Ministry for the Environment
Manatū Mō Te Taiao

New Zealand's Greenhouse Gas Inventory 1990–2009

New Zealand Government

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

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Executive summary

ES.1 Background

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

The inventory reports emissions and removals of the 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 2009 (the current inventory year) and supplementary information required for the Kyoto Protocol. Consistent with the Climate Change Convention reporting guidelines, each inventory report is submitted 15 months after conclusion of the calendar year reported, allowing time for data to be collected and analysed.

Reporting of afforestation, reforestation and deforestation activities since 1990 (Article 3.3 activities under the Kyoto Protocol) is mandatory during the first commitment period of the Kyoto Protocol. 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's intention is to account for Article 3.3 activities at the end of the first commitment period. New Zealand did not elect to report on 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 emissions and 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).

1990–2009

In 1990, New Zealand's total greenhouse gas emissions were 59,112.1 Gg carbon dioxide equivalent (CO_2-e). In 2009, total greenhouse gas emissions had increased by

11,451.7 Gg CO_2-e (19.4 per cent) to 70,563.8 Gg CO_2-e (Figure ES.2.1.1). Between 1990 and 2009, the average annual growth in total emissions was 0.9 per cent per year.

The four emission sources that contributed the most to this increase in total emissions were road transport, dairy enteric fermentation (methane emissions produced from ruminant livestock), public electricity and heat production, and agricultural soils.

2008–2009

Between 2008 and 2009, New Zealand's total greenhouse gas emissions decreased 2,281.4 Gg CO_2-e (3.1 per cent). This decrease was largely due to the decline in energy emissions as a result of an increase in inflows into hydro-electric storage lakes and an increase in electricity supply from geothermal and wind generation. High hydro inflows decrease the demands for thermal electricity generation. A reduction in road transport emissions due to the downstream effects of the 2008 economic downturn, also contributed to the decrease in 2009.

A further factor in the decrease between 2009 and 2008 was the reduction in the use of nitrogen fertiliser applied to agricultural soils. The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a low milk price in 2009 (Ministry of Agriculture and Forestry, 2010) coupled with high prices of nitrogen fertiliser products, the sale and use of nitrogen fertiliser in 2009 decreased. Despite the lower price in milk, the relative returns in dairy continued to be higher than for sheep, non-dairy and beef. This, along with the persistent effects from the 2008 drought, continued to have an effect on those populations in 2009.

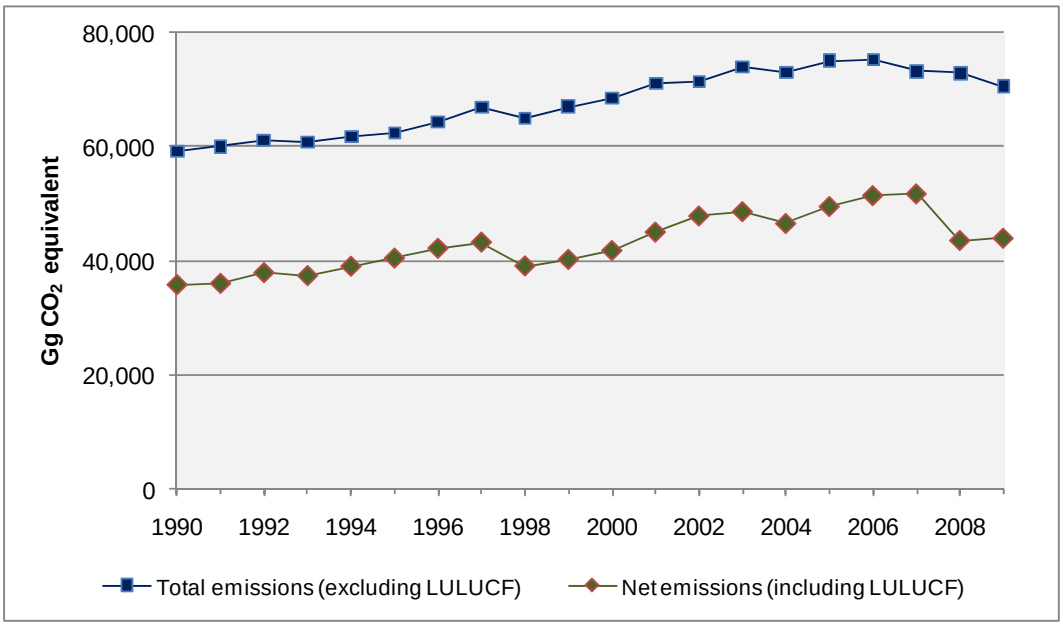
The decrease between 2008 and 2009 is consistent with the trend in New Zealand's total emissions since 2006. This is principally due to changes of circumstance in the two largest sectors, agriculture and energy. There was a decrease in energy emissions in 2007 due to a reduction in coal-fired electricity generation, with the commissioning of Genesis Energy's combined cycle gas turbine at the Huntly power station. Agricultural emissions decreased in 2007 and 2008 due to droughts that affected livestock populations.

Net emissions – Climate Change Convention reporting

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

In 1990, New Zealand's net greenhouse gas emissions were 35,661.0 Gg CO_2-e. In 2009, net greenhouse gas emissions had increased by 8,220.0 Gg CO_2-e (23.1 per cent) to 43,881.1 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 2009



Reporting under the Kyoto Protocol

New Zealand's target under the Kyoto Protocol is to return emissions[1] to 1990 levels on average over the commitment period or otherwise take responsibility for the excess.

New Zealand's initial assigned amount under the Kyoto Protocol is recorded as 309,564,733 metric tonnes CO_2 equivalent (309,565 Gg CO_2-e). The initial assigned amount is five times the total 1990 emissions reported in the inventory submitted as part of *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006). The initial assigned amount does not change during the first commitment period (2008–2012) of the Kyoto Protocol. In contrast, the time-series of emissions and removals reported in each inventory submission are subject to continuous improvement. Consequently, the total emissions in 1990 as reported in this submission are 4.7 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 2009, net removals from land subject to afforestation, reforestation and deforestation were –17,268.4 Gg CO_2-e. This comprised of removals from afforestation and reforestation of –17,624.3 Gg CO_2-e and deforestation emissions of 355.9 Gg CO_2-e in 2009.

ES.3 Gas trends

The proportion of greenhouse gases emitted by New Zealand has changed since 1990. Whereas CH_4 and CO_2 contributed equally to New Zealand's total emissions in 1990, in 2009, 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 to growth in emissions from the energy sector.

[1] New Zealand's target under the Kyoto Protocol for the first commitment period is based on gross (total) emissions and can be met with net emissions (Article 3.3 activities).

Table ES 3.1.1 New Zealand's total (gross) emissions by gas in 1990 and 2009

Direct greenhouse gas emissions	Gg CO_2 equivalent		Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
	1990	2009		
CO_2	25,000.2	33,444.6	+8444.4	+33.8
CH_4	25,303.5	26,136.2	+832.7	+3.3
N_2O	8,163.4	10,037.9	+1,874.5	+23.0
HFCs	NO	879.2	+879.2	NA
PFCs	629.9	46.1	–583.7	–92.7
SF_6	15.2	19.8	+4.5	+29.9
Total	**59,112.1**	**70,563.8**	**+11,451.7**	**+19.4**

Notes: Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF. 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

Although the agriculture sector contributed the largest proportion of total emissions in 2009 (Table ES.4.1.1 and Figure ES.4.1.1), the proportion of emissions from the agriculture sector has generally been decreasing since 1990, while the proportion of emissions from the energy sector has been increasing (Figure ES.4.1.2). For the first time in 2008, energy was the largest contributing sector to total emissions, (agriculture had the greater proportion in 2009 again). The energy sector has experienced the greatest increase over the period 1990–2009 (Figure ES.4.1.3). Energy emissions have increased over three times as much as those from the agricultural sector. The energy sector has had the most influence on the trend in total emissions between 1990 and 2009 (Figure ES.4.1.4).

Energy (chapter 3)

2009

The energy sector was the source of 31,361.4 Gg CO_2-e (44.4 per cent) of total emissions in 2009. The largest sources of emissions in the energy sector were road transport, contributing 12,386.1 Gg CO_2-e (39.5 per cent), and public electricity and heat production contributing 5,954.9 Gg CO_2-e (19.0 per cent) to energy emissions.

1990–2009

In 2009, energy emissions had increased by 8,002.2 Gg CO_2-e (34.3 per cent) from the 1990 level of 23,359.2 Gg CO_2-e. This growth in emissions is primarily from road transport, which increased by 4,931.7 Gg CO_2-e (66.2 per cent) and electricity generation and heat production, which increased by 2,494.3 Gg CO_2-e (72.1 per cent).

2008–2009

Between 2008 and 2009, emissions from the energy sector decreased by 2,245.9 Gg CO_2-e (6.7 per cent). This decrease is primarily due to a decrease in emissions from public electricity and heat production due to high hydro inflows for 2009 and an increase in supply from geothermal and wind generation. High hydro inflows decrease the requirements for thermal electricity generation. A reduction in road transport emissions due to the 2008 economic downturn, also contributed to the decrease in 2009.

Industrial processes (chapter 4)

2009

The industrial processes sector contributed 4,345.5 Gg CO_2-e (6.2 per cent) of total emissions in 2009. The largest source of emissions was from iron and steel production, which contributed 1,563.1 Gg CO_2-e (36.0 per cent) to the industrial processes sector.

1990–2009

Emissions from the industrial processes sector increased 963.0 Gg CO_2-e (28.5 per cent) from the 1990 level of 3,382.6 Gg CO_2-e. This increase was mainly caused by growth in emissions from the consumption of HFCs. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol.

2008–2009

Between 2008 and 2009, emissions from the industrial processes sector increased by 60.9 Gg CO_2-e (1.4 per cent). This growth was largely due to an increase in emissions from the consumption of HFCs.

Solvent and other product use (chapter 5)

In 2009, the solvent and other product use sector was responsible for 27.9 Gg CO_2-e (0.04 per cent) of total emissions. The emission levels from the solvent and other products sector are negligible compared with other sectors.

Agriculture (chapter 6)

2009

The agriculture sector was the largest source of emissions in 2009, contributing 32,810.5 Gg CO_2-e (46.5 per cent) of total emissions. New Zealand has a unique emissions profile amongst developed countries. In most other developed countries, agricultural emissions are typically less than 10 per cent of total emissions.

The largest sources of emissions from the agriculture sector in 2009 were enteric fermentation from dairy cattle and sheep, and nitrous oxide emissions from agricultural soils.

1990–2009

In 2009, New Zealand's agricultural emissions increased by 2,533.0 Gg CO_2-e (8.4 per cent) from the 1990 level of 30,277.5 Gg CO_2-e (Figure 2.3.2). This increase is largely due to the increase in the enteric fermentation emissions from dairy cattle and nitrous oxide emissions from agriculture soils.

2008–2009

Between 2008 and 2009, emissions from the agriculture sector decreased 56.4 Gg CO_2-e (0.2 per cent). This decrease was largely from the reduction in nitrogen fertiliser applied to agricultural soils. The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a low milk price in 2009 (Ministry of Agriculture and Forestry, 2010)

coupled with high prices for nitrogen fertiliser products, the sale and use of nitrogen fertiliser in 2009 decreased. Despite the lower price in milk, the relative returns in dairy continued to be higher than for sheep, non-dairy and beef. This, along with the persistent effects from the 2008 drought, continued to have affect on those populations in 2009.

LULUCF under the Climate Change Convention (chapter 7)

2009

In 2009, net removals from the LULUCF sector under the Climate Change Convention were –26,682.7 Gg CO_2-e. The highest removals in 2009 were from post-1989 forests, reported under land converted to forest land.

The largest source of emissions in LULUCF is from forest land remaining forest land. In 2009 these emissions contributed 2,016.0 Gg CO_2-e. This is largely due to the emissions from harvesting exceeding removals from growth of these forests.

1990–2009

Between 1990 and 2009, net removals from LULUCF have increased by –3,231.7 Gg CO_2-e (13.8 per cent) from the 1990 level of –23,451.1 Gg CO_2-e. This increase in net removals is largely the result of new forest establishment since 1990 (post-1989 forests), as well as the growth of pre-1990 planted forest.

The fluctuations in net removals/emissions from LULUCF across the time-series (Figure 2.3.4) 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 to alternative land uses. The decrease in net removals between 2004 and 2008 was largely due to the increase in the planted forest deforestation that occurred leading up to 2008, before the introduction of the New Zealand Emissions Trading Scheme.[2] The high price of pastoral land between 2004 and 2008 also contributed to an increase in deforestation.

2008–2009

Between 2008 and 2009, net removals from LULUCF decreased by 2,677.4 Gg CO_2-e (9.1 per cent). This decrease in net removals is largely the result of increased new planting (as the biomass of the previous crop is greater than the growth of the new crop meaning emissions are greater than removals during 2009) and of an increase in harvesting of pre-1990 planted forest.

Waste (chapter 8)

The waste sector contributed 2,018.4 Gg CO_2-e (2.9 per cent) to total emissions in 2009. Emissions from the waste sector have decreased by 32.9 Gg CO_2-e (1.6 per cent) from the 1990 level of 2,051.3 Gg CO_2-e. This reduction, despite an increase in New Zealand's economic activity – which is generally coupled with an increase in waste generation – occurred in the solid waste disposal on land category as a result of initiatives to improve solid waste management practices.

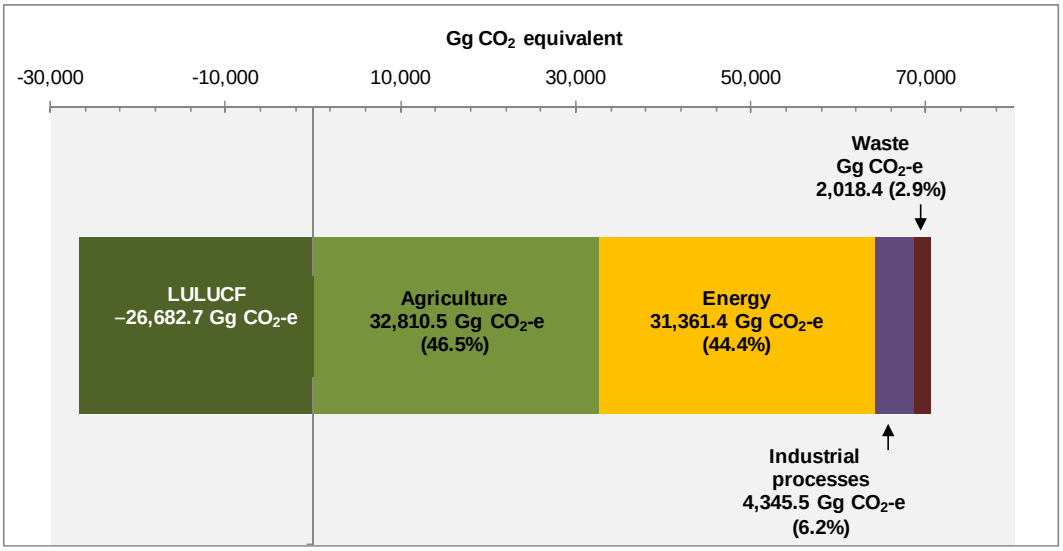
[2] The New Zealand Emissions Trading Scheme included the forestry sector as of 1 January 2008.

Table ES 4.1.1 New Zealand's emissions and removals by sector in 1990 and 2009

Sector	Gg CO_2 equivalent		Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
	1990	2009		
Energy	23,359.2	31,361.4	+8,002.2	+34.3
Industrial processes	3,382.6	4,345.5	+963.0	+28.5
Solvent and other product use	41.5	27.9	–13.6	–32.8
Agriculture	30,277.5	32,810.5	+2,533.0	+8.4
Waste	2,051.3	2,018.4	–32.9	–1.6
Total (excluding LULUCF)	**59,112.1**	**70,563.8**	**+11,451.7**	**+19.4**
LULUCF	–23,451.1	–26,682.7	–3,231.7	–13.8
Net Total (including LULUCF)	**35,661.0**	**43,881.1**	**+8,220.0**	**+23.1**

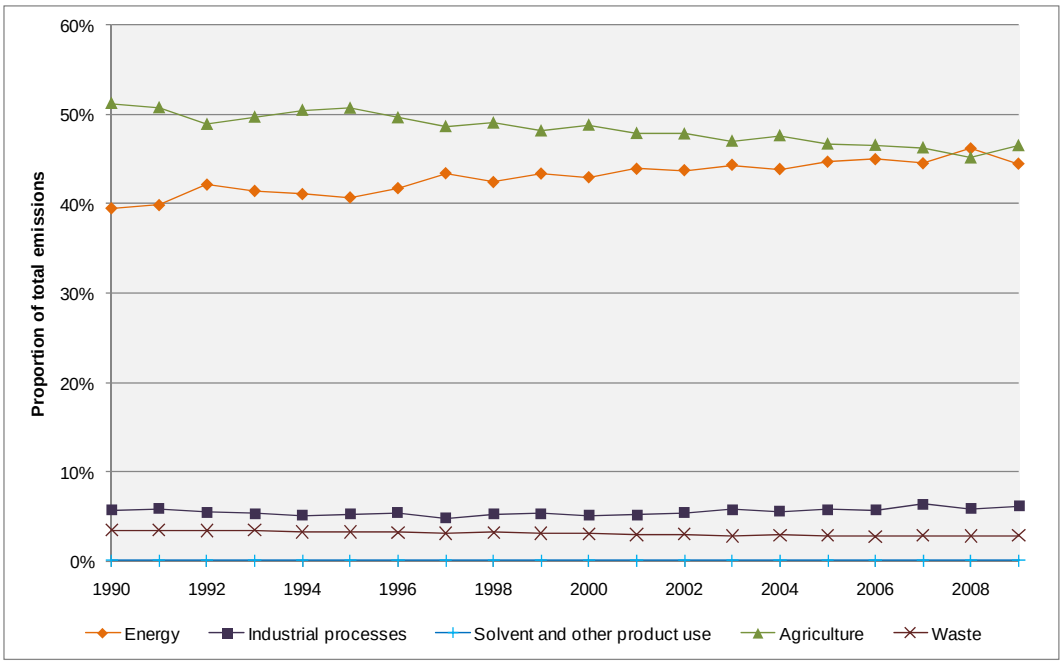
Notes: LULUCF includes CO_2 removals and emissions of CO_2, CH_4 and N_2O. Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Columns may not total due to rounding.

Figure ES 4.1.1 New Zealand's emissions and removals by sector in 2009



Notes: 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 2009



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

Figure ES 4.1.3 Change in New Zealand's emissions by sector from 1990 to 2009

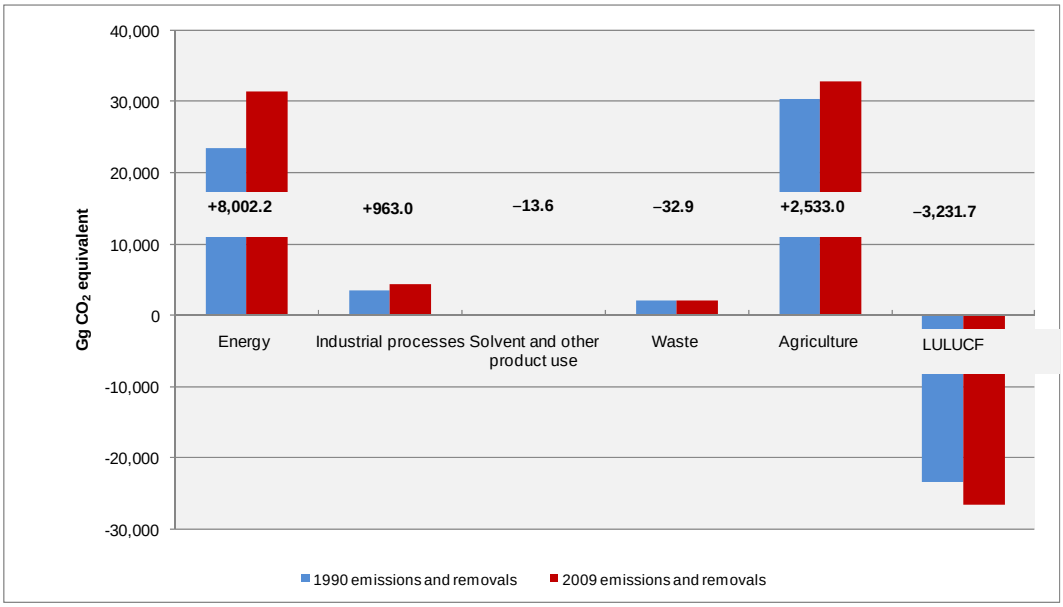
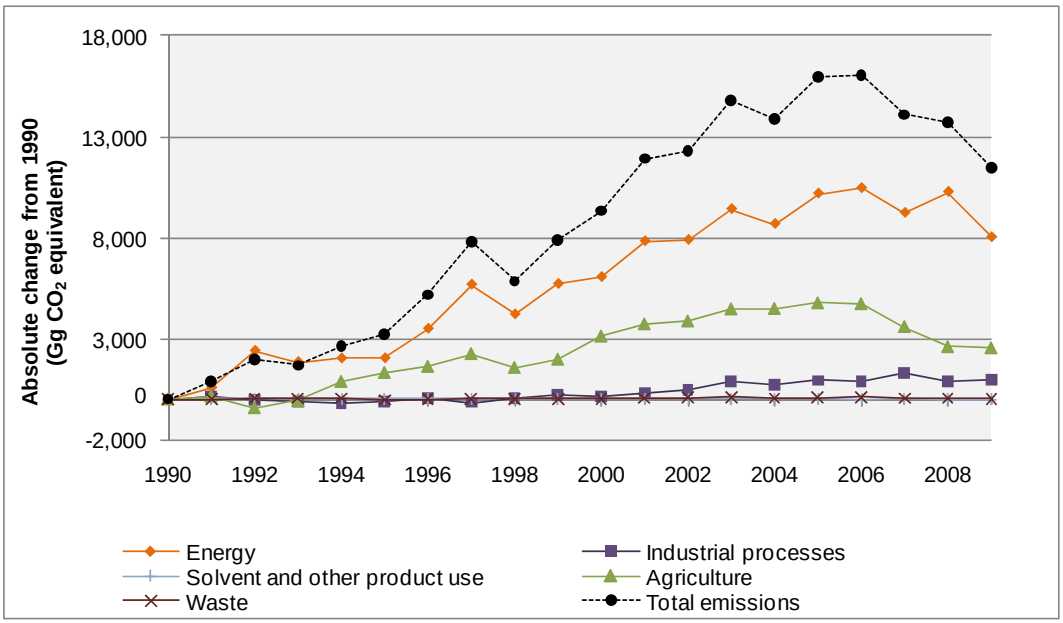


Figure ES 4.1.4 Absolute change from 1990 in New Zealand's total emissions by sector from 1990 to 2009



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

ES.5 Activities under Article 3.3 of the Kyoto Protocol

Estimates of removals and emissions under Article 3.3 of the Kyoto Protocol are included in the 2009 inventory (Table ES 5.1).

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2009 was 591,202 hectares. The net area is the total area of post-1989 forest (606,706 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (15,503 hectares). Removals from this land in 2009 were –17,624 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2009 was 98,668 hectares. The area subject to deforestation in 2009 was 1,644 hectares. In 2009, deforestation emissions were 355.9 Gg CO_2-e, compared with 432.4 Gg CO_2-e in 2008 (a 17.7 per cent reduction). Deforestation emissions include non-carbon emissions and lagged CO_2 emissions that occurred in 2009 as a result of deforestation since 1990. Lagged emissions includes the liming of forest land converted to grassland and cropland, and the disturbance associated with forest land conversion to cropland.

Table ES 5.1 New Zealand's net emissions and removals from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2009

Source	2008	2009
Afforestation/reforestation		
Net cumulative area since 1990 (ha)	587,936	591,202
Area in calendar year (ha)	1,900	4,000
Removals in calendar year (Gg CO_2-e)	–17,531.1	–17,624.3
Deforestation		
Cumulative area since 1990 (ha)	97,024	98,668
Area in calendar year (ha)	1,472	1,644
Emissions in calendar year (Gg CO_2-e)	432.4	355.9
Total area subject to afforestation, reforestation and deforestation (ha)	684,960	689,870
Net removals (Gg CO_2-e)	–17,098.7	–17,268.4

Notes: The areas stated are as at 31 December. They are net areas ie, 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. Columns may not total due to rounding.

ES.6 Improvements introduced

The largest improvements in the accuracy of net emissions, made to *New Zealand's Greenhouse Gas Inventory* following the 2010 submission,[3] were made in the LULUCF, agriculture and waste sectors. Chapter 10 provides a summary of all recalculations made to the estimates. There was also a significant improvement made to deforestation estimates under Article 3.3 of the Kyoto Protocol.

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 – backcasting (section 7.3.4)

The largest improvement introduced to this inventory submission in terms of impact on estimated net emissions is including data on historical land-use 'backcasting' into the LULUCF sector. The introduction of historical land-use data to model land-use change since 1962 (backcasting) has been made to meet the requirements of reporting land in transition in IPCC good practice guidance (GPG-LULUCF, IPCC, 2003) and has improved the completeness and consistency of estimates in the LULUCF sector. The year 1962 is chosen as the start point for backcasting as it is 28 years prior to 1990. Twenty-eight years was chosen by New Zealand as the time it takes for land to reach a state of equilibrium (or maturity) following land-use change as this is the average age at which planted forests are harvested in New Zealand (Ministry of Agriculture and Forestry, 2008a).

Backcasting has identified land in transition in 1990 and lagged emissions and removals from land-use change before 1990 which continue to have an effect on the time-series. For example, if land was converted from grassland to forest land in 1980 there would still

[3] Common reporting format (CRF) version 1.2.

be emissions from loss of soil carbon (which occurs over 20 years) in 1990. These emissions are now reported in the LULUCF sector in the land converted to forest land category. This is explained further in section 7.2.4.

Backcasting reduced net removals in 1990 by 5,084 Gg CO2-e and reduced net removals in 2008 by 24 Gg CO2-e.

Deforestation area (7.2.2 and 11.3)

The accuracy of the land-use area has been improved in this submission particularly the area of deforestation. This is because deforestation areas were estimated from the deforestation intentions survey (Manley, 2009) in the 2010 submission, whereas they have now been mapped from satellite imagery. In 2008, this resulted in a decrease of 2,478.9 Gg CO_2-e (85.1 per cent) in estimated emissions from deforestation under Article 3.3 of the Kyoto Protocol in 2008.

Agricultural soils – dung and urine split (section 6.5)

The accuracy of the estimates for agriculture soils has been improved in this submission through disaggregating nitrogen excreted fractions into urine and dung for cattle, sheep and deer. Before this submission, New Zealand had applied one New Zealand-specific emission factor from cattle and sheep manure that accounted for dung and urine emissions together. However, the research to develop this single New Zealand-specific emission factor was generally carried out on urine samples. New research showed that N_2O emissions from dung are substantially lower than emissions from urine. Consequently, a new emission factor for dung was developed for the purpose of estimating emissions from cattle, sheep and deer. This New Zealand-specific emission factor for dung has been included in this inventory submission and for consistency it has been applied to the entire time-series. This disaggregation has reduced emissions from the agriculture sector by 1,637.9 Gg CO_2-e in 1990 and 1,470.8 Gg CO_2-e in 2008.

Solid waste disposal to land – consistent and specific parameters (section 8.2)

There has been a recalculation of the estimates for the waste sector. This is largely due to improved methodologies for calculating emissions and recovery of emissions from solid waste disposed to land. These improvements have come from:

- a better understanding of the management and design of landfills with operational CH_4 recovery systems
- the application of nationally consistent assumptions on the composition of solid waste.

These improvements are largely responsible for the recalculation of the trend in the waste sector which now shows that waste emissions in 2009 are 0.03 Mt CO_2-e (1.6 per cent) below waste emission in 1990, as opposed to the decrease of 0.8 Mt CO_2-e (31.5 per cent) as reported in the previous inventory submission.

ES.7 National registry

In January 2007, 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 31 December 2010, the registry held 307,098,445 assigned amount units in its Party holding accounts.

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PART I: ANNUAL INVENTORY SUBMISSION

Chapter 1: Introduction

1.1 Background

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

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

1.1.1 The United Nations Framework Convention on Climate Change

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

The Climate Change Convention has been signed and ratified by 188 nations, including New Zealand, and took effect on 21 March 1994.

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

All countries that ratify the Climate Change Convention (henceforth called 'Parties') are required to address climate change including monitoring trends in anthropogenic greenhouse gas emissions. The annual inventory of greenhouse gas emissions and removals fulfils this obligation. Parties are also obligated to protect and enhance carbon sinks and reservoirs, for example, forests, and implement measures that assist in national and/or regional climate change adaptation and mitigation. In addition, Parties listed in Annex II to the Climate Change Convention[4] (developed countries) commit to providing financial assistance to non-Annex I Parties (developing countries).

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

Annex I[5] Parties that ratified the Climate Change Convention also agreed to non-binding targets, aiming to return greenhouse gas emissions to 1990 levels by the year 2000. Only a few Annex I Parties made appreciable progress towards achieving this aim. The international community recognised that the existing commitments in the Climate Change Convention were not enough to ensure greenhouse gas levels would be stabilised at a safe level. More urgent action was needed. In response, Parties launched a new round of talks to provide stronger and more detailed commitments for Annex I Parties. After two-and-a-half years of negotiations, the Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997. New Zealand ratified the Kyoto Protocol on 19 December 2002. The Protocol came into force on 16 February 2005.

1.1.2 The Kyoto Protocol

The Kyoto Protocol shares and expands upon the Climate Change Convention's objective, principles and institutions. Only Parties to the Climate Change Convention that have also become Parties to the Protocol (by ratifying, accepting, approving, or acceding to it) are bound by the Protocol's commitments. The objective of the Kyoto Protocol is to reduce the aggregate emissions of six greenhouse gases from Annex I Parties by at least 5 per cent below 1990 levels in the first commitment period (2008–2012). New Zealand's target is to return emissions to 1990 levels[6] on average over the commitment period or otherwise take responsibility for the excess.

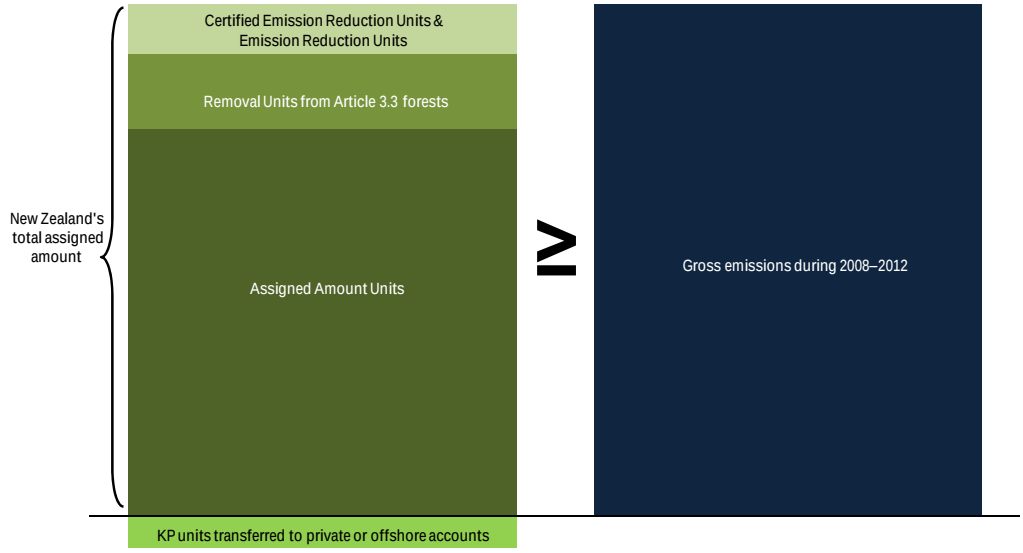
A Party with a commitment under the Kyoto Protocol (as listed in Annex B of the Kyoto Protocol) must hold sufficient assigned amount[7] to cover the total emissions during the first commitment period. A Party's assigned amount comprises assigned amount units, removal units from land use, land-use change and forestry (LULUCF) activities under Article 3.3 or 3.4 activities of the Kyoto Protocol, and any other units acquired under the flexibility mechanisms of the Kyoto Protocol. Flexibility mechanisms include the Clean Development Mechanism, Joint Implementation and the trading of units between Annex I Parties. Further information on these mechanisms can be obtained from the website of the Climate Change Convention (www.unfccc.int). If a Party exceeds its available assigned amount, the equivalent to 1.3 times the amount of excess emissions will be deducted from the assigned amount of the subsequent commitment period. In addition, the Party would have to develop a compliance action plan and would be suspended from trading units. The Kyoto Protocol compliance equation for the first commitment period is depicted in Figure 1.1.1.

[5] Annex I to the Climate Change Convention lists the industrialised countries that were committed to returning their greenhouse gas emissions to 1990 levels by the year 2000 as per Article 4.2(a) and (b).

[6] New Zealand's target under the Kyoto Protocol for the first commitment period is based on gross (total) emissions and can be met with net emissions (Article 3.3 activities).

[7] 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)



Notes: 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. KP stands for Kyoto Protocol.

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 assigned amount is issued in units known as assigned amount units (or AAUs). The initial assigned amount does not include emissions and removals from the land use, land-use change and forestry sector (LULUCF) unless this sector was a source of net emissions in 1990. Carbon sinks that meet Kyoto Protocol requirements for afforestation and reforestation create removal units (popularly known as carbon credits) and these are added to a Party's assigned amount. Units must be cancelled for any harvesting and deforestation emissions.

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. Afforestation, reforestation and deforestation activities are defined below. The definitions are consistent with decision 16/CMP.1 (UNFCCC, 2005).

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

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

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

Reporting of forest management, cropland management, grazing land management and revegetation is voluntary during the first commitment period (Kyoto Protocol Article 3.4).

New Zealand did not elect to report on any of the Article 3.4 activities during the first commitment period.

1.1.3 The inventory

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

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

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

1.1.4 Supplementary information required

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

The supplementary information required includes:

- information on emissions and removals for each activity under Article 3.3 and for any elected activities under Article 3.4 (chapter 11)
- holdings and transactions of units transferred and acquired under Kyoto Protocol mechanisms, for example, carbon trading (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 8 December 2009) enables New Zealand to meet its international obligations under the Climate Change Convention and Kyoto Protocol. A Prime Ministerial directive for the administration of the Climate Change Response Act 2002 names the Ministry for the Environment as New Zealand's 'Inventory Agency'. Part 3, section 32 of the Climate Change Response Act 2002 specifies the following functions and requirements:

1. The primary functions of the inventory agency, are to:
    a. estimate annually New Zealand's anthropogenic emissions by sources and removals by sinks, of greenhouse gases
    b. prepare the following reports for the purpose of discharging New Zealand's obligations:
        i. New Zealand's annual inventory report under Article 7.1 of the Protocol, including (but not limited to) the quantities of long-term certified emission reduction units and temporary certified emission reduction units that have expired or have been replaced, retired, or cancelled
        ii. New Zealand's national communication (or periodic report) under Article 7.2 of the Kyoto Protocol and Article 12 of the Climate Change Convention
        iii. New Zealand's report for the calculation of its initial assigned amount under Article 7.4 of the Kyoto Protocol, including its method of calculation.

2. In carrying out its functions, the inventory agency must:
    a. identify source categories
    b. collect data by means of:
        i. voluntary collection
        ii. collection from government agencies and other agencies that hold relevant information
        iii. collection in accordance with regulations made under this Part (if any)
    c. estimate the emissions and removals by sinks for each source category
    d. undertake assessments on uncertainties
    e. undertake procedures to verify the date
    f. retain information and documents to show how the estimates were determined.

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

1.2.2 The national system

New Zealand is required under Article 5.1 of the Kyoto Protocol to have a national system in place for its greenhouse gas inventory. New Zealand provided a full description of the national system in the initial report for the Kyoto Protocol (Ministry for the

Environment, 2006). This can be found on the Climate Change Convention's website: http://unfccc.int/national_reports/initial_reports_under_the_kyoto_protocol/items/3765.php. Changes to the national system are documented in chapter 13 of this submission.

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

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

The Ministry of Economic Development collects and compiles all emissions from the energy sector and CO_2 emissions from the industrial processes sector.

The Ministry of Agriculture and Forestry compiles emissions from the agricultural sector. Estimates are underpinned by the research and modelling undertaken at New Zealand's Crown research institutes and universities. The Ministry of Agriculture and Forestry provided data from the *National Exotic Forest Description* to estimate afforestation and reforestation during 2008 and 2009, and where information on the timing of planting and harvesting was not available through the Ministry for the Environment's Land Use and Carbon Analysis System (LUCAS).

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. Population census data from Statistics New Zealand is used in the waste, and solvent and other product use sectors. Activity data on lime application is also sourced from Statistics New Zealand.

The Climate Change Response Act 2002 (updated 8 December 2009) establishes the requirement for a registry and a registrar. The Ministry of Economic Development 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/eats/nz/). Information on the annual holdings and transactions of transferred and acquired units under the Kyoto Protocol are provided in the standard electronic format tables accompanying this submission. Refer to chapter 12 for further information.

1.3 Inventory preparation processes

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

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

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

1.4 Methodologies and data sources used

The guiding documents in inventory preparation are the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1996), the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000), *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003) and the Climate Change Convention guidelines on reporting and review (UNFCCC, 2006). 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 and 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 method guidance is provided in a tiered structure of calculations which describes and connects the various levels of detail at which estimates can be made depending on the importance of the source category, availability of data, and other capabilities. The tiered structure ensures that estimates calculated at a very detailed level can be aggregated up to a common minimum level of detail for comparison with all other reporting countries. A more detailed method is referred to as the Tier 3 method which applies country-specific parameters and/or models, while a Tier 1 method applies IPCC default emission factors.

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 Economic Development. New Zealand-specific emission factors are used for CO_2 emission calculations. Applicable IPCC default factors are used for 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 CO_2 emissions are supplied directly to the Ministry of Economic Development by industry sources. The IPCC Tier 2 approach is used and emission factors are New Zealand specific. Activity data for the non-CO_2 gases is collected via an industry survey. Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach, and SF_6 emissions from large users are estimated with the Tier 3a approach (IPCC, 2006a).

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

Land use, land-use change and forestry (chapters 7 and 11): New Zealand uses a combination of Tier 1 and Tier 2 methodologies for estimating emissions and removals for the LULUCF sector under the Climate Change Convention and Kyoto Protocol. A Tier 2 approach has been used to estimate biomass carbon in natural forest, pre-1990 planted forest and post-1989 forest, and a Tier 1 approach for estimating biomass carbon in all other land-use categories. A Tier 2 modelling approach has also been used to estimate carbon in the mineral soil component of the soil organic matter pool, for all land-use categories except for other land, which uses a Tier 1 approach. Changes in organic soils are also estimated using a Tier 1 approach.

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

- use of field plot measurements for natural and planted forests and airborne scanning LiDAR (Light Detection and Ranging) for planted forests (Stephens et al, 2007, 2008)
- use of allometric equations and models to estimate carbon stock and carbon-stock change in natural and planted forests respectively (Beets et al, 2009; Kimberley and Beets, Unpublished)
- 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 in 2009 along with the extrapolation of pre-2008 trends for all other land uses; a New Zealand-specific soil carbon model to estimate changes in soil organic matter with changes in land use; and 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. A mix of New Zealand-specific and IPCC default parameters are used. Methane and N_2O emissions from domestic and industrial wastewater handling are calculated using a refinement of the IPCC methodology (IPCC, 1996). 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, 2006c).

1.5 Key categories

1.5.1 Reporting under the Climate Change Convention

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

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

cent of the total level of emissions, and 95 per cent of the trend of the inventory in absolute terms.

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

For this submission, New Zealand has applied the key category analysis to a more detailed breakdown of the energy sector, in particular to two of the highest key categories; transport and energy industries. More detail is also provided under enteric fermentation with dairy cattle and sheep livestock classes now listed separately.

The key categories identified in the 2009 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 29.5 per cent
- CH_4 emissions from dairy cattle enteric fermentation; a contribution of 8.8 per cent
- CH_4 emissions from sheep enteric fermentation; a contribution of 7.1 per cent
- CO_2 emissions from gasoline used in road transport; a contribution of 6.6 per cent.

The key categories that were identified as having the largest relative influence on the trend in net emissions from 1990 to 2009, compared to the average change in net emissions from 1990 to 2009 (Table 1.5.3(a)), were:

- CH_4 emissions from sheep enteric fermentation; contributed 16.7 per cent to the net emissions trend through a decrease
- CO_2 removals from conversion to forest land; contributed 14.9 per cent to the net emissions trend through an increase
- forest land remaining forest land; contributed a 9.2 per cent to the net emissions trend through an increase
- CO_2 emissions from diesel oil road transportation; contributed 8.6 per cent to the net emissions trend through an increase.

The key category analysis for total emissions contains the same categories for energy, industrial processes, agriculture and waste as the analysis for net emissions. To sum up to 95 per cent, a few extra categories will typically be included in the total emission analysis that were excluded in the net emissions analysis. For example, CO_2 emissions from liquid fuels used in petroleum refining and civil aviation jet kerosene are included in the trend assessment for total emissions, but excluded in the trend assessment for net emissions. Methane emissions from wastewater handling and CO_2 emissions from ammonia production are included in the 95 per cent of categories in the 2009 level assessment for total emissions and are excluded in the 2009 level assessment for net emissions.

Table 1.5.1 Summary of New Zealand's key categories for the 2009 level assessment and the trend assessment for 1990 to 2009 (including and excluding LULUCF activities)

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

Note: Enteric fermentation – other refers to all enteric fermentation excluding enteric fermentation from dairy cattle and sheep.

Table 1.5.2 (a & b) 2009 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): 2009				
IPCC categories	**Gas**	**2009 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	31594.35	29.5	29.5
Enteric fermentation – dairy cattle	CH_4	9,462.8	8.8	38.3
Enteric fermentation – sheep	CH_4	7,615.8	7.1	45.5
Transport – road transport – gasoline	CO_2	7,115.3	6.6	52.1
Agricultural soils – pasture, range and paddock	N_2O	5514.38	5.1	57.3
Enteric fermentation – other	CH_4	5,427.6	5.1	62.3
Transport – road transport – diesel oil	CO_2	5,008.0	4.7	67.0
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,458.7	3.2	70.2
Energy industries – public electricity and heat production – solid fuels	CO_2	2,469.4	2.3	72.5
Agricultural soils – indirect emissions	N_2O	2411.69	2.3	74.8
Manufacturing industries and construction – gaseous fuels	CO_2	2,334.47	2.2	77.0
Grassland remaining grassland	CO_2	2152.98	2.0	79.0
Other sectors – liquid fuels	CO_2	2,042.9	1.9	80.9
Forest land remaining forest land	CO_2	2016.01	1.9	82.8
Manufacturing industries and construction – solid fuels	CO_2	1,601.44	1.5	84.3
Agricultural soils – direct emissions	N_2O	1572.32	1.5	85.7
Metal production – iron and steel production	CO_2	1563.07	1.5	87.2
Solid waste disposal on land	CH_4	1398.56	1.3	88.5
Transport – civil aviation – jet kerosene	CO_2	890.5	0.8	89.3
Manufacturing industries and construction – liquid fuels	CO_2	848.54	0.8	90.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	796.56	0.7	90.9
Manure management	CH_4	783.4	0.7	91.6
Other sectors – gaseous fuels	CO_2	776.7	0.7	92.3
Fugitive emissions – flaring – combined	CO_2	762.7	0.7	93.0
Energy industries – Petroleum refining – gaseous fuels	CO_2	762.16	0.7	93.7
Fugitive emissions – geothermal	CO_2	610.0	0.6	94.3
Mineral products – cement production	CO_2	593.75	0.6	94.9
Metal production – aluminium production	CO_2	451.51	0.4	95.3

(a) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2009				
IPCC categories	**Gas**	**2009 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Enteric fermentation – dairy cattle	CH_4	9,462.8	13.4	13.4
Enteric fermentation – sheep	CH_4	7,615.8	10.8	24.2
Transport – road transport – gasoline	CO_2	7,115.3	10.1	34.3
Agricultural soils – pasture, range and paddock	N_2O	5514.38	7.8	42.1
Enteric fermentation – other	CH_4	5,427.6	7.7	49.8
Transport – road transport – diesel oil	CO_2	5,008.0	7.1	56.9
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,458.7	4.9	61.8

(a) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2009				
IPCC categories	**Gas**	**2009 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Energy industries – public electricity and heat production – solid fuels	CO_2	2,469.4	3.5	65.3
Agricultural soils – indirect emissions	N_2O	2411.69	3.4	68.7
Manufacturing industries and construction – gaseous fuels	CO_2	2,334.47	3.3	72.0
Other sectors – liquid fuels	CO_2	2,042.9	2.9	74.9
Manufacturing industries and construction – solid fuels	CO_2	1,601.44	2.3	77.2
Agricultural soils – direct emissions	N_2O	1572.32	2.2	79.4
Metal production – iron and steel production	CO_2	1563.07	2.2	81.6
Solid waste disposal on land	CH_4	1398.56	2.0	83.6
Transport – civil aviation – jet kerosene	CO_2	890.5	1.3	84.9
Manufacturing industries and construction – liquid fuels	CO_2	848.54	1.2	86.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	796.56	1.1	87.2
Manure management	CH_4	783.4	1.1	88.3
Other sectors – gaseous fuels	CO_2	776.7	1.1	89.4
Fugitive emissions – flaring – combined	CO_2	762.7	1.1	90.5
Energy industries – Petroleum refining – gaseous fuels	CO_2	762.16	1.1	91.6
Fugitive emissions – geothermal	CO_2	610.0	0.9	92.4
Mineral products – cement production	CO_2	593.75	0.8	93.3
Metal production – aluminium production	CO_2	451.51	0.6	93.9
Waste-water handling	CH_4	437.99	0.6	94.5
Chemical industry – ammonia production	CO_2	386.58	0.5	95.1

Table 1.5.3 1990–2009 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)**	**2009 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Enteric fermentation – sheep	CH_4	11,280.0	7,615.8	0.048	16.7	16.7
Conversion to forest land	CO_2	20,910.8	31594.35	0.043	14.9	31.7
Forest land remaining forest land	CO_2	4,446.9	2016.01	0.026	9.2	40.9
Transport – road transport – diesel oil	CO_2	1,416.9	5,008.0	0.025	8.6	49.4
Enteric fermentation – dairy cattle	CH_4	5,057.4	9,462.8	0.024	8.4	57.8
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	2,469.4	0.014	5.0	62.8

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

IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2009 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,756.4	369.00	0.014	4.8	67.6
Enteric fermentation – other	CH_4	5,527.3	5,427.6	0.011	3.7	71.3
Grassland remaining grassland	CO_2	801.7	2152.98	0.009	3.1	74.4
Agricultural soils – pasture, range and paddock	N_2O	5,235.8	5514.38	0.007	2.6	76.9
Agricultural soils – direct emissions	N_2O	517.1	1572.32	0.007	2.5	79.4
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	796.56	0.006	2.1	81.5
Manufacturing industries and construction – solid fuels	CO_2	1,895.3	1,601.44	0.006	2.0	83.5
Metal production – aluminium production	PFCs	629.9	44.82	0.006	1.9	85.4
Other sectors – solid fuels	CO_2	778.3	264.0	0.005	1.8	87.2
Fugitive emissions – flaring – combined	CO_2	228.9	762.7	0.004	1.3	88.5
Solid waste disposal on land	CH_4	1,514.4	1398.56	0.004	1.3	89.8
Fugitive emissions – geothermal	CO_2	228.6	610.0	0.002	0.9	90.6
Manufacturing industries and construction – gaseous fuels	CO_2	1,649.0	2,334.47	0.002	0.8	91.4
Conversion to grassland	CO_2	464.8	334.66	0.002	0.6	92.0
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,969.7	3,458.7	0.002	0.6	92.6
Transport – road transport – gasoline	CO_2	5,570.7	7,115.3	0.002	0.6	93.2
Conversion to wetland	CO_2	164.7	0.00	0.002	0.5	93.7
Other sectors – gaseous fuels	CO_2	471.4	776.7	0.001	0.5	94.2
Transport – road transport – gaseous fuels	CO_2	139.6	2.0	0.001	0.5	94.7
Transport – road transport – liquefied petroleum gases	CO_2	196.7	80.3	0.001	0.4	95.1

(a) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)						
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**2009 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Enteric fermentation – sheep	CH_4	11,280.0	7,615.8	0.069	22.5	22.5
Enteric fermentation – dairy cattle	CH_4	5,057.4	9,462.8	0.041	13.1	35.6
Transport – road transport – diesel oil	CO_2	1,416.9	5,008.0	0.039	12.7	48.3
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	2,469.4	0.023	7.3	55.7
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,756.4	369.00	0.021	6.6	62.3
Enteric fermentation – other	CH_4	5,527.3	5,427.6	0.014	4.5	66.8
Agricultural soils – direct emissions	N_2O	517.1	1572.32	0.011	3.7	70.5
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	796.56	0.009	3.1	73.5
Agricultural soils – pasture, range and paddock	N_2O	5,235.8	5514.38	0.009	2.8	76.4
Metal production – aluminium production	PFCs	629.9	44.82	0.008	2.7	79.1
Other sectors – solid fuels	CO_2	778.3	264.0	0.008	2.6	81.6
Manufacturing industries and construction – solid fuels	CO_2	1,895.3	1,601.44	0.008	2.5	84.2
Fugitive emissions – flaring – combined	CO_2	228.9	762.7	0.006	1.9	86.0
Transport – road transport – gasoline	CO_2	5,570.7	7,115.3	0.006	1.8	87.8
Solid waste disposal on land	CH_4	1,514.4	1398.56	0.005	1.6	89.4
Manufacturing industries and construction – gaseous fuels	CO_2	1,649.0	2,334.47	0.004	1.4	90.8
Fugitive emissions – geothermal	CO_2	228.6	610.0	0.004	1.3	92.1
Other sectors – gaseous fuels	CO_2	471.4	776.7	0.003	0.8	92.9
Transport – road transport – gaseous fuels	CO_2	139.6	2.0	0.002	0.6	93.6
Transport – road transport – liquefied petroleum gases	CO_2	196.7	80.3	0.002	0.6	94.1
Energy industries – Petroleum refining – liquid fuels	CO_2	211.3	135.31	0.001	0.4	94.6
Transport – civil aviation – jet kerosene	CO_2	842.5	890.5	0.001	0.4	95.0

1.5.2 LULUCF activities under the Kyoto Protocol

The LULUCF categories identified as key (level assessment) under the Climate Change Convention in the 2009 year that correspond to the key categories for Article 3.3 activities under the Kyoto Protocol are shown in Table 1.5.4.

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

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

1.6 Quality assurance and quality control

Quality assurance and quality control are an integral part of preparing New Zealand's annual inventory. The Ministry for the Environment developed a quality assurance and control plan in 2004, as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006), to formalise, document and archive the quality assurance and control procedures. Details of the quality control and quality assurance activities performed during the compilation of the 2011 inventory submission are discussed in sections 1.6.1 and 1.6.2 below. Examples of quality control checks are provided in the accompanying Excel spreadsheets to this submission.

1.6.1 Quality control

For this submission, the completion of the IPCC (2000) Tier 1, and in some sectors Tier 2, quality control check sheets for each sector was the responsibility of the leading agency. 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 2009 inventory year were checked.

All sector level data was entered into the common reporting format database by the end of January by the national inventory compiler. This deadline allowed time for the agencies leading each sector to complete their own quality control activities. The energy and agriculture sector contributions to the national inventory report, common reporting format tables and Tier 1 quality control checks were signed off by the Ministry of Economic Development and the Ministry of Agriculture and Forestry respectively by the end of January.

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

Prioritisation of improvements

New Zealand's inventory system is progressively improving its quality assurance system to ensure risks are minimised at all stages of the inventory compilation process. In 2008, KPMG, a professional services firm, developed a risk register to highlight potential risks in the inventory data compilation process. The Ministry for the Environment continues to use the risk register to help prioritise further improvements to the inventory. Risks may be identified through the UNFCCC inventory review process or through independent expert review and internal expert peer review.

Acceptance of improvements

The process of accepting any improvements into the inventory includes demonstrating that the improvement has been independently assessed. Resulting recalculations need to be approved by the national inventory compiler. In the agricultural 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 needs to be reviewed by an independent expert. 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 national inventory compiler. The recalculations need to be sufficiently explained in terms of improving one or more of the IPCC good practice principles. This is completed on a form for documentation and archiving.

Independent agricultural inventory advisory panel

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

Expertise

The technical competence of key contributors to the inventory has continued to increase and with this is 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 UNFCCC inventory review process. During the reviews, experts can learn from each other and from the Party under review. New Zealand government officials that are qualified to review inventory reporting under the UNFCCC and the Kyoto Protocol include one lead reviewer, two energy reviewers, one industrial processes reviewer, three agricultural reviewers, one LULUCF reviewer and one waste reviewer. These reviewers are usually 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 a national inventory compiler manual that documents the tasks required for making an official submission starting from the submission of the previous year. The role of the agricultural and energy sector compilers is well documented within respective manuals. These manuals are designed to help lower the risk of losing compiling knowledge.

1.6.3 Verification activities

Where relevant in a sector, verification activities are discussed under the appropriate section. Section 1.9 provides information about the verification that may become available for the inventory from the New Zealand Emissions Trading Scheme.

1.6.4 Treatment of confidentiality issues

Confidential issues largely apply to sources of emissions in the energy and industrial processes sectors. The majority of this confidential information is held by the Ministry of Economic Development and is not released to the inventory agency. However, the Ministry for the Environment keeps a list of all the confidential information retained by the Ministry of Economic Development.

1.6.5 Climate Change Convention annual inventory review

New Zealand's inventory was reviewed in 2001 and 2002 as part of a pilot study of the technical review process (UNFCCC, 2001a; 2001b; 2001c; 2003). The inventory was subject to detailed in-country, centralised and desk review procedures. The inventories submitted for the years 2001 and 2003 were reviewed in a centralised review process. The 2006 inventory submission was reviewed as part of the Kyoto Protocol initial review (UNFCCC, 2007). This was an in-country review held from 19–24 February 2007. The 2007–-2009 inventory submissions were reviewed during centralised reviews (UNFCC, 2009; UNFCC 2010). The 2010 inventory submission was subject to an in-country review in August/September 2010. The review report for the 2010 inventory submission was not fully completed at the time of finalising this submission. In all instances, the reviews were conducted by an international team of experts nominated by Parties to the Climate Change Convention. 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 national system for the greenhouse gas inventory, the national registry and the 1990 (base year) inventory were reviewed by an international expert review team in February 2007. The expert review report (UNFCCC, 2007) concluded that:

(d) "New Zealand's Greenhouse Gas Inventory is consistent with the Revised 1996 IPCC Guidelines and the IPCC good practice guidance, and adheres to the reporting guidelines under Article 7 of the Kyoto Protocol.

(e) New Zealand's national system is prepared in accordance with the guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol and reported in accordance with the guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol.

(f) New Zealand's national registry is fully compliant with the registry requirements as defined by decisions 13/CMP.1 and 5/CMP.1".

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. 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 estimates such as N_2O fluxes from soils and waterways.

In this submission, New Zealand included a Tier 1 uncertainty analysis of the aggregated figures as required by the Climate Change Convention inventory guidelines (UNFCCC, 2006) and IPCC good practice guidance (IPCC, 2000 and 2003). Uncertainties in the categories are combined to provide uncertainty estimates for the entire inventory for the latest inventory year and the uncertainty in the overall inventory trend over time. LULUCF categories have been included using the absolute value of any removals of CO_2 (Table A7.1). Table A7.2 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 was used to determine uncertainty for N_2O from agricultural soils in the 2001/02 inventory. The

95 per cent confidence intervals developed from the Monte Carlo simulation were extended to the 2009 inventory.

Total (gross) emissions

Uncertainty in 2009

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) is ±11.8 per cent. The high uncertainty in a given year is dominated by emissions of N_2O from agricultural soils (section 6.5) and CH_4 from enteric fermentation (section 6.2). These categories comprised ±10.0 per cent and ±5.1 per cent respectively of New Zealand's total emissions and removals uncertainty in 2009. The uncertainty in these categories reflected 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.

In the 2010 submission, improvements were made to the uncertainty analysis for the energy and industrial processes sectors. Most of the uncertainties for the energy sector were updated based on the most recent New Zealand-specific analysis. Many of the uncertainties in the industrial processes sectors could not be verified in time for this submission, consequently default IPCC uncertainties were applied.

Uncertainty in the trend

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) in the trend from 1990 to 2009 is ±2.8 per cent.

Net emissions

Uncertainty in 2009

The calculated uncertainty for New Zealand's net inventory (including emissions and removals from the LULUCF sector) in 2009 is ±10.2 per cent. Removals of CO_2 from forest land were a major contribution to the uncertainty for 2009 at ±6.1 per cent of New Zealand's net inventory.

Uncertainty in the trend

The uncertainty in net emissions (including emissions and removals from the LULUCF sector) in the trend from 1990 to 2009 is ±4.5 per cent.

1.7.2 LULUCF activities under the Kyoto Protocol

The combined uncertainty for emissions from afforestation and reforestation activities in 2009 was ±11.8 per cent. The combined uncertainty for deforestation in 2009 was ±9.8 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 New Zealand inventory for the period 1990–2009 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 accounted for all carbon pools for Article 3.3 activities under the Kyoto Protocol.

1.9 New Zealand's Emissions Trading Scheme

New Zealand's Emissions Trading Scheme (NZ ETS) is New Zealand's principal policy response to mitigating climate change. The following sections explain how the domestic New Zealand Unit relates to international units and how the NZ ETS may over time help to provide a method of verification for the inventory.

1.9.1 The New Zealand Unit

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

New Zealand Units are issued into the New Zealand Emission Unit 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 our 2010 inventory submission.

The Government allocates NZUs into the market by giving them to eligible individuals or firms in specific sectors, awarding them to individuals or firms conducting approved removal activities, or by selling them. When sectors enter the NZ ETS, participants are required to record and report the greenhouse gas emissions for which they have

obligations or the removals for which they can claim NZUs, and to surrender emission NZUs when required. The methods for estimating emissions are set out in regulations prescribed under the Climate Change Response Act 2002.

Trading NZU's for international units

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

The process for the exchange of a NZU for a 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 New Zealand Initial Assigned Amount of 309,564,733 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. At this point, exchanges of NZUs for AAUs cannot occur.

1.9.2 Verification

The NZ ETS may over time help to provide a method of verification for the inventory. 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, and to surrender emission NZUs when required. How participants estimate their emissions is set out in the regulations prescribed under the Climate Change Response Act 2002. The schedule for sectors entering the NZ ETS is detailed in Table 1.9.1.

While the details of data sharing between the inventory agency and the New Zealand Emission Unit Registry are yet to be finalised, it is likely that the inventory agency will be able to use some of the information provided under the NZ ETS for verifying inventory data.

Table 1.9.1 Dates for sector entry into the New Zealand Emissions Trading Scheme

Sector	Voluntary reporting	Mandatory reporting	Full obligations
Forestry	–	–	1 January 2008
Transport fuels	–	1 January 2010	1 July 2010
Electricity production	–	1 January 2010	1 July 2010
Industrial processes	–	1 January 2010	1 July 2010
Synthetic gases	1 January 2011	1 January 2012	1 January 2013
Waste	1 January 2011	1 January 2012	1 January 2013
Agriculture	1 January 2011	1 January 2012	1 January 2015

1.10 Improvements introduced

This inventory includes improved estimates of emissions and removals compared to the 2010 inventory submission, resulting in a number of recalculations to the estimates. Recalculations of estimates reported in the previous inventory can be due to improvements in:

- activity data
- emission factors and/or other parameters
- methodology
- additional sources identified within the context of the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003)
- availability of activity data and emission factors for sources that were previously reported as a 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 for the inconsistency.

The largest improvements in the accuracy of net emissions, made to the New Zealand greenhouse gas inventory following the 2010 submission[8], were made in the LULUCF, agricultural and waste sectors. Chapter 10 provides a summary of all recalculations made to the estimates. There was also a significant improvement made to deforestation estimates under Article 3.3 of the Kyoto Protocol.

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 – backcasting (section 7.3.4)

The largest improvement introduced to this inventory submission in terms of impact on estimated net emissions is including data on historical land-use 'backcasting' into the LULUCF sector. The introduction of historical land-use data to model land-use change since 1962 (backcasting) has been made to meet the requirements of reporting land in transition in IPCC good practice guidance (GPG-LULUCF, IPCC, 2003) and has improved the completeness and consistency of estimates in the LULUCF sector. The year 1962 is chosen as the start point for backcasting as it is 28 years prior to 1990. Twenty-eight years was chosen by New Zealand as the time it takes for land to reach a state of equilibrium (or maturity) following land-use change as this is the average age at which planted forests are harvested in New Zealand (Ministry of Agriculture and Forestry, 2008).

Backcasting has identified land in transition in 1990 and lagged emissions and removals from land-use change prior to 1990 which continue to have an effect on the time-series. For example, if land was converted from grassland to forest land in 1980 there would still be emissions from loss of soil carbon (which occurs over 20 years) in 1990. These emissions are now reported in the LULUCF sector in the land converted to forest land category. This is explained further in section 7.2.4.

[8] Common reporting format (CRF) version 1.2

Backcasting reduced net removals in 1990 by 5084 Gg CO_2-e and reduced net removals in 2008 by 24 Gg CO_2-e.

Deforestation area (7.2.2 and 11.3)

The accuracy of the land-use area has been improved in this submission, particularly the area of deforestation. This is because deforestation areas were estimated from the deforestation intentions survey (Manley, 2009) in the 2010 submission, whereas they have now been mapped from satellite imagery. In 2008, this resulted in a decrease of 2478.9 Gg CO_2-e (85.1 per cent) in estimated emissions from deforestation under Article 3.3 of the Kyoto Protocol in 2008.

Agricultural soils – dung and urine split (section 6.5)

The accuracy of the estimates for agricultural soils has been improved in this submission through disaggregating nitrogen-excreted fractions into urine and dung for cattle, sheep and deer. Prior to this submission, New Zealand had applied one New Zealand-specific emission factor from cattle and sheep manure that accounted for dung and urine emissions together. However, the research to develop this single New Zealand-specific emission factor was generally carried out on urine samples. New research showed that N_2O emissions from dung are substantially lower than emissions from urine. Consequently, a new emission factor for dung was developed for the purpose of estimating emissions from cattle, sheep and deer. This New Zealand-specific emission factor for dung has been included in this inventory submission and for consistency it has been applied to the entire time-series. This disaggregation has reduced emissions from the agriculture sector by 1637.9 Gg CO_2-e in 1990 and 1470.8 Gg CO_2-e in 2008.

Solid waste disposal to land – consistent and specific parameters (section 8.2)

There has been a recalculation of the estimates for the waste sector. This is largely due to improved methodologies for calculating emissions and recovery of emissions from solid waste disposed to land. These improvements have come from:

- a better understanding of the management and design of landfills with operational CH_4 recovery systems
- the application of nationally consistent assumptions on the composition of solid waste.

These improvements are largely responsible for the recalculation of the trend in the waste sector which now shows that waste emissions in 2009 are 0.03 Mt CO_2-e (1.6 per cent) below waste emissions in 1990, as opposed to the decrease of 0.8 Mt CO_2-e (31.5 per cent) as reported in the previous inventory submission.

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 emissions and 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).

1990–2009

In 1990, New Zealand's total greenhouse gas emissions were 59,112.1 Gg carbon dioxide equivalent (CO_2-e). In 2009, total greenhouse gas emissions had increased by 11,451.7 Gg CO_2-e (19.4 per cent) to 70,563.8 Gg CO_2-e (Figure 2.1.1). Between 1990 and 2009, the average annual growth in total emissions was 0.9 per cent per year.

The four emission sources that contributed the most to this increase in total emissions were road transport, dairy enteric fermentation (methane emissions produced from ruminant livestock), public electricity and heat production, and agricultural soils.

2008–2009

Between 2008 and 2009, New Zealand's total greenhouse gas emissions decreased 2281.4 Gg CO_2-e (3.1 per cent). This decrease was largely due to the decline in energy emissions as a result of an increase in inflows into hydro-electric storage lakes and an increase in electricity supply from geothermal and wind generation. High hydro inflows decrease the demands for thermal electricity generation. A reduction in road transport emissions due to the downstream effects of the 2008 economic downturn, also contributed to the decrease in 2009.

A further factor in the decrease between 2009 and 2008 was the reduction in the use of nitrogen fertiliser applied to agricultural soils. The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a low milk price in 2009 (Ministry of Agriculture and Forestry, 2010) coupled with high prices of nitrogen fertiliser products, the sale and use of nitrogen fertiliser in 2009 decreased. Despite the lower price in milk, the relative returns in dairy continued to be higher than for sheep, non-dairy and beef. This along with the persistent effects from the 2008 drought, continued to have an affect on those populations in 2009.

The decrease between 2008 and 2009 is consistent with the trend in New Zealand's total emissions since 2006. This is principally due to changes of circumstance in the two

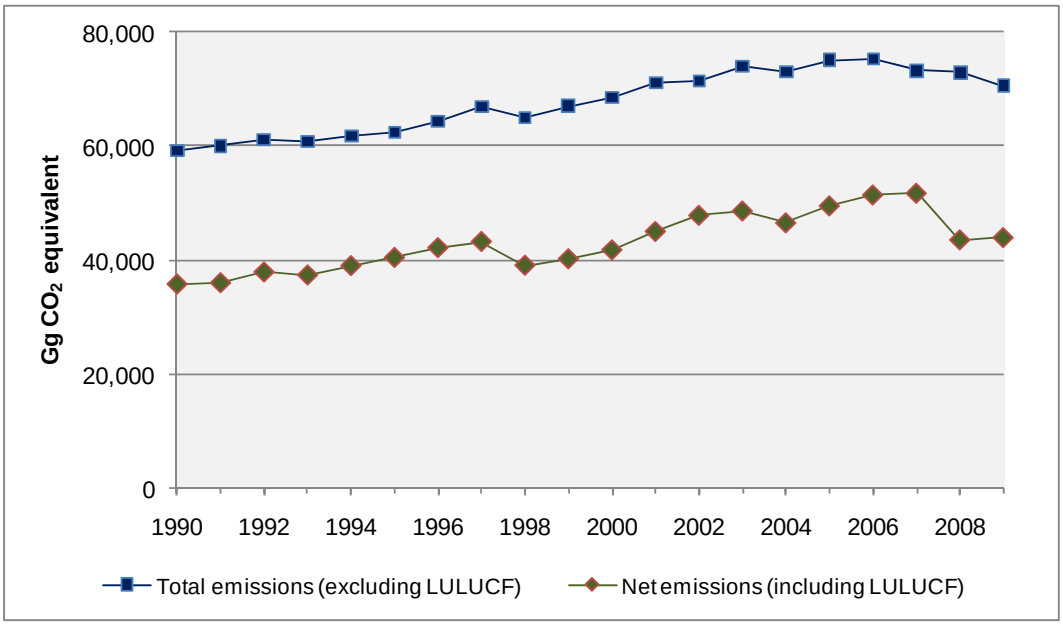
largest sectors; agriculture and energy. There was a decrease in energy emissions in 2007 due to a reduction in coal-fired electricity generation, with the commissioning of Genesis Energy's combined cycle gas turbine at the Huntly power station. Agricultural emissions decreased in 2007 and 2008 due to droughts that affected livestock populations.

