not Consulting, Unpublished).

The values between the surveys have been linearly interpolated. The 1971 value has been applied to 1950 through to 1970. The CH_4 correction factor ranges from 0.6 in 1950 to 1.0 in 2010 and onwards (Eunomia Research and Consulting and Waste Not Consulting, Unpublished). Landfills with CH_4 recovery systems have been assumed to be among the earlier managed fills and the higher CH_4 correction factor has been preferentially applied to them from 1972.

Waste composition

Solid waste composition was estimated in 1995, 2004, 2008 and 2012. The 1995 and 2004 estimates are from national surveys (or partially informed by national surveys) (Ministry for the Environment, 1997; Waste Not Consulting, Unpublished(a)). The 2008 and 2012 estimates are estimated from individual landfill surveys (Waste Not Consulting, Unpublished(b)). These surveys are based on the *Solid Waste Analysis Protocol*, which provides for a comparison of the results (Ministry for the Environment, 2002b).

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40 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.

Linear interpolations were used to provide estimates for the years between the four estimates. The 1995 estimate is used for preceding years, but amended to reduce the proportion of waste in the nappies category to account for the introduction of disposable nappies in the 1960s. The decrease in the proportion of waste in the nappies category is offset by an increase in the proportion of inert waste. Identifying other sources of composition data before 1995 was investigated. However, the sources identified were limited in geographical coverage and used composition categories that could not be translated to the IPCC composition categories.

Table 8.2.1 shows the measured and calculated proportions each waste category has contributed to the total waste stream from 1950 to 2012.

Table 8.2.1 Composition of New Zealand's waste (1950 to 2012)

Year	Food (%)	Garden (%)	Paper (%)	Wood (%)	Textile (%)	Nappies (%)	Inert (%)	Source
1950–1960	17	11	16	7	1	0	48	Eunomia Research and Consulting and Waste Not Consulting (Unpublished)
1961–1969	17	11	16	7	1	1	47	Eunomia Research and Consulting and Waste Not Consulting (Unpublished)
1970–1979	17	11	16	7	1	2	46	Eunomia Research and Consulting and Waste Not Consulting (Unpublished)
1980–1994	17	11	16	7	1	3	45	1995 values applied
1995	17	11	16	7	1	3	45	Ministry for the Environment (1997)
1996	17	11	16	8	1	3	45	Interpolation
1997	17	11	16	9	1	3	44	Interpolation
1998	16	10	16	9	2	3	44	Interpolation
1999	16	10	16	10	2		43	Interpolation
2000	16	10	16	11	2	3	43	Interpolation
2001	15	10	15	12	3	3	43	Interpolation
2002	15	10	15	12	3	3	42	Interpolation
2003	15	9	15	13	4	3	42	Interpolation
2004	14	9	15	14	4	3	41	Waste Not Consulting (Unpublished(a))
2005	15	9	13	13	4	3	42	Interpolation
2006	16	9	12	13	4	3	43	Interpolation
2007	16	9	10	12	4	3	44	Interpolation
2008	17	9	9	12	4	3	45	Waste Not Consulting (Unpublished)
2009	17	9	9	12	4	3	45	Interpolation
2010	17	9	10	12	5	3	44	Interpolation
2011	17	9	10	12	5	3	44	Interpolation
2012	17	8	11	12	6	3	44	Waste Not Consulting (Unpublished(b))

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.

A new DOC value has been determined for 2012, and the 2008 value has been revised. The estimate of degradable organic carbon content tracks the changes in composition described above. The DOC value ranges from its lowest value of 0.145 in the 1950s to its highest value of 0.17470 in 2004.

Oxidation factors

The oxidation factor reflects the shift in uncategorised landfills to managed fills, as per the CH_4 correction factor section. The oxidation value therefore increases from 0 to 0.1 between 1971 and 2010, as per the approach for the CH_4 correction factor.

Methods

New Zealand has applied a Tier 2 approach by using the 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 CH_4 generation rates, for estimating emissions from solid waste disposal.

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 CH_4 in landfill gas (table 8.2.2) (IPCC, 2006a).

Summary of parameters used

Table 8.2.2 provides a summary of the parameter values applied for estimating CH_4 emissions from solid waste disposal to land.

Table 8.2.2 Parameter values applied by New Zealand for estimating solid waste disposal to municipal landfills

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	0.6–1.0	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}):			
All default values	Range of 0.030 to 0.185		
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 that decomposes	0.50	IPCC default	IPCC (2006a)
Fraction of methane in landfill gas	0.50	IPCC default	IPCC (2006a)
Oxidation correction factor	0–0.10	IPCC default	IPCC (2006a)
Degradable organic carbon	Range of 0.145–0.175	New Zealand specific	Ministry for the

Parameter	Value	Source	Reference
(Gg C/Gg waste)			Environment (1997); Waste Not Consulting (Unpublished(a),(b))

Non-municipal landfills

Non-municipal landfills are landfills that do not accept domestic waste. These include cleanfills (fills that accept largely inert waste) industrial fills, construction and demolition fills, and others. There is limited information available on non-municipal landfills, particularly historic information. Information on non-municipal landfills has been obtained from regional councils, landfill operators and specific industries.

Waste placement

Landfill-specific information was received for some of the landfills through direct contact with landfill operators, regional councils and specific industries. All information held by these sources was obtained but, in many cases, there were gaps, particularly regarding historic information. A regression analysis established that there was a relationship between regional GDP and the amount of waste landfilled at sites where the information existed (Tonkin & Taylor, Unpublished(a)).

Waste composition

Information was obtained on the types of waste each landfill accepted. However, only a few sites were able to provide some broad percentages of the proportion of different waste types they accepted. As there was limited information to quantify the waste types accepted at each site, the number of sites allocated with a particular waste type (waste type code) has been counted and the percentage contribution of the total waste has been determined.

Degradable organic carbon

The combined DOC value varies across the time series according to the waste composition data, as discussed above. The default IPCC values of the degradable organic carbon in the different waste composition categories are used.

Methane correction factor

Based on discussions with operators, it appears the majority of the fills were shallow (less than 5 metres deep) and unmanaged, with no daily cover material used. The CH_4 correction factor for unmanaged–shallow sites has been applied to 90 per cent of non-municipal fills. As deeper sites with greater than 5 metres of waste are unlikely, the remaining sites (10 per cent) have had the CH_4 correction factor for uncategorised sites applied (Tonkin & Taylor, Unpublished(a)).

Methane generation rate/half-life

New Zealand applies the IPCC default CH_4 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]

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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.

Oxidation factor

Based on the practices regarding closed sites, it has been assumed that the closed sites, although unmanaged during their operational life, have now at least some form of low permeability cap or have been revegetated. The condition of the cap, however, is not known and the default oxidation value of 0 has been applied.

Recovery

There is no recovery of emissions reported for this source.

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 CH_4 in landfill gas (table 8.2.3) (IPCC, 2006a).

Summary of parameters used

Table 8.2.3 provides a summary of the parameter values applied for estimating CH_4 emissions from solid waste disposal to non-municipal fills.

Table 8.2.3 Parameter values applied by New Zealand for estimating solid waste disposal to non-municipal fills

Parameter	Value	Source	Reference
Landfills without methane recovery systems			
Degradable organic carbon (Gg C/Gg waste)	Range of 0.04–0.43	New Zealand specific	Tonkin & Taylor (Unpublished(a))
Methane correction factor	0.44	New Zealand specific	Tonkin & Taylor (Unpublished(a))
Methane generation rate/half-life ($year^{-1}$):			
All default values used	Range of 0.03–0.185	IPCC default	IPCC (2006a)
Oxidation correction factor	0	IPCC default	IPCC (2006a)
Starting year	1950	IPCC default	IPCC (2006a)
Delay time	6 months	IPCC default	IPCC (2006a)
Fraction of degradable organic carbon that decomposes	0.50	IPCC default	IPCC (2006a)
Fraction of methane in landfill gas	0.50	IPCC default	IPCC (2006a)

Farm fills

Farm fills are private fills that receive on-site waste. This includes non-natural rural waste, such as scrap metal, treated timber and fence posts, plastic wraps and ties, netting, glass, batteries, and some construction and demolition wastes. It also includes organic waste and general domestic waste.

Surveys of farm fills carried out in the Canterbury region in 2012 and 2013 revealed that 92 per cent of this waste was burnt, buried or stored for an indefinite amount of time. The results from these surveys are extrapolated to the rest of the country. As farming practices are fairly similar across the country, this multiplier is likely to provide a fair representation of waste management in farms nationally. However, it should be noted the survey work is based on a limited number of farms in one region (Tonkin & Taylor, Unpublished(a)).

Waste placement

Waste placement is estimated by using waste generation amounts determined from the surveys above. The waste generation amounts are for the different farm types: dairy, livestock (beef, sheep, deer, piggery, poultry and alpaca), arable (crops, vegetables and orchards) and viticulture (grape growing).

The survey results are applied nationally, accounting for prevalence of the different farm types. (Tonkin & Taylor, Unpublished(a)).

Waste composition and degradable organic carbon

Based on information from the survey of farm fills (described above), the DOC for bulk municipal solid waste has been adopted for farm waste as it is expected to comprise a mixture of domestic refuse, inert wastes (scrap metal and glass) and wastes associated with the particular farming activity (Tonkin & Taylor, Unpublished(a)).

Methane correction factor

Based on the surveys, the farm pits encountered ranged in sizes. There is only limited information on

the size of the pits. The majority of the pits (90 per cent) are shallow (less than 5 metres depth of waste) and the CH_4 correction factor for unmanaged–shallow sites has been applied. The remainder are deeper pits with greater than or equal to 5 metres of waste (10 per cent) and the CH_4 correction factor for unmanaged–deep sites has been applied (Tonkin & Taylor, Unpublished(a)).

Methane generation rate/half-life

New Zealand applies the IPCC default CH_4 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.[42]

Oxidation factor

An oxidation value of 0 is considered appropriate for unmanaged sites.

Recovery

There is no recovery of emissions reported for this source.

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 CH_4 in landfill gas (table 8.2.4) (IPCC, 2006a).

Summary of parameters used

Table 8.2.4 provides a summary of the parameter values applied for estimating CH_4 emissions from solid waste disposal to farm fills.

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42 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.

Table 8.2.4 Parameter values applied by New Zealand for estimating solid waste disposal to farm fills

Parameter	Value	Source	Reference
Landfills without methane recovery systems			
Degradable organic carbon (Gg C/Gg waste)	0.28	IPCC default	IPCC (2006a)
Methane correction factor	0.42	New Zealand specific	Tonkin & Taylor (Unpublished(a))
Methane generation rate/half-life ($year^{-1}$):			
Bulk municipal solid waste	0.09	IPCC default	IPCC (2006a)
Oxidation correction factor	0	IPCC default	IPCC (2006a)
Starting year	1950	IPCC default	IPCC (2006a)
Delay time	6 months	IPCC default	IPCC (2006a)
Fraction of degradable organic carbon that decomposes	0.50	IPCC default	IPCC (2006a)
Fraction of methane in landfill gas	0.50	IPCC default	IPCC (2006a)

8.2.3 Uncertainties and time-series consistency

Uncertainty estimates are provided for each of the three categories: municipal landfills, non-municipal landfills and farm fills.

The uncertainty estimate for municipal landfills is ±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 CH_4 recovery, as some metered data is used.

The uncertainty level for non-municipal landfills and farm fills is ±130 per cent. This is due to the high uncertainty for the waste placement to non-municipal landfills and farm fills. Significant efforts were made to obtain more accurate waste placement information (particularly for non-municipal fills) but given the nature of the management of such fills, limited information exists.

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 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

A number of improvements have been made to the emissions estimates from solid waste disposal on land.

- Estimates from non-municipal landfills have been included.
- Estimates from on-site farm fills have been included.
- Waste placement estimates for municipal landfills have been recalculated to incorporate the more accurate data collected under the Waste Minimisation Act 2008.

- Historic waste placement estimates have also been revised based on historic surveys and regression analysis identifying a surrogate measure to back cast.
- Historic waste management practices also provided recalculations of the CH4 correction factor and oxidation factor.
- Investigations of historic composition estimates provided minor amendments to composition values before 1980 and to the application of separate food and garden composition categories (this was not done in previous inventory submissions).
- The development of a 2012 waste composition estimate and a revision of the 2008 estimate resulted in amendments to the interpolated composition estimates between 2004 the and 2008 and 2012 estimates.

8.2.6 Source-specific planned improvements

From 1 January 2013, the waste sector (landfills) has had 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 for incorporation into future inventory submissions.

New Zealand will investigate developing landfill-specific information (amount of waste sent to landfill and k values) for landfills without CH_4 recovery systems for future inventory submissions.

8.3 Wastewater handling (CRF 6B)

8.3.1 Description

In 2012, wastewater handling produced 473.0 Gg CO_2-e (13.1 per cent) of emissions from the Waste sector. This was an increase of 93.5 Gg CO_2-e (24.6 per cent) from the 1990 level of 379.5 Gg CO_2-e and is due to increases in emissions from both the industrial and domestic sectors. This increase is due to increases in the total wastewater handled over this period.

Methane emissions from wastewater handling were identified as a key category in the 2012 level assessment, but only in the analysis of total emissions.

Domestic and commercial wastewater

Domestic and commercial wastewater contributed 277.5 Gg CO_2-e (58.7 per cent) of the 2012 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 nearly 320 municipal wastewater treatment plants in New Zealand and around 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 195.5 Gg CO_2-e (41.3 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 CH_4 from anaerobic treatment is flared. However, there are a number of anaerobic ponds that do not have CH_4 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(a)).

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(a)). In 2012, the total connected population was estimated to be 4.1 million. This is a minor difference between the estimated official 2012 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 & Taylor, Unpublished(b)). 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, 2013).

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(a)). 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. The correction factor for biochemical oxygen demand for these plants range from 77 per cent to 1,490 per cent (Beca, Unpublished(a)).

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum CH_4 producing capacity.

Recovery

Methane removal via flaring or for energy production is known to occur at eight plants in New Zealand. All CH_4 generated at these plants is flared or used for energy production and consequently the net result is zero CH_4 emissions (Beca, Unpublished(a)). Plants using CH_4 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 CH_4 emissions from domestic wastewater treatment.

Table 8.3.1 Parameter values applied by New Zealand for estimating methane emissions from 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 BOD/person/year)	26	New Zealand specific	Beca (Unpublished(a))
Correction factor for BOD	Range of 1.25–14.9	New Zealand specific	Beca (Unpublished(a))
Maximum methane producing capacity (kg CH_4/kg BOD)	0.625	IPCC default	IPCC (1996)

Methane emissions from industrial wastewater treatment

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

Method

The IPCC default method is used to calculate CH_4 emissions from wastewater treatment by the meat processing industry (IPCC, 1996).

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, 2013), venison (obtained from Deer Industry New Zealand, pers. comm., 2013) and poultry (obtained from Poultry Industry Association of New Zealand, pers. comm., 2013).

The total organic wastewater from meat rendering was determined in 2006 (Beca, Unpublished(a)). Using the 2006 figure, a ratio of wastewater from rendering to kills has been determined and has been applied to all years.

The emissions for each of the activities (processing and rendering) are calculated separately and then combined to determine the emission for the meat industry as a whole. These separate calculations allow for the application of different CH_4 conversion factor values.

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 CH_4 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 CH_4 producing capacity and the CH_4 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 CH_4 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 (kgCH_4/kg COD)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand.

Pulp and paper industry

Method

The IPCC default method is used to calculate CH_4 emissions from wastewater treatment by the pulp and paper industry (IPCC, 1996).

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, 2013).

Degradable organic component

The degradable organic component was derived from the chemical oxygen demand per tonne of product, which is determined from industry data (Beca, Unpublished(a)).

Methane conversion factor

The CH_4 conversion factor of 0.02 was determined by SCS Wetherill Environmental (2002). This same conversion factor was also determined by Beca (Unpublished(a)) in 2006.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum CH_4 producing capacity (IPCC, 1996).

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 CH_4 emissions from wastewater treatment by the pulp and paper industry.

Table 8.3.3 Parameter values applied by New Zealand for estimating methane emissions from 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(a))
Methane conversion factor	0.02	New Zealand specific	SCS Wetherill Environmental (2002); Beca (Unpublished(a))
Maximum methane producing capacity (kg CH_4/kg DC)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand.

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 CH_4) 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(a)).

Wine industry

Method

A Tier 2 approach is used to estimate emissions from the wine industry. Information on the wastewater treatment practices of the industry were obtained from a survey (Beca, Unpublished(b)). IPCC default values are used where New Zealand-specific information was not available.

Activity data

Emissions from wastewater for the wine industry are based on the outputs obtained from the national organisation for New Zealand's grape and wine sector. For the purposes of this assessment, an average industry wastewater discharge metric of 2.7 cubic metres of water per tonne of grapes processed is assumed. This value is derived from national data. It is noted that this value is significantly less than IPCC default values (Beca (Unpublished(b)).

Methane conversion factor

The CH_4 conversion factor of the wine industry is 0.1, as determined by Beca (Unpublished(b)).

Degradable organic component

Beca (Unpublished(b)) determined there were 4.6 kilograms of chemical oxygen demand per cubic metre waste water.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum CH_4 producing capacity (IPCC, 1996).

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 CH_4 emissions from wastewater treatment by the wine industry.

Table 8.3.4 Parameter values applied by New Zealand for estimating methane emissions from wastewater treatment by the wine industry

Parameter	Value	Source	Reference
Methane conversion factor	0.1	New Zealand specific	Beca (Unpublished(b))
Degradable organic component (kg COD/m^3)	4.6	New Zealand specific	Beca (Unpublished(b))
Maximum methane producing capacity (kg CH_4/kg COD)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand.

Wool scouring industry

Method

The IPCC default method is used to calculate methane emissions from the wastewater treatment by the wool scouring industry (IPCC, 1996).

Activity data

Emissions from wastewater for the wool scouring industry are based on the outputs obtained and by SCS Wetherill Environmental (2002) for estimates up to 2000. From 2001, the SCS estimates have been prorated against the industry's output data and applied to the output data for subsequent years – up to 2012 when the wool scouring industry started using aerobic treatment of wastewater and emissions were no longer produced.

Methane conversion factor

The CH_4 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 (IPCC, 1996).

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.5 provides a summary of the parameter values applied for estimating CH_4 emissions from wastewater treatment by the wool scouring industry.

Table 8.3.5 Parameter values applied by New Zealand for estimating methane emissions from 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 COD)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand.

Methane emissions from domestic sludge treatment

In large domestic wastewater treatment plants in New Zealand, sludge is handled anaerobically and the CH_4 is almost always flared or used (Tonkin & Taylor, Unpublished(b)). Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds (SCS Wetherill Environmental, 2002).

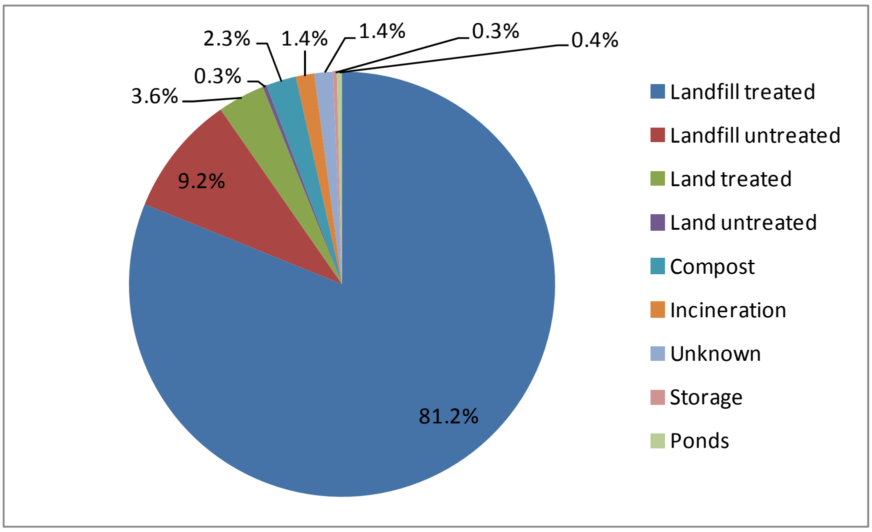
Oxidation ponds accumulate sludge on the pond floor. In New Zealand, these are typically only de-sludged every 20 years. The sludge produced is well stabilised with an average age of nearly 10 years. It has a low, biodegradable organic content and is considered unlikely to be a significant source of CH_4 (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 CH_4 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 CH_4 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(b)). Untreated sludge emissions are included in the estimates for solid waste disposal to land (section 8.2). No emissions occur from the disposal of treated sludge to landfills. Sludge not disposed of to landfills is either composted, disposed of to land (forestry) or stored on site.

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(a); Tonkin & Taylor, Unpublished(b)).

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 CH_4 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(b)). These fractions range from 0 to 0.88.

Methane conversion factors

A CH_4 conversion factor of 1 has been used for anaerobic treatment systems, and a CH_4 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 (IPCC, 1996).

Recovery

In 2012, anaerobic digestion treated nearly 59 per cent of total domestic sludge in New Zealand. Of the sludge treated by anaerobic digestion, 96 per cent was treated by plants that utilise or flare CH_4.

A CH_4 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 1996 IPCC method, where the fate of the gas from an anaerobic digester is unknown, no CH_4 recovery is assumed.

Summary of parameters used

Table 8.3.6 provides a summary of the parameter values applied for estimating methane emissions from domestic wastewater sludge treatment.

Table 8.3.6 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(b))
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(a))
Correction factor for BOD	Range of 1.25–14.9	New Zealand specific	Beca (Unpublished(a))

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(b))

Methane emissions from industrial sludge treatment

In New Zealand, the pulp and paper industry has been determined as the only industry to produce a source of CH_4 from sludge treatment (Tonkin & Taylor, Unpublished(b)). The wood panel production industry produces a small amount of emissions. For completeness, these emissions have been included in the pulp and paper estimates.

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. Sludge removed from the wine industry is generally discharged to land or disposed of to a landfill, where the emissions are accounted for.

Pulp and paper industry

Method

Estimating emissions from the pulp and paper industry uses a Tier 2 approach. Information on the wastewater treatment practices of the industry were obtained from a survey. IPCC default values (1996) were used where New Zealandspecific information was not available.

The estimates consider emissions from both the pulp and paper making and panel wood production sectors of the industry. Sludge removed from the treatment process is dried and used for energy in the manufacturing process, composted, disposed of to land or landfilled. These sludge disposal pathways either produce no emissions or, where emissions are produced, the emissions are accounted for in other sectors.

Activity data

An estimate of the pulp and paper wastewater output is based on the paper, paperboard, pulp, fibreboard, plywood and particle board production (tonnes) from the industry. This information is updated quarterly by the Ministry for Primary Industries (Ministry for Primary Industries, 2013).

Fraction of degradable organic component removed as sludge

A 36.4 per cent chemical oxygen demand removal as sludge has been determined for the pulp and paper making sector, and a 24.2 per cent chemical oxygen demand removal as sludge has been assumed for the panel wood production sector (Beca, Unpublished (b)).

Methane conversion factor

The CH_4 conversion factors range from 0.05 to 0.8, depending on the treatment method. The specific values are provided in table 8.3.7 below.

Default parameters applied

New Zealand uses the lower maximum CH_4 producing capacity of 0.21 kgCH_4/kg chemical oxygen demand. This value is considered more appropriate for New Zealand's estimates, based on a small number of New Zealand studies.

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 CH_4 emissions from wastewater sludge treatment by industry.

Table 8.3.7 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	Range of 0.242–0.364	New Zealand specific	Beca (Unpublished(b))
Methane conversion factor	0.6	New Zealand specific	Beca (Unpublished(b))
• Anaerobic lagoons	0.8	IPCC default	IPCC (1996)
• Aerated lagoons	0.05	New Zealand specific	Beca (Unpublished(b))
• Oxidation ponds	0.2	New Zealand specific	Beca (Unpublished(b))
Maximum methane producing capacity (kg CH_4/kg DC)	0.21	New Zealand specific	Beca (Unpublished(b))

Nitrous oxide emissions from domestic wastewater

There are no methodologies to estimate these N_2O emissions from domestic wastewater within New Zealand.

Nitrous oxide emissions from industrial wastewater treatment

Compared with domestic wastewater, the N_2O 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 N_2O emissions from this source for completeness.

Method

The IPCC does not have a method for calculating N_2O 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 CH_4 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 CH_4 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 Environmental, 2002).

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 N_2O emissions from wastewater sludge treatment by the meat industry.

Table 8.3.8 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 N_2O 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, 2013).

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 2012.

Default parameters applied

New Zealand uses the default IPCC values (2006)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 (IPCC, 2006a).

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.9 provides a summary of the parameter values applied for estimating N_2O emissions from domestic and commercial wastewater sludge treatment.

Table 8.3.9 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(a))
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 CH_4 emissions have an accuracy of ±40 per cent (SCS Wetherill Environmental, 2002; Beca, Unpublished(a)). 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 CH_4 production from industrial wastewater has an estimated accuracy of ±40 per cent (SCS Wetherill Environmental, 2002; Beca, Unpublished(b)). 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 CH_4 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 ±20 per cent. This uncertainty stems from uncertainties in the treatment methods used in the industry.

Nitrous oxide emissions from domestic sludge and industrial wastewater treatment

There are very large uncertainties associated with N_2O 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 an improvement in the transparency of the compilation. This will be addressed in future submissions.

8.3.5 Source-specific recalculations

Methane and nitrous oxide emissions from industrial wastewater treatment

The emission estimates for wastewater treatment by the wool scouring and wine industries have been recalculated. More specific information on the wastewater practices of the wine industry were obtained through an industry survey, which allowed for updated parameters to be used in the estimates. High level information was obtained from the wool scouring industry, which provided an update on wastewater treatment practices.

Methane emissions from industrial wastewater sludge treatment

Recalculations were made to the emission estimates from wastewater sludge treatment by the pulp and paper industry. Pulp and paper operators (including pulp and paper making and wood panel production) were surveyed regarding their wastewater sludge treatment practices. The information obtained provided updated parameters for the estimates.

8.3.7 Source-specific planned improvements

No specific improvements have been confirmed for this category.

8.4 Waste incineration (CRF 6C)

8.4.1 Description

In 2012, 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 (82.1 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 CO_2 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 CO_2, such as that from paper, cardboard and food, is excluded in accordance with the IPCC (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 (IPCC, 2006a). 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 CH_4 emissions from incinerating hazardous waste (IPCC, 2006a). As the CH_4 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 N_2O emissions from incinerating hazardous waste (SKM, Unpublished (b)), (IPCC, 2006a).