Net emissions – Climate Change Convention reporting

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

In 1990, New Zealand's net greenhouse gas emissions were 35,661.0 Gg CO_2-e. In 2009, net greenhouse gas emissions had increased by 8,220.0 Gg CO_2-e (23.1 per cent) to 43,881.1 Gg CO_2-e (Figure 2.1.1).

Figure 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2009



Reporting under the Kyoto Protocol

New Zealand's initial assigned amount under the Kyoto Protocol is recorded as 309,564,733 metric tonnes CO_2 equivalent (309,565 Gg CO_2-e). The initial assigned amount is five times the total 1990 emissions reported in the inventory submitted as part of *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006). The initial assigned amount does not change during the first commitment period (2008–2012) of the Kyoto Protocol. In contrast, the time-series of emissions and removals reported in each inventory submission are subject to continuous improvement. Consequently, the total emissions in 1990 as reported in this submission are 4.7 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 2009, net removals were –17,268.4 Gg CO_2-e[9] from land subject to afforestation, reforestation and deforestation. Removals from afforestation and reforestation were –17,624.3 Gg CO_2-e. Deforestation emissions were 355.9 Gg CO_2-e.

2.2 Emission trends by gas

Inventory reporting under the Climate Change Convention covers six direct greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). Table 2.2.1 provides the change in each gas from 1990 to 2009. In 2009, CO_2 contributed the largest proportion of total emissions (Figure 2.2.1), while in 1990, CO_2 and CH_4 contributed nearly equal proportions to total emissions (Figure 2.2.2). The proportion of CH_4 has been decreasing over the time-series while the proportion of CO_2 has been increasing. This trend reflects the increase in emissions from the energy sector (section 2.3) – nearly 90 per cent of New Zealand's CO_2 emissions come from the energy sector. Carbon dioxide was also the greenhouse gas that has had the strongest influence on the trend in total emissions between 1990 and 2009 (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

2009

Carbon dioxide contributed the largest proportion of total emissions in 2009 at 33,444.6 Gg (47.4 per cent). The largest sources of total CO_2 emissions are from road transport and electricity and heat production. In 2009, road transport contributed 12,205.6 Gg (36.5 per cent) to total CO_2 emissions and public electricity and heat production contributed 5,935.0 Gg (17.7 per cent).

In 2009, net removals of carbon dioxide by forest land (as reported under the Climate Change Convention) were 29,578.3 Gg. This estimate includes emissions from the previous land use on conversion to forest. The highest contributor to removals in 2009 was from post-1989 forests, reported under land converted to forest land. Carbon dioxide removals from afforestation and reforestation activities (as accounted for under Article 3.3 of the Kyoto Protocol) were 17,625.8 Gg. The difference between the two estimates is largely due to the inclusion of pre-1990 forests and land converted to pre-1990 forests. While reporting under the Climate Change Convention includes pre-1990 forests, they are excluded from all but deforestation emissions under the Kyoto Protocol.

In 2009, CO_2 emissions from deforestation of all forests (1644 hectares) contributed 352.5 Gg to net emissions (excluding CO_2 from liming of deforested land). The deforestation was mainly for conversion into grassland, largely due to the relative profitability of pastoral farming, particularly dairy farming, compared with forestry.

[9] Net removals are expressed as a negative value to assist the reader in clarifying that the value is a removal and not an emission.

1990–2009

Total CO_2 emissions have increased 8,444.4 Gg (33.8 per cent) from the 1990 level of 25,000.2 Gg. The two largest sources of this growth were the increased emissions from road transport, and public electricity and heat production.

Between 1990 and 2009, net removals of CO_2 from all forest land increased by 4,220.6 Gg. This increase in removals is largely the result of new forest establishment since 1990 (post-1989 forests), as well as the growth of pre-1990 forests.

2008–2009

Between 2008 and 2009, total CO_2 emissions decreased 2,241.7 Gg (6.3 per cent). This decrease is primarily due to a decrease in emissions from public electricity and heat production due to high hydro inflows for 2009. High hydro inflows decrease the requirements for thermal electricity generation. Carbon dioxide emissions also fell in 2009 as a result of decreased emissions from road transport, which was an effect of the 2008 economic downturn.

Between 2008 and 2009, net removals of CO_2 from all forest land decreased by 2,650.1 Gg. This decrease in removals is largely the result of increased new planting (as the biomass from the previous crop is removed during the year of planting, meaning higher emissions); there was also increased harvesting of pre-1990 planted forest.

Between 2008 and 2009, CO_2 emissions from deforestation of all forests decreased by 76.5 Gg (13.7 per cent) as there was less area deforested in 2009 than in 2008.

Methane

2009

Methane contributed 26,136.2 Gg CO_2-e (37.0 per cent) to total emissions in 2009. The principal source of CH_4 emissions is from enteric fermentation, particularly from the four major ruminant livestock populations of sheep, dairy cattle, non-dairy cattle and deer. In 2009, enteric fermentation CH_4 of these four livestock populations contributed 22,453.2 Gg CO_2-e (85.9 per cent) to total CH_4emissions.

1990–2009

In 2009, CH_4 emissions have increased by 832.7 Gg CO_2-e (3.3 per cent) from the 1990 level of 25,303.5 Gg CO_2-e. While the decline in the population of sheep between 1990 and 2009 has led to a decrease in CH_4 of enteric fermentation from sheep by 3,664.2 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 4,405.4 Gg CO_2-e.

2008–2009

Between 2008 and 2009, CH_4 emissions increased 130.9 Gg CO_2-e (0.5 per cent). This slight increase is due to the increase in emissions from dairy cattle enteric fermentation. While the populations of sheep, non-dairy and deer were still affected by the 2008 drought and by lower returns for sheep, beef and deer relative to dairy, this was offset by the increase in the population of dairy cattle.

Nitrous oxide

2009

Nitrous oxide contributed 10,037.9 Gg CO_2-e (14.2 per cent) to total emissions in 2009. The largest source of N_2O emissions is from agricultural soils. In 2009, the agricultural soils category contributed 9,498.4 Gg CO_2-e (94.6 per cent) to New Zealand's total N_2O emissions.

1990–2009

In 2009, N_2O emissions increased by 1,874.5 Gg CO_2-e (23.0 per cent) from the 1990 level of 8,163.4 Gg CO_2-e. The growth in N_2O is from the increase in emissions from the use of nitrogen fertilisers in the agriculture sector and from an increase in animal excreta. There has been a five-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2009 time-series from 59,265 tonnes in 1990 to 279,752 tonnes in 2009, which has resulted in an increase of direct N_2O emissions from 259.8 Gg CO_2-e in 1990 to 1,225.7 Gg CO_2-e in 2009.

2008–2009

Between 2008 and 2009, emissions of nitrous oxide decreased 257.4 Gg CO_2-e (2.5 per cent). This decrease was largely from the reduction in nitrogen fertiliser applied to agricultural soils. The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a lower milk price in 2009 (Ministry of Agriculture and Forestry, 2010) coupled with high prices for nitrogen fertiliser products, the sale and use of nitrogen fertiliser in 2009 decreased. Despite the lower price in milk, the relative returns in dairy continued to be higher than for sheep, non-dairy and beef. This, along with the persistent effects from the 2008 drought, continued to have an effect on those populations in 2009.

Hydrofluorocarbons, PFCs and SF_6

Hydrofluorocarbons, PFCs and SF_6 contributed the remaining 945.1 Gg CO_2-e (1.3 per cent) to total emissions in 2009.

In 1990, no HFCs were used in New Zealand and therefore no percentage is shown in Table 2.2.1. In 2009, 879.2 Gg CO_2-e of HFC emissions were produced. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol.

Emissions of PFCs have decreased 583.7 Gg CO_2-e (92.7 per cent) from the 629.9 Gg CO_2-e in 1990, to 46.1 Gg CO_2-e in 2009. This decrease is the result of improvements in the aluminium smelting process.

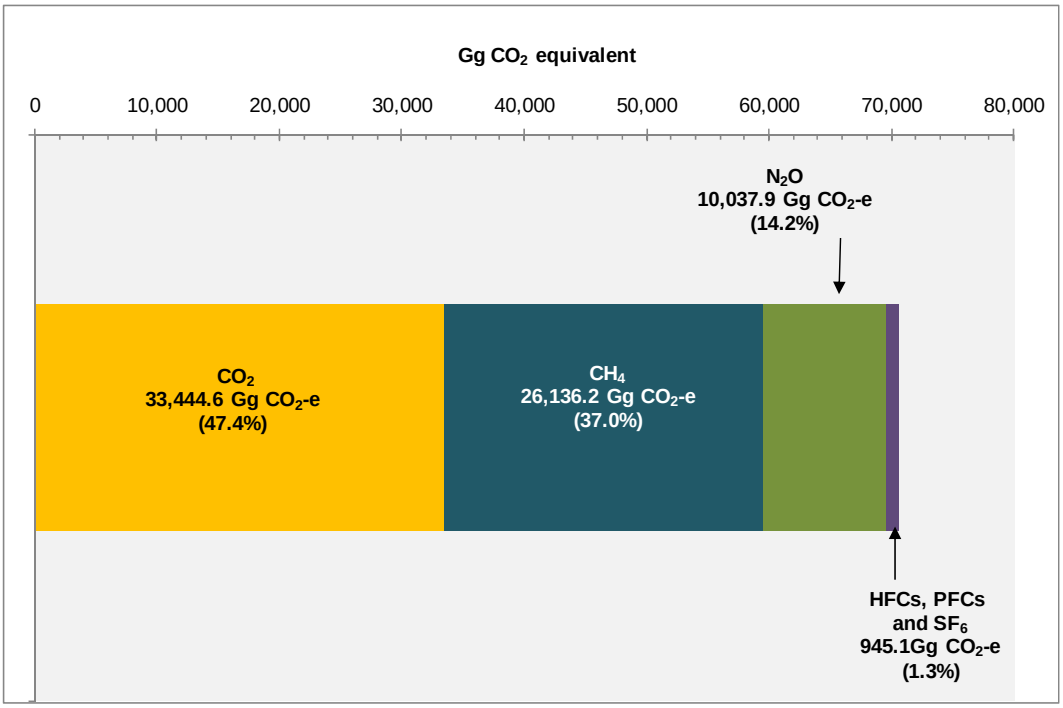
Emissions of SF_6 have increased 4.5 Gg CO_2-e (29.9 per cent), from the 1990 level of 15.2 Gg CO_2-e to the 2009 level of 19.8 Gg CO_2-e. This increase is largely due to the increase in use by electricity generators.

Table 2.2.1 New Zealand's total (gross) emissions by gas in 1990 and 2009

Direct greenhouse gas emissions	Gg CO_2 equivalent		Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
	1990	2009		
CO_2	25,000.2	33,444.6	+8444.4	+33.8
CH_4	25,303.5	26,136.2	+832.7	+3.3
N_2O	8,163.4	10,037.9	+1,874.5	+23.0
HFCs	NO	879.2	+879.2	NA
PFCs	629.9	46.1	–583.7	–92.7
SF_6	15.2	19.8	+4.5	+29.9
Total	**59,112.1**	**70,563.8**	**+11,451.7**	**+19.4**

Notes: Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF. 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 2009



Note: Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF.

Figure 2.2.2 Proportion that gases contributed to New Zealand's total emissions from 1990 to 2009

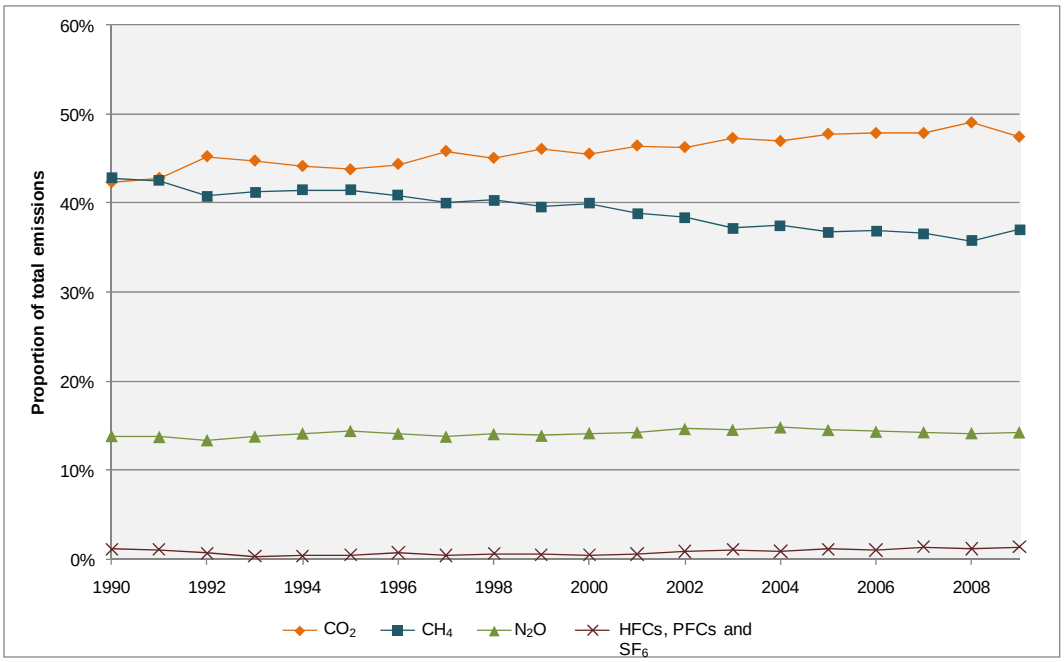
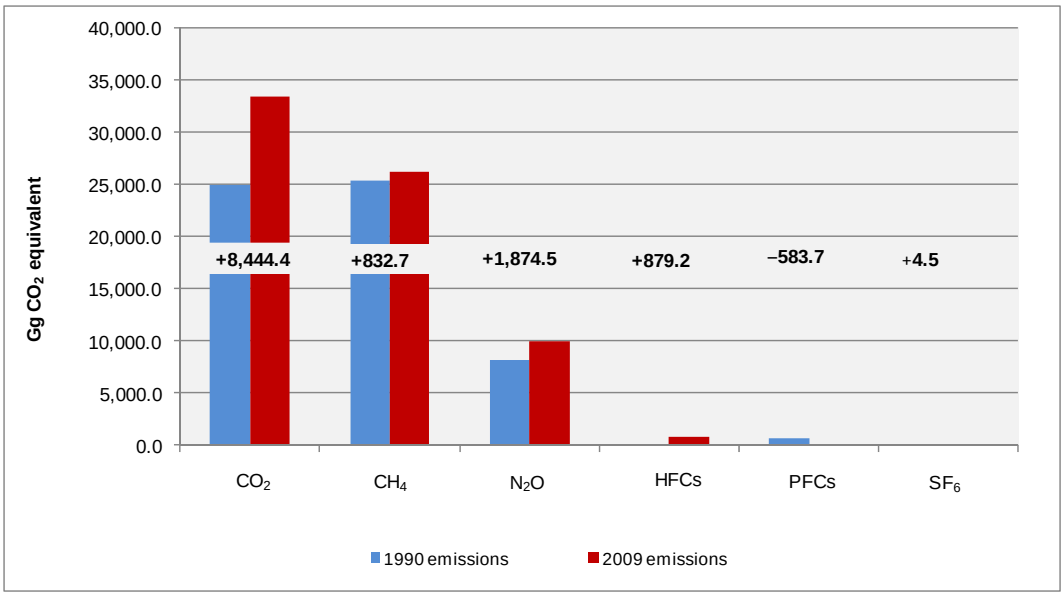
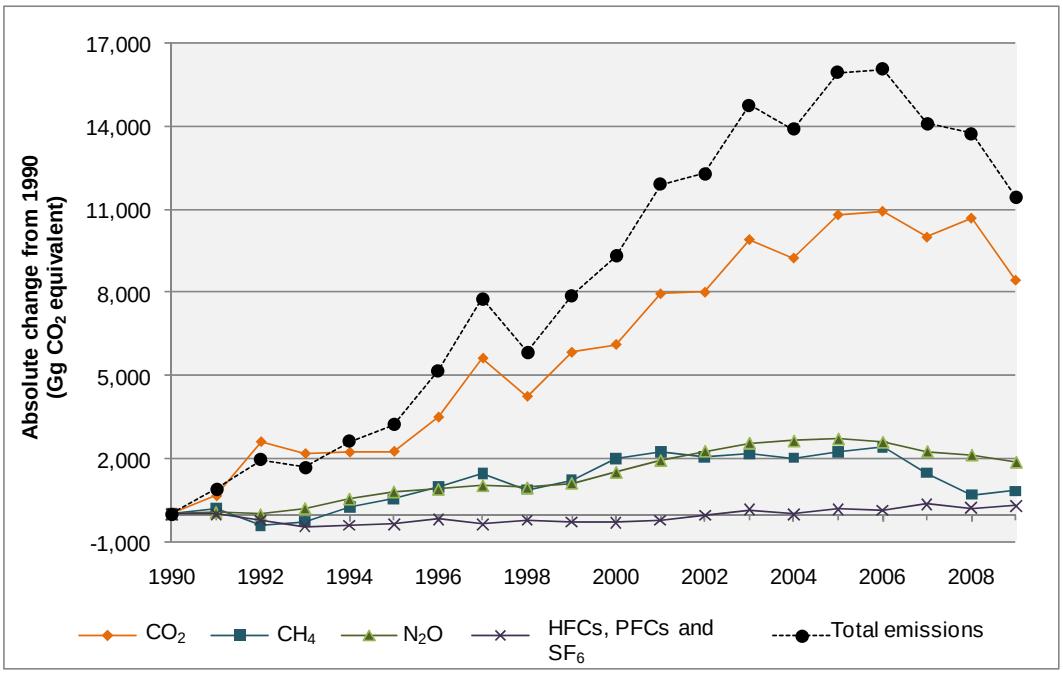


Figure 2.2.3 Change in New Zealand's total emissions by gas from 1990 to 2009



Notes: Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF.

Figure 2.2.4 Change from 1990 in New Zealand's total emissions by gas from 1990 to 2009



Note: Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF.

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. Although the agriculture sector contributed the largest proportion of total emissions in 2009 (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 has been increasing (Figure 2.3.2). For the first time in 2008, energy was the largest contributing sector to total emissions, although agriculture had the greater proportion in 2009 again. This trend reflects that the energy sector has experienced the greatest increase over the period 1990 – 2009 (Figure 2.3.3). Energy emissions have increased over three times as much as those from the agriculture sector (in absolute terms). The energy sector has also been the sector that has had the most influence on the trend in total emissions between 1990 and 2009 (Figure 2.3.4).

Energy (chapter 3)

2009

The energy sector was the source of 31,361.4 Gg CO_2-e (44.4 per cent) of total emissions in 2009. The largest sources of emissions in the energy sector were road transport, contributing 12,386.1 Gg CO_2-e (39.5 per cent), and public electricity and heat production contributing 5,954.9 Gg CO_2-e (19.0 per cent) to energy emissions.

1990–2009

In 2009, energy emissions had increased by 8,002.2 Gg CO_2-e (34.3 per cent) from the 1990 level of 23,359.2 Gg CO_2-e. This growth in emissions is primarily from road

transport, which increased by 4,931.7 Gg CO_2-e (66.2 per cent) and electricity generation and heat production, which increased by 2,494.3 Gg CO_2-e (72.1 per cent).

2008–2009

Between 2008 and 2009, emissions from the energy sector decreased by 2,245.9 Gg CO_2-e (6.7 per cent). This decrease is primarily due to a decrease in emissions from public electricity and heat production due to high hydro inflows for 2009 and an increase in supply from geothermal and wind generation. High hydro inflows decrease the requirements for thermal electricity generation. A reduction in road transport emissions due to the 2008 economic downturn, also contributed to the decrease in 2009.

Industrial processes (chapter 4)

2009

The industrial processes sector contributed 4,345.5 Gg CO_2-e (6.2 per cent) of total emissions in 2009. The largest source of emissions was from iron and steel production, which contributed 1,563.1 Gg CO_2-e (36.0 per cent) to the industrial processes sector.

1990–2009

Emissions from the industrial processes sector increased 963.0 Gg CO_2-e (28.5 per cent) from the 1990 level of 3,382.6 Gg CO_2-e. This increase was mainly caused by growth in emissions from the consumption of HFCs. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol.

2008–2009

Between 2008 and 2009, emissions from the industrial processes sector increased by 60.9 Gg CO_2-e (1.4 per cent). This growth was largely due to an increase in emissions from the consumption of HFCs.

Solvent and other product use (chapter 5)

In 2009, the solvent and other product use sector was responsible for 27.9 Gg CO_2-e (0.04 per cent) of total emissions. The emission levels from the solvent and other products sector are negligible compared with other sectors.

Agriculture (chapter 6)

2009

The agriculture sector was the largest source of emissions in 2009, contributing 32,810.5 Gg CO_2-e (46.5 per cent) of total emissions. New Zealand has a unique emissions profile amongst developed countries. In most other developed countries, agricultural emissions are typically less than 10 per cent of total emissions.

The largest sources of emissions from the agriculture sector in 2009 were enteric fermentation from dairy cattle and sheep, and nitrous oxide emissions from agricultural soils.

1990–2009

In 2009, New Zealand's agricultural emissions increased by 2,533.0 Gg CO_2-e (8.4 per cent) from the 1990 level of 30,277.5 Gg CO_2-e (Figure 2.3.2). This increase is largely due to the increase in the enteric fermentation emissions from dairy cattle and nitrous oxide emissions from agriculture soils.

2008–2009

Between 2008 and 2009, emissions from the agriculture sector decreased 56.4 Gg CO_2-e (0.2 per cent). This decrease was largely from the reduction in nitrogen fertiliser applied to agricultural soils. The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a low milk price in 2009 (Ministry of Agriculture and Forestry, 2010) coupled with high prices for nitrogen fertiliser products, the sale and use of nitrogen fertiliser in 2009 decreased. Despite the lower price in milk, the relative returns in dairy continued to be higher than for sheep, non-dairy and beef. This, along with the persistent effects from the 2008 drought, continued to have an effect on those populations in 2009.

LULUCF (chapter 7)

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

2009

In 2009, net removals from the LULUCF sector under the Climate Change Convention were –26,682.7 Gg CO_2-e. The highest removals in 2009 were from post-1989 forests, reported under land converted to forest land.

The largest source of emissions in LULUCF is from forest land remaining forest land. In 2009, these emissions contributed 2,016.0 Gg CO_2-e. This is largely due to the emissions from harvesting exceeding removals from growth of these forests.

1990–2009

Between 1990 and 2009, net removals from LULUCF increased by 3,231.7 Gg CO_2-e (13.8 per cent) from the 1990 level of 23,451.1 Gg CO_2-e. This increase in net removals is largely the result of new forest establishment since 1990 (post-1989 forests), as well as the growth of pre-1990 planted forest.

The fluctuations in net removals/emissions from LULUCF across the time-series (Figure 2.3.4) 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 to alternative land uses. The decrease in net removals between 2004 and 2008 was largely due to the increase in the planted forest deforestation that occurred leading up to 2008, before the introduction of the New Zealand Emissions Trading Scheme.[10] The high price of pastoral land between 2004 and 2008 also contributed to an increase in deforestation.

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

2008–2009

Between 2008 and 2009, net removals from LULUCF decreased by 2,677.4 Gg CO_2-e (9.1 per cent). This decrease in net removals is largely the result of increased new planting (as the biomass of the previous crop is greater than the growth of the new crop meaning emissions are greater than removals during 2009) and of an increase in harvesting of pre-1990 planted forest.

Waste (chapter 8)

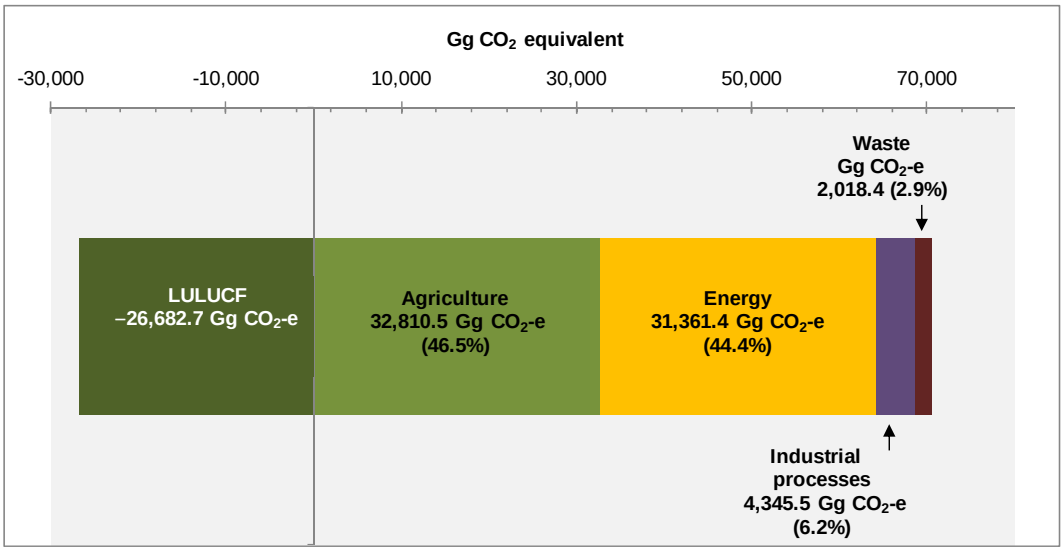
The waste sector contributed 2,018.4 Gg CO_2-e (2.9 per cent) to total emissions in 2009. Emissions from the waste sector have decreased by 32.9 Gg CO_2-e (1.6 per cent) from the 1990 level of 2,051.3 Gg CO_2-e. This reduction, despite an increase in New Zealand's economic activity – which is generally coupled with an increase in waste generation – occurred in the solid waste disposal on land category as a result of initiatives to improve solid waste management practices.

Table 2.3.1 New Zealand's emissions and removals by sector in 1990 and 2009

Sector	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2009	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
Energy	23,359.2	31,361.4	+8,002.2	+34.3
Industrial processes	3,382.6	4,345.5	+963.0	+28.5
Solvent and other product use	41.5	27.9	–13.6	–32.8
Agriculture	30,277.5	32,810.5	+2,533.0	+8.4
Waste	2,051.3	2,018.4	–32.9	–1.6
Total (excluding LULUCF)	**59,112.1**	**70,563.8**	**+11,451.7**	**+19.4**
LULUCF	–23,451.1	–26,682.7	–3,231.7	–13.8
Net Total (including LULUCF)	**35,661.0**	**43,881.1**	**+8,220.0**	**+23.1**

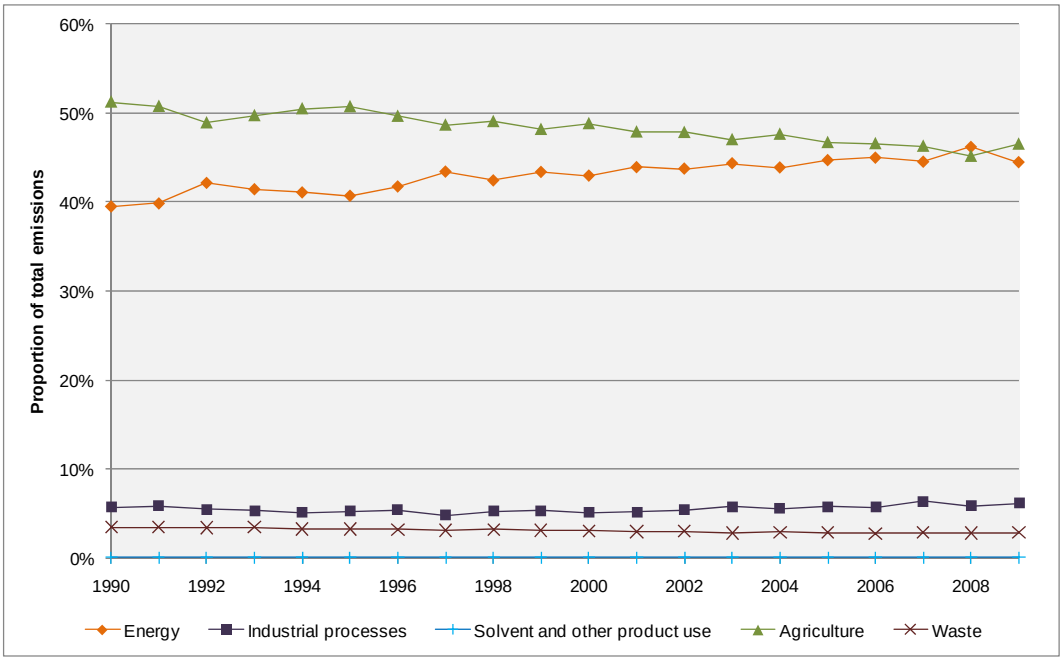
Notes: LULUCF includes CO_2 removals and emissions of CO_2, CH_4 and N_2O. Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Columns may not total due to rounding.

Figure 2.3.1 New Zealand's emissions and removals by sector in 2009



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

Figure 2.3.2 Proportion that sectors contributed to New Zealand's total emissions from 1990 to 2009



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

Figure 2.3.3 Change in New Zealand's emissions and removals by sector from 1990 to 2009

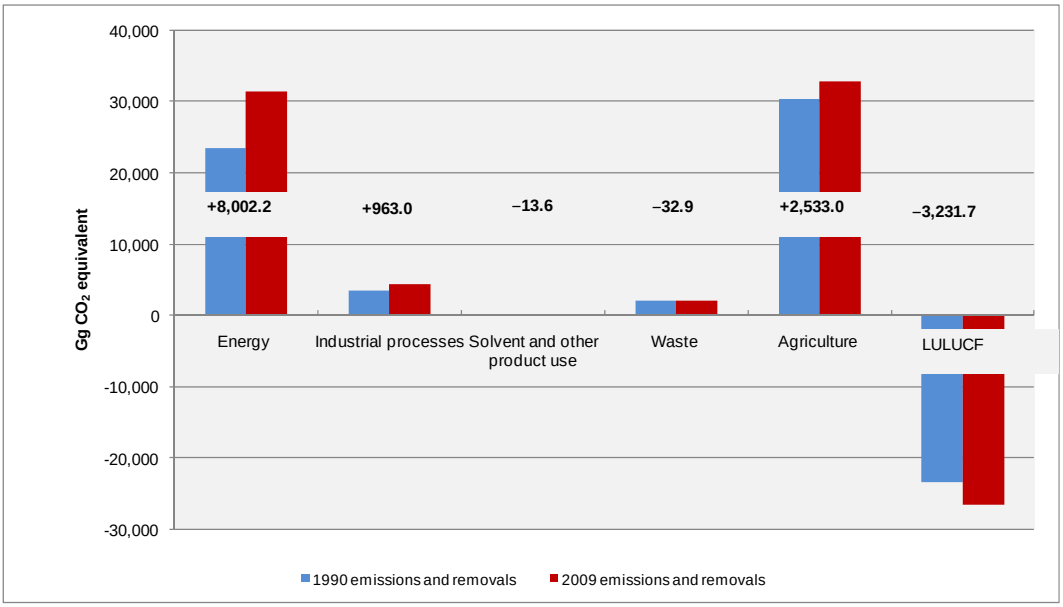
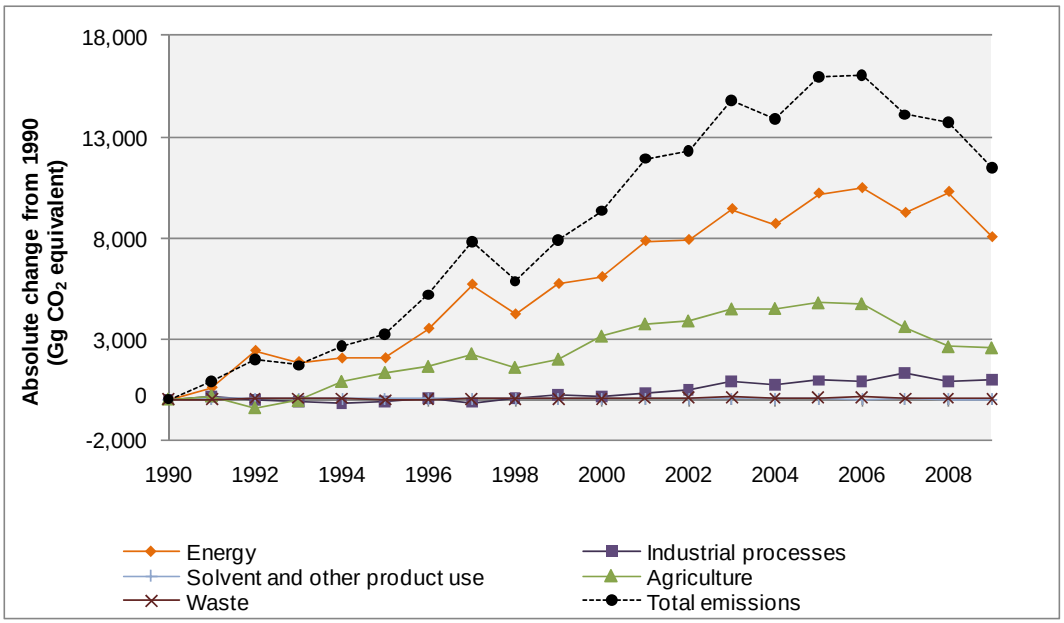
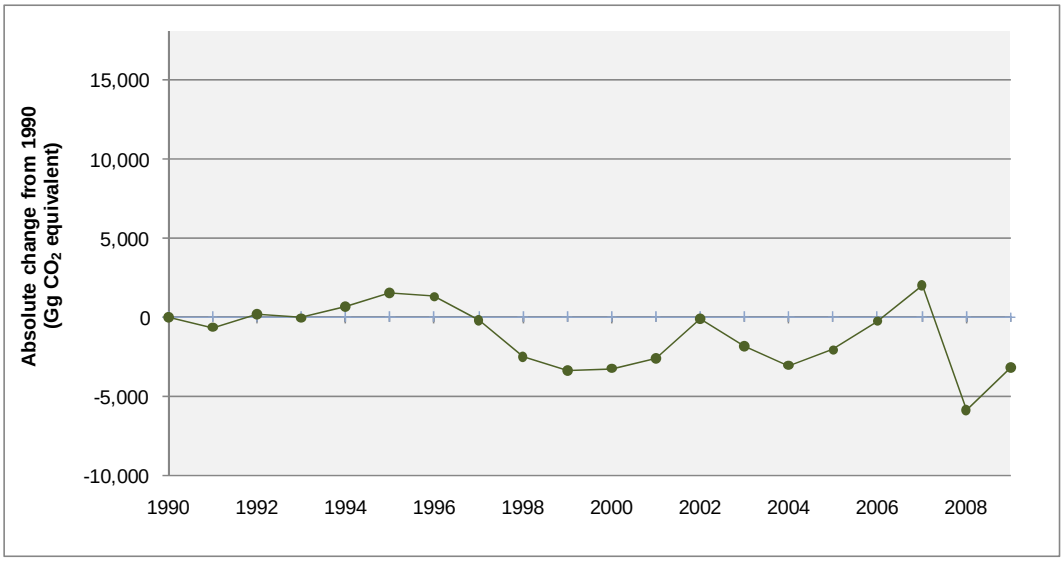


Figure 2.3.4 Absolute change from 1990 in New Zealand's total emissions by sector from 1990 to 2009



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

Figure 2.3.5 Absolute change from 1990 in New Zealand's net removals/ emissions from the LULUCF sector from 1990 to 2009 (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 2009 are shown in Table 2.4.1. Consistent with UNFCCC 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 2009

Indirect gas	Gg of gas(es) 1990	2009	Change from 1990 (Gg)	Change from 1990 (%)
NO_x	99.3	151.7	+52.4	+52.7
CO	632.0	724.5	+92.5	+14.6
NMVOCs	136.8	174.6	+37.7	+27.6
SO_2	58.1	73.4	+15.2	+26.2
Total	**926.3**	**1,124.1**	**+197.8**	**+21.4**

Note: Columns may not total due to rounding.

Emissions of CO and NO_x are largely from the energy sector. The energy sector produced 90.2 per cent of total CO emissions in 2009. 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 (98.2 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 73.1 per cent of NMVOC emissions in 2009. Emissions from road transportation comprised 59.4 per cent of total NMVOC emissions. Other major sources of NMVOCs were in the solvent and other product use sector (20.0 per cent) and the industrial processes sector (6.9 per cent).

In 2009, emissions of SO_2 from the energy sector comprised 86.7 per cent of total SO_2 emissions. The energy industries category contributed 18.2 per cent, manufacturing industries and construction category 34.6 per cent, and the transport category 16.0 per cent, of total SO_2 emissions. The industrial processes sector contributed 13.3 per cent of total SO_2 emissions. Aluminium production accounted for 7.4 per cent of SO_2 emissions.

2.5 Article 3.3 activities under the Kyoto Protocol

In 2009, net removals from land subject to afforestation, reforestation and deforestation (Article 3.3 activities under the Kyoto Protocol) were –17,268.4 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 liming
- 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 pre-1990 forests

- emissions from the liming of afforested and reforested land because this activity does not occur in New Zealand
- non-carbon dioxide emissions from controlled burning on deforested land because there is insufficient data to quantify the emissions from this activity. The notation NE ('not estimated') is reported in the common reporting format tables for controlled burning associated with deforestation
- emissions associated with nitrogen fertiliser use on deforested land because these are reported in the agricultural sector.

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2009 was 591,202 hectares. The net area is the total area of post-1989 forest (606,706 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (15,503 hectares). Removals from this land in 2009 were –17,624 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2009 was 98,668 hectares. The area subject to deforestation in 2009 was 1,644 hectares. In 2009, deforestation emissions were 355.9 Gg CO_2-e, compared with 432.4 Gg CO_2-e in 2008 (a 17.7 per cent reduction). Deforestation emissions include non-carbon emissions and lagged CO_2 emissions that occurred in 2009 as a result of deforestation since 1990. Lagged emissions includes the liming of forest land converted to grassland and cropland, and the disturbance associated with forest land conversion to cropland.

Table 2.5.1 New Zealand's net emissions and removals from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2009

Source	2008	2009
Afforestation/reforestation		
Net cumulative area since 1990 (ha)	587,936	591,202
Area in calendar year (ha)	1,900	4,000
Removals in calendar year (Gg CO_2-e)	–17,531.1	–17,624.3
Deforestation		
Cumulative area since 1990 (ha)	97,024	98,668
Area in calendar year (ha)	1,472	1,644
Emissions in calendar year (Gg CO_2-e)	432.4	355.9
Total area subject to afforestation, reforestation and deforestation (ha)	684,960	689,871
Net removals (Gg CO_2-e)	–17,098.7	–17,268.4

Notes: The areas stated are as at 31 December. They are net areas ie, 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. Columns may not total due to rounding.

Chapter 3: Energy

3.1 Sector overview

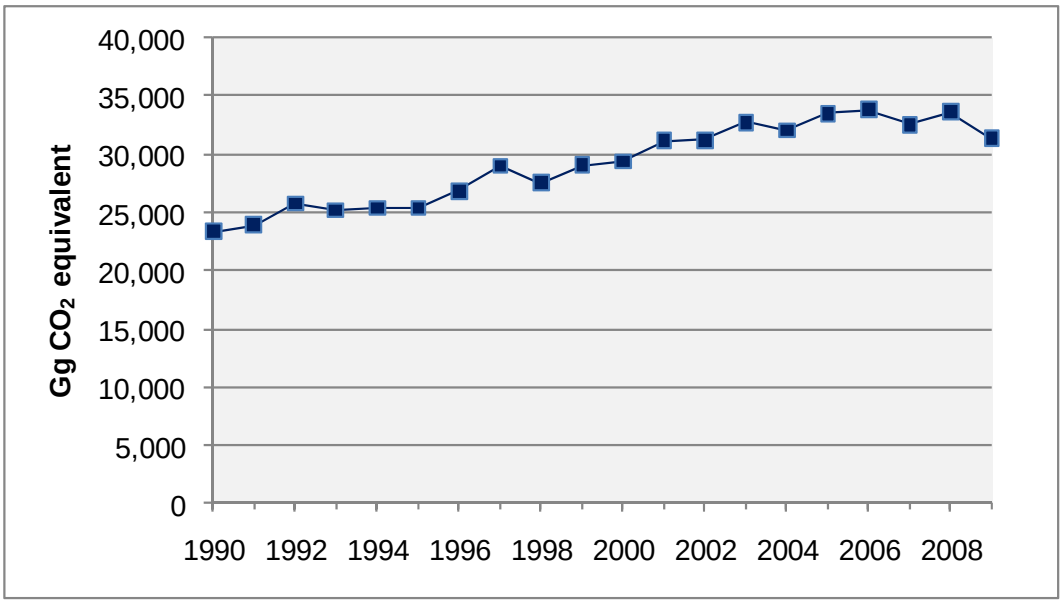
The energy sector produced 31,361.4 Gg carbon dioxide equivalent (CO_2-e) emissions in 2009, contributing 44.4 per cent of New Zealand's total greenhouse gas emissions. Emissions from the energy sector were 34.3 per cent (8,002.2 Gg CO_2-e) above the 1990 level of 23,359.2 Gg CO_2-e (Figure 3.1.1). The sources contributing most to this increase were emissions from the road transportation subcategory, an increase of 4931.7 Gg CO_2-e (66.2 per cent), and the public electricity and heat production subcategory, an increase of 2494.3 Gg CO_2-e (72.1 per cent). Emissions from the manufacture of solid fuels and the other energy industries subcategory have decreased by 1376.3 Gg CO_2-e (78.3 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997.

Changes in emissions between 2008 and 2009

Between 2008 and 2009, emissions from the energy sector decreased by 2245.9 Gg CO_2-e (6.7 per cent). This is primarily due to an 1853.0 Gg CO_2-e (23.7 per cent) decrease in emissions from public electricity and heat production. Public electricity and heat production emissions decreased because of the increased hydro-inflows and increase in electricity supply from geothermal and wind.

A decrease of 230.2 Gg CO_2-e (1.6 per cent) between 2008 and 2009 in the transport category also contributed to the decrease in energy emissions. This reduction was due to the 2008 economic downturn.

Figure 3.1.1 New Zealand's energy sector emissions from 1990–2009



Energy flows

This inventory submission includes energy flow diagrams (Annex 2). These diagrams provide a snapshot of the flow of various fuels from the suppliers to the end users within New Zealand for the 2009 calendar year.

3.2 Background information

3.2.1 Comparison of sectoral approach with reference approach

Greenhouse gas emissions from the energy sector are calculated using a detailed sectoral approach. This is calculated using a bottom-up (demand-based) approach based on energy data collected through various surveys. For verification, New Zealand has also applied a reference approach to estimate carbon dioxide emissions from fuel combustion for the time-series. The reference approach is calculated using a top-down (supply-based) approach based on production, import and export data.

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

The majority of the carbon dioxide 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 sole refinery, the New Zealand Refining Company. Where this data is not available, an Intergovernmental Panel on Climate Change (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 carbon dioxide emission factors for solid fuels are sourced from the *New Zealand Energy Information Handbook* (Baines, 1993).

The activity data for the reference approach is obtained from "calculated" energy-use figures. 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. From this value, energy use for transformation activities (such as the use of coal in steel production and natural gas in methanol production) is subtracted to get apparent consumption. 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 Economic Development (MED). The differences between "calculated" and "observed" figures are reported as statistical differences in the energy balance tables contained in the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b).

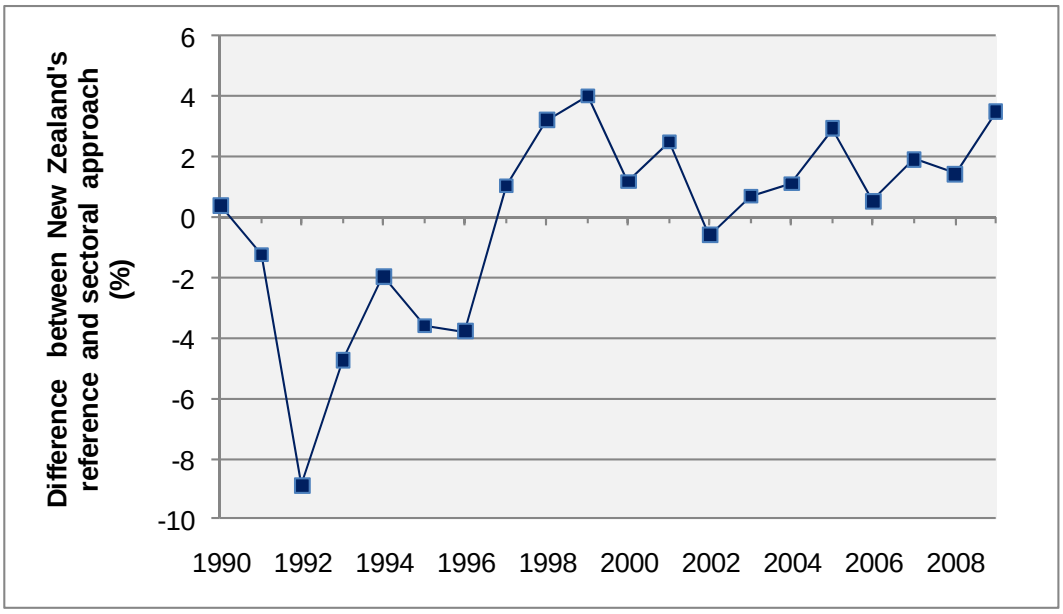
Comparison of the two approaches in 2009 shows the sectoral total of carbon dioxide emissions is 3.5 per cent less than the reference total (Figure 3.2.1). The fuel which showed the largest difference was liquid fuels with the reference approach being 8.3 per cent more than the sectoral approach. This is partially due to the combustion of refinery gas being included under gaseous fuels consumption in the sectoral approach and under liquid fuels consumption in the reference approach (see below) and partially due to the large statistical difference found in the energy balance table (see Table A2.6 (Annex 2)).

The energy-use and calculated emissions for the major fuel categories are not directly comparable between the reference and sectoral approaches. Firstly, this is because the reference approach includes the use of the fuels when fuel combustion for energy is not the primary purpose (ie, gas used as a feedstock in methanol production and coal used in steel production and bitumen use), while the sectoral approach does not. To reconcile this difference, the carbon in these fuels is included under stored carbon and excluded from the reference approach.

Secondly, combustion of refinery gas is included under gaseous fuels consumption in the sectoral approach and under liquid fuels consumption in the reference approach. This is because refinery gas is a by-product of the refining process derived from crude oil inputs. Consequently, emissions from the combustion of refinery gas have been included under crude oil in the reference approach.

In some years, there are large differences between the reference and sectoral approaches, particularly from the mid-1990s to the year 2000. Much of this difference is due to the statistical differences found in the energy balance tables (Ministry of Economic Development, 2010b) that are used as the basis for the reference and sectoral approach.

Figure 3.2.1 Difference between the reference and sectoral approach for New Zealand's energy sector from 1990 to 2009



3.2.2 International bunker fuels

The data on fuel use by international transportation comes from the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b). This report uses information from oil company monthly survey returns provided to the Ministry of Economic Development.

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

3.2.3 Feedstock and non-energy use of fuels

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

In New Zealand there are four main sources of stored carbon:

- part of the natural gas used in methanol and synthetic petrol production (although synthetic petrol production ceased in 1997) is stored in the product and therefore has no associated emissions. The rest of the natural gas used in methanol production results in emissions which are industrial processes emissions sector but are reported under the energy sector due to confidentiality concerns. The rest of the natural gas used in synthetic petrol production results in emissions which are reported under the energy sector
- emissions from the use of natural gas used in urea production are reported under the industrial processes sector
- bitumen produced in New Zealand is not used as a fuel but rather used by the company Fulton Hogan in making road (non-energy use). Bitumen therefore has no associated emissions
- coal used in steel production at New Zealand Steel is used as a reductant and therefore treated as an industrial process rather than an energy process. There are therefore no emissions from this coal in the energy sector. Instead, it is dealt with under industrial processes.

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

There was no carbon dioxide capture from flue gases and subsequent carbon dioxide storage occurring in New Zealand between 1990 and 2009.

3.2.5 Country-specific issues

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

- 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 sector approach (IPCC, 2000) and have been netted out of the energy reference approach using the "estimating the carbon stored in products" table (common reporting format Table 1.A(d))
- the sectoral activity data excludes energy sources containing carbon that is later stored in manufactured products, specifically methanol. Consequently, subsequent subtraction of emissions is not needed to account for this carbon sequestration.

3.2.6 Energy balance

The *New Zealand Energy Data File* (Ministry of Economic Development, 2010b) is an annual publication from the Ministry of Economic Development. It covers energy statistics including supply and demand by fuel types, energy balance tables, pricing information and international comparisons. An electronic copy of this report is available online at: www.med.govt.nz/energy/edf. Table A2.6 (Annex 2) provides an overview of the 2009 energy supply and demand balance for New Zealand.

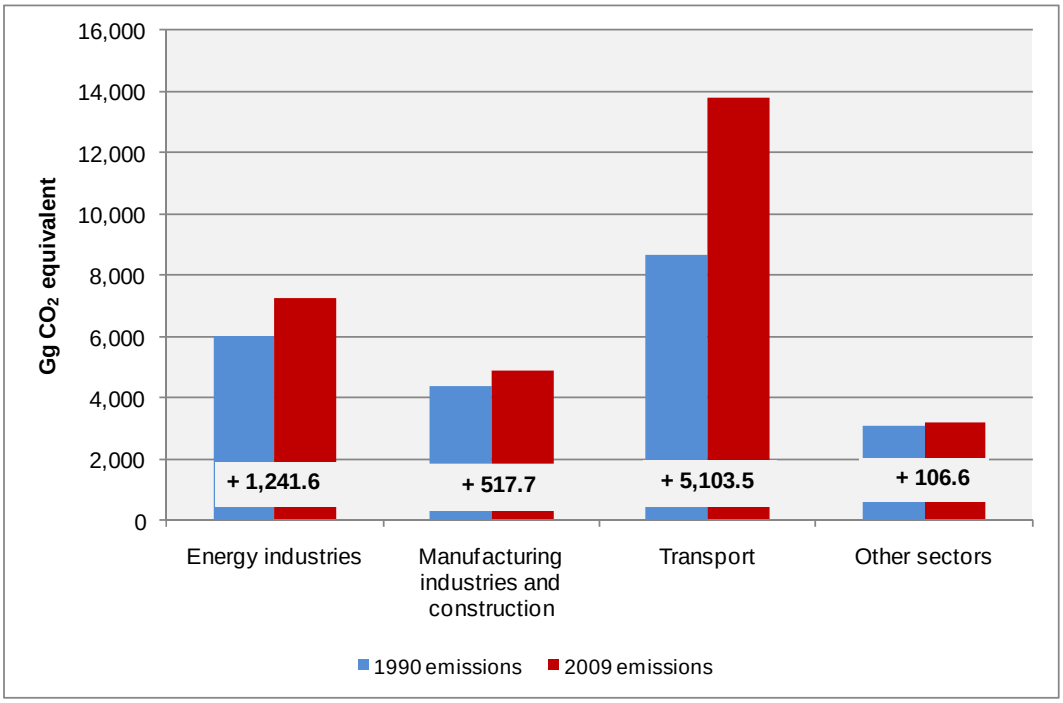
3.3 Fuel combustion (CRF 1A)

Description

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

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

Figure 3.3.1 Change in New Zealand's emissions from the fuel combustion categories from 1990–2009



Methodological issues

Energy emissions are compiled using the Ministry of Economic Development's energy statistics along with relevant New Zealand-specific emission factors. These greenhouse gas emissions are calculated by multiplying the emission factor of specific fuels by the relevant activity data.

Activity data – liquid fuels

The Ministry of Economic Development conducted the *Delivery of Petroleum Fuels by Industry Survey* in 2009. 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 Economic Development with the volume of petroleum fuels delivered to resellers, industry, commercial and residential sectors. The volume of petroleum fuels is currently collected in litres (in metric tonnes prior to 2009). Year-specific calorific values are used for all liquid fuels reflecting changes in liquid fuel properties over time.

Emissions from fuel sold for use in international transport (eg, international bunker fuels) are reported separately as a memo item as required (UNFCCC, 2006).

In previous inventories, emissions from the national transport sector included emissions from liquid fuels sold via resellers (eg, service stations, truck stops and independent fuel distribution companies). This resulted in an overstatement of emissions attributed to national transport as not all fuel sold via resellers is used for transport – some of this fuel is on-sold to other businesses, such as farms, and used off-road. These emissions should therefore be treated as emissions from primary industries, but at the time there was a lack of information available to estimate and reallocate the fuel on-sold for non-transport uses.

A survey commissioned by the Ministry of Economic Development in 2008 (Ministry of Economic Development, 2008) found that there were 19 independent fuel distribution companies operating in New Zealand that resell fuel bought wholesale from the oil companies. The study recommended starting an annual survey of the independent distributor companies' petrol and diesel deliveries to sectors. This data could then be used to reallocate the fuel from national transport to the correct sectors.

The new Annual Liquid Fuel Survey (ALFS) 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 these data, each company's deliveries between 1990 and 2006 were estimated as no information was available for these years. The Ministry of Economic Development report *Delivering the Diesel: Liquid Fuel Deliveries in New Zealand 1990–2008* (Ministry of Economic Development, 2010) outlines in more detail the methodology employed to perform this calculation.

With this new information, some liquid fuel demand that was previously allocated to national transport has now been reallocated to the correct sectors' demand. In terms of energy sector emission estimates, emissions attributed to the transport category have decreased by around 20 per cent and emissions attributed to other categories, such as the agricultural, forestry and fisheries subcategory have increased significantly. These changes have been applied to the entire time-series from 1990–2009.

Activity data – solid fuels

The Ministry of Economic Development now conducts the *New Zealand Quarterly Statistical Return of Coal Production and Sales*. The survey covers coal produced and sold by coal producers in New Zealand. The three grades of coal estimated are bituminous, sub-bituminous and lignite.

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

Activity data – gaseous fuels

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

Activity data – biomass

Activity data for the use of biomass comes from a number of different sources. Electricity and cogeneration data is received by the Ministry of Economic Development from electricity generators. Commercial biomass data is provided by the Cogeneration Association of New Zealand. Residential biomass data is estimated based on census results and data from the Building Research Association of New Zealand (2002). Finally, industrial biomass data is based on information from the Bioassociation of New Zealand Heat Plant Database (Ministry of Economic Development, 2010b).

Liquid biofuels data is included in this inventory for the first time. Activity data for this is based on information collected under the Petroleum or Engine Fuel Monitoring Levy as reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b).

Emission factors

New Zealand emission factors are based on gross calorific values. A list of emission factors for carbon dioxide, methane and nitrous oxide for all fuel types is listed in Annex 2. 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.

Emission factors – liquid fuels

The carbon dioxide emission factors for oil products are from the New Zealand Refining Company data, Baines (1993) and IPCC (1996) defaults. The liquid fuel emission factors are calculated on an annual basis. This inventory submission includes further improvements in liquid fuel emission factors because of improved New Zealand Refining

Company data on carbon content and calorific values becoming available. Improvements on emission factors have also been made when the fuel specifications of liquid fuels change, such as lower sulphur content of diesel oil being introduced in 2006. Annex 2 includes further information on liquid fuels emission factors, including a time-series of gross calorific values.

Emission factors – solid fuels

Emission factors for solid fuels are sourced from *New Zealand Energy Information Handbook* (Baines, 1993). They are shown in table 3.3 below.

Table 3.3.1 Carbon dioxide emission factors for solid fuels

Solid fuel type	Emission factor (kt CO_2/PJ)
Bituminous	88.8
Sub-bituminous	91.2
Lignite	95.2

Emission factors – gaseous fuels

The gaseous fuels emission factor is the calculated 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 because the decline in production of both Maui and Kapuni gas fields has been replaced by other new gas fields (eg, Pohoukura) coming on stream. This 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 seem to have higher carbon content than most international gas fields.

The Kapuni gas field has particularly high carbon dioxide 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 carbon dioxide 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). The emissions from this removal of carbon dioxide are included under the manufacture of solid fuels and other energy industries category (section 3.3.2).

Emission factors – 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 less 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 (UNFCCC, 2006). Carbon dioxide emission factors for liquid biofuels are sourced from the *New Zealand Energy Information Handbook* (Baines, 1993) while methane and nitrous oxide emission factors are IPCC (2006) default emission factors.

Sector-wide planned improvements

All source-specific planned improvements will be discussed in their corresponding sections. However, the Ministry of Economic Development will continue to examine the use of more specific solid fuel carbon dioxide emission factors. The introduction of the New Zealand Emissions Trading Scheme (NZ ETS) means more data and analysis around

carbon content of solid fuels may become available for verification in future inventory submissions as per section 1.9.2.

Uncertainties and time-series consistency

Uncertainty in greenhouse gas emissions from fuel combustion varies depending on the gas. The uncertainty of carbon dioxide emissions is relatively low, which is important as carbon dioxide emissions comprised 95.9 per cent of energy sector emissions in 2009. In comparison, emissions of the non-carbon dioxide gases are much less certain as emissions vary with combustion conditions. Many of the non-carbon dioxide emission factors used by New Zealand are the IPCC default values. More detailed information around uncertainties can be found in Annex 2.

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

		Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)
CO_2	Liquid Fuels	±2.88	±0.5
	Solid Fuels	±11.26	±3.5
	Gaseous Fuels	±2.58	±2.7
	Fugitive – Geothermal	±5.00	±5.0
	Fugitive – Venting/Flaring	±2.58	±2.7
	Fugitive – Oil Transport	±5.00	±50.0
	Fugitive – Transmission & Distribution	±2.58	±5.0
CH_4	Liquid Fuels	±2.88	±50.0
	Solid Fuels	±11.26	±50.0
	Gaseous Fuels	±2.58	±50.0
	Biomass	±5.00	±50.0
	Fugitive – Geothermal	±5.00	±5.0
	Fugitive – Venting/Flaring	±2.58	±50.0
	Fugitive – Coal Mining	±11.26	±50.0
	Fugitive – Transmission & Distribution	±2.58	±5.0
	Fugitive – Other Leakages	±5.00	±50.0
	Fugitive – Oil Transportation	±5.00	±50.0
N_2O	Liquid Fuels	±2.88	±50.0
	Solid Fuels	±11.26	±50.0
	Gaseous Fuels	±2.58	±50.0
	Biomass	±5.00	±50.0

3.3.1 Fuel combustion: energy industries (CRF 1A1)

Description

This category comprises emissions from fossil fuels burnt in stationary combustion. It 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 carbon dioxide 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.

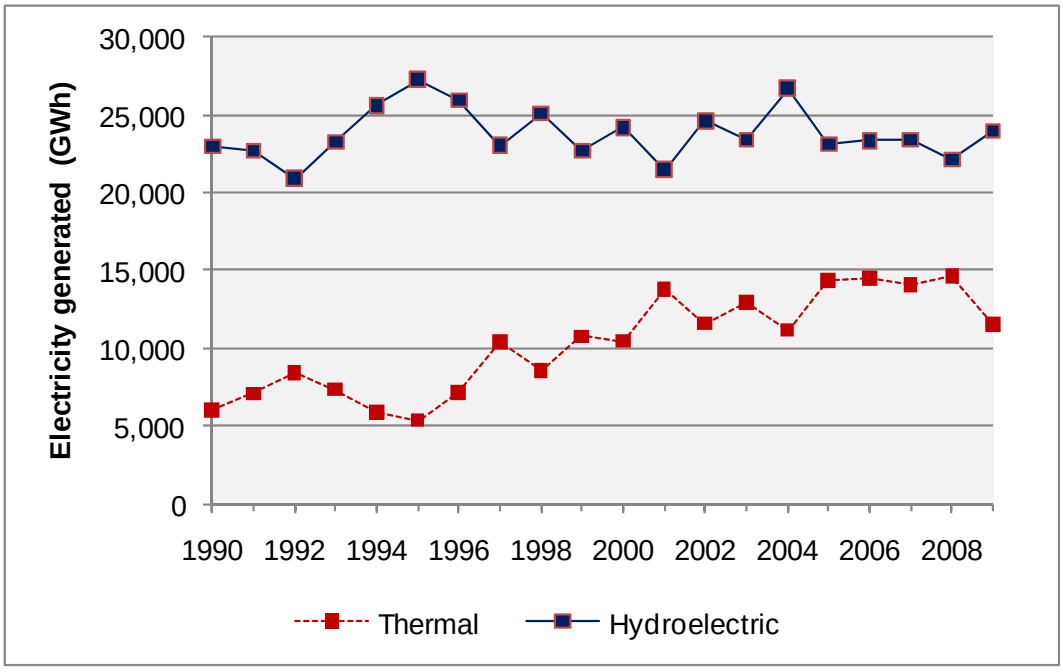
In 2009, emissions in the energy industries category totalled 7235.1 Gg CO_2-e (23.1 per cent) of the energy sector. Emissions from energy industries have increased 1241.6 Gg CO_2-e (20.7 per cent) since the 1990 level of 5993.5 Gg CO_2-e. The public electricity and heat production subcategory accounted for 5954.9 Gg CO_2-e (82.3 per cent) of the emissions from the energy industries category in 2009. This is an increase of 2494.3 Gg CO_2-e (72.1 per cent) from the 1990 level of 3460.6 Gg CO_2-e.

Between 2008 and 2009, there was a decrease of 1853.0 Gg CO_2-e (23.7 per cent) in emissions from public electricity and heat production. This decrease is largely due to high hydro inflows for 2009 and the increase in electricity supplied by low-emissions or emission-free sources such as geothermal and wind. This led to a decreased reliance on thermal electricity generation.

New Zealand's electricity generation is dominated by hydro-electric generation. For the 2009 calendar year, hydro generation provided 57 per cent of New Zealand's electricity generation. A further 11 per cent came from geothermal, 4 per cent from wind and 1 per cent from biomass. The remaining 27 per cent was provided by fossil fuel thermal generation plants using oil, gas and coal (Ministry of Economic Development, 2010b).

Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990 and 2009. 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 hydro generation (Figure 3.3.2). In a dry year, where low rainfall and/or snowmelt affects the majority of New Zealand's hydro-electric lake levels, the shortfall is made up by thermal electricity generation. 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 3.3.2 New Zealand's hydro-electric and thermal generation from 1990 to 2009 (Ministry of Economic Development, 2010b)



Note: This figure does not include generation from other renewable sources of electricity including wind, biomass, waste heat and geothermal.

Key categories identified in the 2009 level assessment from the energy industries category include CO_2 emissions from:

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

Key categories identified in the 1990–2009 trend assessment from the energy industries category include CO_2 emissions from:

- public electricity and heat production – solid fuels
- petroleum refining – liquid fuels (only identified in the total emissions assessment).

Methodological issues

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 Economic Development.

Around 6 per cent of New Zealand's electricity is supplied by cogeneration (also known as combined heat and power) (Ministry of Economic Development, 2010b). Most of the major cogeneration plants are attached to large industrial facilities that consume most of the electricity and heat generated.

For previous inventory submissions, it was thought there was only one cogeneration plant that fitted the IPCC (1996) definition of public electricity and heat production. However, under closer examination there are six cogeneration plants that fit the IPCC (1996) definition of public electricity and heat production, who produce electricity as its primary purpose. The emissions from these plants are included under the public electricity and heat production subcategory, while emissions from other cogeneration plants are included within the manufacturing industries and construction category (section 3.2.2).

A Tier 1 method is used to calculate emissions for these cogeneration plants. This uses activity data from the Ministry of Economic Development's *Monthly Survey of Electricity Generation* supplemented by its annual statistical returns for electricity generators and the weighted average gas emission factor.

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

Petroleum refining

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

Manufacture of solid fuels and other energy industries

Activity data for synthetic petrol production was provided by Methanex New Zealand while the plant was in operation (production of synthetic petrol ceased in 1997). A Tier 1 methodology was used to estimate emissions based on the annual weighted average gas emission factor. The low implied emission factors for the manufacture of solid fuels and other energy industries subcategory for gaseous fuels between 1990 and 1996 were caused by the sequestration of carbon during the synthetic petrol production process.

Activity data and emission factors for the combustion of natural gas during oil and gas extraction are provided to the Ministry of Economic Development by each individual gas/oil field operator. In 2009, liquid fuels were combusted during oil and gas extraction. The activity data for this is provided by the individual gas/oil field operator while the IPCC default for crude oil combustion is used.

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

In preparation of this inventory, the energy industries category underwent Tier 1 quality assurance and quality-control checks.

Source-specific recalculations

As mentioned under 'methodological issues', some cogeneration plants are now assigned under the public electricity and heat production subcategory rather than the manufacturing industries and construction subcategory. This has resulted in recalculations for the public electricity and heat production subcategory.

Activity data for liquid fuels under the public electricity and heat production subcategory is now split between diesel and fuel oil and different emission factors applied. This improvement may not change the activity data total but will change the corresponding emissions.

The reporting of the own use of natural gas at gas fields has been improved. This has resulted in slight revisions in activity data (and corresponding emissions for the manufacture of solid fuels and other energy industries subcategory. This subcategory now also includes natural gas liquids that were previously incorrectly included under LPG for road transport.

There have been small activity data revisions in some categories due to revisions in solid fuels data sources.

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

Description

This category comprises emissions from fossil fuels burnt in iron and steel, other nonferrous metals, chemicals, pulp, paper and print, food processing, beverages and

tobacco, and other uses. Emissions from cogeneration plants that do not meet the definition of cogeneration as provided in the revised 1996 IPCC guidelines (IPCC, 1996) are included in this category.

In 2009, emissions from the manufacturing industries and construction subcategory accounted for 4906.7 Gg CO_2-e (15.6 per cent) of emissions from the energy sector. Emissions were 517.7 Gg CO_2-e (11.8 per cent) above the 1990 level of 4389.0 Gg CO_2-e.

Key categories identified in the 2009 level assessment from the manufacturing industries and construction category includes CO_2 emissions from:

- gaseous fuels
- liquid fuels
- solid fuels.

Key categories identified in the 1990–2009 trend assessment from the manufacturing industries and construction category includes CO_2 emissions from:

- gaseous fuels
- solid fuels.

Methodological issues

As mentioned in section 3.3, this inventory includes the results of a new Annual Liquid Fuel Survey (ALFS). With this new information, some liquid fuel demand that was previously allocated to national transport has now been reallocated to the correct sectors' demand. In terms of energy sector emission estimates, emissions attributed to the transport category have decreased by around 20 per cent and emissions attributed to other categories, such as agricultural, forestry and fisheries subcategory have increased significantly. These changes have been applied to the entire time-series from 1990–2009.

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

Emissions from methanol production would normally be reported in the industrial processes sector as the emissions are from the chemical transformation of materials and not from the combustion of fuel. However, due to confidentiality concerns (there is only one methanol producer in New Zealand) emissions from methanol production are hidden by being reported under the manufacturing industries and construction subcategory for all years. This means there are no emissions from methanol production under the industrial processes category but rather all emissions are under the energy category.

This inventory submission disaggregates emissions from the manufacturing industries and construction category into specific subcategories. This has resulted in the 'other' subcategory becoming much smaller.

For the first time, the energy balance tables used in the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b) split out industrial uses of energy using the Australia New Zealand Standard Industrial Classification (ANZSIC) 2006. This was possible because of the collection of more detailed information from the various surveys used to compile the energy balance tables.

This has allowed a further disaggregation of the manufacturing industries and construction category and therefore greater transparency. Four new ANZSIC subcategories have been added to this category – 'mining and construction', 'textiles', 'non-metallic minerals' and 'mechanical/electrical equipment'.

To further disaggregate the manufacturing industries and construction category, estimates of the historical use of energy across these subcategories have been made. These are described in further detail below.

Solid fuels

The 2010 *New Zealand Energy Data File* (Ministry of Economic Development, 2010b) disaggregated the 'industrial' category for coal. This is the first time this category has been disaggregated and applied to the 2009 calendar year. These percentage splits have been applied to activity data for *New Zealand's Greenhouse Gas Inventory* across the whole time-series (ie, back to 1990). Carbon dioxide, methane and nitrous oxide emissions have been split out using the same percentage splits.

Table 3.3.3 Splits used for Manufacturing Industries and Construction Category – Solid Fuels

	Bituminous Coal	Sub-bituminous Coal	Lignite Coal
Iron and Steel	0.00%	0.00%	0.00%
Non-Ferrous Metals	0.00%	0.06%	0.00%
Chemicals	0.00%	0.00%	0.00%
Pulp, Paper and Print	0.00%	6.82%	2.41%
Food Processing, Beverages and Tobacco	10.89%	72.17%	95.10%
Mining and Construction	0.21%	1.15%	0.45%
Textiles	0.00%	1.10%	0.00%
Non-metallic Minerals	28.77%	5.19%	0.00%
Mechanical/Electrical Equipment	0.00%	0.12%	0.00%
Other	60.13%	13.38%	2.04%

Solid biomass

The Bioenergy Association of New Zealand conducted a 2006 Heat Plant Survey of New Zealand (Ministry of Economic Development, 2010b) 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. The survey showed that most solid biomass in New Zealand was used by the wood processing industry. The industrial splits from the survey were used to separate out solid biomass activity data for *New Zealand's Greenhouse Gas Inventory*. These splits were applied across the whole time-series (ie, back to 1990) for activity data and carbon dioxide, methane and nitrous oxide emissions.

Table 3.3.4 Splits used for Manufacturing Industries and Construction Category – Solid Biomass

Manufacturing Industries and Construction subcategories	Percentage share of solid biomass emissions
Iron and Steel	0.00%
Non-Ferrous Metals	0.00%
Chemicals	0.00%
Pulp, Paper and Print	99.94%
Food Processing, Beverages and Tobacco	0.05%
Mining and Construction	0.00%
Textiles	0.00%
Non-metallic Minerals	0.00%
Mechanical/Electrical Equipment	0.00%
Other	0.01%

Liquid fuels (diesel)

Statistics New Zealand conducted a Manufacturing Energy Use Survey (Statistics New Zealand, 2007) in 2006 which looked at energy use across manufacturing industries. This area specifically focussed on on-road and off-road diesel use. The off-road use statistics for diesel have been used to create a breakdown for the manufacturing industries and construction category in *New Zealand's Greenhouse Gas Inventory*. These splits were applied to the diesel time-series within the liquid fuels time-series (diesel accounts for around 50–70 per cent of liquid fuels within the manufacturing industries and construction category). These splits were applied across the whole time-series (ie, back to 1990) for activity data and carbon dioxide, methane and nitrous oxide emissions.

Table 3.3.5 Splits used for Manufacturing Industries and Construction Category – Diesel

Manufacturing Industries and Construction subcategories	Percentage share of diesel emissions
Iron and Steel	0.00%
Non-Ferrous Metals	3.04%
Chemicals	3.00%
Pulp, Paper and Print	8.69%
Food Processing, Beverages and Tobacco	14.74%
Mining and Construction	60.57%
Textiles	0.56%
Non-metallic Minerals	8.29%
Mechanical/Electrical Equipment	0.87%
Other	0.24%

Disaggregating the manufacturing industries and construction category for solid fuels, solid biomass and diesel has led to the 'other' category (1.A.2.F) under manufacturing industries and construction decreasing significantly.

Iron and steel

Activity data for coal used in iron and steel production is reported to the Ministry of Economic Development by New Zealand Steel Ltd. A considerable amount of coal is

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

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.

In addition, estimates for methanol production are also included in the chemicals subcategory because of confidentiality concerns. 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.

Carbon dioxide emissions are calculated by comparing the amount of carbon in the gas purchased by the plant with the amount stored in methanol. The major non-fuel related emissions from the methanol process are methane and NMVOCs.

Uncertainties and time-series consistency

Uncertainties in emission and activity data estimates are those relevant to the entire energy sector (Table 3.3.2 and Annex 2).

Source-specific QA/QC and verification

In preparation of this inventory, the manufacturing industries and construction category underwent Tier 1 quality assurance and quality-control checks.

Source-specific recalculations

As mentioned under methodological issues, this inventory includes the results of a new Annual Liquid Fuel Survey (ALFS). With this new information, some liquid fuel demand that was previously allocated to national transport has now been reallocated to the correct sectors' demand. This has resulted in revisions for activity data and corresponding emissions for liquid fuels in most subcategories.

In previous inventory submissions biomass activity data was being overestimated. A more accurate activity data source based on the Bioassociation of New Zealand Heat Plant Database is now used.

There have been small activity data revisions in some categories due to revisions in liquid fuels, natural gas and solid fuels data sources.

Source-specific planned improvements

The Ministry of Economic Development will continue to investigate the further dissaggregation of this category and how this information is best displayed in future inventory submissions.

On 1 July 2010, the stationary energy and industrial processes sector came into the New Zealand Emissions Trading Scheme (NZ ETS). In March 2011, the NZ ETS companies will fill in their returns stating the emissions they produced from 1 July to 31 December 2010. This may provide verification for this category for future inventory submissions.

3.3.3 Fuel combustion: transport (CRF 1A3)

Description

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

In 2009, the transport category was responsible for 13,782.5 Gg CO_2-e (43.9 per cent) of emissions from the energy sector, or 19.5 per cent of total emissions. Emissions increased 5103.5 Gg CO_2-e (58.8 per cent) from the 8679.0 Gg CO_2-e emitted in 1990. The transport emissions profile in 2009 was dominated by emissions from the road transportation subcategory. In 2009, road transport accounted for 12,386.1 Gg CO_2-e (89.9 per cent) of total transport emissions. This was an increase of 4931.7 Gg CO_2-e (66.2 per cent) from the 1990 level of 7454.4 Gg CO_2-e.

Between 2008 and 2009, emissions from transport decreased by 230.2 Gg CO_2-e (1.6 per cent). This was due to the economic downturn in 2009.

Key categories identified in the 2009 level assessment from the transport category include CO_2 emissions from:

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

Key categories identified in the 1990–2009 trend assessment from the transport category include CO_2 emissions from:

- road transport – gasoline
- road transport – diesel oil
- road transport – liquefied petroleum gases
- road transport – gaseous fuels
- civil aviation – jet kerosene (only identified in the total emissions analysis).

Methodological issues

Activity data on the consumption of fuel by the transport sector was sourced from the *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Economic Development. Liquefied petroleum gas and compressed natural gas consumption figures

are reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b).

As mentioned in section 3.3, this inventory includes the results of a new Annual Liquid Fuel Survey (ALFS). With this new information, some liquid fuel demand that was previously allocated to national transport has now been reallocated to the correct sectors' demand. In terms of energy sector emission estimates, emissions attributed to the transport category have decreased by around 20 per cent, and emissions attributed to other categories, such as agricultural, forestry and fisheries subcategory have increased significantly. These changes have been applied to the entire time-series from 1990–2009.

Road transportation

The IPCC (2000) Tier 1 approach was used to calculate carbon dioxide and non-carbon dioxide emissions from road transportation. New Zealand-specific emission factors have been used to estimate carbon dioxide, while because of insufficient information, default emission factors have been used to estimate non-carbon dioxide emissions. The emission factors for carbon dioxide and non-carbon dioxide gases for the various fuel types used in the road transportation subcategory can be found in Annex 2. Liquid biofuel non-CO_2 emissions have been included for the first time in this inventory. More information on the activity data and emission factors used for liquid biofuels can be found in section 3.3.

Railways

Emissions from the railways subcategory (including both liquid and solid fuels) were estimated using a Tier 1 approach (IPCC, 1996). New Zealand-specific emission factors were used to estimate carbon dioxide emissions and, because of insufficient data, the IPCC default emission factors were used to estimate methane and nitrous oxide emissions. The emission factors for carbon dioxide and non-carbon dioxide gases for the various fuel types used in the railway subcategory can be found in Annex 2.

Navigation (domestic marine transport)

Emissions from the navigation subcategory in New Zealand were estimated using a Tier 1 approach (IPCC, 1996). Activity data on fuel use by domestic transport is sourced from the quarterly *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Economic Development. New Zealand-specific emission factors have been used to estimate carbon dioxide emissions and, because of insufficient data, the IPCC 1996 default emission factors have been used to estimate methane and nitrous oxide emissions.

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. There is no gain in inventory quality by moving from a Tier 1 to a Tier 2 approach using landing and take-off cycles (IPCC, 2000).

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

> "*The National Inventory Report (NIR) reports that the allocation of fuel consumption between domestic and international air transport is based on refuelling*

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

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

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

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

Some international flights from New Zealand contain a domestic leg, eg, 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 doesn't attract GST will be coded as international.

Although this is a supply-side approach, the Ministry of Economic Development believes the split of international and domestic transport to be accurate because BP, Shell, ExxonMobil and Chevron control 100 per cent of the aviation fuels market in New Zealand. Based on the above findings, the Ministry of Economic Development believes that our current data collection methodology is sufficient and robust enough to ensure all the domestic aviation fuels are reported accordingly and do not result in missing or misallocation of domestic fuel use.

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

In preparation of this inventory the transport category underwent Tier 1 quality assurance and quality-control checks.

Source-specific recalculations

As mentioned under methodological issues, this inventory includes the results of a new Annual Liquid Fuel Survey (ALFS). With this new information, some liquid fuel demand that was previously allocated to national transport has now been reallocated to the correct sectors' demand. This has resulted in revisions for activity data and corresponding emissions for gasoline and diesel oil in the road transport subcategory.

Natural gas liquids (NGLs) were previously incorrectly assigned to the LPG for road transport subcategory. These NGLs are now included in category 1.AA.1.C.

There have been small activity data revisions in some categories due to revisions in liquid fuels activity data provided by companies.

The emission factor for natural gas has been slightly revised across the whole time-series. Because this emission factor is a weighted average emission factor, small historical revisions in gas field production data means the historical emission factor will change.

Source-specific planned improvements

The Ministry of Economic Development continues to work with the Ministry of Transport on developing a Tier 2 methodology for estimating road transportation emissions. In the UNFCCC (2010) report, the expert review team stated:

> *"New Zealand applied a constant EF (1.5 kg N_2O/TJ to gasoline powered cars for the whole period 1990–-2007 which is an approach that is only appropriate for uncontrolled vehicles (ie, vehicles without catalytic converters). This approach does not correspond to the present fleet of cars in New Zealand which likely contains a significant number of cars equipped with catalytic converters for which N_2O EFs will be considerably higher than 1.5 kg N_2O/TJ. The ERT strongly recommends that New Zealand revise its approach to estimating non-CO_2 emissions taking into consideration advances in vehicle technology since 1990."*

A project team made up of representatives from the Ministry of Economic Development and the Ministry of Transport (MOT) was established in mid 2010 to examine a new estimation method and define the scope of the project. During the initial meeting, it was agreed to adopt the Vehicle Fleet Emission Model (VFEM) which is used by the Ministry of Economic Development for energy projection work. It was also agreed to adopt the 2006 IPCC guidelines as they better reflect New Zealand's current situation.

The project can be split into three stages:

1. project establishment and planning (June–September 2010)
2. data and model development (September 2010–March 2011)
3. ongoing model operation, sensitivity analysis and improvement (potentially including research into New Zealand-specific emission factors) (March 2011–June 2011).

The Ministry of Economic Development will include the results in the 2012 submission once the results have gone through New Zealand's national system processes for quality assurance and quality control.

3.3.4 Fuel combustion: other sectors (CRF 1A4)

Description

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

In 2009, fuel combustion of the other sectors category accounted for 3174.3 Gg CO_2-e (10.1 per cent) of the emissions from the energy sector. This is an increase of 106.6 Gg CO_2-e (3.5 per cent) below the 1990 value of 3067.7 Gg CO_2-e.

Emissions from the agricultural, forestry and fisheries subcategory were 1771.6 Gg CO_2-e (55.8 per cent) of the other sectors category in 2009. This is an increase of 527.0 Gg CO_2-e (42.3 per cent) from the 1990 level of 1244.6 Gg CO_2-e.

Emissions from the commercial and institutional subcategory were 751.1 Gg CO_2-e (23.7 per cent) of the other sectors category in 2009. This is a decrease of 428.6 Gg CO_2-e (36.3 per cent) from the 1990 level of 1179.7 Gg CO_2-e.

Emissions from the residential subcategory were 651.5 Gg CO_2-e (20.5 per cent) of the other sectors category in 2009. This is an increase of 8.1 Gg CO_2-e (1.3 per cent) from the 1990 level of 643.4 Gg CO_2-e.

Key categories identified in the 2009 level assessment from the other sectors category include CO_2 emissions from:

- liquid fuels
- gaseous fuels.

Key categories identified in the 1990–2009 trend assessment from the other sectors category include CO_2 emissions from:

- solid fuels
- gaseous fuels.

Methodological issues

As mentioned in section 3.3, this inventory uses information from the new Annual Liquid Fuel Survey (ALFS). With this new information, some liquid fuel demand that was previously allocated to national transport has now been reallocated to the correct sectors' demand. In terms of energy sector emission estimates, emissions attributed to the transport category have decreased by around 20 per cent, and emissions attributed to other categories, such as agricultural, forestry and fisheries subcategory have increased significantly. These changes have been applied to the entire time-series from 1990–2009.

Uncertainties and time-series consistency

Uncertainties in emission estimates for data from other sectors are relevant to the entire energy sector (Table 3.3.1).

Source-specific QA/QC and verification

In preparation of this inventory the other sectors category underwent Tier 1 quality assurance and quality-control checks.

Source-specific recalculations

As mentioned under methodological issues, this inventory includes the results of a new Annual Liquid Fuel Survey (ALFS). With this new information, some liquid fuel demand that was previously allocated to national transport has now been reallocated to the correct sectors' demand. This has resulted in revisions for activity data and corresponding emissions for liquid fuels in the commercial, residential and agricultural, forestry and fisheries subcategories.

Natural gas for one retailer was not previously available has now become available. This has resulted in revisions across the whole time-series for the commercial and agricultural, forestry and fisheries subcategories.

The emission factor for natural gas has been slightly revised across the whole time-series. Because this emission factor is a weighted average emission factor, small historical revisions in gas field production data means the historical emission factor will change.

There have been small activity data revisions in some categories due to revisions in liquid, solid and gaseous fuels data sources.

Activity data for residential use of biomass has been slightly revised due to a revision in New Zealand household numbers provided by Statistics New Zealand. These numbers feed into the calculation of the activity data for residential use of biomass.

Source-specific planned improvements

There are no current planned improvements for this specific category.

3.4 Fugitive emissions from fuels (CRF 1B)

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

In 2009, fugitive emissions from fuels accounted for 2262.7 Gg CO_2-e (7.2 per cent) of emissions from the energy sector. This is an increase of 1032.8 Gg CO_2-e (84.0 per cent) from the 1990 level of 1230.0 Gg CO_2-e.

Key categories identified in the 2009 level assessment and the 1990–2009 trend assessment from the fugitive emissions category includes CO_2 emissions from:

- flaring
- geothermal.

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

Description

In 2009, fugitive emissions from the solid fuels subcategory produced 348.9 Gg CO_2-e (15.4 per cent) of emissions from the fugitive emissions category. This is an increase of 74.5 Gg CO_2-e (27.1 per cent) from the 274.5 Gg CO_2-e reported in 1990.

New Zealand's fugitive emissions from the solid fuels subcategory are a by-product of coalmining operations. Methane is created during coal formation. The amount of methane released during coalmining is dependent on the coal grade and the depth of the coal seam. In 2009, 81.2 per cent of the methane from coalmining (including post-mining emissions) came from underground mining. This includes the emissions from post-underground mining activities such as coal processing, transportation and use. There is no known flaring of methane at coalmines, and methane captured for industrial use is negligible. In 2009, New Zealand coal production was 4.6 million tonnes, a 7 per cent decrease from the 2008 production level of 4.9 million tonnes.

Methodological issues

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

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

In preparation of this inventory the fugitive category underwent Tier 1 quality assurance and quality-control checks.

Source-specific recalculations

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

Source-specific planned improvements

There are no current planned improvements for this specific category.

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

Description

In 2009, fugitive emissions from the oil and natural gas subcategory contributed 1913.8 Gg CO_2-e (84.6 per cent) of emissions from the fugitive emissions category. This is an increase of 958.3 Gg CO_2-e (100.3 per cent) from 955.5 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 carbon dioxide from a portion of the Kapuni gas (a high carbon dioxide gas when untreated) before it enters the national transmission network.

The large increase in carbon dioxide 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 95–99 per cent, leaving some fugitive emissions as a result of incomplete combustion.

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

The oil and natural gas subcategory also includes estimates for emissions from geothermal operations. While some of the energy from geothermal fields is transformed into electricity, emissions from geothermal electricity generation are reported in the fugitive emissions category because they are not the result of fuel combustion, unlike the emissions reported under the energy industries category. Geothermal sites, where there is no use of geothermal steam for energy production, have been excluded from the inventory. In 2009, emissions from geothermal operations were 723.2 Gg CO_2-e, an increase of 448.6 Gg CO_2-e (163.4 per cent) since the 1990 level of 274.6 Gg CO_2-e.

Between 2008 and 2009 emissions from geothermal have increased by 40.3 per cent. This was mainly due to the new 100 MW Kawerau geothermal plant coming online in late 2008.

Methodological issues

Venting and flaring from oil and gas production

Data on the amount of carbon dioxide released through flaring was supplied directly by the gas field. Vector Ltd, New Zealand's gas transmission company, supplies estimates of carbon dioxide released during the processing of the natural gas.

Gas transmission and distribution

Carbon dioxide and methane emissions from gas leakage mainly occur from low-pressure distribution pipelines rather than from high-pressure transmission pipelines. In

this inventory, submission emissions from transmission and distribution have been separated out.

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

Oil transport

Fugitive emissions from the oil transport subcategory are calculated using an IPCC Tier 1 approach (IPCC, 1996). The activity data is New Zealand's total production of crude oil reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b). The carbon dioxide emission factor is the IPCC (2000) default for oil transport using tanker trucks and rail cars while the methane emission factor is the mid-point of the IPCC (1996) default value range.

Oil refining and storage

Fugitive emissions from the oil refining and storage subcategory are calculated using an IPCC Tier 1 approach (IPCC, 1996). Activity data are based on oil intake at New Zealand's single oil refinery. The methane emission factor for oil refining is the same as that for oil transport. The emission factor for oil storage is 0.14 tonnes of CH_4/PJ, a New Zealand-specific emission factor. The combined emissions factor for oil refining and storage is 0.885 tonnes of CH_4/PJ.

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'.

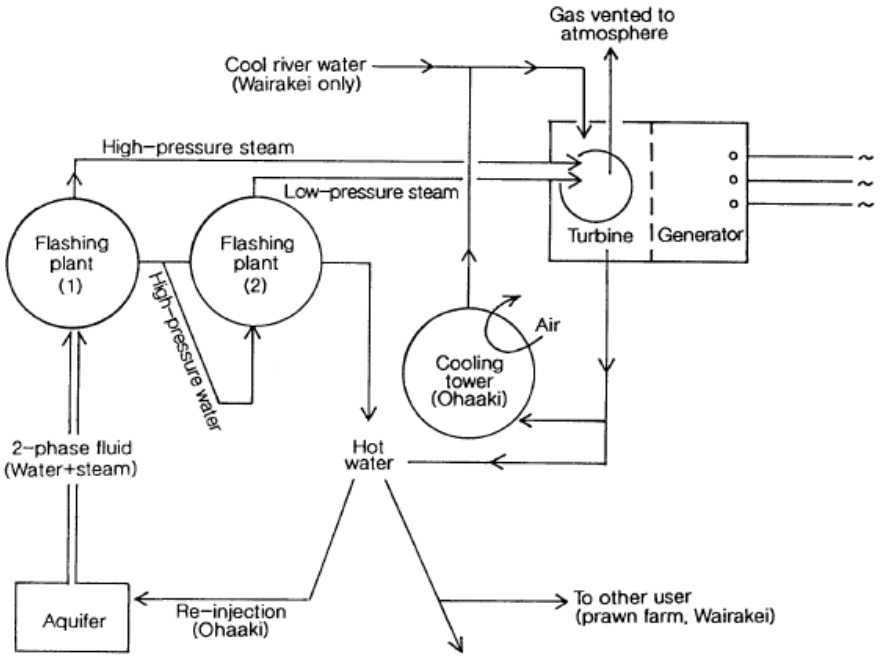
Activity data for leakages at industrial plants and power stations is taken from the total natural gas used for industrial and electricity generation use. The emission factor used is the midpoint of the 1996 IPCC default for 'leakage at industrial plants and power stations'.

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 midpoint of the 1996 IPCC default for 'leakage in the residential and commercial sectors'.

Geothermal

When geothermal fluid is discharged, small amounts of carbon dioxide and methane emissions are also released. The largest proportion is carbon dioxide with smaller amounts of methane. 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.

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)



Estimates of carbon dioxide and methane emissions for the geothermal subcategory are obtained directly from the geothermal power companies. There are currently 12 geothermal power stations, most of these owned by two major power companies. The methodology used to estimate emissions by each company is explained below.

Geothermal Methodology for Company A

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

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

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

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

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

$$582.3\,\frac{tonnes\,of\ steam}{hour}\quad x\frac{0.612\,CO_2}{100}\,by\,weight\,of\ steam = 3.565\frac{tonnes of\ CO_2}{hour}\quad x8760\frac{hours}{year}$$

= 31,230 tonnes of carbon dioxide.

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

Geothermal Methodology for Company B

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

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 coming online in late 2008.

Ozone precursors and SO_2 from oil refining

New Zealand only has one oil refinery which does not have a catalytic cracker but rather a hydrocracker. There are therefore no emissions from fluid catalytic cracking but there are from sulphur recovery plants and storage and handling. All the emission factors used to calculate these emissions are IPCC default values.

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 preparation of this inventory the fugitive category underwent Tier 1 quality assurance and quality-control checks.

Source-specific recalculations

Activity data for oil transport has been revised due to a revision in crude oil production data provided by the New Zealand Refinery Company. Carbon dioxide emissions for oil transport are also included for the first time (they were previously 'NE').

Methane emissions from natural gas other leakage are included for the first time in this inventory submission. In previous inventory submissions this category was 'NE'.

Historical venting and flaring activity data has been revised slightly due to historical data revisions provided by companies.

Activity data for gas distribution emissions has been revised due to a more accurate estimate of natural gas used in distribution pipelines becoming available.

Chapter 4: Industrial processes

4.1 Sector overview

In 2009, New Zealand's industrial processes sector produced 4,344.5 Gg of carbon dioxide equivalent (CO_2-e), contributing 6.2 per cent of New Zealand's total greenhouse gas emissions. The largest source of industrial process emissions are from the metal production category (CO_2 and perfluorocarbons (PFCs)) contributing 47.4 per cent of sector emissions in 2009.

Emissions from industrial processes had increased by 963.0 Gg CO_2-e (28.5 per cent) above the 1990 level of 3,382.6 Gg CO_2-e (Figure 4.1.1). This increase has largely been driven by emissions from the consumption of halocarbons and sulphur hexafluoride. Emissions from this category increased by 888.0 Gg CO_2-e.

Figure 4.1.1 New Zealand's industrial processes sector emissions from 1990 to 2009

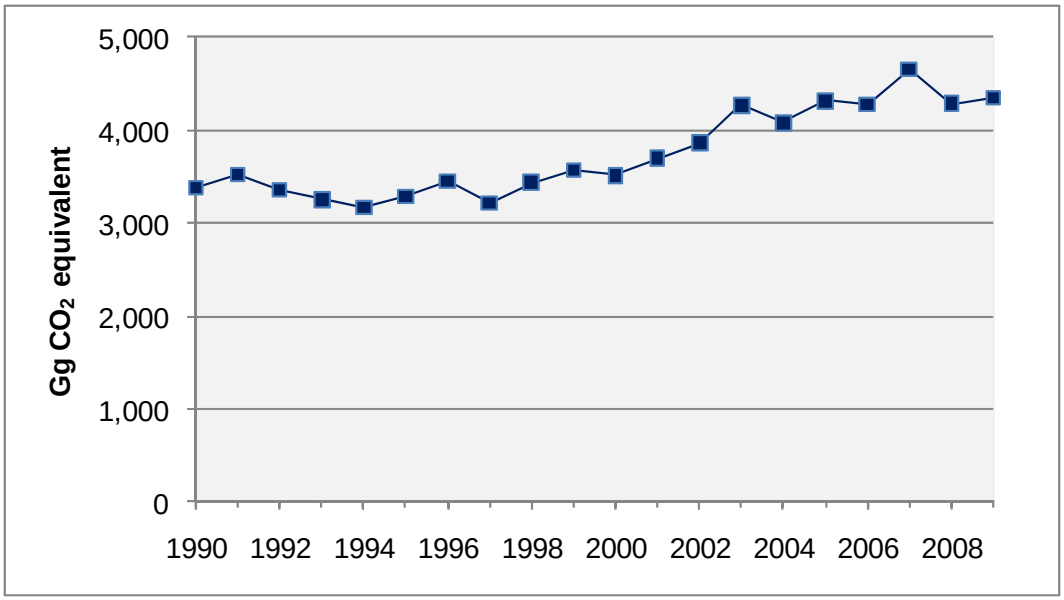
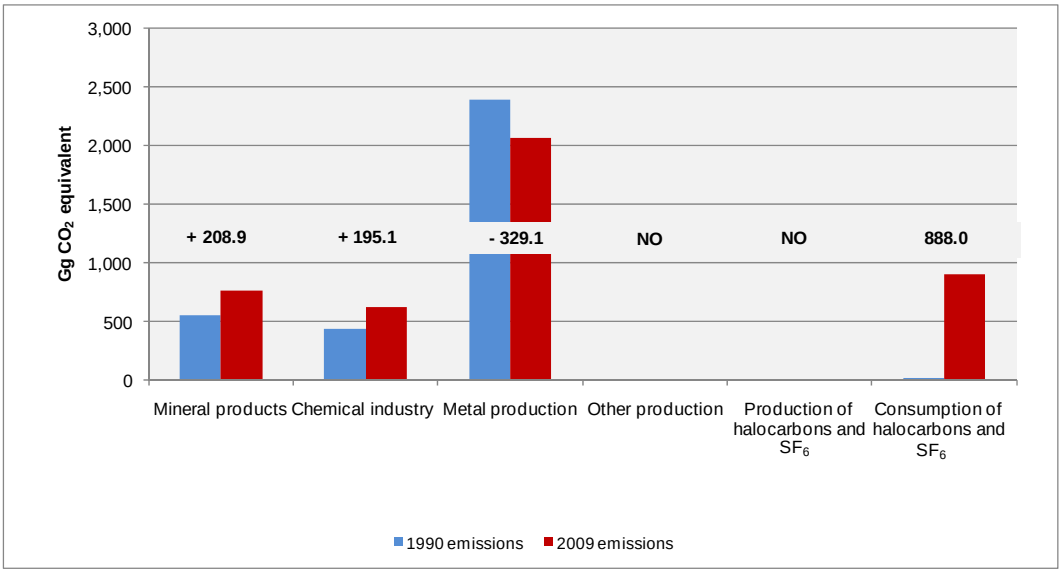


Figure 4.1.2 Change in New Zealand's industrial processes sector emissions from 1990 to 2009



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

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

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

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

Changes in emissions between 2008 and 2009

Between 2008 and 2009, emissions from the industrial processes sector increased by 60.2 Gg CO_2-e (1.4 per cent). The largest increase between 2008 and 2009 was 78.4 Gg CO_2-e (9.5 per cent) from emissions from the consumption of HFCs.

4.1.1 Methodological issues

Emissions of CO_2 from industrial processes are compiled by the Ministry of Economic Development from information collected through industry surveys. The results are

reported in *New Zealand Energy Greenhouse Gas Emissions* (Ministry of Economic Development, 2010).

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

Between 1990 and 2009, the only known methane (CH_4) emissions from the industrial processes sector came from methanol production. For confidentiality reasons, CH_4 emissions from methanol production are reported under the energy sector.

4.1.2 Uncertainties

The uncertainties for CO_2 and non-CO_2 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.

4.2 Mineral products (CRF 2A)

4.2.1 Description

In 2009, the mineral products category accounted for 760.5 Gg CO_2 (17.5 per cent) of total emissions from the industrial processes sector. Emissions in this category have increased by 208.9 Gg CO_2 (37.9 per cent) from the 1990 level of 551.6 Gg CO_2. There are no known emissions of CH_4 or nitrous oxide (N_2O) from the mineral products category.

This category includes emissions produced from the production of cement and lime, soda ash production and use, limestone and dolomite use, and glass production.

In 2009, cement production accounted for 593.8 Gg CO_2 (78.1 per cent) of emissions from the mineral products category. In the same year, lime production accounted for 121.0 Gg CO_2 (15.9 per cent). Only the emissions related to the calcination process for lime and cement production are included in this category. The emissions from the combustion of coal, used to provide heat for the calcination process, are reported in the energy sector.

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

Key categories identified in the 2009 level assessment from the minerals category include only CO_2 emissions from cement production. There were no sources identified in the 1990–2009 trend assessment as key categories from the minerals category.

4.2.2 Methodological issues

Cement production

In 2009, there were two cement production companies operating in New Zealand, Holcim New Zealand Ltd and Golden Bay Cement Ltd. Both companies produce general purpose and portland cement. Holcim New Zealand Ltd also produces general, blended cement. From 1995 to 1998 inclusive, another smaller cement company, Lee Cement Ltd, was also operating.

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

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

Methodology

Estimates of CO_2 emissions from cement production are calculated by the companies using the Cement CO_2 Protocol (World Business Council for Sustainable Development, 2005). The amount of clinker produced by each cement plant is multiplied by a plant-specific clinker emission factor. The emission factors are based on the calcium oxide (CaO) and magnesium oxide (MgO) content of the clinker produced. The inclusion of MgO results in the emission factors being slightly higher than the IPCC default of 0.50 t CO_2/t cement. This method is consistent with the IPCC (2000) Tier 2 method.

The cement companies supply their emission data to the Ministry of Economic Development during an annual survey. The IPCC (2000) default cement-kiln dust correction factor, 1.02, is included in Holcim New Zealand Ltd's CO_2 emissions calculation. 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

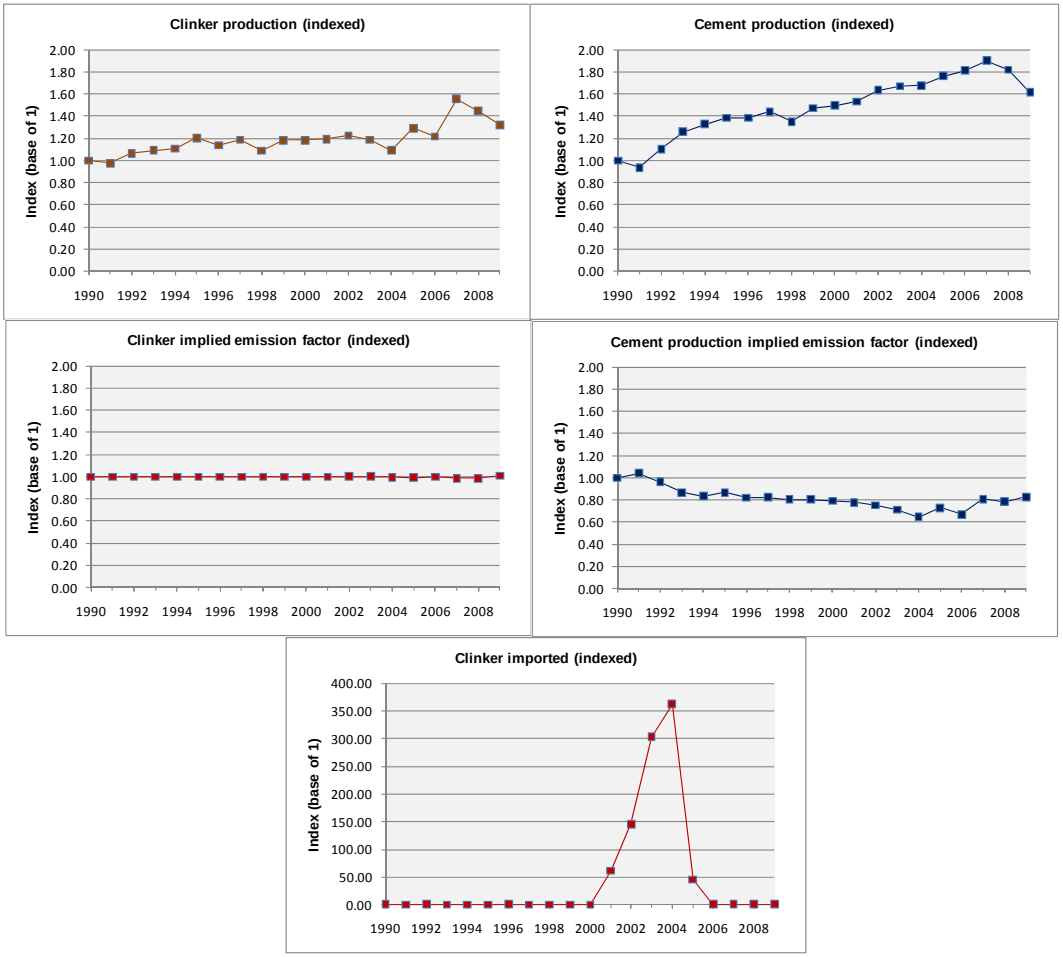
Figure 4.2.1 shows the trends in New Zealand clinker and cement production, imported clinker and the implied emission factor for clinker and cement for the 1990–2009 time-series. In general, the figure shows clinker and cement production increasing over the time-series 1990–2009. Relatively, over the same time-series, cement production has increased more than clinker production. The cement-implied emission factor decreased between 2000 and 2004 with increasing amounts of imported clinker. Meanwhile, the implied emission factor for clinker remained relatively unchanged.

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

SO_2

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. Seventy-five to 95 per cent of the SO_2 will be absorbed by the alkaline clinker product (IPCC, 1996). The emission factor for SO_2, used by New Zealand, is calculated using information from a sulphur mass-balance study on one company's dry kiln process. The mass-balance study enabled the proportion of sulphur, originating in the fuel and the sulphur in the raw clinker material as sodium and potassium salts, to be determined. The average emission factor was calculated as 0.64 kg SO_2/t clinker and was weighted to take into account the relative activity of the two cement companies. 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 1990–2009



Lime production

There are three companies (McDonalds Ltd, Websters Hydrated Lime Ltd and Perrys Group Ltd) producing burnt lime in New Zealand. All three companies produce high-calcium lime, and two companies produce hydrated lime.

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

Methodology

Lime production data are supplied to the Ministry of Economic Development by the lime production companies. Emissions are calculated using the IPCC (2000) Tier 1 method by multiplying lime activity data by the IPCC default emission factor of 0.75 (IPCC, 2000). In alignment with good practice, a correction factor is applied to the hydrated lime produced.

Although there are currently no verified country or plant-specific emission factors available for lime production, emissions factor data from the New Zealand Emissions Trading Scheme may be able to be used if companies choose to submit applications to use a unique emission factor. Mandatory reporting under the New Zealand Emissions Trading Scheme started 1 January 2010.

SO_2

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 kg SO_2/tonne of lime. The emission factor was weighted to take SO_2 measurements at the various lime plants into account (CRL Energy, 2006). This submission has continued to use the 2005 emission factor.

Limestone and dolomite use

Limestone and dolomite can be used in pulp and paper processing and mining. However, the majority of limestone quarried in New Zealand is calcinated to produce lime or cement. Emissions from the use of limestone for these activities are reported under the lime and cement production categories as specified in the IPCC guidelines (IPCC, 1996). Ground limestone used in the liming of agricultural soils is reported in the land use, land-use change and forestry sector.

Small amounts of limestone are used in the production of iron and steel by New Zealand Steel Ltd. In the iron production process, the coal is blended 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 1–2 per cent of total iron and steel process emissions.

This subcategory also includes emissions from the use of soda ash and from glass production. These emissions are included here because of confidentiality concerns by the respective companies.

Soda ash production and use

There is no soda ash production in 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, 2006). The glass manufacturer provided information on the amount of imported soda ash used in 2005. The manufacturer also provided approximate proportions of recycled glass over the previous 10 years to enable CO_2 emissions from soda ash to be estimated from 1996 to 2005. This is because 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 subsequent years was provided by the glass manufacturer through an external consultant. The IPCC default emission factor of 415 kg CO_2/tonne of soda ash was applied to the soda ash activity data to calculate the CO_2 emissions.

The activity data and resulting CO_2 emissions are considered confidential by the glass manufacturer. Consequently, the emissions resulting from the use of soda ash are reported under the limestone and dolomite use subcategory.

New Zealand, Rio Tinto Alcan Ltd (NZAS) uses soda as in the aluminium production process. However, due to the confidential treatment of soda ash from glass production, the estimates from NZAS are reported under aluminium production.

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 kg non-methane volatile organic compound (NMVOC) per tonne of product and 0.0095 kg carbon monoxide (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 2006–2009.

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 that asphalt paving is not considered a significant source of indirect emissions. New Zealand uses a wet 'cut-back' bitumen method rather than bitumen emulsions that are common in other countries.

The revised 1996 IPCC guidelines (IPCC, 1996) make no reference to cut-back bitumen but do provide default emission factors for the low rates of SO_2, oxides of nitrogen (NOx), CO and NMVOC emissions that arise from an asphalt plant. The IPCC default road-surface emissions factor of 320 kg NMVOC/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 2004 inventory submission, the New Zealand Bitumen Contractors' Association provided a method (Box 4.1) for calculating total NMVOC emissions from the use of solvents in the roading industry. The industrial processes survey for the 2005 calendar year (CRL Energy, 2006) showed that the fraction by weight of bitumen used to produce chip-seal has been changing over recent years 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. 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 2006–2009.

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

NMVOC emitted = A x B x C x D

where

A = The amount of bitumen used for road paving

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

C = Solvent added to the bitumen as a fraction of the chip-seal (0.04)

D = The fraction of solvent emitted (0.75)

Glass production

There is one major glass manufacturer in New Zealand, O-I New Zealand. Production data is considered confidential by O-I New Zealand, consequently emissions are reported under the limestone and dolomite use subcategory. Estimates of CO_2 from soda ash use were obtained from the industrial processes survey (CRL Energy, 2010) and are reported with limestone and dolomite use because of confidentiality concerns.

Non-methane volatile organic compounds may be emitted from the manufacture of glass and the IPCC (1996) suggest a default emissions factor of 4.5 kg NMVOC/t of glass output (IPCC, 1996). It has been assumed that the IPCC default emission factor for NMVOCs was based on total glass production that includes recycled glass input. Like CO_2 estimates, the NMVOCs and SO_2 emissions are now reported under the limestone and dolomite use subcategory because of confidentiality concerns.

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

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 uncertainty for CO_2 from glass production has been assessed by CRL Energy (2010).

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 the IPCC (2000). As the data is provided directly from the companies to the Ministry of Economic Development the lower end of the range has been selected. The IPCC (2000) defaults for the plant-level data on 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 activity data is ±50 per cent. This 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) ±2per cent uncertainty for the emission factor for lime has been applied.

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

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	±1	±1 (CO_2)
		±50 (NMVOC)
		±10 (SO_2)

4.2.4 Source-specific QA/QC and verification

In 2009, CO_2 emissions from cement production were a key category (2009 level assessment). In the preparation of this inventory, the data for these emissions underwent IPCC Tier 1 quality checks. The estimates for a non-key category, lime production were also subject to IPCC Tier 1 quality checks.

4.2.5 Source-specific recalculations

Lime production

The plant specific emission factors applied for the 2010 submission could not be verified in time for this submission. Consequently, the IPCC (2000) default emission factor for high calcium lime and the correction factor for hydrated lime have been applied.

4.2.6 Source-specific planned improvements

There are no planned improvements for this source.

4.3 Chemical industry (CRF 2B)

4.3.1 Description

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

In 2009, emissions from the chemical industry category comprised 625.3 Gg CO_2-e (14.4 per cent) of total emissions from the industrial processes sector. Emissions have increased by 195.1 Gg CO_2-e (45.4 per cent) from the 1990 level of 430.2 Gg CO_2-e. In 2009, CO_2 emissions from ammonia production accounted for 386.6 Gg CO_2-e (61.8 per cent) of emissions in the chemical industry category. In 2009, ammonia production was a qualitative key category (Table 1.5.1) due to the increase in nitrogenous fertiliser use in the agriculture sector since 1990. Hydrogen production contributed the remaining 238.8 Gg CO_2-e (38.2 per cent) of emissions from the chemical industry in 2009.

Key categories identified in the 2009 level assessment from the chemical industry category include only CO_2 emissions from ammonia production. This was only identified in the total emissions assessment. There were no sources identified in the 1990–2009 trend assessment as key categories from the chemical industry category.

4.3.2 Methodological issues

Ammonia/urea

Ammonia is manufactured in New Zealand by the catalytic steam reforming of natural gas. Liquid ammonia and CO_2 are reacted together to produce urea. The total amount of natural gas supplied to the plant is provided to the Ministry of Economic Development by Balance 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 gas (from different gas fields) by their respective emission factors. The proportion of gas from each of these fields used in ammonia production changes on an annual basis. This explains the fluctuation in the CO_2 implied emission factor over the 1990–2009 time-series.

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

Methanol

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

Hydrogen

Emissions of CO_2 from hydrogen production are supplied directly to the Ministry of Economic Development by the two production companies. The majority of hydrogen produced in New Zealand is made by the New Zealand Refining Company as a feedstock at the Marsden Point refinery. Another company, Degussa Peroxide Ltd, produces a small amount of hydrogen that is converted to hydrogen peroxide. The hydrogen is produced from CH_4 and steam. Carbon dioxide is a by-product of the reaction and is vented to the atmosphere. Company-specific emission factors are used to determine the CO_2 emissions

from the production of hydrogen. In 2009, the implied emission factor for the sum of both companies was 6.0 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 kg NMVOC/t of product. Emissions of CO and CH_4 are not reported under this subcategory as these emissions relate to fuel combustion and are consequently reported in the energy sector.

Fertiliser

The production of sulphuric acid during the manufacture of superphosphate fertiliser produces indirect emissions of SO_2. In New Zealand, there are two companies, Balance 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 2006–2009. Plant-specific emission factors used in previous years were applied to the 2009 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 kg SO_2 (range of 1 to 25) per tonne of sulphuric acid. However, New Zealand industry experts have recommended that this is a factor of 2 to 10 times too high for the New Zealand industry. Consequently, emission estimates are based on emission factors supplied by industry. In 2009, the combined implied emission factor is 1.5 kg SO_2/t 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 (2006a) defaults as no default uncertainties are provided in the IPCC (1996) and (2000).

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

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

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

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

4.3.4 Source-specific QA/QC and verification

In the preparation of this inventory, the data for emission from ammonia production (as key category) underwent IPCC Tier 1 quality checks.

4.3.5 Source-specific recalculations

The emission factor for natural gas for the ammonia/urea subcategory has been slightly revised across the entire time-series. This is because the emission factor is a weighted average emission factor and small historical revisions in gas field production data causes the historical emission factor to change.

4.3.6 Source-specific planned improvements

There are no planned improvements for this source.

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 2009, emissions from the metal production category were 2,059.4 Gg CO_2-e (47.4 per cent) of emissions from the industrial processes sector. Emissions from this category decreased 329.1 Gg CO_2-e (13.8 per cent) from the 1990 level of 2,388.5 Gg CO_2-e.

Carbon dioxide emissions accounted for 97.8 per cent of emissions in this category with another 2.2 per cent from PFCs. In 2009, the level of CO_2 emissions increased by 256.0 Gg CO_2-e (14.6 per cent) above the 1990 level.

Perfluorocarbon emissions have decreased from the 629.9 Gg CO_2-e in 1990 to 44.8 Gg CO_2-e in 2009, a decrease of 585.1 Gg CO_2-e (92.9 per cent). This decrease is due to

improvements made by the aluminium smelter. These improvements are discussed further in the following section.

Key categories identified in the 2009 level assessment from the metal production category include CO_2 emissions from iron and steel production and CO_2 emissions from aluminium production.

Key categories identified in the 1990–2009 trend assessment from the metal production category include PFC emissions from aluminium production.

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 (Ure, 2000) from titanomagnetite ironsand. The iron is then processed into steel. Pacific Steel Ltd 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 Economic Development but is confidential and is reported as such in the CRF 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, 2006).

New Zealand Steel Ltd

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

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

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

Sub-bituminous coal and limestone in the multi-hearth furnaces are heated and dried together with the ironsand. This iron mixture is then fed into the reduction kilns, where it is converted to 80 per cent metallic iron. Melters then convert this into molten iron. The iron, at a temperature around 1480°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 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 t CO_2/GJ is applied to the sub-bituminous coal used as a reducing agent.

CO_2 emissions = mass of reducing agent × EF reducing agent – mass C in finished steel

Care has been taken not to double-count coal use for iron and steel making. The coal used in the iron-making process at New Zealand Steel Ltd acts both as a reductant and an energy source. However, all of the coal is first fed into the reduction kilns and, consequently, all CO_2 emissions associated with coal use are reported in the industrial processes sector, regardless of the end use (IPCC, 2000). Following the calculation of carbon dioxide, to ensure there is no double counting between the energy and industrial processes sectors, New Zealand Steel provides plant specific analysis of the proportions of coal and natural gas that contribute to the chemical transformation and to the combustion.

Carbon dioxide emissions arising from limestone, coke and electrodes used in the iron and steel making process are reported under the limestone and dolomite use subcategory (CRF 2.A.3), because the data on limestone could not be separated from those on coke and electrodes. These emissions are reported in section 4.2.2.

Pacific Steel

Emissions from Pacific Steel's production of steel arise from the combustion of the carbon charge to the electric arc furnace. Reported emissions exclude the minor carbon component of the additives that are subsequently added to the ladle, as the emissions are generally a contaminant of the vanadium, manganese or silicon additives. These additives are excluded for two reasons; they are considered negligible and are contained in the final steel product.

Due to limited process data at Pacific Steel, emissions between 1990 and 1999 are calculated using the average of the implied emission factors for 2000 – 2008 based on production volume. Emissions from 2000 onwards are reported using the IPCC Tier 2 method. Pacific Steel provides this data directly to the Ministry of Economic Development.

Aluminium

Aluminium production is a source for CO_2 and PFC emissions. There is one aluminium smelter in New Zealand, Rio Tinto Alcan Ltd (NZAS). The smelter produces aluminium from raw material using the centre worked prebaked technology.

In 2009, aluminium emissions were 496.3 Gg CO_2-e, a decrease of 582.6 Gg CO_2-e (54.0 per cent) from the 1990 level of 1,078.9 Gg CO_2-e.

Carbon dioxide is emitted during the oxidation of the carbon anodes. The PFCs are emitted from the cells during anode effects. An anode effect occurs when the aluminium oxide concentration in the reduction cell electrolyte is low. The emissions from combustion of various fuels used in the aluminium production process, such as heavy fuel oil, liquefied petroleum gas, petrol and diesel, are included in the energy sector. The indirect emissions are reported at the end of this section.

Estimates of CO_2 and PFC emissions were supplied by NZAS to the Ministry of the Economic Development.

Carbon dioxide

NZAS calculates the process CO_2 emissions using the International Aluminium Institute (2006) Tier 3 method (equations 1-3) which is the equivalent to the IPCC (2000) Tier 2 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. NZAS has assumed that all of the carbon content of the soda ash is released as carbon dioxide. The emissions are estimated using the Tier 3 International Aluminium Institute (2006) method (equation 7).

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 × 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).

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 kg CF_4/t of aluminium and 0.04 kg C_2F_6/t 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 to PFC emissions than the IPCC default value.

The smelter advises that there are no plans to directly measure PFC emissions. A smelter-specific long-term relationship between measured emissions and operating parameters is not likely to be established in the near future.

Trends

As Figure 4.4.1 indicates, the implied emission factors for emissions from aluminium production have fluctuated over the time-series. These fluctuations are identified and explained in Table 4.4.2.

Figure 4.4.1 New Zealand's implied emission factors for aluminium production from 1990 to 2009

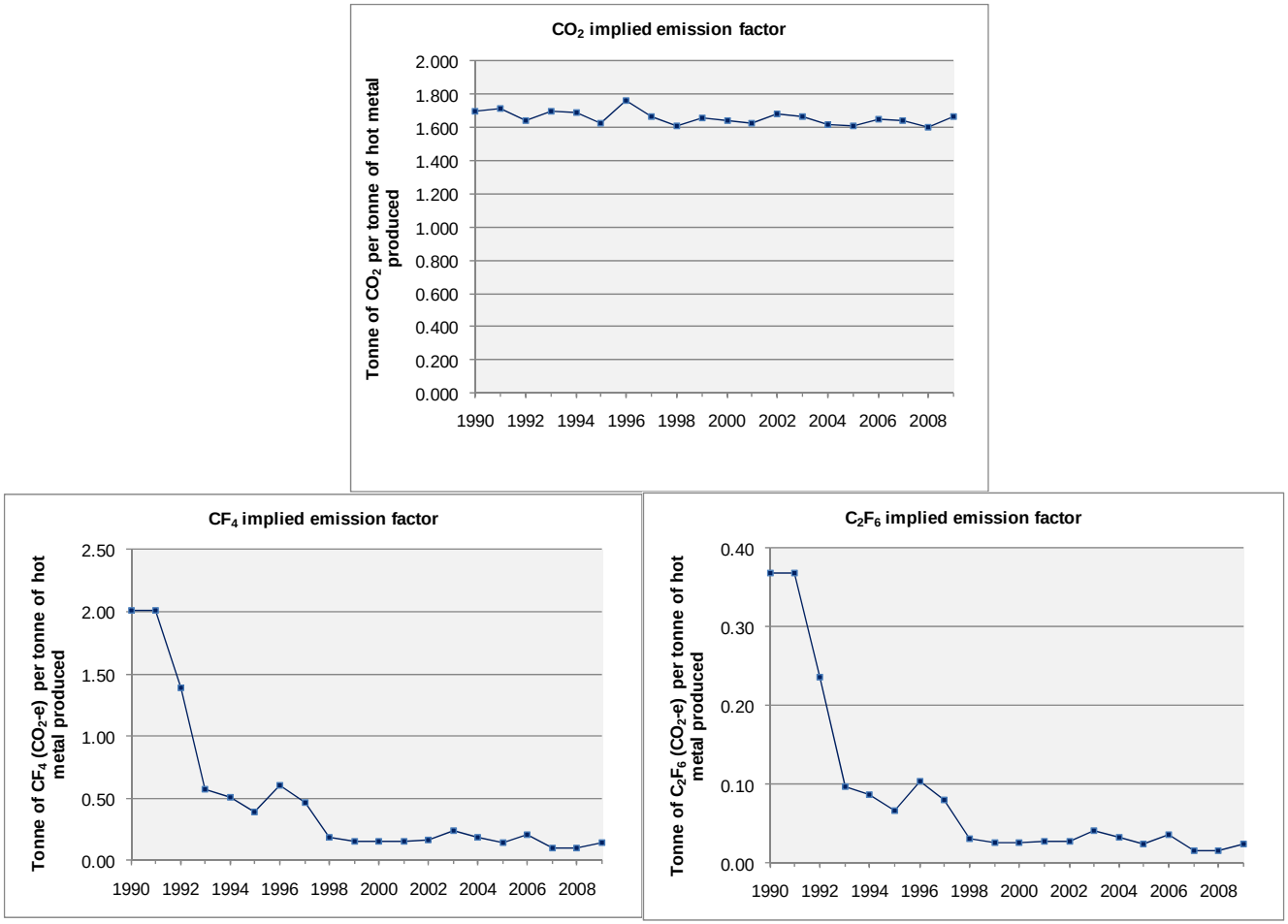


Table 4.4.2 Explanation of variations in New Zealand's aluminium emissions

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	Less cells operating from reduced aluminium production due to reduced electricity supply
	Good anode performance contributed in 2001
Increase in CO_2 emissions in 1995	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 kg CO/t was based on measurements and comparison with Australian CO emission factors. The IPCC default emission factor was used for NO_x emissions.

Other metal production

Small amounts of SF_6 were used as a cover gas in a magnesium foundry to prevent oxidation of molten magnesium from 1990–1999. The company has since changed to zinc technology so SF_6 is no longer used and emitted.

The only other metals produced in New Zealand are gold and silver. Companies operating in New Zealand confirm they do not emit indirect gases (NO_x, CO and SO_2) with one using the Cyanisorb recovery process to ensure everything is kept under negative pressure to ensure no gas escapes to the atmosphere. Gold and silver production processes are listed in IPCC (1996) as sources of non-CO_2 emissions. However, no details or emission factors are provided and no published information on emission factors has been identified. Consequently, no estimation of emissions from this source has been included.

4.4.3 Uncertainties and time-series consistency

The IPCC (2000) default assessment for uncertainty in activity data has been applied as ±5 per cent for both iron and steel and aluminium. A ±7 per cent uncertainty for the emission factors for iron and steel production include ±5 per cent uncertainty for the carbon content of the steel (IPCC, 2000), and ±5 per cent for the reducing agent. The IPCC (2006) default uncertainty of ±2 per cent has been applied to CO_2 emissions factors from aluminium production.

Uncertainties in non-CO_2 emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy, 2006). These are documented in Table 4.4.3.

Table 4.4.3 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, 2006).

4.4.4 Source-specific QA/QC and verification

Carbon dioxide emissions from iron and steel production and aluminium production (2009 level assessment), and PFC emissions from aluminium production (trend assessment) underwent IPCC Tier 1 quality checks.

4.4.5 Source-specific recalculations

Pacific Steel

Improvements were made to the time-series 1990–1999 for Pacific Steel as the emission factor now reflects it is the average of the implied emission factors for the period 2000–2008. While the 2010 submission improved the accuracy of the emission estimates for 2000–2008, the implied emission factor was not updated to reflect these improvements.

4.4.6 Source-specific planned improvements

There are no planned improvements for these subcategories.

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 2009, emissions from this category totalled 7.6 Gg NMVOC. This was an increase of 1.7 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

Pulp and paper

There are a variety of pulping processes in New Zealand. These include:

- chemical (Kraft)
- chemical thermomechanical
- thermomechanical
- mechanical.

Pulp production in New Zealand is evenly split between mechanical pulp production and chemical production. Estimates of emissions from the chemical pulping process are calculated from production figures obtained from the Ministry of Agriculture and Forestry. 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, 2006). Emissions of CO and NO_x from these processes are related to fuel combustion and not reported under industrial processes.

Food and drink

Emissions of NMVOCs are produced during the fermentation of cereals and fruits in the manufacture of alcoholic beverages. These emissions are also produced during all processes in the food chain that follow after the slaughtering of animals or harvesting of crops. Estimates of indirect greenhouse gas emissions for the period 1990–2005 have been calculated using New Zealand production figures from Statistics New Zealand and relevant industry groups with default IPCC emission factors (IPCC, 1996). No New Zealand-specific emission factors could be identified. Subsequent NMVOC estimates from food and drink have been estimated using linear extrapolation as no industry survey was conducted. In 2009, NMVOC emissions were estimated to be 6.7 Gg, an increase of 1.5 Gg from the 1990 level of 5.2 Gg.

4.5.3 Uncertainties and time-series consistency

Uncertainties in non-CO_2 emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy, 2006). These are documented in Table 4.5.1.

Table 4.5.1 Uncertainty in New Zealand's non-CO_2 emissions from the other production category

Product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Pulp and paper	±5	±50 (chemical pulp)
		±70 (thermal pulp)
Food – alcoholic beverages	±5 (beer)	±80 (beer and wine)
	±20 (wine)	±40 (spirits)
	±40 (spirits)	
Food – food production	±5–20 (varies with food type)	±80 (IPCC factors)

4.5.4 Source-specific QA/QC and verification

Other production was not a key category and no specific quality-assurance or quality-control activities were performed.

4.5.5 Source-specific recalculations

There were no recalculations for this category.

4.5.6 Source-specific planned improvements

There are no planned improvements for this category.

4.6 Production of halocarbons and SF_6 (CRF 2E)

New Zealand does not manufacture halocarbons and SF_6. Emissions from consumption are reported under section 4.7.

4.7 Consumption of halocarbons and SF_6 (CRF 2F)

4.7.1 Description

In 2009, emissions from the consumption of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) totalled 880.6 Gg CO_2-e (20.3 per cent) of emissions from the industrial processes sector. 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 2009 level assessment and in the trend assessment.

Hydrofluorocarbons and PFCs are used in a wide range of equipment and products from refrigeration systems to aerosols. No HFCs or PFCs are manufactured within New Zealand. Perfluorocarbons are produced from the aluminium-smelting process (as discussed in section 4.4.2).

The use of synthetic gases, especially HFCs, has increased since the mid-1990s when chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) began to be phased out under the Montreal Protocol. In New Zealand, the Ozone Layer Protection Act 1996 sets out a programme for phasing out the use of ozone-depleting substances by 2015.

According to the 1996 IPCC guidelines, emissions of HFCs and PFCs are separated into seven subcategories:

- aerosols
- solvents
- foam
- mobile air conditioning
- stationary refrigeration and air conditioning
- fire protection
- other.

In 2009, sulphur hexafluoride (SF_6) emissions were 19.8 Gg CO_2-e. This is an increase of 7.4 Gg CO_2-e (60.1 per cent) from the 1990 level of 12.3 Gg CO_2-e. The majority of SF_6 emissions are from use in electrical equipment.

The emissions inventory for SF_6 is broken down into two subcategories: electrical equipment and other. In New Zealand, one electricity company accounts for 75–80 per cent of total SF_6 used in electrical equipment.

4.7.2 Methodological issues

HFCs/PFCs

Activity data on the bulk imports and end use of HFCs and PFCs in New Zealand was collected through an annual survey of HFC and PFC importers and distributors. This data has been used to estimate the proportion of bulk chemicals used in each sub-source category. The total quantity of bulk chemical HFCs imported each year was compared with import data supplied by Statistics New Zealand. Imports of HFCs in products and bulk imports of PFCs and SF_6 are more difficult to determine as import tariff codes are not specific enough to identify these chemicals.

New Zealand uses the IPCC Tier 2 approach to calculate emissions from the consumption of HFCs and PFCs (IPCC, 2000). The Tier 2 approach accounts for the time lag between consumption and emissions of the chemicals. A summary of the methodologies and emission factors used in emission estimates are included in Table 4.7.1.

Potential emissions for HFCs and PFCs are included for completeness as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006). Potential emissions for HFCs and PFCs have been calculated using the IPCC Tier 1b approach. Incomplete data is available on imports into New Zealand of HFC and PFC gases contained in equipment. Models have been developed to provide a complete data set (CRL Energy, 2010).

Table 4.7.1 New Zealand's halocarbon and SF_6 calculation methods and emission factors

HFC source	Calculation method	Emission factor
Aerosols (including metered dose inhalers)	IPCC (2006a) equation 7.6	IPCC default factor of 50 per cent of the initial charge per year
Foam	IPCC (2006a)	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 (2000a) equation 3.44	Top-down approach First fill: 0.5 per cent
Stationary refrigeration/ air conditioning	IPCC (2006a) equation 7.9	Not applicable
Fire protection	IPCC (2006a)	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 75 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 2b approach)
Other applications	IPCC (2000) equation 3.22	No emission factor required as 100 per cent is emitted within two years

Aerosols and metered dose inhalers

New Zealand reports HFC-134a emissions from metered dose inhalers and other aerosols separately. The significant increase in emissions over the time-series from both aerosols and metered dose inhalers can be attributed to HFC-134a being used as a substitute propellant for HCFCs and CFCs, as discussed in section 4.7.1.

Aerosols

Emissions from aerosols contributed 28.7 Gg CO_2-e in 2009, an increase from the 1996 level of 1.6 Gg CO_2-e. Aerosols were not widely used in New Zealand until 1994, and therefore emissions from aerosols are estimated from 1996. The initial charge is expected to be emitted within the first two years of sale.

Activity data on aerosol usage was provided by Arandee Ltd, the only New Zealand aerosol manufacturer using HFCs, and the Aerosol Association of Australia/ New Zealand. Arandee Ltd also provided activity data on annual HFC use, domestic and export sales, and product loading emission rates.

Due to insufficient information at a sub-application level, a Tier 1a method (IPCC, 2006a), 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 2009, emissions from metered dose inhalers contributed 53.7 Gg CO_2-e, an increase 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 2009 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 upon expert opinion (CRL Energy, 2010).

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

Solvents

A survey of distributors of solvent products and solvent recycling firms did not identify any use of HFCs or PFCs as solvents in New Zealand (CRL Energy, 2010).

Foam

In New Zealand, only emissions from closed-cell foam (hard foam) are known to have occurred between 2000 and 2009. In 2009, emissions from the use of HFC-134a in hard foam blowing were 0.12 Gg CO_2-e, an increase from the 2000 level of 0.07 Gg CO_2-e.

The HFC-245fa/365mfc mixture is only known to have been used in New Zealand in foam blowing from 2004 to 2009. These emissions are estimated to have increased from 0.1 tonne in 2004 to 0.6 tonne in 2009. However, a global warming potential for this mixture has not been agreed by the IPCC and the Climate Change Convention. 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 2009, activity data was provided by the sole supplier of HFCs for foam blowing (CRL Energy, 2010). Fisher and Paykel provided information on foam containing HFCs imported. 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 (2006a) Tier 2 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 4.5 per cent annual loss of the initial charge over an assumed 20-year lifetime is applied.

Stationary refrigeration/air conditioning

Emissions from the use of HFCs and PFCs in stationary refrigeration and air conditioning were 649.1 Gg CO_2-e in 2009. This is an increase from the 1992 level of 1.3 Gg CO_2-e. In 2009, stationary refrigeration and air conditioning made up 72.1 per cent of the emissions from the halocarbon and SF_6 consumption category. In 1992, only HFC-134a was used, while in 2009 HFCs -32, -23, -152a, -134a, -125, -143a and PFC-218 (C_3F_8) were consumed. There was no use of HFCs and PFCs before 1992.

The increase in emissions from 1992 to 2009 is due to HFCs and PFCs used as replacement refrigerants for CFCs and HCFCs in refrigeration and air-conditioning equipment (section 4.7.1).

New Zealand uses the top-down IPCC (2006a) 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 1990–2009, Table 4.7.3 provides a breakdown of the annual sales of new refrigerant in New Zealand for 1990–2009; 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, 2006a)

Emissions = (annual sales of new refrigerant) – (total charge of new equipment) + (original total charge of retiring equipment) – (amount of intentional destruction)

Table 4.7.2 HFC and PFC emissions from stationary refrigeration in New Zealand (CRL Energy, 2010)

Year	Annual sales of new refrigerant (tonnes)[1]	Total charge of new equipment sold (tonnes)	Emissions from retiring 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	2.9	0.9	0.0	0	2.0
1994	49.6	10.3	0.0	0	39.3
1995	110.4	23.9	0.0	0	86.5
1996	170.1	39.2	0.0	0	130.9
1997	81.7	41.2	0.0	0	40.4
1998	227.6	56.4	0.0	0	171.2
1999	208.5	67.3	0.0	0	141.3
2000	202.9	75.2	0.0	0	127.7
2001	209.6	76.0	0.0	0	133.6
2002	245.3	57.8	0.0	0	187.6
2003	304.3	65.2	0.1	0	239.2
2004	232.5	82.7	1.0	0	150.8
2005	345.9	127.8	2.8	0	220.8
2006	363.8	167.7	6.0	0	202.1
2007	480.8	205.6	9.8	0	284.9
2008	441.1	235.0	15.2	0	221.2
2009	442.3	213.2	21.4	0	250.5

[1] **Note:** Annual sales of new refrigerant includes chemicals imported in bulk and in equipment (minus exports).