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 and industrial waste is used for calculating CH_4 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 N_2O 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 CH_4 emissions from incinerating sewage sludge. The IPCC 2006 guidelines note that the most detailed observations of CH_4 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 N_2O 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	N/A	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)

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 CH_4 and N_2O emissions have a much higher uncertainty (IPCC, 2006a); hence, the estimated uncertainty for default CH_4 and N_2O 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.

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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 the Inventory following the 2013 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.

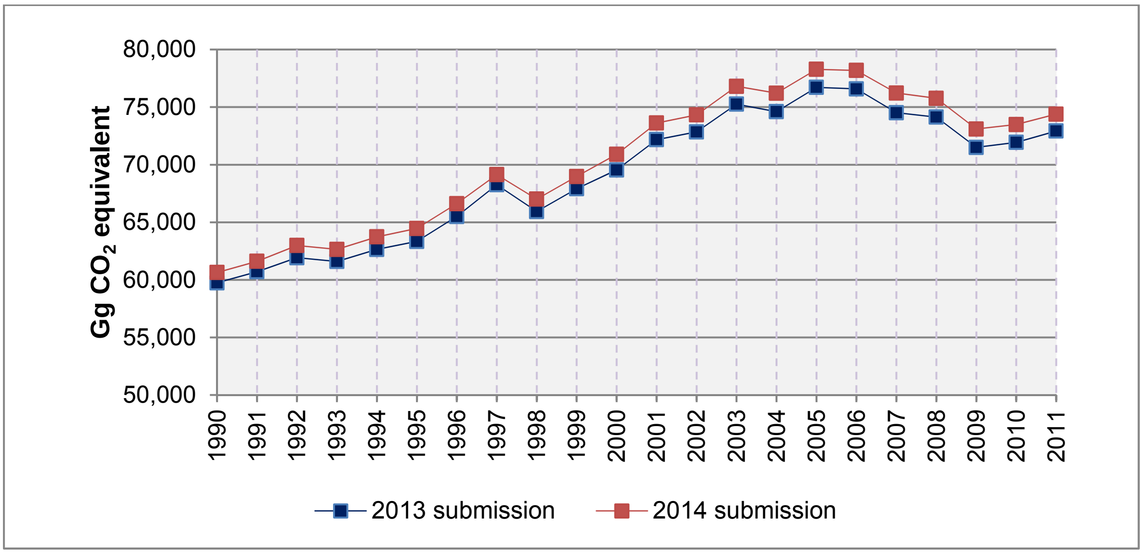
10.1 Implications and justifications

The effect of recalculations on New Zealand's total (gross) emissions in the 2014 Inventory submission is shown in figure 10.1.1. There was a 1.5 per cent (895.2 Gg carbon dioxide equivalent (CO_2-e)) increase in total (gross) emissions for the base year, 1990, and a 2.0 per cent (1,470.0 Gg CO_2-e) increase in total emissions for the 2011 year. The effect of recalculations when including the land use, land-use change and forestry (LULUCF sector was a decrease of 26.1 per cent (8,242.5 Gg CO_2-e) in net emissions for the base year, 1990, and a 24.6 per cent (14,584.7 Gg CO_2-e) decrease in net emissions in 2011.

In the 2013 Inventory submission (1990–2011), total (gross) emissions for 2011 were 22.1 per cent above 1990 levels. As a result of the recalculations in the 2014 Inventory submission, total emissions for 2011 were 22.7 per cent above 1990. The greatest influence on recalculations of net emissions was the improvements made in the LULUCF sector.

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 2011



10.1.1 Energy

The improvements made in the Energy sector have resulted in a 0.04 per cent (8.8 Gg CO_2-e) decrease in energy emissions in 1990 and a 0.5 per cent (168.1 Gg CO_2-e) increase in energy emissions in 2011 (figure 10.1.2). The most significant contribution to this recalculation was a review of carbon dioxide emission factors for solid fuels, including public electricity and heat production across the time series from 1990–2012. This is in response to the 2013 expert review team (ERT) recommendation. Values are now calculated by interpolation between 1990 and 2008. For further information on this improvement, see section 3.3.6.

Explanations and justifications for recalculations of New Zealand's energy emission estimates in the 2014 submission are summarised in table 10.1.1.

Figure 10.1.2 Effect of recalculations on New Zealand's Energy sector from 1990 to 2011

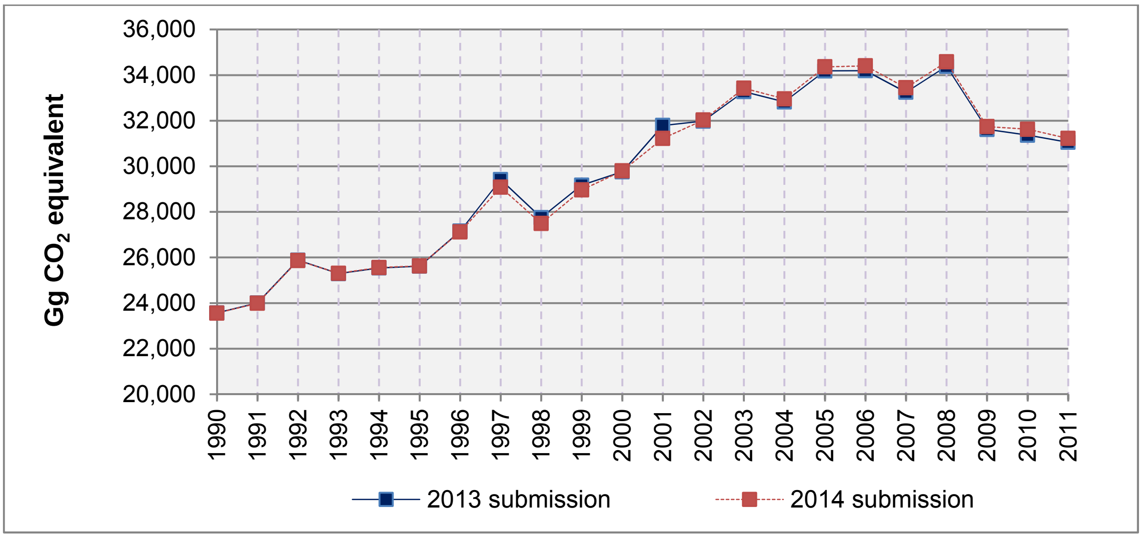


Table 10.1.1 Explanations and justification for recalculations in the Energy sector

Explanation of recalculation	Good practice principle that was improved	Additional information
Following expert review team (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 (2007 in-country review).
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. 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.	Transparency	In response to the 2013 ERT recommendation.
The emission factors for solid fuels have been revised for the entire time series. This is in response to the 2013 ERT recommendation. Values are now calculated by interpolation between 1990 and 2008.	Accuracy	This is in response to the 2013 ERT recommendation.
Production of methanol has been moved from 1.A.2.C Chemicals to 2. Industrial Processes. This is in response to the 2013 ERT recommendation. Natural gas used for production of methanol has been split into feedstock gas, which is included in 2.B.5.5 Methanol, and energy-use gas, which is included in 1.A.2.C Chemicals. Further details are included in Chapter 4 Industrial Processes. The calculation of emissions resulting from combusting of the energy use gas uses default emission factors.	Transparency, accuracy and comparability	This is in response to the 2013 ERT recommendation.
Venting of natural gas has been separated from flaring and included in 1.B.2.C.1 Venting.	Comparability and transparency	This is in response to the 2013 ERT recommendation.
Emissions of nitrous oxide as a result of flaring have been included and are now aligned with the IPCC 1996 reporting methodology.	Completeness	This is in response to the 2013 ERT recommendation.
The previous submission included all feedstock and flared gas under 1.AB as carbon stored. This was done as an attempt to balance the reference and sectoral approaches. This submission only reports carbon that is stored in products under 1.AB as carbon stored.	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes.
Fugitive emissions from industrial plants have been revised to include both energy-use and non-energy-use gas.	Accuracy	This is in response to the 2013 ERT recommendation.

Explanation of recalculation	Good practice principle that was improved	Additional information
Activity data for international bunkers have been aligned to a more consistent data source. See section 3.2.2 for more detailed explanation	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 3.9 per cent (130.8 Gg CO_2-e) decrease in industrial processes emissions in 1990 and a 2.9 per cent (160.5 Gg CO_2-e) decrease in industrial processes emissions in 2011. The overall effect of recalculations on the Industrial Processes sector from 1990 to 2011 is presented in figure 10.1.3.

The improvement that had the largest impact on emissions in the 2011 year was the improvement made to the activity data reported for the ammonia and urea category under 2.B Chemical Industry (see section 4.3.5 for further information). Other improvements are summarised in table 10.1.2 below.

Figure 10.1.3 Effect of recalculations on the Industrial Processes sector from 1990 to 2011

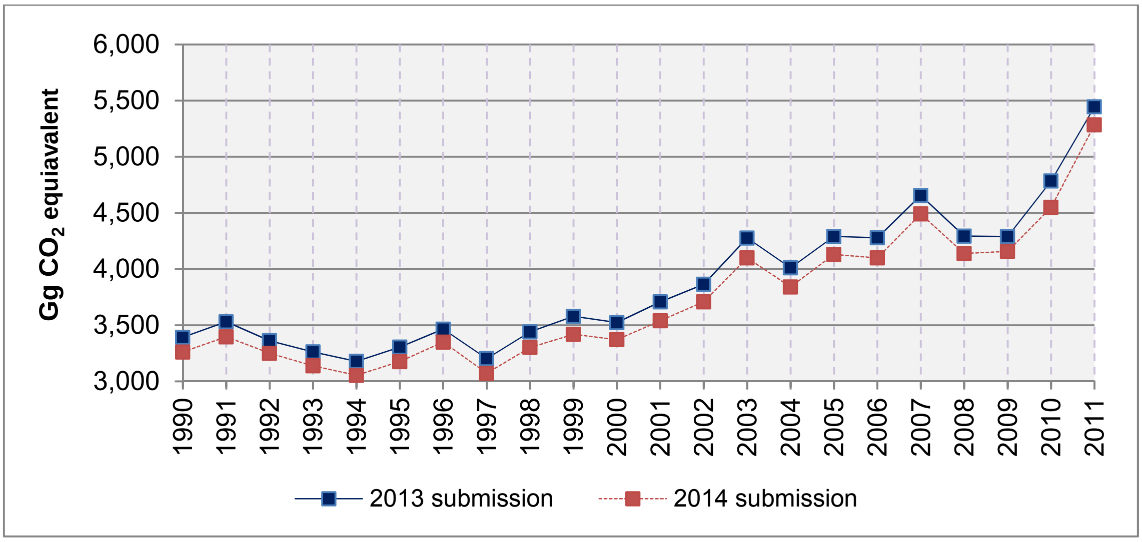


Table 10.1.2 Explanations and justifications for recalculations of New Zealand's previous industrial processes estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Activity data for methanol production reported under 2.B Chemical Industry	Accuracy and transparency	Data now published by industry so no longer regarded as confidential
Revised the activity data time series for ammonia and urea category under 2.B Chemical Industry. Natural gas used for production of ammonia/urea has been split into feedstock gas, which is included in the Industrial Processes sector, and energy-use gas, which is included in the Energy sector. See section 4.3.5 for further detail.	Accuracy and transparency	Correction identified and resolved through quality-assurance and quality-control processes.
Error corrected by New Zealand Steel Ltd in the calculation of emissions from Iron and Steel category. See section 4.4.5 for further detail.	Accuracy	Improved information from industry.

Explanation of recalculation	Good practice principle that was improved	Additional justification
Error corrected by Pacific Steel Ltd in the calculation of emissions from Iron and Steel category. See section 4.4.5 for further detail.	Accuracy	Improved information from industry.
Error corrected provided by Fisher and Paykel in the estimation of emissions associated with HFC-134a imports. See section 4.7.5 for further detail.	Accuracy	Improved information from industry.
Inclusion of a third major importer of fire protection equipment has resulted in increase in HFC-227ea activity data. See section 4.7.5 for further detail.	Accuracy and completeness	Correction provided by contractor.
Revision of sulphur hexafluoride nameplate capacity of electrical equipment. See section 4.7.5 for further detail.	Accuracy	Correction identified and resolved through quality assurance and quality-control processes.

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 0.7 per cent (212.6 Gg CO_2-e) decrease in agricultural emissions in 1990 and a 0.6 per cent (198.4 Gg CO_2-e) decrease in agricultural emissions in 2011 (figure 10.1.4). 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 the Agriculture sector from 1990 to 2011

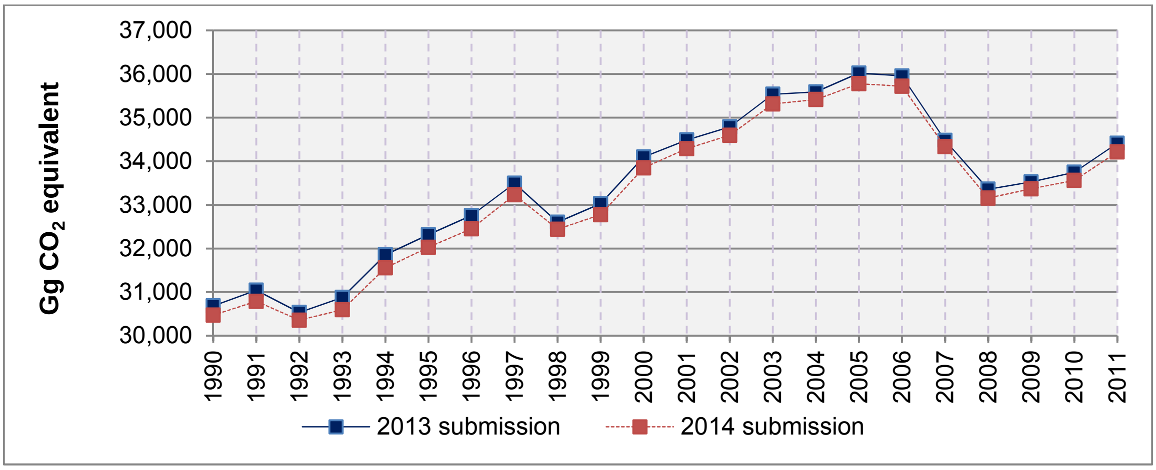


Table 10.1.3 Explanations and justifications for recalculations of New Zealand's previous agriculture estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
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.
Revised the equation to partition nitrogen in excreta between dung and urine. Nitrogen in dung and urine has different emission factors so direct nitrous oxide emissions from pasture, range and	Transparency, accuracy and consistency	ERT recommendation and new equation available.

Explanation of recalculation	Good practice principle that was improved	Additional justification
paddock were recalculated.		
Reductions in nitrous oxide emissions from atmospheric deposition from the application of urease inhibitors 2001 to 2011. Commensurate increase in direct emissions from synthetic fertiliser. Refer to section 6.5.5 for further details.	Transparency, accuracy and consistency	Improvement plan and inclusion of mitigation technology into the inventory.
Updated data for 2011. Provisional 2012 data was replaced with final 2012 data. Revised data on herbage seed from Plant and Food Research became available for 2004 to 2011.	Accuracy and consistency	Improved data is available.
Correction to goat enteric fermentation emission factor. Refer to section 6.2.5 for further details.	Accuracy and consistency	Correction identified and resolved through quality-assurance and quality-control processes.
Revision to milk yield in small regions (Nelson and Gisborne). Refer to section 6.2.5 for further details.	Consistency, accuracy and transparency	Improvement identified and resolved through quality-assurance and quality-control processes.
Revision to monthly proportions of annual milk data produced for dairy cattle.	Consistency, accuracy and transparency	New data available.

10.1.5 Land use, land-use change and forestry

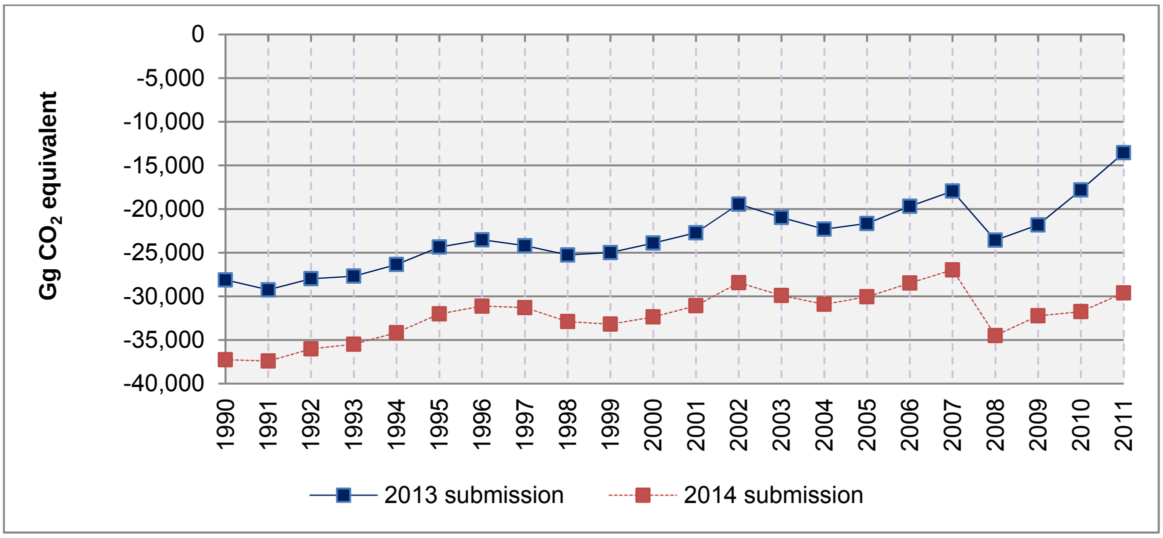
Improvements made to the LULUCF sector have resulted in a 32.5 per cent (9,137.7 Gg CO_2-e) increase in net LULUCF removals in 1990 and a 118.6 per cent (16,054.7 Gg CO_2-e) increase in net LULUCF removals in 2011 (figure 10.1.5). These recalculations are the result of a fifth year of significant enhancements to the LULUCF inventory following the introduction in the 2010 Inventory submission of a new data collection and modelling programme for the New Zealand LULUCF sector – the Land Use and Carbon Analysis System (LUCAS).

In this 2014 Inventory submission, significant improvements include:

- the introduction of estimates of carbon stock change in natural forests following re-measurement of the natural forest plot network
- a change to modelling of the net planted forest area to improve alignment with the activity data
- use of data from the re-measurement of the post-1989 planted forest to refine the post-1989 planted forest yield table
- incorporation of new activity data including changes to previous maps to maintain time-series consistency with the 2012 land-use map
- a return to a Tier 2 methodology for estimating change in mineral soil carbon stocks
- revision of the estimates for biomass burning so the amount of biomass burnt aligns with the revised yield tables.

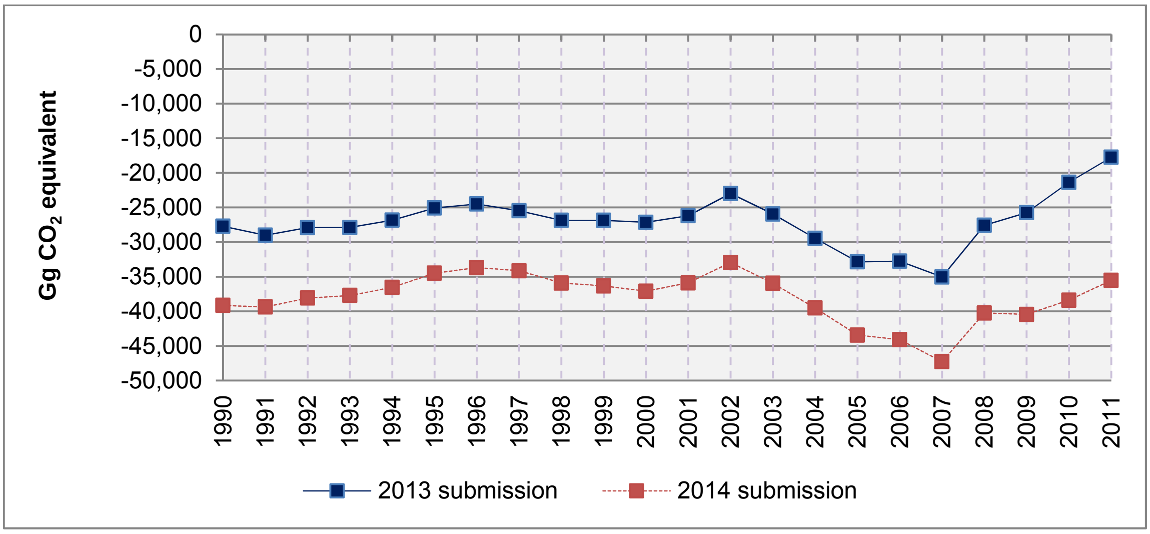
Further details on these changes are in chapter 7. The effect of recalculations on emissions and removals in the forest land and grassland categories are shown in figures 10.1.6 and 10.1.7. The explanations and justifications for the major recalculations to New Zealand's LULUCF estimates in the 2014 Inventory 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 2011



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 2011



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 2011

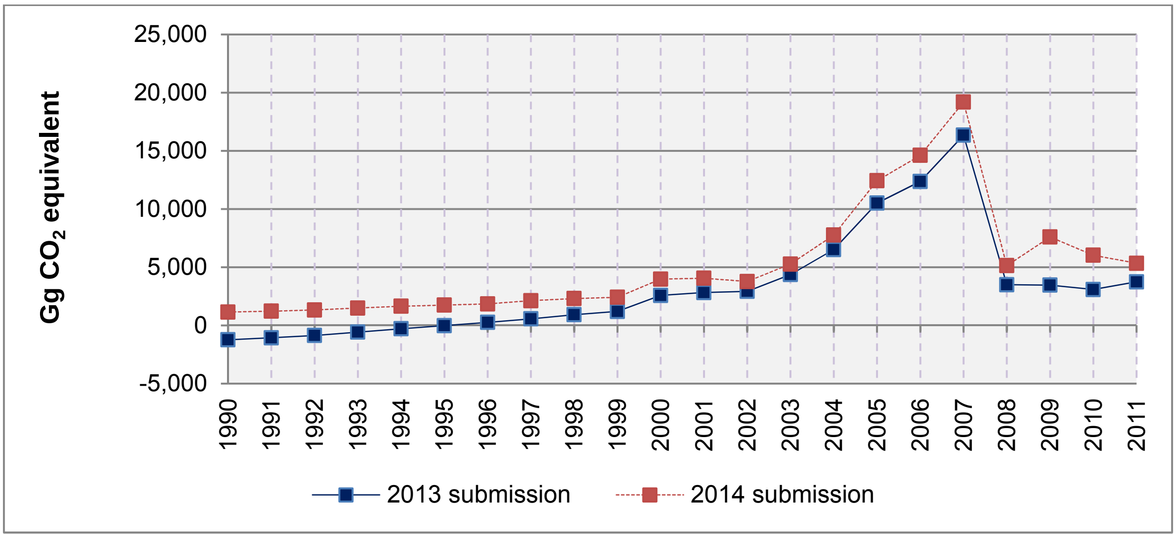


Table 10.1.4 Explanations and justifications for recalculations of New Zealand's previous LULUCF estimates

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 information from the process of creating the 2012 land-use map, New Zealand Emissions Trading Scheme, field visits and notified errors. Additional data has been received for the extent of perennial cropland, and soil and climate factors that could limit forest regeneration. These improvements have been incorporated for the entire time series to maintain consistency in reporting.	Accuracy and consistency	Key category improvement (land converted to forest land; land converted to grassland).
The incorporation of re-measured and additional plots in the development of the post-1989 planted forest yield table.	Accuracy	Key category improvement (land converted to forest land).
The inclusion of estimates for post-1989 natural forest for the first time.	Accuracy	Key category improvement (land converted to forest land).
The stratification and modelling of the net planted forest area for better alignment with the harvesting and new planting activity data derived from a different source. See section 7.4.2 for further details.	Accuracy and consistency	Key category improvement (land converted to forest land, forest land remaining forest land).
Amendment to harvest methodology to allow the model to run with the correct area of harvesting.	Accuracy	Key category improvement (forest land remaining forest land; land converted to forest land).
Stratification of the area of grassland with woody biomass area to better reflect the types of vegetation included in this sub-category.	Accuracy	Key category improvement (land converted to grassland, and grassland remaining grassland).
Removal of the land-use area threshold for calculating emissions when total area of change between categories was less than 100 hectares between 1990 and 2007, resulting in an increase in the area of change.	Accuracy, consistency and transparency	

10.1.6 Waste

The methodological improvements made in the Waste sector have resulted in a 60.6 per cent (1,247.4 Gg CO_2-e) increase in calculated waste emissions in 1990 and a 83.6 per cent (1,660.8 Gg CO_2-e) increase in waste emissions in 2011 (figure 10.1.8). The overall increase was largely due to the inclusion of emissions from non-municipal and farm fills. Other recalculations are provided in table 10.1.5.

Figure 10.1.8 Effect of recalculations on the Waste sector from 1990 to 2011

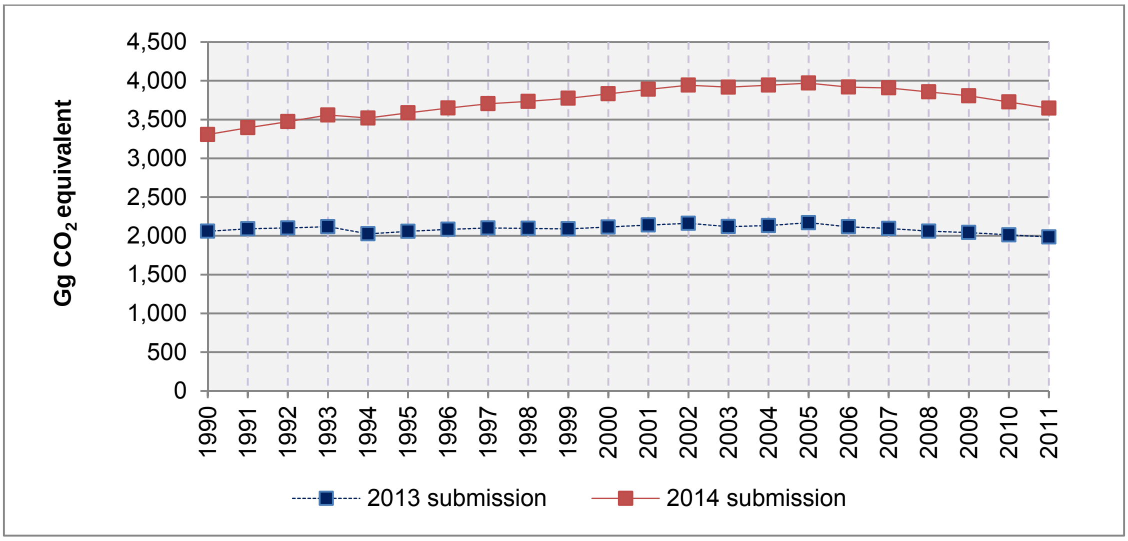


Table 10.1.5 Explanations and justifications for recalculations of New Zealand's previous waste estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Updating waste composition at municipal solid waste disposal sites.	Accuracy and comparability	Updated information on the composition of waste at municipal solid waste disposal sites is available.
Improving the wastewater emissions calculations for the pulp and paper, wine, and wool scouring industries.	Accuracy and comparability	Providing more accurate information on the industrial wastewater sector.
Improving the historic waste placement activity data, waste management activities and incorporating the more accurate and regular placement data from the Waste Minimisation Act 2008.	Accuracy and comparability	Some parameters updated based on expert review team recommendations. Other parameters updated to provide more accurate estimates on the solid waste disposal to land sector.
Including emissions from non-municipal landfills and farm fills.	Accuracy and completeness	Providing more complete information on the solid waste disposal to land sector.