Table 4.7.3 Annual sales of new refrigerant in New Zealand (CRL Energy, 2010)

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	2.9
1994	0	55.1	0	2.0	7.5	49.6
1995	0	123.1	0	5.9	18.5	110.4
1996	0	180.9	0	8.4	19.2	170.1
1997	0	90.6	0	8.8	17.7	81.7
1998	0	234.2	0	9.2	15.8	227.6
1999	0	211.9	0.1	13.4	16.7	208.5
2000	0	207.1	0.4	14.6	18.5	202.9
2001	0	216.6	0.8	14.6	20.8	209.6
2002	0	248.4	0.9	19.2	21.4	245.3
2003	0	306.1	2.4	25.7	25.1	304.3
2004	0	231.0	6.0	37.3	29.7	232.5
2005	0	303.1	6.5	76.3	27.0	345.9
2006	0	286.2	6.7	112.7	28.5	363.8
2007	0	377.5	12.1	157.2	41.8	480.8
2008	0	339.2	13.3	175.2	60.1	441.1
2009	0	356.1	16.6	161.8	58.9	442.3

Table 4.7.4 Total charge of new equipment sold in New Zealand (CRL Energy, 2010)

Year	Chemical to charge domestically manufactured + imported equipment[1] (tonnes)	Chemical contained in factory charged imported equipment (tonnes)	Total charge of new equipment sold (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	0.9
1994	8.4	2.0	10.3
1995	18.0	5.9	23.9
1996	30.8	8.4	39.2
1997	32.5	8.8	41.2
1998	47.2	9.2	56.4
1999	53.9	13.4	67.3
2000	60.6	14.6	75.2
2001	61.5	14.6	76.0
2002	38.6	19.2	57.8
2003	39.5	25.7	65.2
2004	45.4	37.3	82.7

Year	Chemical to charge domestically manufactured + imported equipment[1] (tonnes)	Chemical contained in factory charged imported equipment (tonnes)	Total charge of new equipment sold (tonnes)
2005	51.6	76.3	127.8
2006	55.0	112.7	167.7
2007	48.4	157.2	205.6
2008	59.8	175.2	235.0
2009	51.5	161.8	213.2

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

To estimate HFCs and PFCs emissions, all refrigeration equipment is split into two groups: factory-charged equipment and all other equipment that is charged with refrigerant on site. This is because some information is available on the quantities of factory-charged imported refrigeration and air-conditioning equipment and on the amount of bulk HFC refrigerant used in that equipment.

The amount of new refrigerant used to charge all other equipment (charged on site after assembly) is assumed to be the amount of HFC refrigerant sold each year minus that used to manufacture factory-charged equipment and that used to top up all non-factory-charged equipment.

Factory-charged equipment consists of all equipment charged in factories (both in New Zealand and overseas), including all household refrigerators and freezers and all factory-charged, self-contained refrigerated equipment used in the retail food and beverage industry. All household air conditioners and most medium-sized, commercial air conditioners are also factory charged, although some extra refrigerant may be added by the installer for piping.

It is estimated there are about 2.2 refrigerators and freezers per household in New Zealand. This calculation included 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, 2010) 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 2009, HFC-134a emissions from mobile air conditioning were 113.5 Gg CO_2-e, an increase over the 1994 level of 1.0 Gg CO_2-e. Emissions from mobile air conditioning

made up 12.9 per cent of total emissions from the halocarbon and SF_6 consumption category in 2009. 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/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. Refrigerated transport is included in the stationary refrigeration/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 1994–2009.

Box 4.3 Equation 3.44 (IPCC, 2000)

Emissions = first-fill emissions + operation emissions + disposal emissions – intentional destruction

Table 4.7.5 HFC-134a emissions from mobile air conditioning in New Zealand (CRL Energy, 2010)

Year	First-fill emissions (tonnes)	Operation emissions (tonnes)	Disposal emissions (tonnes)	Intentional destruction (tonnes)	Annual emissions of HFC-134a (tonnes)
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	13.3	3.0	0	16.3
2000	0.005	17.6	5.0	0	22.6
2001	0.007	23.5	7.4	0	30.9
2002	0.010	30.0	10.2	0	40.2
2003	0.015	37.2	11.4	0	48.7
2004	0.003	47.4	14.8	0	62.2
2005	0.001	55.4	21.5	0	76.9
2006	0.001	60.8	29.1	0	89.9
2007	0.001	66.3	35.0	0	101.3
2008	0.002	59.6	40.2	0	99.8
2009	0.001	71.7	41.8	0	113.5

First-fill emissions are calculated from vehicle fleet numbers provided by Statistics New Zealand and the New Zealand Transport Registry Centre. Assumptions are made on the percentage of mobile air-conditioning installations. Operation and disposal data are obtained from a survey of the industry and data from Land Transport New Zealand.

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, 2010).

Fire protection

In 2009, HFC-227ea emissions from fire protection were 1.4 Gg CO_2-e, an increase over the 1994 level of 0.1 Gg CO_2-e. There was no use of HFCs in fire protection systems before 1994 in New Zealand. The increase was due to HFCs used as substitutes to halons in portable and fixed fire protection equipment.

Within the New Zealand fire protection industry, the two main supply companies are identified as using relatively small amounts of HFC-227ea. The systems installed have very low leak rates, with most emissions occurring during routine servicing and accidental discharges.

A simplified version of the Tier 2b method, mass-balance approach (IPCC, 2006a) has been used to estimate emissions. A New Zealand-specific annual emission rate of 1.5 per cent has been applied to the total amount of HFC installed. This rate is based on industry experience. Due to limited data, it has been assumed that HFC from any retirements was totally recovered for use in other systems.

Electrical equipment

In 2009, SF_6 emissions from electrical equipment were 16.9 Gg CO_2-e, an increase over 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 75 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 2b approach to be taken for the rest of the industry (CRL Energy, 2010).

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, 2010).

The IPCC (2000) Tier 1 method (equation 3.18) is used to calculate potential emissions of SF_6 (including estimates for SF_6 other applications). This is based on total annual imports of SF_6 into New Zealand. Potential SF_6 emissions are usually two-to-three times greater than actual emissions in a given year. However, in 2005, potential emissions were less than actual emissions because there was less SF_6 imported compared with previous years. Import data from 2006 to 2009 shows potential SF_6 emissions are again greater than actual emissions.

Other SF_6 applications

Emissions from other SF_6 applications in 1990 and 2009 were 2.9 Gg CO_2-e. In New Zealand, other applications include medical uses for eye surgery, tracer gas studies, magnesium casting, plumbing services, tyre manufacture and industrial machinery equipment. A Tier 2 method (IPCC, 2000) is applied and no emission factor is used as 100 per cent is assumed to be emitted over a short period of time.

Activity data for 2005 to 2009 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 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 many sources, there is no statistical measure of uncertainty but a quantitative assessment is provided from expert opinion.

Table 4.7.6 New Zealand's uncertainties in the consumption of halocarbons and SF_6 category (CRL Energy, 2010)

HFC source	**Uncertainty estimates (%)**
Aerosols	Combined uncertainty ±62
Metered dose inhalers	Combined uncertainty ±10
Solvents	Not occurring
Foam	Combined uncertainty ±62
Stationary refrigeration/air conditioning	Combined uncertainty ±34
Mobile air conditioning	Combined uncertainty ±31
Fire protection	Combined uncertainty ±32
SF_6 source	**Uncertainty estimates**
Electrical equipment	Combined uncertainty ±24
Other applications	±60

4.7.4 Source-specific QA/QC and verification

In the preparation of this inventory, the data for the consumption of halocarbons 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

Metered dose inhalers

On the basis of improved understanding of individual metered dose inhaler products, Pharmac has continued to amend its figures for total inhaler doses and for HFC doses for 1999–2008 compared with the estimates reported in CRL Energy (2009). The consequent

relative decreases in HFC-134a emissions compared with the 2009 survey ranged from 1 per cent to 10 per cent (up to 1.1 tonnes in absolute terms).

Stationary refrigeration and air conditioning

A number of improvements were made to emission estimates from stationary refrigeration and air conditioning. The total combined impact of these improvements for the 2009 year resulted in a 21.4 tonne reduction in the bank. The revised equivalent figures for 2008 accounted for 15.2t compared with 5.3t exported for destruction. The revised figures for earlier years were relatively minor. There is still a significant HFC-32 gap to be accounted for in 2008 and 2009, but this gap may prove to be an anomaly for 2009 in particular because the retirement amounts are projected to increase markedly over the next 5 years.

The combined recalculations of these improvements are more significant for stationary refrigeration and air conditioning emissions from 1994 to 1997 (6 per cent to 17 per cent reductions) and for 2002 to 2007 (8 per cent to 20 per cent increases) and less significant for 2008 (6 per cent increase).

Impact of the mobile air conditioning improvements on stationary refrigeration and air conditioning supply

The most significant change in the current report was the increased supply of HFC-134a for stationary refrigeration and air conditioning as a result of the improvements made to estimates from mobile air conditioning. The impact of a reduced mobile air conditioning supply (to service a significantly reduced refrigerant bank in mobile air conditioned vehicles) is a more realistic assessment of the total HFC use in the stationary refrigeration and air conditioning sector. This is calculated by the difference between total bulk HFC-134a imports and the sum of mobile air conditioning use and aerosol filling.

Air conditioning gas supply and equipment retirement rates

Improvements were made to the retirement rate for the air conditioning sector. This improvement was required as there was a marked increase in the amount of HFCs exported for destruction by Refrigerant Recovery in 2009 (partly due to anomalies in the timing of shipments). This revealed some distinct inconsistencies in the stationary refrigeration and air conditioning model that were likely to cause reporting challenges in future years as increasing amounts of these gases might have exceeded the theoretical retired refrigerant quantities.

In particular, the assumption for the source of retired HFC-32 has been improved. It had previously been assumed that no HFC-32 would be retired until around 2012, assuming a 10 to 20 year retirement cycle for all air conditioning equipment using R410A (which is 50 per cent HFC-32). With the assistance of industry, the assumption now reflects that the more likely source of retired HFC-32 was from the air conditioning refrigerant R407C (23 per cent HFC-32). R407C had previously been treated in the model as insignificant compared with the large quantities of R410A imported and exported in equipment from around 2003–2007. R407C was used mainly in large scale commercial air conditioning equipment whereas R410A is now used for that purpose as well as in smaller scale household and commercial units.

For the improved model used in this submission, it has been assumed that from 1996, 10 per cent of commercial air conditioning units in the New Zealand market contained R407C (half imported and half filled in New Zealand) and the remainder with R22. This

proportion rose to 20 per cent in 1997, remained constant at 30 per cent from 1998–2005 and dropped to 20 per cent of imported units in 2006 and 2007 (with 10 per cent and 50 per cent R410A respectively) and zero beyond.

Eliminating likely double counting of R410A imported in 2008

An elimination of double counting of R410A imported in 2008 led to an improvement in accuracy, particularly for filling new equipment. Discussions with suppliers indicated that 65 tonnes of imported R410A in 2007 had been double counted. The figure appeared to be approximate for a calendar year but has been re-evaluated as likely to have been a financial year figure. The resultant increase in production of air conditioning units for 2007 appeared anomalous compared with later years. CRL Energy (2010) concluded that most of the increase was double counted in the 2008 figure and therefore the imported amount was equivalent to the estimated usage of 22.4 tonnes. This has a larger effect on the amounts filled in new equipment, but less impact on the refrigerant bank (and future emissions) because 80 per cent of R410A is assumed to be exported.

Reassessing commercial air conditioning sales numbers, sizes and refrigerant charges

New information from the Energy Efficiency and Conservation Authority minimum energy performance standards and industry stakeholders led to the improved assumption that large annual fluctuations in sales of three phase (large commercial) air conditioning units appeared to be more accurate, reflecting shifts in market demand and stocks. Unit numbers were consequently reduced for 2004, 2006 and 2008 in particular. Previously it had been assumed that some of the summaries of survey returns from the Energy Efficiency and Conservation Authority were incomplete due to the large fluctuations and it was the opinion of some industry experts that the market was reasonably consistent.

Assumptions about size and charge distribution in this sub-sector were also improved, especially after identifying a significant proportion of larger commercial units as pre-charged (for both exports and New Zealand sales) with only a 1 kg holding charge rather than the full refrigerant charge.

Equipment retirement scheme improvements

To incorporate a range of industry expert views on average air conditioning unit lifetimes, the retirement scheme was improved by adjusting it to 8 to 19 years instead of 10 to 19 years. Similarly, the retirement period assumption for dehumidifiers has been changed to 6 to 15 years (instead of 10 to 15) to account for shorter lifetimes that industry sources suggested would be appropriate for lower quality units (perhaps the majority of the market).

Dehumidifier exports, refrigerant charges and HFC proportions

As a result of further discussion with industry stakeholders, there were minor improvements made to the household refrigeration model by including small numbers of dehumidifier exports, by reducing the average charge size (by 25 per cent), and by increasing the HFC (vs R22) proportion assumptions in recent years. The overall impact of these improvements was relatively minor with 12.5 tonnes for the calculated dehumidifier HFC bank at the end of 2008 compared with 13.6 tonnes for the last study.

Earlier commercial refrigeration transition to R404A

The accuracy of the commercial refrigeration model was improved to reflect that larger quantities of R404A for remote cabinet systems (mainly supermarkets) were introduced earlier than previously assumed. There was supporting evidence for this from one supermarket chain providing a detailed refrigerant inventory. The impact of this improvement was an estimated refrigerant bank in 2008 of 204.5 tonnes (30 tonnes more than the previous assumption).

Earlier dairy refrigeration transition to R404A

The dairy refrigeration sector of the model was improved by providing for an earlier introduction of R404A to account for the build-up of the refrigerant bank. This was informed by new information from the main equipment supplier. The impact was an estimated refrigerant bank in 2008 of 113.2 tonnes (about 7 tonnes more than the previous assumption).

Transport refrigeration a more complex mix of pre-charged and locally filled units

New information from industry led to improvements in emission estimates from transport refrigeration. The model now reflects that larger units are largely imported pre-charged (and 25 per cent filled in New Zealand) while for smaller units, the reverse is true. This has replaced the previous assumption that all imported units were pre-charged.

Industry has also informed minor improvements in the proportions of HFC-134a, R404A and R22 in pre-charged and locally filled units at different periods since 1994.

Assumption improvements (regarding pre-charged vs local filling) were also required for refrigerated containers as a result of new information from industry experts but there were no changes for refrigerated ships. The impact of these improvements on the estimated refrigerant bank in 2008 was 57.1 tonnes (about 1 tonne more than the previous assumption).

Historical gas supply for filling new equipment

Interpolations have been made to 1994–1997 to correct an underestimation of the supply of HFC-125 and HFC-143a for the filling of new equipment. The impact of the other improvements made to estimates for stationary refrigeration and air conditioning, was that HFC emissions for individual gases in RAC Table 4 were negative because installations in new equipment appeared to exceed supply. This led to a reassessment of some of the early inventory data (MWH, 2002). CRL Energy (2010) has assessed that the quality of the inventory import data for 1994 to 2000 for individual gases was not high and may not have been complete. A previous revision of 2000 data (based on a detailed Ministry of Economic Development assessment) concluded that HFC-125 and HFC-143a (the main components of R404A) had been significantly underestimated for the inventory assessment. At that stage (CRL Energy 2007), the supply of these gases was increased from 4.1 tonnes and 6.4 tonnes respectively to 24.1 tonnes and 24.6 tonnes for 2000 (and interpolated values for 1998 and 1999).

In reassessing the historical data in the current study, CRL Energy (2010) interpolations were required for 1994 to 1997. The interpolations have avoided the anomaly of negative emissions (where the amounts filled in new equipment would have appeared to exceed bulk supply for some gases).

Reassessment of imported gas shipment timing

A discrepancy for imported gas shipment timing was corrected for HFC-134a imports in 2009. One minor supplier discovered the imports had begun in 2008 (rather than 2009 as they estimated a year earlier). The supply figure for that anomalous year was increased by 9.5 tonnes for this submission.

Correcting omissions of small bulk gas exports

Discrepancies were corrected in small bulk gas exports. These were identified in check totals between total gases and the individual component gases for 1999–2001.

Mobile air conditioning

The accuracy of emission estimates from mobile air conditioning has improved due to three factors. Vehicle fleet calculations are now based on Statistics New Zealand net import figures for each vehicle class to account for the changes in stocks of unregistered vehicles. These figures more accurately represent the total vehicle fleet than the previous use of registration figures alone.

Following extensive consultation with industry experts, more realistic mobile air conditioning HFC phase-in periods and refrigerant charges have been developed for new, used, assembled and retrofitted vehicles in the separate car, bus, light and heavy truck classes. Previous assumptions were not sufficiently detailed to account for differences between new and used vehicles and the improvements in mobile air conditioning technology.

Improved statistics from the New Zealand Transport Agency on the detailed age distribution of deregistered vehicles have been obtained from 1999 and this has improved the calculation of consequent emissions assumed from scrapping those vehicles containing HFC mobile air conditioning systems (with similar distributions interpolated for 1994 to 1998).

The combined impact of improvements made to the estimates from mobile air conditioning was a decrease of 20 tonnes of HFC-134a for the 2008 year, from 120 tonnes reported in the 2010 submission to 100 tonnes in this submission. In 1995 and 2000, the current assessments are 3t and 23t compared with 9t and 44t in the 2010 submission.

SF_6 from electrical equipment

An improved methodology was developed for equipment imports and this has had an impact on the calculation of potential emissions (but no effect on actual emissions). It has now been assumed that all new equipment not supplied by ABB was imported in each year from 2001 to 2009. The effect has been to increase potential emissions ranging from 0.6 tonne in 2001 up to 1.9 tonnes in both 2005 and 2007 compared with the previous submission.

The completeness of the estimates was improved due to four instances where electricity providers corrected for omissions.

Checking for consistency in calculations revealed two errors in previous calculations. The corrections have resulted in minor emissions increases for 2006 and 2008.

4.7.6 Source-specific planned improvements

Future submissions are unlikely to result in major assumption changes because the current submission was intended to make all those required for the foreseeable future. Instead, future submissions will focus on greater transparency for the calculation of equipment retirement emissions and investigation of non-electrical uses of SF_6.

New Zealand had considered providing estimates for refrigeration and air conditioning under domestic, commercial, transport and industrial processes in future inventory submissions, however other improvements are likely to be prioritised.

4.8 Other (CRF 2G)

4.8.1 Description

Panel products

Particleboard and medium-density fibreboard activity data is obtained from the Ministry of Agriculture and Forestry. The NMVOC emission factors for particleboard and medium-density fibreboard are derived from two major manufacturers (CRL, 2006). 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 2009 were 1.2 Gg. This is an increase of 0.3 Gg over the 1990 level of 0.9 Gg.

The other production category was not identified as a key category in either the 2009 level assessment or the trend assessment.

Chapter 5: Solvent and other product use

5.1 Sector overview

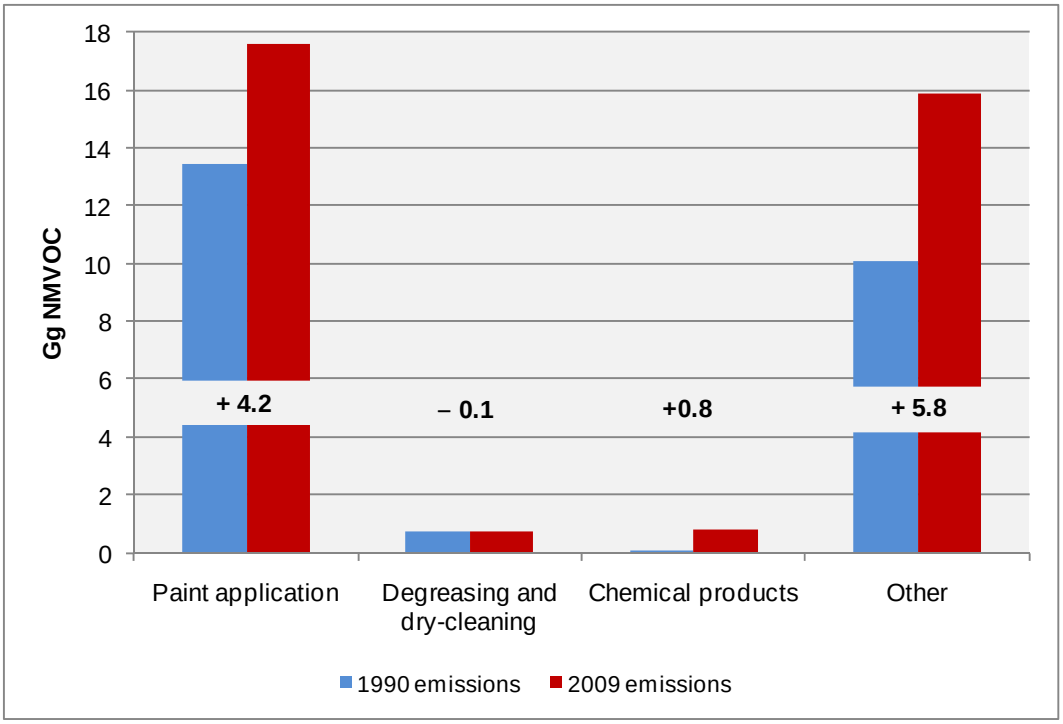
The only direct greenhouse gas reported in this category is nitrous oxide (N_2O) emissions from anaesthesia use. In 2009, N_2O emissions from anaesthesia use totalled 27.9 Gg carbon dioxide equivalent (CO_2-e). This was a decrease of 13.6 Gg CO_2-e (32.8 per cent) from the 1990 level of 41.5 Gg CO_2-e.

This sector also includes emissions from chemical cleaning substances used in dry-cleaning, printing, metal degreasing and from the use of paints, lacquers, thinners and related materials. The emissions arise from the evaporation of the volatile chemicals when solvent-based products are exposed to air.

In 2009, non-methane volatile organic compound (NMVOC) emissions from the solvent and other product use sector were 34.9 Gg, or 20.0 per cent of total NMVOC emissions. This was an increase of 10.7 Gg (44.0 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 2009 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 2009



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 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 2009 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 2009 calendar year (CRL Energy, 2010). As the importer supplies its competitor with its requirements, the emission estimate represents full coverage of N_2O use in New Zealand. Most of the N_2O is used for anaesthesia and the production of Entonox (a half-and-half mixture of nitrous oxide and oxygen for pain relief). There is a very small amount used in motor sports and scientific analysis.

Paint application

Activity and emissions data for 2006 to 2009 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 2009 calendar years. Most dry-cleaners in New Zealand-use perchloroethylene and a small number use white spirits. Trichloroethylene has never been used in dry-cleaning but it is used in degreasing, for example, in the leather manufacturing industry. In general, solvent losses from the dry-cleaning industry have reduced substantially as closed circuit machines and refrigerated recovery units are increasingly used. Consumption of perchloroethylene and trichloroethylene are assumed to equal the volume of imports. Import data was supplied by Statistics New Zealand.

Chemical products (manufacturing and processing)

The solvents tetrabutyl urea and alkyl benzene are used in the production of hydrogen peroxide. Emissions of NMVOCs were provided by Degussa Peroxide Ltd. The hydrogen peroxide plant has an online, continuous, activated-carbon solvent recovery system. Solvent losses were recorded annually as the difference between input solvent and solvent collected for incineration.

Losses of ethanol (and other minor components such as methanol, acetaldehyde and ethyl acetate) were monitored in the three ethanol plants in New Zealand. Using these values, an emission factor for NMVOCs of 6 g/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 kg NMVOC/capita/year (United States EPA, 1985). It is assumed that the emissions rate per capita derived by the United States Environmental Protection Agency is applicable to the average product use in New Zealand (CRL Energy, 2006). Population data is from the Statistics New Zealand website.

5.1.3 Uncertainties and time-series consistency

Estimates of uncertainty are based on information provided by industry in the questionnaires and discussions with respondents (CRL Energy, 2006). The overall uncertainties are shown in Table 5.1.1.

Table 5.1.1 New Zealand's uncertainties in the solvent and other product use sector (CRL Energy, 2006)

HFC source	Combined uncertainty estimates (%)
Paint application	±40
Degreasing/dry-cleaning	±30
Chemical products	±20
Printing	±50
Aerosols	±20
Domestic/commercial use	±60
Anaesthesia (N_2O)	±10

5.1.4 Source-specific recalculations

There were no recalculations for this sector.

5.1.5 Source-specific planned improvements

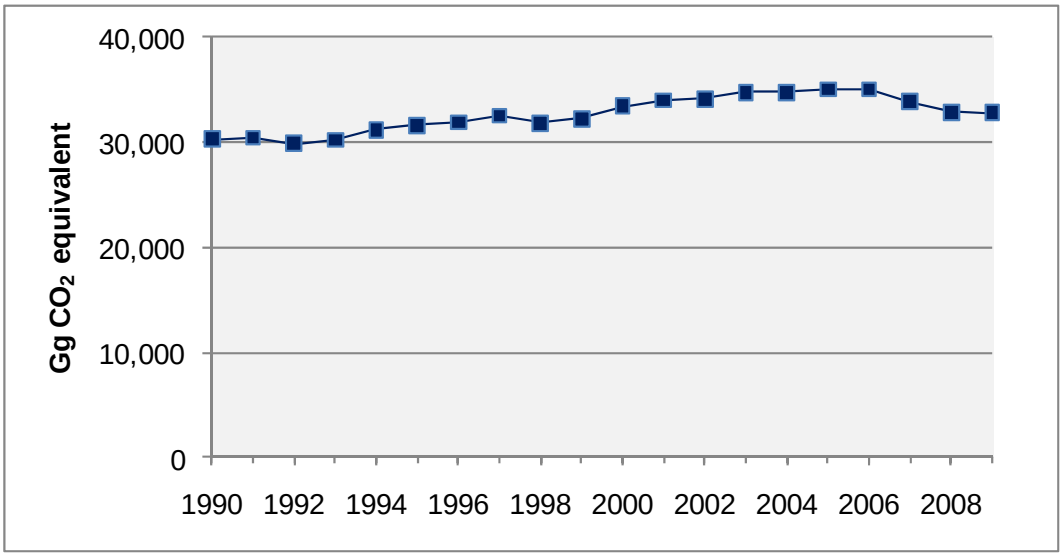
There are no planned improvements for this sector. There are large uncertainties; however, the emission levels from the solvent and other products sector are negligible compared with other sectors. In accordance with good practice, New Zealand will continue to focus its inventory development on key source categories (IPCC, 2000).

Chapter 6: Agriculture

6.1 Sector overview

In 2009, the agriculture sector contributed 32,810.5 Gg carbon dioxide equivalent (Gg CO_2-e) (46.5 per cent) of New Zealand's total greenhouse gas emissions. Emissions in this sector have increased by 2,533.0 Gg CO_2-e (8.4 per cent) from the 1990 level of 30,277.5 Gg CO_2-e (Figure 6.1.1). The increase since 1990 is primarily due to a 641.6 Gg CO_2-e (2.9 per cent) increase in methane (CH_4) emissions from the enteric fermentation category and a 1,736.0 Gg CO_2-e (22.4 per cent) increase in nitrous oxide (N_2O) emissions from the agricultural soils category.

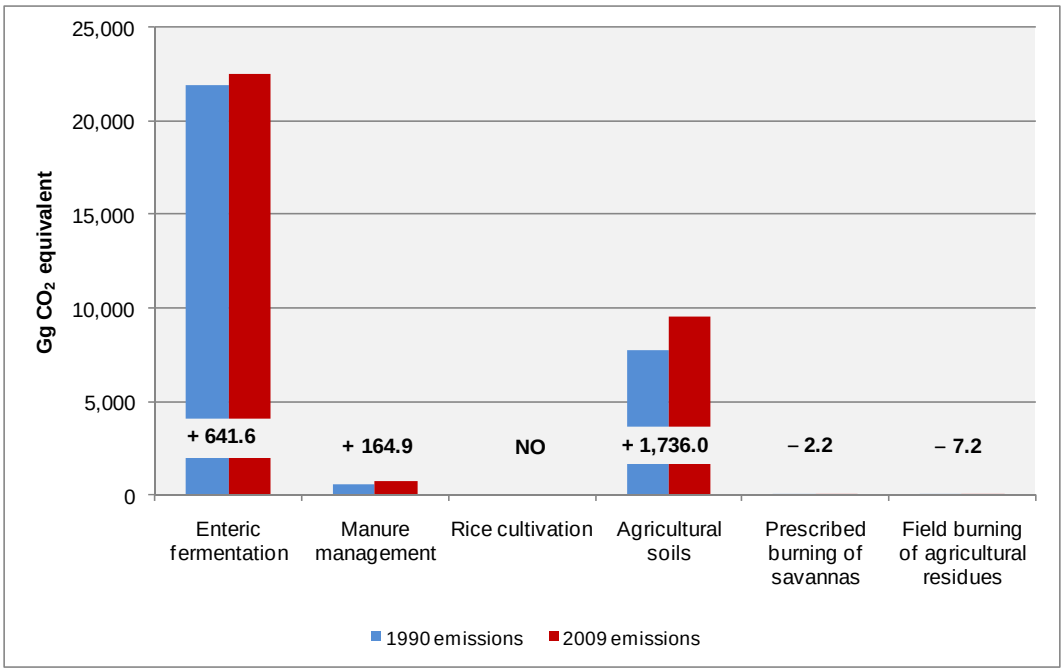
Figure 6.1.1 New Zealand agriculture sector emissions from 1990 to 2009



In 2009, CH_4 emissions from enteric fermentation were 68.6 per cent (22,506.2 Gg CO_2-e) of agricultural emissions and 31.9 per cent of New Zealand's total emissions. Nitrous oxide emissions from the agricultural soils category were 28.9 per cent (9,498.4 Gg CO_2-e) of agricultural emissions and 13.5 per cent of total emissions.

Agriculture is a major component of the New Zealand economy, and agricultural products comprise 56 per cent of total merchandise exports (Ministry of Agriculture and Forestry, 2009). This is facilitated by the favourable temperate climate, the abundance of agricultural land and the unique farming practices used in New Zealand. These practices include the use of year-round extensive grazing systems and a reliance on nitrogen fixation by legumes rather than nitrogen fertiliser as the nitrogen source.

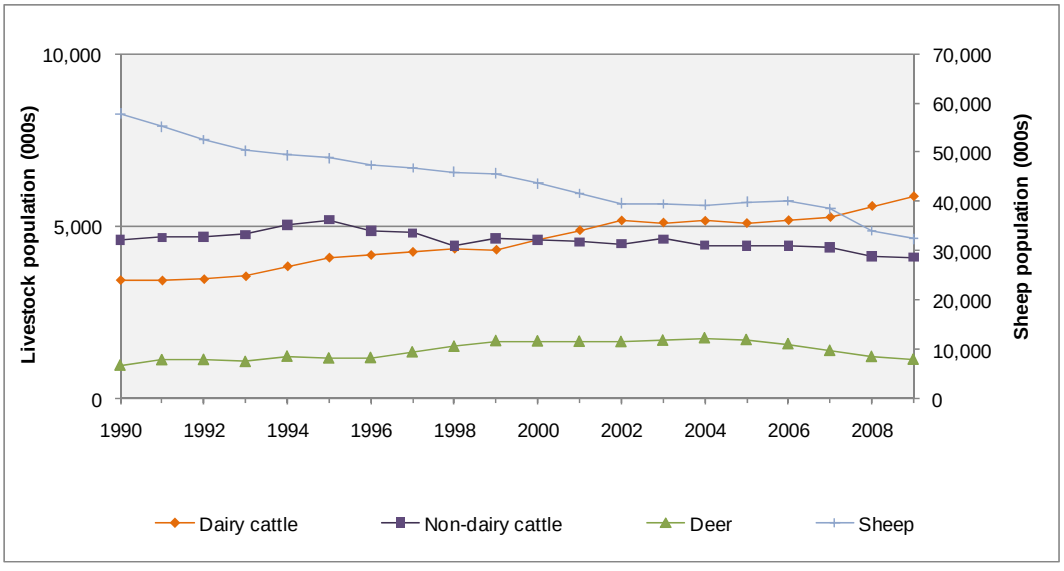
Figure 6.1.2 Change in New Zealand's emissions from the agriculture sector from 1990 to 2009



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

Since 1990, there have been changes in the proportions of the main livestock species farmed in New Zealand. Since 1990, the profitability of dairy products has become relatively higher while the profitability of sheep products has reduced. Therefore, there has been an increase in dairy production with the extra land required to accommodate the extra dairy production mainly coming out of sheep farming. Over the period since 1990 beef numbers have remained relatively static although in recent years there has been a fall in numbers due to drought (Ministry of Agriculture and Forestry, 2010).

Figure 6.1.3 Population of New Zealand's major ruminant livestock from 1990 to 2009



There was a gradual increase in the implied emission factors for dairy cattle and beef cattle since 1990 that reflects the increased levels of productivity achieved by

New Zealand farmers since 1990. 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. There was a drop in implied emission factors in 2008 due to a small reduction in productivity as a consequence of the nationwide drought in 2008. Although some regions in New Zealand were affected by drought in 2009 it was not as severe or as widespread as in previous years. Therefore, the livestock productivity national average has improved resulting in implied emissions being generally steady or increasing again in 2009.

The land area used for horticulture has increased by 50 per cent since 1990 and the types of produce grown have changed (Ministry of Agriculture and Forestry, 2010). There is now less cultivated land area for barley, wheat, and fruit but more for grapes (for wine production) and vegetable production than in 1990. There has also been a net increase in land planted in forestry, reducing the land available for agricultural production.

Changes in emissions between 2008 and 2009

Total agricultural emissions in 2009 were 56.4 Gg CO_2-e (0.2 per cent) lower than the 2008 level. This was largely due to a decrease in the population of sheep (1,704,275 or 5 per cent), deer (77,466 or 6 per cent), and non-dairy cattle (36,154 or 1 per cent) as well as a decrease in nitrogen fertiliser (48,585 tonnes or 14.8 per cent). The decrease in these livestock numbers is primarily due to the aftermath of the drought in 2009 that affected nearly all of New Zealand throughout 2008, along with some regions experiencing further drought in 2009 (Ministry of Agriculture and Forestry, 2010). This was the third year in a row that some regions of New Zealand experienced drought. The dairy industry is the main user of nitrogen fertiliser in New Zealand. However, the milk price was low in 2009 (Ministry of Agriculture and Forestry, 2010) and coupled with high prices for nitrogen fertiliser products this reduced the sale and use of nitrogen fertiliser in 2009.

6.1.1 Methodological issues for the agricultural sector

Agricultural Inventory Advisory Panel

New Zealand has formed an independent Agricultural Inventory Advisory Panel. This panel is made up of representatives from the Ministry of Agriculture and Forestry, 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. New Zealand Methanet and NzOnet are two groups of New Zealand experts in the areas of agricultural inventory methane and inventory nitrous oxide emissions respectively. The panel is independent of policy and industry influences and has been formed to advise on whether changes to New Zealand's agricultural section of the national inventory are scientifically robust. Reports and 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 of Agriculture and Forestry of their recommendations. The 2010 meeting of the panel was held on 17 August 2010 where one change was recommended for inclusion into the agricultural greenhouse gas inventory. Changes are detailed in the relevant sections of this report.

New Zealand tier 2 model for determining energy requirements for key livestock categories

Methane from enteric fermentation and manure management, and nitrous oxide 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 methane and nitrous oxide emissions are carried out.

New Zealand uses a different characterisation for dairy and beef cattle compared to the 1996 and 2006 IPCC Guidelines. In the New Zealand inventory, dairy cattle encompasses 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 under the beef herd. These include breeding lactating cows used for breeding slaughter animals from, calves, dry cows, bulls and all slaughter classes. The full characterisation list for both these herds can be found in the inventory methodology document on the Ministry of Agriculture and Forestry website (http://www.maf.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx).

Activity data

Population data from Statistics New Zealand's annual Agricultural Production Survey (APS) and census (Annex 3.1), and productivity data from New Zealand Dairy Statistics, Beef and Lamb New Zealand and slaughter statistics collected by the Ministry of Agricultural and Forestry are all used by the model to estimate greenhouse gas emissions. Most of this data is collected on a June year end basis but the inventory is calculated on a calendar year. New Zealand uses a June year for animal statistics as this reflects the natural biological cycle for animals in the southern hemisphere. The models developed to estimate agricultural emissions, work on a monthly time step, beginning on 1 July of one year and ending on 30 June of the next year. To calculate emissions for a single calendar year (January–December), calculated emission data from the last six months of a July–June year 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 comparable to other countries.

Livestock population data

The detailed livestock population characterisation for each livestock type is subdivided in the population models. These population models estimate species subcategory population changes throughout the year on the monthly time step required by the inventory model, and have been developed by using industry knowledge and assumptions as detailed in Clark (2008). The populations within a year are adjusted on a monthly basis to account for births, deaths and transfers between age groups. This is necessary because the numbers present at one point in time may not accurately reflect the numbers present at other times of the year. For example, the majority of lambs are born and slaughtered between August and May and, therefore, do not appear in the June census or survey data. Details of the subcategories for dairy cattle, beef cattle, sheep and deer are reported in the inventory methodology document on the Ministry of Agriculture and Forestry website (http://www.maf.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx).

Livestock numbers required for the population models are provided by Statistics New Zealand from census and survey data conducted in June each year (Agricultural

Production Survey and Census). For all livestock other than dairy, national population numbers are used. However, 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.

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 manipulation of data was required.

Livestock productivity data

Productivity data comes from New Zealand Dairy Statistics, Beef and Lamb New Zealand and slaughter statistics collected by the Ministry of Agriculture and Forestry. To ensure consistency, the same data sources are used each year. This ensures the data provides a time-series that reflects changing farming practices, even if there is uncertainty surrounding the absolute values.

Obtaining data on the productivity of ruminant livestock in New Zealand, and how it has changed over time, is a difficult task. Some of the information collected is complete and collected regularly. For example, the slaughter weights of all livestock exported from New Zealand are collected by the Ministry of Agriculture and Forestry 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 liveweight of dairy cattle and breeding bulls, is collected at irregular intervals from small survey populations, or is not available.

Livestock productivity and performance data are summarised in the time-series tables in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate/). The data includes average estimated liveweights, milk yields and milk composition of dairy cows, average liveweights of beef cattle (beef cows, heifers, bulls and steers), average liveweights of sheep (ewes and lambs), and average estimated liveweights of deer (breeding and growing hinds and stags).

The inventory model was developed to conform to the IPCC good practice guidelines and is constantly under improvement. To ensure consistency, a single livestock population characterisation and feed-intake estimate is used to estimate CH_4 emissions for the enteric fermentation category, CH_4 and N_2O emissions for the manure management category, and N_2O emissions for the pasture, range and paddock manure subcategory.

***Dairy cattle*:** Data on milk production is provided by the Livestock Improvement Corporation, a dairy-farmer-owned company providing services to the dairy, beef and deer industries (2010). This data includes the amount of milk processed through New Zealand dairy factories and milk for the domestic market.

Productivity data (milk yield and composition) is collected by the Livestock Improvement Corporation at the same territorial authority level as the population data is collected by Statistics New Zealand. Ministry of Agriculture and Forestry officials then aggregated this data up into the regional council boundaries used for the population data. Before 2004, not all productivity data required could be collected from the Livestock Improvement Corporation at a territorial authority level. Therefore, some manipulation of

data was required to obtain the required values. For example from 1993–2003 milk per cow was determined by the following equation:

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

From 2004, annual milk yields per animal are obtained by dividing the total milk produced by the total number of milking dairy cows and heifers. For all years, lactation length is assumed to be 280 days. In 1992, no productivity data was available at a territorial authority level and therefore trends were fitted to data from 1990–2008 to estimate data.

Average liveweight data for dairy cows is obtained by taking into account the proportion of each breed in the national herd and its age structure based on data from the Livestock Improvement Corporation. Dairy cow liveweights are only available from the Livestock Improvement Corporation from 1996 onwards for six large livestock improvement regions, each comprising of several regional councils. As there are 16 regional council regions, some regions have the same liveweight data as other regions. Due to the lack of liveweight data before 1996, for years in the time-series before 1996, liveweights were estimated using the trend in liveweights from 1996 to 2008, together with data on the breed composition of the national herd.

Dairy replacement animals (calves) at birth are assumed to be 9 per cent of the weight of the average cow and 90 per cent of the weight of the average adult cow at calving. Growth between birth and calving (at two years of age) is divided into two periods: birth to weaning, and weaning to calving. Higher growth rates are applied between births and weaning, when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

No data is available on the liveweights and performance of breeding bulls. An assumption is made that the average mature weight is 500 kg and that they are growing at 0.5 kg per day. This is based on expert opinion taking into account industry data. For example, dairy bulls range from small Jerseys through to larger framed European beef breeds. The assumed weight of 500 kg and growth rate of 0.5 kg/day provides an average weight (at the mid-point of the year) of 592 kg. This is almost 25 per cent higher than the average weight of a breeding dairy cow but it is realistic given that some of the bulls will be of a heavier breed (eg, Friesian and some beef breeds). Total emissions are not highly sensitive to these assumed values, as breeding bulls only make a small contribution to total emissions eg, breeding dairy bulls contribute less than 0.1 per cent of emissions from the dairy sector due to the small population of breeding bulls.

***Beef cattle*:** The principal source of information for estimating productivity for beef cattle is livestock slaughter statistics provided by the Ministry of Agriculture and Forestry. 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. As with dairy cattle, growth rates of all growing animals are divided into two periods: birth to weaning, and weaning to slaughter. Higher growth rates are applied before weaning when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

The carcass weights obtained from the Ministry of Agriculture and Forestry slaughter statistics do not separate carcass weights of adult dairy cows and adult beef cows.

Therefore, a number of assumptions[11] are made to estimate the liveweights of beef breeding cows. A total milk yield of 800 litres per breeding beef cow is assumed.

***Sheep*:** Livestock slaughter statistics from the Ministry of Agriculture and Forestry are used to estimate the liveweights of adult sheep and lambs, assuming killing-out[12] percentages of 43 per cent for ewes and 45 per cent for lambs. Lamb liveweights at birth are assumed to be 9 per cent of the adult ewe weight, with all lambs assumed to be born on 1 September. Growing breeding and non-breeding ewe hoggets are assumed to reach full adult size at the time of mating when aged 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. Wool growth (greasy fleece growth) is assumed to be 5 kg/annum in mature sheep (ewes, rams and wethers) and 2.5 kg/annum in growing sheep and lambs.

From 2010, wool yield data will not be supplied by beef and lamb. Before this a levy was imposed on wool sales and wool yield was collected through this method. However, this levy has been removed and therefore wool data can no longer be collected through this method. There are however, only a few wool testing houses in New Zealand and therefore data may be able to be collected from these. Historic data from the wool testing houses will be compared with data from beef and lamb to determine any historical inconsistencies and to ensure a consistent time-series of wool yield data.

***Deer*:** Liveweights of growing hinds and stags are estimated from Ministry of Agriculture and Forestry slaughter statistics, assuming a killing-out percentage of 55 per cent. A fawn birth weight of 9 per cent of the adult female weight and a common birth date of mid-December are assumed. Liveweights of breeding stags and hinds are based on published data that has liveweights changing every year by the same percentage change recorded in the slaughter statistics for growing hinds and stags above the 1990 base. It is assumed there is no pattern of liveweight change with any given year. The total milk yield of lactating hinds is assumed to be 240 litres (Kay, 1995).

Dry-matter intake calculation

Dry-matter intake (DMI) for the major livestock classes (dairy cattle, beef cattle, sheep and deer) and sub-classes of animals (breeding and growing) is estimated by calculating the energy required to meet the levels of animal performance (metabolisable energy (ME)) and dividing this by the energy concentration of the diet consumed. For dairy cattle, beef cattle and sheep, energy requirements are calculated using algorithms developed in Australia (CSIRO, 2007). These algorithms are chosen as they specifically include methods to estimate the energy requirements of grazing animals, the feeding method used in New Zealand. This method estimates a maintenance requirement (a function of liveweight, the amount of energy expended on the grazing process), and production energy requirement influenced by the level of productivity (eg, milk yield and

[11] The number of beef breeding cows was assumed to be 25 per cent of the total beef breeding cow herd and other adult cows slaughtered were assumed to be dairy cows. The carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing-out percentage of 40 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 50 per cent.

[12] Percentage of carcass weight in relation to liveweight.

liveweight gain), physiological state (eg, pregnant or lactating), and the stage of maturity of the animal. All calculations are performed on a monthly basis. The equation below is the general equation from the Australian feeding standards. This has been adjusted to suit New Zealand conditions and the term ECOLD (additional energy expenditure in cold stress by animals in below lower critical temperature) has been removed as it was found not to apply to New Zealand conditions.

$$\mathbf{ME_m(MJ\ ME/d)} = \frac{K \times S \times M \times (0.28W^{0.75} \times \exp(-0.03A)}{km} + 0.1MEp + \frac{EGRAZE}{km}$$

Where:

ME_m	= metabolisable energy
K	= 1.0 for sheep and 1.4 for cattle
S	= 1.0 for females and castrates or 1.15 for entire males
M	= 1 for animals except milk fed animals. This factor has been removed in the New Zealand calculations and adjustment for milk feed animals is carried out through a milk adjustment factor detailed later
W	= liveweight (kg)
A	= age in years, with a maximum value of 6
K_m	= (net efficiency of use of ME for maintenance) 0.02*ME + 0.5 where ME is the metaboliseable energy (MJ ME per kg dry matter) of pasture that has a gross energy content of 18.4 MJ per kg dry matter
MEp	= the amount of dietary ME being used directly for production (MJ ME/d). $0.1ME_p$ accounts for the accepted effect of feed intake level on the maintenance metabolism of ruminants (CSIRO, 2007).
EGRAZE	= additional energy expenditure of grazing compared with similar housed animals (MJ ME/d)

For deer, an approach compatible to that used for cattle is adopted using algorithms derived from New Zealand studies on red deer (Fennessy et al, 1981). The algorithms take into account animal liveweight and production requirements based on the rate of liveweight gain, sex, milk yield and physiological state. Total energy requirements for deer are the sum of the energy required for maintenance, milk production, conception/gestation, liveweight gain and velvet production.

For detailed methodology and examples of activity data see the inventory methodology document on the Ministry of Agriculture and Forestry website (http://www.maf.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx).

Monthly diet energy concentrations

A single data set of monthly energy concentrations of the diets consumed by beef cattle, dairy cattle, sheep and deer is used for all years in the time-series. 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 is derived from research trial data and publications, and supplemented with actual data from farm surveys on commercial cattle and sheep farms.

Minor species

For goats, swine, poultry, horses and alpaca the IPCC Tier 1 methodology is used with a combination of default and country specific emission factors. The country specific emission factors are detailed in the relevant sections.

The populations of goats, poultry, horses and swine are reported using the animal census (or survey) data from Statistics New Zealand. The population of alpacas are reported using the animal census (or survey) data from Statistics New Zealand in years where it is available. For other years an equation derived from a fitted polynomial trend was used.

Due to the tier 1 nature of the calculation for these species, emissions are not based on productivity outputs. Species populations are currently not broken down into age subcategories.

6.2 Enteric fermentation (CRF 4A)

6.2.1 Description

Methane is a by-product of digestion in ruminants eg, cattle and some non-ruminant animals such as swine and horses. Within the agricultural sector, ruminants are the largest source of CH_4 as they are able to digest cellulose. The amount of CH_4 released depends on the type, age and weight of the animal, the quality and quantity of feed, and the energy expenditure of the animal.

Methane emissions from dairy cattle and sheep enteric fermentation category were identified as the largest key categories for New Zealand in the 2009 level assessment (excluding land use, land-use change and forestry (LULUCF)). Methane emissions from sheep enteric fermentation were also the largest key category in the trend assessment for net emissions (including LULUCF). Methane emissions from dairy cattle enteric fermentation were also assessed as a key category for trend assessment. The CH_4 emissions from enteric fermentation of all other animals was assessed together and identified as key category in the 2009 level and 1990–2009 trend assessment. In accordance with IPCC good practice guidance (IPCC, 2000), the methodology for estimating CH_4 emissions from enteric fermentation in domestic livestock is a Tier 2 modelling approach.

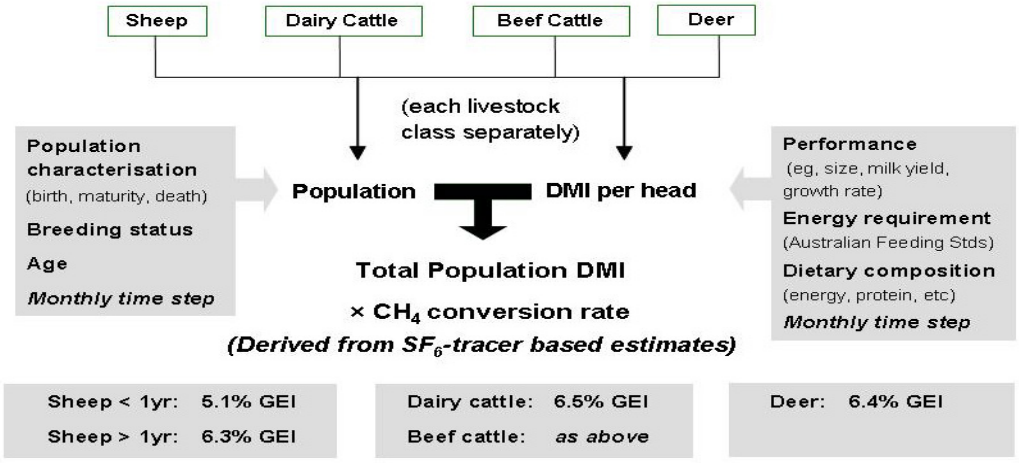
In 2009 enteric fermentation contributed 22,506.2 Gg CO_2-e. This represented 31.9 per cent of New Zealand's total CO_2-e emissions and 68.6 per cent of agricultural emissions. Cattle contributed 14,300.7 Gg CO_2-e (63.5 per cent) of emissions from the enteric fermentation category, and sheep contributed 7,615.8 Gg CO_2-e (33.8 per cent) of emissions from this category. Emissions from the enteric fermentation category in 2009 were 641.6 Gg CO_2-e (2.9 per cent) above the 1990 level of 21,864.7 Gg CO_2-e. Since 1990, there were changes in the source of emissions within the enteric fermentation category. The largest increase came from emissions from dairy cattle. In 2009, dairy cattle were responsible for 9,462.8 Gg CO_2-e, an increase of 4,405.4 Gg CO_2-e (87.1 per cent) from the 1990 level of 5,057.4 Gg CO_2-e. Meanwhile, there have been decreases in emissions from sheep and minor livestock populations such as goats, horses and swine. In 2009, emissions from sheep were 7,615.8 Gg CO_2-e, a decrease of 3,664.2 Gg CO_2-e (32.5 per cent) from the 1990 level of 11,280.0 Gg CO_2-e.

6.2.2 Methodological issues

Emissions from cattle, sheep and deer

Using the dry matter intake and population data calculated by New Zealand's Tier 2 Inventory model (section 6.1.1) the amount of CH_4 emitted per animal 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 (kg CH_4 per head per month) is:

$M = (DMI \times CH_4 \text{ conversion rate} / 1000)$

Where M = methane from enteric fermentation (kg CH_4 per head per month)
DMI = dry matter intake (kg DM per head per month)
CH_4 conversion rate values in Table 6.2.1 (g CH_4 per kg DMI)

Methane emissions per unit of feed intake (CH_4 conversion rate)

There are a number of published algorithms and models[13] 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 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 SF_6 tracer technique (Lassey et al, 1997; Ulyatt et al, 1999). New Zealand now has one of the largest data-sets in the world of CH_4 emissions determined using the SF_6 technique on grazing ruminants. To obtain New Zealand-specific values, published and unpublished data on CH_4 emissions from New Zealand

[13] For example, Blaxter and Clapperton, 1995; Moe and Tyrrel, 1975; Baldwin et al, 1988; Djikstra et al, 1992; and Benchaar et al, 2001 – all cited in Clarke et al, 2003.

were collated and average values for CH_4 emissions from different categories of livestock were obtained. Sufficient data was available to obtain values for adult dairy cattle, sheep more than one year old and growing sheep (less than one year old). This data is presented in Table 6.2.1 together with the IPCC default values for per cent gross energy 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. Measurements using open-circuit respiration chamber techniques that provided complete gas balances were conducted to further confirm the SF_6 tracer technique.

Table 6.2.1 Methane emissions from New Zealand measurements and IPCC default values

	Adult dairy cattle	Adult sheep	Adult 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 greater than one year of age. An average of the adult cow and adult ewe value (21.25g CH_4/kg DMI) is assumed to apply to all deer. 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 2008

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	70.0	50.7	9.3	18.7
1995	73.3	53.3	9.4	20.6
2000	77.2	56.1	10.7	21.7
2005	79.0	57.7	11.1	22.2
2006	78.7	58.6	10.9	22.2
2007	77.3.	57.2	10.7	22.2
2008	76.9	55.9	11.0	22.4
2009	76.9	56.2	11.2	22.3

Emissions from other farmed species

A Tier 1 approach is adopted for minor livestock such as goats, horses, alpaca and swine using either IPCC default emission factors (horses, alpaca and swine) or New Zealand-derived values (goats). These minor species comprised 0.2 per cent of total enteric CH_4 emissions in 2009.

Livestock population data

The populations of goats, horses, pigs and alpaca's are reported using statistical data and trends as reported in section 6.1.1.

Livestock emissions data

Horses and swine: In the absence of data to develop New Zealand emissions' factors, IPCC default values were used to determine emissions from enteric fermentation from these livestock species.

***Goats*:** There is no published data available to attempt a detailed categorisation of the performance characteristics, as has been done for the major livestock categories. New Zealand uses a country-specific value of 9 kg CH_4/head/yr. This was calculated by assuming a default CH_4 emission value from goats for all years that is equal to the per head value of the average sheep in 1990 (ie, total sheep emissions/total sheep population). The goat 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.

Alpacas: The IPCC default value from the IPCC 2006 guidelines (IPCC, 2006b) is based on a study carried out in New Zealand. In the absence of further work carried out on alpacas in New Zealand this value has been used but is yet to be taken on as a country specific value.

6.2.3 Uncertainties and time-series consistency

Livestock numbers

Many of the calculations in this sector require livestock numbers. Both census and survey data are used. Surveys occur each year between each census. Detailed information from Statistics New Zealand on the census and survey methods is included in Annex 3.1.

Methane emissions from enteric fermentation

In the 2003 inventory submission, the CH_4 emissions data from domestic livestock in 1990 and 2001 were 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 of Agriculture and Forestry commissioned a report on re-calculating the uncertainty of the enteric fermentation methane emissions for sheep and cattle (Kelliher et al, 2009). Since the Monte Carlo analysis carried out in 2003 there has been extensive research in the area of measuring enteric methane emissions from sheep and cattle. The initial analysis expressed the coefficient of variation (CV) according to the standard deviation of the methane yield. The recent report investigated calculating the uncertainty by expressing the CV according to the standard error of the methane yield. Since further research has been carried out since 2003, the number of studies this uncertainty analysis is based on a larger sample. The current analysis was restricted to one diet, grass, the predominant diet of sheep and cattle in New Zealand. The new overall uncertainty of the enteric methane emissions inventory, expressed as a 95 per cent confidence interval, is ± 16 per cent (Kelliher et al, 2009).

Table 6.2.3 New Zealand's uncertainty in the annual estimate of enteric fermentation emissions for 1990 and 2009, estimated using the 95 per cent confidence interval of ± 16 per cent

Year	Enteric CH_4 emissions (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	1,041.2	874.6	1,207.8
2009	1,071.7	900.2	1,243.2

Note: The CH_4 emissions used in the Monte Carlo analysis exclude those from swine, horses, goats and alpaca.

Uncertainty in the annual estimate is dominated by variance in the measurements of the 'CH_4 per unit of intake' factor. For the measurements used to determine this factor, the CV (standard error as a per cent of the mean) is equal to 0.03. This uncertainty is predominantly due to natural variation from one animal to the next. Uncertainties in the estimates of energy requirements, herbage quality and population data are much smaller (0.005–0.05).

6.2.4 Source-specific QA/QC and verification

In 2009, CH_4 from enteric fermentation was identified as a key category (level and trend assessment). In 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 are 329 (±153) g CH_4/day/cow compared to 365 (±61) g CH_4/day/cow for the scaled-up measurements reported by Waghorn et al, (2003, Unpublished). Methane emissions from lactating dairy cows have also been measured using the New Zealand SF_6 tracer method and open-circuit respiration chamber techniques (Grainger et al, 2007). Total CH_4 emissions were similar, 322 and 331 g CH_4/day, when measured using calorimeter chambers or the SF_6 tracer technique respectively.

Table 6.2.4 shows a comparison of the New Zealand-specific 2009 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, 2009). New Zealand data was also run through the Agricultural and Land Use National Greenhouse Gas inventory model (ALU) for further Tier 2 checks. Colorado State University developed ALU through GHG inventory capacity-building projects for countries in Central America and Southeast Asia, which were funded by US Environmental Protection Agency, the US Agency for International Development and the US Forest Service. All calculations in this model are based on the 1996 IPCC Guidelines, 2000 and 2003 Good Practice Guidelines and the IPCC 2006 Guidelines (IPCC, 2006b).

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 to the Oceania average. The converse is true when comparing the implied emission factor to Australia, the United Kingdom and the results from the ALU inventory model. New Zealand livestock have a predominant diet of pasture with a higher digestibility than the value that

reported in Table A-1 of the revised 1996 IPCC guidelines (IPCC, 1996) which would result in a lower implied emission factor compared to Australia and the United Kingdom. Also, in New Zealand's Tier 2 Inventory model dairy cattle encompasses 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 emissions factor for sheep is higher than the IPCC default, Australian, United Kingdom and the results from the ALU inventory model as New Zealand takes into account lambs when determining actual methane emissions but not when estimating the implied emission factor, hence a higher implied emission factor than when the lamb population is taken into account. Other countries report an implied emission factor including lambs. Also, the ALU inventory model does not have enhanced characterisation for sheep and therefore only a Tier 1 calculation could be taken into account.

Table 6.2.4 Comparison of IPCC default emission factors and country-specific implied emission factors for CH_4 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[14] (kg CH_4/head/year)
IPCC (2006) Oceania default value	68	53	8
Australian specific IEF 2008 value	113	72	6.9
United Kingdom specific IEF 2008 value	105	43	4.7
Specific IEF from ALU model run	88	44	5
New Zealand-specific 2008 value	76.9	56.2	11.2

For beef cattle the implied emission factor is similar to the others, and differences such as feed type and quality, which animals are characterised as non-dairy, breed etc will influence the implied emission factor.

Overall, IPCC default values and values from some countries for methane emissions from cattle are also determined from relationships based on analyses of the higher-quality feeds typically found in the United States temperate agriculture system (IPCC, 1996). New Zealand methane emissions from cattle have been based on algorithms related to a pastoral diet and will therefore produce different values for emissions. Differences to implied emission factors calculated by the ALU inventory model are also a result of not being able to input exactly the same data due to the different methodologies between the two models. Therefore, some default and some estimated data was used when running the ALU inventory model.

6.2.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2010), Livestock Improvement Corporation statistics (2010)). Activity data for the time-series of potato production and alpaca population were reviewed in 2010 and updated values have been used (Thomas, 2010; Henderson and Cameron, 2010).

[14] All values except for New Zealand include lambs in implied emission factor calculation.

Enhancements to New Zealand's Tier 2 Inventory model has resulted in recalculations of dairy, non-dairy and deer.

6.2.6 Source-specific planned improvements

New Zealand scientists are investigating improvements to the population models and live animal weights used in the Tier 2 method. Research is also underway to determine if satellite imagery can obtain more accurate spatial and temporal values of the metabolisable energy concentration, digestibility and nitrogen content of the diets consumed by New Zealand's grazing ruminants.

A national inter-institutional ruminant CH_4 expert group has been running for 8 years. The group was formed to identify the key strategic directions of research into the CH_4 inventory and mitigation, and to develop a collaborative approach to improve the certainty of CH_4 emission data. This expert group is supported through the Ministry of Agriculture and Forestry. The improved uncertainty analysis and the implementation of the Tier 2 approach for CH_4 emissions from enteric fermentation and manure management are a consequence of the research identified and conducted by the expert group.

The Pastoral Greenhouse Gas Research Consortium has been established to carry out research, primarily into mitigation technologies and management practices but also on improving on-farm inventories. The consortium is funded from both public and private sector sources.

6.3 Manure management (CRF 4B)

6.3.1 Description

In 2009, emissions from the manure management category comprised 783.4 Gg CO_2-e (2.4 per cent) of emissions from the agricultural sector. Emissions from manure management had increased by 164.9 Gg CO_2-e (26.7 per cent) from the 1990 level of 618.5 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 (level assessment) for 2009.

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 (55.7 Gg CO_2-e) in 2009. In comparison, N_2O emissions from the agricultural soils category totalled 9,498.4 Gg CO_2-e in 2009.

In New Zealand, dairy cows only have a fraction (5 per cent) of their excreta stored in anaerobic lagoon waste systems (Ledgard and Brier, 2004). 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 to the time they spend in the milking shed. Other livestock species (sheep, beef cattle, goats, deer, alpaca and horses) graze outdoors all year and deposit all of their faecal material (dung and urine) directly

onto pastures. This distribution is consistent with the revised 1996 IPCC guidelines (IPCC, 1996) for the Oceania region. New Zealand scientists and Ministry of Agriculture and Forestry officials consider the default distributions are applicable to New Zealand farming practices for the ruminant animals listed. Further work is being carried out to confirm proportions of different waste management systems for swine and poultry in the manure management systems. Table 6.3.1 shows the current distribution of livestock in animal waste management systems in New Zealand.

Table 6.3.1 Distribution of livestock across animal waste management systems in New Zealand

	Proportion of animals in each animal waste management system (%)			
Livestock	**Anaerobic lagoon**	**Pasture, range and paddock**	**Solid storage and dry-lot**	**Other**
Non-dairy cattle	–	100	–	–
Dairy cattle	5	95	–	–
Poultry[15]	–	3	–	97
Sheep	–	100	–	–
Swine[16]	55	–	17	28
Goats	–	100	–	–
Deer	–	100	–	–
Horses	–	100	–	–
Alpaca	–	100	–	–

6.3.2 Methodological issues

Methane from manure management

A Tier 2 approach, which is consistent with the IPCC Good Practice Guidelines, is used to calculate CH_4 emissions from ruminant animal wastes from cattle, sheep and deer in New Zealand. The Tier 2 approach is based on the methods recommended by Saggar et al (2003) in a review commissioned by the Ministry of Agriculture and Forestry.

The approach relies on (1) an estimation of the total quantity of faecal material produced; (2) the partitioning of this faecal material between that deposited directly onto pastures and that stored in anaerobic lagoons; and (3) the development of New Zealand-specific emission factors for the quantity of CH_4 produced per unit of faecal dry-matter deposited directly onto pastures, and that stored in anaerobic lagoons.

Faecal dry matter output is calculated monthly for each species subcategory from the follow equation:

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

Where:

FDM = faecal dry matter output
DMI = dry matter intake
DMD = dry matter digestibility

[15] IPCC default waste management proportions for Oceania.

[16] IPCC default waste management proportions for Oceania.

These feed intake and dry-matter digestibility estimates are the same as is used in the enteric CH_4 and N_2O Tier 2 model calculations and 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 methane yields determined from each.

Table 6.3.2 Derivation of CH_4 emissions from manure management in New Zealand

Animal species	Proportion of faecal material deposited on pasture (%)	CH_4 from animal waste on pastures (g CH_4/kg faecal dry-matter)	Proportion of faecal material stored in anaerobic lagoons (%)	Water dilution rate (litres water/kg faecal dry-matter)	Average depth of a lagoon (metres)	CH_4 from anaerobic lagoon (g CH_4/m^2/ year)
Dairy cattle	0.95	0.98[17]	0.05	90[18]	4.6[19]	3.27[20]
Beef cattle	1.0	0.98[21]	0.0	–	–	–
Sheep	1.0	0.69[22]	0.0	–	–	–
Deer	1.0	0.92[23]	0.0	–	–	–

Using the above values, methane from pasture is therefore determined using the following equation:

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

Where: M = methane from manure management
FDM = faecal dry matter output
MMS = proportion of faecal material deposited on pasture
Ym = country specific methane yield methane yield (g CH_4 per year)

And for anaerobic lagoons the following equation is used:

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

Where: M = methane from manure management
MMS = proportion of faecal material deposited on pasture
W = water dilution rate (litres per kg faecal dry matter)
d = average depth of a lagoon (metres)
Ym = methane yield (g CH_4 per m^2 per year)

[17] Sherlock et al, 2003 and Saggar et al, 2003.

[18] Heatly, 2001.

[19] McGrath and Mason, 2002.

[20] McGrath and Mason, 2002.

[21] Sherlock et al, 2003 and Saggar et al, 2003.

[22] Carran et al, 2003.

[23] Average of sheep and cattle values. See text for details.

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 g 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 litres of water per kilogram 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 (2002). McGrath and Mason (2002) 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 g 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 0.69g 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 g 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).

Other minor livestock categories

New Zealand-specific emission factors are not available for CH_4 emissions from manure management for goats, swine, horses and poultry. These are minor livestock categories in New Zealand and IPCC default emission factors are used to calculate emissions.

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/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.

Nitrous oxide from manure management

This subcategory reports N_2O emissions from the anaerobic lagoon, solid storage and dry-lot, and other animal waste management systems. Emissions from the pasture range and paddock animal waste management system are reported in the agricultural soils category.

The calculations for the quantity of nitrogen in each animal waste management system are based on the nitrogen excreted (N_{ex}) per head per year multiplied by the livestock population, the allocation of animals to animal waste management systems (Table 6.3.1), and a N_2O emission factor for each animal waste management system.

The N_{ex} values are calculated from the nitrogen intake less the nitrogen retained in animal products. Nitrogen intake is determined from feed intake and the nitrogen content of the feed. Feed intake and animal productivity values are the same as used in the Tier 2 model for determining dry matter intake (Clark et al, 2003, section 6.1.1). The nitrogen content of feed is estimated from a review of over 6000 pasture samples of dairy and sheep and beef systems (Ledgard et al, 2003).