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 2013 Inventory 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
Improvements to the accuracy of the 1990 and 2008 land-use maps based on the process of creating the 2012 land-use map, information from the New Zealand Emissions Trading Scheme, field visits and notified errors. Additional data has been received for the extent of perennial cropland and soil and climate factors that could limit forest regeneration. These improvements have been incorporated for the entire time series to maintain consistency in reporting.	Accuracy and consistency	Key category improvement (Afforestation/reforestation and Deforestation).
The incorporation of re-measured and additional plots in the development of the post-1989 planted forest yield table.	Accuracy	Key category improvement (Afforestation/reforestation).
The inclusion of estimates for post-1989 natural forest for the first time.	Accuracy	Key category improvement (Afforestation/reforestation).
The modelling of the net planted forest area for better alignment with the new planting activity data derived from a different source. See section 7.4.2 for further details.	Accuracy and consistency	Key category improvement (Afforestation/reforestation).
Error correction to the methodology used to estimate emissions under afforestation – forest land harvested since the beginning of the commitment period was under reported.	Accuracy, transparency and completeness	Allows proper application of the ARDC rule within Kyoto Protocol accounting.

Table 10.1.7 Impact of the recalculations of New Zealand's net removals under Article 3.3 of the Kyoto Protocol in 2011

Activity under Article 3.3 of the Kyoto Protocol	2011 net emissions (Gg CO_2-e) 2013 submission	2011 net emissions (Gg CO_2-e) 2014 submission	Change from 2013 submission (%)
Afforestation/reforestation	–18,440.1	–18,575.7	0.7
Forest land not harvested since the beginning of the commitment period	–18,551.5	–18,828.8	1.5
Forest land harvested since the beginning of the commitment period	111.4	253.1	127.1
Deforestation since the beginning of the commitment period	1,674.6	3,376.0	101.6
Total	–16,765.5	–15,199.7	–9.3

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 2011 activity data under Article 3.3 of the Kyoto Protocol

Activity under Article 3.3 of the Kyoto Protocol	2011 areas (ha)		Change from 2013 submission (%)
	2013 submission	2014 submission	
Afforestation/reforestation	599,269	642,449	7.2
Forest land not harvested since the beginning of the commitment period	596,869	636,765	6.7
New planting	12,000	13,692	14.1
Forest land harvested since the beginning of the commitment period	2,400	5,684	136.8
Deforestation	3,700	6,127	65.6
Natural forest	700	853	21.8
Pre-1990 planted forest	1,500	4,182	178.8
Post-1989 forest	1,500	1,092	–27.2

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 2012 Inventory submission (UNFCCC, 2013) and New Zealand's responses are included below in table 10.2.1. There were no recommendations made for Solvent and Other Product Use sector. The ERT report for the 2013 Inventory 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 New Zealand's 2012 Inventory submission

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
Energy	Para (30b): The expert review team (ERT) recommended that New Zealand provide additional explanations for the recalculation for natural gas, including reallocations between categories, in its next annual submission.	**Completed.** New Zealand provided this information in 2013 Inventory submission under section 3.3 Fuel Consumption: Gaseous fuels.
Energy	Para 30f. The ERT recommended New Zealand improves the transparency of the information on the recalculations for agriculture/forestry/fisheries.	**Completed.** New Zealand provided this information in the 2013 Inventory submission, section 3.3.2 Fuel combustion: Manufacturing industries and construction under the subsection Liquid fuels (diesel, gasoline and fuel oil).
Energy	Para 37. Enhance the quality assurance and quality control procedures for the Energy sector and address the inconsistencies identified.	**Completed.** New Zealand addressed this response in the 2013 Inventory submission, chapter 10 and chapter 13.
Energy	Para 38. Review the carbon dioxide (CO_2) emission factor (EF) for solid fuels and report the findings.	**Work in progress.** This will be implemented in future submissions. Note that the EF for solid fuels is well within the IPCC range and is only 2 per cent below the IPCC medium.
Energy – Comparison of the reference approach with the	Para 39. Include additional information on the comparison of the reference and sectoral approaches when venting and	**Completed.** New Zealand provided this information in the 2013 Inventory submission, section 3.2.5.

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
sectoral approach	flaring are excluded from the reference approach.	
Energy – Comparison of the reference approach with the sectoral approach	Para 40. Disaggregate liquefied petroleum gas from natural gas liquids.	**Work in progress.** New Zealand will provide further information in the future Inventory submissions.
Energy – International bunker fuels	Para 41. Improve the transparency of the information on domestic civil aviation and international aviation.	**Completed.** New Zealand provided this information in the 2013 Inventory submission.
Energy – International bunker fuels	Para 43. Address the inconsistency in the reporting of the consumption of jet kerosene	**Completed.** New Zealand provided this information in the 2013 Inventory submission.
Energy – International bunker fuels	Para 44. Correct the CH_4 EF and the source of the value for jet kerosene used for international aviation, correct the reference to the source of the value and recalculate the associated emissions.	**Completed.** New Zealand provided this information in the 2013 Inventory submission.
Energy – Feedstocks and non-energy use of fuels	Para 45. Improve the consistency of the information on methanol production.	**Completed.** In this 2014 Inventory submission, New Zealand included the split of the natural gas inputs into the feedstocks (reported in the Industrial Processes sector) and fuel (reported in the Energy sector).
Energy	Para 46. Improve the transparency of the information on the CO_2 and CH_4 EFs used for geothermal energy and on the consistency of the time series, and reassess the country-specific unique emission factor when more data becomes available.	**Work in progress.** New Zealand will report the information when more data becomes available in the future Inventory submissions.
Energy – Stationary combustion: solid and gaseous fuels – CO_2	Para 48. Include additional information on the revision of the activity data (AD) for natural gas.	**Completed.** New Zealand provided this information in the 2013 Inventory submission.
Energy – Stationary combustion: solid and gaseous fuels – CO_2	Para 49. Include additional information on how the CO_2 EFs used for solid fuels were calculated and the applicability of total solid fuels used in New Zealand across the entire time series.	**Work in progress.** New Zealand will report the information when more data becomes available in the future Inventory submissions.
Energy – Road transportation: liquid fuels – all gases	Para 36 & 50. Address the inconsistency in the values of the CO2 EF for diesel oil reported in the national inventory report (NIR).	**Completed.** New Zealand provided this information in the 2013 Inventory submission.
Energy – Road transportation: liquid fuels – all gases	Para 51 & 52. Include additional information on the recalculation in the 2010 annual submission due to the double counting of fuels sold by resellers.	**Completed.** New Zealand provided information in the 2013 Inventory submission, see 1.A.3.B
Energy – oil and natural gas – CO_2 and CH_4	Para 53: Report emissions from venting and flaring separately.	**Completed.** New Zealand provided information in the 2013 Inventory submission.
Energy – Manufacturing industries and construction: biogas – CH_4 and nitrous oxide (N_2O)	Para 54: Report estimates of CH_4 and N_2O emissions resulting from the use of biogas recovered from the treatment of wastewater from a dairy plant.	**Completed.** New Zealand provided information in the 2013 Inventory submission.
Industrial Processes and Solvent and Other	Para 60: Improve the transparency of the information provided on	**Work in progress:** New Zealand will keep working with the industry to continue to improve the transparency of its reporting in

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
Product Use – overall	categories considered confidential.	future submissions, while maintaining the confidentiality of sensitive data.
Industrial Processes and Solvent and Other Product Use – Consumption of halocarbons and sulphur hexafluoride – hydrofluorocarbons and perfluorocarbons (PFCs)	Para 69: Include additional information on PFC emissions from refrigeration and air-conditioning equipment.	**Completed.** New Zealand provided information in the 2013 Inventory submission.
Industrial Processes and Solvent and Other Product Use – other (chemical industry) – CO_2 and CH_4	Para 70 & 71: Report additional information on how emissions for methanol production are estimated, and continue to work with the producer to resolve the confidentiality issues.	**Completed.** New Zealand has included the required information in this 2014 Inventory submission.
Agriculture – Overview	Para 77: Include more information on the digestibility of cattle feed.	**Work in progress.** New Zealand will continue to work to improve the transparency of its reporting in future submissions.
Agriculture – prescribed burning of savanna – CH_4 and N_2O	Para 83: Explain how the time series 1990–2010 is consistent.	**Completed.** New Zealand provided information in the 2013 Inventory submissions.
Land Use, Land-Use Change and Forestry (LULUCF)	Para 88: New Zealand estimated all of the emissions from the conversion of natural forest to grassland, wetlands, settlements and other land using the biomass carbon stock value before conversion of 173 tonnes carbon (C)/ha through to the year 2007 (NIR table 7.1.4). For 2008 onward, the Party disaggregated the natural forest into shrub and tall forests, assuming carbon stocks of 57.1 tonnes C/ha and 217.9 tonnes C/ha, respectively. However, the Party has not applied the same disaggregation to the conversion of natural forest prior to 2008. The ERT recommends that the Party ensures a consistent time series and, if appropriate, recalculates the emission estimates for this conversion in the next annual submission.	**Completed.** In this 2014 Inventory submission, New Zealand applies the same methodology and disaggregation to all natural forest conversions back to 1990 to improve consistency of the time series.
LULUCF	Para 92: New Zealand estimated the changes in carbon stock in mineral and organic soils for forest land, cropland and grassland using a Tier 1 method. For most of the country a classification by soil type and climate zone was possible. However, for some areas (around the margins of mainland New Zealand and offshore islands), data were not available and the attributes of neighbouring areas were used to fill the data gaps. The ERT agrees with the approach used. However, for islands not touching mainland New Zealand for which the climate and soil types were unknown, emissions from mineral soils were not estimated. Although the total	**Not complete.** With the change to using a Tier 2 model approach for modelling soils for the 2014 submission, estimation of climate and soil types is no longer needed. Using the Tier 2 model, the country-specific soil carbon stock values are applied to all New Zealand so reporting now includes these small islands (there is now complete coverage).

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
	area of such islands is small (around 109 kha, representing 0.0004 per cent of the total area of the country), the ERT recommends that the Party uses proxy variables, such as vegetation cover and meteorological data, to classify the islands' climate and soil types and report carbon stock changes in soils for the islands in order to improve the geographical completeness of the reporting in its next annual submission.	
LULUCF	Para 93: Soils modelling. The ERT commends the Party for its efforts to acquire additional data in order to make the model results more robust and encourages New Zealand to apply the revised Tier 2 model for its next annual submission, as planned.	**Completed.** New Zealand has applied the results of the revised Tier 2 model in this submission.
LULUCF	Para 94: New Zealand has developed an average reference soil organic carbon stock based on the areas of the soil and climate classification and the default reference values in the Intergovernmental Panel on Climate Change (IPCC) good practice guidance for LULUCF. Only 5 per cent of soils were not included in the estimates. Additionally, the Party included estuarine soils, for which the IPCC good practice guidance for LULUCF does not provide a default reference value. Although the ERT agrees with the approach used to develop an average reference value (92.59 tonnes C/ha) for mineral soils, it noted that it would be more precise to use the specific reference values for each soil type and climate zone than the average. Considering that the country already uses geographic information systems that could facilitate the integration of different databases, the ERT encourages the Party to use the specific reference values instead of the average reference value for its next annual submission.	**Completed.** This encouragement relates to use of the Tier 1 approach. With the change to using a Tier 2 model approach for modelling soils for the 2014 submission this encouragement is no longer relevant.
LULUCF	Para 95: Uncertainties. The ERT recommends that the Party provides, in its next annual submission, a detailed, disaggregated assessment of uncertainty, as well as the aggregated uncertainty associated with the LULUCF sector, consistent with the IPCC good practice guidance for LULUCF.	**Completed.** This additional information has been provided in annex 3.2.1.
LULUCF	Para 98: The ERT strongly recommends that New Zealand provides estimates of changes in carbon stock in natural forest for forest land remaining forest land in	**Completed.** New Zealand is now reporting carbon stock change estimates in natural forest for the first time. See section 7.4.

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
	its next annual submission, even if they are based on the analysis of a sample from the full set of permanent plots to be updated at a later date, in order to improve completeness.	
LULUCF	Para 99: In the previous review report it was recommended that the Party presents more information on the subcategory natural forest (conversion) to pre-1990 planted forest and on the methods applied to estimate carbon stock changes. Although some additional information has been provided in the Party's 2012 annual submission, the ERT reiterates the recommendation made in the previous review report that the Party include, in the NIR of its next annual submission, additional explanations for any large variations in the time series, in order to improve the transparency of the reporting.	**Completed.** New Zealand has included additional information on the subcategory natural forest (conversion) to pre-1990 planted forest and on the methods applied to estimate carbon stock changes, in this submission. See section 7.4.2.
LULUCF	Para 100: For the carbon stock in all biomass pools for grassland with woody vegetation, the Party used a value (29 tonnes C/ha, reported in NIR table 7.1.4, page 175, provided by a single reference 12) which the ERT considers to be high for a temperate region. The ERT recommends that the Party reviews the estimated carbon stock changes for grassland with woody vegetation for its next annual submission, or provides additional references to support the value used, even if they are for countries with similar conditions.	**Completed.** As discussed in section 7.6 New Zealand now uses the carbon stock figure for all biomass pools of grassland with woody biomass. This is based on sample plots. It should also be noted that 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) This means the grassland with woody biomass subcategory contains some areas that other temperate countries using a wider definition of forest would include as forest land.
LULUCF	Para 101: The Party has provided estimates of carbon stock change in the dead organic matter pool for grassland with woody biomass. The ERT commends the Party for providing those estimates and recommends that the Party reports, in the documentation box of the appropriate common reporting format (CRF) table in its next annual submission, that the Tier 1 assumption of no change in carbon stock has been made.	**Completed.** For grassland remaining grassland New Zealand has reported this information in the documentation box of the appropriate CRF table in this submission. Where there is land-use change to grassland with woody biomass dead organic matter emissions are included in the CRF tables.
LULUCF	Para 102: The ERT considered that the annual biomass growth for grassland with woody biomass (1.04 tonnes C/ha/year, reported in NIR table 7.1.4) seemed high for a temperate climate zone and for the 28-year cycle assumed by New Zealand. In response to a question raised by the ERT during the review, the Party clarified that there were no references available	**Completed.** Further work has been completed for grassland with woody biomass. This has involved splitting the subcategory into land that is transitional and land that is more permanently grassland with woody biomass (usually due to environmental factors). Using data from the plot network, the annual biomass growth factors for each type of grassland with woody biomass have been estimated. These values and more detail on the methodology are provided in section 7.6.1

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
	to support the value in addition to the one reported in the NIR, which was published in 2004. The ERT recommends that the Party clarifies, in its next annual submission, that the annual estimate of biomass growth for grassland has been adjusted to take into account the 28-year cycle by including the estimate of carbon stock derived from the aforementioned 2004 publication, and that it clarify the meaning of "all biomass pools" mentioned in NIR table 7.1.4.	and 7.6.2. A note defining 'all biomass pools' has been added under NIR tables 7.1.4 and 7.1.5.
LULUCF	Para 103: The ERT noted that the carbon stock in perennial crops reported by the Party is country specific and based on a single reference. The ERT also noted that table 3.3.6 from the IPCC good practice guidance for LULUCF indicates that, for a Tier 2 method, at least some country-specific carbon stock parameters to estimate carbon stock changes from land use conversion to cropland should be used. The ERT thus encourages New Zealand to seek to increase the number of country-specific references on this issue to be more in line with the IPCC good practice guidance for LULUCF.	**Not complete.** In sections 7.5.2 and 7.5.4, New Zealand has provided additional explanation of why a country-specific value for perennial cropland is used instead of using the Tier 1 emission factor provided in the Good Practice Guidance for LULUCF. The IPCC default value is based on just four studies of agroforestry systems where crops are grown in rotation with trees, and none of these are New Zealand specific. The country-specific emission factor used is based on a New Zealand study that takes into account New Zealand's main perennial crops are not grown in rotation with trees (are not part of an agroforestry system) and that New Zealand's main perennial crops are vine fruit (ie, kiwifruit and grapes). These crop types have lower carbon content per area in living biomass at maturity than the cropland types included in the study on which the IPCC default value is based. For this reason, New Zealand considers use of country-specific data, even if based on a synthesis of existing data from one research report, is more appropriate than an emission factor based on only four studies worldwide for land types and practices that do not occur in New Zealand.
LULUCF	Para 105: The ERT recommends that the Party clarifies, in the NIR of its next annual submission, how the net annual carbon stock changes for land converted to wetlands were calculated for 1990 to 2009 and, if a 28-year transition period has been assumed, that it continue to report the associated emissions accordingly.	**Completed.** See section 7.7.2.
LULUCF	Para 106: New Zealand has reported in CRF table 5.D the area of land converted to wetlands (3.60 kha), but the corresponding changes in carbon stock for all pools have been reported as 'NO'. The ERT strongly recommends that the Party reports these carbon stock changes in its next annual submission, in order to improve the completeness of the reporting.	**Completed.** Where this land-use change occurs, and methodology for estimating these emissions are provided within Good Practice Guidance for LULUCF, these emissions are now reported in the CRF tables.
LULUCF	Para 107: New Zealand assumed a value of 18.76 tonnes C/ha (0.67 tonnes C/ha/year and 28 years until a steady state) for the above-ground biomass in perennial	**Completed.** New Zealand has added additional information to section 7.5.2 and 7.5.4 of the NIR clarifying that the New Zealand-specific plot-based estimate is based on the types of crops found growing in New

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
	cropland before conversion to other land uses. The ERT noted that this value is substantially lower than the default value in table 3.3.2 of the IPCC good practice guidance for LULUCF for a temperate climate region (63 tonnes C/ha)… The ERT recommends that the Party provides more information about the value used in the Inventory, if possible disaggregated by the main crops indicated by the Party, in its next annual submission.	Zealand (mainly grape and kiwifruit vines). The expected biomass/unit area is lower than the IPCC default because of this. Note the IPCC default for temperate regions is based on only one study on crops grown as part of an agroforestry system so does not reflect New Zealand land management practices.
LULUCF	Para 108: The ERT recommends that the Party includes clarification of the source of the above-ground biomass emission factor for perennial cropland as provided during the review in its next annual submission and provides more information regarding the representativeness of the value used, given the large discrepancy compared with the default value provided by the IPCC.	**Completed.** New Zealand has added additional information to section 7.5.2 and 7.5.4 of the NIR clarifying that the New Zealand-specific plot-based estimate is based on the types of crops found growing in New Zealand (mainly grape and kiwifruit vines). The expected biomass/unit area is lower than the IPCC default because of this. Note the IPCC default for temperate regions is based on only one study on crops grown as part of an agroforestry system so does not reflect New Zealand land management practices.
LULUCF	Para 109: The ERT recommends that the Party provides information in the documentation box of CRF table 5(IV) in its next annual submission on the reporting of the amount of lime for other as 'IE' in CRF table 5(IV), in order to increase the transparency of the reporting.	**Completed.** This information is now included.
LULUCF	Para 110: New Zealand has reported in the NIR that emissions from controlled burning on land converted to grassland have not been reported owing to a lack of information on the proportion of land burned during that conversion. The ERT commends the Party for its efforts to continuously improve its reporting and strongly recommends that estimates of emissions from all sources currently not reported, even if such emissions are at a low level, be provided in its next annual submission. The ERT also recommends that the Party continues the investigation to identify whether controlled burning occurs on forest land remaining forest land, in order to increase the accuracy of its reporting.	**Completed.** New Zealand has provided estimates for controlled burning associated with land converted to grassland. See section 7.10.5.
Waste – solid waste disposal on land – CH_4	Para 120: Justify why a linear interpolation between 1995 and 2004 is appropriate or conduct additional surveys to collect more information on waste composition between 1995 and 2004 and outside the time period 1995–2004, and improve the degradable organic carbon (DOC) values.	**Completed.** In this submission, the 2008 waste composition estimate has been revised and a 2012 estimate has been included. There have been minor revisions to historic compositions to reflect the trend in nappy disposal. The food and garden categories, which were previously grouped by New Zealand, are now reported as separate categories. New Zealand investigated obtaining further waste composition information between the period 1995 and 2004. There was insufficient information to

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
		include additional estimates.
Kyoto Protocol land use, land-use change and forestry sector (KP-LULUCF)	Para 129: New Zealand has not provided estimates of non-CO_2 emissions from controlled burning and wildfires on land subject to deforestation activities under Article 3, paragraph 3, of the Kyoto Protocol, owing to lack of data. In the previous review report, it was recommended that the Party applies the IPCC Tier 1 method to estimate and report such emissions in its 2012 annual submission. New Zealand, however, has reported in the NIR that it is searching for possible sources of information to allow the reporting of the emissions in a future annual submission. The ERT reiterates the recommendation made in the previous review report that the Party reports estimates of the emissions concerned in its next annual submission and provides in the NIR additional information on potential future improvements.	**Completed.** New Zealand has provided estimates for controlled burning associated with deforestation. See section 7.10.5.
KP-LULUCF	Para 135: The ERT commends the Party for its efforts and reiterates the recommendation made in previous review reports that the Party provides in its next annual submission more transparent information on how it will avoid the potential underestimation of deforestation at the end of the first commitment period.	**Completed.** New Zealand has provided this additional information in sections 7.2.2 and 11.4 of this submission.
KP-LULUCF	Para 137: For its 2012 annual submission, the Party modified the deforestation mapping, classifying destocked land into harvested, deforested and awaiting (areas that cannot be classified as harvested or deforested because there is no clear evidence)… New Zealand indicated that there is insufficient data to estimate the total awaiting area at present but that it will continue its efforts to provide a complete estimate in its 2014 annual submission. The ERT commends the Party for its efforts to provide this information and recommends that the Party reports any updates in its next annual submission.	**Completed.** New Zealand has provided this additional information in sections 7.2.2 and 11.4 of this submission.
Waste – solid waste disposal on land – methane (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 New Zealand Emissions Trading Scheme 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	**Completed.** Activity data is included in this 2014 Inventory submission.

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
	the wine and wool scouring industries.	

Since the receipt of the report for the 2013 Inventory submission (UNFCCC, 2014) on 4 March 2014, New Zealand has made progress to address those recommendations from the expert review team for the 2013 Inventory submission. Table 10.2.2 depicts additional information on improvements progress made from the recommendations of the expert review team for the 2013 Inventory submission.

Table 10.2.2 New Zealand's response to expert review team recommendations from the individual review of New Zealand's 2013 Inventory submission

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
Energy - Sector Overview	Para 23. Include more background information on each recalculation with a view to enhancing the transparency of the GHG inventory.	**Completed.** Recalculation explanations have been entered into the 2014 CRF tables where applicable.
Energy - Comparison of reference and sectoral approach	Para 26. Apply greater rigour in its investigation of underlying reasons for the differences over the time series, especially for the later years when it is greater than 2.0 per cent.	**Completed.** New Zealand has undertaken a systematic and rigorous investigation into differences between the reference and sectoral approaches. Explanations of differences have been reported in the 2014 Inventory submission. Sources of differences that can be easily quantified have been hypothetically added to the sectoral approach for a more accurate and useful comparison with the reference approach.
Energy - International bunker fuels	Para 29. Addresses the inconsistency between CRF table 1.A (b) and table 1.C	**Completed.** This is addressed in section 3.2.2 of the 2014 Inventory submission, and also in section 3.3.8 of the 2014 Inventory submission.
Energy - feedstock and non-energy use of fuels	Para 31. Clarity where emissions from methanol production are reported.	**Completed.** This has been addressed and the reporting of emissions from methanol production now follows IPCC guidelines.
Energy - Stationary combustion: solid fuel – CO_2	Para 32. Investigate the appropriateness of the 2007 EF for use in the earlier years of the inventory time series, and report thereon	**Completed.** The emissions factors for solid fuels have been revised for the time series 1990-2007. Values are now calculated by interpolation between 1990 and 2008.
Energy - Oil and natural gas – CO_2, CH_4	Para 34. Report estimates of emissions from venting and flaring separately. Para 34. Report estimates of emissions from oil exploration and production and natural gas exploration and production/processing.	**Completed.** New Zealand has included this information in the 2014 Inventory submission.
	Para 35. Include background information on the methodologies used to calculate emissions from natural gas distribution, transmission and storage.	**Completed.** New Zealand has included this information in the 2014 Inventory submission.
Energy - Navigation: liquid fuels – CO_2, CH_4, N_2O	Para 37. Clarify the text in the NIR regarding the collection of data for marine diesel use in domestic navigation.	**Completed.** This has been clarified in section 3.3.8 of the 2014 Inventory submission.
Energy - Oil and Natural Gas – N_2O	Para 38. New Zealand includes information on the revised estimates in its next annual	**Completed.** This is reported in section 3.2.7 of the Inventory submission. Emissions of N_2O as a result of flaring have been included and are now aligned with the 1996 IPCC

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
	submission.	Guidelines methodologies.
Industrial processes and solvent and other product use – General	Para 40. Continue efforts to improve the transparency of its reporting by providing more detailed information in the NIR, while maintaining the confidentiality of the sensitive data.	**Work in Progress.** This submission reports activity data for methanol, and improvements have been made for ammonia. Other improvements are under review.
Industrial processes and solvent and other product use – Soda ash use – CO_2	Para 41. Report AD for the use of soda ash and assess whether it is necessary to report the AD for limestone use as confidential, noting its multiple uses and ability to calculate the AD from the known CO_2 EF.	**Work in Progress.** Under review (see para 42 below).
	Para 42. Include detailed information and methodological descriptions on how plant-specific data are estimated. Such information can include frequency of measurements, source streams considered and uncertainty tolerance for measurements of different parameters.	**Work in Progress.** This methodological information, as well as activity data for limestone and other inputs and types of lime produced, is not reported annually by NZ ETS participants. Ongoing audits carried out under the ETS will provide improved data over time. In addition, the inventory agency will continue to work with industry to improve the documentation.
Industrial processes and solvent and other product use – Consumption of halocarbons and SF_6 – HFCs and PFCs	Para 43. Consider the guidance on reporting of background information provided in the IPCC good practice guidance for all subcategories and report accordingly in the NIR,	**Work in Progress.**
	Para 44. Try to obtain the information necessary to calculate actual emissions.	**Work in Progress.** Currently New Zealand considers that adequate data is unlikely to be available.
	Para 45. Improve QC activities to identify completeness problems in its inventory submission.	**Work in Progress.** Ongoing improvements will address this in future submissions, including better documentation of QC activities in this sector.
Industrial processes and solvent and other product use – Lime production CO_2	Para 46. Report on the results of the work to disaggregate the types of lime produced by the three lime production companies (i.e. hydrated vs. non-hydrated) and revise the whole time series for lime production if appropriate.	**Work in Progress.** (See response to para 42 above).
	Para 47. Reassess the uncertainty value assigned to lime production.	**Work in Progress.** The uncertainty value for the minerals category as a whole has been recalculated in this submission. For future submissions the possibility of non-market lime production will be investigated and this uncertainty will be reviewed again,
Industrial processes and solvent and other product use – Limestone and dolomite use – CO_2	Para 48. Include information on the revised emission estimates and continue to work with industries reporting under the NZ ETS with a view to identifying and resolving methodological differences.	**Work in Progress.** (See response to para 42 above).
	Para 49. Investigate the possibilities of other uses of carbonate in the inventory and consider developing balances of limestone and dolomite (import plus production minus export) to verify that no major uses are not	**Work in Progress.** Investigation to date suggests that there are no other industrial uses of carbonate (or non-market lime production) in New Zealand, and this will be reassessed for future submissions.