The nitrogen content of product is derived from industry data. For lactating cattle, the nitrogen content of milk is derived from the protein content of milk (nitrogen = protein/6.25) published annually by the Livestock Improvement Corporation. The nitrogen content of sheep meat and wool and beef, and the nitrogen retained in deer velvet, are taken from New Zealand-based research.

Table 6.3.3 shows N_{ex} values increasing over time reflecting the increases in animal productivity in New Zealand since 1990. For full details of how N_{ex} is derived for each species see the inventory methodology document on the Ministry for the Environment website (www.maf.govt.nz).

Table 6.3.3 N_{ex} values for New Zealand's main livestock classes from 1990 to 2009

Year	Sheep N (kg/head/year)	Non-dairy cattle N (kg/head/year)	Dairy cattle N (kg/head/year)	Deer N (kg/head/year)
1990	12.61	65.51	105.18	24.85
1995	12.81	68.95	108.94	27.37
2000	14.58	72.60	113.95	28.85
2005	15.19	74.60	117.62	29.40
2006	15.01	75.81	116.76	29.52
2007	14.75	73.85	115.17	29.63
2008	15.16	74.83	114.11	29.74
2009	15.45	72.44	114.85	29.64

New Zealand-specific N_{ex} values are not available for swine, horses and poultry. These are minor livestock categories in New Zealand and IPCC default emission factors are used to calculate emissions.

There is no IPCC default value available for N_{ex} for alpacas. Therefore, this was calculated by assuming a default N_{ex} value for alpacas for all years that is equal to the per head value of the average sheep in 1990 (ie, total sheep emissions/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 N intake close to that of sheep, and no significant difference in the partitioning of N (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.

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 and manure management system distribution, and activity data which includes the livestock population (IPCC, 2000).

New Zealand does not currently have country specific uncertainty values for methane from manure management. Also, the IPCC Good Practices Guidelines do not list default uncertainty values for methane 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 kg N_2O-N/kg N. Recent research has shown that the dung of cattle, sheep and deer produce much smaller amounts of nitrous oxide than urine. Therefore, a country specific emission factor to be applied to the nitrogen contained in the dung from cattle, sheep and deer has been developed ($EF_{3\ (PR\&P\ DUNG)}$). For further details see section 6.5.2. The IPCC default values have uncertainties of –50 per cent to +100 per cent (IPCC, 2000).

6.3.4 Source-specific QA/QC and verification

Methane from manure management was identified as a key category (level assessment) in 2009. In preparation for this inventory submission, the data for this category underwent Tier 1 and Tier 2 quality checks.

Table 6.3.4 shows a comparison of the New Zealand-specific 2009 implied emission factor for methane from manure management with the IPCC Oceania default, the Australian and United Kingdom implied emission factor, and the implied emission factor calculated from the ALU inventory model for dairy, beef cattle and sheep.

New Zealand has a lower implied emission factor for methane from manure management than the 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 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 ie, 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. The implied emission factors calculated from ALU are slightly higher than those from the New Zealand Tier 2 model. This difference is due to differences in the two models including how cattle are proportioned into each category and the methods used for the calculation of emissions. The data required by each model differs slightly due to the different methodologies. For example, for the manure methane emission factor a country specific emission factor the default Oceania value was used and not a country specific emission factor.

Table 6.3.4 Comparison of IPCC default emission factors and country-specific implied emission factors for CH_4 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 2008 value	0.89	0.04	0.00
United Kingdom specific IEF 2008 value	25.79	4.18	0.11
Specific IEF from ALU model run	8.5	0.9	0.16
New Zealand-specific 2008 value	3.3	0.7	0.11

6.3.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2010), Livestock Improvement Corporation statistics (2010). Activity data for the time-series of potato production and alpaca population were reviewed in 2010 and updated values have been used (Thomas, 2010; Henderson and Cameron, 2010).

Enhancements to New Zealand's Tier 2 Inventory model has resulted in recalculations of dairy, non-dairy and deer.

6.3.6 Source-specific planned improvements

Both the Poultry Industry Association New Zealand and New Zealand Pork are currently gathering data to improve knowledge on the distribution of each industry's manure into each of the manure management categories. This work will be assessed for incorporation once completed.

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. Therefore, currently 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 2009, the agricultural soils category contributed 9,498.4 Gg CO_2-e (13.5 per cent) to New Zealand's total emissions and 94.6 per cent to total N_2O emissions. Emissions were 1,736.0 Gg CO_2-e (22.4 per cent) above the 1990 level of 7,762.4 Gg CO_2-e. The category comprises three subcategories. Each of these subcategories has been identified as a key category. The subcategories are:

- Direct N_2O emissions from agricultural soils as a result of adding nitrogen in the form of synthetic fertilisers, animal waste, biological fixation in crops, inputs from crop residues and cultivation of organic soils. Direct N_2O soil emissions contributed 1,572.3 Gg CO_2-e (16.6 per cent) to emissions from the agricultural soils category in 2009. This was an increase of 1,055.2 Gg CO_2-e (204.1 per cent) from the 1990 level of 517.1 Gg CO_2-e. Direct N_2O emissions from agricultural soils were identified as a key category (level and trend assessment).
- Indirect N_2O from nitrogen lost from the field as NO_3, NH_3 or NO_x through volitastation and leaching. In 2009, indirect N_2O emissions from nitrogen used in agriculture contributed 2,411.7 Gg CO_2-e (25.4 per cent) to emissions from the agricultural soils category. This was an increase of 402.2 Gg CO_2-e (20.0 per cent) from the 1990 level of 2,009.5 Gg CO_2-e. Indirect N_2O emissions from agricultural soils were identified as a key category (level assessment).
- Direct N_2O emissions from animal production (the pasture, range and paddock animal waste management system). Nitrous oxide emissions from animal production contributed 5,514.4 Gg CO_2-e (58.1 per cent) to emissions from the agricultural soils category. This is an increase of 278.5 Gg CO_2-e (5.3 per cent) from the 1990 level of 5,235.8 Gg CO_2-e. Direct N_2O emissions from animal production were identified as a key category (trend and level assessment).

Carbon dioxide emissions from limed soils are reported in the LULUCF sector (chapter 7).

6.5.2 Methodological issues

The two main inputs of nitrogen to the soil are excreta deposited during animal grazing and the application of nitrogen fertilisers. Emission factors and the fraction of nitrogen deposited on the soils are used to calculate N_2O emissions.

Six New Zealand-specific emission factors and parameters are used in the inventory: EF_1, $EF_{3(PR\&P\ DUNG)}$, $EF_{3(PR\&P)}$, $Frac_{LEACH}$, $Frac_{GASM}$ and $Frac_{GASF}$. The use of a country-specific emission factor for EF_1 (direct emissions from nitrogen input to soil) of one per cent, is based on work by Kelliher and de Klein (2006). The country-specific $EF_{3(PR\&P)}$ emission factor of one per cent and $Frac_{LEACH}$ of 0.07 are based on extensively reviewed literature and field studies (Carran et al, 1995; de Klein et al, 2003; Muller et al, 1995; Thomas et al, 2005). Recently, extensive research has shown that nitrous oxide emissions from dung are substantially lower than nitrous oxide emissions from urine. Therefore, separate emission factors are now allocated to dung and urine for cattle, sheep and deer; $EF_{3(PR\&P)}$ (0.01) for urine from cattle, sheep and deer and manure for all other species and $EF_{3(PR\&P\ DUNG)}$ (0.0025) for dung from cattle, sheep and deer. Further details of this split can be found under the animal production section. A value of 0.1 has been adopted for the emission factor $Frac_{GASM}$ after an extensive review of scientific literature (Sherlock et al, 2009). The 1996 IPCC default value of 0.1 for $Frac_{GASF}$ has been verified as appropriate

to New Zealand after an extensive review of the scientific literature (Sherlock et al, 2009) and has therefore been adopted as a country specific emission factor. Details of recalculations can be found in section 6.5.5 and chapter 10.

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

Direct N_2O emissions from agricultural soils

The N_2O emissions from the direct soils emissions subcategory arise from synthetic fertiliser use, spreading animal waste as fertiliser, nitrogen fixing in soils by crops, and decomposition of crop residues left on fields. For all of these nitrogen inputs a New Zealand-specific emission factor (EF_1) of 0.01 kg N_2O–N/kg N (Kelliher and de Klein, 2006) is applied to calculate total direct emissions from non-organic soils. Many of these subcategories have N_2O emissions from indirect pathways as well, but these calculations are described in detail in later sections.

Where N_{ex} values and allocation to animal waste management systems are used, these are the same as are discussed in section 6.3. The N_{ex} values have been calculated based on the same animal intake and animal productivity values used for calculating CH_4 emissions for the different animal classes and species in the Tier 2 model (section 6.1.1). This ensures the same base DM intake 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 of Agriculture and Forestry website (www.maf.govt.nz).

Synthetic fertiliser

Anthropogenic N_2O emissions from fertiliser are a relatively small proportion of total N_2O emissions, although still significant. The majority of synthetic N 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 New Zealand Fertiliser Manufacturers' Research Association from sales records for 1990 to 2009. There has been a five-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2009 time-series from 59,265 t in 1990 to 279,752 t in 2009, which has resulted in an increase of direct N_2O emissions from 259.8 Gg CO_2-e in 1990 (0.9 per cent of agricultural emissions) to 1,225.7 Gg CO_2-e (3.7 per cent of agricultural emissions) in 2009.

In accordance with IPCC good practice guidance (IPCC, 2000) the following equations are used to determine direct N_2O emissions from the application of nitrogen fertiliser.

$$F_{SN} = N_{fert} \times (1\text{-}Frac_{gasf})$$

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

Where:

F_{SN} = annual amount of synthetic fertiliser nitrogen applied to soils after adjusting for the amount that volatilises

N_{fert} = amount of nitrogen fertiliser applied to soils

$Frac_{gasf}$ = fraction of total synthetic fertiliser emitted as NOx or NH_3

EF_1 = proportion of direct emissions from N input to 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 then is applied to soils at a later date as an organic fertiliser. 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 130.2 Gg CO_2-e (0.4 per cent of agricultural emissions) and in 2009 this had increased to 216.8 Gg CO_2-e (0.7 per cent of agricultural emissions).

In accordance with IPCC good practice guidance (IPCC, 2000) the following equations are used to determine direct N_2O emissions from the application of animal waste to soil.

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

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

Where:

F_{AW} = the total amount of animal manure nitrogen applied to soils from waste management systems (other than pasture range and paddock) after adjusting for the amount which volatilises

N_{AW} = the amount of animal manure nitrogen in each waste management system, other than pasture range and paddock, for all species

N_{AW} = $Nex \times MS$

Where N_{ex} = nitrogen excreted for each species

MS = fraction of N in each management system except pasture range and paddock for each species

$Frac_{GASM}$ = fraction of total animal manure emitted as NOx or NH_3

EF_1 = proportion of direct emissions from N input to soil

Nitrogen fixing crops

The tonnage of nitrogen fixing crops grown in New Zealand is supplied by Statistics New Zealand from their agricultural production survey. It is made up of peas grown for both processing and seed markets as well as lentil production. Emissions from this subcategory make up a very small amount of New Zealand's agricultural emission and in 2009 N_2O emission from this subcategory totalled 10.6 Gg CO_2-e (0.03 per cent of agricultural emissions), which is a decrease from the 1990 value of 24.8 Gg CO^2-e (0.08 per cent of agricultural emissions). This is mainly due to a decrease in pea and lentil production in New Zealand. The IPCC Tier 1A methodology is used to calculate emissions from this section.

$$F_{BN} = 2 \times Crop_{BF} \times Frac_{NCRBF}$$

$$N_2O_{direct\ N\ fix}\text{-}N = F_{BN} \times EF_1$$

Where:

F_{BN} = amount of nitrogen fixed by N-fixing crops cultivated annually

$Crop_{BF}$ = seed yield of pulses and soybeans

$Frac_{NCRBF}$ = the fraction of crop biomass that is nitrogen

EF_1 = proportion of direct emissions from N input to soil

Nitrous oxide from crop residue returned to soil

Crop residues are made up from both N-fixing and non N-fixing crops. The non N-fixing crops in New Zealand include barley, wheat, maize, oats and potato. The tonnage of these crops is supplied by Statistics New Zealand from their agricultural production survey. 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 62.9 Gg CO_2-e (0.2 per cent of agricultural emissions) in 1990 and in 2009 79.8 Gg CO_2-e (0.2 per cent of agricultural emissions). A slightly modified IPCC Tier 1A calculation is then used to calculate N_2O emissions from crop residue as legume crops are not burned in New Zealand.

$$F_{CR} = 2 \times ((Crop_O \times Frac_{NCRO)} \times (1\text{-}Frac_R) \times (1\text{-}Frac_{BURN}) + 2 \times (Crop_{BF} \times Frac_{NCRBF})$$

$$N_2O_{direct\ crop\ residue}\text{-}N = F_{CR} \times EF_1$$

Where:

F_{CR} = amount of nitrogen returned to soils annually through incorporation of crop residues

$Crop_O$ = annual crop production of other crops

$Frac_{NCRBF}$ = the fraction of other crop biomass that is nitrogen

$Crop_{BF}$ = seed yield of pulses and soybeans

$Frac_{NCRBF}$ = the fraction of N-fixing crop biomass that is nitrogen

$Frac_R$ = fraction of above ground biomass that is removed from the field as product

$Frac_{BURN}$ = fraction of above ground biomass that is burned

$Frac_{BURN}$ = fraction of above ground biomass that is burned

EF_1 = proportion of direct emissions from N input to soil

Cultivation of histols

Direct N_2O emissions from organic soils are calculated by multiplying the area of cultivated organic soils by an emission factor (EF_2). Analysis identified 202,181 hectares of organic soils under agricultural pasture in New Zealand (Kelliher et al, 2002). The definition of organic soils used in the agriculture sector to determine emission from the cultivation of histols, differs to that used in the LULUCF section of the inventory, as the agricultural section also includes mineral soils with peaty horizons. Therefore, the area reported in the agricultural section is larger than the LULUCF section. These extra soils are included as expert opinion is that cultivation of these soils would result in similar nitrous oxide emissions to the cultivation of organic soils. Therefore, for completeness they were included.

The definition used in the agricultural section currently is:

- 17 per cent organic matter content (includes slightly peaty, peaty and peat soils of 17 – 30, 30 – 50 and > 50 per cent organic matter content)
- 0.1 m of this depth occurring within 0.3 m of the surface.

Kelliher et al (2002) estimated that 5 per cent (ie, 10,109 ha) of these soils under agricultural pasture are cultivated on an annual basis. New Zealand uses the IPCC default emission factor (EF_2 equal to 8 kg N_2O-N/kg N) and Tier 1 methodology for all years of the time-series. The contribution of organic soils to the overall agricultural emissions is relatively small with 39.4 Gg CO_2-e (0.1 per cent of agricultural emissions) in 1990 and in 2009 39.4 Gg CO_2-e (0.1 per cent of agricultural emissions).

Animal production (N_2O)

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 (http://www.maf.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx). In accordance with IPCC good practice guidance (IPCC, 2000) the following equation are used to determine direct N_2O emissions from animal production.

$$(N_2O\text{-}N) = N \times Nex_{(T)} \times MS \times EF_{3(PR\&P)}$$

Where N = population

Nex = 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 waste management system (i.e. manure deposited directly onto pasture during grazing)

New Zealand uses a country-specific emission factor for $EF_{3(PR\&P)}$ of 0.01 (Carran et al, 1995; Muller et al, 1995; de Klein et al, 2003; Kelliher et al, 2003) for the urine of cattle, sheep and deer and the manure form all other livestock classes. For the dung of cattle, sheep and deer a new country specific emission factor for $EF_{3(PR\&P\ DUNG)}$ of 0.0025 has been implemented. Further details on this new emission factor are reported later.

Considerable research effort has gone into establishing a New Zealand-specific emission factor for $EF_{3(PR\&P)}$. Field studies have been performed as part of a collaborative research effort called NzOnet. The $EF_{3(PR\&P)}$ parameter has been measured by NzOnet researchers in the Waikato (Hamilton), Manawatu (Palmerston North), Canterbury (Lincoln), and Otago (Invermay) regions for pastoral soils of different drainage classes (de Klein et al, 2003). 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 $EF_{3(PR\&P)}$ data and its distribution to pastoral soil drainage class, to determine an appropriate national annual mean value. The complete $EF_{3(PR\&P)}$ data set of NzOnet was synthesised using the national assessment of three pastoral soil drainage classes. These studies recognise that:

- environmental (climate) data is not used to estimate N_2O emissions using the methodology in the revised 1996 IPCC guidelines (IPCC, 1996)
- the N_2O emission rate can be strongly governed by soil water content
- soil water content depends on drainage that can moderate the effects of rainfall and drought
- drainage classes of pastoral soils, as a surrogate for soil water content, can be assessed nationally using a geographic information system.

An earlier analysis in New Zealand showed that the distribution of drainage classes for pasture land is highly skewed with 74 per cent well drained, 17 per cent imperfectly drained, and 9 per cent poorly drained (Sherlock et al, 2001).

As with the $EF_{3(PR\&P)}$ parameter, considerable research effort has gone into establishing a New Zealand-specific value for dung. This included field studies ranging over 8 years being performed in the Waikato, Southern Hawke's Bay, Manawatu, Canterbury and Otago regions on free and poorly drained soils, in the spring summer, autumn and winter. These field studies used methodologies developed during the research into the original New Zealand-specific parameter for $EF_{3(PR\&P)}$.

Luo et al, (2009) assessed all available $EF_{3(PR\&P\ DUNG)}$ data and its distribution to pastoral soil drainage class, and carried out a further trial to confirm data during the spring, to determine an appropriate national annual mean value. This review found that:

- results confirm a disaggregation of $EF_{3(PR\&P)}$ between dung and urine is warranted
- EF_3 decreases as follows: cow urine > cow or cattle dung > sheep dung
- however, when seasonal data was pooled there was no significant difference between cattle and sheep dung.

It was recommended that the N_2O emission factor for urine remain at the country specific value of 1 per cent and the N_2O emission factor for cattle and sheep dung be reduced to one quarter of a per cent.

Incorporation of the mitigation technology DCD into the agriculture inventory

A methodology to incorporate a N_2O mitigation technology, the nitrification inhibitor dicyandiamide (DCD), 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 for 2008 take into account the use of nitrification inhibitors on dairy farms using the methodology described in Clough et al (2008). For the 2009 calendar year, DCD mitigated 21.9 Gg CO_2-e, a 0.1 per cent decrease in total agricultural N_2O emissions.

Dicyandiamide is a well researched and environmentally safe nitrification inhibitor that has been demonstrated to reduce N_2O emissions and nitrate leaching in pastoral grassland

systems grazed by ruminant animals. There have been 28 peer reviewed, published New Zealand studies on the use and effects of DCD.

The method to incorporate DCD mitigation of N_2O emissions into New Zealand's agricultural inventory is by an amendment to the existing IPCC methodology. Activity data on livestock numbers is drawn from Statistics New Zealand's annual agricultural survey. This survey has recently included questions on the area that DCD is applied to on grazed pastures.

The DCD product is applied to pastures based on research that has identified good management practice to maximise N_2O emission reductions. This is at a rate of 10kg/ha of DCD applied twice per year in autumn and early spring within seven days of the application of excreta or fertiliser nitrogen. 'Good practice' application methods of DCD can be by slurry or granule.

Changes to the emission factors $EF_{3PR\&P}$, EF_1 and parameter $Frac_{LEACH}$ were established for use with DCD application. These emission factors and parameters were modified based on comprehensive field-based research that showed significant reductions in N_2O emissions and nitrate leaching where DCD was applied.

The peer-reviewed literature on DCD use in grazed pasture systems was critically reviewed and it was determined that on a national basis, reductions in EF_1, $EF_{3PR\&P}$, and $Frac_{LEACH}$ of 67 per cent, 67 per cent and 53 per cent could be made respectively (Clough et al, 2008). However, due to the limited amount of data available on N fertiliser use in New Zealand it is currently not possible to apply these reductions to EF_1 in the inventory calculations. There has been some research into the effect of DCD on $EF_{3(PR\&P\ DUNG)}$ however, this data is limited and further work needs to be assessed before the incorporating this research into the New Zealand inventory.

The reductions in the emission factors and parameters are used along with the fraction of dairy land treated with DCD to calculate DCD weighting factors.

$$DCD\ weighting\ \ factor = (1 - \frac{\%\ reduction\ in\ EF_x}{100} \times \frac{DCD\ treated\ area}{Effective\ dairy\ area})$$

The appropriate weighting factor is then used as an additional multiplier in the current methodology for calculating indirect and direct emissions of N_2O from grazed pastures. The calculations use a modified $EF_{3PR\&P}$ of 0.0099 and $Frac_{LEACH}$ of 0.0696 for dairy grazing area in the months that DCD is applied (May to September). The modified emission factors are based on information from the agricultural production survey that 3.1 per cent of the effective dairying area in New Zealand received DCD in 2008.

Table 6.5.1 Emission factors and parameters for New Zealand's DCD calculations

	New Zealand emission factor or parameter value for untreated area (kg N_2O-N/kg N)	Reduction from DCD treatment (%)	Proportion land treated with DCD (%)	Final modified emission factor or parameter (kg N_2O-N/kg N)
$EF_{3PR\&P}$	0.01	67	3.1	0.0099
$Frac_{LEACH}$	0.07	53	3.1	0.0696

All other emission factors and parameters relating to animal excreta and fertilizer use ($Frac_{GASM}$, $Frac_{GASF}$, EF_4 and EF_5) remain unchanged when DCD is used as an N_2O mitigation technology. DCD was found to have no effect on ammonia volatilisation

during May to September when DCD is applied. This is supported by the results of field studies (Clough et al, 2008, Sherlock et al, 2009).

The derivations of the modified emission factors and the resulting calculations are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate/).

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

Indirect N_2O from nitrogen used in agriculture

Nitrous oxide is emitted indirectly from nitrogen lost from agricultural soils through leaching and run-off. This nitrogen enters water systems and eventually reaches the sea, with N_2O being emitted along the way. The amount of nitrogen that leaches is a fraction ($Frac_{LEACH}$) of that deposited or spread on land.

Research studies and a literature review in New Zealand have shown lower rates of nitrogen leaching than are suggested in the revised 1996 IPCC guidelines (IPCC, 1996). A New Zealand parameter for $Frac_{LEACH}$ of 0.15 was used in inventories submitted before 2003. However, using a $Frac_{LEACH}$ of 0.15, IPCC-based estimates for different farm systems were found on average to be 50 per cent higher than those estimated using the OVERSEER® nutrient-budgeting model (Wheeler et al, 2003). The OVERSEER® model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems. In pastoral systems, nitrogen leaching is determined by the amount of nitrogen applied in fertiliser, in dairy farm effluent and that excreted in urine and dung by grazing animals. The latter is calculated from the difference between nitrogen intake by grazing animals and nitrogen output in animal products, based on user inputs of stocking rate or production and an internal database with information on the nitrogen content of pasture and animal products and calibrated against field measurements.

The IPCC estimates were closer for farms using high rates of nitrogen fertiliser, indicating that the IPCC-based estimates for nitrogen leaching associated with animal excreta were too high for New Zealand. When the IPCC method was applied to field sites where nitrogen leaching was measured (four large-scale, multi-year animal grazing trials), it resulted in values that were double the measured values. This indicated that a value of 0.07 for $Frac_{LEACH}$ more closely followed actual field leaching in New Zealand (Thomas et al, 2005). The 0.07 value has been adopted and is used for all years as it best reflects New Zealand's national circumstances. In 2009, nitrous oxide emissions from leaching made up 4.7 per cent (1533.5 Gg CO_2-e) of agricultural emissions, an increase of 0.5 per cent from the 1990 value of 1278.8 Gg CO_2-e.

Some of the nitrogen contained in animal excreta and fertiliser deposited or spread on land, is emitted into the atmosphere as ammonia (NH_3) and nitrogen oxides (NO_x) through volatilisation. A fraction of this returns to the ground during rainfall and 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 nitrous oxide 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 has 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 measurements and nine New Zealand papers covering 19 individual measurements 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 measurements 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 2009, nitrous oxide emissions from volatilisation made up 2.7 per cent (878.2 Gg CO_2-e) of agricultural emissions, an increase of 0.3 per cent from the 1990 value of 730.7 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 5000 scenarios with the @RISK software (Kelliher et al, 2003) (Table 6.5.2). The emissions' distributions are strongly skewed, reflecting pastoral soil drainage whereby 74 per cent of soils are classified as well drained and 9 per cent are classified as poorly drained. For the 2008 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value (ie, in 2002, the uncertainty in annual emissions was +74 per cent and –42 per cent).

Table 6.5.2 New Zealand's uncertainties in N_2O emissions from agricultural soils for 1990, 2002 and 2009 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2009)

Year	N_2O emissions from agricultural soils (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	25.0	14.5	43.6
2002	31.9	18.5	55.5
2009	30.6	17.8	53.3

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 uncertainty for an annual estimate.

The Monte Carlo numerical assessment is also used to determine the effects of variability in the nine most influential parameters on uncertainty of the calculated N_2O emissions in 1990 and 2002. These parameters are shown in Table 6.5.3, together with their percentage contributions to the uncertainty. There was no recalculation of the influence of parameters for the 2009 data. The Monte Carlo analysis confirmed that uncertainty in parameter

$EF_{3(PR\&P)}$ has the most influence on total uncertainty, accounting for 91 per cent of the uncertainty in total N_2O emissions in 1990. This broad uncertainty reflects natural variance in EF_3, determined largely by the vagaries of the weather and soil type.

Table 6.5.3 Proportion contribution of the nine most influential parameters on the uncertainty of New Zealand's total N_2O emissions for 1990 and 2002

	1990	2002
Parameter	Contribution to uncertainty (%)	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

6.5.4 Source-specific QA/QC and verification

In 2009, N_2O emissions from the direct soil emissions and pasture range and paddock manure subcategories were key categories (level and trend assessment), and N_2O from the indirect emissions category was also a key category (level assessment). In preparation for this inventory, the data for these categories underwent Tier 1 and Tier 2 quality checks.

In 2008, Ministry of Agriculture and Forestry commissioned a report investigating nitrous oxide emission factors and activity data for crops. 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 received from the New Zealand Fertiliser Manufacturers' Research Association was verified with data collected from the *Agricultural Production Survey* from Statistics New Zealand for year end June 2009. Data from the New Zealand Fertiliser Manufacturers' Research Association was yearend May. The Agricultural Production Survey data for fertiliser use in New Zealand was within 46,000 tonnes (~16 per cent) of the fertiliser sales value supplied by the New Zealand Fertiliser Manufacturers' Research Association. The New Zealand Fertiliser Manufacturers' Research Association data is used rather than the Agricultural Production Survey data as 95 per cent of New Zealand nitrogen fertiliser is provided by two large companies. Therefore, this information will be more accurate than the errors associated with a survey of some 35,000 farmers. There are a large number of differently named nitrogen fertilisers and the Agricultural Production Survey respondents often have difficulty filling in the fertiliser question in the annual questionnaire. Although the 16 per cent variation in nitrogen fertiliser data between the New Zealand Fertiliser Manufacturers' Research Association and the Agricultural Production Survey is not as ideal as in previous years where a lower variation was obtained, it is still considered acceptable, with high confidence placed on the fertiliser manufacturers' figures.

Dicyandiamide data obtained from the Agricultural Production Survey was verified with data from the main supplier of DCD. This company has 90 per cent share of the market. Values obtained from this company were approximately 87 per cent of the reported DCD usage data obtained from the Agricultural Production Survey indicating the values were reasonably accurate.

Table 6.5.4 compares the New Zealand-specific values for EF_1, $EF_{3PR\&P}$ and $EF_{3(PR\&P\ DUNG)}$ with the 1996 IPCC default value and emission factors used by Australia and the United Kingdom where available. For EF_1 and $EF_{3PR\&P}$ the New Zealand value is lower than the IPCC default value. This is due to the large proportion of well drained soils within New Zealand as well as the type 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 $EF_{3(PR\&PDung)}$, 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 nitrous oxide emissions from dung and urine deposits on the silt loams than other countries and soil types.

Table 6.5.4 Comparison of IPCC default emission factors and country-specific implied emission factors for EF_1 and $EF_{3PR\&P}$

	EF_1 (kg N_2O-N/kg N)	EF_{3PRP} (kg N_2O-N/kg N excreted)	$EF_{3(PRP\ DUNG)}$ (kg N_2O-N/kg N excreted)
IPCC (2006b) developed temperate climate/Oceania default value	0.0125	0.02	NA
Australian specific IEF 2008 value	0.0125 (except animal production = 0.01)	0.004	0.005
United Kingdom specific IEF 2008 value	0.0125	0.02	NA
New Zealand-specific 2008 value	0.01	0.01	0.0025

Table 6.5.5 compares the New Zealand-specific values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$ with the 1996 IPCC default and fractions used by Australia and the United Kingdom. Details on these three fractions can be found in more 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 volatised and hence the higher $Frac_{GASM}$ for the default value compared to the country specific New Zealand value (Sherlock et al, 2009).

New Zealand also has a much lower $Frac_{LEACH}$. Research showed that New Zealand applies a much lower rate of nitrogen fertiliser than what was assumed when developing the 1996 IPCC default value. When the OVERSEER® nutrient-budgeting model (Wheeler et al, 2003) took this lower rate into account the rate of leaching was much lower than when compared to farms with a high nitrogen fertiliser rate which can be typical in other developed countries.

Table 6.5.5 Comparison of IPCC default emission factors and country-specific implied emission factors for $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$

	$Frac_{GASF}$ (kg NH_3-N and NO_x-N/kg of N input)	$Frac_{GASM}$ (kg NH_3-N and NO_x-N/kg of N excreted)	$Frac_{LEACH}$ (kg N/kg fertiliser or manure N)
IPCC (1996) developed temperate climate/Oceania default value	0.1	0.2	0.3
Australian specific IEF 2008 value	0.1	0.21	0.3
United Kingdom specific IEF 2008 value	0.1	0.20	0.3
New Zealand-specific 2008 value	0.1	0.1	0.07

6.5.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2010), Livestock Improvement Corporation statistics (2010)). Activity data for the time-series of potato production and alpaca population were reviewed in 2010 and updated values have been used (Thomas, 2010; Henderson and Cameron, 2010).

Enhancements to New Zealand's Tier 2 Inventory model has resulted in recalculations of dairy, non-dairy and deer.

New Zealand has dissagregated nitrogen excreted from cattle, sheep and deer into urine and dung portions. Two country specific EF's are now used in the calculation of emissions from animal production, $EF_{3(PR\&P)}$ = 0.01 for cattle, sheep and deer urine, and all manure from other species, and $EF_{3(PR\&P\ DUNG)}$ = 0.0025 for cattle, sheep and deer dung. As this is a change in methodology which has been applied to all years back to 1990, recalculations have been carried out for all years from 1990. This dissagregation has reduced emissions from the agriculture sector by 1637.9 Gg CO_2-e in 1990 and 1470.8 Gg CO_2-e in 2008.

6.5.6 Source-specific planned improvements

New Zealand scientists are continuing to research N_2O emission factors for New Zealand's pastoral soils. This includes development of New Zealand-specific emission factors for sheep and cattle dung and emission factors for New Zealand hill country pastures. New Zealand is also continuing research to refine the methodology used to estimate N_2O emission reductions using dicyandiamide (DCD) nitrification inhibitors.

Enhancements to the New Zealand Tier 2 Inventory model which will improve usability are currently in progress. These enhancements will also permit the use of regional DCD data as activity data allow, 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.

Forage brassicas have been identified as an important crop in New Zealand but activity data is currently inadequate to be able to carry out emission calculations. Therefore, improvements to this data collection are underway so that this crop can be included in future submissions.

Assessment of the fertiliser question in the Agricultural Production Survey is being carried out with the view to try and improve data obtained from the questionnaire and therefore improve the verification of nitrogen fertiliser data from Fertiliser Manufacturers' Research Association.

A follow up report to the 2008 Ministry of Agriculture and Forestry commissioned report investigating nitrous oxide emission factors and activity data for crops (Thomas et al, 2008) has been commissioned to further investigate the methodologies used to estimate emissions from crop residues. Also, the activity data for the inclusion of other crops is also being investigated. Inclusion of these crops will be assessed for future inventories.

A report has been commissioned on feed supplements feed to livestock in New Zealand to assess the current industry practices. Waste additions to agricultural soils are also currently being assessed. Any potential changes to the methodologies used to determining emissions from livestock resulting from these reports will be assessed in future inventories.

As is noted in section 6.5.2 the definition of organic soils used in the agriculture sector to determine emission from the cultivation of histols, differs to that used in the LULUCF section of the New Zealand inventory, as it also includes mineral soils with peaty horizons. A report has been commissioned to update the current definition used in the Agricultural section of the New Zealand inventory. The report also aims to improve the transparency of the definition of organic soils used in the agricultural section relative to that used in the LULUCF section. The outcome of this review will be noted in future inventories.

Further, Monte Carlo simulations on the uncertainties in N_2O emissions from agricultural soils are planned for future submissions.

6.6 Prescribed burning of savanna (CRF 4E)

6.6.1 Description

In 2009, prescribed burning of savanna was not a key category in New Zealand. The inventory includes burning of tussock (*Chionochloa*) grassland in the South Island for pasture renewal and weed control. The amount of burning has been steadily decreasing over the past 50 years as a result of changes in lease tenure and a reduction in grazing pressure. In 2009, prescribed burning emissions accounted for 1.0 Gg CO_2-e, a 2.2 Gg CO_2-e (68.0 per cent) reduction in emissions from the 3.2 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, 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 five 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 granted consent (a legal right) for burning, under New Zealand's Resource Management Act (1991). Only those areas with consent are legally allowed to be burned. Expert opinion obtained from local government is that approximately 20 per cent of the area allowed to be burnt is actually burnt in a given year.

The following equations are used to estimate the total amount of carbon released during the burning of tussock land in New Zealand.

Biomass burned (t dam) = area of tussock burned annually × above-ground biomass density (t dm/ha) × fraction actually burned

C released from live biomass (t C) = biomass burned (t dm) × fraction that is alive× fraction oxidised × C content of live biomass (t C/t dm)

C released from dead biomass (t C) = biomass burned (t dm) × fraction that is dead × fraction oxidised × C content of dead biomass (t C/t dm)

Total C released (t C) = C released from live material (t C/t dm) + C released from dead material (t C/t dm)

Total carbon released is then used to estimate CH_4, CO, N_2O and NO_x emissions

CH_4 emissions = total C released × emission ratio × 16/12

CO emissions = total C released × emission ratio × 28/12

N_2O emissions = Total C released × emission ratio × N:C ratio × 44/28

NO_x emissions = Total C released × emission ratio × N:C ratio × 46/14

Current practice in New Zealand is to burn in damp spring conditions, reducing the amount of biomass consumed in the fire. The composition and burning ratios used in calculations are from New Zealand-specific research (Payton and Pearce, 2001) and the revised 1996 IPCC guidelines (IPCC, 1996). Table 6.6.1 details the emission factors used.

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	0.32	Payton and Pearce, 2001
C content of live biomass (t C)	0.45	Revised IPCC 1996 Guidelines
C content of dead biomass (t C)	0.4	Revised IPCC 1996 Guidelines
Fraction of live material	0.361	Payton and Pearce, 2001
Fraction of dead material	0.639	Payton and Pearce, 2001
Fraction of live material oxidised	0.8	Revised IPCC 1996 Guidelines
Fraction of dead material oxidised	1	Revised IPCC 1996 Guidelines
CH_4 emission ratio	0.004	Revised IPCC 1996 Guidelines
CO emission ratio	0.06	Revised IPCC 1996 Guidelines
N_2O emission ratio	0.007	Revised IPCC 1996 Guidelines
NO_x	0.121	Revised IPCC 1996 Guidelines
N:C ratio	0.006	Revised IPCC 1996 Guidelines

6.6.3 Uncertainties and time-series consistency

The same emission factors and sources of data were used for the whole time-series. This gives confidence in comparing emissions through the time-series. The major sources of uncertainty are the percentage of consented area actually burnt in that season, extrapolation of biomass data from two study sites for all areas of tussock, and that many of the other parameters are the IPCC default values (ie, the carbon content of the live and dead components, the fraction of the live and dead material that oxidises, and the nitrogen to carbon ratio for the tussocks). Uncertainty in the New Zealand biomass data has been quantified at ±6 per cent (Payton and Pearce, 2001). However, many IPCC parameters vary by ±50 per cent and some parameters do not have uncertainty estimates.

6.6.4 Source-specific QA/QC and verification

Other than cross cutting QA/QC, there was no source-specific QA/QC for this category in 2008.

6.6.5 Source-specific recalculations

There were no source-specific recalculations for this category in 2008.

6.6.6 Source-specific planned improvements

Investigations into improving the tussock burning activity data have been carried out (Thomas et al, 2008). A new question on the burning on tussock land in New Zealand has been added to the Agricultural Production Survey. A review was carried out and a subsequent report has been commissioned to further investigate this area before a final assessment on the potential to include this data in future inventory submissions can be made.

6.7 Field burning of agricultural residues (CRF 4F)

6.7.1 Description

Burning of agricultural residues produced 21.5 Gg CO_2-e in 2009. This was a decrease of 7.2 Gg CO_2-e (–25.2 per cent) below the level of 28.7 Gg CO_2-e in 1990. Burning of agricultural residues was not identified as a key category in 2009.

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 the equation on page 4.82 of the revised 1996 IPCC guidelines (IPCC, 1996). This calculation uses crop production statistics, the ratio of residue to crop product, the dry-matter content of the residue, the fraction of residue actually burned, the fraction of carbon oxidised, and the carbon fraction of the residue. These parameters were multiplied to calculate the carbon released. The emissions of CH_4, CO, N_2O and NO_x were calculated using the carbon released and an emissions ratio. Nitrous oxide and NO_x emissions' calculations also used the nitrogen to carbon 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 is highly desirable" (IPCC, 2000). For the years 1990 to 2003, it was estimated that 50 per cent of stubble was burnt. For the years 2004 to 2008, experts assessed this to have decreased to 30 per cent. These values were developed from opinions of the Ministry of Agriculture and Forestry officials working with the arable production sector (M Doak, pers comm). 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. The proportion of stubble burnt each year varies greatly and depends on climatic conditions and the value of using or selling the waste stubble as supplementary feed for cattle. Table 6.7.1 and 6.7.2 detail the emission factors used to estimate emissions from field burning.

Table 6.7.1 Values used to calculate New Zealand emissions from burning of agricultural residues

Crop	Residue/yield (Revised IPCC 1996 Guidelines)	Dry-matter fraction (Revised IPCC 1996 Guidelines)	C fraction (% dm) (Revised IPCC 1996 Guidelines)	N:C ratio (Revised IPCC 1996 Guidelines)	Fraction oxidised (Revised IPCC 1996 Guidelines)	Fraction burned in fields (NZ specific value)
Wheat	1.3	0.83	0.4853	0.012	0.9	0.3
Barley	1.2	0.83	0.4567	0.015	0.9	0.3
Oats	1.3	0.92	0.4567	0.015	0.9	0.3

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

6.7.3 Uncertainties and time-series consistency

No numerical estimates for uncertainty are available for these emissions. The fraction of agricultural residue burned in the field was considered to make the largest contribution to uncertainty in the estimated emissions.

6.7.4 Source-specific QA/QC and verification

Table 6.7.1 compares the New Zealand-specific values $Frac_{BURN}$ with the IPCC default value and fractions used by Australia and the United Kingdom. New Zealand's value is higher than that of the 1996 IPCC 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. This fraction is also being further looked into as detailed in section 6.7.6.

Table 6.7.1 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 2008 value	NA[24]
United Kingdom specific IEF 2008 value	0
New Zealand specific 2008 value	0.3

6.7.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2010).

6.7.6 Source-specific planned improvements

In a report commissioned by the Ministry of Agriculture and Forestry (Thomas et al, 2008) there was discussion on the proportion of the total area of barley, wheat and oats that are burned. The report suggested that the demand for products from the crop residues may have increased and therefore a smaller proportion of residue burning may occur in some instances. However, there is no information available on the amount of cereal crop residues that are baled and therefore we cannot currently revise our expert judgment on $Frac_{BURN}$. The report also recommended changing the method for how crop residue is calculated for barley, wheat and oats. These recommendations will be assessed for feasibility of incorporation into future inventory submissions.

[24] Australia report that there is no field residue burning and therefore they do not use $Frac_{BURN}$.

Chapter 7: Land use, land-use change and forestry (LULUCF)

7.1 Sector overview

In 2009, net removals by the land use, land-use change and forestry (LULUCF) sector were 26,682.7 Gg carbon dioxide equivalent (CO_2-e). This comprises net removals of 26,745.5 Gg carbon dioxide, and emissions of 55.0 Gg CO_2-e of methane (CH_4) and 7.7 Gg CO_2-e of nitrous oxide (N_2O).

Net removals have increased by 3231.7 Gg CO_2-e (13.8 per cent) from the 1990 level of 23,451.1 Gg CO_2-e (Table 7.1.1). This is largely the result of new forest establishment since 1990, as well as the growth of existing plantation forests. Figure 7.1.1 shows the changes in emissions and removals by land-use category from 1990 to 2009. The increase in emissions in the grassland land-use category is primarily due to the increased deforestation and conversion to grassland of plantation forests that occurred in the five years prior to 2008, as emissions from land-use change are reported in the 'land converted to' category.

Table 7.1.1 New Zealand's greenhouse gas emissions and removals for the LULUCF sector by land-use category in 1990 and 2009 as well as their share and trend

Land-use category	1990	2009	Difference 1990–2009	% Change 1990–2009	1990	2009
	Emissions (Gg CO_2-e)				Share (%)	
Forest land	–25,344.9	–29,559.4	–4214.6	–16.6	+108.1	+110.8
Cropland	395.3	337.5	–57.8	–14.6	–1.7	–1.3
Grassland	1,309.1	2,529.4	1,220.4	93.2	–5.6	–9.5
Wetlands	164.7	NO/NE	–164.7	–100.0	–0.7	NO/NE
Settlements	–7.2	2.5	9.7	134.7	0.03	–0.009
Other land	31.9	7.2	–24.6	–77.3	–0.1	–0.03
Total LULUCF	**–23,451.1**	**–26,682.7**	**–3,231.7**	**–13.8**	**+100.0**	**+100.0**

Carbon dioxide emissions and removals in the LULUCF sector are primarily caused by the uptake from plant growth, emissions from harvesting production forests, deforestation and the decomposition of organic material. 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).

All emissions and removals from the LULUCF sector are excluded from national totals unless otherwise specified. This is consistent with the Climate Change Convention reporting guidelines.

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 and conversion to grassland are key categories for New Zealand in 2009.

Figure 7.1.1 New Zealand's annual emissions and removals from the LULUCF sector from 1990 to 2009

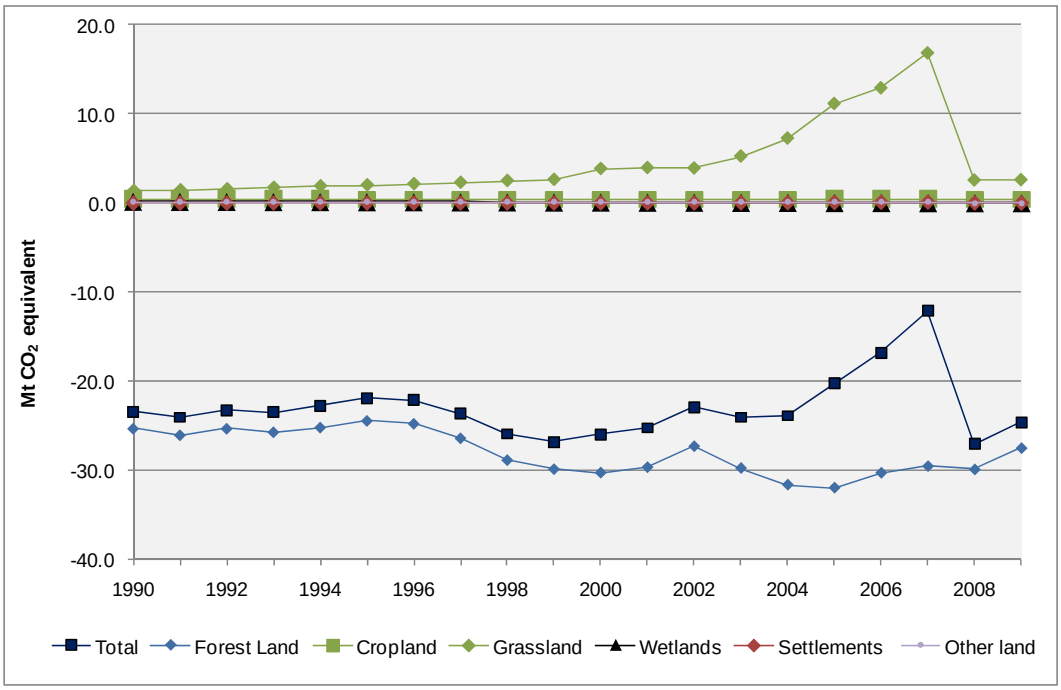
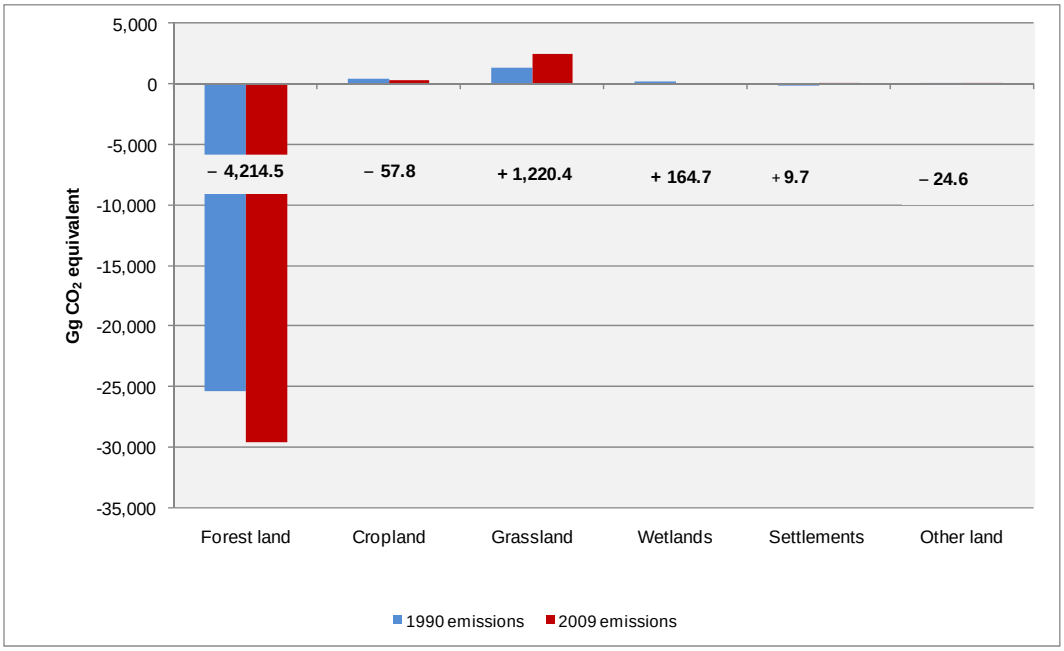


Figure 7.1.2 Change in New Zealand's emissions and removals from the LULUCF sector from 1990 to 2009



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

New Zealand has a land area of approximately 270,000 km^2, which is similar to Japan or the United Kingdom, with extensive coastlines (11,500 km). Its climate is temperate and highly influenced by the surrounding ocean, with 60 per cent of the land hilly or mountainous with many lakes and fast-flowing rivers and streams.

Before human settlement, natural forests were New Zealand's predominant land cover, estimated at 75 per cent of total land area. Today, natural forest covers around 30 per cent of the total land area of New Zealand (see Table 7.1.2). Nearly all lowland areas have been cleared of natural forest for agriculture, horticulture, plantation forestry and urban development. Much of the remaining natural vegetation, however, is now legally protected, with 31 per cent of the total country – 8.4 million hectares – within the conservation estate.

Forestry and agriculture are core to the New Zealand economy and the main determinants of its LULUCF emissions and removals profile. Intensive forest management plus a temperate climate, fertile soils and high rainfall means New Zealand has amongst the highest CO_2 removals under Article 3.3 of Kyoto Protocol, and the highest rates of Kyoto 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 2009, plantation forests covered approximately 2.0 million hectares – around 7.5 per cent of New Zealand's total land area. This includes areas not managed for timber supply, for instance, areas planted for erosion control.

Since 1990, New Zealand has undergone land-use change on approximately 3.0 per cent of the total land area.

Table 7.1.2 Land use in New Zealand in 2009

Land-use category	Subcategory	Net area in 2009 (ha)	Proportion of total area (%)
Forest land	Natural forest	8,095,651	30.1
	Pre-1990 planted forest	1,445,869	5.4
	Post-1989 forest	591,202	2.2
	Subtotal	*10,132,722*	37.6
Cropland	Annual	334,818	1.2
	Perennial	101,770	0.4
	Subtotal	*436,588*	1.6
Grassland	High producing	5,796,529	21.5
	Low producing	7,671,209	28.5
	With woody biomass	1,134,605	4.2
	Subtotal	*14,602,343*	54.2
Wetlands		652,807	2.4
Settlements		207,033	0.8
Other land		893,651	3.3
Total		**26,925,143**	100.0

Note: Areas as at 31 December 2009 and includes deforestation of post-1989 forest since 1990.

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 and removals for the LULUCF sector. A Tier 1 approach, based on a simple land-use change matrix, has been used to estimate carbon change in the four biomass pools for all land-use categories except for forest land and grassland with woody biomass, which use a Tier 2 approach.

A Tier 2 modelling approach has also been used to estimate carbon in the mineral soil component of the soil organic matter pool for all land-use categories. Carbon stock change in organic soils has been estimated using Tier 1 defaults, as this soil type makes up just 0.9 per cent of New Zealand's total land area.

Emission factors

The emission factors required to estimate carbon stock changes using the Tier 1 and Tier 2 equations are provided in Tables 7.1.3 and 7.1.4. These are split into biomass carbon stocks by land use prior to conversion and annual growth in stocks after land-use change.

Table 7.1.3 New Zealand's biomass carbon stock emission factors in land use before conversion

Land-use category	Land-use subcategory	2011 submission emission factors (t C ha^{-1})	Carbon pools	Reference
Forest land	Natural forest national average	173.0	All biomass pools	Beets et al, 2009
	Natural forest: shrub	57.1	All biomass pools	Beets et al, 2009
	Natural forest: tall forest	217.9	All biomass pools	Beets et al, 2009
	Pre-1990 planted forest	Based on an age-based carbon yield table	All biomass pools	Wakelin, 2008
	Post-1989 forest	Based on an age-based carbon yield table	All biomass pools	Kimberley et al, 2009
Cropland	Annual	5	Above- and below-ground biomass	Table 3.3.8, GPG-LULUCF 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, GPG-LULUCF, IPCC, 2003
	Low producing	3.05	Above- and below-ground biomass	Table 3.4.9, GPG-LULUCF, IPCC, 2003
	With woody biomass	29	All biomass pools	Wakelin, 2004
Wetlands		NE	NA	section 3.5.2.2 and Annex 3A, GPG-LULUCF, IPCC, 2003
Settlements		NE	NA	section 3.6.2, GPG-LULUCF, IPCC, 2003
Other land		NE	NA	section 3.7.2.1, GPG-LULUCF, IPCC, 2003

Notes: NE =not estimated. NA =not applicable. Biomass pools include above- and below-ground biomass, litter and dead organic matter. See below in section 7.1.2 and under *Methodological issues* in each category-specific section for further details.

Table 7.1.4 New Zealand's emission factors for annual growth in biomass for land converted to another use

Land-use category	Land-use subcategory	2011 submission emission factor (t C ha^{-1})	Years to reach steady state	Carbon pools	Reference
Forest land	Natural forest	173	1(1)	All biomass pools	Beets et al, 2009
	Pre-1990 planted forest	Based on age-based carbon yield table	28	All biomass pools	Wakelin, 2008
	Post-1989 forest	Based on age-based carbon yield table	28	All biomass pools	Kimberley et al, 2009
Cropland	Annual	5	1	Above- and below-ground biomass	Table 3.3.8, IPCC, 2003
	Perennial	0.67	28	Above-ground biomass	Davis and Wakelin, 2010
Grassland	High producing	6.75	1	Above- and below-ground biomass	Table 3.4.9, IPCC, 2003
	Low producing	3.05	1	Above- and below-ground biomass	Table 3.4.9, IPCC, 2003
	With woody biomass	1.04	28	All biomass pools	Wakelin, 2004
Wetlands		NE	NA	NA	Assume steady state, IPCC, 2003
Settlements		NE	NA	NA	Assume steady state, IPCC, 2003
Other land		NE	NA	NA	Assume steady state, IPCC, 2003

Note: NE =not estimated. NA =not applicable. (1) No conversions to natural forest occur after 1990. The indicated stock accrues instantaneously for conversions prior to 1990. See section 7.3 for further details.

In order to meet reporting requirements under the Kyoto Protocol, New Zealand is estimating carbon stock change for each of the five Kyoto Protocol carbon pools and aggregating the results to the three Climate Change Convention reporting pools. Table 7.1.5 summarises the methods being used to estimate carbon by pool for each land use.

Table 7.1.5 Relationships between carbon pool, land-use category, LULUCF activity and model calculations used by New Zealand

Climate Change Convention reporting pool		Living biomass		Dead organic matter		Soils	
						Soil organic matter	
Kyoto Protocol reporting pool		Above-ground biomass	Below-ground biomass	Dead wood	Litter	Mineral soils	Organic soils
Land-use category	Natural forest	Allometric equations	Per cent of above-ground biomass	Allometric equations	Lab analysis	Soil carbon monitoring system	Not applicable
	Natural forest [D]	Look-up table based on natural forest national average tonnes C ha^{-1}					
	Pre-1990 planted forest	A NEFD-based yield table and the C_Change model				Soil carbon monitoring system	IPCC Tier 1 default parameters
	Pre-1990 planted forest [D]	Look-up table based on Forest Carbon Predictor model (table is split by tree age, stocking and site index)					
	Post-1989 forest [AR]	Forest Carbon Predictor model	Per cent of above-ground biomass	Forest Carbon Predictor model		Soil carbon monitoring system	IPCC Tier 1 default parameters
	Post-1989 forest harvesting	Forest Carbon Predictor model, with emissions parameter	Per cent of above-ground biomass	Forest Carbon Predictor model, with emissions parameter			
	Post-1989 forest [D]	Look-up table based on Forest Carbon Predictor model (table is split by tree age, stocking and site index)					
	Cropland – annual	IPCC Tier 1 default parameters	Not estimated	Not estimated	Not estimated	Soil carbon monitoring system	IPCC Tier 1 default parameters
	Cropland – perennial	Country-specific emission factor	Not estimated	Not estimated	Not estimated	Soil carbon monitoring system	IPCC Tier 1 default parameters
	Grassland (high and low producing)	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	Soil carbon monitoring system	IPCC Tier 1 default parameters
	Grassland with woody biomass	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	Soil carbon monitoring system	IPCC Tier 1 default parameters
	Wetlands	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	Soil carbon monitoring system	Not estimated
	Settlements	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	Soil carbon monitoring system	Not estimated
	Other land	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	Soil carbon monitoring system	Not estimated

Notes: AR = afforestation/reforestation, D = deforestation and NEFD = the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2010). See the methodology sections on soils (section 7.1.3) and forests (section 7.3.2) for explanations of the soil carbon, C_Change and Forest Carbon Predictor models.

Calculation of national emission and removal estimates

To calculate emissions and removals for the New Zealand LULUCF sector, the following data are used:

- land use and land-use change areas from 1962 to 1989 which provides land in a transition state as at 1990 for each land-use subcategory
- annual land use and land-use change area data from 1990 to 2009 (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 (see Tables 7.1.3 and 7.1.4)
- age-based carbon yield tables for pre-1990 planted forests and post-1989 forests
- emission factors and country-level activity data on biomass burning and liming
- IPCC default conversion factors.

The formula used to calculate emissions from biomass changes is:

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

The formula used to calculate emissions from soil changes is:

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

For example, the annual change in carbon stock in the first year of conversion of 100 hectares of low-producing grassland to perennial cropland would be calculated as follows:

Biomass change = (–3.05 x 100) + (0.67 x 100) = –238 t C
Soil change = (((101.24 – 105.8) / 20) x 100) = –22.8 t C
Total carbon stock change = –260.8 t C

Total emissions = (carbon stock change / 1000 x –1) x (44/12)
Total emissions = 0.956 Gg CO_2-e

These calculations are performed to produce estimates of annual carbon stock and carbon stock changes since 1990 to inform the Climate Change Convention and Kyoto Protocol Article 3.3 reporting.

New Zealand land use and carbon analysis system

New Zealand's LULUCF estimates are calculated using a data collection and modelling programme called the Land Use and Carbon Analysis System (LUCAS) (see www.mfe.govt.nz/issues/climate/lucas/). The LUCAS Data Management System stores, manages and retrieves data for international greenhouse gas reporting for the LULUCF sector. The system comprises the Geospatial System, a data warehousing 'Gateway' and the Calculation and Reporting Application. These systems are used for managing the land-use spatial databases and the plot and reference data, and for combining the two sets

of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting. Details on these databases and applications are provided in Annex 3.2.

7.1.3 Soils

In this submission, New Zealand uses a combination of Tier 2 and Tier 1 methods to estimate soil carbon emissions for mineral soils and organic soils respectively.

Mineral soils

New Zealand uses a Tier 2 method to estimate soil carbon stock and stock change for mineral soils, with the use of New Zealand-specific land-use and soil pedon data (Scott et al, 2002). The resulting peer-reviewed Soil Carbon Monitoring System (Soil CMS) is used to quantify 1990 baseline soil carbon stocks for the organic fraction of the mineral soils and to estimate subsequent changes in soil carbon stocks associated with land-use change (Tate et al, 2003a, b; Tate et al, 2004).

Model

Given that the concentration of soil carbon is largely controlled by soil type, climate and land use (Tate et al, 1999), the Soil CMS pre-stratified the country by these three factors, namely: soil class, climate and land use. This resulted in 39 combinations of these three factors, called cells, and described 93 per cent of the New Zealand landscape (Tate et al, 2003a, b). An 'erosion index' (slope x rainfall) factor was later added (Tate et al, 2005). Geo-referenced soil carbon data (0–0.3 metre depth increment) is used to quantify average soil carbon (t C ha^{-1}) for each combination using a General Linear Model.

A key assumption of the model is that the soil carbon values in the national soil pedon database represent equilibrium soil carbon values for each soil or land-use combination, with a variety of tests indicating that this is a reasonable assumption (Tate et al, 2002, 2005). It is further assumed that change in land use is the key determinant of change in soil carbon (Tate et al, 2005). Estimation of change in soil carbon with change in land use is calculated based on the differences in equilibrium soil carbon values (t C ha^{-1}) between the initial and final land use (Tate et al, 2002) over a 20-year period (IPCC default). The change in carbon is then multiplied by the area of change mapped (Table 7.2.3). Detailed description of the Soil CMS model and estimate uncertainties is included in Annex 3.3.

Data

The LUCAS soil dataset consists primarily of historical data extracted from the National Soils Database (Landcare Research Limited), that gives national coverage of undisturbed representative or modal soil pedons collected for soil survey purposes, and from the Forest Nutrition dataset (Forest Research Institute Limited). It has been supplemented with recent data collected specifically for the Soil CMS to fill gaps in the geographical coverage and to increase the number of data points for land uses of particular interest to help reduce uncertainty for these land uses (Baisden et al, 2006b).

The consolidated LUCAS dataset has been reclassified to use the current land-use categories. This reclassification was based on data from the original plot sheets. Potential bias in cropland soil carbon stock estimates from using data from undisturbed pedons has been removed by invalidating any records that were not specifically collected within the cultivated area (Fraser et al, 2009).

Recent research (Parfitt et al, 2010) shows that the earlier hammer field sampling method for collecting fine earth bulk density samples underestimates the true bulk density by 5 per cent on average, depending on soil type and horizon. Bulk density correction factors have been developed and applied to the historical data from the National Soils Database, and a new pedotransfer function developed for predicting bulk density for those samples where it has not been measured. The Soil CMS model has been re-fitted using updated soil carbon values derived from updated bulk density estimates (McNeill et al, 2010).

The LUCAS dataset has been further supplemented this year with annual cropland and high-producing grassland data from the Land Management Index (New Zealand Institute of Plant and Food Research Limited) (Lawrence-Smith et al, 2010) and natural forest and grassland data collected specifically for the Soil CMS.

The current dataset consists of 1959 records, distributed across land uses as shown in Figure 7.1.3 and Figure 7.1.4.

Figure 7.1.3 New Zealand soil plot distribution (plots used for model estimation of soil carbon stocks)

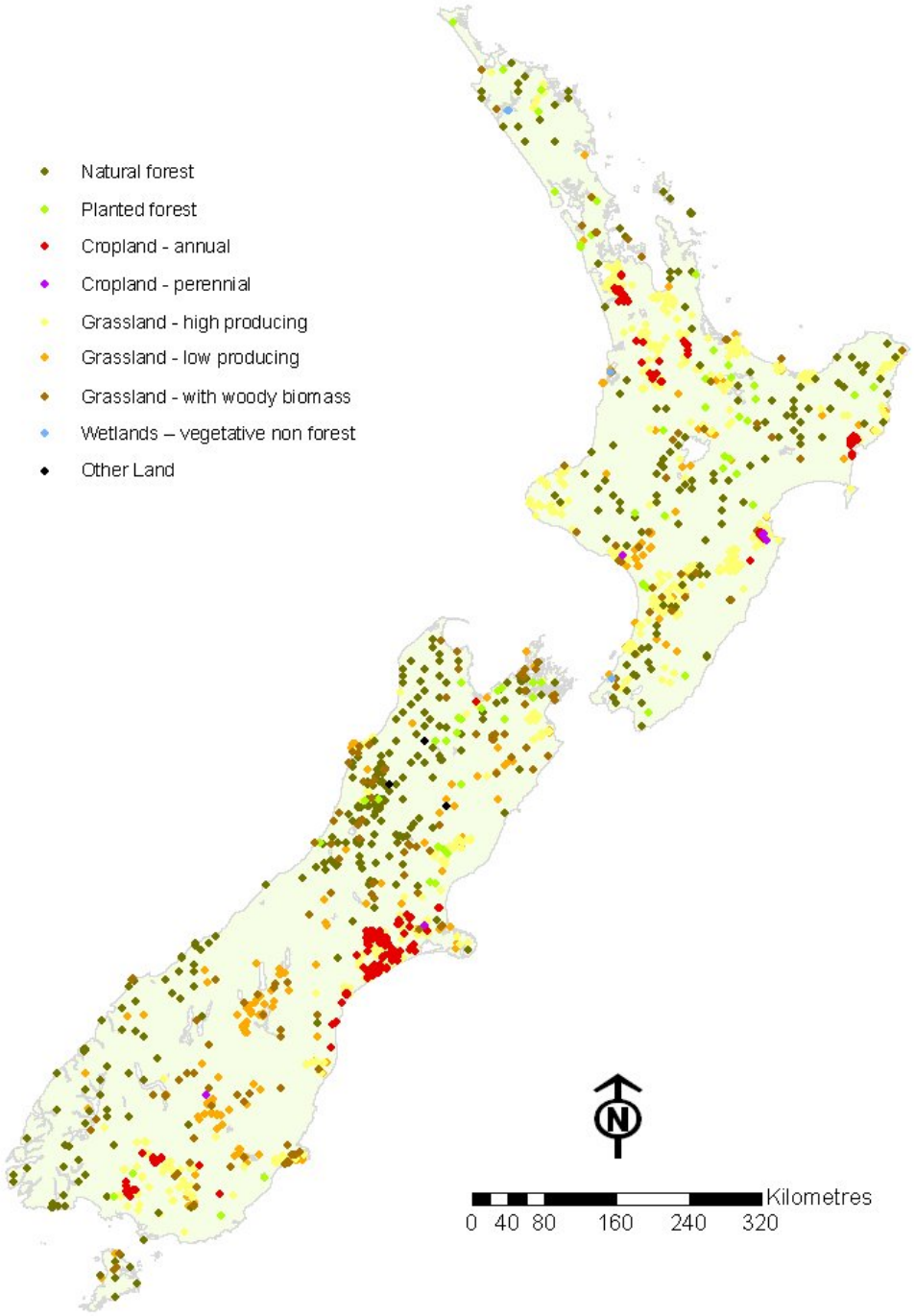
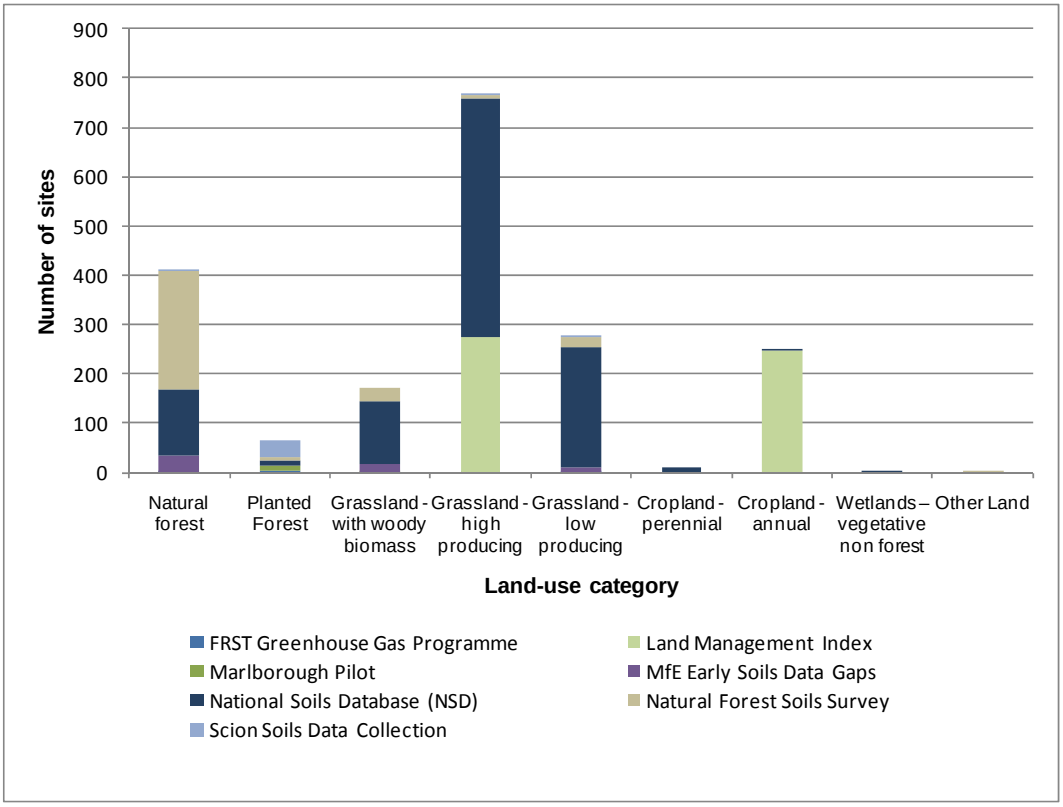


Figure 7.1.4 Number of New Zealand soil plot sites by land-use and dataset



Note: FRST – Foundation for Research Science and Technology

MfE – Ministry for the Environment.