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
	accounted for.	
Agriculture – Enteric fermentation – CH_4	Para 55. Provide in the NIR a clear explanation of the reasons for using an EF for emissions from swine that is lower than the IPCC default.	**Completed.** A longer, more detailed explanation regarding the emission factor used for swine has been included in the 2014 Inventory submission in section 6.2.2 as recommended by the 2013 ERT.
	Para 57. Report a summary of the findings from the current project on pasture quality either in future versions of its detailed methodology or in future NIRs and also progress its new research, and report back on progress either in future NIRs or in the detailed methodology with a direct section reference to the information included in the text of future NIRs. Provide a brief summary of how monthly milk production is calculated, including the data source with a comment on data quality of the milk production estimates used in the diary emission model.	**Work in Progress.** There is no current project however a project has been proposed. The proposed project includes collaboration with industry organisations (in beef, sheep, deer and dairy industries), conducting the research over several years and using multiple research organisations. Therefore there will be a lot of administration to get the project started. Given the size of the project and the fact that business case for the project is not just related to climate change the project will take a few years. A report by Bown et al (2013) was finished late in 2013, so the results could not be provided to the 2013 ERT and considered for the 2014 Inventory submission. The Bown et al (2013) report identified there were gaps in national datasets for pasture quality and made recommendations for the proposed project. There were some results from this report such as for dairy pasture quality indicators that could possibly be implemented in the 2015 submission. A graph showing the results for dairy pasture quality (figure 6.3.4) is provided in section 6.2.4 of the 2014 Inventory submission as a source specific QA/QC and verification. The graph shows a good agreement with the values based on expert judgement and used in the model from when the model was originally developed in 2003. Monthly metabolisable energy (ME) and nitrogen content (N%) values from this report, appear robust and may be used for the 2015 submission if approved by the Agriculture Inventory Advisory Panel later in 2014. Additional information about collection of milk production data, quality of milk data, plus a graph of national monthly milk production for 2012, has been included in section 6.1.3 of the 2014 Inventory submission as recommended by the 2013 ERT. Note that additional information for daily yield (kg/day) previously reported by New Zealand in the CRF table 4A is no longer reported and the notation key 'NA' is now used. Daily milk production in New Zealand is not constant and varies throughout the year following a lactation curve where the milk production will peak through during October/November every year. Monthly milk production data are used in the model and have been reported in the NIR. The reporting of a simple average daily values seem to have caused some confusion.
Agriculture – Manure management – N_2O	Para 58. Carry out a thorough QC check of the model code to minimise calculation errors in future submissions.	**Work in Progress.** As was recommended by the 2013 ERT the population models for the other livestock sectors with monthly population estimates were checked (ie non-dairy and

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
		sheep) during the 2013 review week. A correction was made to non-dairy population and resulted in a recalculation (reduction) in emissions from non-dairy cattle. As the error resulted in an overestimate the correction was implemented with the 2014 Inventory submission. Details of the on-going quality control process will be confirmed in future inventories.
	Para 59. Include information on the sources for the ratios used to distribute nitrogen between urine and dung used in the development of the EF for pasture, range, paddock, in the text of the NIR or in an annex, or in the detailed methods document with a direct section reference to the information included in the text of the NIR.	**Work in Progress.** Further to the original recommendation of the 2013 ERT New Zealand has implemented a new equation from a more recent study (Luo & Kelliher 2010) that partitions nitrogen between urine and dung into the modelling for the 2014 Inventory submission. A description of the impact of the recalculation is included under section 6.3.5.Copies of the paper and a briefing are also on the Agriculture Inventory Advisory Panel website. The new equation will also be included in the 2014 update of the detailed methodology document that is released as soon as possible after the inventory is published.
	Para 60. Include access to information on the Australian Feeding Standards algorithms for cattle and sheep to estimate manure management emissions of CH4 and explanations of the difference between the estimates produced by the New Zealand methodology and the IPCC tier 2 methodologies.	**Work in Progress.** The Ministry for Primary Industries is progressively making all reports used for the inventory available on a webpage page provided copyright permits. As recommended by the 2013 ERT the report by Sagger el at (2003) will be included on this webpage.
Agriculture – Direct soil emissions – N_2O	Para 61. Include greater detail in the NIR on the derivation of the national EF.	**Completed.** This was clarified in the 2014 Inventory submission. Section 6.5.2 Pasture range and paddock manure (nitrous oxide) now explains that a weighted average of soil types is used as recommended by the 2013 ERT.
	Para 62. Provide a clear explanation of the methodology used to carry out the uncertainty analysis.	**Completed.** The explanation has been revised in the 2014 Inventory submission, under section 6.5.3. The text which had caused some confusion linking weather uncertainty with the modelling uncertainty in the estimates was removed and the input parameters for the Monte Carlo analysis are listed in table 6.5.4. The text was revised as recommended by the 2013 ERT.
Waste – Solid waste disposal on land – CH_4	Para 71. Explore how to improve the quality and temporal coverage of municipal solid waste data and report thereon.	**Completed.** There were a number of improvements to the municipal solid waste data in this submission. The major changes are the inclusion of emission estimates from non-municipal and farm fills and a review of the municipal landfills emissions estimates. The review resulted in improvements to the historic waste disposed of to these fills (including quantities, composition, oxidation factors and methane correction factors). The review also resulted in the incorporation of more accurate waste disposal information from 2010.
Information on Kyoto units.	Para 78. Include in the publicly available information the years of issuance of ERUs.	**Completed.** The recommendation was addressed through a change of text in the publically available information to make clear the date when ERUs are issued.

10.2.2 Planned improvements

Priorities for the 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) ERT 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 before 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 Inventory users into three stakeholder groups, namely: (1) the UNFCCC and international group, (2) the 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 Iinventory report.

Chapter 10: References

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Chapter 11: KP-LULUCF

11.1 General information

Emissions summary

For reporting under Article 3.3 of the Kyoto Protocol, New Zealand has categorised its forests into three subcategories: pre-1990 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 United Nations Framework Convention on Climate Change (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 pre-1990 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,[43] reforestation and deforestation are reported for the first Commitment Period.

2012

In 2012, net emissions from afforestation, reforestation and deforestation activities were -14,968.6 Gg carbon dioxide equivalent (CO_2-e) (table 11.1.1). This value is the 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; and emissions from liming, biomass burning, and soil disturbance associated with land-use conversion to cropland of any land subject to afforestation, reforestation or deforestation since 1990.

Table 11.1.1 New Zealand's emissions from land subject to afforestation, reforestation and deforestation, as reported under Article 3.3 of the Kyoto Protocol, in 2012

Activity	Gross area (ha) 1990–2012	Net area (ha) 2012	Emissions in 2012 (Gg CO_2-e)
Afforestation/reforestation	674,945	654,354	–18,965.1
Forest land not harvested since the beginning of the commitment period (accounting quantity)	–	653,686	–19,145.9
Forest land harvested since the beginning of the commitment period	4,951	668	180.8
Deforestation	151,544	6,762	3,996.5
Net emissions			**–14,968.6**
Accounting quantity			**–15,149.5**

Note: Removals are expressed as a negative value as per section 3.1.7 of *Good Practice Guidance for Land Use, Land-use Change and Forestry* (IPCC, 2003) (GPG-LULUCF). Afforestation/reforestation refers to new forest established since 31 December 1989. The gross afforestation/reforestation area includes 20,591 hectares of land in transition to post-1989 forest that has subsequently been deforested. The 2012 areas are as at 31 December 2012. The

43 Including emissions from harvesting of post-1989 forest.

accounting quantity is calculated by deducting the emissions from afforestation/reforestation forest land harvested (ie, by applying the ARDC rule, Decision 16, CMP.1, annex, para 4). Columns may not total due to rounding.

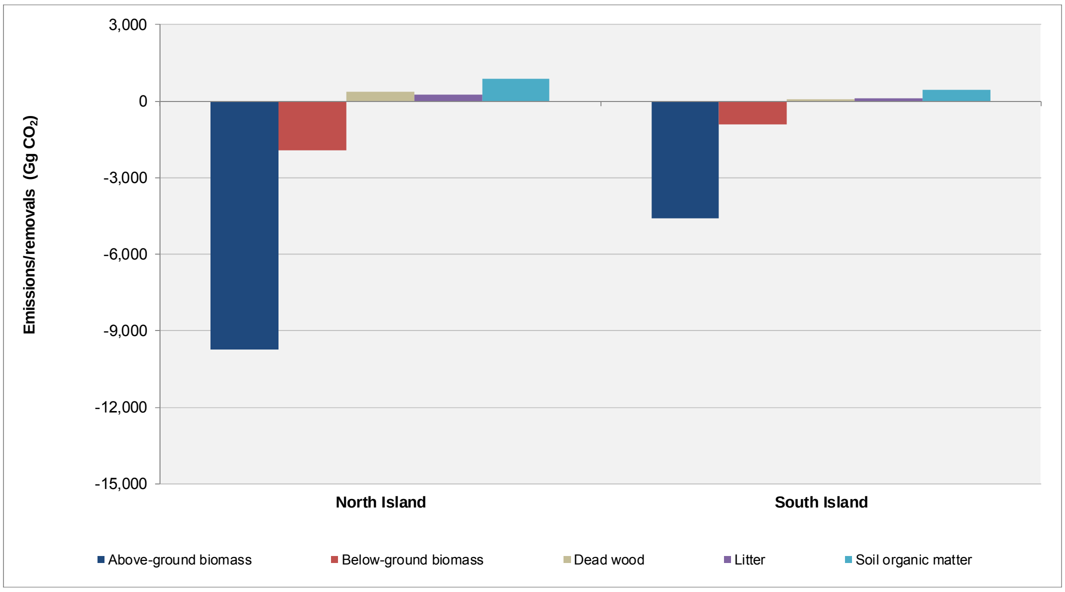
1990–2012

Between 1990 and 2012, 674,945 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities – an average of 29,300 hectares per year (see figure 7.4.1 and table 11.1.1). During 2012, an estimated 12,539 hectares of new forest were planted, a decrease from 13,692 hectares in 2011.

Deforestation of all subcategories of forest land (post-1989, pre-1990 planted and pre-1990 natural forest) during 2012 was estimated at 6,762 hectares. Since 1990, the area of deforestation of all subcategories of forest is estimated as 151,544 hectares. This deforestation has resulted in 20,242.6 Gg CO_2-e net emissions during the Commitment Period.

Emissions are reported separately for the North Island and South Island for the five carbon pools (figure 11.1.1). Conversion to forest land (afforestation and reforestation) and conversion to grassland (deforestation) are key categories for New Zealand (table 1.5.4).

Figure 11.1.1 New Zealand's net CO_2 emissions by carbon pool associated with carbon stock change due to afforestation, reforestation and deforestation activities in 2012



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 as per section 3.1.7 of GPG-LULUCF.

A breakdown of New Zealand's 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 emissions under Article 3.3 of the Kyoto Protocol by greenhouse gas source category

Greenhouse gas source category	Source form	Emissions in 2012 (Gg) Source emission	CO$_2$-equivalent
CO_2 emissions from afforestation/reforestation and deforestation activities	CO_2	–15,024.4	–15,024.4
Disturbance associated with forest conversion to cropland	N_2O	0.0003	0.1
Agricultural lime application on deforested land	C	6.6	24.0
Biomass burning of afforestation/reforestation and deforestation land	CH_4	1.4	28.4
Biomass burning of afforestation/reforestation and deforestation land	N_2O	0.01	2.9
Net emissions			**–14,968.6**

Note: CO_2 = carbon dioxide; N_2O = nitrous oxide; C = carbon; CH_4 = methane. Columns may not total due to rounding.

Emissions associated with nitrogen fertiliser use on deforested land cannot be separated from other fertiliser use in New Zealand so emissions from all fertiliser use are reported under the agriculture sector to avoid double counting (GPG-LULUCF, section 3.2.1.4).

Table 11.1.3 Summary of Article 3.3 reporting during the first Commitment Period

Source	2008	2009	2010	2011	2012
Afforestation/reforestation					
Net cumulative area since 1990 (ha)	621,401	623,924	629,782	642,382	654,354
Area in calendar year (ha)	2,324	5,024	6,940	13,692	12,539
Emissions from afforestation/reforestation land not harvested in CP1 (Gg CO_2-e)	–17,405.4	–17,957.2	–18,458.1	–18,828.8	–19,145.9
Emissions from afforestation/reforestation land harvested in CP1 (Gg CO_2-e)	41.9	121.1	265.0	253.1	180.8
Emissions in calendar year (Gg CO_2-e)	–17,363.5	–17,836.0	–18,193.1	–18,575.7	–18,965.1
Deforestation					
Net cumulative area since 1990 (ha)	121,030	131,434	138,656	144,783	151,544
Area in calendar year (ha)	5,984	10,405	7,222	6,127	6,762
Emissions in calendar year (Gg CO_2-e)	3,166.9	5,616.0	4,087.2	3,376.0	3,996.5
Total area subject to afforestation, reforestation and deforestation	742,431	755,359	768,438	787,165	805,898
Net emissions (Gg CO_2-e)	**–14,196.6**	**–12,220.0**	**–14,105.9**	**–15,199.7**	**–14,968.6**
Accounting quantity (Gg CO_2-e)	**–14,238.5**	**–12,341.2**	**–14,370.9**	**–15,452.8**	**–15,149.5**

Note: CP1 = commitment period one. The areas stated are as at 31 December of that year. 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 31 December 1989. Deforestation includes deforestation of pre-1990 natural forest, pre-1990 planted forest and post-1989 forest. 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 2012, it is estimated that 674,945 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities (table 11.1.4). The net area of post-1989 forest as at the end of 2012 was 654,354 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.

While new planting rates were high from 1992 to 1998 (averaging 61,000 hectares per year), the rate of new planting declined from 1998 and reached a low of 2,324 hectares in 2008. The planting rate has slowly recovered over the past three years, with a provisional estimate for 2012 of 12,539 hectares. The activity data used to estimate new planting in planted forests between 2008 and 2012 is obtained from a national survey of forest owners (Ministry for Primary Industries, 2013). The survey respondents report areas as net stocked area rather than gross stocked area as reported in the inventory. To account for the difference between the two sources of data (mapping and survey); the net planted forest area has been identified and modelled separately. An unstocked area component is added to the new planting statistic between 2008 and 2012 to maintain consistency with the mapped area used prior to 2008. This ensures the new planting data used in the inventory is consistent with that reported by the Ministry for Primary Industries.

New Zealand's post-1989 forests are described in further detail in section 7.4.

Table 11.1.4 New Zealand's estimated annual area of afforestation / reforestation from 1990 to 2012

	Annual area of post-1989 forest (ha)			
Year	**New forest planting**	**Harvesting**	**Deforestation**	**Net cumulative area**
1990	14,641	0	0	14,641
1991	14,292	0	0	28,934
1992	44,859	0	0	73,793
1993	54,802	0	0	128,595
1994	86,736	0	0	215,331
1995	65,650	0	0	280,981
1996	74,348	0	0	355,329
1997	57,123	0	0	412,453
1998	46,737	0	0	459,190
1999	36,897	0	0	496,087
2000	31,928	0	0	528,015
2001	28,933	0	0	556,948
2002	21,933	0	721	578,161
2003	20,666	0	2,273	596,553
2004	12,987	0	2,089	607,451
2005	9,243	200	2,376	614,318
2006	6,323	600	2,036	618,604
2007	6,327	600	4,889	620,043
2008	2,324	804	965	621,401
2009	5,024	979	2,501	623,924
2010	6,940	1,385	1,082	629,782
2011	13,692	1,115	1,092	642,382
2012$_P$	12,539	668	567	654,354
Total	**674,945**	**6,351**	**20,591**	**654,354**

Note: P = Provisional figure. Columns may not total due to rounding.

Since 1993, the New Zealand Government has introduced legislation and government initiatives to encourage forest establishment and discourage deforestation of planted forests. These include the:

- 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, 2008b)
- Hill Country Erosion Programme (Ministry of Agriculture and Forestry, 2008a)
- 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.

The East Coast Forestry Project is a grant scheme that was established in 1993. Its aim is to afforest erosion-prone land in the Gisborne district and has approved funding to 2020. To date around 35,000 hectares of forest has been established under the scheme (Ministry of Agriculture and Forestry, 2011).

The Permanent Forest Sink Initiative promotes the establishment of permanent forests on non-forest land. The scheme is currently under review but is likely to be retained and aligned with the NZ ETS (Ministry of Agriculture and Forestry, 2011).

The Hill Country Erosion Programme, like the East Coast Forestry Project, is focused on the retiring and afforestation of erosion-prone, hill-country farmland in the mid and lower North Island. It is also under review but is likely to continue with an expanded target area and integration with other schemes, for example the East Coast Forestry Project (Ministry of Agriculture and Forestry, 2011).

The Afforestation Grant Scheme was established in 2008 to promote carbon sequestration and sustainable land use. Funding ended in 2013 and no new application rounds are planned at present (Ministry of Agriculture and Forestry, 2011).

Deforestation

In 2012, deforestation emissions were 3,996.5 Gg CO_2-e, compared with 3,376.0 Gg CO_2-e in 2011. These emissions result from the carbon stock loss caused by deforestation activity in the year that it occurred, and lagged emissions from previous deforestation events (ie, soil carbon stock change). It also includes emissions from biomass burning and liming of deforested land and removals from biomass change of the new land use.

The estimated area of deforestation reported in 2012 was 6,762 hectares, higher (10.4 per cent) than the 6,127 hectares reported in 2011, and the higher deforestation emissions reported in 2012 reflect this. The area of deforestation has been updated from last year’s submission following completion of deforestation mapping for 2008–2012. This mapping identified/confirmed areas of deforestation occurring between 1 January 2008 and 31 December 2012 using satellite imagery and field observations captured in oblique aerial photography. Further information on this process can be found in sections 7.2.2 and 7.2.3.

Table 11.1.5 shows the areas of forest land subject to deforestation since 1990, by forest subcategory, and total emissions from deforestation for 2008–2012.

Table 11.1.5 New Zealand's forest land subject to deforestation since 1990, and associated emissions from carbon stock change from 2008 to 2012

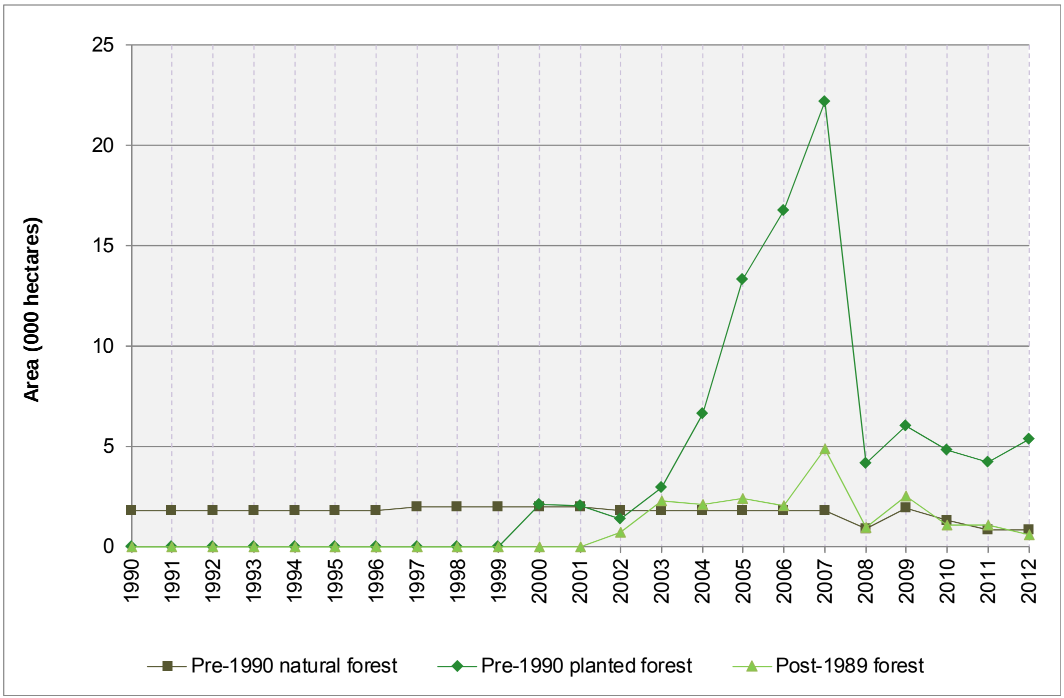
Forest land subcategory	Since 1990	Area of deforestation (ha)				
		2008	2009	2010	2011	2012
Pre-1990 natural forest	39,098	864	1,895	1,297	853	811
Pre-1990 planted forest	91,855	4,154	6,008	4,842	4,182	5,384
Post-1989 forest	20,591	965	2,501	1,082	1,092	567
Total area	**151,544**	**5,983**	**10,404**	**7,221**	**6,127**	**6,762**
Emissions from carbon stock change (Gg CO_2)		**3,126.3**	**5,562.4**	**4,041.6**	**3,331.7**	**3,969.9**

Note: 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 2012



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 and tree weeds within the conservation estate (Ministry of Agriculture and Forestry, 2009a). 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). It should be noted that the area of pre-1990 planted forest deforestation in 2012 was only 0.5 per cent of the total pre-1990 planted forest area.

The area of deforestation of pre-1990 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. However, a number of factors suggest that the rate of pre-1990 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 1993 when amendments were made to the Forests Act 1949. Further restrictions on 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 pre-1990 natural forest deforestation since 2002.

The rate of pre-1990 natural forest deforestation occurring during the Commitment Period is on average lower than that reported pre-2008. This observed reduction in the rate of deforestation confirms that the rate of deforestation pre-2008 was likely to already be in decline (see figure 7.2.5 for details of the mapping process).

Deforestation in New Zealand is described in more detail in sections 7.2, 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 land category. Linear shelterbelts can vary in width and height, 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 is included within the pre-1990 natural forest as reported in this submission; however, it excludes areas of regenerating vegetation that do not meet the forest definition but have the potential to under current management. The latter largely equates to pre-1990 planted forest and post-1989 planted forest.

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

Between 1990 and 2012, 674,945 hectares were afforested/reforested, 12,539 hectares of this occurred in 2012. Of the total area afforested or reforested between 1990 and 2012, an estimated 20,591 hectares were deforested between 1990 and 2012. 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

The land transition matrix is based on data derived from the 1990, 2008 and 2012 land-use maps and an estimate of total afforestation for the period 2008 to 2012 from the *National Exotic Forest Description* (Ministry for Primary Industries, 2013). Mapping of land-use change is described in sections 7.2.2 and 7.2.3. Further information on the estimation of the total area of afforestation occurring between 2008 and 2012 can be found in section 7.4.1

Essential to accurate determination of the area to be reported as afforestation in the land transition matrix is accurate classification of the pre-1990 planted forest and post-1989 forest subcategories in the 2008 and subsequent land-use maps. Satellite imagery at various dates near to 1990 and mapping from the NZ ETS have been used to ensure that these forests are classed correctly. An illustration of this process is shown in figure 7.2.4.

Transitions to deforestation are based on deforestation mapping as described in section 7.2.2. All areas of deforestation are confirmed using oblique aerial photography. For deforestation occurring between 2008 and 2012, annual Landsat satellite imagery is used to estimate the year of the conversion.

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 (pre-1990 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 7.4.2.

Pre-1990 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 Land Cover Database 3 (LCDB3), 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 LCDB3 layer, refer to: www.nlrc.org.nz/resources/datasets/lcdb3.

Table 11.3.1 New Zealand's areas of pre-1990 natural forest deforestation by sub-classification from 2008 to 2012

Pre-1990 natural forest sub-classification	Area of natural forest deforestation since 2008 (ha)					
	2008	2009	2010	2011	2012	Total
Shrub	746	1,210	717	465	521	3,659
Tall forest	118	686	580	387	289	2,060
Total	**864**	**1,895**	**1,297**	**853**	**811**	**5,720**

Note: Columns may not total due to rounding.

The carbon densities for pre-1990 natural forest and post-1989 planted forest have been updated following scheduled re-measurement and/or re-modelling of these forests as described in section 7.4.2.

Following deforestation, carbon on the new land use then accumulates at rates given in table 7.1.5.

Liming (CRF 5(KP-II)4)

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 7.10.4.

Non-CO_2 emissions

Direct N_2O emissions from nitrogen fertilisation (CRF 5(KP-II)1)

New Zealand's activity data on nitrogen fertilisation is not currently disaggregated by land use, and therefore all nitrous oxide (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.

N_2O emissions from drainage of soils (CRF 5(KP-II)2)

New Zealand reports NA (not applicable) in the CRF table for N_2O emissions from drainage of soils as this only applies to forest management and New Zealand has not elected to report on this Article 3.4 activity.

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland (CRF 5(KP-II)3)

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).

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland resulted in emissions of 0.0003 Gg of N_2O in 2012 (0.1 Gg CO_2-e).

Biomass burning (CRF 5(KP-II)5)

Non-CO_2 emissions from wildfires in land converted to forest land are reported under afforestation. The activity data does not distinguish between forest land subcategories (post-1989 forest/afforestation or pre-1990 planted forest); therefore, non-CO_2 emissions resulting from wildfire are attributed to afforestation by the proportion of area that 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).