Testing and validation

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 24,000 hectares of South Island low-producing grassland (Scott et al, 2002) and for an area of the South Island (about 6000 hectares) containing a range of land-cover and soil-climate categories (Tate et al, 2003a, b). A regional-scale validation exercise has also been performed using the largest climate/soil/land-use combination cell (Moist Temperate Volcanic Grassland), with independent random sampling of 12 profiles taken on a fixed grid over a large area (2000 km^2). Mean values derived from the random sampling were well within the 95 per cent confidence limits of the database values (Wilde et al, 2004; Tate et al, 2005). Overall, these tests indicated that the Soil CMS estimates soil carbon stocks reasonably well at a range of scales (Tate et al, 2005). A further regional-scale validation exercise on a climate/soil/land-use combination cell (Dry Temperate/High Activity Clay/Low-producing Grassland) was recently undertaken, with sampling at 15 randomly selected sites. Results show that there was no significant difference between the validation dataset and either the Soil CMS calibration dataset for that combination or the modelled value, although all values have large uncertainties associated with them (Hedley et al, *in press*).

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 a 'paired-site' approach (Tate et al, 2003b; Baisden et al, 2006a). The paired-site approach compares two nearby sites that have reasonably uniform morphological properties, which originally were under a single land use, and where one site has since

changed to a different land use, with sufficient time having elapsed for it to have reached steady-state values for soil carbon (Baisden et al, 2006a, b). Therefore, the influence that differing soil types, climatic conditions and erosion regimes may have on soil carbon are removed and any resulting changes in soil carbon can be attributed to the change in land use. Results indicate that, once a weighting for forest species type has been 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 are in agreement within 95 per cent confidence intervals (Baisden et al, 2006a, b).

Model outputs

Table 7.1.6 gives the national soil carbon stock density estimates for all land-use categories and the associated standard errors. All estimates are produced by the Soil CMS.

Table 7.1.6 New Zealand's soil carbon stock density (0–0.3 m) for land-use categories

Land use	Soil carbon stock density (t C ha^{-1})
Natural forest	92.04 ± 3.66
Planted forest (pre-1990, post-1989)	88.96 ± 5.45
Annual cropland	90.99 ± 4.38
Perennial cropland	101.24 ± 11.83
High-producing grassland	104.99 ± 3.08
Low-producing grassland	105.80 ± 4.15
Grassland with woody biomass	98.42 ± 3.59
Wetlands – vegetative non forest	97.35 ± 18.22
Settlements	105.80 ± 4.15
Other land	64.94 ± 20.63

Figure 7.1.5 shows the national soil carbon stock density estimates for all land-use categories, and their associated uncertainties in a graphic form.

Soil carbon stocks in land converted to settlements are unable to be estimated using the Tier 2 method for mineral soils as described in section 7.1.3, as there is no soil data for this land use. In the absence of either land-use specific data or an IPCC default, the value for low-producing grassland was used as the default for mineral soils.

Figure 7.1.5 New Zealand's soil carbon stock density (0–0.3 m) for land-use categories and associated land-use effect uncertainties (McNeill 2010)

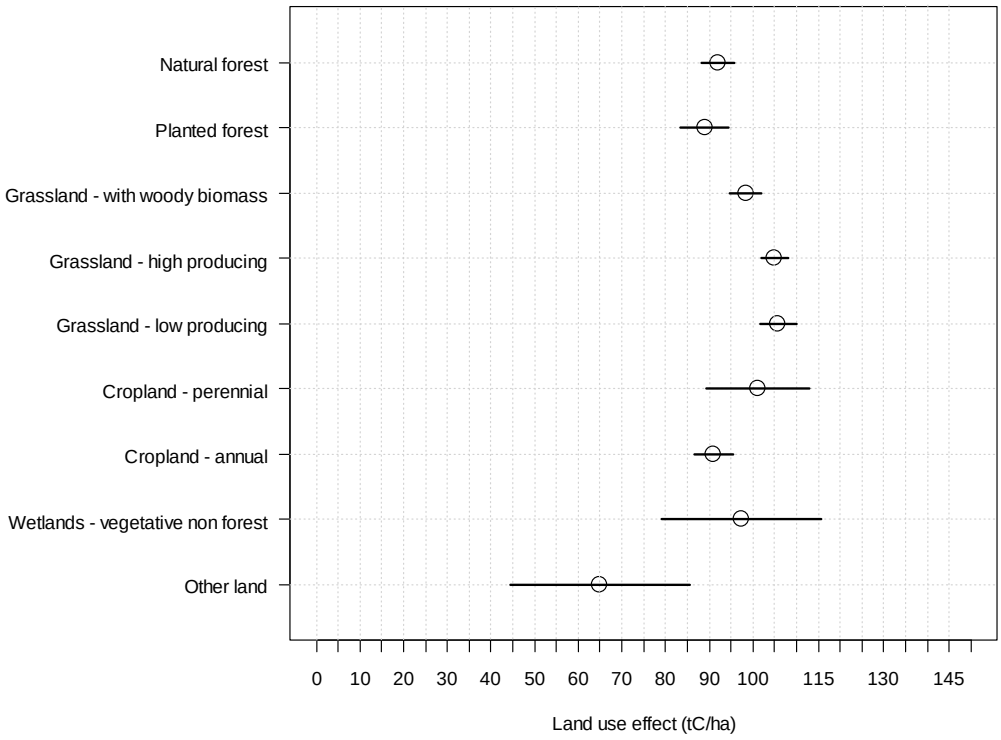


Table 7.1.7 gives the land-use effects (LUE, in t C/ha) on national soil carbon estimates of conversion between land-use categories, and the associated standard errors.

Table 7.1.7 Land-use effects (LUE, t C/ha) of conversion between land-use categories, with estimated standard errors (McNeill 2010)

Origin land use	Land converted to	LUE	Standard error
Planted forest	Natural forest	3.08	5.26
Grassland – with woody biomass	Natural forest	–6.39	3.65
Grassland – high producing	Natural forest	–12.95	3.58
Grassland – low producing	Natural forest	–13.77	6.54
Cropland – perennial	Natural forest	–9.2	12.01
Cropland – annual	Natural forest	1.04	4.75
Wetlands – vegetative non forest	Natural forest	–5.31	18.31
Other land	Natural forest	27.09	20.55
Grassland – with woody biomass	Planted forest	–9.47	5.53
Grassland – high producing	Planted forest	–16.03	5.25
Grassland – low producing	Planted forest	–16.85	7.78
Cropland – perennial	Planted forest	–12.28	12.63
Cropland – annual	Planted forest	–2.04	6.11
Wetlands – vegetative non forest	Planted forest	–8.39	18.79
Other land	Planted forest	24.02	20.99
Grassland – high producing	Grassland – with woody biomass	–6.56	3.62
Grassland – low producing	Grassland – with woody biomass	–7.38	6.4
Cropland – perennial	Grassland – with woody biomass	–2.81	11.99

Origin land use	Land converted to	LUE	Standard error
Cropland – annual	Grassland – with woody biomass	7.43	4.77
Wetlands – vegetative non forest	Grassland – with woody biomass	1.07	18.28
Other land	Grassland – with woody biomass	33.48	20.71
Grassland – low producing	Grassland – high producing	–0.81	6.21
Cropland – perennial	Grassland – high producing	3.75	11.6
Cropland – annual	Grassland – high producing	14	3.36
Wetlands – vegetative non forest	Grassland – high producing	7.64	18.2
Other land	Grassland – high producing	40.05	20.68
Cropland – perennial	Grassland – low producing	4.57	12.96
Cropland – annual	Grassland – low producing	14.81	7.01
Wetlands – vegetative non forest	Grassland – low producing	8.45	18.94
Other land	Grassland – low producing	40.86	21.27
Cropland – annual	Cropland – perennial	10.24	11.74
Wetlands – vegetative non forest	Cropland – perennial	3.89	21.49
Other land	Cropland – perennial	36.29	23.65
Wetlands – vegetative non forest	Cropland – annual	–6.36	18.47
Other land	Cropland – annual	26.05	20.92
Other land	Wetlands – vegetative non forest	32.41	27.42

Organic Soils

New Zealand uses a Tier 1 method to estimate soil carbon stock change in organic soils. Area data for organic soils is from the Soil CMS spatial layer, which maps all soil types within New Zealand. The mapping is based on the Fundamental Soils Layer associated with the New Zealand Land Resources Inventory (Newsome et al, 2000), with soil types converted to IPCC classifications (Daly & Wilde, 1997). Area data for organic soils by land use is obtained by intersecting the Soil CMS spatial layer with the land-use mapping layer.

The definition of organic soils is from the New Zealand Soil Classification (Hewitt, 1998) and is broadly summarised as having at least 18 per cent organic carbon in 30cm or more thick horizons within 60cm of the soil surface.

New Zealand has used IPCC default emission factors for organic soils under forest, grassland and cropland to estimate emissions, as shown in Table 7.1.8 (IPCC GPG-LULUCF sections 3.2.1.3, 3.3.1.2 and 3.4.1.2). 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. 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 and other land, and therefore emissions from organic soils under these land uses are not estimated. It is not known whether the use of IPCC defaults for organic soils results in either an overestimate or an underestimate of New Zealand's soil carbon emissions. However, organic soils occupy a relatively small proportion of New Zealand's total land area (0.9 per cent).

Table 7.1.8 New Zealand emission factors for organic soils

Land use	Climatic temperature regime	IPCC Tier 1 default emission factor applied & error (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 GPG-LULUCF section 3.2.1.3.
Pre-1990 planted forest Post-1989 forest	Temperate	0.68 (range 0.41–1.91)	IPCC GPG-LULUCF section 3.2.1.3, Table 3.2.3.
Cropland	Cold temperate Warm temperate	1.0 ± 90 % 10.0 ± 90 %	IPCC GPG-LULUCF section 3.3.1.2, Table 3.3.5.
Grassland	Cold temperate Warm temperate	0.25 ± 90 % 2.5 ± 90 %	IPCC GPG-LULUCF 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 GPG-LULUCF section 3.5.2.1.
Settlements Other land	NA	NE	No IPCC guidance is available. IPCC GPG-LULUCF chapters 3.6, 3.7.

Methodological change

In the previous submission, New Zealand estimated emissions from organic soils by aggregating the activity data for organic and mineral soils together and using the emission factors for mineral soils as the default emission factors for organic soils, noting that organic soils occupied only 0.9 per cent of New Zealand's total land area. For this submission, New Zealand has applied Tier 1 default emission factors for organic soils. This represents a significant change in method from the previous submission.

New Zealand has significantly revised the soils carbon stock values used to estimate soil organic carbon for mineral soils to improve their accuracy, completeness and transparency. The LUCAS dataset has been further supplemented this year with annual cropland and high-producing grassland data from the Land Management Index (New Zealand Institute of Plant and Food Research Limited) (Lawrence-Smith et al, 2010) and natural forest, grassland and other category data collected specifically for the Soil CMS. Bulk density correction factors have been developed and applied to the historical data from the National Soils Database, and a new pedotransfer function developed for predicting bulk density for those samples where it has not been measured. The Soil CMS model has been re-fitted using updated soil carbon values derived from updated bulk density estimates (McNeill, 2010). The combined improvements have resulted in an increase in the difference in stock estimates for mineral soils between low-producing grassland and post-1989 forest (the major land-use change) from –13.35 t C ha^{-1} (McNeill et al, 2009) to -–16.85 t C ha^{-1} (McNeill, 2010).

Uncertainties and time-series consistency

Use of a General Linear Model allows estimates to be made of uncertainties associated with estimates of soil carbon changes. The standard errors for each land-use soil carbon estimate are given in Table 7.1.6 and shown in Figure 7.15. The standard errors for the land-use effects of conversion between land-use categories are given in Table 7.1.7.

Improvements undertaken within the last year have resulted in reduced uncertainties for all land-use category estimates, in particular annual cropland and low-producing grassland. The relatively high uncertainties associated with perennial cropland, vegetative non-forest wetlands and other land are due to having small datasets as these land uses occupy only minor land areas within New Zealand. There is, however, a plan to obtain data for perennial cropland over the next year.

Uncertainties also arise from lack of soil carbon data for some soil/climate/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 (Wilde, 2003; Baisden et al, 2006a). Other uncertainties in the Soil CMS include: the assumption that soil carbon is at steady state for all land uses, 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).

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).
- Details of the quality-management system for data collection, laboratory analysis and database extractions and conversion of the Land Management Index are given in Lawrence-Smith et al (2010).
- 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 and validation (eg, Scott et al, 2002; Tate et al, 2005; Baisden et al, 2006a; McNeill et al, 2009, 2010, Hedley et al, *in press*), and has been published in peer-reviewed international journals (Scott et al, 2002; Tate et al, 2003a, b; Tate et al, 2005).

Source-specific planned improvements

Recent reviews of the Soil CMS identify a range of potential areas for improvement of the system (Baisden et al, 2006b; Kirschbaum et al, 2009). Those areas identified for future improvement include the following, and will be prioritised before any further improvements are agreed and funded:

- improvement in the data by collecting more data for under-represented land-use and soil-climate cells, and to correct the data by removing sampling and analysis anomalies. This is to address issues highlighted during the ERT review of the 2010 submission
- improvement in the model by recalibration and analysis of the effects of including other datasets in the Soil CMS
- improvement in the model to better reflect the landform processes on landscapes where land-use change is occurring (eg, mass-movement erosion processes on hill-country landscapes)

- further validation of the Soil CMS model by checking the results it gives against randomly selected paired sites for specific land-use categories to investigate soil carbon changes following land-use change (eg, low-producing grassland to planted forest) time-series sampling to investigate the rate of soil carbon change following specific land-use change, and to further test the equilibrium state assumption.

7.1.4 Uncertainties in LULUCF

The LULUCF sector introduces 7.5 per cent uncertainty into the 2009 net uncertainty for the whole inventory. Table 7.1.9 shows the seven land-use transitions within the LULUCF sector with the greatest contribution to uncertainty in the net carbon emissions for the LULUCF sector. These are given in descending order.

Table 7.1.9 Land-use transitions with the greatest contribution to uncertainty in the LULUCF sector

Land-use transitions	Per cent error attributed to activity data (area)	Per cent error attributed to emission factors	Total per cent error by land-use transition
Pre-1990 planted forest remaining pre-1990 planted forest	7.9%	19.1%	20.7%
Low-producing grassland converted to post-1989 forest	3.1%	5.5%	6.3%
Grassland with woody biomass converted to pre-1990 planted forest	2.1%	5.8%	6.2%
High-producing grassland remaining high-producing grassland	0.2%	3.6%	3.6%
Low-producing grassland converted to pre-1990 planted forest	1.1%	3.1%	3.3%
Grassland with woody biomass converted to post-1989 forest	1.0%	1.8%	2.1%
High-producing grassland converted to post-1989 forest	0.8%	1.5%	1.8%

The land-use subcategory which introduces the greatest uncertainty (when expressed as a proportion of total net LULUCF carbon emissions) is pre-1990 planted forest remaining pre-1990 planted forest. The error attributed to the emission factor for the pre-1990 planted forest is high at 19.1 per cent. This will be improved once New Zealand incorporates plot data from the pre-1990 planted forest inventory undertaken in 2010 (this data will be available for the 2012 submission).

The second greatest contributor is low-producing grassland converted to post-1989 forest. This is the land-use transition with the largest area change with 354,400 ha of change between 1990 and 2009.

More details on the emission factor and activity data uncertainties for specific land uses and non-carbon emissions are given within the relevant sections of this chapter.

7.1.5 Recalculations in LULUCF

For the 2011 submission, New Zealand has recalculated its emission and removal estimates for the LULUCF sector from 1990 to 2008 to incorporate new activity data, New Zealand-specific emission factors and improved methodology. These improvements are in addition to the significant improvements made in 2008, for the 2010 inventory

submission, with the introduction of the new data collection and modelling programme for the LULUCF sector – the Land Use and Carbon Analysis System (LUCAS). See Annex A3.2 for further details on LUCAS.

The recalculations have resulted in significant improvements to the accuracy, completeness and transparency of the LULUCF estimates. Their impact on total net LULUCF removals in 1990 and 2008, based on a comparison of the current and previous submissions, is summarised in Table 7.1.10. The overall effect of the recalculations has been to decrease removals in 1990 by 24.5 per cent, and increase removals in 2008 by 12.2 per cent.

Table 7.1.10 Recalculations to New Zealand's total net LULUCF emissions

	Reported net emissions		Change in estimate	
	2010 submission (Gg CO_2-e)	2011 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	–31,066.3	–23,451.1	7,615.2	24.5
2008	–26,176.8	–29,360.1	–3,183.3	–12.2

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions and removals reported in the 2010 submission are the result of (in decreasing order of magnitude):

- the use of historical land-use data (backcasting) to model land-use change since 1962, in order to identify land in transition in the inventory base year of 1990. The result of this inclusion is that lagged emissions and removals from land-use change events prior to 1990 are now reported. The main impact of this is due to the change to pre-1990 planted forest emissions and removals as harvesting residue decay emissions resulting from historical (pre-1990) harvesting events are now included
- improved measurement of deforestation, through the introduction of polygon-specific mapping (IPCC Approach 2) of deforestation from the start of the first commitment period (1 January 2008) onwards. The mapping of deforestation up to 1 January 2008 has also been improved, based on land-use change mapping
- correction of the area of pre-1990 forest harvested. In the 2010 submission the total area of pre-1990 planted forest harvested was assumed to be forest remaining forest when some of this area is harvesting as part of a deforestation event. This resulted in New Zealand overestimating emissions in the forest remaining forest category and has now been corrected
- new activity data on organic soils by land-use category, and inclusion in the estimates for the first time of emissions from organic soils using appropriate IPCC default emission factors
- mapping improvements to better distinguish pre-1990-planted forest from post-1989 forest, identify young newly planted post-1989 forest and to update areas of perennial cropland
- revised emission factors for natural forest deforestation. The 2008 submission reported all natural forest deforested against the national average emission factor of 173 t C/ha. For this submission, for natural forest deforestation that occurred during 2008 or 2009, the species composition has been determined using the ECOSAT spatial layer. This spatial layer enables more accurate reporting of the dominant natural forest type, ie, tall forest or shrubland, within the deforested area, resulting in more accurate emission factors. For more information on the ECOSAT layer refer to: http://www.landcareresearch.co.nz/services/informatics/ecosat/about.asp

- new mineral soil stock density estimates for all land-use categories, resulting from the application of a bulk density correction factor, and the incorporation of new annual cropland soil data
- introduction of a New Zealand-specific emission factor for perennial croplands, replacing the previous IPCC default emission factor
- the inclusion of new, disaggregated activity data on dolomite and liming emissions, sourced from Statistics New Zealand
- new biomass burning emission factors and activity data
- the revised reporting of emissions from the decay of below-ground biomass following harvesting events, which was previously reported in the below-ground biomass pool instead of the dead organic matter pool. As this is merely a pool allocation change there are no resulting impacts on total LULUCF emissions or removals
- the impact of these recalculations on net CO_2-e removals in each land-use category is provided in Table 7.1.11. The differences shown are a result of recalculations for all carbon pools used for Climate Change Convention and Kyoto Protocol reporting for the whole time-series for the LULUCF sector. This table only includes recalculations from 1990 to 2008, to enable a comparison of the two approaches
- in this submission, New Zealand has only reported land-use change within the estimated mapping margin of error. New Zealand is currently undertaking an accuracy assessment of the LUCAS mapping programme. However, until it is completed the true mapping margin of error will not be known. For this submission, therefore, land-use changes of less than 100 ha in total for 1990 to 2009 are not reported, given the lack of confidence that these minor areas represent a real change.

Table 7.1.11 Recalculations to New Zealand's net emissions and removals for 1990 and 2008

Land-use category	Net emissions and removals (Gg CO_2-e)				Change in 1990 estimate (%)	Change in 2008 estimate (%)
	2010 submission: 1990 estimate	2011 submission: 1990 estimate	2010 submission: 2008 estimate	2011 submission: 2008 estimate		
Forest land	–32,856.7	–25,344.9	–29,757.9	–32,215.7	22.9	–8.3
Cropland	29.9	395.3	–23.7	338.3	1,220.3	1530.3
Grassland	1,742.4	1,309.1	3,557.0	2,499.9	–24.9	–29.7
Wetlands	0.0	164.7	0.8	8.7	1,497,350.5	946.2
Settlements	6.6	–7.2	20.0	1.6	–209.2	–92.2
Other land	11.5	31.9	26.9	7.2	176.2	–73.4
Total	**–31,066.3**	**–23,451.1**	**–26,176.8**	**–29,360.1**	**24.5**	**–12.2**

Detailed information on the recalculations is provided below in the relevant source-specific recalculations sections, and in chapter 10.

7.1.6 LULUCF planned improvements

Category-specific planned improvements are reported separately under each of the relevant sections of this chapter. The major themes are:

- continuation of data collection programmes
- ground and aerial-based forest stock inventories

- improvements to carbon assessment of planted forests and associated emissions relating to forest management practices
- improvements to land-use mapping
- improvements to soil carbon assessment.

7.2 Representation of land areas

7.2.1 Land-use category definitions

The New Zealand land-use categories and subcategories are shown in Table 7.2.1. The land-use subcategories are consistent with those used for the 2010 submission.

Table 7.2.1 New Zealand's land-use categories and subcategories

IPCC land-use category	New Zealand land-use subcategory
Forest Land	Natural forest
	Pre-1990 planted forest
	Post-1989 forest
Cropland	Cropland – Annual
	Cropland – Perennial
Grassland	Grassland – High producing
	Grassland – Low producing
	Grassland – With woody biomass
Wetlands	Wetlands(1)
Settlements	Settlements
Other land	Other land

Note: (1) Mapped as 'wetlands – open water' and 'wetlands – vegetated non-forest'.

The land-use subcategories were chosen for their conformation with the dominant land-use types in New Zealand, while still enabling reporting under the land-use categories specified in IPCC (2003).

The national thresholds used by New Zealand to define forest land for both Convention and Kyoto Protocol reporting are:

- a minimum area of 1 hectare
- a crown cover of 30 per cent, and
- a minimum height of 5 metres (Ministry for the Environment, 2006).

For this submission, wetlands have been mapped separately as 'open water' and 'vegetated non-forest'. These divisions will be introduced as wetlands subcategories in the 2012 submission. See section 7.6 for details.

The definitions of New Zealand's land-use subcategories, as they have been mapped, are provided in Table 7.2.2.

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

Land-use subcategory	Definition
Natural forest	Areas that on 1 January 1990 were: • tall forest on public conservation land including self-sown exotic trees such as wilding pines and grey willows • short forest or shrubland (with potential to reach ≥ 5 m at maturity (*in situ*) on public conservation land • roads/tracks less than minimum width on public conservation land within the above two categories • tall, non-planted forest (≥ 30 per cent cover) on other (non-public conservation) land • broadleaved hardwood shrubland, manuka/kanuka shrubland and other woody shrubland (≥ 30 per cent cover, with potential to reach ≥ 5 m at maturity *in situ*) on other (non-public conservation) land under current land management • areas of bare ground of any size which were previously forested but cleared due to non-anthropogenic land-use change such as erosion
Pre-1990 planted forest	• radiata pine (*Pinus radiata*), Douglas-fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.), or other planted species (with potential to reach ≥5 metre height at maturity *in situ)* established before 1 January 1990. This includes riparian or erosion control plantings that meet the forest definition • harvested areas within pre-1990 planted forest (assumes these will be replanted, unless deforestation is later detected) • this includes roads/tracks/skid sites/unstocked areas less than minimum area/width of 30 metres within pre-1990 planted forest areas
Post-1989 forest	• includes forests that meet the forest definition and have either been planted or established on or after 1 January 1990 onto land that was non-forest land as at 31 December 1989. Generally, these forests are planted with exotic species, but they may arise from natural regeneration of indigenous tree species as a result of management change after 1 January 1990 • for exotic forest, may include radiata pine (*Pinus radiata*), Douglas-fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.), or other planted species (with the potential to reach ≥5 metres height at maturity *in situ*) • includes harvested areas within post-1989 planted forest (assumes these will be replanted, unless deforestation is later detected) • includes roads/tracks/skid sites/unstocked areas less than a minimum area/width of 30 metres within post-1989 forest areas
Cropland – annual	• all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland
Cropland – perennial	• all orchards and vineyards. • linear shelterbelts associated with perennial cropland.
Grassland – high producing	• grassland with high quality pasture species • mostly in intensive dairy areas with high fertilizer application • includes linear shelterbelts that are smaller than the minimum area/width criteria (Larger shelterbelts are mapped separately as grassland – with woody biomass.)
Grassland – low producing	• low fertility grassland • mostly on hill country • tussock grasslands (eg, *Chionochloa* and *Festuca* spp) • montane herbfields at either an altitude higher than above-timberline vegetation, or where the herbfields are not mixed up with woody vegetation • includes linear shelterbelts that are smaller than the minimum area/width criteria (larger shelterbelts are mapped separately as grassland – with woody biomass) • other areas of limited vegetation cover and significant bare soil
Grassland – with woody biomass	• grassland with tall tree species (<30 per cent cover), such as golf courses in rural areas (and except where the Land Cover Database (LCDB) has classified these as settlements) • grassland with riparian or erosion control plantings (<30 per cent cover)

Land-use subcategory	Definition
	• grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (eg, mahoe (*Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), manuka/kanuka (*Leptospermum scoparium*/*Kunzea ericoides*), manuka/kanuka (*Leptospermum scoparium*/*Kunzea ericoides*) shrubland and other woody shrubland (<5 metres and any per cent cover) where under current management it is expected that the forest criteria will not be met over a 30–40 year time period • above timberline shrubland vegetation and intermixed with montane herbfields (does not have the potential to >5 metres height *in situ*) • linear shelterbelts that meet area/width criteria of 30 metres
Wetlands	• classified and mapped separately as 'wetlands – open water' and 'wetlands – vegetated non-forest' • open water comprises lakes and rivers • vegetated non-forest wetlands comprise herbaceous and/or non-forest woody vegetation that may be periodically flooded. Includes scattered patches of tall tree-like vegetation in the wetland environment where cover <30 per cent • estuarine/tidal areas including mangroves
Settlements	• built-up areas and impervious surfaces • grassland within 'settlements' including recreational areas • urban parkland and open spaces
Other land	• largely bare ground (if not cropland) • montane rock/scree • erosion scars • any other remaining land

Further refinements are planned to improve New Zealand's estimates of land-use change, as stated at the end of this section under planned improvements. Land areas reported as 'converted' and 'remaining' within each land-use category are the best current estimates and will be improved should additional activity data become available.

7.2.2 Land-use mapping

Land-use area

In this submission, the total land area of New Zealand used for all estimates of activity data is 26,925.1 kha. This value 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 2008 (IPCC, 2003, chapter 2.3.2.3). The areas of forest as at 1 January 1990 and 1 January 2009 are based on wall-to-wall mapping of satellite and aircraft remotely sensed imagery taken in, or close to the start of, 1990 and 2008. The area includes improvements made in 2009 using additional satellite imagery, aerial photography and data from New Zealand's Emissions Trading Scheme (NZ ETS). Land-use changes during 2009 are then interpolated from other sources. This is described in further detail under the *Land-use change during 2009* section.

Land-use mapping – 1 January 1990

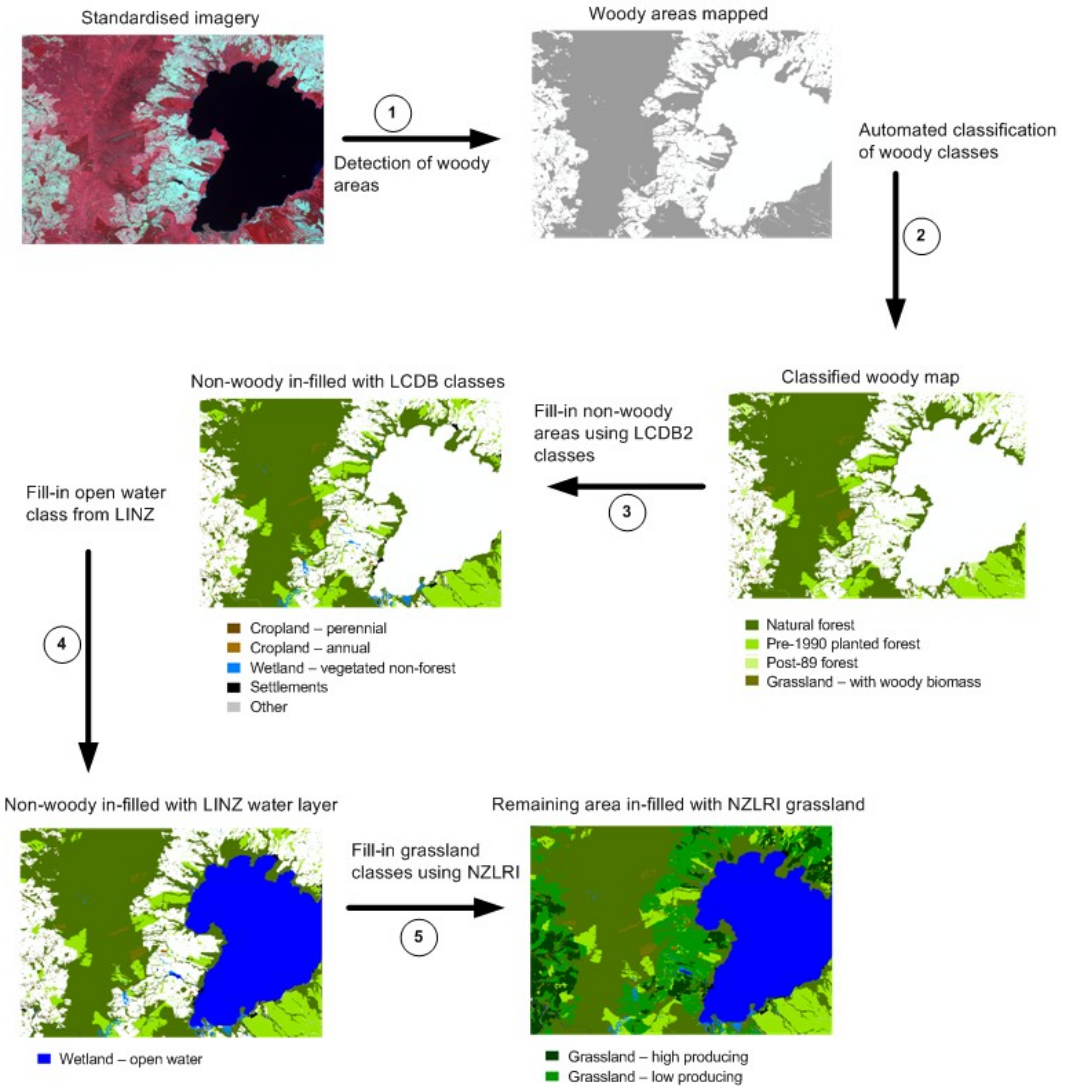
The 1990 land-use map is derived from 30-metre spatial resolution Landsat 4 and Landsat 5 satellite imagery taken in, or close to, 1990. The first of the images used were taken in November 1988 and the last in February 1993. In addition to orthorectification and atmospheric correction, the satellite images were standardised for spectral reflectance using the Ecosat algorithms documented in Dymond et al (2001), Shepherd and Dymond (2003) and Dymond and Shepherd (2004). These standardised images were used for the automated mapping of woody biomass, and then used to map woody biomass classes into the land-use subcategories being used for reporting. These land-use subcategories at 1990 included natural forest, pre-1990 planted forest and grassland with woody biomass.

This classification process was validated and improved using 15-metre resolution Landsat 7 ETM+ imagery acquired in 2000–2001, and SPOT 2 and 3 data acquired in 1996–1997. The use of this higher-resolution imagery (coupled with the use of concurrent aerial photography) enabled more certain land-use mapping decisions to be made. A detailed description of this mapping process is provided in chapter 11, section 11.2.2.

To determine the spatial location of the other land-use categories and subcategories as at 1990 and 2008, information from two Land Cover Databases, LCDB1 (1996) and LCDB2 (2001) (Thompson et al, 2004), the New Zealand Land Resource Inventory (NZLRI) (Eyles, 1977) and hydrological data from Land Information New Zealand (a government agency) have been used (Shepherd and Newsome, 2009a, b).

The NZLRI database was used to better define the area of high- and low-producing grassland. Areas tagged as ‘improved pasture’ in the NZLRI vegetation records were classified as grassland – high producing in the land-use maps. All other areas were classified as grassland – low producing. Figure 7.2.1 illustrates this mapping process.

Figure 7.2.1 New Zealand's land-use mapping process



An interpretation guide for automated and visual interpretation was prepared and used to ensure a consistent basis for all mapping processes (Dougherty et al, 2009). 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 what land use the point fell within. The two operators were in agreement at least 95 per cent of the time. This is described in more detail in GNS Science (2009).

Land-use mapping – 1 January 2008

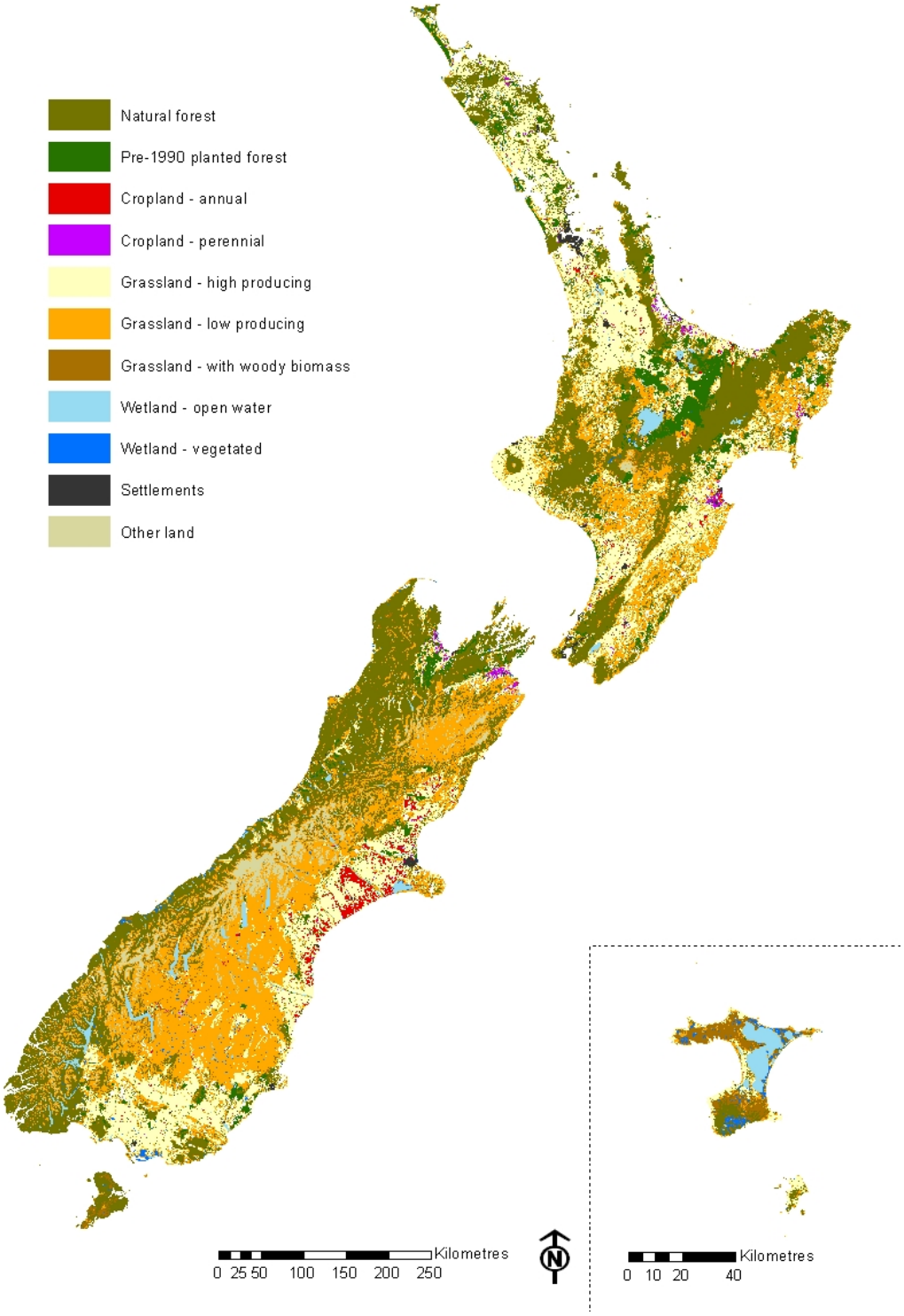
The 2008 land-use map (land use as at 1 January 2008) is derived from 10-metre spatial resolution SPOT 5 satellite imagery and was processed into standardised reflectance images, using the same approach as for the 1990 imagery. The SPOT 5 imagery was taken over the summers of 2006–07 and 2007–08 (November to April), to establish a national set of cloud-free imagery. Where the SPOT 5 imagery pre-dates 1 January 2008, a combination of aerial photography, Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery and field verification has been used to identify where deforestation has occurred to ensure that the 2008 land-use map is as accurate as possible.

Land-use mapping – 2008 and 2009

Updates to the 2008 land-use map (land use at 1 January 2008) made for the calendar years 2008 and 2009 have been derived from DMC (Disaster Monitoring Constellation) 22-metre resolution satellite imagery. This imagery, acquired between December 2009 and May 2010 has been used to map land-use change from all forest subcategories during 2008 and 2009. Land-use change from other land-use categories has been estimated from a variety of sources (see section "Land-use change").

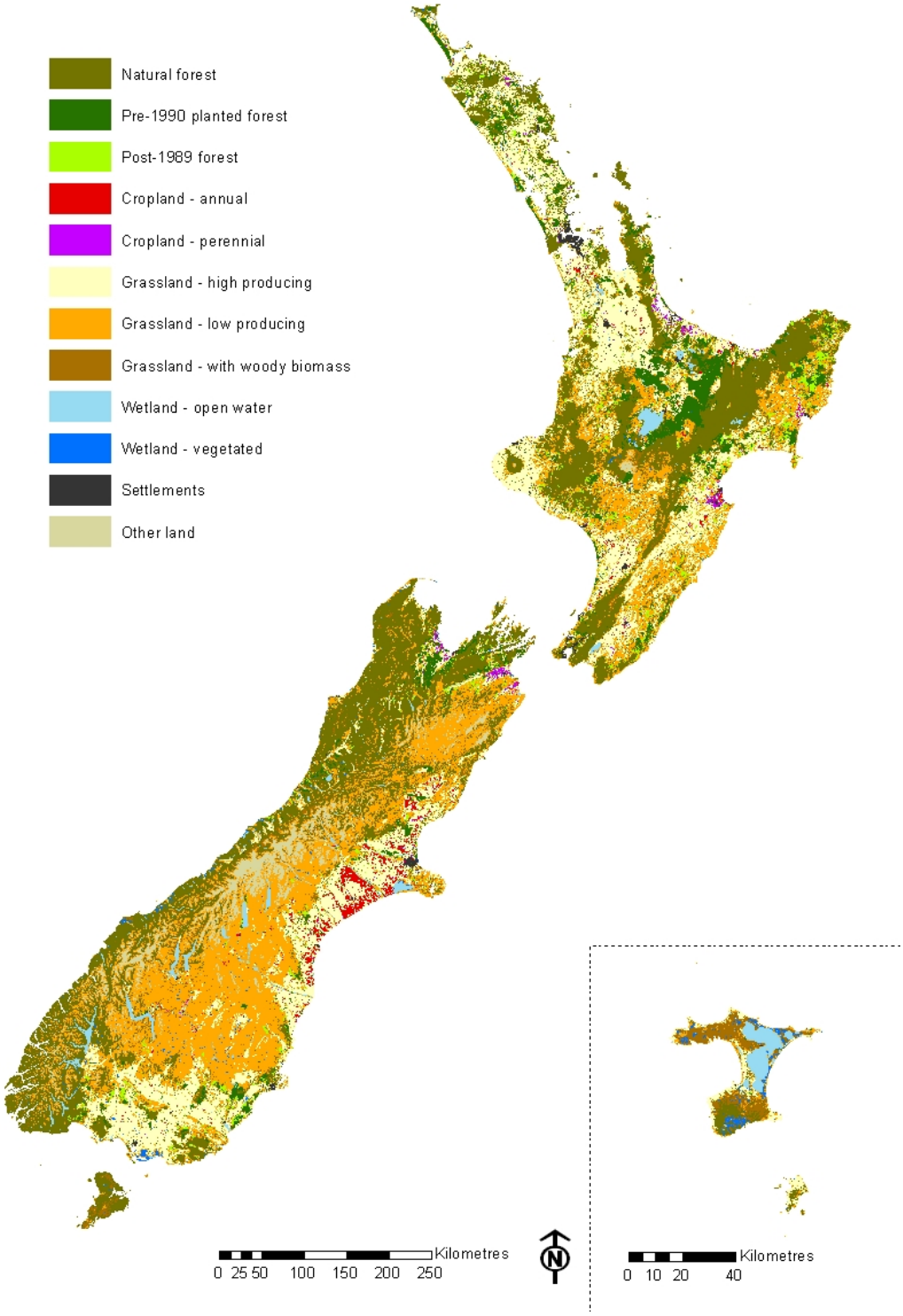
A list of the land-use categories and subcategories used to map land use and land-use change from 1990 to 2009 is provided in Table 7.2.1. Maps showing the land use in New Zealand as at 1 January 1990 and 31 December 2009 are shown in Figures 7.2.2 and 7.2.3.

Figure 7.2.2 Land-use map of New Zealand as at 1 January 1990



Note: The insert map is of the Chatham Islands, which lie approximately 660 km south-east of the Wairarapa coast, or 800 km due east of Banks Peninsula.

Figure 7.2.3 Land-use map of New Zealand as at 31 December 2009



Note: The insert map is of the Chatham Islands, which lie approximately 660 km south-east of the Wairarapa coast, or 800 km due east of Banks Peninsula.

Mapping of deforestation 2008–2009

New Zealand has used a combination of data sources to identify the location and timing of deforestation after 1 January 2008. Land-use data generated from classification of SPOT 5 satellite imagery acquired between November 2006 and April 2008 was compared with DMC (Disaster Monitoring Constellation) satellite imagery acquired in 2009/10 summer in conjunction with some field verification. From this, temporarily destocked land and land converted from a forest land use to a non-forest land use was identified. Evidential information to confirm land-use change was collected using higher-resolution aerial photography and field visits. This is illustrated in Figure 7.2.4.

Areas of possible deforestation were confirmed using oblique aerial photography. Supporting information from regional councils, Ministry of Agriculture and Forestry district offices and forestry consultants was also consulted to see if deforestation or restocking could be confirmed.

Areas of forest destocking which were unable to be confirmed as either harvesting or deforestation, were flagged for tracking for four years from the date of clearing. Those areas which are not replanted within four years will be deemed to be deforested at the clearing date.

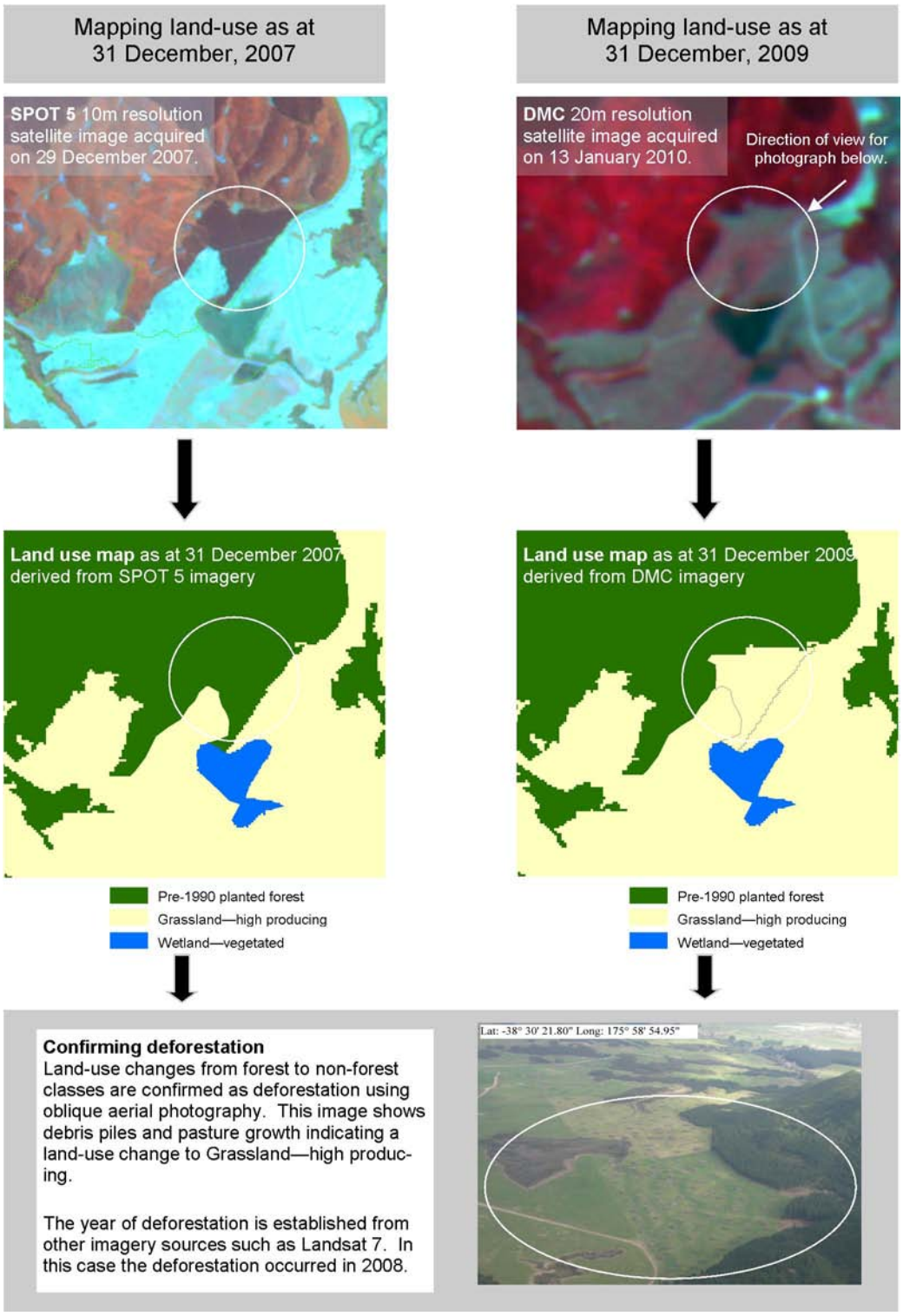
Estimation of harvesting 2008–2009

The estimate of the total area of planted forest harvested each year between 1990 and 2009 is based on the harvested area reported in the *National Exotic Forest Description*, a survey conducted by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2010). This data source is used to ensure a consistent approach is applied from 1990 to 2008 and throughout the commitment period. Data for the year ending 31 December 2009 was not available so a combination of roundwood statistics (the volume of roundwood harvested, also produced by the Ministry of Agriculture and Forestry) and the ratio of roundwood volume to area harvested over the five-year period 2003–2008 was used to estimate the area harvested in 2009 from the volume of roundwood produced. The harvesting values for 2009 will be updated in next year's submission when finalised planted forest data for 2009 becomes available.

The total area harvested was 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 of Agriculture and Forestry, as outlined above) and the amount of post-1989 forest harvesting estimated
- *Post-1989 forest:* There is no published information available for the area of post-1989 forest harvesting in New Zealand, but most post-1989 forest harvesting is of eucalypt species for the supply of pulp for export, or to local pulp and paper mills. Experts in the various regions where eucalypts are commercially grown were contacted and asked about the level of harvesting they believed was occurring. Where possible, these expert opinions were corroborated with publically available information from companies' websites and various other reports
- *Natural forest:* In 2009, 0.05 per cent of New Zealand's total forest timber production was from the harvesting of natural forests (Ministry of Agriculture and Forestry, 2009c).

Figure 7.2.4 New Zealand's identification of deforestation



7.2.3 Land-use change

Land-use change during 2008 and 2009

With the exceptions of deforestation and post-1989 afforestation, land-use change during 2008 and 2009 has been extrapolated based on the change which occurred during the period 1990–-2008. Deforestation for 2008 and 2009 has been mapped, and post-1989 afforestation has been based on data from the *National Exotic Forest Description* as at 1 April 2009 (Ministry of Agriculture and Forestry, 2010). These data for 2009 are still provisional and will be updated for the 2012 submission. All other land-use activity data during this period is extrapolated from the change which occurred during the period 1990–2008.

Land-use change from 1990 to 2009

Land-use change from 1990 to 2009 is based on:

- mapped land-use change from 1 January 1990 to 1 January 2008
- mapped deforestation occurring in 2008 and 2009
- afforestation in 2008 and 2009, estimated from the *National Exotic Forest Description* as at 1 April 2009 (Ministry of Agriculture and Forestry, 2010)
- estimates of the age profile of deforested forests from the *2008 Deforestation Survey* (Manley, 2009) and unpublished work by Scion (the NZ Forest Research Institute). The work by Scion is referred to in Wakelin, 2008
- all other 2008 and 2009 land-use change is extrapolated from pre-2008 trends.

Table 7.2.3 shows a land-use change matrix for the years 1990 to 2009 using the 1990 and 2009 land-use maps, and activity data on land-use change during 2009 from the Ministry of Agriculture and Forestry.

Prominent land-use changes between 1990 and 2009 include:

- forest establishment of 606,706 hectares (classified as post-1989 forest) that has mostly occurred on land that was previously grassland, primarily low-producing grassland. Approximately 15,500 hectares of this post-1989 forest has subsequently been deforested
- deforestation of 98,668 hectares. This includes the 15,500 ha of post-1989 forest mentioned above. This deforestation has occurred mainly since 2004. Between 1990 and 2004 there was very little deforestation in New Zealand, due to market conditions.

Table 7.2.4 shows a land-use change matrix, for the period 31 December 2008 to 31 December 2009.

Table 7.2.3 New Zealand's land-use change matrix from 1990 to 2009

2009 \ 1990		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2009 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,095.7											8,095.7
	Pre-1990 planted	19.0	1,426.9										1,445.9
	Post-1989						107.1	354.4	125.0			4.8	591.2
Cropland	Annual				331.4		2.4	1.0					334.8
	Perennial		0.3		4.4	76.9	18.0	2.1	0.1				101.8
Grassland	High producing	9.1	43.8			0.3	5,726.4		16.6	0.3			5,796.5
	Low producing	21.0	4.5					7,613.6	31.7			0.4	7,671.2
	With woody biomass	2.6	0.3			0.3	8.8	27.2	1,094.1			1.4	1,134.6
Wetlands	Wetlands									652.8			652.8
Settlements	Settlements	0.1	0.4			0.2	2.2	0.7	0.2		203.3		207.0
Other land	Other land	0.9	0.2				0.2					892.3	893.7
Area as at 1 Jan 1990 (kha)		8,148.4	1,476.3	–	335.8	77.7	5,865.1	7,998.9	1,267.7	653.1	203.3	898.9	26,925.1
Net change 1 Jan 1990–31 Dec 2009		–52.7	–30.4	591.2	–1.0	24.1	–68.5	–327.7	–133.1	–0.3	3.7	–5.2	0.0
Net change 1990–2009 (%)		–0.65%	–2.06%	N/A	–0.30%	30.96%	–1.17%	–4.10%	–10.50%	–0.04%	1.84%	–0.58%	NA

Notes: Units in 000's hectares. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 ha, however, areas are mapped to 1 ha resolution. Blank cells indicate no land-use change during the period greater than 100 ha. Land-use change areas do not include deforestation of post-1989 forest since 1990 (15,503 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 point in time indicated (31 December for 2008 and 2009, 1 January for 1990.) Columns and rows may not total due to rounding.

Table 7.2.4 New Zealand's land-use change matrix from 2008 to 2009

2009 \ 2008		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2009 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,095.7											8,095.7
	Pre-1990 planted		1,445.9										1,445.9
	Post-1989			587.2			0.7	2.3	0.9			0.0	591.2
Cropland	Annual				334.6		0.1	0.0					334.8
	Perennial				0.2	100.5	0.9	0.1	0.0				101.8
Grassland	High producing	0.1	0.1	0.1		0.0	5,795.4		0.8	0.0			5,796.5
	Low producing	0.4	0.3	0.7				7,668.2	1.6			0.0	7,671.2
	With woody biomass					0.0	0.4	1.4	1,132.7			0.1	1,134.6
Wetlands	Wetlands									652.8			652.8
Settlements	Settlements					0.0	0.1	0.0	0.0		206.9		207.0
Other land	Other land						0.0					893.6	893.7
Net area as at 31 Dec 2008 (kha)		8,096.1	1,446.3	587.9	334.9	100.6	5,797.7	7,672.1	1,136.1	652.8	206.9	893.8	26,925.1
Net change 31 Dec 2008–31 Dec 2009		–0.5	–0.4	3.3	–0.1	1.2	–1.1	–0.9	–1.5	0.0	0.2	–0.1	0.0
Net change 2008–2009 (%)		–0.01%	–0.03%	0.56%	–0.02%	1.18%	–0.02%	–0.01%	–0.13%	0.00%	0.08%	–0.01%	NA

Notes: Units in 000's hectares. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 ha, however, areas are mapped to 1 ha resolution. Blank cells indicate no land-use change during the period greater than 100 ha. Land-use change areas do not include deforestation of post-1989 forest since 1990 (15,503 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 point in time indicated (31 December for 2008 and 2009, 1 January for 1990.) Columns and rows may not total due to rounding.

7.2.4 Methodological change

The total land area of New Zealand used in this submission is 26,925.1 kha. This is an increase of 103.5 kha (3.9 per cent) on the total area used in the calculation of estimates for the 2010 submission, of 26,821.6 kha. The difference arises from the inclusion of remote, offshore islands which were not accounted for in the previous submission. This means that the total area of New Zealand in this submission is the same as that derived from the official coastal and offshore island boundaries provided by Land Information New Zealand, the official government agency responsible for cadastral mapping in New Zealand (www.linz.govt.nz).

Of the additional area included in the 2011 submission, 66.6 kha is accounted for by the Auckland Islands and Campbell Island. These remote uninhabited sub-Antarctic islands are located over 400 km south of New Zealand, and are protected for conservation purposes. Their predominant land cover is grassland, and they are not subject to cultivation or land-use change.

Estimating land-use change prior to 1990

New Zealand's 2010 LULUCF submission assumed that all land was in a steady state at 1990. A consequence of this was land-use changes that occurred prior to 1990 were not reported as 'land in transition', and the associated carbon changes weren't accurately reflected.

This assumption is not consistent with international IPCC good practice guidance, which requires identification of land in a conversion state as at 1990 (IPCC, 2006c, Vol 4, chapter 3, page 9). New Zealand has therefore developed and applied a procedure for estimating land use and land-use change back to 1962 (28 years prior to 1990, equivalent to one rotation of a *Pinus radiata* exotic plantation forest).

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 analysis undertaken by New Zealand to determine land-use area data prior to 1990 includes:

- data for each land-use subcategory assembled from best-available sources for years from 1962 to 1989
- land-use area data estimated on an annual basis, derived from a mix of direct (time-dated) sources, and time trends
- data totals which are national in character but which are allocated between the North and South Islands
- estimates of what land uses have changed to what other land uses, through the whole period, on an annual basis.

To determine land-use change trends, the proportion of land converted to another land use was estimated using constraint-based solutions and expert opinion.

The land-use data and methodology to determine land use prior to 1990 has been peer-reviewed by Landcare Research Ltd (Hunter and McNeill, 2010), who provided independent subject-matter expertise. This review examined:

- the data sources, and included identifying new sources where appropriate
- land-use cover data and methods of determining them, including annual values and temporal trends
- assumptions, data, rules and constraints, and the methods used to apportion land-use change tends
- overall suitability and robustness of the approach.

The review also provided recommendations for enhancing the quality of land-use data and estimates of land use in transition, including an assessment of 'cost-benefits'; and expert commentary on the data and methodology undertaken against the five general principles of IPCC good practice guidance (transparency, accuracy, completeness, comparability and consistency).

The review detected no source of bias arising from the choice of methods or data sources used to estimate land use and change prior to 1990, and judged the land-use and change estimates to be fair, with no evident tendency to report over or under.

However, the review identified a number of areas where improvements could be made to the backcasting estimates, focused mainly on improving the data time-series for non-key categories. New Zealand will be addressing the peer-review findings over subsequent inventories, addressing priority findings first.

Table 7.2.5 New Zealand's land-use change matrix from 1962 to 1989

1989 \ 1962		Forest land			Grassland			Cropland		Wetlands	Settlements	Other land	Net area 1 Jan 1962
		Natural	Pre-1990 Planted	Post-1989	With woody biomass	High producing	Low producing	Perennial	Annual				
Forest land	Natural	8,089.9			58.5								8,689.0
	Pre-1990 planted	215.4	427.5		564.3		269.1						427.5
	Post-1989			NA									NA
Grassland	With woody biomass	23.0			1,047.3		200.2						2,209.3
	High producing	47.1			482.6	4,797.1	374.4	16.6	73.3	63.5			4,830.5
	Low producing	293.9			50.2	0.0	7,662.2						8,516.1
Cropland	Perennial					5.1	2.5	69.0	1.1				88.6
	Annual					21.5	5.1	1.4	307.8				382.8
Wetlands		14.4								638.7			702.2
Settlements		5.4			6.4	6.8	2.5	1.5	0.6		180.0		180.0
Other land												899.0	899.0
Area as at 31 Dec 1989		8148.4	1476.3	NA	1270.6	5854.6	8006.3	77.7	335.8	653.0	203.3	899.0	26,925.1
Net change 1962 – 1989		–540.6	833.4		–938.8	887.1	–803.7	11.9	46.9	–63.5	23.3	0.0	
% Change 1962 – 1989		–6.6%	56.5%		–73.9%	15.2%	–10.0%	15.3%	14.0%	7.5%	11.5%	0.0	

Notes: Units in 000's hectares. Blank cells indicate where no land-use change has been estimated during the period.

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 2009 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. One of the planned improvements for the activity data is to perform an accuracy assessment and determine the uncertainty for the woody biomass categories mapped under LUCAS. The levels of uncertainty for non-woody classes (±6.0 per cent) and for natural forest (±4.0 per cent) are similar to what was reported in previous submissions because the same data sources have been used.

7.2.6 Source-specific QA/QC and verification

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, consistent with GPG-LULUCF and New Zealand's inventory quality-control and quality-assurance plan. Data quality and data assurance plans are established for each type of data used to determine carbon stock and stock changes, as well as for the mapping of the areal extent and spatial location of land-use changes.

The 1990 and 2008 land-use mapping data have been checked to determine the level of consistency in satellite image classification to the requirements set out in the *Guide to Mapping Woody Land-use classes Using Satellite Imagery* (Dougherty et al, 2009). Through this process, approximately 28,000 randomly selected points in the 1990 and 2008 woody classes were evaluated by independent assessors. From this exercise, 91 per cent of the time, independent assessors agreed with the original classification. Where there was disagreement, the points were recorded in a register and this has been used as the basis for preparing the improvement plan described in this report. The process does not determine errors of omission/commission that would provide an accuracy assessment and definitive level of uncertainty. (An error of commission is where a particular class has been mapped incorrectly, eg, as a result of similarities in spectral signatures; an error of omission error is where mapping has failed to detect a particular land use, eg, a planted forest block visible in imagery.)

Each mapping improvement activity carried out on the 1990 and 2008 maps has been subject to quality assurance to ensure accuracy and consistency. Quality-assurance strategies have been tailored to each improvement activity, usually including a combination of random sampling of updated areas and analysis of the changes in land-use areas.

During 2010, data from the New Zealand Emissions Trading Scheme (NZ ETS) was reconciled with the 1 January 2008 land-use map. The NZ ETS data contains post-1989 forest boundaries as submitted by forest owners and verified by the New Zealand Ministry of Agriculture and Forestry (MAF). The NZ ETS post-1989 forest areas were checked against the 2008 land-use map. Where missing forests were identified, these areas were assessed against satellite imagery and the LUCAS land-use definition for post-1989 forest to determine whether they should be added to the 2008 land-use map. After integration, quality-assurance checks were performed to ensure that updates to the 2008 land-use map were accurate and complete.

Quality assurance of the 2008 and 2009 deforestation mapping was a multi-stage process. The contractor undertook initial quality assurance by cross-checking operator interpretation of harvesting/deforestation events in satellite imagery. Key areas of

deforestation were then field checked using oblique aerial photography acquired from light aircraft. Finally, all areas of mapped deforestation were visually checked by LUCAS analysts to verify both the deforestation decision and the original mapped land use.

The approach used to implement quality-assurance processes is documented in the LUCAS Data Quality Framework (PricewaterhouseCoopers, 2008).

7.2.7 Source-specific planned improvements

The quality-control and quality-assurance process followed during mapping exposed a number of limitations in the mapping method. Future improvements to both the 1990 and 2008 maps will focus on these areas:

- the mapping of 1990 land use presented challenges, particularly in identifying newly established exotic forests using Landsat satellite imagery. Where trees are planted within three years of the image acquisition date, they (and their surrounding vegetation) are unlikely to show a distinguishable spectral signature on 30-metre resolution imagery. For LUCAS mapping, this situation is compounded by the lack of ancillary data to support land-use classification decisions at 1990. Land-use mapping will continually be updated and improved with information from the NZ ETS. The Ministry of Agriculture and Forestry is administering the forestry component of the NZ ETS and applicants to the scheme are providing new land-management and land-use information as at 1990
- the Ministry of Agriculture and Forestry administers a number of other funds to encourage forest planting and preservation. Spatial data from the Afforestation Grants Scheme, the Permanent Forest Sink Initiative and the East Coast Forestry Project will also be used to improve the accuracy of forest mapping in the 1990 and 2008 land-use maps.

At the end of the first commitment period New Zealand will create a 2012 land-use map using high-resolution satellite data as the key source of information. This mapping will be used to make comparisons with the 2008 land-use map (prepared using similar high-resolution imagery) to improve the spatial determination of harvesting, deforestation and land-use changes between 1 January 2008 and 31 December 2012.

7.3 Forest land (CRF 5A)

7.3.1 Description

In New Zealand's *Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006), national forest definition parameters were specified as required by UNFCCC Decision 16/CMP.1. The New Zealand parameters are a minimum area of 1 hectare, a height of 5 metres and a minimum crown cover of 30 per cent. Where the height and canopy cover parameters are not met at the time of mapping, the land has been classified as forest land where the land-management practice/s and local site conditions (including climate) are such that the forest parameters will be met.

New Zealand also uses a minimum forest width of 30 metres from canopy-edge to canopy-edge. This removes linear shelterbelts from the forest land category. The width and height of linear shelterbelts can vary as they are trimmed and topped from time to time. Further, they form part of non-forest land uses, namely cropland and grassland (as shelter to crops and/or animals).

New Zealand has adopted the definition of managed forest land as provided in GPG-LULUCF: "Forest management is the process of planning and implementing practices for stewardship and use of the forest aimed at fulfilling relevant ecological, economic and social functions of the forest". Accordingly, all of New Zealand's forests, both those planted for timber production and natural forests managed for conservation values, are considered managed forests.

Forest land is the most significant contributor to carbon stock changes in the LULUCF sector. Forests cover 37.6 per cent (around 10 million hectares) of New Zealand. In 2009, forest land contributed 29,559.4 Gg CO_2-e of net removals. This value includes removals from the growth of pre-1990 planted forests and post-1989 forests, and emissions from the conversion of land to planted forest, harvesting, deforestation and fire. Net removals from forest land have increased by 4214.5 Gg CO_2-e (16.6 per cent) on the 1990 level of 25,344.9 Gg CO_2-e (Table 7.3.1).

In 2009, forest land remaining forest land and conversion to forest land were key categories (trend and level assessment).

Table 7.3.1 New Zealand's land-use change within the forest land category in 1990 and 2009, and associated CO_2-e emissions

Forest land land-use category	Net area in 1990 (ha)	Net area in 2009 (ha)	Change from 1990 (%)	Net emissions/ removals (Gg CO_2-e) 1990	2009	Change from 1990 (%)
Forest land remaining forest land	8,734,197	9,149,311	4.8	–4,438.7	2,033.4	145.8
Land converted to forest land	902,625	983,411	9.0	–20,906.3	–31,592.8	51.1
Total	**9,636,822**	**10,132,722**	**5.1**	**–25,344.9**	**–29,559.4**	**16.6**

Notes: 1990 and 2009 areas are as at 31 December. Net area values include land in a state of conversion (due to land-use change prior to 1990) and afforestation and deforestation since 1990. Net removals/emission estimates are for the whole year indicated.

For UNFCCC and Kyoto Protocol reporting, New Zealand has subdivided its forest land into three forest land subcategories: natural forest (predominantly native forest pre-dating 1990), pre-1990 planted forest, and post-1989 forest (all forest established after 31 December 1989).

Table 7.3.2 shows land-use change by forest subcategory since 1990, and the associated CO_2 emissions and removals from carbon stock change alone.