For calculating the emissions from controlled burning, a survey of planted forest related controlled burning activities was carried out in 2011 to estimate controlled burning activity on forest land in New Zealand. The survey indicated that on average 5 per cent of conversions to planted forest between 1990 and 2011 involved burning to clear vegetation. This area is 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, 2012).

An estimate is provided for controlled burning of post-harvest slash associated with deforestation. No information is available on the extent of burning associated with deforestation in New Zealand. Therefore it is assumed that 30 per cent of conversions involve burning. This percentage is chosen as a conservative proportion of one of the four main methods for disposing of residues in New Zealand. The other methods for residue disposal are chipping and removal, mulching into the soil and leaving to decay (Goulding, 2007). The IPCC default combustion proportion for the burning of harvest residue in non-eucalypt temperate forest (0.62) is applied to an emission factor derived from the national plot network to estimate emissions from this activity. The emission factor excludes the proportion of logs taken offsite (70 per cent of above-ground biomass) and is taken from the plot-network-derived yield tables by forest subclass at the average age of harvest in New Zealand.

Expert opinion suggests that controlled burning of post-harvest residues prior to replanting 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).

Estimates are provided for wildfire on deforested land (forest land converted to grassland) for the first time in this submission. The activity data does not identify deforested land; therefore, non-CO_2 emissions resulting from wildfire are attributed to deforested land by the proportion of area that deforested land makes up of the total grassland area. The methodology follows that described in section 7.10.5. Around 1 per cent of wildfire emissions in grassland are estimated to occur on deforested land between 2008 and 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.

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 and 7.2 and chapter 10. The impact of the recalculations on New Zealand’s 2011 Kyoto Protocol estimates is shown in table 11.3.2.

Table 11.3.2 Impact of the recalculations of New Zealand's emissions under Article 3.3 of the Kyoto Protocol in 2011

Activity under Article 3.3 of the Kyoto Protocol	2011 emissions ($Gg\ CO_2$-e)	
	2013 submission	**2014 submission**
Afforestation/reforestation	–18,440.1	-18,575.7
Forest land not harvested since the beginning of the commitment period	–18,551.5	-18,828.8
Forest land harvested since the beginning of the commitment period	111.4	253.1
Deforestation	1,674.6	3,376.0
Total	**–16,765.5**	**–15,199.7**

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 activity data used to estimate new planting in planted forests is obtained from a national survey of forest owners (Ministry for Primary Industries, 2013). The survey respondents report areas as net stocked area rather than gross stocked area as reported in the inventory. To account for these area differences, the net planted forest area has been identified and modelled separately in this submission. This ensures the new planting data used in the inventory is consistent with that reported by the Ministry for Primary Industries.

Table 11.3.3 shows that since the last submission there has been an increase in the total area of afforestation. This is largely due to improvements made to the 2008 land-use map based on new planting information from the NZ ETS and other forestry schemes such as the Afforestation Grants Scheme.

Deforestation areas for 2011 have also increased as they are now mapped rather than estimated from other data sources. The carbon price has dropped since the 2011 deforestation estimates were originally made and this may have contributed to the discrepancy between the original estimated and final mapped areas.

New Zealand's post-1989 planted forests were first sampled in 2007 and 2008 and were re-measured in 2011 and 2012. The inventory provides a plot-based estimate of carbon stock within this forest subcategory. 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 additional plots were measured in 2011 and 2012. This includes the sampling of post-1989 natural forest. The inclusion of these plots in the analysis has provided an unbiased and representative sample of post-1989 forests. The re-measurement data and the additional plot data have been introduced for the first time in this submission.

An estimate is provided for burning of post-harvest slash associated with deforestation for the first time in this submission. Estimates are provided for wildfires occurring on deforested land for the first time in this submission.

The emission factor for pre-1990 natural forest has been revised following improvements to analysis methodology, the inclusion of re-measured plot data and improvements to original source data. This is described in more detail in section 7.4.2.

Table 11.3.3 Recalculations to New Zealand's 2011 activity data under Article 3.3 of the Kyoto Protocol

Activities under Article 3.3 of the Kyoto Protocol	Area as at 2011 (ha)		Change from 2013 submission (%)
	2013 submission	2014 submission	
Afforestation/reforestation	599,269	642,449	7.2
Forest land not harvested since the beginning of the commitment period	598,669	636,765	6.4
Forest land harvested since the beginning of the commitment period	2,400	5,684	136.8
Deforestation	105,512	144,783	37.2
Activities occurring in 2011	**Area change in 2011 (ha)**		**Change from 2013 submission (%)**
New planting	12,000	13,692	1.4
Deforestation			
Pre-1990 natural forest	1,500	853	–43.1
Pre-1990 planted forest	1,500	4,182	178.8
Post-1989 forest	700	1,092	56.0

Uncertainty and time-series consistency

The uncertainty in net emissions from afforestation and reforestation is 10.2 per cent, based on the uncertainty in emissions from post-1989 forest (see tables 11.3.4 and 11.3.5 for further details). The uncertainty in emissions from deforestation units is determined by type of forest land deforested. This may be pre-1990 natural forest, pre-1990 planted forest or post-1989 forest (see table 11.3.4 for further details). The combined uncertainty introduced into emissions from deforestation is 3.8 per cent (table 11.3.5). Further detail on the uncertainty in emissions for pre-1990 natural forest, pre-1990 forest and post-1989 forest is provided in section 7.4.

Table 11.3.4 Uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2012

	Uncertainty (%) at a 95% confidence interval			
	Afforestation/ reforestation	Deforestation		
	Post-1989 forest	Pre-1990 natural forest	Pre-1990 planted forest	Post-1989 forest
Activity data				
Uncertainty in land area	7.0	10.0	10.0	10.0
Emission factors				
Uncertainty in biomass carbon stocks	8.5	9.5	12.4	8.5
Uncertainty in soil carbon stocks	9.6	6.1	9.6	9.6
Uncertainty introduced into emissions for Kyoto Protocol	**10.2**	**0.4**	**3.8**	**0.1**

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 pre-1990 natural forest, pre-1990 planted forest or post-1989 forest.

Total uncertainty in New Zealand's 2012 estimates from afforestation, reforestation and deforestation is shown in table 11.3.5.

Table 11.3.5 Total uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2012

Variable	Uncertainty (%) at a 95% confidence interval
Afforestation/reforestation uncertainty introduced into emissions for Kyoto Protocol	10.2
Deforestation uncertainty introduced into emissions for Kyoto Protocol	3.8
Total uncertainty for Kyoto Protocol	**10.9**

Other methodological issues

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, to be consistent with GPG-LULUCF 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 have also undergone quality assurance as described in section 7.4.4.

Year of the onset of an activity

Paragraph 18 of the annex to 16/CMP.1 (Land Use, Land-use Change and Forestry) requires New Zealand to 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 2012, an estimated 12,539 hectares of post-1989 forest were established and 6,762 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, which includes information from the Afforestation Grants Scheme and the East Coast Forestry Project (Ministry for Primary Industries, 2013). This information ensures that the activity is attributed to the correct year of onset.

The deforestation area is based on 2008–2012 deforestation mapping completed in 2013 and supported by earlier deforestation mapping activities. Deforestation is confirmed using oblique aerial photography, and the year of onset (destocking year) is determined using annual Landsat imagery. 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 demonstrating that activities under Article 3.3 began on or after 31 December 1989 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 changes, including deforestation, are therefore a result of human decisions to change the vegetation cover and/or change the way land is managed.

New Zealand has used satellite imagery collected around the start of 1990, 2008 and 2012 to detect changes in land use between these periods.

To estimate land-use change between 2008 and 2012, Land Use and Carbon Analysis System (LUCAS) mapping was augmented with data from the Afforestation Grants Scheme (Ministry of Agriculture and Forestry, 2009c), the NZ ETS (Ministry of Agriculture and Forestry, 2009a) and the *National Exotic Forest Description* (Ministry for Primary Industries, 2013). This was used to estimate afforestation and reforestation during 2012. Deforestation occurring between 2008 and 2012 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.

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 as "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).

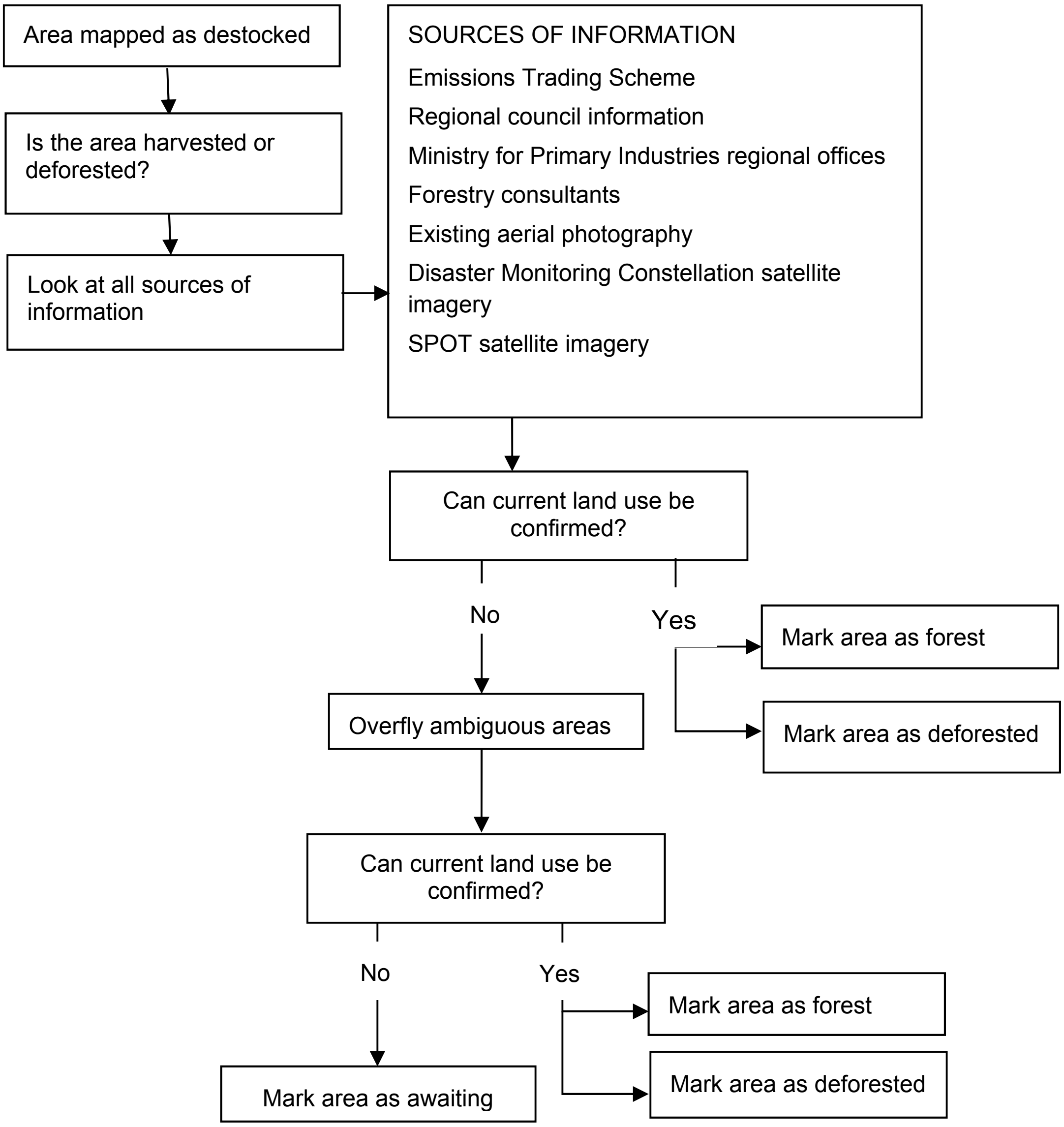
In New Zealand, temporarily unstocked or cleared areas of forest (eg, harvested areas and areas subject to disturbances) remain designated as forest land unless there is a confirmed change in land use or if, after four years, no reforestation (replanting or regeneration) has occurred. The four-year time 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 (GPG-LULUCF, section 4.2.6.2.1).

Prior to the four-year time period, there are a number of activities that have been 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 allows for the Ministry for Primary Industries, the agency that administers the forestry aspects of the NZ ETS, to 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



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 main classes: harvested, deforested and awaiting. 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 has now been completed. Because of New Zealand's four-year rule, there is now no awaiting land that was destocked in 2008. Any areas destocked in 2008 that show no evidence of replanting have been classed as deforested.

Areas destocked after 2008, which have been classed as awaiting land, are still considered to be forested land until either evidence of land-use change is identified, or four years have passed since destocking (whichever comes first). This is consistent with section 4.2.6.2.1 of GPG-LULUCF which states that:

> *In the absence of land-use change or infrastructure development, and until the time for regeneration has elapsed, these units of land remain classified as forest. Note that this is consistent with the approach suggested for afforestation and reforestation, i.e., units of land that have not been confirmed as afforested/reforested remain classified as non-forest land.*

Estimates of the total areas of awaiting land for 2009 to 2012 are shown in table 11.4.1.

Table 11.4.1 Estimate of land destocked in New Zealand between 2009 and 2012 awaiting a land-use determination

Pre-1990 natural forest (ha)	Pre-1990 planted forest (ha)	Post-1989 forest (ha)	Total (ha)
4,779	16,138	2,972	23,889

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 (CRF NIR-3)

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's 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
NO	Not occuring
NZEUR	New Zealand Emission Unit Register
CDM	Clean Development Mechanism

(for *table 2b Annual external transactions* in table 12.2.2 in the column 'Transfers and acquisitions')

AT	Austria
AU	Australia
CH	Switzerland
EE	Estonia
ES	Spain

EU	European Economic Community
GB	United Kingdom of Great Britain and Northern Ireland
JP	Japan
NL	Netherlands

12.2 Summary of the standard electronic format tables for reporting Kyoto Protocol units

At the beginning of the calendar year 2013, New Zealand's national registry held 306,041,662 assigned amount units, 16,153,534 emissions reduction units, 8,680,399 certified emission reduction units and 9,050,000 removal units (table 1 in table 12.2.2).

At the end of 2013, there were 305,777,516 assigned amount units, 79,861,097 emission reduction units, 10,864,195 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 or long-term certified emissions reduction units during 2013 (table 4 in table 12.2.2).

The transactions made to New Zealand's national registry during 2013 (tables 2(a), (b), (c) in table 12.2.2) are summarised below.

- No assigned amount units were added to New Zealand's national registry. There were 272,793 assigned amount units subtracted from the registry. There were 264,146 converted to emission reduction units and 8,647 were voluntarily cancelled. There were no external subtractions.
- There were 86,407,353 emission reduction units added to New Zealand's national registry and 22,699,790 were subtracted. There were 264,146 units added in respect of New Zealand verified projects under Article 6 of the Kyoto Protocol. The biggest external addition of emission reduction units was 48,065,487 units from Switzerland. Seven registries were the recipients of external subtractions of emission reduction units, with the largest being 13,584,834 to Switzerland. There were no internal subtractions.
- There were 6,506,641 certified emission reduction units added to New Zealand's national registry and 4,346,016 were subtracted. The greatest addition was 3,256,536 certified emission reduction units from the European Economic Community. There were three external subtractions of certified emission reduction units, with the largest being 2,794,599 to the United Kingdom of Great Britain and Northern Ireland. There were 23,171 units subtracted internally through voluntary cancellation.
- No removal units were added to New Zealand's national registry. No removal units were subtracted from the New Zealand registry.
- There were no transactions of temporary certified emission reduction units or long-term certified emissions reduction units.

During 2013, 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	The standard electronic format report for 2013 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	2014
Reported year	2013
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	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	2014
Reported year	2013
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		264146					264146		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							8647	NO	NO	23171	NO	NO
Sub-total		264146	NO				272793	NO	NO	23171	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	2014
Reported year	2013
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	12558	NO	NO	NO	NO
AU	NO	NO	NO	50000	NO	NO	NO	150000	NO	112826	NO	NO
CH	NO	48065487	NO	1038689	NO	NO	NO	13584834	NO	1415420	NO	NO
EE	NO	1000000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
ES	NO	2369809	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
EU	NO	24188232	NO	3256536	NO	NO	NO	5	NO	NO	NO	NO
GB	NO	9419679	NO	411677	NO	NO	NO	8799483	NO	2794599	NO	NO
JP	NO	NO	NO	1749739	NO	NO	NO	60000	NO	NO	NO	NO
NL	NO	1100000	NO	NO	NO	NO	NO	92910	NO	NO	NO	NO
Sub-total	NO	86143207	NO	6506641	NO	NO	NO	22699790	NO	4322845	NO	NO

Additional information

Independently verified ERUs								NO				

Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	NO	86407353	NO	6506641	NO	NO	272793	22699790	NO	4346016	NO	NO

Party New Zealand
Submission year 2014
Reported year 2013
Commitment period 1

Table 3. Expiry, cancellation and replacement

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

Party	New Zealand
Submission year	2014
Reported year	2013
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	302802271	45535954	8012771	7601797	NO	NO
Entity holding accounts	2948595	34325143	1037229	3238427	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	26650	NO	NO	23971	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	305777516	79861097	9050000	10864195	NO	NO

Party	New Zealand
Submission year	2014
Reported year	2013
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	86407353	NO	6506641	NO	NO	272793	22699790	NO	4346016	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	105935754	9050000	25588365	NO	NO	3833399	26074657	NO	14748141	NO	NO
Total	309584265	105935754	9050000	25588365	NO	NO	3833399	26074657	NO	14748141	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	2014
Reported year	2013
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 2013. For completeness, the report R-2 is included with 'Nil' discrepant transactions during the reporting period.
15/CMP.1 annex I.E, paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2013. 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 2013. 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 existed as at 31 December 2013. 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/ search-the-register) (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 with which a	Yes (refer Search the Register: Accounts: Click	Up to date (real-time).	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/ search-the-register) (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
cancellation or retirement account is associated.	on Account Number hyperlink to access Account Information Report).		
(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 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.
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 Issuance tab or through the Ministers' Directions menu item). This lists directions relating to the transfer of emission reduction units to individual Joint Implementation Projects. The NZEUR Unit Holding and Transaction Summary Report shows in aggregate the total	Joint Implementation (JI) Projects – annually by 31 January for the previous calendar year. Ministers' directions – up to date (real-time).	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/ search-the-register) (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
	ERUs converted from AAUs by year).		
(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 http://www.mfe.govt.nz/issues/climate/policies-initiatives/joint-implementation/notice.html and is not replicated on 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 financial information that is considered to be commercially sensitive and confidential.	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
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	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

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/ search-the-register) (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
	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).		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
(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.	Section 27(j) of the Climate Change Response Act 2002 requires that only the following be made publicly available: • total quantity of units transferred; and • total quantity and type of unit transferred; and • 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	Yes (refer Search the Register: NZEUR	Annually by 31 January for the	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/ search-the-register) (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
Article 3, paragraphs 3 and 4.	Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	previous calendar year. The registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	
(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. The identity of the individual acquiring 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.	Section 27(k) of the Climate Change Response Act 2002 requires that only the following be publicly available: • total quantity of units transferred; and • total quantity and type of unit transferred; and • 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	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/ search-the-register) (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
		on 1 January of each year, if the event occurred during the reporting period.	
(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).	Annually by 31 January for the previous calendar year. The registry makes this information available on 1 January of each 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.
	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.)	1 January for the beginning of 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	Yes (refer Search the Register: Account Holders for list of authorised entities).	Up to date (real time).	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/ search-the-register) (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
RMUs under its responsibility.			

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* (UNFCCC, 2007).

The commitment period reserve level as at 31 December 2013 is:

Commitment period reserve limit:	*278,608,260*
Units held:	*405,552,808*
Commitment period reserve level:	*405,552,808*
Commitment period reserve level = (% of assigned amount):	*131.01%*

CPR level comprises of the following units:

AAUs	*305,777,516*
ERUs (converted from AAUs)	*79,861,097*
CERs	*10,864,195*
RMUs	*9,050,000*
Total units	*405,552,808*

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

UNFCCC. 2007. FCCC/IRR/2007/NZL. New Zealand. *Report of the review of the initial report of New Zealand.* In-country Review (19–24 February 2007).

Chapter 13: Information on changes to the national system

Governance

New Zealand uses a hybrid approach to the Inventory programme management. Management and coordination of the Inventory programme as well as compilation, publication and submission of the Inventory are carried out by the Ministry for the Environment in a centralised manner. Sector-specific work that includes obtaining and processing activity data, estimating emissions, preparing sectoral common reporting format (CRF) tables and writing sectoral inventory chapters is carried out by the designated agencies across the New Zealand's Natural Resource Sector. The Reporting Governance Group (RGG) includes representatives from all government agencies involved in the production of major climate change reports, including the inventory, projections and modelling. The RGG is responsible for approving all changes, improvements and major recalculations in the inventory.

The Terms of Reference for the RGG 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 2014.

New Zealand's Inventory team follows New Zealand's National Inventory System Guidelines (NIS Guidelines) for compiling New Zealand's Greenhouse Gas Inventory. This document is updated on a yearly basis. The document is peer-reviewed by third parties and all the changes in the document are approved by the RGG. The document was updated in 2013 to include updated maps for the sectoral Quality Control processes and procedures and a revised inventory delivery plan.

Quality assurance

- New Zealand continued to strengthen a process-based approach to the Quality Assurance and Quality Control (QA/QC) system for the inventory production, delivery and governance continued during 2013. The following has been undertaken (and this will be continued during the Inventory 2014 production cycle):
- Revising New Zealand's QC procedures for each individual sector and mapping QC processes and procedures at the sectoral level. The revised process maps were included in the NIS Guidelines.
- Moving to more automated methods of control, especially where large quantities of data are to be moved between different source documents. For example, a Sector Lead for Waste sector identified the most error-prone and time consuming steps in checking data from the Waste sector, and an easy-to-use MS Excel tool to automate those checks was created. A similar approach was used for the key category analysis and uncertainty analysis for the Inventory after cross-sectoral compilation.
- Developing a new VBA (visual basic application) model to assist processing significant portions of the Agriculture sector data
- Identifying gaps in New Zealand's QC processes, discussing ways of improvement with the Sector Leads and incorporating the new QC steps in check sheets for the 2014 inventory submission
- Emphasising the importance of the QC procedures and educating new Inventory team members in the application of correct procedures.

All sector leads are 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). In 2013-14 the Waste sector undertook a comprehensive QA review of the GHG estimates from non-municipal landfills. Regular meetings to discuss progress with QA/QC processes and relevant issues with each Sector Lead have been put in place.

Data archiving, 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.

New Zealand's archiving system reflects this organisational approach. Specifically:

- Submitted data files for CRF, CRF tables, backup database files from the CRF Reporter, sectoral chapters, compiled NIR, sign-off confirmations, supplementary materials that are included into the Inventory submission pack, communication between New Zealand's Inventory team and the ERTs, NIS, process maps, NIR project planning and documentation, and similar documents are stored in MfE's secure file management system and backed up in several different devices.
- Sectoral data, including communication with contractors, activity data, emission factors, preliminary calculations, and specific software applications containing sectoral data models are kept at secure file systems at each sectoral agency. For example, the Ministry of Primary Industries holds the information regarding the Agriculture sector, the Ministry for Business, Innovation and Employment (former Ministry for Economic Development) holds the materials specific to the Energy sector and a portion of the materials related to CO2 emissions from the Industrial Processes sector. The Environmental Protection Authority is responsible for the storage of the information related to New Zealand's ETS reports and communications.
- MfE holds the information for LULUCF, Waste, Industrial Processes (non-CO2 emissions) and Solvents and Other Products Use sectors because the Sector Leads for these sectors work at MfE.
- each of the agencies has security procedures in place in case of natural disasters, fire, flood or other accidents, which are kept at a high standard. For example, despite several earthquakes of 6.5–6.9 strength that happened in Wellington, New Zealand's capital, in July and August 2013 and January 2014, all of the information regarding the Inventory support remained undamaged and the processes of the Inventory-2014 production and responses to the ERT questions proceeded without interruption. No information was lost.

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 Energy, 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 (Energy sector) and one government official has completed generalist exams.

In 2013-14, New Zealand nominated several government officials for the Inventory reviewer training that cover all inventory sectors. New Zealand's goal is that the Inventory Sector Leads and peer reviewers are certified Inventory experts for their sectors and the officials responsible for cross-sectoral inventory compilation and review are certified generalists. This is to ensure better understanding of the Inventory principles, processes and quality criteria, more efficient participation in the Inventory review process and that the high quality of the New Zealand's Inventory is maintained.

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 2013 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 2014' 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 2013, the contact details for the national registry have been changed. Changes have been made to the Alternative Contact, and the position of Release Manager was removed. Refer to table 14.4 below for details. The National Focal Point advised the United Nations Framework Convention on Climate Change Secretariat (UN/ITL) of these changes. The changes have taken effect from 30 October 2013.
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 in the discrepancies procedures occurred during the reporting period.
15/CMP.1 Annex II.E, paragraph 32.(f): Change in security	No changes in security occurred during the reporting period.
15/CMP.1 Annex II.E, paragraph 32.(g): Change in the list of publicly available information	No changes to the list of publicly available information occurred during the reporting period.
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.

Table 14.2 Previous recommendations for New Zealand from the expert review team

Previous annual review recommendations	New Zealand addressed the recommendation as follows
The 2013 report of the individual review of the annual submission of New Zealand included a recommendation to include in the publicly available information the years of issuance of emission reduction units (ERUs).	The recommendation was addressed through a change of text in the publically available information to make clear the date when ERUs are issued.
The 2013 Standard Independent Assessment Report included a recommendation to include in the publicly available information the years of issuance of ERUs.	The recommendation was addressed through a change of text in the publically available information to make clear the date when ERUs are issued.

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 4 916 2426 Fax: +64 4 978 3661 Web: http://www.epa.govt.nz
Main contact	Guy Windley Team Leader, Registry Operations, ETS 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	Chris Ballantyne Manager, Registry Operations, ETS Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 474 5511 Fax: +64 4 978 3661 Email: chris.ballantyne@epa.govt.nz
Release manager	N/A

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 2013 submission. However, some revised information is provided for the following:

- information on a capacity-building workshop around fossil fuel subsidy reform (see section 15.2)
- further information on energy projects in the Cook Islands, Tokelau, Tonga and Tuvalu (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 members of the public. Policy advice is coordinated between Ministries and involves analysis of all relevant parameters. The Ministry of Foreign Affairs and Trade provides advice to the Government on international aspects of proposed policies. Through this process decision-makers in New Zealand can and frequently do consider the social and economic impacts of our policies on other countries, whether informed by bilateral engagement or other forms of analysis. During the public consultation phase, concerns and issues about the proposed measure can be raised by any person or organisation. There is no pre-prescribed process for analysis of impacts across all policies. This allows for flexibility in policy making, and enables the most relevant advice to be put before decision-makers.