Table 7.3.2 New Zealand's land-use change within forest land subcategories in 1990 to 2009, and associated CO_2 emissions from carbon stock change

Forest land land-use category	Net area in 1990 (ha)	Net area in 2009 (ha)	Change from 1990 (%)	Net emissions/ removals (Gg CO_2 only) 1990	2009	Change from 1990 (%)
Natural forest[(1)]	8,145,503	8,095,651	0.6	61.6	0.0	NA
Pre-1990 planted forest	1,477,363	1,445,869	2.1	–25,604.0	–11,952.5	53.3
Post-1989 forest	13,955	591,202	4,136.5	184.6	–17,625.8	9,646.1
Total	**9,636,822**	**10,132,722**	**5.1**	**–25,357.8**	**–29,578.3**	**16.6**

Notes: 1990 and 2009 areas are as at 31 December. Net area values include land in a state of conversion (due to land-use change prior to 1990) and afforestation and deforestation since 1990. Net removals/emission estimates are for the whole year indicated.

Table 7.3.3 shows New Zealand's carbon stock change by carbon pool within the forest land category from 1990 to 2009. From 1990 to 2009, the total carbon stock stored in forest land had increased by 161,592.3 Gg C, equivalent to removals of 592,274.1 Gg CO_2 by forest land since 1990.

Table 7.3.3 New Zealand's net carbon stock change by carbon pool within the forest land category from 1990 to 2009

Forest land subcategory	Net carbon stock change 1990-2009 (Gg C)				Emissions/ removals 1990–2009 (Gg CO_2)
	Living Biomass	Dead organic matter	Soils	Total	
Natural Forest[(1)]	NA	NA	–180.5	–180.5	661.8
Pre-1990 Planted Forest	97,468.5	17,525.1	–5,254.6	109,739.0	–402,376.5
Post-1989 Forest	43,813.7	14,216.4	–6,059.4	51,970.7	–190,559.4
Total	**141,282.2**	**31,741.5**	**–11,494.4**	**161,529.3**	**–592,274.1**

Note: NA – not applicable. (1) At the national scale, natural forest is assumed to be at steady state. The soil organic carbon loss indicated is the result of land conversions to natural forest prior to 1990.

Natural forest

Natural forest is the term used to distinguish New Zealand's native and unplanted (self-sown or naturally regenerated) forests that existed prior to 1990 from pre-1990 planted and post-1989 forests. The category includes both mature forest and areas of regenerating vegetation that have the potential to return to forest under the management regime that existed in 1990. Natural forest ecosystems comprise a range of indigenous and some naturalised exotic species. In New Zealand, two principal types of natural forest exist: beech forests (mainly *Nothofagus* species) and podocarp/broadleaf forests. In addition, a wide range of seral plant communities fit into the natural forest category if they have the potential to succeed to forest *in situ*. Currently, New Zealand has an estimated 8.1 million hectares of natural forest (including these successional communities).

In 2009, 0.05 per cent of New Zealand's total forest timber production was from harvesting of natural forests, as New Zealand's wood needs are now almost exclusively met from planted production forests (Ministry of Agriculture and Forestry, 2009c). No timber is legally harvested from New Zealand's publicly owned natural forests (an area approximately 5.5 million hectares in size). Most other harvesting of natural forests is required by law to be undertaken on a sustainable basis. The only natural forest harvesting that is not required by law to be on a sustainable basis is the harvesting of forests on land returned to Māori under the South Island Landless Natives Act 1906. These forests are currently exempt from provisions that apply to all other privately owned natural forests that require a sustainable forest management plan or permit before any harvesting. Approximately 57,500 hectares are covered by the South Island Landless Natives Act 1906. A survey of this land was completed in 1999; this indicated that 17,300 hectares of this land was natural forest available for harvest (Ministry of Agriculture and Forestry, 2011).

Harvesting under the sustainable forest plans and permits is restricted to the removal of growth and sometimes takes place on a selective logging basis. This means the area from where trees are extracted still meets the forest definition chosen by New Zealand. Therefore, over the long term, the carbon stored in these forests is in steady state.

Carbon stock change in natural forest remaining natural forest is not estimated, as while we now have some evidence that natural forests are not in steady state, they are a sink, we

require the full set of plot re-measurement data to quantify carbon stock changes. The small reduction in total soil organic carbon stocks since 1990, reported in Table 7.3.3, is due to land conversions to natural forest prior to 1990. The emissions associated with the conversion of natural forest to other land uses are reported in the land-use category the land was converted to.

Pre-1990 planted forest

New Zealand has a substantial estate of planted forests created specifically for timber supply purposes. In 2009, pre-1990 planted forests covered an estimated 1.45 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 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 have relatively standard silviculture regimes applied.

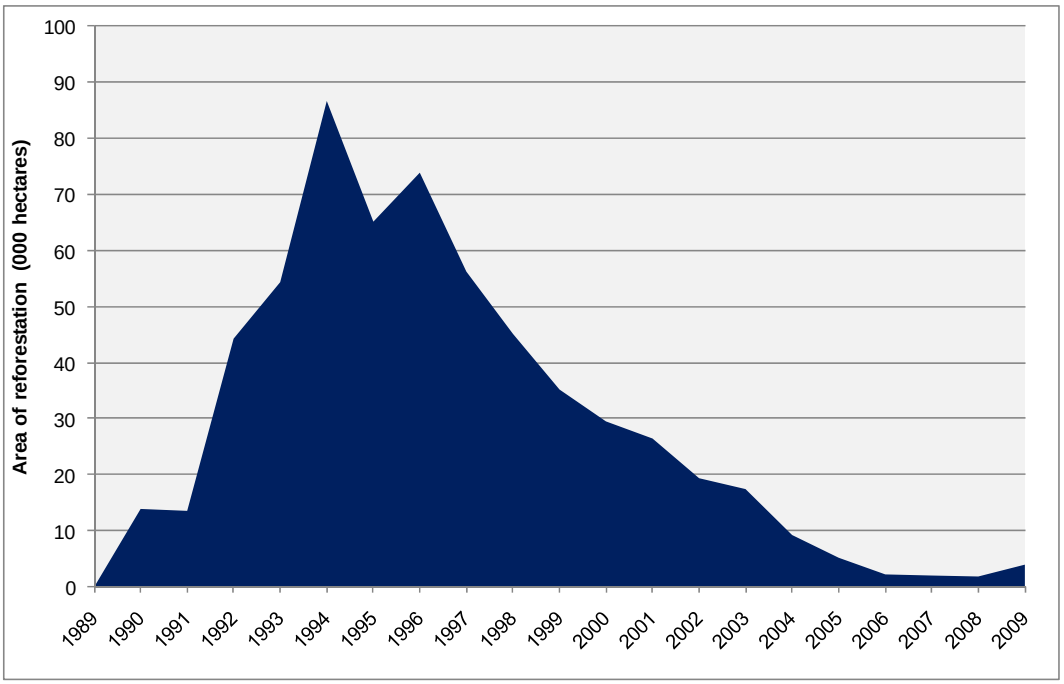
Post-1989 forest

Between 1 January 1990 and 31 December 2009, the net area of forest established as a result of reforestation activities was 591,202 hectares (taking account of deforestation). Based on the plots measured, 95 per cent of this forest subcategory comprises planted tree species (Paul et al, 2009), with the remaining area comprising regenerating native tree species. *Pinus radiata* comprises 89 per cent of the planted tree species in this forest subcategory, with Douglas-fir (*Pseudotsuga menziesii*) and *Eucalyptus* species being the two species making up most of the remainder (Ministry of Agriculture and Forestry, 2010).

The new forest planting rate (land reforested) between 1990 and 2009 was, on average, 30,000 hectares per year (Figure 7.3.1). New planting rates were high from 1992 to 1998 (averaging 61,000 hectares per year). This followed a change in the taxation regime, an unprecedented price spike for forest products with subsequent favourable publicity, a government focus on forestry as an instrument for regional development, and the conclusion of the state forest assets sale (Rhodes and Novis, 2002). The removal of agricultural subsidies and generally poor performance of the New Zealand and international share market also encouraged investors to seek alternatives (Rhodes and Novis, 2002).

Since 1998, the rate of new planting declined rapidly, reaching a low of 1900 hectares in 2008. In 2009, the new planting rate increased, and it was estimated that 4000 hectares of new plantation forest were established (Ministry of Agriculture and Forestry, 2009a).

Figure 7.3.1 Annual areas of afforestation/reforestation in New Zealand from 1990 to 2009

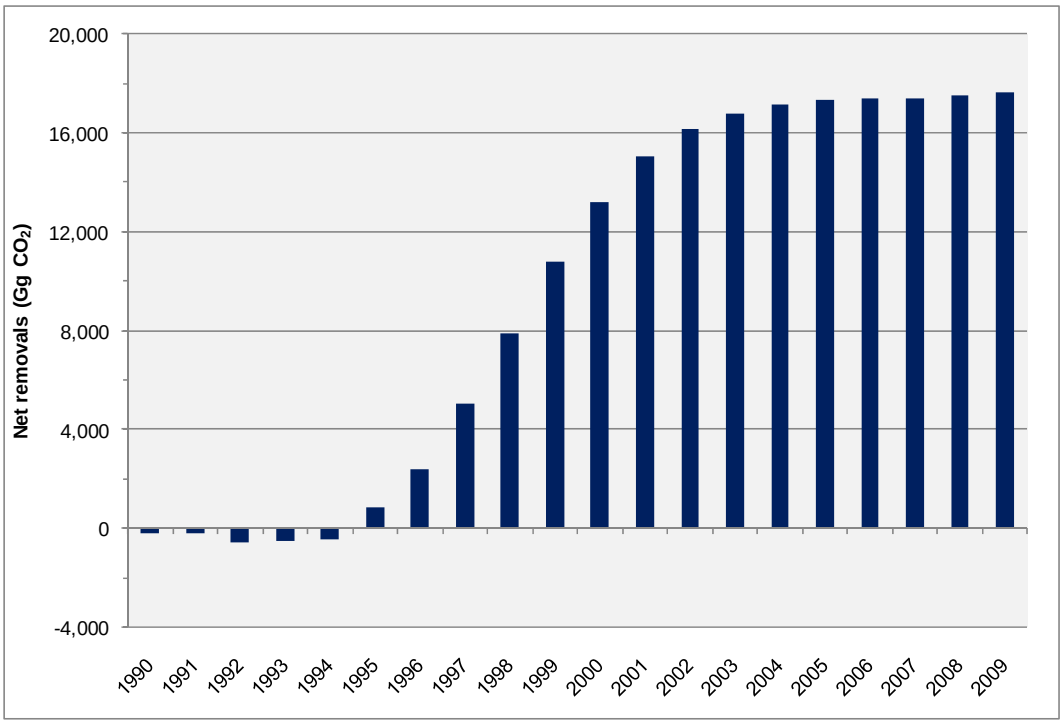


Note: Annual planting estimates are derived from annual surveys of forest nurseries, as published in the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2009a) and have been scaled downwards using a ratio derived from the LUCAS mapping of post-1989 forest area.

The area of new planting is slowly increasing with the introduction of the NZ ETS, Permanent Forest Sinks Initiative and Afforestation Grant Scheme that have been introduced since 2007 by the New Zealand Government to encourage new planting and regeneration of natural species (Ministry of Agriculture and Forestry, 2009b).

The trend in removals is shown in Figure 7.3.2. This graph shows that the post-1989 forests did not become a net sink until 1995. This was due to the emissions from loss of biomass carbon stocks associated with the previous land use and the change (loss) of soil carbon with a land-use change to forestry, outweighing removals by forest growth.

Figure 7.3.2 New Zealand's net CO_2 removals by post-1989 forests from 1990 to 2009



Deforestation

In 2009, 1644 hectares of forest land were converted to other land uses, primarily grassland. Table 7.3.4 below shows the areas of forest land subject to deforestation in 2009, and since 1990. The land uses that forest land has been converted to following deforestation are shown in Tables 7.2.3 and 7.2.4 in section 7.2 – representation of land areas.

Table 7.3.4 New Zealand's forest land subject to deforestation

Forest land subcategory	Area of forest in 1990 (hectares)	Deforestation since 1990		Deforestation in 2009	
		Area (hectares)	Proportion of 1990 area (%)	Area (hectares)	Proportion of 1990 area (%)
Natural forest	8,148,377	33,715	0.45	462	0.01
Pre-1990 planted forest	1,476,307	49,450	3.35	449	0.03
Post-1989 forest	0	15,503	NA	734	NA
Total	**9,624,684**	**98,668**	**1.05**	**1,644**	**0.02**

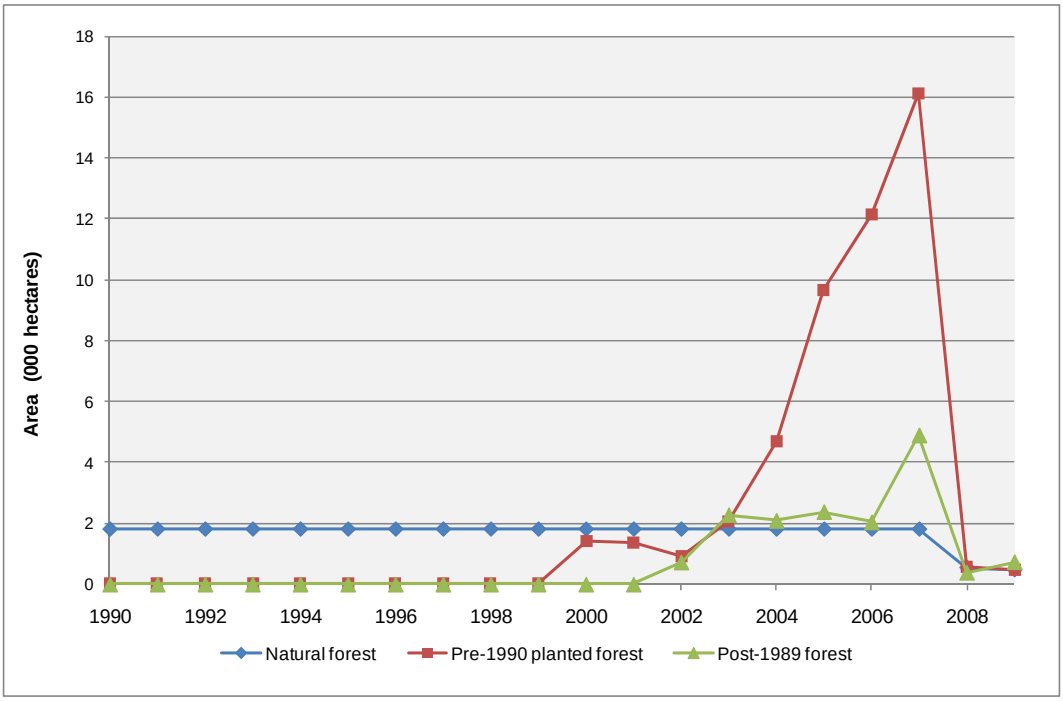
Notes: 2009 areas as at 31 December 2009, 1990 areas as at 1 January 1990, and therefore differ from 1990 area values in the common reporting format tables, which are at 31 December 1990.

The conversion of forest land to grassland is due in part to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry.

Figure 7.3.3 illustrates the trends in the net emissions associated with deforestation since 1990. This shows the increase in the planted forest deforestation that occurred leading up to 2008, and decrease after the introduction of the NZ ETS in 2008.

During the remainder of the first Kyoto Protocol commitment period (2008–2012), it is expected that the level of planted forest deforestation will continue to be less than seen prior to 2008 (Manley, 2009).

Figure 7.3.3 New Zealand's net CO_2 emissions from deforestation since 1990, by forest subcategory



The rate of natural forest deforestation has also decreased since 2007. A number of factors suggest that the rate of natural forest deforestation is unlikely to have been constant over the 18-year period between 1990 and 2007, but instead mostly occurred prior to 2002. The area available for harvesting (and potentially deforestation) was higher before amendments were made to the Forests Act 1949 in 1993. Further restrictions to the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand in 2002. Both of these developments are likely to have reduced natural forest deforestation since 2002. The reduced rate of natural forest deforestation has been confirmed for 2008 and 2009 through satellite image mapping of deforestation (see Figure 7.2.4 in section 7.2 – representation of land areas).

New Zealand assumes instant emissions of all biomass carbon at the time of deforestation, and soil carbon changes are modelled over a 20-year time period (refer to the previous section 7.1.3 – soils). This approach is adopted because:

- the majority of deforestation since 2000 has resulted from land converted to high-producing grassland, resulting in the rapid removal of all biomass as the land is prepared for intensive dairy farming (see Figure 7.2.4)
- it is not practical to estimate the volume of residues left on site after the deforestation activity, given the rapid conversion from one land use to another. Further estimating any residue biomass carbon pools and decay rates is difficult and costly
- there is insufficient data prior to 2008 to estimate deforestation biomass residue coming into the first commitment period. If a different approach was adopted for deforestation before and after 2008, this might not meet GPG-LULUCF.

These deforestation emissions are reported in the relevant 'land converted to' category, as are all emissions from land-use change. See section 11.1 of chapter 11 for further information on deforestation.

7.3.2 Methodological issues

Forest land remaining forest land

Only natural forest and pre-1990 planted forest are described in this section because land in the post-1989 forest subcategory is included in the 'land converted to forest land' category. Land is transferred to the 'land remaining' category after a conversion period of 28 years. New Zealand has chosen 28 years as the time taken for land to reach a state of equilibrium (or maturity) under its new land use, as this is the average age at which planted forests are harvested (Ministry of Agriculture and Forestry, 2008a). Land areas converted to post-1989 forest have been in that land use for a maximum of 19 years in 2009.

Land-use change occurring in the forest land remaining forest land category was detected in the previous submission (2010 submission). This was natural forest which had been cleared and re-planted with exotic plantation forest. The area subject to this change has been reported as natural forest conversion to pre-1990 planted forest in this submission for the first time. The carbon stocks and changes for each of these subcategories have been adjusted to reflect this change.

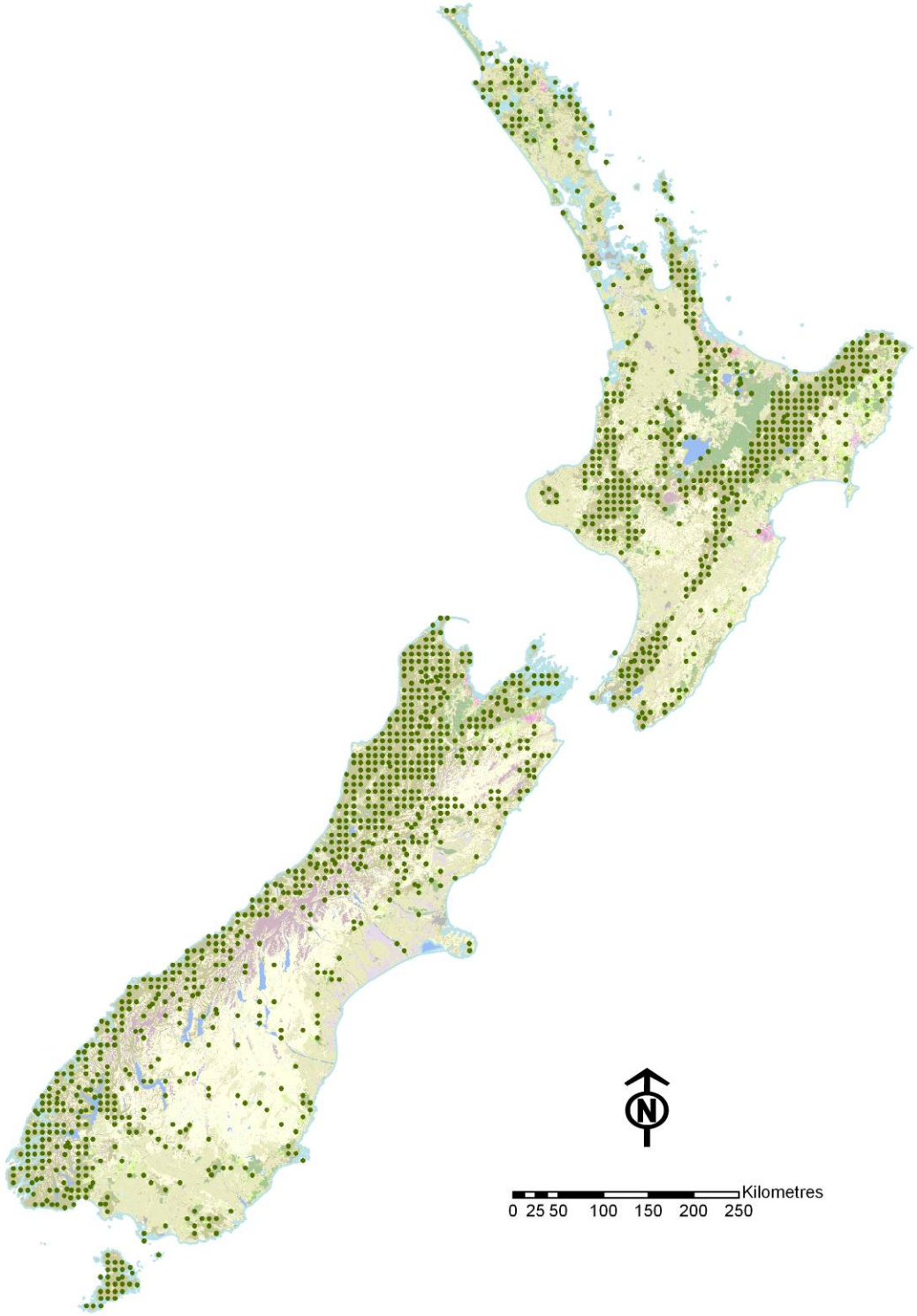
New Zealand has established a sampling framework for forest inventory purposes based on a grid system established across the country. The grid has a randomly selected origin and provides an unbiased framework for establishing plots for field and/or LiDAR measurements. The grid is an 8-kilometre grid with divisions on a 4-kilometre grid being used for measurement of post-1989 forest areas. Pre-1990 planted forests were sampled in 2010 and the results from the analysis of the data collected will provide, for the first time, a plot-based estimate of carbon stock within this forest subcategory. This plot-based estimate will be included in the 2012 submission (see section 7.3.6 for more information on this planned improvement).

Natural forest

A national monitoring programme to enable unbiased estimates of carbon stock and change for New Zealand's natural forests was developed between 1998 and 2001 (see Goulding et al, 2001). There were 1255 permanent plots installed systematically on the 8-kilometre grid across New Zealand's natural forests and first measured between 2002 and 2007.

The plots were sampled using a method designed specifically for the purpose of calculating carbon stocks (Payton and Moss, 2001; Payton et al, 2004). As the plot network is re-measured, the data collected will be suitable for determining if New Zealand's natural forests are carbon neutral (as assumed in this submission), or whether they are a net source of emissions or a sink for carbon. Where possible, the network incorporated plots that had been previously established, and re-measured them during the establishment phase of the national network to enable an initial assessment of forest changes over time. Figure 7.3.4 shows the distribution of the carbon monitoring plots throughout New Zealand.

Figure 7.3.4 Location of New Zealand's natural forest carbon monitoring plots



Re-measurement of the national plot network has begun. The re-measurement programme will run from 2009–2013 following methodology revised for this purpose (Payton and Brandon, 2010). Once field work has been completed and the data has been quality-assured and analysed, national carbon estimates will be updated for the 2012 inventory (to be submitted in 2014).

At each plot, data is collected to calculate the volumes of trees, shrubs and dead organic matter present. These measurements are then used to estimate the carbon stocks for the following biomass pools:

- living biomass (comprising above-ground biomass and below-ground biomass)
- dead organic matter (comprising dead wood and litter).

Table 7.3.5 summarises the method used to calculate the carbon stock in each biomass pool from the information collected at each plot.

Table 7.3.5 Summary of methods used to calculate New Zealand's natural forest biomass carbon stock from plot data

Pool		Method	Source
Living biomass	Above-ground biomass	Allometric equations (Beets et al, 2008b)	Plot measurements; method (Beets et al, 2009)
	Below-ground biomass	Assumed to be 20 per cent of total biomass	Coomes et al, 2002
Dead organic matter	Dead wood	Allometric equations (Beets et al, 2008a; Beets et al, 2008b)	Plot measurements; method (Beets et al, 2009)
	Litter	Laboratory analysis of samples collected at plots. (Garrett et al, 2009)	Plot measurements; method (Beets et al, 2009)

Living biomass

Living biomass is separated into two carbon pools:

- above-ground biomass: the carbon content of individual trees and shrubs is calculated using species-specific allometric relationships between diameter, height and wood density (for trees), a non-specific conversion factor with diameter and height (for tree ferns), or volume and biomass (for shrubs). 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 studies that report root to total biomass ratios of 9 to 33 per cent (discussed in Coomes et al, 2002). Coomes et al (2002) acknowledge more work is needed but use the average of the cited studies to justify allocating 20 per cent of total biomass to below-ground biomass.

Dead organic matter

Dead organic matter is separated into two 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 d diameter > 10 cm

- litter: the carbon content of the fine debris is calculated by laboratory analysis of sampled material. Litter comprises fine woody debris (FWD) (dead wood from 2.5 to 10 cm diameter) and the litter (all material <2.5 cm diameter) and the fermented humic (FH) horizons. Samples were taken at approximately one-third of the natural forest plots.

Biomass carbon stocks in New Zealand's natural forests (excluding the soils pool) of 173 (±6) t C ha^{-1} were estimated from the first full round of measurements (Beets et al, 2009) and those data are used for this report. The subset of plots for historic data that exist were separately analysed to estimate the change. Thirteen per cent of the natural forest LUCAS plots were used in the analysis, which found that natural forests in New Zealand were a net carbon sink between 1990 and 2004 (Beets et al, 2009). Until the entire plot network has been re-measured, New Zealand will continue to report natural forests remaining natural forests as carbon neutral and therefore no removals or emissions are estimated in this submission.

Soil organic carbon

Soil organic carbon stocks in natural forest land remaining natural forest land are estimated using a Tier 2 method that uses New Zealand-specific land-use and soil pedon data for mineral soils, as described in section 7.1.3. The mineral soil carbon stock density at equilibrium state is estimated to be 92.04 t C ha^{-1} with a standard error of 3.66 (Table 7.1.6).

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 (GPG-LULUCF section 3.2.1.3). In New Zealand, natural forests are not drained, and therefore oxidation processes associated with drainage are not occurring. It is therefore assumed that there are no carbon emissions from organic soils in natural forest remaining natural forest.

Natural forest carbon

Total carbon stocks in natural forest are determined by combining the biomass and soil carbon pools (of 173 t C ha^{-1} and 92.04 t C ha^{-1} respectively) to give a mean of 284.85 t C ha^{-1}. The mean value is then multiplied by the area of natural forest land remaining natural forest land to give a national total.

Pre-1990 planted forest

Living biomass and dead organic matter

Pre-1990 planted forests were sampled in 2010 and the results from the analysis of the data collected will provide, for the first time, a plot-based estimate of carbon stock within this forest subcategory. This plot-based estimate will be included in the 2012 submission. Currently, New Zealand uses a Tier 2 method to estimate biomass carbon for pre-1990 planted forest. This involves:

- data from the annual National Exotic Forest Description surveys
- stem wood volume yield tables, compiled periodically for combinations of species, silvicultural regime and location
- the C_Change model (see Beets et al, 1999 for more details on this model), which is used to derive forest biomass and carbon by pool from stem volume yield tables.

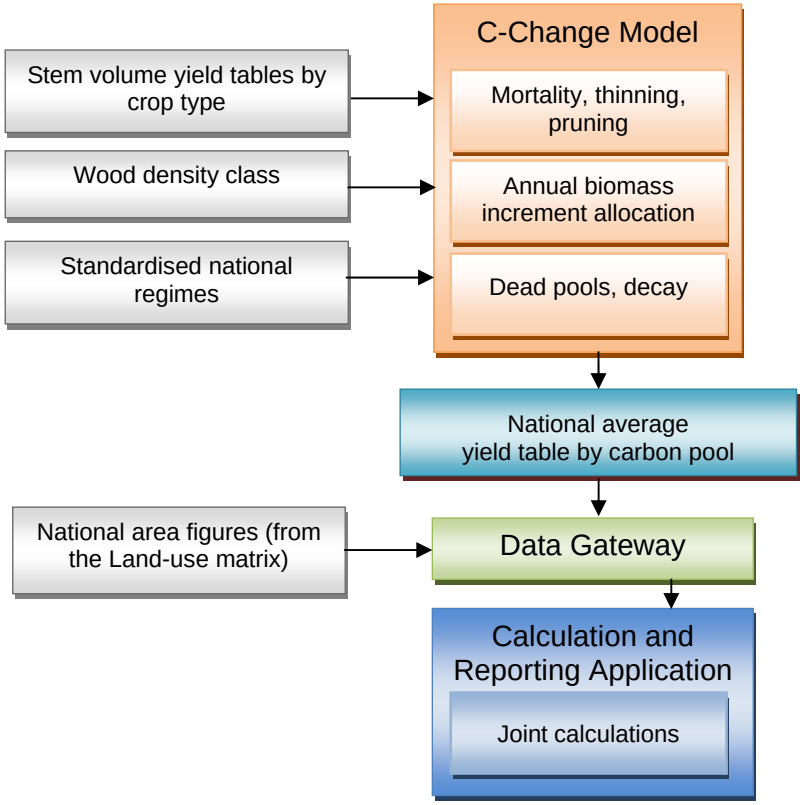
This method is essentially the same as used in the 2010 submission. The process is illustrated in Figure 7.3.5. The methodological differences between the 2010 submission and this submission are described below:

- New Zealand has revised the reporting of emissions from the decay of below-ground biomass following harvesting events. These harvest residues were previously reported in the below-ground biomass pool instead of the dead organic matter pool. As this is simply a pool allocation change there are no resulting impacts on total LULUCF emissions or removals
- the introduction of 'backcasting' to identify historical land-use changes between 1962 and 1990 and hence identify planted forest "in transition" in 1990.

Inputs to the C_Change model include the *National Exotic Forest Description* stem volume yield tables, wood density classes for regions and species, and silvicultural regime details. The C_Change model is used to:

- derive stem wood biomass increment from volume increment and wood density
- apply an increment expansion factor to convert this to total biomass fixed
- partition the total biomass to live biomass pools
- calculate transfers from live to dead pools from mortality functions and regime details (ie, pruning/thinning)
- apply decay functions to estimate dry-matter loss from dead pools within rotation.

Figure 7.3.5 New Zealand's pre-1990 planted forest inventory modelling process



The planted forest modelling process is expanded upon under *Modelling and LiDAR double sampling* in the section below on land converted to forest. More detail on the joint calculations is given in Annex 3.2.

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 default for organic soils, as described in section 7.1.3 – soils. The mineral soil carbon stock density in pre-1990 planted forests at equilibrium state is estimated to be 88.96 t C ha^{-1}, with a standard error of ±5.45 (Table 7.1.6). The IPCC default emission factor for organic soils under planted forest is 0.68 t C ha^{-1} per annum. Soil carbon change with harvesting is not explicitly estimated, as the long-term soil carbon stock for this land use includes any emissions associated with harvesting.

Non-CO_2 emissions

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 category 'direct soils emissions'.

Biomass burning

There are no emissions reported for controlled burning in forest land remaining forest land in New Zealand as this practice is not common and there is currently no data available on this activity (Wakelin et al, 2009). However, investigations are underway to source controlled burning data in forest land remaining forest land. The inventory reports only emissions resulting from wildfire for this category, and reports the notation key NE ('not estimated') for emissions from controlled burning in the common reporting format tables. New Zealand estimates non-CO_2 emissions from wildfire using:

- the IPCC default temperate forest fuel consumption rate of 45 per cent of total biomass (GPG-LULUCF Table 3A.1.12, IPCC, 2003)
- wildfire activity data for April 1991 to March 2010. This data is collected and managed by the New Zealand Fire Service and the National Rural Fire Authority. The average over the period is then applied back to earlier years where no data is available. Activity data for wildfire is generally poor quality, but it is believed that there have not been major changes in wildfire occurrence since 1990 (N Challands, New Zealand Fire Service, pers comm; Wakelin et al, 2009).

Carbon dioxide emissions from wildfire in planted forest are captured by the stock change calculation at the time of harvest, as there is no reduction in carbon stock for areas burnt prior to harvesting or deforestation. Therefore, carbon dioxide emissions may be underestimated or overestimated using this approach. However, the total area of wildfires in planted forest is small and this is not regarded as a significant source of error.

Land converted to forest land

Post-1989 forests

All land converted to forest land since 1990, either by planting or as a result of human-induced changes in land-management practice (eg, removing grazing stock and allowing revegetation of tree species), is included in the subcategory post-1989 forests.

Survey data

As the majority of post-1989 forests are privately owned, field access to the forests has not been guaranteed and a double-sampling approach involving airborne scanning LiDAR

(with digital aerial photography) and ground-based measurements has been used (Stephens et al, 2007; Stephens et al, 2008; Beets et al, 2010). This approach has allowed corrections to be made for unexpected loss of access to some field plots while simultaneously improving precision.

The double-sampling approach being used by New Zealand follows that described by Parker and Evans (2004) and Corona and Fattorini (2008), where LiDAR and conventional plot field measurements are used for the forest inventory. Double sampling (or two-phase sampling) involves field and LiDAR data of permanent sample plots (PSPs). All plots are sampled by LiDAR and a sub-sample of the plots are measured in the field. A multiple linear regression between derived LiDAR metrics and plot carbon (Stephens et al, 2007; Kimberley et al, 2009) is then established. Standard double-sampling regression estimator procedures are then used to obtain an estimate of the average carbon stock per hectare and carbon in each biomass pool for the post-1989 forest estate with known precision (Kimberley et al, 2009).

The steps used in the inventory for post-1989 forests and to determine the average level of carbon per hectare for the PSPs are briefly described and are shown in Figure 7.3.5. The key steps involved in determining carbon per pool for post-1989 forests include the following.

- identification of the plots on the 4-kilometre grid that fell in post-1989 forest and seeking approval for field teams to access land (see Figure 7.3.7)
- training field and audit teams in the use of the post-1989 forest data collection manual (Payton et al, 2008) and in the use of the PSP data storing and checking software used in hand-held instruments. At each 4-kilometre grid point where a field plot was measured, four circular plots were established. The centre plot was 0.06 hectares in area and the other three were 0.04 hectares in area. While plots larger than 0.04 hectares were shown not to decrease the variance between plots (Moore and Goulding 2005), the 0.06 hectare plot was chosen for the central plot because this was deemed optimal for use with LiDAR
- collecting and storing tree, dead wood, litter and soil fertility measurements on plots. Soil fertility measurements are made to help predict wood density (Beets et al, 2007a)
- acquiring airborne-scanning LiDAR and digital aerial photography measurements made of plots on a 4-kilometre grid (Stephens et al, 2007; Stephens et al, 2008). LiDAR data was acquired for at least three points m^2 and the photography had a spatial resolution of 20 centimetres. The LiDAR and photography swath width was 170 metres
- estimating total carbon per plot and per biomass pool using the 'Forest Carbon Predictor' (FCP) model (Kimberley and Beets, 2008). More information on this modelling system is provided in the modelling and LiDAR double-sampling section
- deriving LiDAR metrics per plot (vegetation height percentile, crown volume and canopy skewness – Stephens et al, 2007) and then determining multiple linear regression between metrics and carbon estimates (Kimberley et al, 2009)
- determining the average carbon content (t C ha^{-1}) for all plots on the 4-kilometre grid, using a LiDAR-based, double-sampling regression estimator. This value provides the carbon stock, as at 1 January 2008, for post-1989 forests (Kimberley et al, 2009).

Figure 7.3.6 New Zealand's approach used to inventory post-1989 forests and estimate the average carbon stock per pool for the plots within the forest

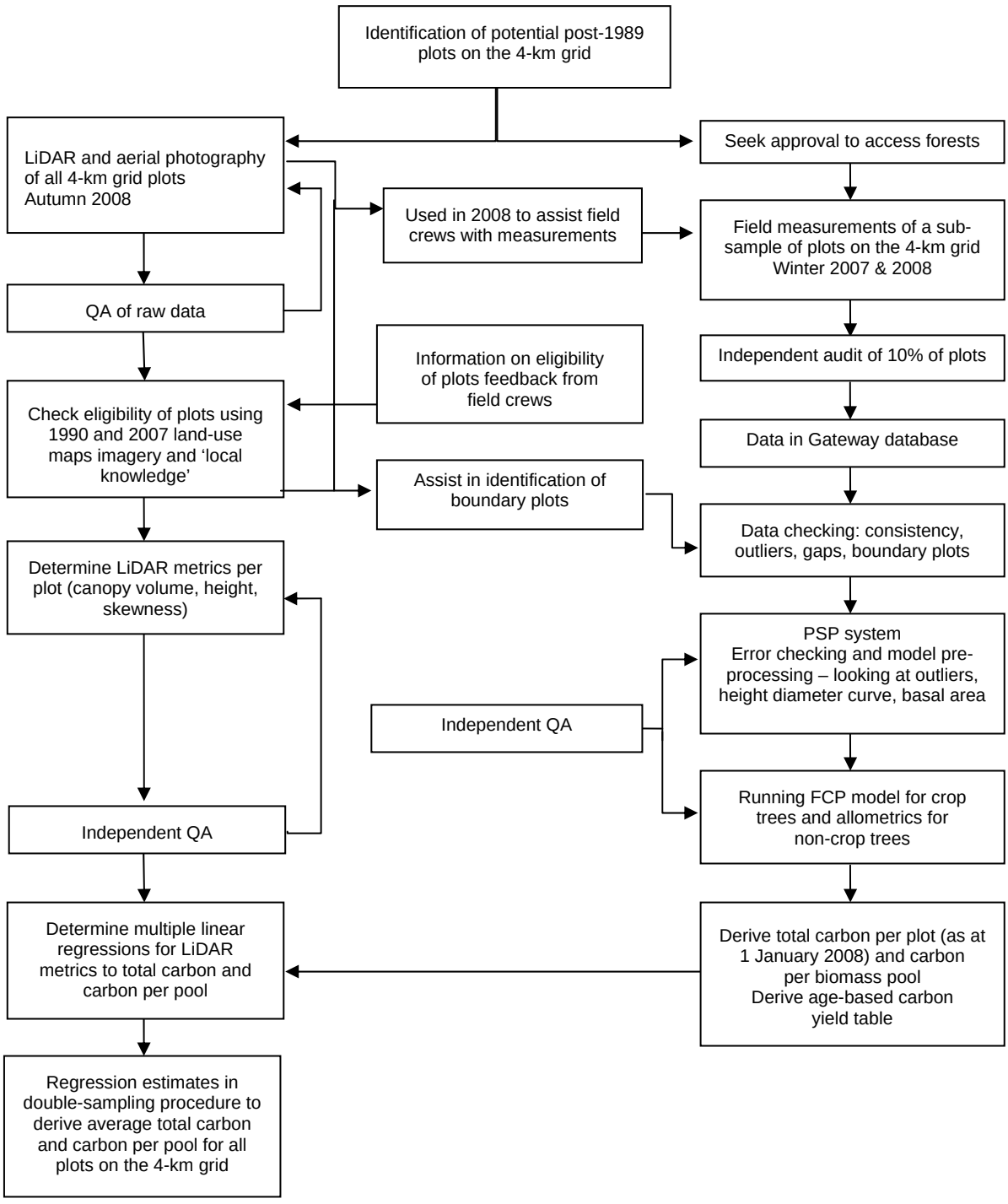
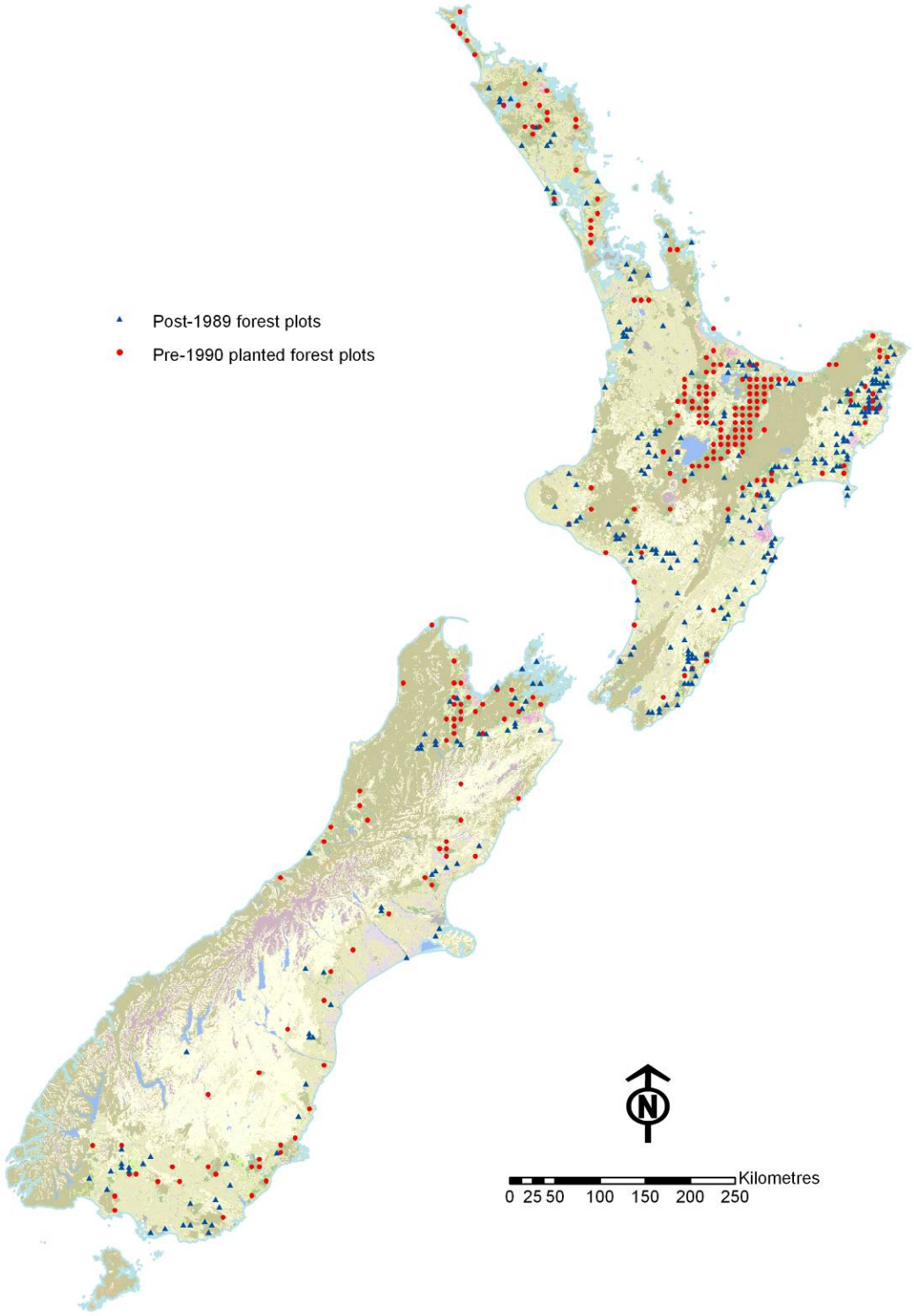


Figure 7.3.7 Location of New Zealand's pre-1990 planted forest and post-1989 forest plots



Quality assurance and quality control

Quality-assurance and quality-control (QA/QC) activities were conducted throughout the post-1989 forest data capture and processing steps. These QA/QC activities are indicated in Figure 7.3.6, and were associated with the following: acquisition of raw LiDAR data and LiDAR processing; checking eligibility of plots; audits of field plot measurements; data processing and modelling; and regression analysis and double-sampling procedures (Brack, 2009); and investigating LiDAR and ground plot co-location (Brack, 2010). These activities are described more fully in section 7.3.4.

Modelling and LiDAR double sampling

The plot data collected was modelled using a forest carbon modelling system called the 'Forest Carbon Predictor', version 2.2 (FCPv2.2) (Kimberley and Beets, 2008). This integrates the 300 Index Growth model (Kimberley et al, 2005), a wood density model (Beets et al, 2007a), and the C_Change model (Beets et al, 1999), to enable predictions of carbon stocks and changes in New Zealand's planted forests. The individual components of the Forest Carbon Predictor are explained below.

The 300 Index Growth Model produces a productivity index for forest plots derived from stand parameters. Stand parameters gathered from the national planted forest plot network are input into the 300 Index. These include: stand age, mean top height, basal area, stocking, and stand silvicultural history. The 300 Index uses 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 used to estimate the total live and dead stem volume by annual increment. The 300 Index accounts for past and future silviculture treatments using plot data and assumptions of future management events based on standard regimes. The 300 Index is designed so that the productivity index conforms to the basal area and mean top height taken at the time of measurement. A nationally appropriate volume equation is then applied to be consistent with actual stem volume from planting to harvesting age (Kimberley et al, 2005).

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 inputted into the wood density model, temperature and stand age have the greatest influence on wood density, followed by site fertility and stocking. The influence of the individual effects on wood density is provided in Table 7.3.6. The combined result of these individual effects can be large. For example, the 15-year growth sheath of a stand of standard genetics *Pinus radiata*, at a low stocking (200 stems ha^{-1}) on a fertile (C/N=12), cool (8°C) site has a predicted wood density of 339 kg m^{-3}, while a stand of the same age and genetics at a high stocking (500 stems ha^{-1}) on a moderately fertile (C/N=25), warm (16°C) site has a predicted wood density of 467 kg m^{-3} (Beets et al, 2007a).

Table 7.3.6 Influence of individual site and management factors on predicted wood density for New Zealand planted forest

Factor affecting wood density	Range in predicted density (kg m^{-3})	(% 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 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 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 Forest Carbon Predictor summarises the outputs from C_Change into estimates of above ground biomass, below ground biomass, dead wood, and litter (four of the five Good Practice Guidance (GPG) pools (IPCC 2003) collectively in an area-weighted and age-based carbon yield table.

More information on the C_Change and 300 Index models can be found in Beets et al, 1999 and Kimberley et al, 2005.

Analysis by Paul and Kimberley (2009) has demonstrated that using the FCPv2.2 for all planted forest tree species produces an average t C ha^{-1} value little different to using more specific carbon models/allometric equations for the non-radiata species (mainly Douglas-fir (*Pseudotsuga menziesii*) and eucalypts (*Eucalyptus* spp.)). They established there was a marginal decrease (0.77 t C ha^{-1}) in the average amount of carbon removals per plot using the model for all planted forest species. A correction factor for the growth trajectory of Douglas-fir in the 300 Index is to be implemented in the 2012 submission and New Zealand is investigating reporting of the post-1989 forest and pre-1990 planted forest subcategories by species.

Good relationships were found between carbon pools estimated using ground-based tree measurements and carbon modelling using FCPv2.2 with airborne-scanning LiDAR metrics for the post-1989 forests. The best fitting LiDAR metric for predicting total carbon was a height metric (the 30 per cent height percentile), but significant variation was also explained by a canopy cover metric (namely, per cent cover). A regression model explaining 74 per cent of the variation in total carbon was developed using these two LiDAR metrics. Beets et al (*in press* (b)) established strong relationships between LiDAR data and ground-based measurements of leaf area index, biomass carbon stocks, and annual carbon sequestration in radiata pine plots selected across a range of micro-sites that differed in mean height and basal area. In this study, involving 36 plots independent of post-1989 or pre-1990 planted forest plots, LiDAR metrics explained between 80–97 per cent of the variation in cumulative leaf area index, depending on the canopy depth examined, and the LiDAR data also explained 86 per cent of the variation in above-ground biomass carbon.

Regression models using the same model form were also fitted for each of the four biomass pools, providing good predictions for above-ground biomass carbon (R^2=81 per cent and below-ground biomass carbon (R^2=80 per cent), but less successful predictions for litter carbon (R^2=38 per cent) and dead wood carbon (R^2=21 per cent) (Kimberley et al, 2009). The R^2 for a regression between the best LiDAR metric, 95th height percentile, and mean top height calculated from ground measurement was 96 per cent, with a root mean square error of 1.09 metres. Given this relationship, it has been assumed that the LiDAR and ground data have been well co-located.

These regression models were used to obtain estimates, as at 1 January 2008, of the national level of carbon stock in the post-1989 forests using double-sampling procedures, and to develop a national age-based and area-weighted carbon yield table for the resource. Carbon estimates from 246 ground plots were supplemented with LiDAR data

from 46 additional plots. The regression estimators (using the LiDAR data) improved precision by 6 per cent compared with the ground-based estimates. The carbon stock estimate from using LiDAR and double sampling is 88.21 ± 2.76 t C ha^{-1} (at the 95 per cent confidence interval) and the comparable value from just the field measured plot data is 88.46 ± 2.94 t C ha^{-1} (Kimberley et al, 2009). This carbon stock estimate, while high, is consistent with the international comparisons provided in Table 3A.1.4 (GPG-LULUCF, IPCC, 2003), and reflects the composition of the forest made up of 95 per cent actively managed production forestry. The average age of post-1989 forest trees as at 1 January 2009 is 13 years.

Living biomass

The living biomass pool is separated into two pools.

- above-ground biomass: the carbon content of plantation crop trees and shrubs under crop trees is estimated using the FCPv2.2 model as described above. For shrubs and non-crop tree species measured within the plot network, the carbon content is estimated using species-specific allometric equations that enable carbon to be determined from diameter, height and wood density (for trees) (Paul et al, 2009). When non-forest land is converted to forest land, all living biomass that was present at the time of forest establishment is instantly emitted as part of the forest land preparation. Between 1990 and 2008, approximately 30 per cent of the non-forest land converted to post-1989 forest has been from grassland with woody biomass, and this land-use subcategory provides the largest source of emissions associated with land-use change to forestry
- below-ground biomass: this is derived from the above-ground biomass estimates. For plantation crop trees, the above- to below-ground biomass ratio is 0.2 (Beets et al, 2007b). The ratio for non-crop trees and shrubs is 0.25 (Coomes et al, 2002).

Dead organic matter

The dead organic matter carbon pools are separated into two pools.

- dead wood: the carbon content of the dead wood pool is estimated using the FCPv2.2 model as described above. Immediately following harvesting, 30 per cent of the above-ground biomass pool is transferred to the dead wood pool, with the other 70 per cent being instantaneously emitted. All material in this pool is decayed over a 20-year period
- litter: the carbon content of the litter pool in post-1989 forests is estimated using the FCPv2.2 model.

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 default for organic soils, as described in section 7.1.3. There is not a specific post-1989 forest value as the number of data points in this land type is small and, as this forest is only 19 years old (at a maximum), it is not considered to have reached steady state. As 95 per cent of post-1989 forests are planted forest, the planted forest value of 88.96 t C ha^{-1} has been used instead.

In the absence of country and land-use specific data on the time rate of change, the IPCC default method of a linear change over a 20-year period is used to estimate the change in soil organic carbon stocks between the original land use and planted forest land for any given period. For example, the soil carbon change associated with a land-use change from

low-producing grassland (soil carbon stock 105.80 t C ha^{-1}) to planted forest (soil carbon stock 88.96 t C ha^{-1}), would be a loss of 16.84 t C ha^{-1} over the 20-year period.

The IPCC default emission factor for organic soils under planted forest is 0.68 t C ha^{-1} per annum. This is also applied to organic soils on land converted to post-1989 forest.

Non-CO_2 emissions

Direct N_2O emissions from nitrogen fertilisation of forest land and other

Nitrous oxide emissions from nitrogen fertilisation are covered in the agriculture sector under the agricultural soils category.

Biomass burning

It is estimated that 25 per cent of the grassland converted to forest land is cleared using controlled burning. A country-specific fuel consumption rate of 70 per cent of above-ground biomass (Wakelin et al, 2009) is used to estimate emissions from controlled burning. The remainder (30 per cent of above-ground biomass) and all biomass on un-burned sites are assumed to decay over 20 years (IPCC default value, GPG-LULUCF Table 3.4.9, IPCC, 2003).

Emissions of carbon dioxide from controlled burns for afforestation are reported as a stock change in the grassland category. All non-CO_2 emissions from wildfires in land converted to forest land are reported under the forest land remaining forest land category, as the annual area involved is relatively small and the activity data does not distinguish between the two forest land categories. Investigations to separate wildfire emissions into the forest land remaining and land converted to forest categories are underway. Carbon dioxide emissions resulting from wildfire events are not reported, as the methods applied do not capture subsequent regrowth (GPG-LULUCF, section 3.2.1.4.2, IPCC, 2003). See section 7.9.5 for further details on biomass burning.

7.3.3 Uncertainties and time-series consistency

Removals and emissions from forest land are 6.1 per cent of New Zealand's net emissions and removals uncertainty in 2009 (Annex 7). Forest land introduces 2.6 per cent uncertainty into the trend in the national total from 1990 to 2009. This is the largest impact on the trend and second largest impact on the 2009 net removals and emissions following agricultural soils.

Natural forest

The uncertainty in mapping natural forest is ± 4 per cent. More details on this are given in section 7.2.5.

The natural forest plot network provides biomass carbon stock estimates that are within 95 per cent confidence intervals of 3.63 per cent of the mean (173 ± 6.27 t C ha^{-1}) in natural forests (Beets et al, 2009). Natural forests are assumed to be in steady state therefore no emissions are reported from this forest type and no uncertainty is introduced into net emissions from this land-use subcategory.

The uncertainty in soil carbon stocks for natural forests is ± 4 per cent. More details on this are given in Annex 3.3.

Table 7.3.7 Uncertainty in New Zealand's 2009 estimates from natural forest

Variable	Value	Uncertainty at a 95% confidence interval
Activity data		
Uncertainty in land area	8,095,651ha	4.0%
Uncertainty introduced into net LULUCF emissions	–26,682.7 Gg CO_2-e	0.0%
Emission factors		
Uncertainty in biomass carbon stocks	173 t C ha^{-1}	3.6%
Uncertainty in soil carbon stocks	92.04 t C ha^{-1}	4.0%
Uncertainty in liming emissions	NO	
Uncertainty introduced into net LULUCF emissions	–26,682.7Gg CO_2-e	0.0%

Notes: Land area includes land in transition in 2009.

Pre-1990 planted forest

Adopting a Tier 2 modelling approach has allowed the large body of plantation forestry knowledge in New Zealand to be applied to the greenhouse gas inventory. Attempts have been made to quantify the uncertainties in the carbon dioxide removal estimates for planted forests but it is difficult to quantify the overall uncertainty due to the assumptions implicit in the models. Combining the uncertainties indicates that the proportional error in the carbon sequestration estimates is likely to be ± 16.9 per cent. This includes uncertainty in the C_Change model and the *National Exotic Forest Description* yield tables which are assumed to be accurate to within ± 5 per cent.

Table 7.3.8 Uncertainty in New Zealand's 2009 estimates from pre-1990 planted forest

Variable	Value	Uncertainty at a 95% confidence interval
Activity data uncertainty		
Uncertainty in land area	1,445,869 ha	7.0%
Uncertainty introduced into net LULUCF emissions	–26,682.7Gg CO_2-e	*8.3%*
Emission factor uncertainty		
Uncertainty in biomass accumulation rates	Varies by age	16.9% based on:
C_Change model: wood density		3.0%
C_Change model: carbon allocation		15.0%
C_Change model: carbon content		5.0%
NEFD yield table		5.0%
Uncertainty in soil carbon stocks		6.1%
Uncertainty in liming emissions	NO	
Uncertainty introduced into net LULUCF emissions	–26,682.7Gg CO_2-e	*20.2%*

Notes: Land area includes land in transition in 2009. NEFD is the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2009a). Lime application to pre-1990 planted forest does not occur (NO) in New Zealand. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

This uncertainty will be reduced once data from the plot network in pre-1990 planted forest is incorporated.

Post-1989 forest

Biomass

The models within the FCPv2.2 forest carbon modelling system that have been used for post-1989 forests have been individually validated.

- The 300 Index Growth model has been extensively tested, although most of this work is so far unpublished (Mark Kimberley, Scion, pers comm). An unpublished industry report on validation of this model (Kimberley and Dean, 2005) is summarised in Kimberley et al (2005). The 300 Index Growth model is being used in New Zealand forest industry applications (MacLaren and Knowles, 2005; Palmer et al (*in press*)).
- Validation of the C_Change model has been studied by Beets et al (1999). This work showed that above-ground stand carbon was highly correlated with that predicted by C_Change ($r2=0.97$, $n=25$, $p<0.01$). In this study, the understory and forest floor carbon were excluded. Uncertainties within the C_Change model have also been described by Hollinger et al (1993). These include ± 3.0 per cent for wood density, ± 15.0 per cent for carbon allocation and ± 5.0 per cent for carbon content.

Beets et al (*inpress* (a)) tests the empirical accuracy and precision of carbon stock and change estimates and predictions derived using the Forest Carbon Predictor modelling system, using independent biomass data acquired from a range of sites in New Zealand. Carbon stocks from biomass measurements were compared with carbon stock estimates and predictions obtained using FCPv2.2. The overall model error was calculated by subtracting the carbon predictions from the biomass estimates, and therefore the error includes both model error and biomass estimation error. The error averaged –1.2 per cent for stem volume, 6.3 per cent for above-ground biomass carbon and 10.3 per cent for total carbon (excluding roots and mineral soil C) based on plot measurements obtained in the same year the biomass study took place. The prediction error, based on plot data acquired five years before or five years after the biomass study, was 5.0 per cent (not significant) greater than the estimation error obtained using the reference year.

Another potential source of error and bias can occur if some grid intersections located within the mapped forest are not sampled, either by LiDAR or field measurements. New Zealand has operational measures in place to ensure that this source of error is addressed, such as continually validating the plot network to ensure that relevant plots are included in analyses.

Soils

Ninety-nine per cent of land converted to post-1989 forest land is from grassland. There has been paired-site validation of the ability of the Soil CMS to predict soil carbon changes in mineral soils between grassland and planted forest land. There was reasonable agreement between modelled estimates and observed data for the 0–0.1 metre soil depth increment, but significant differences for the 0.1–0.3 metre increment. This is due partly to a lack of observed data for the 0.1–0.3 metre increment, as well as a greater emphasis in the observed data on species other than *Pinus radiata* (the dominant planted forest species in New Zealand). Results indicate that, once a weighting for forest species type had been applied (to remove potential bias in the paired-site dataset because *Pinus radiata* was under-represented), the Soil CMS model and paired-site predictions of mean soil carbon are in agreement within 95 per cent confidence intervals (Baisden et al, 2006a, b).

In addition, the Soil CMS has recently been modified to remove the effect of bias from spatial clustering of soil pedon data points. As the dataset used by the model consists primarily of historical data collected for specific purposes, it is not a random sample of

the soils in New Zealand, with some soil/climate/land-use combinations over-represented and some under-represented. As soil samples are correlated to some extent according to the distance between them, the incorporation of a correction factor for spatial correlation into the Soil CMS model has resulted in a decrease in difference between stock estimates for grassland and planted forest, and improved agreement between the modelled estimates and the paired site observed data.

Table 7.3.9 Uncertainty in New Zealand's 2009 estimates from post-1989 forest

Variable	Value	Uncertainty at a 95% confidence interval
Activity data uncertainty		
Uncertainty in land area	591,202 ha	7.0%
Uncertainty introduced into net LULCUF emissions	–26,682.7Gg CO_2-e	*3.3%*
Emission factor uncertainty		
Uncertainty in biomass accumulation rates	Varies by age	11.9% based on:
Modelling		*10.3%*
Sampling		*5.9%*
Forecasting		*1.0%*
Uncertainty in soil carbon stocks		6.1%
Uncertainty in liming emissions		NO
Uncertainty introduced into net LULUCF emissions	–26,682.7Gg CO_2-e	*6.0%*

Notes: Land area includes land in transition in 2009. Lime application to post-1990 forest does not occur (NO) in New Zealand. Nitrous oxide emissions are calculated as a proportion of carbon stock change, with the same uncertainty as for CO_2, and therefore it does not add to the combined uncertainty value. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

7.3.4 Category-specific QA/QC and verification

Carbon dioxide removals 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 QA/QC. Details of these checks are provided below.

For the pre-1990 planted forests, one of the primary input data sets used is the *National Exotic Forest Description*. The *National Exotic Forest Description* is New Zealand's official source of statistics on planted production forests and, as such, is subject to formalised data-checking procedures. Each *National Exotic Forest Description* report is reviewed by a technical *National Exotic Forest Description* committee before publication. Broad comparisons of forest areas reported in the *National Exotic Forest Description* reports are made with independent sources of information such as the Land Cover Database (LCDB) estimates and the annual results of Statistics New Zealand's *Agricultural Production Survey*. *National Exotic Forest Description* yield tables have been subject to review (eg, Jaakko Poyry Consulting, 2003; Manley, 2004) and have recently been revised.

For post-1989 forests, quality-assurance and control procedures were specified for both the field and LiDAR data (see Figure 7.3.6). The field measurements of the permanent sample plots were formally audited through the re-measurement of 10 per cent of the sites by a team independent of the field inventory contractor. The sites audited were randomly

selected throughout the measurement period and revisited shortly after the original measurement. Audit results for a site were provided to the measurement contractor as soon as possible so any issues found could be addressed with the field team. The data pre-processing (in the Scion PSP system) and modelling (using FCPv2.2) were also independently checked (Woollons, 2009).

Quality-assurance and control procedures of the LiDAR data involved checking the raw data as it was acquired following the method outlined in Stephens et al (2008). The key characteristics considered included sensor calibration, positional accuracy, density of first return, data decimation, consistent classification of the ground returns within the point cloud and accurate data administration. The LiDAR sensor calibration was flown four times with 600 height difference samples taken, the point positioning tested on six occasions and a summary of first returns provided for eight delivery dates. Sites that failed to meet the required pulse density were re-flown. FUSION LiDAR visual and analysis software (McGaughey et al, 2004) and ERDAS IMAGINE software were used for quality assurance of the delivered LiDAR data sets continuously throughout the operation, with results and feedback provided to the contractor within 10 days of data delivery. When the data was subsequently analysed on a plot-by-plot basis, the results of this analysis were also audited with the more than 30 LiDAR variables produced and checked by an independent agency for 10 per cent of the plots.

7.3.5 Category-specific recalculations

In this submission, New Zealand has recalculated its emissions and removal estimates for the whole LULUCF sector from 1990, including for the forest land category. These recalculations have involved improved country-specific methods, activity data and emission factors. The impact of the recalculations on net CO_2-e emissions estimates for the forest land category is provided in Table 7.3.10. The differences shown are a result of recalculations for all carbon pools used in Climate Change Convention and Kyoto Protocol reporting for the whole time-series for the LULUCF sector.

Table 7.3.10 Recalculations of New Zealand's estimates for the forest land category in 1990 and 2008

Forest land recalculations		Net removals and areas		Change from the 2010 submission	
		2010 submission	2011 submission		(%)
Net removals	1990	–32,856.7 Gg CO^2-e	–25,344.9 Gg CO^2-e	7,511.8 Gg CO^2-e	22.9
	2008	–29,757.9 Gg CO^2-e	–32,215.7 Gg CO^2-e	–2457.8 Gg CO^2-e	–8.3
Land areas	1990	9,644,551 ha	9,636,822 ha	–7,729 ha	–0.1
	2008	10,128,813 ha	10,130,366 ha	1,553 ha	+0.0

Note: Areas are as at the end of the year indicated.

For forest land, the reasons for the recalculation differences are explained below.

Activity data

Historical land use

The estimated area of pre-1990 planted forest land has been updated as a result of the use of historical land-use data (backcasting) to model land-use change since 1962, in order to identify land in transition in the inventory base year of 1990. The result of this inclusion is that lagged emissions and removals from land-use change events prior to 1990 are now

reported. Backcasting results in the revision of the estimates of emissions and removals from pre-1990 planted forest to include harvesting residue decay emissions resulting from historical (before 1990) harvesting events.

Deforestation

The area estimates of deforestation have also been updated from the previous submission. These are reported in the 'land converted to' category, primarily high-producing grassland.

Estimates of pre-1990 planted and natural forest deforestation between 1990 and 2007 are based on LUCAS land-use mapping, whilst deforestation of post-1989 forest has been estimated from a variety of sources, such as the carbon inventory of New Zealand's planted forests for the 2007 Greenhouse Gas Inventory (Wakelin, 2008) and the Deforestation Intentions Survey (Manley, 2009).

Additional deforestation data sourced from the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2009a) has been used as the basis for estimating when the actual deforestation event occurred between 1990 and 2007.

Deforestation occurring during 2008 and 2009 has been mapped using a national coverage of DMC (Disaster Monitoring Constellation) satellite imagery acquired between December 2009 and May 2010. Mapping methods and data sources are described in further detail in section 7.2.

Emission factors

Natural forest carbon stock

The current estimate of natural forest carbon stock was used for the first time in the 2010 submission. It is based on data collected from a complete set of plots that were installed on the national grid-based network. The methods used are fully documented, repeatable and will be comparable once the full network of plots has been re-measured.

For the 2011 submission, natural forest has also been classified into tall forest and shrub, and the carbon stocks for these sub-classifications used to estimate emissions from natural forest deforestation.

Planted forest carbon stock change

New Zealand has revised the reporting of emissions from the decay of below-ground biomass following harvesting events. These harvest residues were previously reported in the below-ground biomass pool instead of the dead organic matter pool. As this is merely a pool allocation change there are no resulting impacts on total LULUCF emissions or removals.

Soil carbon stock

New Zealand has revised the soil carbon stock values used to estimate soil organic carbon for mineral soils to improve their accuracy, completeness and transparency, with additional data for annual cropland, grassland and natural forest, bulk density correction factors for historical data and refitting of the Soil CMS model. The current reference value for mineral soils is 105.80 ± 4.15 t C ha^{-1} (Table 7.1.2.10), and the stock values for natural forest and planted forest are 92.04 ± 3.66 t C ha^{-1} and 88.96 ± 5.456.44 t C ha^{-1} respectively. The difference in stock values between low-producing grassland and natural forest is –13.77 t C ha^{-1} (compared with –5.81 t C ha^{-1} in the previous submission), and

between low-producing grassland and planted forest is –16.85 t C ha^{-1} (compared with –13.35 t C ha^{-1} in the previous submission).

7.3.6 Category-specific planned improvements

A natural forest re-measurement is underway. After this re-measurement is complete, New Zealand will be better able to illustrate whether its natural forests are a net source, sink or carbon neutral.