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 adverse 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 impacts 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.

The New Zealand Aid Programme also works with partner countries to strengthen governance and improve their ability to respond to changing circumstances. 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 2014 year has been designated as the first International Year of Small Island Developing States by the United Nations General Assembly and will mark a renewed focus by the United Nations on the particular challenges these countries face. Small Island Developing States are increasing their uptake of renewable energy, which is a critical element of their long-term sustainable development efforts. New Zealand will support Samoa as it hosts the third International Conference on Small Island Developing States (SIDS III) in September 2014.

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 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.

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. In March 2013, New Zealand, along with the United States, co-hosted a capacity-building workshop on building support for reform through effective communication and consultation strategies. New Zealand also supported development of the G20 fossil fuel subsidy reform peer review mechanism. Associated outreach activities included, with the United States, co-hosting in a G20 roundtable on recent progress and peer review of a fossil fuel subsidy reform in April 2013. New Zealand also made a presentation to the G20's Energy Sustainability Working Group on how the G20 might best structure its proposed voluntary peer reviews for fossil fuel subsidy reform in July 2013.

New Zealand was 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). All policy measures that directly or indirectly support fossil fuels were reported. 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 achieving relevant policy objectives efficiently.

In line with New Zealand's commitment to transparency and information sharing, New Zealand was also the first APEC economy to volunteer for fossil fuel subsidy reform peer review under guidelines finalised by the APEC Energy Working Group in December 2013. New Zealand is seeking to progress the peer review in 2014. Consistent with New Zealand's approach under APEC's fossil fuel subsidy reform voluntary reporting mechanism, New Zealand intends to put forward for peer review all policy measures that directly or indirectly support fossil fuels.

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.

15.4Technological 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 participated actively 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), 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.

The New Zealand Aid Programme maintains a focus on energy efficiency, and the transition away from fossil fuel dependency to clean energy generation, for sustainable economic development. One example is New Zealand's commitment to a major energy programme in Tonga. Working closely alongside development partners, New Zealand is supporting the practical implementation of Tonga's Energy Roadmap, an ambitious 10-year sector-wide plan to improve Tonga's energy efficiency and energy self-reliance. Part of New Zealand's NZ$22.5 million support commitment is focused on upgrading Tonga's power distribution network, as well as investigating the feasibility of using wind as a renewable energy resource.

A further example is New Zealand's support to Tokelau, which was 100 per cent dependent upon diesel for electricity generation until 2013, with heavy economic and environmental costs. A New Zealand-funded project to construct solar-based mini-grids on three atolls now provides more than 90 per cent of Tokelau's electricity needs through solar generation. Projects to harness solar energy for remote atoll communities are also in progress in the Cook Islands and Tuvalu, scheduled to deliver in 2014/15, alongside wider regional projects focusing on capacity building, asset management and energy sector reform.

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.

The New Zealand Aid Programme provides support to a number of non-Annex I Parties for purposes of economic diversification and renewable energy generation (refer to section 15.6).

For example, 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, developing the aquaculture sector and providing capacity and capability building for small business in rural areas, particularly those run by women. 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. A key focus for New Zealand's development assistance in Timor-Leste is to support sustainable economic development through private sector investment.

Introducing clean and affordable energy technologies is a high priority for the Pacific region. On average, 10 per cent of the region's gross domestic product (GDP) is expended on imported fossil fuel and 80 per cent of electricity generation depends on the combustion of diesel. New Zealand is a member of the International Renewable Energy Agency (IRENA), an intergovernmental organisation that aims to promote the widespread use of all forms of renewable energy. New Zealand is involved with a number of IRENA's work streams in the Pacific and further afield.

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.

In March 2013, the New Zealand Government and the European Union co-hosted the Pacific Energy Summit. The Summit aimed to connect Pacific Island leaders with the finance and expertise to accelerate their countries' energy plans. The Summit secured donor commitments of NZ$635 million (US$525 million). This includes NZ$255 million in grant funding and NZ$380 million in concessional loans sufficient to support over 40 of the proposed projects over the next three years.

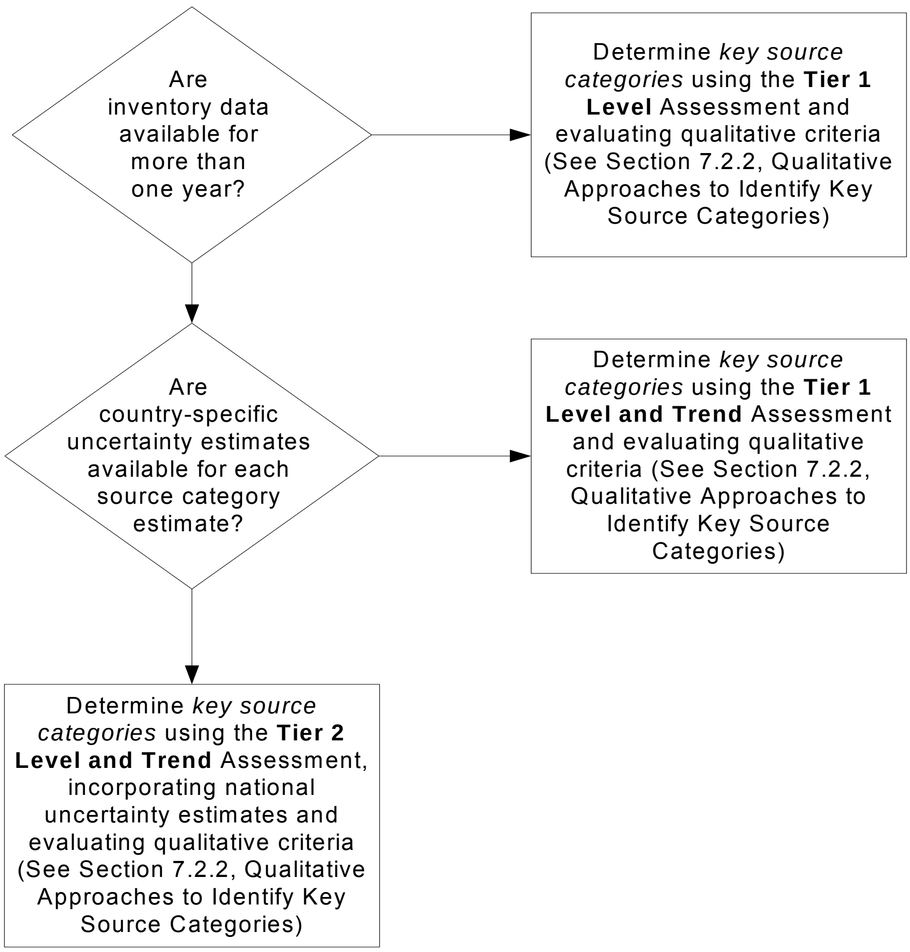
New Zealand is committed to providing long-term assistance to non-Annex I Parties in achieving economic diversification that is independent of fossil fuels and that includes the provision of secure, sustainable energy.

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.

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 2012

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2012				
IPCC categories	**Gas**	**2012 estimate (Gg CO2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	25,210.1	21.8	21.8
Enteric fermentation – dairy cattle	CH_4	10,807.7	9.3	31.1
Forest land remaining forest land	CO_2	7,954.6	6.9	38.0
Enteric fermentation – sheep	CH_4	7,948.1	6.9	44.9
Transport – road transport – gasoline	CO_2	6,884.8	5.9	50.8
Agricultural soils – pasture, range and paddock	N_2O	5,817.6	5.0	55.8
Transport – road transport – diesel oil	CO_2	5,372.8	4.6	60.5
Enteric fermentation – non-dairy cattle	CH_4	4,648.0	4.0	64.5
Conversion to grassland	CO_2	3,914.2	3.4	67.9
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,631.7	3.1	71.0
Solid waste disposal on land	CH_4	3,120.5	2.7	73.7
Energy industries – public electricity and heat production – solid fuels	CO_2	2,643.8	2.3	76.0
Agricultural soils – indirect emissions	N_2O	2,621.7	2.3	78.2
Manufacturing industries and construction – gaseous fuels	CO_2	2,306.9	2.0	80.2
Grassland remaining grassland	CO_2	2,013.9	1.7	82.0
Agricultural soils – direct emissions	N_2O	1,901.5	1.6	83.6
Other sectors – liquid fuels	CO_2	1,880.3	1.6	85.2
Manufacturing industries and construction – solid fuels	CO_2	1,737.1	1.5	86.7
Metal production – iron and steel production	CO_2	1,718.9	1.5	88.2
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,717.6	1.5	89.7
Manufacturing industries and construction – liquid	CO_2	1,128.7	1.0	90.7

fuels				
Other sectors – gaseous fuels	CO_2	831.6	0.7	91.4
Transport – civil aviation – jet kerosene	CO_2	826.7	0.7	92.1
Energy industries – Petroleum refining – liquid fuels	CO_2	779.2	0.7	92.8
Manure management	CH_4	672.1	0.6	93.4
Fugitive emissions – geothermal	CO_2	629.6	0.5	93.9
Mineral products – cement production	CO_2	568.6	0.5	94.4
Metal production – aluminium production	CO_2	521.0	0.5	94.9
Other sectors – solid fuels	CO_2	496.8	0.4	95.3
Enteric fermentation – deer	CH_4	485.4	0.4	95.7
Fugitive emissions – natural gas	CH_4	425.0	0.4	96.1
Fugitive emissions – natural gas	CO_2	420.7	0.4	96.1
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	397.0	0.3	96.4
Cropland remaining cropland	CO_2	383.4	0.3	96.7
Fugitive emissions – coal mining and handling	CH_4	292.9	0.3	97.0
Wastewater handling	CH_4	289.5	0.3	97.3
Transport – navigation – residual oil	CO_2	289.2	0.2	97.5
Chemical industry – hydrogen production	CO_2	251.4	0.2	97.7
Fugitive emissions – flaring – combined	CO_2	235.8	0.2	97.9
Wastewater handling	N_2O	183.5	0.2	98.1
Chemical industry – ammonia production	CO_2	167.7	0.1	98.2
Transport – railways – liquid fuels	CO_2	151.3	0.1	97.8
Energy industries – Petroleum refining – gaseous fuels	CO_2	136.7	0.1	98.0
Mineral products – lime production	CO_2	112.0	0.1	98.1
Conversion to cropland	CO_2	109.8	0.1	98.2
Fugitive emissions – geothermal	CH_4	109.0	0.1	98.3
Transport – road transport – gasoline	N_2O	100.0	0.1	98.3
Consumption of halocarbons and SF_6 – foam blowing	HFCs & PFCs	85.2	0.1	98.4
Mineral products – limestone and dolomite use	CO_2	63.0	0.1	98.5
Manufacturing industries and construction – biomass	N_2O	62.5	0.1	98.5
Enteric fermentation – other	CH_4	46.7	0.0	98.6
Other sectors – biomass	CH_4	43.6	0.0	98.6
Conversion to wetland	CO_2	43.4	0.0	98.6
Fugitive emissions – flaring – combined	CH_4	41.6	0.0	98.7
Metal production – aluminium production	PFCs	40.8	0.0	98.7
Manure management	N_2O	36.0	0.0	98.7
Transport – road transport – diesel oil	N_2O	34.4	0.0	98.8
Transport – civil aviation – aviation gasoline	CO_2	34.3	0.0	98.8
Emissions from solvents (N_2O use)	N_2O	34.1	0.0	98.8
Grassland remaining grassland	CH_4	27.8	0.0	98.9
Emissions from agricultural residue burning	CH_4	23.5	0.0	98.9
Transport – road transport – liquefied petroleum	CO_2	21.6	0.0	98.9

gases				
Fugitive emissions – venting – combined	CH4	19.9	0.0	98.9
Transport – road transport – gasoline	CH_4	19.4	0.0	98.9
Other sectors – liquid fuels	N_2O	18.6	0.0	98.9
Conversion to other land	CO_2	17.8	0.0	98.9
Consumption of halocarbons and SF6 – electrical equipment	SF_6	17.3	0.0	99.0
Manufacturing industries and construction – biomass	CH_4	15.8	0.0	99.0
Conversion to cropland	N_2O	14.0	0.0	99.0
Energy industries – public electricity and heat production – solid fuels	N_2O	13.8	0.0	99.0
Forest land remaining forest land	CH_4	9.7	0.0	99.0
Manufacturing industries and construction – liquid fuels	N_2O	9.6	0.0	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 CO2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Forest land remaining forest land	CO_2	21,108.3	20.8	20.8
Conversion to forest land	CO_2	18,045.9	17.7	38.5
Enteric fermentation – sheep	CH_4	11,723.0	11.5	50.0
Transport – road transport – gasoline	CO_2	5,582.2	5.5	55.5
Agricultural soils – pasture, range and paddock	N_2O	5,330.4	5.2	60.8
Enteric fermentation – dairy cattle	CH_4	4,999.3	4.9	65.7
Enteric fermentation – non dairy cattle	CH_4	4,820.2	4.7	70.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	2.9	73.3
Solid waste disposal on land	CH_4	2,912.4	2.9	76.2
Manufactuing industries and construction – solid fuels	CO_2	2,162.6	2.1	78.3
Agricultural soils – indirect emissions	N_2O	2,039.6	2.0	80.3
Other sectors – liquid fuels	CO_2	1,721.7	1.7	82.0
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.2	1.7	83.7
Manufactuing industries and construction – gaseous fuels	CO_2	1,640.7	1.6	85.3
Transport – road transport – diesel oil	CO_2	1,409.5	1.4	86.7
Metal production – iron and steel production	CO_2	1,306.7	1.3	88.0
Transport – civil aviation – jet kerosene	CO_2	883.7	0.9	88.9
Grassland remaining grassland	CO_2	875.1	0.9	89.7
Manufactuing industries and construction – liquid fuels	CO_2	827.3	0.8	90.6
Energy industries – Petroleum refining – liquid fuels	CO_2	773.9	0.8	91.3
Metal production – aluminium production	PFCs	629.9	0.6	91.9

Other sectors – gaseous fuels	CO_2	523.3	0.5	92.4
Fugitive emissions – natural gas	CH_4	521.5	0.5	93.0
Other sectors – solid fuels	CO_2	511.8	0.5	93.5
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	0.5	93.9
Agricultural soils – direct emissions	N_2O	460.5	0.5	94.4
Manure management	CH_4	459.1	0.5	94.8
Metal production – aluminium production	CO_2	449.0	0.4	95.3
Mineral products – cement production	CO_2	448.7	0.4	95.7
Cropland remaining cropland	CO_2	379.1	0.4	96.1
Enteric fermentation – deer	CH_4	349.1	0.3	96.4
Fugitive emissions – coal mining and handling	CH_4	283.2	0.3	96.7
Conversion to grassland	CO_2	238.5	0.2	96.9
Wastewater handling	CH_4	235.4	0.2	97.2
Transport – navigation – residual oil	CO_2	230.6	0.2	97.4
Fugitive emissions – geothermal	CO_2	228.6	0.2	97.6
Conversion to wetland	CO_2	218.1	0.2	97.8
Enteric fermentation – other	CH_4	209.6	0.2	98.0
Chemical industry – hydrogen production	CO_2	152.3	0.1	98.2
Chemical industry – ammonia production	CO_2	147.1	0.1	98.3
Wastewater handling	N_2O	144.1	0.1	98.5
Transport – road transport – gaseous fuels	CO_2	139.6	0.1	98.6
Conversion to cropland	CO_2	116.2	0.1	98.7
Fugitive emissions – flaring – combined	CO_2	113.5	0.1	98.8
Fugitive emissions – natural gas	CO_2	110.8	0.1	98.8
Transport – road transport – liquefied petroleum gases	CO_2	101.0	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 2012

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

IPCC categories	Gas	1990 estimate (Gg CO2-e)	2012 estimate (Gg CO2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Forest land remaining forest land	CO_2	21,108.3	7,954.6	0.122	29.4	29.4
Enteric fermentation – sheep	CH_4	11,723.0	7,948.1	0.041	9.9	39.2
Enteric fermentation – dairy cattle	CH_4	4,999.3	10,807.7	0.039	9.4	48.6
Conversion to forest land	CO_2	18,045.9	25,210.1	0.035	8.5	57.1
Transport – road transport – diesel oil	CO_2	1,409.5	5,372.8	0.029	6.9	64.0
Conversion to grassland	CO_2	238.5	3,914.2	0.028	6.7	70.7
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	2,643.8	0.016	3.9	74.6

Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,717.6	0.013	3.1	77.7
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.2	397.0	0.012	2.8	80.5
Agricultural soils – direct emissions	N_2O	460.5	1,901.5	0.010	2.5	83.1
Grassland remaining grassland	CO_2	875.1	2,013.9	0.008	1.9	84.9
Enteric fermentation — non-dairy cattle	CH_4	4,820.2	4,648.0	0.006	1.5	86.5
Manufacturing industries and construction – solid fuels	CO_2	2,162.6	1,737.1	0.005	1.3	87.8
Metal production – aluminium production	PFCs	629.9	40.8	0.005	1.2	89.0
Transport – road transport – gasoline	CO_2	5,582.2	6,884.8	0.004	1.0	90.0
Manufacturing industries and construction – gaseous fuels	CO_2	1,640.7	2,306.9	0.003	0.8	90.8
Fugitive emissions – geothermal	CO_2	228.6	629.6	0.003	0.7	91.5
Agricultural soils – indirect emissions	N_2O	2,039.6	2,621.7	0.002	0.5	92.0
Fugitive emissions – natural gas	CO_2	110.8	420.7	0.002	0.5	92.5
Agricultural soils – pasture, range and paddock	N_2O	5,330.4	5,817.6	0.002	0.5	93.0
Other sectors – gaseous fuels	CO_2	523.3	831.6	0.002	0.4	93.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	3,631.7	0.002	0.4	93.9
Metal production – iron and steel production	CO_2	1,306.7	1,718.9	0.002	0.4	94.3
Conversion to wetland	CO_2	218.1	43.4	0.002	0.4	94.7
Solid waste disposal on land	CH_4	2,912.4	3,120.5	0.001	0.4	95.0
Enteric fermentation – other	CH_4	209.6	46.7	0.001	0.4	95.4
Manufacturing industries and construction – liquid fuels	CO_2	827.3	1,128.7	0.001	0.3	95.7
Transport – civil aviation – jet kerosene	CO_2	883.7	826.7	0.001	0.3	96.0
Fugitive emissions – natural gas	CH_4	521.5	425.0	0.001	0.3	96.3
Transport – road transport – gaseous fuels	CO_2	139.6	1.8	0.001	0.3	96.6
Manure management	CH_4	459.1	672.1	0.001	0.3	96.9
Energy industries – Petroleum refining – gaseous fuels	CO_2	0.0	136.7	0.001	0.2	97.2
Fugitive emissions – flaring – combined	CO_2	113.5	235.8	0.001	0.2	97.4
Energy industries – Petroleum refining – liquid fuels	CO_2	773.9	779.2	0.001	0.2	97.5
Transport – road transport –	CO_2	101.0	21.6	0.001	0.2	97.7

liquefied petroleum gases						
Enteric fermentation – deer	CH_4	349.1	485.4	0.001	0.2	97.9
Other sectors – solid fuels	CO_2	511.8	496.8	0.001	0.2	98.0
Consumption of halocarbons and SF_6 – foam blowing	HFCs & PFCs	0.0	85.2	0.001	0.2	98.2
Other sectors – liquid fuels	CO_2	1,721.7	1,880.3	0.001	0.1	98.3
Chemical industry – hydrogen production	CO_2	152.3	251.4	0.001	0.1	98.5
Transport – railways – liquid fuels	CO_2	77.6	151.3	0.000	0.1	98.6
Mineral products – cement production	CO_2	448.7	568.6	0.000	0.1	98.7
Fugitive emissions – geothermal	CH_4	46.0	109.0	0.000	0.1	98.8
Cropland remaining cropland	CO_2	379.1	383.4	0.000	0.1	98.9
Transport – road transport – gasoline	CH_4	50.4	19.4	0.000	0.1	99.0
Transport – road transport – gaseous fuels	CH_4	31.3	0.0	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:

$$\text{Net calorific value} = 0.95 \times \text{gross calorific value for coal and liquid fuels}$$

$$\text{Net calorific value} = 0.90 \times \text{gross calorific value for gas.}$$

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:

$$\text{Gross EF} = \text{Net EF} \times \text{Factor.}$$

Table A2.1 Gross carbon dioxide emission factors used for New Zealand's energy sector in 2012 (before oxidation)

	Emission factor (t CO_2/TJ)	Emission factor (t C/TJ)	Source
Gas			
Maui	52.31	14.3	1
Kapuni	53.83	14.7	1
McKee	53.52	14.6	3
Kaimiro	54.54	14.9	3
Ngatoro	54.54	14.9	3
TAWN	52.72	14.4	3
Mangahewa	53.25	14.5	3
Turangi	54.97	15	3
Pohokura	53.71	14.6	1
Rimu/Kauri	51.04	13.9	3
Maari	51.57	14.1	3
Weighted Average	53.04	14.5	
Kapuni LTS	85.84	23.4	1
Methanol - Mixed Feed – to 94	62.44	17	3
Methanol – LTS – to 94	83.97	22.9	3
Liquid fuels			
Crude oil	69.81	19.0	5
Regular petrol	66.56	18.2	4
Petrol – premium	66.74	18.2	4
Diesel (10 parts (sulphur) per million)	69.73	19.0	4

	Emission factor ($t CO_2/TJ$)	Emission factor (t C/TJ)	Source
Jet kerosene	68.56	18.7	4
Av gas	65.89	18.0	4
LPG	57.01	15.5	2
Heavy fuel oil	73.49	20.0	4
Light fuel oil	72.88	19.9	4
Power station fuel oil	73.82	20.1	4
Bitumen (asphalt)	76.97	21.0	4
Biomass			
Biogas	100.98	27.5	5
Wood (industrial)	104.15	28.4	5
Bioethanol	64.20	17.5	6
Biodiesel	62.40	17.0	6
Wood (residential)	104.15	28.4	5
Coal			
All sectors excl. electricity (sub-bituminous)	92.00	25.1	7
All sectors (bituminous)	89.10	24.3	7
All sectors (lignite)	93.10	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. New Zealand Refinery Company.
5. IPCC guidelines (1996).
6. *New Zealand Energy Information Handbook: Energy data conversion factors and definitions* (Eng, Bywater & Hendtlass, 2008).
7. *Review of Default Emissions Factors in Draft Stationary Energy and Industrial Processes Regulations: Coal* (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 2012 (before oxidation factor)

	Emission factor ($t CO_2/TJ$)
1990	91.20
1991	91.24
1992	91.29
1993	91.33
1994	91.38
1995	91.42
1996	91.47
1997	91.51
1998	91.56
1999	91.60
2000	91.64
2001	91.69
2002	91.73
2003	91.78
2004	91.82
2005	91.87
2006	91.91
2007	92.43
2008	92.31
2009	92.39
2010	92.20
2011	92.00
2012	92.00

Table A2.3 IPCC (1996) methane emission factors used for New Zealand's energy sector for 1990 to 2012

	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)	2.85	IPCC Tier 2 (table 1–16) residual oil boilers

	Emission factor ($t CH_4/PJ$)	Source
– residual oil		
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
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 2012

	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

	Emission factor (t N_2O/PJ)	Source
		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
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. As it is a census, there is no sampling error. The only possible sources or error are non-sample error (such as respondent error and processing error). The 2012 statistical difference for liquid fuels in the balance table of the *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2013) was 3.2 per cent. This is used as the activity data uncertainty for liquid fuels in 2012.

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 by the New Zealand Refinery 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 ±0.5per 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 2012

	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
2012	46.98	47.03	45.66	46.18	47.30	43.03	43.71	42.72	41.27

Table A2.6 Carbon content (per cent mass) for liquid fuels for 1990 to 2012

	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 2012 statistical difference for solid fuels in the balance table of *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2013) was 13.3 per cent. This is used as the activity data uncertainty for solid fuels in 2012.

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 that 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 2012 statistical difference for gaseous fuels in the balance table of *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2012) was 8.5 per cent. This is used as the activity data uncertainty for gaseous fuels in 2012.

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								

	N_2O emission factors (mg/km)				CH_4 emission factors (mg/km)			
	Urban		**Rural**	**Highway**	**Urban**		**Rural**	**Highway**
	Cold	**Hot**			**Cold**	**Hot**		
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
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 cm3	1	1	1	1	219	219	219	219
>50 cm3 2-stroke	2	2	2	2	150	150	150	150
>50 cm3 4stroke	2	2	2	2	200	200	200	200

A2.4 Energy balance for year ended December 2012

Table A.2.8 **New Zealand energy balance for year ended December 2012 (Ministry of Business, Innovation and Employment, 2013)**

	Converted into Petajolues using Gross Calorific Values	COAL			OIL							
		Bituminous & Sub-bitum.	Lignite	Total	Crudes/ Feedstocks/NGL	LPG	Petrol	Diesel	Fuel Oil	Av. Fuel/ Kero	Others	Total
SUPPLY	Indigenous Production	122.27	5.00	127.27	86.55	7.20						93.75
	+ Imports	0.04	0.00	0.04	247.70	0.43	51.24	21.72	0.89	1.22	5.41	328.61
	- Exports	69.43	-	69.43	82.60	0.64	-	-	11.11	-	-	94.35
	- Stock Change	-11.96	-0.01	-11.98	-5.96	0.06	4.90	0.19	1.85	0.81	0.16	2.01
	- International Transport						-	1.54	8.77	35.78	-	46.08
	TOTAL PRIMARY ENERGY	**64.84**	**5.02**	**69.86**	**257.62**	**6.93**	**46.34**	**19.99**	**-20.85**	**-35.36**	**5.25**	**279.92**
	ENERGY TRANSFORMATION	**-47.97**	**-0.24**	**-48.21**	**-255.48**	**-0.00**	**61.92**	**91.62**	**32.25**	**48.40**	**5.34**	**-15.96**
	Electricity Generation	-29.32	-	-29.32				-0.04	-			-0.04
	Cogeneration	-7.42	-0.24	-7.66								
	Oil Production				-255.48		63.89	92.54	31.51	48.46	13.29	-5.79
	Other Transformation	-11.06	-	-11.06								
	Losses and Own Use	-0.17	-	-0.17	-	-0.00	-1.97	-0.88	0.74	-0.06	-7.95	-10.13
Non-energy Use											**-10.59**	**-10.59**
CONSUMER ENERGY (calculated)		**16.87**	**4.78**	**21.65**	**2.14**	**6.92**	**108.26**	**111.61**	**11.40**	**13.03**	**-**	**253.36**
DEMAND	**Agriculture, Forestry and Fishing**	**3.66**	**0.02**	**3.68**		**0.06**	**1.46**	**15.56**	**2.33**	**0.31**		**19.73**
	Agriculture	3.66	0.02	3.68		0.06	1.45	10.53	-	0.31		12.36
	Forestry and Logging	-	-	-			0.00	3.11	-	0.00		3.11
	Fishing	-	-	-			0.00	1.93	2.33	0.00		4.26
	Industrial	**14.78**	**4.23**	**19.01**		**2.67**	**0.08**	**12.18**	**0.97**	**0.12**		**16.02**
	Mining	0.00	0.00	0.00			0.00	3.53	0.02	0.00		3.55
	Food Processing	9.93	4.21	14.13			-	-	-	-		-
	Textiles	0.08	-	0.08								
	Wood, Pulp, Paper and Printing	0.74	0.01	0.75								
	Chemicals	-	-	-								
	Non-metallic Minerals	3.54	0.01	3.55								
	Basic Metals	0.03	-	0.03			-	-	-	-		-
	Mechanical/Electrical Equipment	0.04	0.00	0.04								
	Building and Construction	0.03	-	0.03			0.00	4.19	0.01	0.08		4.29
	Unallocated	0.39	-	0.39		2.67	0.07	4.46	0.93	0.03		8.17
	Commercial	**0.75**	**0.63**	**1.38**		**1.11**	**0.17**	**4.03**	**0.01**	**0.51**		**5.83**
	Transport	**0.00**	**0.00**	**0.01**		**0.37**	**104.42**	**80.02**	**4.00**	**11.15**		**199.96**
	Residential	**0.26**	**0.18**	**0.44**		**2.72**	**-**	**0.29**	**-**	**0.62**		**3.63**
CONSUMER ENERGY (observed)		**19.46**	**5.06**	**24.52**	**-**	**6.92**	**106.14**	**112.09**	**7.31**	**12.71**	**-**	**245.17**
Statistical Differences		**-2.59**	**-0.29**	**-2.88**	**2.14**	**-**	**2.12**	**-0.48**	**4.09**	**0.32**	**-**	**8.19**

NATURAL GAS	RENEWABLES								ELECTRICITY	WASTE HEAT	
Total	Hydro	Geothermal	Solar	Wind	Liquid Biofuels	Biogas	Wood	Total	Total	Total	TOTAL
176.73	82.25	161.28	0.36	7.39	0.28	3.09	60.22	314.87		1.52	714.14
											328.65
											163.77
-1.95											-11.92
											46.08
178.68	**82.25**	**161.28**	**0.36**	**7.39**	**0.28**	**3.09**	**60.22**	**314.87**		**1.52**	**844.85**
-80.67	**-82.25**	**-151.95**		**-7.39**	**-0.28**	**-2.76**	**-4.95**	**-249.59**	**143.66**	**-1.52**	**-252.29**
-53.58	-82.25	-150.65		-7.39		-1.95		-242.24	149.40		-175.78
-19.34		-1.31				-0.82	-4.95	-7.08	10.24	-1.52	-25.36
-					-0.28			-0.28			-6.07
											-11.06
-7.74									-15.99		-34.03
-31.74											**-42.33**
66.27		**9.33**	**0.36**	**-**	**-**	**0.33**	**55.26**	**65.28**	**143.66**	**-**	**550.23**
1.56		**0.79**						**0.79**	**6.59**		**32.35**
1.54		0.79						0.79	5.91		24.27
0.03									0.16		3.30
-									0.52		4.78
44.85		**5.90**					**47.98**	**53.89**	**51.02**		**184.79**
0.00									1.44		5.00
10.87									6.75		31.75
0.38									0.36		0.83
5.45									11.03		17.24
22.57									2.60		25.18
0.70									0.91		5.16
3.08									23.24		26.35
1.62									0.60		2.27
0.05									0.60		4.99
0.11		5.90					47.98	53.89	3.48		66.03
7.89		**2.32**				**0.28**		**2.60**	**32.52**		**50.22**
0.03						**-**		**-**	**0.22**		**200.22**
6.28		**0.31**	**0.36**				**7.28**	**7.96**	**46.21**		**64.51**
60.61	**-**	**9.33**	**0.36**	**-**		**0.28**	**55.26**	**65.23**	**136.57**	**-**	**532.10**
5.66		**-**	**-**	**-**		**0.05**	**-**	**0.05**	**7.09**	**-**	**18.13**

A2.5 Fuel flow diagrams for year ended December 2012

Figure A2.1 New Zealand coal energy flow summary for 2012

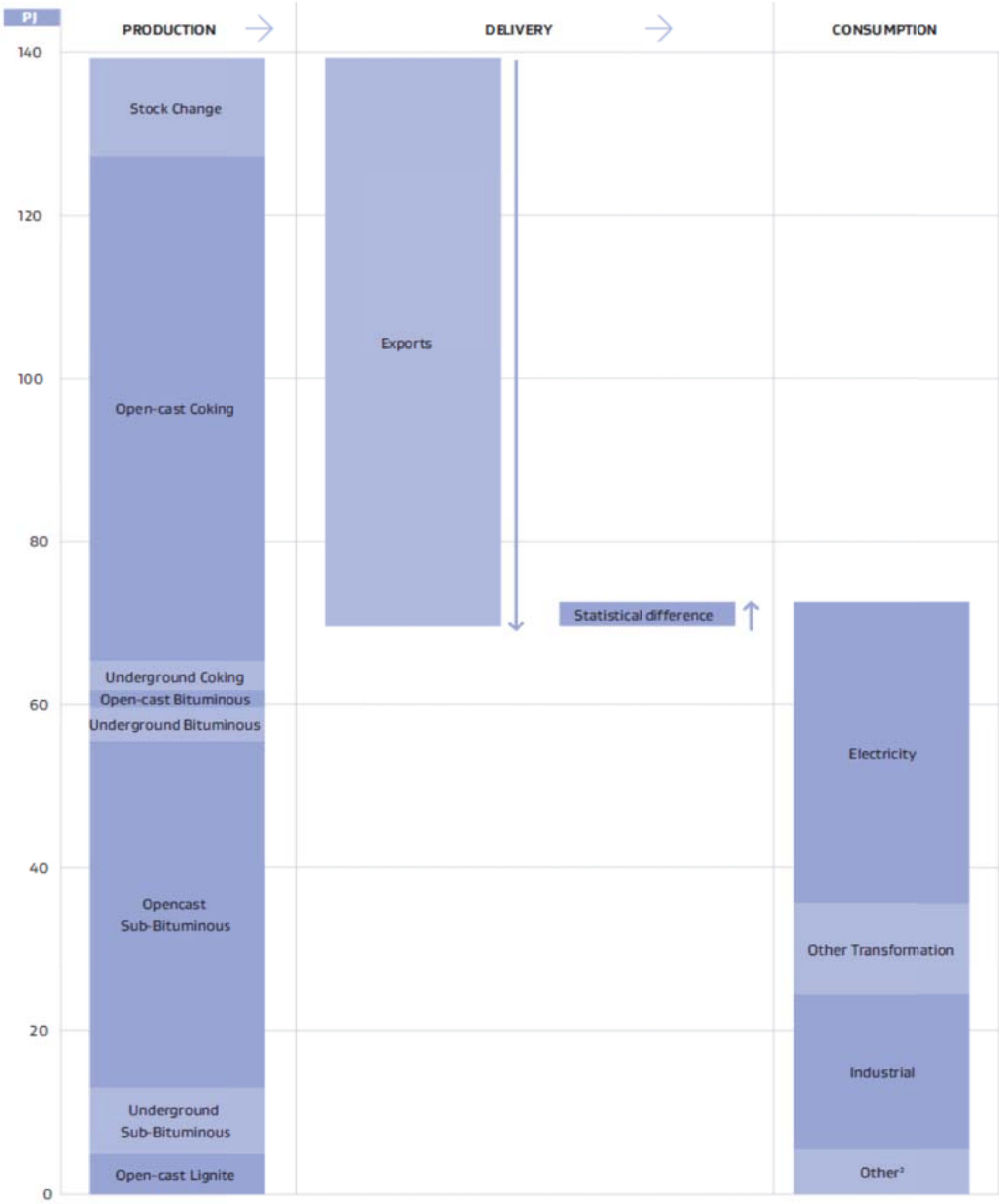


Figure A2.2 New Zealand oil energy flow summary for 2012

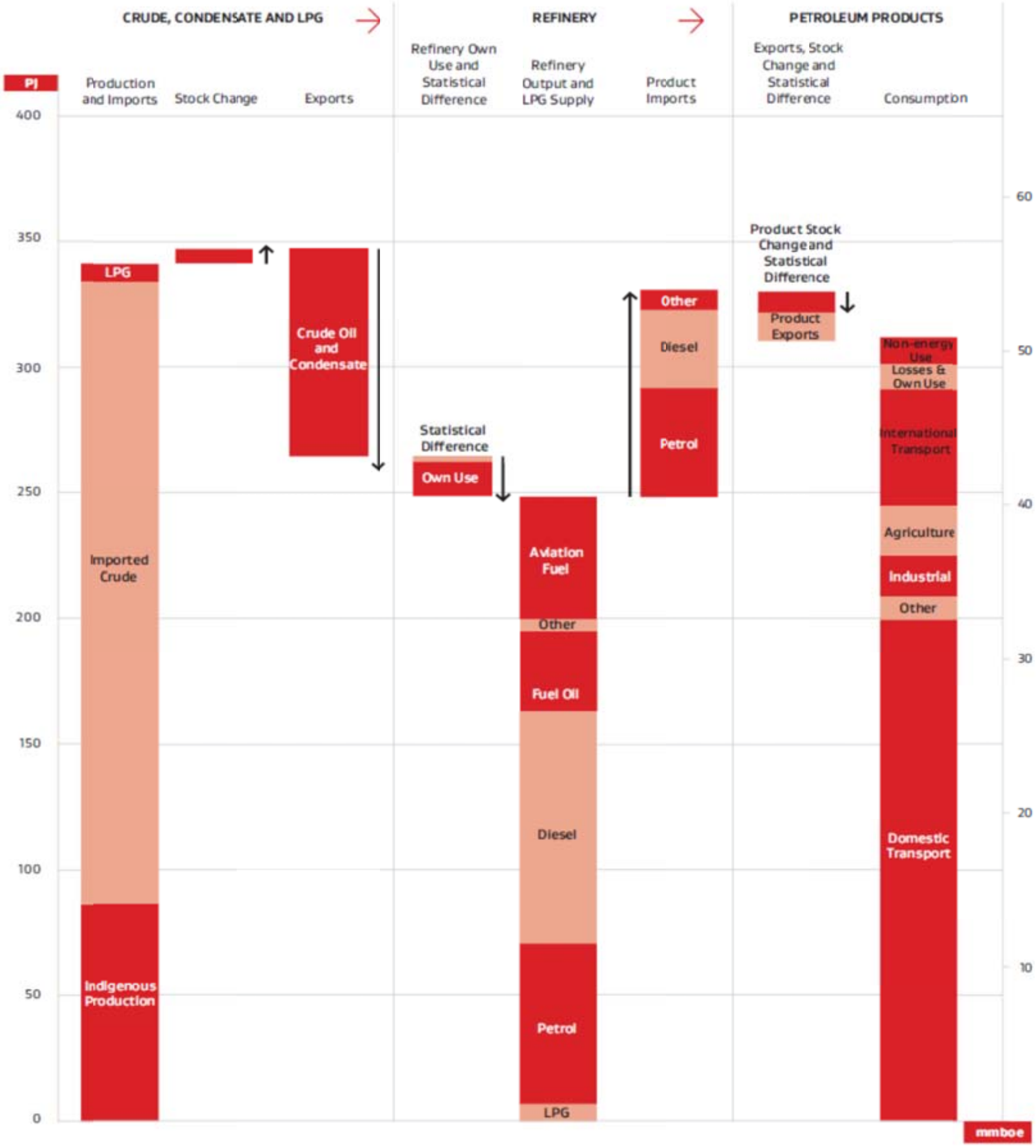
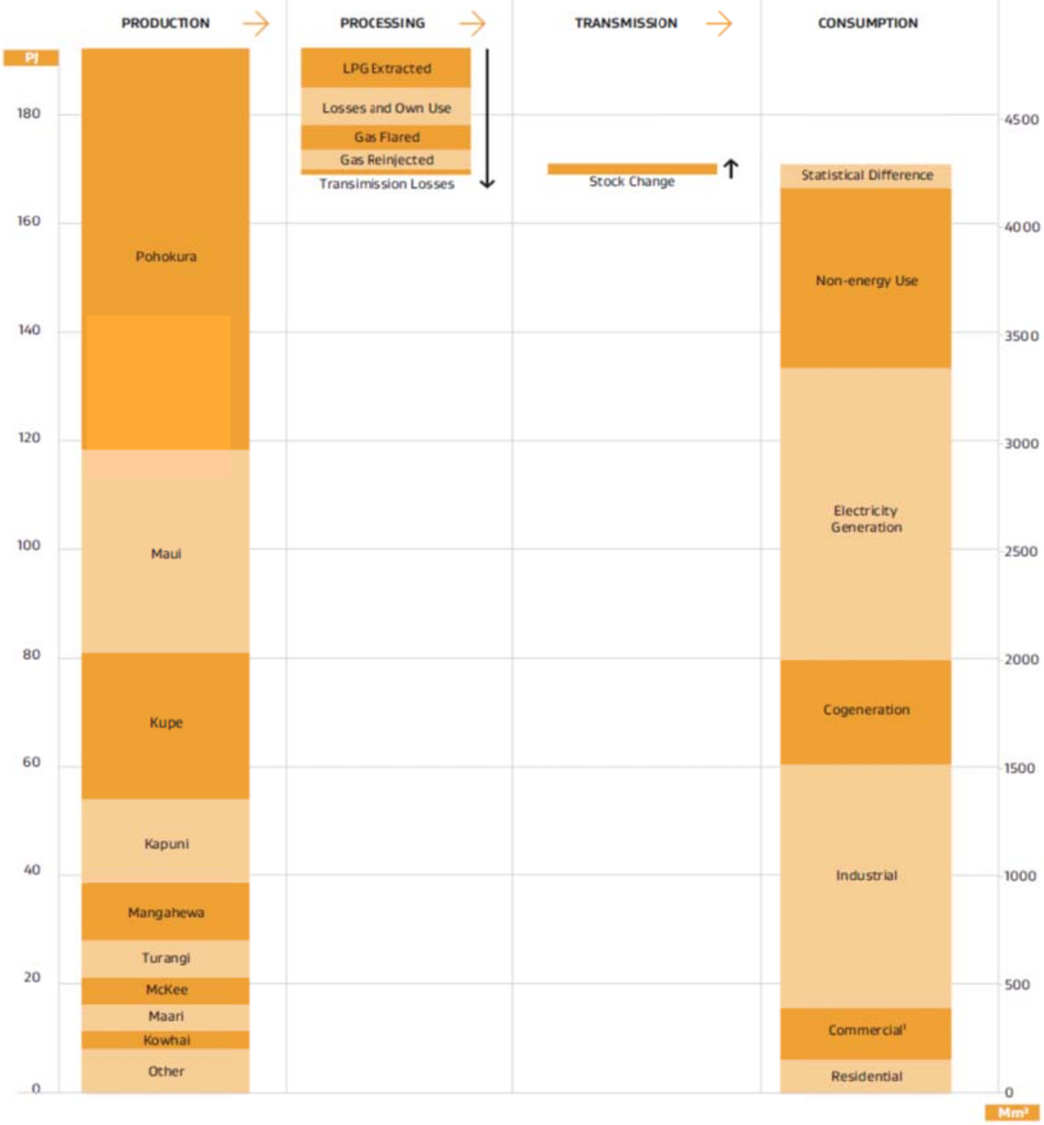


Figure A2.3 New Zealand natural gas energy flow summary for 2011



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 cogenerators 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 2012 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 2012. 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
Calves born alive to dairy heifers / cows	21	4
Female deer mated	14	7
Total number of deer	14	7

Statistic	Proportion of total estimate imputed (%)	Sample error (%)
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: Thomas 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[44]
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	2.08
MM_{MULES}	Manure management – mules and asses	IPCC (1996), table 4.5	10
MM_{SWINE}	Manure management – swine	Hill (2012)	20
$MM_{BROILERs}$	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[45]	0.091

[44] 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 – 2012 are interpolated and extrapolated based on an assumption that the dairy goat population has remained in a near constant state over time.

[45] As was reported in the first year that alpacas were included in *New Zealand's Greenhouse Gas Inventory* (Ministry for the Environment, 2010).

Table A3.1.6 Monthly digestibility of feed (decimal) and energy concentration of feed (MJ ME/kg dry matter) for dairy for entire time series

Collected from a 12 month study in 2001 – 2002 of 10 dairy farms (Ian Brookes, personal communication).

Monthly Digestibility (Decimal)												
Month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Digestibility of feed	0.8366	0.7945	0.7906	0.8048	0.785	0.7377	0.762	0.7362	0.7436	0.7861	0.8121	0.8022
ME of feed	12.582	11.53	11.686	12.007	11.637	10.817	11.084	10.611	10.69	11.329	11.936	11.655

Table A3.1.7 Monthly digestibility of feed (percentage as a decimal) and energy concentration of feed (MJ ME/kg dry matter) for all years in the time series for sheep, and beef animals. Average monthly digestibility of feed and energy concentration of feed for 1990 and latest year for deer.

Collected from a national survey of 19 beef and sheep farms conducted between March 2001 and February 2002 (Litherland *et al*, 2002).

Monthly Digestibility (Decimal)												
Month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Sheep and beef												
Digestibility of feed	0.738	0.738	0.777	0.777	0.777	0.681	0.681	0.681	0.661	0.661	0.661	0.738
ME of feed	10.8	10.8	11.4	11.4	11.4	9.9	9.9	9.9	9.6	9.6	9.6	10.8
Deer 1990												
Digestibility of feed	0.783	0.764	0.783	0.790	0.781	0.707	0.718	0.706	0.699	0.719	0.731	0.768
ME of feed	11.6	11.1	11.5	11.7	11.5	10.3	10.4	10.2	10.1	10.4	10.7	11.2
Deer 2011												
Digestibility of feed	0.748	0.744	0.778	0.780	0.778	0.687	0.689	0.687	0.669	0.674	0.676	0.744
ME of feed	11.0	10.9	11.4	11.5	11.4	10.0	10.0	10.0	9.7	9.8	9.8	10.9

Table A3.1.8 Nitrogen content (percent) of the diet for dairy, beef, sheep and deer

Percent nitrogen in diet												
Species	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Dairy	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Beef	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Sheep	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Deer												
1990	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
2011	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07

Table A3.1.9 Proportion of annual milk yield each month

Month	Dairy	Beef	Sheep	Deer
July	0.00880	0	0	0
August	0.05779	0	0	0
September	0.12132	0.167	0.25	0
October	0.15035	0.167	0.25	0
November	0.14247	0.167	0.25	0.1
December	0.12816	0.167	0.25	0.258333333
January	0.11094	0.167	0	0.258333333
February	0.09004	0.167	0	0.233333333
March	0.08514	0	0	0.15
April	0.06544	0	0	0
May	0.03347	0	0	0
June	0.00607	0	0	0

Source: Dairy Companies Association New Zealand (www.dcanz.com/statistics), Suttie (2012), and Pickering and Wear (2013)

Annex 3.1: References

Some references may be downloaded directly from the following webpage:

http://www.mpi.govt.nz/environment-natural-resources/climate-change/research-and-funded-projects/greenhouse-gas-inventory-projects-table.aspx

The Ministry for Primary Industries is progressively making reports used for the inventory available on this page provided copyright permits.

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A3.2 Supplementary information for the LULUCF sector

A3.2.1 Uncertainty analysis for the LULUCF sector

This section contains the disaggregated uncertainty analysis for the LULUCF sector. This additional information has been provided as a result of the review of New Zealand's 2010 inventory (2012 submission). One of the recommendations of that review was that New Zealand provides "a detailed disaggregated assessment of uncertainty, as well as the aggregated uncertainty associated with the LULUCF sector, consistent with the IPCC good practice guidance for LULUCF". This information is now provided in Table A3.2.1.

Table A3.2.1 Uncertainty analysis for the LULUCF sector

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2012 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission factor uncertainty (biomass) (%)	Emission factor uncertainty (mineral soil) (%)	Combined uncertainty (%)	Contribution to variance by category in 2012 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in trend in LULUCF emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in LULUCF emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total LULUCF emissions (%)	Emission factor quality indicator	Activity data quality indicator
Pre-1990 natural forest remaining pre-1990 natural forest	CO_2	4,396,510.4	4,384,980.0	4.0	9.3	6.1	75.3	44.3	14.4	33.2	0.8	0.8	1.2	M	M
Land converted to pre-1990 natural forest	CO_2	11,562.1	5,897.6	4.0	9.3	6.1	87.6	0.1	0.0	0.0	0.0	0.0	0.0	M	M
Pre-1990 planted forest remaining pre-1990 planted forest	CO_2	802,800.6	2,401,401.2	7.0	12.4	9.6	93.8	30.3	14.7	18.2	1.5	1.5	2.1	M	M
Land converted to pre-1990 planted forest	CO_2	7,169,945.9	1,855,622.6	7.0	12.4	9.6	9.4	2.3	–16.5	14.1	–1.6	–1.6	2.3	M	M
Post-1989 forest remaining post-1989 forest	CO_2	0.0	0.0	7.0	8.6	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Land converted to post-1989 planted forest	CO_2	26,390.5	5,186,814.5	7.0	8.6	9.6	8.0	5.6	39.2	39.3	3.9	3.9	5.5	M	M
G-WB remaining G-WB	CO_2	10,141.8	6,927.6	6.0	75.0	5.8	90.2	0.1	0.0	0.1	0.0	0.0	0.0	M	M
Land converted to G-WB	CO_2	123,055.4	18,321.9	6.0	75.0	5.8	128.0	0.3	–0.4	0.1	0.0	0.0	0.0	M	M

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2012 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission factor uncertainty (biomass) (%)	Emission factor uncertainty (mineral soil) (%)	Combined uncertainty (%)	Contribution to variance by category in 2012 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in trend in LULUCF emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in LULUCF emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total LULUCF emissions (%)	Emission factor quality indicator	Activity data quality indicator
G-HP remaining G-HP	CO_2	308,123.4	304,055.0	6.0	75.0	4.7	90.2	3.7	1.0	2.3	0.1	0.1	0.1	M	M
Land converted to G-HP	CO_2	140,643.1	8,239.3	6.0	75.0	4.7	117.7	0.1	–0.5	0.1	0.0	0.0	0.1	M	M
G-LP remaining G-LP	CO_2	63,681.5	61,703.7	6.0	75.0	16.5	90.2	0.7	0.2	0.5	0.0	0.0	0.0	M	M
Land converted to G-LP	CO_2	19,664.2	1,093,879.3	6.0	75.0	16.5	12.6	1.9	8.2	8.3	0.7	0.7	1.0	M	M
Cropland – perennial remaining cropland – perennial	CO_2	22,007.7	20,529.2	6.0	75.0	10.9	90.2	0.2	0.1	0.2	0.0	0.0	0.0	M	M
Land converted to cropland – perennial	CO_2	14,471.4	9,677.3	6.0	75.0	10.9	185.7	0.2	0.0	0.1	0.0	0.0	0.0	M	M
Cropland –-annual remaining cropland – annual	CO_2	73,046.6	70,634.9	6.0	75.0	7.5	90.2	0.9	0.2	0.5	0.0	0.0	0.0	M	M
Land converted to cropland – annual	CO_2	19,257.1	22,494.6	6.0	75.0	7.5	27.2	0.1	0.1	0.2	0.0	0.0	0.0	M	M
Wetlands – open water remaining wetlands – open water	CO_2	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	M

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2012 emissions or absolute value of removals (Gg CO_2-e)	Activity data uncertainty (%)	Emission factor uncertainty (biomass) (%)	Emission factor uncertainty (mineral soil) (%)	Combined uncertainty (%)	Contribution to variance by category in 2012 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in trend in LULUCF emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in LULUCF emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total LULUCF emissions (%)	Emission factor quality indicator	Activity data quality indicator
Land converted to wetlands – open water	CO_2	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Wetlands – vegetative non-forest remaining wetlands – vegetative non-forest	CO_2	0.0	0.0	6.0	75.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Land converted to wetlands – vegetative non-forest	CO_2	0.0	0.0	6.0	75.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Settlements remaining settlements	CO_2	0.0	0.0	6.0	75.0	95.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Land converted to settlements	CO_2	1,729.8	730.8	6.0	75.0	95.0	131.3	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Other land remaining other land	CO_2	0.0	0.0	7.0	75.0	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Land converted to other land	CO_2	1,697.6	4,746.7	7.0	75.0	45.0	16.3	0.0	0.0	0.0	0.0	0.0	0.0	M	M
Total emissions/removals		13,204,729.2	7,448,078.6												

Note: M = measurements.

A3.2.2 LUCAS Data Management System

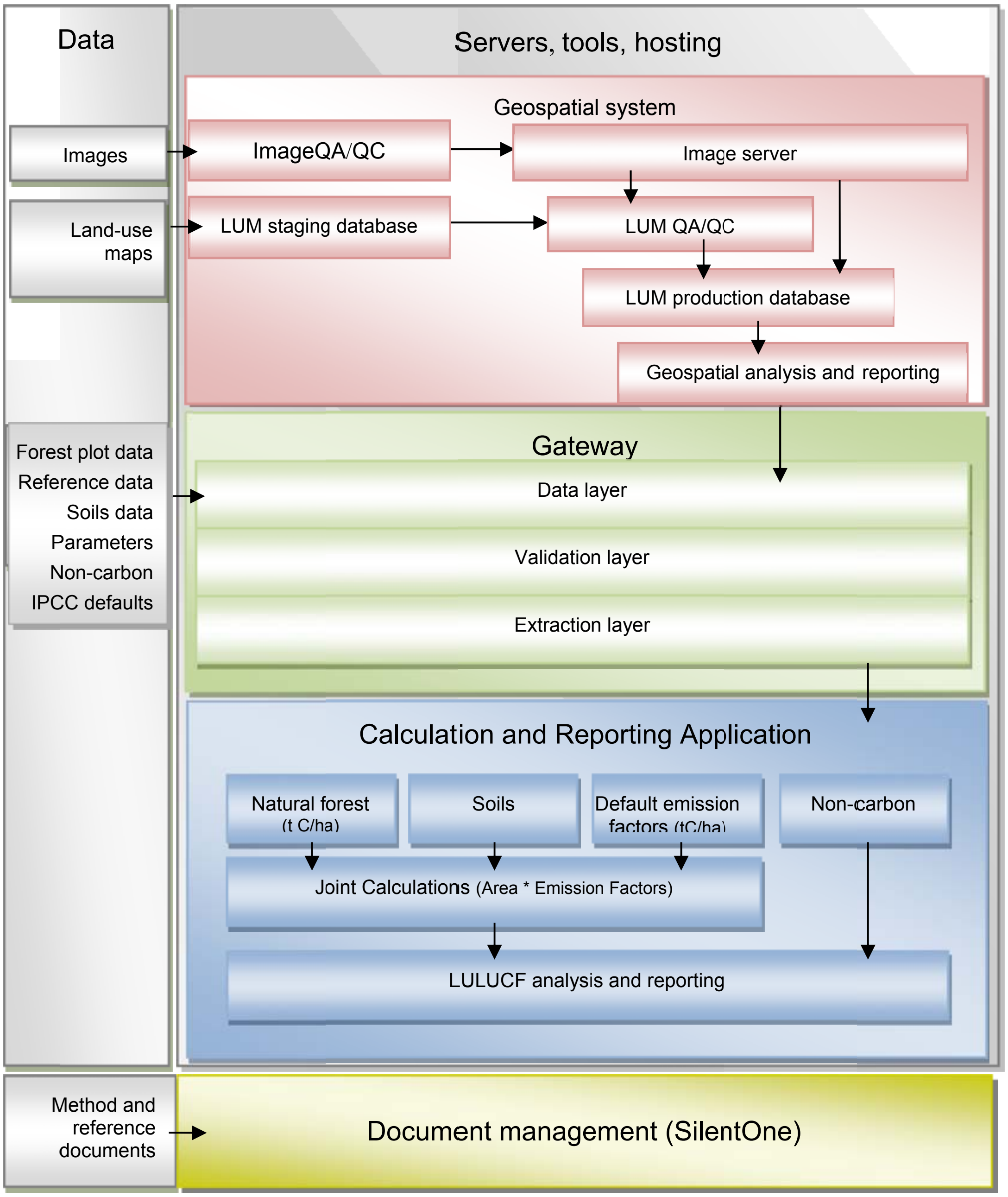
The LUCAS Data Management System stores, manages and archives data for international greenhouse gas reporting for the LULUCF sector. These systems are used for managing the land-use spatial databases, plot and reference data, and for combining the two sets of data to calculate the numbers required for 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.

Figure A3.2.1 New Zealand's LUCAS data management system



Note: LUM = land-use map. Joint calculations are described below.

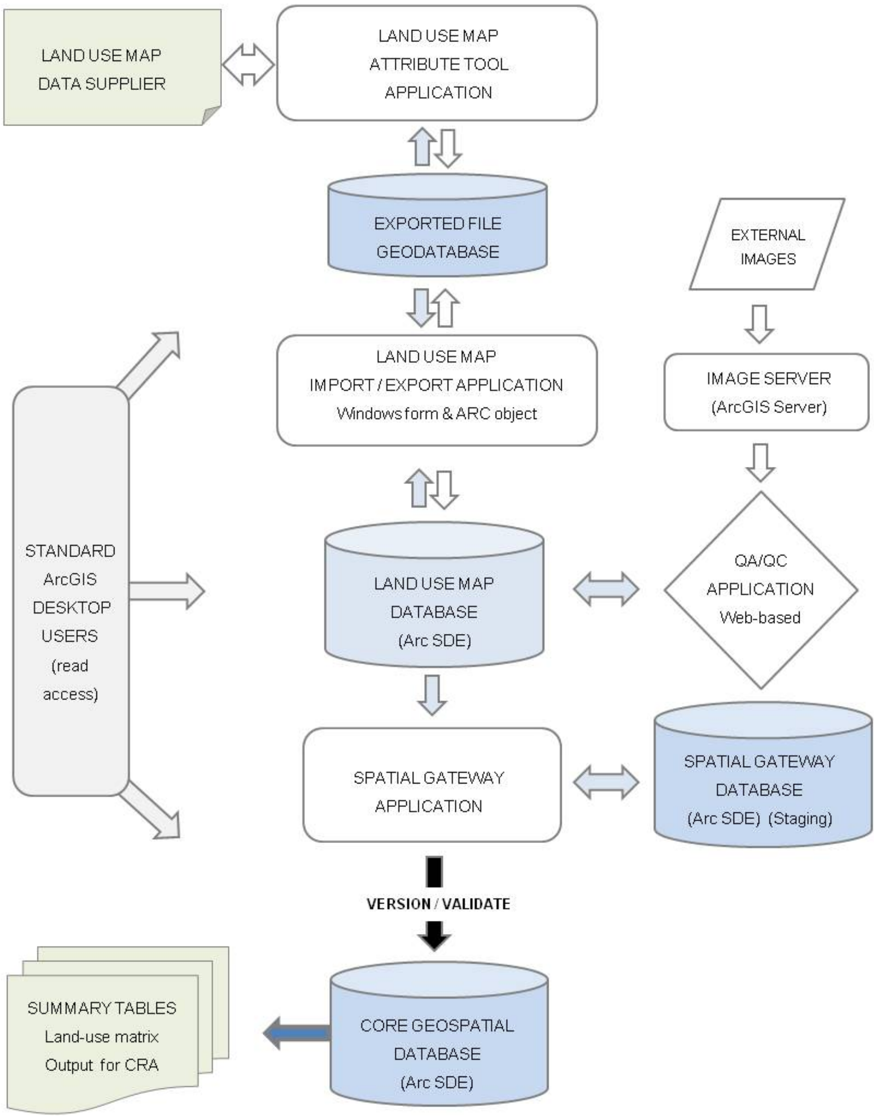
The module "Joint Calculations" refers to the process New Zealand uses to estimate national average carbon values by carbon pool for each land-use category and subcategory.

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 in figure A3.2.2 below.

Figure A3.2.2 New Zealand's Geospatial Systemcomponents



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. The five components within the LUM functionality are:

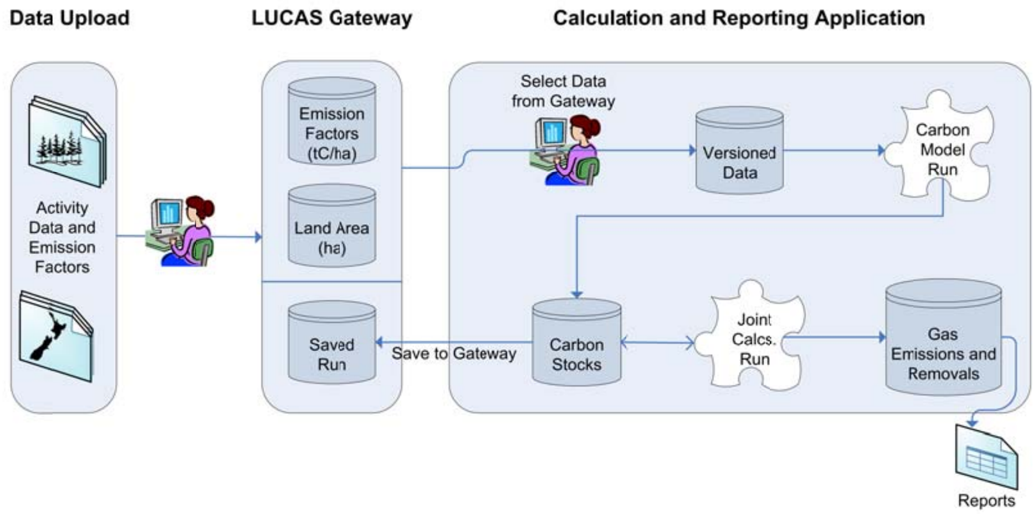
- LUM Import/Export Application – which provides functionality for managing the importing and exporting of land-use mapping information in to and out of the database
- LUM Attribute Tool Application – an extension to the standard ArcGIS Desktop software that facilitates maintenance and updates to the 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 – which is 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 – which stores final versioned geospatial data sets 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 (figure A3.2.3) 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 emission 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.

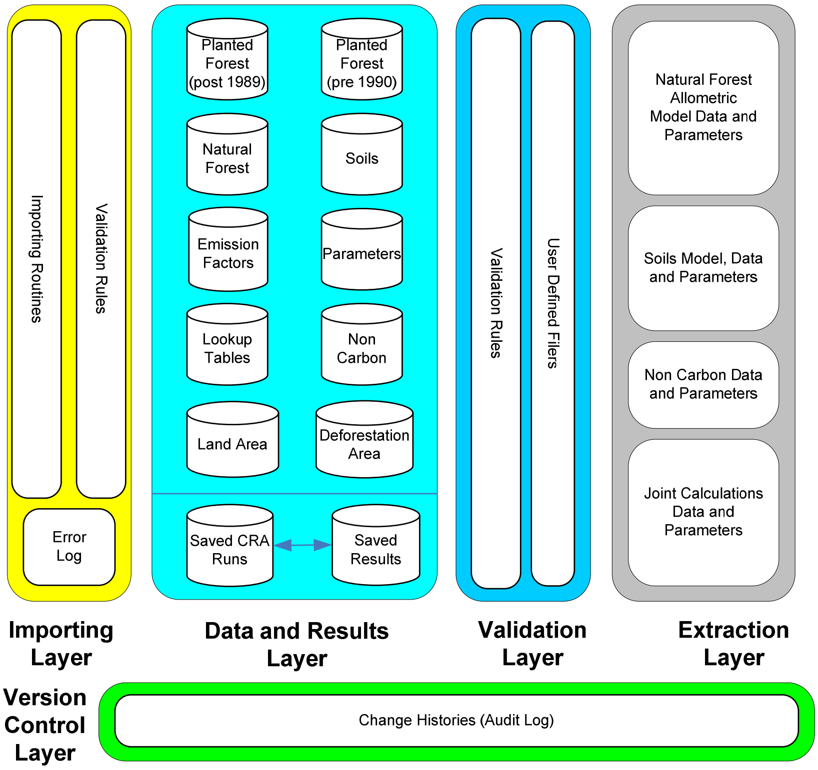
The LUCAS Gateway provides a viewing, querying and editing interface to the source (plot, land-use area, carbon and non-carbon) data. It also stores any published or saved results from running the Calculation and Reporting Application.

All activity data and emission factors are stored within the Gateway database (figure A3.2.4). It contains the following 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 data set 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 data sets, 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.

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 data set to be used, the model version and other calculation parameters. The natural forest and soil carbon modules use R statistical language as the base program 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 following the methodology set out in section 3.1.4 of the *Good Practice Guidance for Land Use, Land-use Change and Forestry* (IPCC, 2003). 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.

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.

Document management

All reference material, including scientific reports containing information on methodologies or emission factors used in the production of the LULUCF and Kyoto Protocol estimates, are archived on the Ministry for the Environments document management store SilentOne.

The emission factors and area estimates just for published runs are also archived within Gateway and can be accessed via the Gateway or the Calculation and Reporting Application.

Annex 3.2.1: References

IPCC. 2003. *Good Practice Guidance for Land Use, Land-Use Change and Forestry*. IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

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 percentage 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 – 2012* (IPCC, Tier 1)

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2012 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 2012 (%)	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	11677.70	17372.98	3.2	0.5	3.3	0.5	0.0401	0.1708	0.0200	0.7809	0.8	R	M
Energy – solid fuels	CO_2	3146.87	4878.13	13.3	2.2	13.5	0.6	0.0127	0.0480	0.0276	0.9023	0.9	M	M
Energy – gaseous fuels	CO_2	7005.39	7305.76	8.5	2.4	8.9	0.6	-0.0066	0.0718	-0.0158	0.8676	0.9	M	M
Energy – fugitive – geothermal	CO_2	228.58	629.56	5.0	5.0	7.1	0.0	0.0036	0.0062	0.0182	0.0438	0.0	D	D
Energy – fugitive – venting/flaring	CO_2	227.03	655.27	8.5	2.4	8.9	0.1	0.0039	0.0064	0.0094	0.0778	0.1	M	M
Energy – fugitive – oil transport	CO_2	3.18	3.18	5.0	50.0	50.2	0.0	0.0000	0.0000	-0.0002	0.0002	0.0	D	D
Energy – fugitive – transmission and distribution	CO_2	1.46	1.23	8.5	5.0	9.9	0.0	0.0000	0.0000	0.0000	0.0001	0.0	D	M
Industrial processes – mineral production	CO_2	561.85	752.13	20.0	7.0	21.2	0.1	0.0011	0.0074	0.0077	0.2092	0.2	D	D
Industrial processes – chemical industry	CO_2	299.43	419.07	2.0	6.0	6.3	0.0	0.0008	0.0041	0.0046	0.0117	0.0	D	D
Industrial processes – metal production	CO_2	1755.71	2239.96	5.0	7.0	8.6	0.2	0.0024	0.0220	0.0166	0.1557	0.2	D	D
LULUCF – forest land	CO_2	39,154.1	33,164.7	[46]	54.1	54.1	15.5	-0.1117	0.3261	-6.0441	0.0000	6.0	M	R

[46] Uncertainties for LULUCF are calculated externally to the IPCC Tier 1 uncertainty analysis using a more comprehensive approach. Therefore, only combined uncertainties for LULUCF are provided in this table. For a comprehensive breakdown of LULUCF uncertainties see annex 3

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2012 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 2012 (%)	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
LULUCF – non–forested land	CO_2	1,839.6	6,480.5	[1]	4.3	4.3	0.2	0.0431	0.0637	0.1859	0.0000	0.2	M	R
Waste – waste incineration	CO_2	12.9	0.9	50.0	40.0	64.0	0.0	-0.0001	0.0000	-0.0054	0.0006	0.0	D	D
Energy – liquid fuels	CH_4	56.80	28.61	3.2	50.0	50.1	0.0	-0.0004	0.0003	-0.0177	0.0013	0.0	D	M
Energy – solid fuels	CH_4	23.78	4.31	13.3	50.0	51.7	0.0	-0.0002	0.0000	-0.0112	0.0008	0.0	D	M
Energy – gaseous fuels	CH_4	36.38	5.77	8.5	50.0	50.7	0.0	-0.0004	0.0001	-0.0175	0.0007	0.0	D	M
Energy – biomass	CH_4	57.38	59.60	5.0	50.0	50.2	0.0	-0.0001	0.0006	-0.0028	0.0041	0.0	D	D
Energy – fugitive – geothermal	CH_4	46.02	108.98	5.0	5.0	7.1	0.0	0.0006	0.0011	0.0028	0.0076	0.0	D	D
Energy – fugitive – venting/flaring	CH_4	55.49	61.51	8.5	50.0	50.7	0.0	0.0000	0.0006	-0.0008	0.0073	0.0	D	M
Energy – fugitive – coal mining & handling	CH_4	283.21	292.89	13.3	50.0	51.7	0.1	-0.0003	0.0029	-0.0145	0.0542	0.1	D	M
Energy – fugitive – transmission and distribution	CH_4	235.16	163.73	8.5	5.0	9.9	0.0	-0.0010	0.0016	-0.0051	0.0194	0.0	D	M
Energy – fugitive – other leakages	CH_4	286.3	261.3	5.0	50.0	50.2	0.1	-0.0006	0.0026	-0.0318	0.0182	0.0	D	D
Energy – fugitive – oil transportation	CH_4	4.8	6.0	5.0	50.0	50.2	0.0	0.0000	0.0001	0.0003	0.0004	0.0	D	D
Agriculture – enteric fermentation	CH_4	22,101.3	23,935.9	0.0	16.0	16.0	3.3	-0.0120	0.2353	-0.1922	0.0000	0.2	M	M
Agriculture – manure management	CH_4	459.1	672.1	5.0	30.0	30.4	0.2	0.0015	0.0066	0.0441	0.0467	0.1	M	M
Agriculture – prescribed	CH_4	22.2	4.4	20.0	60.0	63.2	0.0	-0.0002	0.0000	-0.0123	0.0012	0.0	D	R

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2012 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 2012 (%)	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
burning														
Agriculture – burning of residues	CH_4	19.0	23.5	0.0	40.0	40.0	0.0	0.0000	0.0002	0.0007	0.0000	0.0	D	R
LULUCF	CH_4	51.0	64.9	6.0	105.0	105.2	0.1	0.0001	0.0006	0.0071	0.0054	0.0		
Waste – solid waste disposal	CH_4	2,912.4	3,120.5	147.0	40.0	152.3	4.1	-0.0019	0.0307	-0.0767	6.3785	6.4	M	R
Waste – wastewater handling	CH_4	235.4	289.5	50.0	50.0	70.7	0.2	0.0002	0.0028	0.0106	0.2013	0.2	D	R
Waste – waste incineration	CH_4	0.0	0.0	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	118.01	175.52	3.2	50.0	50.1	0.1	0.0004	0.0017	0.0202	0.0079	0.0	D	M
Energy – solid fuels	N_2O	16.29	24.98	13.3	50.0	51.7	0.0	0.0001	0.0002	0.0032	0.0046	0.0	D	M
Energy – gaseous fuels	N_2O	8.45	8.72	8.5	50.0	50.7	0.0	0.0000	0.0001	-0.0004	0.0010	0.0	D	M
Energy – biomass	N_2O	46.29	73.20	5.0	50.0	50.2	0.0	0.0002	0.0007	0.0101	0.0051	0.0	D	D
Solvents – N_2O use	N_2O	41.5	34.1	10.0	0.0	10.0	0.0	-0.0001	0.0003	0.0000	0.0047	0.0	R	
Agriculture – agricultural soils	N_2O	7,830.5	10,340.8	0.0	74.0	74.0	6.6	0.0140	0.1017	1.0371	0.0000	1.0	M	M
Agriculture – manure management	N_2O	25.8	36.0	5.0	100.0	100.1	0.0	0.0001	0.0004	0.0065	0.0025	0.0	R	R
Agriculture – prescribed burning	N_2O	8.1	1.6	20.0	60.0	63.2	0.0	-0.0001	0.0000	-0.0045	0.0005	0.0	D	R
Agriculture – burning of residues	N_2O	5.0	6.0	6.0	40.0	40.4	0.0	0.0000	0.0001	0.0001	0.0005	0.0	D	R
LULUCF	N_2O	13.2	20.8	30.0	42.0	51.6	0.0	0.0001	0.0002	0.0024	0.0087	0.0	R	R

IPCC source category	Gas	1990 emissions or absolute value of removals (Gg CO_2-e)	2012 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 2012 (%)	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
Waste – wastewater handling	N_2O	144.1	183.5	25.0	1200.0	1200.3	1.9	0.0002	0.0018	0.2285	0.0638	0.2	D	R
Waste – waste incineration	N_2O	1.6	1.3	50.0	100.0	111.8	0.0	0.0000	0.0000	-0.0006	0.0009	0.0	D	D
Industrial processes	HFCs	0.0	1,804.69	15.0	5.0	15.8	0.2	0.0177	0.0177	0.0887	0.3764	0.4	R	R
Industrial processes – aluminium production	PFCs	629.9	40.75	5.0	30.0	30.4	0.0	-0.0066	0.0004	-0.1995	0.0028	0.2	R	D
Industrial processes – consumption of hydrofluorocarbons	PFCs	0	0.00	20.0	5.0	20.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	R	R
Industrial processes	SF_6	15.2	20.20	25.0	10.0	26.9	0.0	0.0000	0.0002	0.0003	0.0070	0.0	R	R
Total emissions/removals		**101,703.5**	**115,778.9**		**Uncertainty in the year**		**17.8%**		**Uncertainty in the trend**			**9.0%**		

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 percentage 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	11,677.70	17,372.98	3.2	0.5	3.3	0.7	0.0449	0.2865	0.0225	1.3097	1.3	R	R
Energy – solid fuels	CO_2	3,146.87	4,878.13	13.3	2.2	13.5	0.9	0.0154	0.0804	0.0332	1.5133	1.5	R	R
Energy – gaseous fuels	CO_2	7,005.39	7,305.76	8.5	2.4	8.9	0.9	-0.0244	0.1205	-0.0587	1.4552	1.5	R	R
Energy – fugitive – geothermal	CO_2	228.58	629.56	5.0	5.0	7.1	0.1	0.0057	0.0104	0.0283	0.0734	0.1	D	D
Energy – fugitive – venting/flaring	CO_2	222.81	655.27	8.5	2.4	8.9	0.1	0.0062	0.0108	0.0149	0.1305	0.1	R	R
Energy – fugitive – oil	CO_2	3.18	3.18	5.0	50.0	50.2	0.0	0.0000	0.0001	-0.0007	0.0004	0.0	D	D
Energy – fugitive – transmission and distribution	CO_2	1.46	1.23	8.5	5.0	9.9	0.0	0.0000	0.0000	0.0000	0.0002	0.0	R	R
Industrial processes – mineral production	CO_2	561.85	752.13	20.0	7.0	21.2	0.2	0.0008	0.0124	0.0055	0.3508	0.4	D	D
Industrial processes – chemical industry	CO_2	299.43	419.07	2.0	6.0	6.3	0.0	0.0007	0.0069	0.0043	0.0195	0.0	D	D
Industrial processes – metal production	CO_2	1,755.71	2,239.96	5.0	7.0	8.6	0.3	0.0006	0.0369	0.0044	0.2612	0.3	D	D
Waste – waste incineration	CO_2	12.9	0.9	50.0	40.0	64.0	0.0	-0.0003	0.0000	-0.0101	0.0011	0.0	D	D
Energy – liquid fuels	CH_4	56.80	28.61	3.2	50.0	50.1	0.0	-0.0007	0.0005	-0.0351	0.0022	0.0	D	D
Energy – solid fuels	CH_4	23.78	4.31	13.3	50.0	51.7	0.0	-0.0004	0.0001	-0.0210	0.0013	0.0	D	D
Energy – gaseous fuels	CH_4	36.38	5.77	8.5	50.0	50.7	0.0	-0.0007	0.0001	-0.0329	0.0011	0.0	D	D
Energy – biomass	CH_4	57.38	59.60	5.0	50.0	50.2	0.0	-0.0002	0.0010	-0.0102	0.0069	0.0	D	D
Energy – fugitive – geothermal	CH_4	46.02	108.98	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 percentage 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	55.49	61.51	8.5	50.0	50.7	0.0	-0.0001	0.0010	-0.0067	0.0123	0.0	R	R
Energy – fugitive – coal mining & handling	CH_4	283.21	292.89	13.3	50.0	51.7	0.2	-0.0010	0.0048	-0.0513	0.0909	0.1	R	R
Energy – fugitive – transmission and distribution	CH_4	235.16	163.73	8.5	5.0	9.9	0.0	-0.0022	0.0027	-0.0108	0.0326	0.0	R	R
Energy – fugitive – other leakages	CH_4	286.3	261.3	5.0	50.0	50.2	0.2	-0.0016	0.0043	-0.0806	0.0305	0.1	D	D
Energy – fugitive – oil transportation	CH_4	4.8	6.0	5.0	50.0								D	D
Agriculture – enteric fermentation	CH_4	22,101.3	23,935.9	0.0	16.0	16.0	5.0	-0.0621	0.3947	-0.9938	0.0000	1.0	M	M
Agriculture – manure management	CH_4	459.1	672.1	5.0	30.0	30.4	0.3	0.0016	0.0111	0.0477	0.0784	0.1	M	M
Agriculture – prescribed burning	CH_4	22.2	4.4	20.0	60.0	63.2	0.0	-0.0004	0.0001	-0.0232	0.0021	0.0	D	R
Agriculture – burning of residues	CH_4	19.0	23.5	0.0	40.0	40.0	0.0	0.0000	0.0004	-0.0003	0.0000	0.0	D	R
Waste – solid waste disposal	CH_4	2,912.4	3,120.5	147.0	40.0	152.3	6.3	-0.0088	0.0515	-0.3506	10.6976	10.7	M	R
Waste – wastewater handling	CH_4	235.4	289.5	50.0	50.0	70.7	0.3	-0.0001	0.0048	-0.0046	0.3376	0.3	D	R
Waste – waste incineration	CH_4	0.0	0.0	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	118.01	175.52	3.2	50.0	50.1	0.1	0.0005	0.0029	0.0227	0.0132	0.0	D	D
Energy – solid fuels	N_2O	16.29	24.98	13.3	50.0	51.7	0.0	0.0001	0.0004	0.0038	0.0077	0.0	D	D
Energy – gaseous fuels	N_2O	8.45	8.72	8.5	50.0	50.7	0.0	0.0000	0.0001	-0.0016	0.0017	0.0	D	D
Energy – biomass	N_2O	46.29	73.20	5.0	50.0	50.2	0.0	0.0002	0.0012	0.0125	0.0085	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 percentage 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
Solvents – N_2O use	N_2O	41.5	34.1	10.0	0.0	10.0	0.0	-0.0003	0.0006	0.0000	0.0080	0.0	R	
Agriculture – agricultural soils	N_2O	7,830.5	10,340.8	0.0	74.0	74.0	10.1	0.0086	0.1705	0.6347	0.0000	0.6	M	M
Agriculture – manure management	N_2O	25.8	36.0	5.0	100.0	100.1	0.0	0.0001	0.0006	0.0060	0.0042	0.0	R	R
Agriculture – prescribed burning	N_2O	8.1	1.6	20.0	60.0	63.2	0.0	-0.0001	0.0000	-0.0085	0.0008	0.0	D	R
Agriculture – burning of residues	N_2O	5.0	6.0	6.0	40.0	40.4	0.0	0.0000	0.0001	-0.0002	0.0008	0.0	D	R
Waste – wastewater handling	N_2O	144.1	183.5	25.0	1200.0	1200.3	2.9	0.0000	0.0030	0.0534	0.1070	0.1	D	R
Waste – waste incineration	N_2O	1.6	1.3	50.0	100.0	111.8	0.0	0.0000	0.0000	-0.0013	0.0015	0.0	D	D
Industrial processes	HFCs	0.0	1,804.69	15.0	5.0	15.8	0.4	0.0298	0.0298	0.1488	0.6313	0.6	R	R
Industrial processes – aluminium production	PFCs	629.9	40.75	5.0	30.0	30.4	0.0	-0.0124	0.0007	-0.3706	0.0048	0.4	M	M
Industrial processes – consumption of hydrofluorocarbons	PFCs	0	0.00	20.0	5.0	20.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	R	R
Industrial processes	SF_6	15.2	20.20	25.0	10.0	26.9	0.0	0.0000	0.0003	0.0002	0.0118	0.0	R	R
Total emissions		**60,641.4**	**76,047.9**		**Uncertainty in the year**		**13.3%**		**Uncertainty in the trend**			**11.1%**		

Note: *D = default; IE= included elsewhere; M = measurements; NA = not applicable; NE = not estimated; NO = not occurring; R = national referenced information.*