Pre-1990 planted forests were sampled in 2010 and the results from the analysis of the data collected will provide, for the first time, a plot-based estimate of carbon stock within this forest subcategory (see 'land converted to forest land', section 7.3.2). This plot-based estimate will be included in the 2012 submission. A double-sampling approach was employed using LiDAR in combination with ground-based permanent sample plots. The pre-1990 approach is consistent with the inventory approach used for post-1989 forests. Around 200 ground sites (see Figure 7.3.7) were sampled on the 8-kilometre grid where this intersects pre-1990 planted forests to ensure that a robust, unbiased regression model may be estimated. This sample intensity is sufficient to estimate the stock of carbon to a PLE[25] of less than 10 per cent, excluding any error due to measurement or calculations of individual tree and carbon pool content. Following the completion of the field and LiDAR measurements in the pre-1990 planted forests, the methods to estimate carbon of the two subcategories (pre-1990 planted and post-1989 forests) will be standardised.

Mapping of forest areas will be iteratively improved by comparison with other spatial forest data sets administered by the Ministry of Agriculture and Forestry. 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 (AGS) and the Permanent Forest Sink Initiative (PFSI).

To ensure that all of the 4-kilometre grid intersections located within mapped post-1989 forests are sampled, plot locations will be updated as new areas of post-1989 forests are added to the map. Newly mapped plots will be measured to ensure carbon estimates are unbiased. Sampling at the grid intersections will be undertaken using LiDAR and/or field measurements. The post-1989 forests will be re-measured near the end of the commitment period during 2011–2012, allowing an accurate estimation of carbon stock changes over the commitment period.

New Zealand has a long-term research programme that underpins forest carbon inventory and modelling. This work aims to improve carbon modelling, including partitioning in species other than *Pinus radiata*, plantation understory carbon and biomass decay rates.

The specific improvements expected from this research effort include:

- establishment of the carbon regression between LiDAR and field measured pre-1990 planted forest plots
- determination of how effectively LiDAR estimates carbon stock change with and without ground measurements
- investigation of species cohort yield tables for minor species in the plantation forest estate

[25] A probable limit of error (PLE) refers to the confidence limits expressed as a percentage of the estimated mean. For example, a PLE of 10 per cent at the 95 per cent probability level implies that there is a 95 per cent chance that the true mean is within 10 per cent of the estimated mean.

- improvement in knowledge of decay rates associated with silviculture operations and forest harvesting residues
- improvement of the growth trajectory and biomass allocation method for Douglas-fir using the Forest Carbon Predictor modelling system
- improvement of the planted forest growth model and carbon allocation model for *Pinus radiata*. This will be achieved through peer-reviewed research to better understand decay rates of roots, dead wood and litter, drivers of wood density and improvements in the wood density model used in the carbon allocation model
- investigation of potential additional sources of information to improve estimates of biomass burning following afforestation, reforestation and deforestation.

Planned future improvements also include further soil data collection for land under planted forest, and further measurement of paired sites for validation.

7.4 Cropland (CRF 5B)

7.4.1 Description

Cropland in New Zealand is separated into two subcategories: annual cropland and perennial. In 2009, there were 334,818 hectares of annual cropland in New Zealand (1.2 per cent of total land area) and 101,770 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, or removed from permanent cropland depends on crop type, management practices and soil and climate variables. Annual crops are harvested each year, with no long-term storage of carbon in biomass. However, the amount of carbon stored in woody vegetation in orchards can be significant, with the amount depending on the species, density, growth rates, and harvesting and pruning practices.

In 2009, the net emissions from cropland were 337.5 Gg CO_2-e, comprised of 291.2 Gg CO_2 from carbon stock change, 0.007 Gg N_2O (2.0 Gg CO_2-e) from the cultivation of land converted to cropland and 44.3 Gg CO_2 from liming.

Net emissions from cropland have decreased by 57.8 Gg CO_2-e (14.6 per cent) from the 1990 level when net emissions were 395.3 Gg CO_2-e (Table 7.4.1). This decrease is largely due to the gradual reduction in the area of land in a state of conversion to cropland since 1990 as it transfers to the land remaining category.

Cropland categories were not identified as key categories for 2009.

Table 7.4.1 New Zealand's land-use change within the cropland category from 1990 to 2009, and associated emissions

Cropland land-use category	Net area in 1990 (ha)	Net area in 2009 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2-e) 1990	2009	Change from 1990 (%)
Cropland remaining cropland	380,445	402,929	+5.9	334.8	339.2	+1.3
Land in conversion to cropland	34,229	33,659	–1.7	60.5	–1.7	–102.8
Total	**414,674**	**436,588**	**+5.3**	**395.3**	**337.5**	**–14.6**

Notes: 1990 and 2009 areas are as at 31 December. Land in conversion to cropland includes land that was converted prior to 1990. Net emission/removal values are for the whole year indicated.

The cropland remaining cropland category is responsible for the majority of cropland emissions, as this category comprised 92.3 per cent of all cropland area in 2009. The emissions for this land use are the result of annual cropland being converted to perennial cropland. Table 7.4.2 shows land-use change by cropland subcategory since 1990, and the associated CO_2 emissions and removals from carbon stock change.

Table 7.4.2 New Zealand's land-use change within cropland subcategories from 1990 to 2009, and associated CO_2 emissions from carbon stock change

Cropland land-use subcategory	Net area in 1990 (ha)	Net area in 2009 (ha)	Change from 1990 (%)	Net emissions/ removals (Gg CO_2 only) 1990	2009	Change from 1990 (%)
Annual cropland	335,775	334,818	–0.3	267.7	227.6	–15.0
Perennial cropland	78,899	101,770	+29.0	100.0	63.7	–36.3
Total	**414,674**	**436,588**	**+5.3**	**367.7**	**291.2**	**–20.8**

Notes: 1990 and 2009 areas are as at 31 December.

A summary of land-use change within the cropland category, by subcategory and land conversion status, is provided in Table 7.4.2. This shows that land-use change within the croplands category has been dominated by conversions to perennial cropland, both from within the cropland category as well as from other land-use categories. This conversion has predominantly been for the establishment of vineyards (Davis and Wakelin, 2010).

Table 7.4.3 New Zealand's land-use change within the cropland category from 1990 to 2009

Cropland category	Subcategory	Net area in 1990 (ha)	Net area in 2009 (ha)	Change from 1990 (%)
Cropland remaining cropland	Annual remaining annual	308,593	323,402	4.8
	Perennial remaining perennial	69,247	74,401	7.4
	Annual to perennial	1,247	4,724	278.7
	Perennial to annual	1,358	402	–70.4
	Subtotal	*380,445*	*402,929*	*5.9*
Land in conversion to cropland	Annual cropland	25,824	11013.6	–57.4
	Perennial cropland	8,405	22,645	+169.4
	Subtotal	*34,229*	*33,659*	*–1.7*
Total		**414,674**	**436,588**	**+5.3**

Carbon stock change within the cropland category is shown in Table 7.4.4, from 1990 to 2009, the total carbon stock stored in cropland had decreased by 1858.8 Gg C, equivalent to removals of 6815.5 Gg CO_2 from cropland since 1990. The majority of these emissions are from losses in the soil organic carbon pool.

Table 7.4.4 New Zealand's carbon stock change by carbon pool within the cropland category from 1990 to 2009

Crop land subcategory	Net carbon stock change 1990–2009 (Gg C)				Emissions/removals 1990–2009 (Gg CO_2)
	Living Biomass	Dead organic matter	Soils	Total	
Annual cropland	–2.4	NE	–1,348.4	–1,350.8	4,953.0
Perennial cropland	38.3	–4.3	–541.9	–508.0	1,862.5
Total	**35.9**	**–4.3**	**–1,890.3**	**–1,858.8**	**6,815.5**

Notes: Dead organic matter (DOM) is not estimated (NE) as there is insufficient information to provide a basic approach with default parameters to estimate carbon stock change in this pool (IPCC, 2003). The reported DOM losses result from the loss of DOM of woody land-use classes on conversion to cropland.

7.4.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using IPCC Tier 1 emission factors for annual cropland, Tier 2 emission factors for perennial cropland (Davis and Wakelin, 2010), and activity data as described in section 7.2 – representation of land areas. 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. This is described in section 7.1.3 – soils.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions and removals for cropland are summarised in Table 7.4.5.

Table 7.4.5 Summary of New Zealand's carbon stock change emission factors for cropland

Cropland land-use subcategory	Carbon p	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	118.27	[1]	20	NZ Tier 2 Soil CMS
	Organic	NE	–1.0 / –10.0		IPCC default EF: cold temperate / warm temperate
Perennial	**Biomass**				
	Living biomass	18.76	0.67	28	NZ-specific EF
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral	114.91		20	NZ Tier 2 Soil CMS
	Organic	NE	–1.0 / 10.0		IPCC default EF: cold temperate / warm temperate

Notes: EF = Emission factor. (1) Annual carbon stock change in mineral soils on land undergoing land-use change will depend on the land-use category the land has been converted to or from.

Cropland remaining cropland

For cropland remaining cropland, the Tier 1 assumption is that for annual cropland there is no change in carbon stocks (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 but only where there is 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 2009 there was 5126 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 t C ha^{-1}. 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 t C ha^{-1} is removed).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 t C ha^{-1} yr^{-1}. This value is based on the New Zealand-specific value of 18.76 t 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 default for organic soils, as described in section 7.1.3.

The Tier 2 value for mineral soil carbon stock density in annual cropland at equilibrium state is estimated to be 90.99 t C ha^{-1}, with a standard error of 4.38, and for perennial cropland is estimated to be 101.24 t C ha^{-1}, with a standard error of 11.83 (Table 7.1.6).

Mineral soil carbon change for annual cropland converted to perennial cropland is estimated using a Tier 2 method with the change in soil carbon reflecting a linear rate of change over 20 years (the IPCC default method) from the equilibrium state value for annual cropland (90.99 t C ha^{-1}) to the equilibrium state perennial cropland value (101.24 t C ha^{-1}).

The estimate for annual cropland has been improved with the addition of annual cropland soil carbon data from the Land Management Index, bringing the standard error down from 22.47 to 4.38. There is still a large standard error associated with the soil carbon stock value for perennial cropland due to the small size of the dataset. Perennial cropland occupies only 0.4 per cent of New Zealand's total land area, and there has been little focus placed on collecting soil data under this land use. Planned future improvements in the soils area include soil data collection for identified gaps.

The IPCC default emission factors for organic soils under cropland are 1.0 and 10.0 t C ha^{-1} per annum for cold temperate and warm temperate regimes respectively (Table 7.1.8). These defaults are applied in proportion to the area of land in New Zealand where the Mean Annual Temperature is below or above 10°C respectively.

Liming

The calculation of carbon dioxide emissions from the liming of cropland soil is based on equation 3.4.11 in GPG-LULUCF (IPCC, 2003) as outlined in section 7.9.4 – liming. The total amount of agricultural lime (limestone) applied is provided by Statistics New Zealand (New Zealand's official statistics agency). This is split into lime applied to cropland and grassland based on analysis of agricultural lime use by land use and farm type from the 2008 Agricultural Census. This analysis indicates that, each year, around 6 per cent of agricultural lime used in New Zealand is applied to cropland. The amount of lime applied to cropland is then converted to carbon emissions using a conversion factor of 0.12 from GPG-LULUCF, section 3.3.1.2.1.1 (IPCC, 2003).

Non-CO_2 emissions

Biomass burning

This 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. Agricultural residue burning is reported in the agriculture sector.

Land converted to cropland

Living biomass

New Zealand uses a Tier 1 method, and a combination of IPCC default and New Zealand-specific emission factors to calculate emissions for land converted to cropland. The Tier 1 method multiplies the area of land converted to cropland annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass and dead organic matter immediately after conversion is zero, that is, the land is cleared of all vegetation before planting crops. The amount of biomass cleared when land at steady state is converted is shown in Tables 7.1.3 and 7.1.4.

The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place, as outlined in equation 3.3.8 of GPG-LULUCF (IPCC, 2003).

To estimate growth after conversion to annual cropland, New Zealand uses the IPCC default biomass accumulation rate of 5 t 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 t C ha^{-1} yr^{-1}. This value is based on the New Zealand-specific value of 18.76 t C ha^{-1} (Davis and Wakelin, 2010), sequestered over 28 years, which is the maturity period New Zealand uses for its lands to reach steady state.

Dead organic matter

New Zealand reports only losses in dead organic matter associated with the previous land use for this category. The losses are calculated based on the carbon in dead organic matter at the site prior to conversion to cropland. It is assumed that immediately after conversion dead organic matter is zero (all carbon in dead organic matter prior to conversion is lost). There is insufficient information to estimate gain in carbon stock in dead organic matter pools after land is converted to cropland (IPCC, 2003). Consequently, where there is no dead organic matter losses associated with the previous land use, the notation key NE ('not estimated') is used in the common reporting format tables.

Soil organic carbon

Soil carbon stocks in land converted to annual and perennial cropland are estimated using a Tier 2 method for mineral soils and a Tier 1 default for organic soils, as described in section 7.1.3. In the absence of country- and land-use specific data on the time rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original and new land use.

The IPCC default emission factors for organic soils under cropland are also applied to land converted to cropland.

Non-CO_2 emissions

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland

Nitrous oxide (N_2O) emissions from disturbance associated with land-use conversion to cropland are described in section 7.9.3.

Biomass burning

Biomass burning with land conversion to cropland is not thought to be a significant activity in New Zealand, and there is no activity data available that would indicate otherwise. The notation key NE ('not estimated') is reported in the common reporting format tables.

7.4.3 Uncertainties and time-series consistency

The uncertainty in mapping cropland is ± 6 per cent. More details on this are given in section 7.2.5.

New Zealand uses IPCC default values for biomass accumulation in annual cropland. For perennial cropland we use a New Zealand-specific emissions factor. As the emission factor is based on only limited number of biomass studies the uncertainty in these figures is estimated as ± 75 per cent.

The uncertainty in soil carbon stocks for annual and perennial cropland is ± 4.8 per cent and ± 11.7 per cent respectively. More details on this are given in Annex 3.3.

Uncertainty in liming emissions is based on activity data uncertainty (amount of lime applied) from Statistics NZ. This is estimated as ± 6 per cent for limestone and ± 21 per cent for dolomite. These values are then weighted to give overall uncertainty for liming emissions of ± 6.2 per cent.

As shown in Table 7.4.6, while uncertainty in activity data is low, the uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand.

Table 7.4.6 Uncertainty in New Zealand's 2009 cropland estimates

Variable	**Uncertainty at a 95% confidence interval (%)**	
Land-use subcategory	Annual cropland	Perennial cropland
Activity data uncertainty		
Uncertainty in land area	6.0%	6.0%
Uncertainty introduced into net LULUCF emissions	*0.0%*	*0.0%*
Emission factor uncertainty		
Uncertainty in biomass accumulation rates	75.0%	75.0%
Uncertainty in soil carbon stocks	4.8%	11.7%
Uncertainty in liming emissions	6.2%	6.2%
Uncertainty introduced into net LULUCF emissions	*0.7%*	*0.4%*

7.4.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for these emissions underwent Tier 1 QA/QC checks.

7.4.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the cropland category is shown in Table 7.4.7. Recalculations of the entire time-series were carried out for this category as a result of:

- updates to mapping of the extent of annual and perennial cropland based on aerial photography and data from the AgriBase cropland database
- introduction of a new, country-specific perennial cropland emission factor for above-ground biomass
- updated liming activity data
- revised soil carbon stock estimates
- new estimates of organic soil emissions.

Table 7.4.7 Recalculations of New Zealand's net emissions and removals from the cropland category in 1990 and 2008

Year	Net emissions and removals (Gg CO_2-e)		Change from the 2010 submission	
	2010 submission	2011 submission	(Gg CO_2-e)	(%)
1990	29.9	395.3	365.4	1,220.3
2008	-23.7	338.3	361.9	–1,530.3

Further explanation of these recalculations is provided below.

Activity data

Cropland mapping, originally derived from the Land Cover Data Base 2 (LCDB2) dated at 2001, has been updated for the 2011 submission using data from a national agricultural and cropland database (AgriBase) and aerial photography. This update has added approximately 15,000 ha of perennial cropland to the 2008 land-use map.

For the 2011 submission, New Zealand has also employed historical land-use data to model land-use change since 1962, in order to identify land in a state of conversion at 1990. The effect of this recalculation has been to transfer a proportion of land area from the 'land remaining land' category to the 'land converted to' category, with the effect that lagged emissions and removals from land-use change events prior to 1990 have now been incorporated into the emission and removal estimates. See section 7.2.4 for further detail.

Emissions factors

Perennial cropland

The annual growth in biomass for land converted to perennial cropland has been decreased (from 2.25 to 0.67 t C ha^{-1} – see Table 7.1.3).

The Ministry for the Environment commissioned an independent expert report on the carbon accumulation rates in New Zealand perennial croplands (Davis and Wakelin, 2010). The review identified updated estimates of above-ground biomass and carbon accumulation rates, crop longevity and carbon stocks at the end of the crop cycle.

The review found that mean carbon uptake rates, estimated from the limited available biomass data for the key perennial crop species – grapes, kiwifruit, pip fruit and associated shelterbelts – are substantially lower than the IPCC perennial crop default values.

The area weighted annual average carbon uptake of all crops, including associated shelterbelts, was estimated for the years 1982–2007. The estimates varied over a narrow range (0.66–0.68 t C ha^{-1} yr^{-1}), and were considerably lower than the IPCC default value of 2.1 t C ha^{-1} yr^{-1}.

New Zealand has accordingly updated its above-ground biomass emission factor for perennial cropland from the IPCC default of 2.25 t C ha^{-1} yr^{-1} to a country-specific value of 0.67 t C ha^{-1} yr^{-1}, with a steady state value of 18.76 t C ha^{-1} reached after the New Zealand default maturity period of 28 years, and recalculated the entire time-series.

Soil organic carbon

The soil carbon stock factors have been improved (see section 7.1.3), including a reduction in the mineral soil carbon stock estimate for annual cropland and its associated

uncertainty with the addition of data from the Land Management Index. The current reference value for mineral soils is 105.80 ± 4.15 t C ha^{-1} (Table 7.1.6), and the stock values for annual and perennial cropland are 90.99 ± 4.38 t C ha^{-1} and 101.24 ± 11.83 t C ha^{-1} respectively. The difference in stock values between low-producing grassland and annual cropland is –14.81 t C ha^{-1} (compared with 0.61 t C ha^{-1} in the previous submission), and between low-producing grassland and perennial cropland is –4.57 t C ha^{-1} (compared with –2.75 t C ha^{-1} in the previous submission).

Other recalculations

For the 2011 submission, New Zealand has reported estimates for all years of the time-series of CO_2 emissions from the cultivation of organic soils. See section 7.1.3.

New Zealand has also introduced reporting of N_2O emissions from disturbance associated with land-use conversion to cropland, on mineral soils. These emissions were estimated for the last submission but not reported in the common reporting format (CRF) tables as they fell under a 1 tonne threshold for reporting. For the 2011 submission, New Zealand has removed this threshold and reported recalculated estimates of N_2O emissions based on the updated activity data (described above) on the area of land converted to cropland.

The amount of agricultural lime (limestone) applied has been updated following the release of the final results from the 2009 Agricultural Census.

7.4.6 Category-specific planned improvements

As outlined above, there are plans to improve the soil dataset to reduce the uncertainty in the cropland estimates. Further detail on this is included in section 7.1.3 – soils.

Possible areas of future improvement could include additional biomass sampling, particularly for vineyards and shelterbelts, to reduce uncertainty in carbon accumulation rates.

7.5 Grassland (CRF 5C)

7.5.1 Description

In New Zealand, grassland covers a range of land-cover types. In this submission, three subcategories of grassland are used: high producing, low producing and with woody biomass.

High-producing grassland consists of intensively managed pasture land. Low-producing grassland consists of low-fertility grasses on hill country, areas of native tussock or areas composed of low, shrubby vegetation, both above and below the timberline. Grassland with woody biomass consists of grassland areas where the cover of woody species is less than 30 per cent and/or does not meet, nor have the potential to meet, the New Zealand forest definition due to either the current management regime (eg, periodically cleared for grazing) or the characteristics of the vegetation (eg, shrubland). A summary of land-use change within the grassland category is provided in Table 7.5.1.

Land-use research indicates that, under business-as-usual grassland farming operations, areas of woody shrublands 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. As soon as it is evident that the farmer has modified land management in a way that encourages sustained growth of woody vegetation, such as by removing stock, then these areas will be mapped as forest. A description of the land-management approaches that result in the sustained growth of woody vegetation is contained in the mapping interpretation guide (Dougherty et al, 2009).

In 2009, there were 5,796,529 hectares of high-producing grassland (21.5 per cent of total land area) 7,671,209 hectares of low-producing grassland (28.5 per cent of total land area), and 1,134,605 hectares of grassland with woody biomass (4.2 per cent of total land area).

The net emissions from grassland were 2529.4 Gg CO_2-e in 2009 (Table 7.5.1). These emissions comprise CO_2 emissions and removals from carbon stock change and agricultural lime application, and emissions of methane (CH_4) and nitrous oxide (N_2O) from biomass burning.

The grassland remaining grassland category was identified as a key category for the level and trend assessment in 2090. Land converted to grassland was identified as a key category (trend) for 2009.

Net emissions from grassland have increased by 1220.4 Gg CO_2-e (93.2 per cent) from the 1990 level of 1309.1 Gg CO_2-e. This increase has occurred primarily on grassland remaining grassland, and is due to multiple factors including increased agricultural liming, and the influence of land-use changes between grassland subcategories on soil and biomass carbon accumulation over time. The reduced emissions from land converted to grassland are likely due to the reduced deforestation since 2008, and the decreasing pool of land in a conversion state to grassland, as it reaches maturity and is transferred to the land remaining land category. Consistent with IPCC reporting guidelines, emissions from deforestation are reported in the land converted to category.

Table 7.5.1 New Zealand's land-use change within the grassland category from 1990 to 2009

Grassland land-use category	Area in 1990 (ha)	Area in 2009 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2-e) 1990	2009	Change from 1990 (%)
Grassland remaining grassland	14,618,899	14,432,496	–1.3	844.3	2,194.8	+159.9
Land in conversion to grassland	499,357	169,847	–66.0	464.8	334.7	-28.0
Total	**15,118,256**	**14,602,343**	**–3.4**	**1,309.1**	**2,529.4**	**+93.2**

Notes: 1990 and 2009 areas are as at 31 December. Net emission/removal estimates are for the whole year indicated. Land in conversion to grassland includes land converted up to 28 years prior to 1990.

Land-use change by grassland subcategory is shown in Table 7.5.2, together with the associated CO_2 emissions from carbon stock change.

Table 7.5.2 New Zealand's land-use change within grassland subcategories from 1990 to 2009, and associated CO_2 emissions from carbon stock change

Grassland land-use subcategory	Area in 1990 (ha)	Area in 2009 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2 only) 1990	2009	Change from 1990 (%)
Grassland – high producing	5,851,872	5,796,529	–0.9	765.3	1,127.0	+47.3
Grassland – low producing	7,999,120	7,671,209	–4.1	722.6	753.8	+4.3
Grassland – with woody biomass	1,267,263	1,134,605	–10.5	–572.2	–67.8	–88.2
Total	**15,118,256**	**14,602,343**	**–3.4**	**915.7**	**1,813.0**	**+98.0**

Notes: 1990 and 2009 areas are as at 31 December. Net emission/removal estimates are for the whole year indicated.

From 1990 to 2009, the net carbon stock change attributed to grassland was a decrease of 20,924.5 Gg C, equivalent to emissions of 76,723.1 Gg CO_2 from grassland since 1990. The majority of these emissions are due to the loss of living biomass carbon stock, associated with forest land conversion to grassland.

Table 7.5.3 New Zealand's carbon stock change by carbon pool within the grassland category from 1990 to 2009

Grassland subcategory	Net carbon stock change 1990-2009 (Gg C) Living Biomass	Dead organic matter	Soils	Total	Emissions/removals 1990–2009 (Gg CO_2)
Grassland – high producing	–10,954.7	–1,400.6	–3,747.7	–16,103.0	59,044.3
Grassland – low producing	–4,344.1	–1,104.2	–309.6	–5,757.8	21,112.1
Grassland – with woody biomass	826.4	532.4	–422.4	936.4	–3,433.3
Total	**–14,472.4**	**–1,972.4**	**–4,479.7**	**–20,924.5**	**76,723.1**

Non-CO_2 emissions from grassland in 2009 comprised 1.8 Gg CH_4 (37.8 Gg CO_2-e) and 0.013 Gg N_2O (4.0 Gg CO_2-e) from biomass burning, while emissions from liming of grassland accounted for 674.7 Gg CO_2-e (26.7 per cent) of net emissions in 2009. Net liming emissions from grassland have increased by 323.9 Gg CO_2-e (92.3 per cent) compared with the 1990 level of 350.8 Gg CO_2-e.

Grassland remaining grassland

There were 14,432,496 hectares of grassland remaining grassland in 2009, equivalent to 53.6 per cent of New Zealand's total land area. Estimates of land-use change in this category have been split into three subcategories of grassland and the changes between them, as shown in Table 7.5.4.

Table 7.5.4 New Zealand's land-use change between grassland subcategories from 1990 to 2009

Land-use changes within grassland remaining grassland	Net area in 1990 (ha)	Net area in 2009 (ha)	Change from 1990 (ha)	Change from 1990 (%)
High producing remaining high producing	4,830,720	5,410,852	+580,131	+12.0
Low producing remaining low producing	7,667,129	7,558,413	–108,717	–1.4
With woody biomass remaining with woody biomass	1,051,915	1,089,360	+37,445	+3.6
Subtotal	*13,549,765*	*14,058,625*	*+508,859*	*+3.8*
High producing to low producing	0	0	0	NA
High producing to with woody biomass	438	8,764	+8,326	+1,900.0
Low producing to high producing	350,651	62,212	–288,439	–82.3
Low producing to with woody biomass	192,662	31,602	–161,060	–83.6
With woody biomass to high producing	477,343	214,584	–262,759	–55.0
With woody biomass to low producing	48,039	56,709	+8,670	+18.0
Subtotal	*1,069,134*	*373,872*	*–695,262*	*–65.0*
Total	**14,618,899**	**14,432,496**	**–186,403**	**–0.01**

Note: The areas of land converted to another land use are cumulative net values for land-use change since 1 January 1990, as at 31 December 2009.

Land undergoing land-use change from one land-use subcategory to another remains in a state of conversion for 28 years (the New Zealand maturity period), until it reaches steady state and transfers to the land remaining land (or subcategory remaining subcategory) category. The most significant trend observable within the grassland remaining grassland category is the overall movement of land from a state of conversion between grassland subcategories – in particular, away from low-producing grassland – to a steady state as mature, high-producing grassland.

Land converted to grassland

Between 1990 and 2009, 83,992 hectares of land was converted to grassland, while 613,314 hectares of grassland was converted to other land-use categories, resulting in a net reduction in the total grassland area of 529,323 hectares. As at the end of 2009, however, there was a total of 169,847 hectares of land in a state of conversion to grassland, as areas of land converted prior to 1990 remain in a state of conversion for 28 years (New Zealand's land-use maturity period).

Much of New Zealand's grassland is grazed, with pastoral agriculture being the main land use. Most New Zealand agriculture is based on extensive pasture systems, with animals grazed outdoors year-round. Increased profitability of pastoral farming relative to other land uses has seen a recent trend for conversion of forest to pasture (deforestation).

The majority (98.2 per cent) of land converted to grassland since 1990 is land that was previously forest land. The 81,312 hectares of forest land converted to grassland since 1990 comprises an estimated 32,713 hectares of natural forest deforestation and

48,599 hectares of pre-1990 planted forest deforestation. A further 15,503 hectares of newly-established, post-1989 forest (land that was not grassland at the start of 1990) has also been deforested and converted to grassland. (For more information on deforestation, see sections 7.2 and 7.3 and chapter 11.) The effect of this land-use change between 1990 and 2009 was a net carbon stock loss of 95.4 Gg C, equivalent to net emissions of 349.8 Gg CO_2.

7.5.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using a combination of IPCC Tier 1 emission factors and country-specific factors. Emissions and removals by the soil pool are estimated using a Tier 2 method as described in section 7.1.3 – soils, and the activity data used is described in section 7.2 – representation of land areas.

A summary of the New Zealand biomass emission factors and other parameters used to estimate greenhouse gas emissions and removals for the grassland category are summarised in Table 7.5.5.

Table 7.5.5 Summary of New Zealand's biomass emission factors for grassland

Grassland subcategory	Carbon pool	Steady state carbon stock (t c ha^{-1})	Annual carbon accumulation (t c ha^{-1})	Years to reach steady state	Source
High producing	**Living biomass**	**6.75**	**6.75**	**1**	IPCC default EF
	AGB	1.35	1.35	1	
	BGB	5.4	5.4	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
Low producing	**Living biomass**	3.05	3.05	1	IPCC default EF
	AGB	0.8	0.8	1	
	BGB	2.25	2.25	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
With woody biomass	**Living biomass**	29	1.04	28	NZ-specific EF
	AGB	16.0	0.57	28	
	BGB	4.0	0.14	28	
	Dead organic matter	9.0	0.32	28	NZ-specific EF
	Deadwood	3.0	0.11	28	
	Litter	6.0	0.21	28	

Notes: AGB = above-ground biomass. BGB = below-ground biomass. NE = not estimated. NA = not applicable. EF = emissions factor.

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 (79,401 hectares) converted from one grassland subcategory to another. The carbon stock changes for these land-use changes are reported under grassland remaining grassland.

Living biomass

To calculate carbon change in living biomass on land converted from one subcategory to another (eg, high-producing grassland converted to low-producing grassland) it is assumed the carbon in living biomass immediately after conversion is zero, that is, the land is cleared of all vegetation. In the same year, carbon stocks in living biomass increase by the amount given in Table 7.1.4 – annual growth in biomass for land converted to another land use. The values given in Table 7.1.4 for high-producing and low-producing grassland are Tier 1 defaults. The value given for grassland with woody biomass is a country-specific factor based on Wakelin (2004).

Dead organic matter

New Zealand does not report estimates of dead organic matter for high-producing grassland or low-producing grassland as GPG-LULUCF states there is insufficient information to develop default coefficients for estimating the dead organic matter pool (IPCC, 2003). The notation key NE ('not estimated') is used in the common reporting format tables.

For grassland with woody biomass, an estimate of dead organic matter is available from Wakelin (2004), and estimates of dead organic matter 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 and a Tier 1 default for organic soils, as described in section 7.1.3.

The mineral soil carbon values for the three grassland subcategories at equilibrium state are given in Table 7.5.6.

Table 7.5.6 New Zealand's soil carbon stock values for the grassland subcategories

Land-use	Soil carbon stock density (t C ha^{-1})
High-producing grassland	104.99 ± 3.08
Low-producing grassland	105.80 ± 4.15
Grassland with woody biomass	98.42 ± 3.59

The IPCC default emission factors for organic soils under grassland are 0.25 and 2.5 t C ha^{-1} per annum for cold temperate and warm temperate regimes respectively. These defaults are applied in proportion to the area of land in New Zealand where the Mean Annual Temperature is below or above 10°C respectively.

Liming

The calculation of carbon dioxide emissions from the liming of grassland soil is based on equation 3.4.11 in GPG LULUCF (IPCC, 2003) as outlined in section 7.9.4 – liming. 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 applied to cropland and grassland based on analysis of agricultural lime use by land use and farm type from the 2007 Agricultural Census. This analysis indicates that, each year, around 94 per cent of agricultural lime used in New Zealand is applied to grassland. The amount of lime applied to grassland is then converted to carbon emissions using a conversion factor of 0.12 from GPG-LULUCF, section 3.3.1.2.1.1 (IPCC, 2003).

Non-CO_2 emissions

Biomass burning

Only non-carbon dioxide emissions from wildfires in grasslands are reported for the LULUCF sector. Emissions from the burning of crop stubble and controlled burning of savannah are reported in the agriculture sector, and carbon dioxide emissions from natural disturbance events are not reported because the subsequent regrowth is not captured in the inventory (GPG-LULUCF, section 3.2.1.4.2, IPCC, 2003). In both these cases, the notation key NA ('not applicable') is used for controlled burning in common reporting format table 5(V).

To estimate the non-carbon dioxide emissions for wildfire in grassland remaining grassland, activity data is sourced from the National Rural Fire Authority database that has data from the year ending 31 March 1992. The average area burnt between April 1992 and April 2008 from this database is used as the estimate of area burnt for 1990 to 1991, as the estimates for this period are inaccurate due to the incomplete coverage in data collection. The April year data is then converted to calendar years for use in the inventory (Wakelin et al, 2009).

New Zealand-specific proportions of biomass burned during wildfire are used in the inventory. This is set at 100 per cent for high- and low-producing grassland and at 70 per cent for grassland with woody biomass (Wakelin, 2004). The biomass quantity for high- and low-producing grassland is a weighted value based on IPCC defaults (GPG-LULUCF, Table 3.4.2) and New Zealand-specific values (Payton and Pearce, 2001) compiled by Wakelin et al (2009). Different biomass quantity values are used for wildfire and controlled burning of grassland with woody biomass. The different values reflect the fact that grassland with woody biomass burnt for land conversion is of a lesser stature than other scrubland (type burnt by wildfire) (Wakelin, 2004).

Land converted to grassland

Living biomass

New Zealand uses a Tier 1 method to calculate emissions for land converted to grassland. The Tier 1 method multiplies the area of land converted to grassland annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass immediately after conversion is zero, that is, the land is cleared of all vegetation at conversion. The amount of biomass cleared when land at steady state is converted is shown in Table 7.1.3. The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place as outlined in equation 3.3.8 of GPG-LULUCF (IPCC, 2003).

Dead organic matter

For land conversion to high- and low-producing grassland, New Zealand reports only losses in dead organic matter. The losses are calculated based on the carbon in dead

organic matter at the site prior to conversion to grassland. It is assumed that immediately after conversion dead organic matter is zero (all carbon in dead organic matter prior to conversion is lost). There is insufficient information to estimate changes in carbon stock in dead organic matter pools after land is converted to high- or low-producing grassland (IPCC, 2003). Therefore, where there is no dead organic matter losses associated with the previous land use the notation key NE ('not estimated') is used in the common reporting format tables.

For land converted to grassland with woody biomass, there is a country-specific value for carbon in dead organic matter. Where land is converted to grassland with woody biomass, dead organic matter accumulates at 3 t C ha^{-1} over 28 years (the maturity period New Zealand has chosen for land to reach steady state) (Wakelin, 2004).

Soil organic carbon

Soil carbon stocks in land converted to grassland are estimated using the Soil Carbon Monitoring System, a Tier 2 method that uses New Zealand-specific, land-use and soil pedon data for mineral soils and a Tier 1 default for organic soils, as described in section 7.1.3. In the absence of country- and land-use specific data on the time rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original 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.

Non-CO_2 emissions

Biomass burning

Biomass burning on land converted to grassland 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.

7.5.3 Uncertainties and time-series consistency

As shown in Table 7.5.7, while the uncertainty introduced into the LULUCF net emissions by activity data is low, uncertainty in the IPCC default variable (GPG-LULUCF, Table 3.4.2, IPCC, 2003) dominates the overall uncertainty in the estimate for grassland provided by New Zealand.

The uncertainty in mapping grassland is ± 6 per cent. More details on this are given in section 7.2.5.

New Zealand uses IPCC default values for biomass accumulation in high-producing and low-producing grassland. The uncertainty in these figures is given as ± 75 per cent. New Zealand uses a New Zealand specific value for biomass accumulation in grassland with woody biomass. No uncertainty is available for this so the uncertainty value used is the same as for the IPCC default.

The uncertainties in soil carbon stocks for the three grassland subcategories are given in 7.5.7. More details on these are available in Annex 3.3.

Uncertainty in liming emissions is based on activity data uncertainty (amount of lime applied) from Statistics New Zealand. This is estimated as ± 6 per cent for limestone and ± 21 per cent for dolomite. These values are then weighted to give overall uncertainty for liming emissions of ± 6.2 per cent.

Of the grassland subcategories the largest per cent uncertainty is introduced into the net emissions by high-producing grassland.

Table 7.5.7 Uncertainty in New Zealand's 2009 estimates for the grassland category

Variable	Uncertainty at a 95% confidence interval (%)		
Grassland subcategory	High producing	Low producing	With woody biomass
Activity data uncertainty			
Uncertainty in land area	6.0%	6.0%	6.0%
Uncertainty introduced into net LULUCF emissions	*0.2%*	*0.1%*	*0.0%*
Emission factor uncertainty			
Uncertainty in biomass accumulation rates	75.0%	75.0%	75.0%
Uncertainty in soil carbon stocks	2.9%	3.9%	3.6%
Uncertainty in liming emissions	6.2%	6.2%	6.2%
Uncertainty introduced into net LULUCF emissions	*3.6%*	*0.9%*	*0.4%*

7.5.4 Category-specific QA/QC and verification

Carbon dioxide emissions from the 'grassland remaining grassland' and 'land converted to grassland' categories are key categories (level and trend, and level assessment, respectively). In the preparation of this inventory, the data for these emissions underwent Tier 1 QA/QC checks.

7.5.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the grassland category is shown in Table 7.5.8 below.

Table 7.5.8 Recalculations of New Zealand's net emissions from the grassland category in 1990 and 2008

	Net emissions		Change from the 2010 submission	
Grassland recalculations	2010 submission (Gg CO_2-e)	2011 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990 estimate	1,742.4	1,309.1	–433.3	–24.9
2008 estimate	3,557.0	2,499.9	–1,057.1	–29.7

Further explanation of these recalculations is provided below.

Activity data

For the 2011 submission, New Zealand has employed historical land-use data to model land-use change since 1962, in order to identify land in a state of conversion at 1990. The effect of this recalculation has been to transfer a proportion of land area from the 'land

remaining land' category to the 'land converted to' category, with the effect that lagged emissions and removals from land-use change events prior to 1990 have now been incorporated into the emission and removal estimates. See section 7.2.4 for further detail.

Emissions factors

The soil carbon stock factors have been improved (see section 7.1.3). The current reference value for mineral soils is 105.80 ± 4.15 t C ha^{-1} (Table 7.1.6), and the stock values for the three grassland subcategories are 104.99 ± 3.08, 105.80 ± 4.15 and 98.42 ± 3.59 t C ha^{-1} for high-producing, low-producing and woody biomass grasslands, respectively. The difference in stock values between low-producing grassland and high-producing grassland is –0.81 t C ha^{-1} (compared with –2.73 t C ha^{-1} in the previous submission), between low-producing grassland and grassland with woody biomass is –7.38 t C ha^{-1} (compared with –6.09 t C ha^{-1} in the previous submission).

7.5.6 Category-specific planned improvements

The carbon stock for the 'grassland with woody biomass' land-use subcategory will be improved using existing datasets. Additional work to improve the mapping of this land-use class will also be carried out.

7.6 Wetlands (CRF 5D)

7.6.1 Description

New Zealand has 425,000 kilometres of rivers and streams, and almost 4000 lakes that are larger than 1 hectare. Damming, diverting and extracting water for power generation, irrigation and human consumption has modified the nature of these waterways and can deplete flows and reduce groundwater levels. Demand for accessible land has also led to the modification of a large proportion of New Zealand's vegetated wetland areas in order to provide pastoral land cover. Just over 10 per cent of wetlands present prior to European settlement remain across New Zealand (McGlone, 2009).

Section 3.5 of GPG-LULUCF defines wetlands as "land that is covered or saturated by water for all or part of the year (eg, peat land) and that does not fall into the forest land, cropland, grassland or settlements categories". This category can be further subdivided into managed and unmanaged wetlands according to national definitions. The definition includes reservoirs and flooded land as managed subdivisions, and natural rivers and lakes as unmanaged subdivisions. Flooded lands are defined in GPG-LULUCF as "water bodies regulated by human activities for energy production, irrigation, navigation, recreation, etc, and where substantial changes in water area due to water regulation occur. Regulated lakes and rivers, where the main pre-flooded ecosystem was a natural lake or river, are not considered as flooded lands". As the majority of New Zealand's hydro-electric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river, they are not defined as flooded lands.[26] 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

[26] For example, the Clyde Dam was created from the damming of the Clutha River in the South Island, creating Lake Dunstan. The area flooded was mostly low-producing grassland.

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: 'wetland – open water', which includes lakes and rivers, and 'wetland – vegetated non-forest', which includes herbaceous vegetation that is periodically flooded, and estuarine and tidal areas. New Zealand has mapped its vegetated wetlands using existing LCDB data. Areas of open water have been mapped using hydrological boundaries defined by Land Information New Zealand (LINZ).

There were 652,807 hectares of wetlands in 2009 in New Zealand, a decrease of 242 hectares (0.04 per cent) since 1990. This category is 2.4 per cent of the total New Zealand land area.

In 2009, there were no emissions from wetlands, compared with emissions of 164.7 Gg CO_2-e from wetlands in 1990. This is because carbon stock changes are not estimated for wetlands remaining wetlands (see section 7.6.2), and there were no new land conversions to wetlands in 2009.

Conversion to wetlands was a key category in 2009 in the trend assessment. Conversion to wetland shows up as a key category because there were no new land conversions to wetlands in 2009. This means the trend analysis compares 1990 emissions with the value of 0 for 2009 so a small change appears to be significant.

Table 7.6.1 New Zealand's land-use change for the wetlands category in 1990 and 2009, and associated CO_2-equivalent emissions

Wetlands land-use category	Net area in 1990 (ha)	Net area in 2009 (ha)	Change from 1990 (%)	Net emissions/ removals (Gg CO_2-e) 1990	2009	Change from 1990 (%)
Wetlands remaining wetlands	639,177	648,696	+1.5	NE	NE	NA
Land in conversion to wetlands	13,872	4,110	–70.4	164.7	NE/NO	NA
Total	**653,049**	**652,807**	**–0.04**	**164.7**	**0.0**	**–100.0**

Notes: 1990 and 2009 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions from the wetlands remaining wetlands land-use category are not estimated (NE); see section 7.6.2 for details. Land in conversion to wetlands consists of land converted to hydro lakes prior to 1990.

As at 2009, there were 4110 hectares in a state of conversion to wetlands. 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.

Carbon stock change within the wetlands category is shown in Table 7.6.2. From 1990 to 2009, the net carbon stock change for wetlands decreased by 449.2 Gg C, equivalent to emissions of 1647.2 Gg CO_2 in total since 1990. These carbon stock losses are from the historical (pre-1990) conversion of forest land to hydro-electric dams, the lagged effect of which continues to impact on soil organic carbon on into the inventory period.

Table 7.6.2 New Zealand's carbon stock change by carbon pool within the wetlands category from 1990 to 2009

Wetlands subcategory	Net carbon stock change 1990–2009 (Gg C)				Emissions/ removals 1990–2009 (Gg CO_2)
	Living Biomass	Dead organic matter	Soils	Total	
Wetland – vegetative non forest	0.0	0.0	0.0	0.0	0.0
Wetland – open water	0.0	0.0	–449.2	–449.2	1,647.2
Total	0.0	0.0	–449.2	–449.2	1,647.2

Note: 'Wetlands – vegetated non-forest' and 'wetlands – open water are new subcategories within the wetlands category, which will be incorporated into the common reporting format tables in the 2012 submission.

7.6.2 Methodological issues

Wetlands remaining wetlands

Living biomass and dead organic matter

A basic method for estimating CO_2 emissions in wetlands remaining wetlands is provided in Appendix 3A.3 of GPG-LULUCF. The appendix covers emissions from flooded land and extraction from peat land. Recultivation of peat land is included under the agriculture sector.

Due to the current lack of data on biomass carbon stock changes in wetlands remaining wetlands, New Zealand has not prepared estimates for change in living biomass or dead organic matter for this category, as allowed for in the IPCC GPG-LULUCF, chapter 1.7.

Soil carbon

Soil carbon stocks in wetlands remaining wetlands are estimated using a Tier 2 method for mineral soils as described in section 7.1.3. 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.

The mineral soil carbon stock at equilibrium state for vegetated non-forest wetlands is estimated to be 97.35 t C ha^{-1}, with a standard error of 18.22 (Table 7.1.6).

The high level of uncertainty associated with this estimate is due to the small size of the dataset. Historically, little focus has been placed on collecting soil data under this land use as it represents 0.5 per cent of New Zealand's total land area, and the historical emphasis of soil data collection has been on productive land uses.

Non-CO_2 emissions

Biomass burning

Biomass burning on wetlands remaining 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.

Land converted to wetlands

Living biomass and dead organic matter

New Zealand uses a Tier 1 method to calculate emissions for land converted to wetlands (GPG-LULUCF, equation 3.5.6, IPCC, 2003). A key assumption is that all land converted to wetlands becomes flooded land. 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 conversions are equal to zero.

Soil carbon

Soil carbon stocks in land converted to wetlands are estimated using a Tier 2 method as described in section 7.1.3. In the absence of country- and land-use specific data on the time rate of change, the IPCC default method of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and wetlands for any given period.

Non-CO_2 emissions

Non-CO_2 emissions from drainage of soils and wetlands

New Zealand has not prepared estimates for this category as allowed for in IPCC GPG-LULUCF, chapter 1.7. The drainage of soils and wetlands is a relatively minor activity in New Zealand, and there is insufficient information to reliably report on this activity. New Zealand has accordingly reported NE ('not estimated') in the common reporting format tables.

Biomass burning

Biomass burning on land converted to wetlands is a relatively minor activity in New Zealand, and there is insufficient information to reliably report on this activity. The notation key NE ('not estimated') is used in the common reporting format tables.

7.6.3 Uncertainties and time-series consistency

The uncertainty in mapping wetlands is ± 6 per cent. More details on this are given in section 7.2.5.

New Zealand uses IPCC default values for biomass accumulation in wetlands which is given as ± 75 per cent.

The uncertainties in soil carbon stocks for wetlands is given in section 7.1.6. More details on these are available in Annex 3.3

New Zealand's emissions from wetlands is very low so despite these high uncertainty figures for biomass accumulation and soil carbon stocks the uncertainty introduced into net emissions by wetlands is very low.

Table 7.6.3 Uncertainty in New Zealand's 2009 estimates for the wetlands category

Variable	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	
Uncertainty in land area	6.0%
Uncertainty introduced into net LULUCF emissions	*0.0%*
Emission factor uncertainty	
Uncertainty in biomass accumulation rates	75.0%
Uncertainty in soil carbon stocks	18.7%
Uncertainty introduced into net LULUCF emissions	*0.0%*

Note: The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

7.6.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data and emissions factor for soil carbon change underwent Tier 1 quality checks.

7.6.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the wetlands land-use category is shown in Table 7.6.4. Recalculations were carried out for this category as a result of new activity data from the improved mapping process as described in section 7.2 – representation of land areas.

The carbon stock in soils at equilibrium state has also been recalculated since the last submission. Details of this process are described in section 7.1.3.

Table 7.6.4 Recalculations for New Zealand's net emissions from the wetlands category in 1990 and 2008

	Net emissions		Change from the 2010 submission	
Wetlands recalculations	**2010 submission (Gg CO_2-e)**	**2011 submission (Gg CO_2-e)**	**(Gg CO_2-e)**	**(%)**
1990	0.0	164.7	164.7	1,497,350.5
2008	0.8	8.7	7.8	946.2

7.6.6 Category-specific planned improvements

For the 2011 submission, New Zealand has mapped wetlands into two subcategories, 'wetlands – open water' and 'wetlands – vegetated non-forest'. The estimates for these subcategories have been separately calculated but reported in aggregate in the common reporting format tables. In the 2012 submission, these subcategories will be incorporated into the CRF tables and the emissions for each reported separately.

No additional improvements to the estimates for the wetlands category are currently planned.

7.7 Settlements (CRF 5E)

7.7.1 Description

The settlements land-use category, as described in GPG-LULUCF chapter 3.6, includes "all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories". Settlements include trees grown along streets, in public and private gardens, and in parks associated with urban areas.

There were 207,033 hectares of settlements in 2009 in New Zealand, an increase of 3567 hectares since 1990. This category was 0.8 per cent of New Zealand's total land area in 2009. The largest area of change to settlements between 1990 and 2009 was from high-producing grassland, with 4185 hectares of high-producing grassland converted to settlements between 1990 and 2009.

In 2009, the net emissions from settlements were 2.5 Gg CO_2-e. These emissions are entirely from the subcategory of land converted to settlements.

Settlements were not a key category in 2009.

Table 7.7.1 New Zealand's land-use change within the settlements category from 1990 to 2009, and associated CO_2-equivalent emissions

Settlements land-use category	Net area as at 1990 (ha)	Net area as at 2009 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2-e) 1990	2009	Change from 1990 (%)
Settlements remaining settlements	180,856	197,417	+9.2	NE	NE	NA
Land converted to settlements	22,610	9,615	–57.5	–7.2	2.5	–134.7
Total	**203,466**	**207,033**	**+1.8**	**–7.2**	**2.5**	**–134.7**

Notes: 1990 and 2009 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for the settlements remaining settlements land-use category are not estimated (NE) as New Zealand has insufficient activity data for this subcategory; see section 7.6.2 for details.

In 2009, there were 197,417 hectares of settlements remaining settlements. Carbon in living biomass and dead organic matter are not estimated for this land-use category. The carbon stock in soil for this land use is assumed to be in steady state.

There were 9615 hectares of land converted to settlements between 1990 and 2009.

Carbon stock change within the settlements category is shown in Table 7.7.2. From 1990 to 2009, the net carbon stock change for settlements decreased by 82.4 Gg C, equivalent to emissions of 302.2 Gg CO_2 in total since 1990. These carbon stock losses are predominantly due to the loss of living biomass on land converted to settlements (see Table 7.7.3).

Table 7.7.2 New Zealand's carbon stock change by carbon pool within the settlements category from 1990 to 2009

Land-use category	Net carbon stock change 1990–2009 (Gg C) Living Biomass	Dead organic matter	Soils	Total	Emissions/removals 1990–2009 (Gg CO_2)
Settlements	–113.8	–9.6	41.0	–82.4	302.2

7.7.2 Methodological issues

Greenhouse gas emissions and removals within the settlements land-use category derive principally from carbon stock changes within the living biomass pool. The IPCC notes that "while dead organic matter and soil carbon pools may also be sources or sinks of CO_2 in settlements, and CH_4 and N_2O emissions may result from urban land management practices, little is known about the role and magnitude of these pools in overall greenhouse gas fluxes" (GPG-LULUCF, section 3.6, IPCC, 2003).

Therefore, the focus of New Zealand's methodological approach to estimating greenhouse gas emissions and removals for the settlements land-use category is on changes in carbon stock change in living biomass.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions and removals for settlements are summarised in Table 7.7.3.

Table 7.7.3 Summary of New Zealand emission factors for the settlements land-use category

Settlements greenhouse gas source category	Steady state carbon stock (t C ha^{-1})	Years to reach steady state	Carbon stock change on conversion to settlements (t C ha^{-1})	Reference
Biomass – all pools	NE	28	Instantaneous loss of previous land-use carbon stock	IPCC Tier 1 default (section 3.6.2, GPG-LULUCF, IPCC, 2003)
Soils – mineral	117.66	20	Linear change over the conversion period between before and after stock values	NZ Tier 2 Soil Carbon Monitoring System (McNeill et al, 2009)
Biomass burning	NE	NA	NE	

Notes: NE = Not estimated. NA =Not applicable.

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 (IPCC, 2003). New Zealand does not have this level of activity data and is therefore unable to estimate emissions for this subcategory. The reporting of settlements remaining settlements is optional (GPG-LULUCF, chapter 1.7, IPCC, 2003).

Soil carbon

Soil carbon stocks in settlements remaining settlements are unable to be estimated using the Tier 2 method for mineral soils as described in section 7.1.3, as there is no soil data for this land use. Soil data has not been collected for this land use as it represents only 0.8 per cent of New Zealand's total land area, and the historical emphasis of soil data collection has been on productive land uses. In the absence of either land-use specific data or an IPCC default, the Soil CMS model reference value (105.80 t C ha^{-1}) is used as the default. There is no Tier 1 default for estimating soil carbon stocks in organic soils for this land use.

Land converted to settlements

Living biomass and dead organic matter

New Zealand has applied a Tier 1 method for estimating carbon stock change with land conversion to settlements (GPG-LULUCF, equation 3.6.1, IPCC, 2003). This is the same as that used for other areas of land-use conversion (eg, land converted to cropland). The default assumptions for a Tier 1 estimate are that all living biomass and dead organic matter present before conversion are lost in the same year as the conversion takes place and that carbon stocks in living biomass and dead organic matter following conversion are equal to zero (GPG-LULUCF, section 3.6.2, IPCC, 2003).

Soil carbon

Soil carbon stocks in land converted to settlements are unable to be estimated using the Tier 2 method for mineral soils as described in section 7.1.3, as there is no soil data for this land use. Soil data has not been collected for this land use as it represents only 0.8 per cent of New Zealand's total land area, and the historical emphasis of soil data collection has been on productive land uses. In the absence of either land-use specific data or an IPCC default, the Soil CMS model reference value (105.80 t C ha^{-1}) was used as the default for mineral soils. In the absence of either country- or land-use specific data on the time rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and settlements for any given period.

Non-CO_2 emissions

Biomass burning

Biomass burning on land converted to settlements 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 settlements is ± 6 per cent. More details on this are given in section 7.2.5.

New Zealand uses the IPCC default values for biomass accumulation. The uncertainty in these figures is given as ± 75 per cent.

The uncertainties in soil carbon stocks are given in section 7.1.6. More details on these are available in Annex 3.3

Table 7.7.4 Uncertainty in New Zealand's 2009 estimates for the settlements category

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	6.0%
Emission factor uncertainty	75.0%
Uncertainty introduced into net LULUCF emissions	*0.001%*

Note: The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

7.7.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.7.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the settlements land-use category is shown in Table 7.7.5. 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 – representation of land areas.

The carbon stock in soils at equilibrium state has also been recalculated since the last submission. Details of this process are described in section 7.1.3.

Table 7.7.5 Recalculations for New Zealand's net emissions from the settlements category in 1990 and 2008

	Net emissions (Gg CO_2-e)		Change from the 2010 submission	
Settlements recalculations	2010 submission	2011 submission	(Gg CO_2-e)	(%)
1990 estimates	6.6	–7.2	–13.8	–209.2
2008 estimates	20.0	1.6	–18.5	–92.2

7.7.6 Category-specific planned improvements

New Zealand plans to introduce further improvements to the soil carbon stock values used in the Soil CMS, which may affect the soil reference stock value used for settlements. See section 7.1.3 – soils for details.

Activity data on the land area of settlements will be updated as new information on urban expansion becomes available.

No other changes to the settlements emission factors or methodology are planned.

7.8 Other land (CRF 5F)

7.8.1 Description

Other land is defined in GPG-LULUCF section 3.7 as including bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five land-use categories. It mostly consists 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 2009, the net emissions from other land were 7.2 Gg CO_2-e. These emissions occur in the land converted to other land category, and are 24.6 Gg CO_2-e (77.3 per cent) lower than the 1990 level of 31.9 Gg CO_2-e. This is primarily due to the smaller area of land estimated to have been converted to other land in 2009 than in 1990. Other land was not a key category in 2009.

The LCDB analysis shows that most of the land converted to other land between 1990 and 2009 (1108 hectares) was from the forest land category (Table 7.1.3). Between 1990 and 2009, 887 hectares of natural forest and 221 hectares of pre-1990 planted forest were converted to other land. This is likely to be mainly due to erosion of forested land. The net effect of this forest land conversion from 1990–2009 was a loss of –217.1Gg C, equivalent to emissions of 796.1 Gg CO_2-e over the period.

Other land was not a key category in 2009.

Table 7.8.1 New Zealand's land-use change within the other land land-use category from 1990 to 2009

Other land land-use category	Net area as at 1990 (ha)	Net area as at 2009 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2-e) 1990	2009	Change from 1990 (%)
Other land remaining other land	898,817	892,326	–0.7	NE	NE	NA
Land in conversion to other land	60	1,325	+2,103.0	31.9	7.2	–77.3
Total	**898,877**	**893,651**	**–0.6**	**31.9**	**7.2**	**–77.3**

Notes: 1990 and 2009 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for other land remaining other land are not applicable (NA) as change in carbon stocks and non-CO_2 emissions are not assessed for this category; see section 7.8.2 for details.

7.8.2 Methodological issues

Other land remaining other land

The area of other land has been estimated based on LCDB2. The method used is described more fully in section 7.2 – representation of land areas.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions and removals for other land are summarised in Table 7.8.2.

Table 7.8.2 Summary of New Zealand emission factors for the other land land-use category

Other land greenhouse gas source category	Steady state carbon stock (t C ha^{-1})	Years to reach steady state	Carbon stock change on conversion to other land (t C ha^{-1})	Reference
Biomass	NE	NA	Instantaneous loss of previous land-use carbon stock	IPCC Tier 1 default assumption (equation 3.7.1, GPG-LULUCF, IPCC, 2003)
Soils (Mineral)	88	20	Linear change over the conversion period between before and after stock values	Tier 2 NZ Soil Carbon Modelling System
Biomass burning	NE	NA	NE	–

Notes: NE =Not estimated. NA = Not applicable.

Living biomass and dead organic matter

All of New Zealand's land area in the other land category is classified as 'managed'. New Zealand considers all land to be managed as all land is under some form of

management plan, regardless of the intensity and/or type of land-management practices. No guidance is provided in GPG-LULUCF for estimating carbon stocks in living biomass or dead organic matter for other land that is managed, and, as a result, the change in carbon stocks and non-CO_2 emissions and removals are not assessed for this category.

Soil carbon

Soil carbon stocks in other land remaining other land are estimated using a Tier 2 method for mineral soils as described in section 7.1.3. The mineral soil carbon stock at equilibrium state for other land is estimated to be 64.9 t C ha^{-1}, with a standard error of 20.6 (Table 7.1.6).

The high level of uncertainty associated with this estimate is due to the small size of the dataset. Historically, little focus has been placed on collecting soil data under this land use as it represents just 3.3 per cent of New Zealand's total land area, and the historical emphasis of soil data collection has been on productive land uses.

There is no Tier 1 default for estimating emissions from organic soils for this land use.

Land converted to other land

Living biomass and dead organic matter

New Zealand uses a Tier 1 method to calculate emissions for land converted to other land (GPG-LULUCF, equation 3.7.1, IPCC, 2003). This is the same as that used for other areas of land-use conversion (eg, land converted to cropland). The Tier 1 method assumes carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place and that carbon stock in living biomass and dead organic matter following conversions are 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 as described in section 7.1.3. In the absence of country- and land-use specific data on the time rate of change, the IPCC default method of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and other land for any given period.

Non-CO_2 emissions

Biomass burning

Biomass burning on land converted to other land 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.

7.8.3 Uncertainties and time-series consistency

Uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. Uncertainty in other land introduces 0.001 per cent uncertainty into the LULUCF net carbon emissions. This is low as the area in other land and the emissions from other land are low.

Table 7.8.3 Uncertainty in New Zealand's 2009 estimates for the other land land-use category

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	6.0%
Emission factor uncertainty	75.0%
Uncertainty introduced into net LULUCF emissions	*0.001%*

Note: The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

7.8.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.8.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the other land category is shown in Table 7.8.4. Recalculations were carried out for this category as a result of new activity data from the improved mapping process as described in section 7.2 – representation of land areas.

Table 7.8.4 Recalculations for New Zealand's net emissions from the other land land-use category in 1990 and 2008

	Net emissions		Change from the 2010 submission	
	2010 submission (Gg CO_2-e)	2011 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	11.5	31.9	20.3	176.2
2008	26.9	7.2	–19.7	–73.4

7.8.6 Category-specific planned improvements

New Zealand plans to review its current mapping of forest land converted to other land, and the extent to which this is due to erosion, and will update its activity data in the next submission if this is warranted. Final estimates of land use and land-use change areas will be updated following production of the 2012 land-use map.

7.9 Non-CO_2 emissions (CRF 5(I-V))

7.9.1 Direct N_2O emissions from N 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 nitrous oxide (N_2O) emissions from nitrogen fertilisation are reported in the agriculture sector under the category 'direct soils emissions' (CRF 4D).

7.9.2 Non-CO_2 emissions from drainage of soils and wetlands (CRF 5.II)

New Zealand has not prepared estimates for this voluntary reporting category, as allowed for in the IPCC Good Practice Guidance for LULUCF, chapter 1.7.

7.9.3 N_2O emissions from disturbance associated with land-use conversion to cropland (CRF 5.III)

Description

Nitrous oxide emissions result from the mineralisation of soil organic matter with conversion to cropland. This mineralisation results in an associated conversion of nitrogen previously in the soil organic matter to ammonium and nitrate. Microbial activity in the soil converts some of the ammonium and nitrate present to N_2O. An increase in this microbial substrate caused by a net decrease in soil organic matter can therefore be expected to give an increase in net N_2O emissions (GPG-LULUCF, section 3.3.2.3).

Nitrous oxide emissions from disturbance associated with land-use conversion to croplands are minor in New Zealand, estimated at 7 tonnes in 2009, and 214 tonnes N_2O (66.2 Gg CO_2-e) in total since 1990 (Table 7.9.1). This reflects the relatively small area of land converted to croplands since 1990, and the moderately high carbon stocks of New Zealand's cropland soils (section 7.1.3).

Table 7.9.1 N_2O emissions from disturbance associated with land-use conversion to cropland

Area and associated emissions	1990	2009	Change since 1990
Area of land in conversion to cropland (ha)	34,229	33,659	–1.7%
Emissions from disturbance (Gg N_2O)	0.015	0.007	–77.3%

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, to estimate these emissions. The inputs to these equations are:

- change in carbon stocks in mineral soils, and estimated carbon losses from organic soils, on land converted to cropland: these values are calculated from the land converted to cropland soil carbon calculations
- EF1: the emission factor for calculating emissions of N_2O from nitrogen in the soil. New Zealand uses a country-specific value of 0.01 kg N_2O – N/kg N (Kelliher and de Klein, 2006)
- C:N ratio: the IPCC default ratio of carbon to nitrogen in soil organic matter (1:15) is used (IPCC, 2003)
- where an area of land converted to cropland has a lower mineral soil organic carbon stock than the subcategory of cropland it has been converted to, no N_2O emissions have been estimated as occurring, as there is no associated loss of soil organic carbon. 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 (see section 7.1.3).

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 7.9.2 Uncertainty in New Zealand's 2009 estimates for N_2O

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	5.5%
Emission factor uncertainty	40.0%
Uncertainty introduced into net N2O emissions for LULUCF	*24.7%*

Category-specific recalculations

For the 2011 submission, New Zealand has reported N_2O emissions from disturbance associated with land-use conversion to cropland in the common reporting format tables for the first time. In the previous submission, annual emissions were estimated at less than 1 tonne N_2O (0.1 tonnes N_20 in 2008, and 0.7 tonnes N_2O in total since 1990), and therefore were not reported in the CRF due to rounding.

Category-specific planned improvements

No additional improvements are currently planned to New Zealand's estimation of emissions from disturbance associated with land-use conversion to cropland.

7.9.4 Liming (CRF 5(IV))

Description

In New Zealand, agricultural lime is mainly applied to acidic grassland and cropland soils to maintain or increase the productive capability of soils and pastures.

Methodological issues

Information on agricultural lime (limestone) application is collected by the national statistics agency, Statistics New Zealand, as part of its annual *Agriculture Production Survey*. The *Agriculture Production Survey* has gaps in its time-series. No survey was carried out in 1991, or between 1997 and 2001. Linear interpolation has been used to represent the data for these years. Since 2002, there has been a drop in the amount of lime applied. It is unclear why this occurred but quantities applied do vary from year to year depending on a number of factors, including farming profitability.

Analysis of the results of the *Agriculture Production Survey* indicate 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. Emissions associated with liming are estimated using a Tier 1 method (GPG-LULUCF equation 3.4.11, IPCC, 2003), and the IPCC default emission factor for carbon conversion of 0.12.

Uncertainties and time-series consistency

The uncertainty in LULUCF net emissions introduced by liming has been reported under the relevant land use, namely cropland and grassland.

Category-specific recalculations

In previous *Agriculture Production Surveys*, data on lime and dolomite application have been aggregated together, and New Zealand reported IE for dolomite in the CRF tables. For the 2008 and 2009 surveys, however, estimates of limestone use and dolomite use were reported separately. These data showed that 1.2 per cent of total agricultural lime in New Zealand was comprised of dolomite. This has been used to report the emissions from limestone and dolomite application separately in CRF tables 5(IV) under cropland remaining cropland and grassland remaining grassland.

Category-specific planned improvements

New Zealand will continue to update activity data on liming as it becomes available from Statistics New Zealand. No other future improvements are currently planned.

7.9.5 Biomass burning (CRF 5.V)

Description

Biomass burning may occur as a result of wildfires or controlled burning, and results in emissions of CO_2, CH_4, N_2O, CO and NO_x. The general approach for estimating greenhouse gas emissions from biomass burning is the same regardless of the specific land-use type.

Biomass burning is not a significant source of emissions for New Zealand as the practice of controlled burning is limited and wildfires are not common due to New Zealand's temperate climate and vegetation.

Methodological issues

New Zealand reports on emissions from wildfire in forest land and grassland, and controlled burning associated with land-use change from grassland to forest land based on activity data and an assumption of the proportion of these areas burnt. Emissions from controlled burning in land converted to grassland are not reported in the inventory because there is insufficient information on the proportion of land burnt during this change. Emissions from the burning of crop stubble and controlled burning of savannah are reported in the agriculture sector (chapter 6).

Tier 2 methodologies are employed to estimate emissions from biomass burning in New Zealand. Country-specific emission factors are applied (Wakelin et al, 2009) along with IPCC equations to derive emissions (IPCC, 2003 sections 3.4.2.1.1.2 and 3A.1.12). 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 – representation of land areas. For the land remaining land categories, activity data is sourced from the National Rural Fire Authority database, which has data from 1992 onwards.

The average area burnt between 1992 and 2009 from this database is used as the estimate of area burnt for 1990 to 1991 as the estimates for this period are inaccurate because of incomplete coverage in data collection. The March year data is then converted to calendar years for use in the inventory (Wakelin et al, 2009).

There has not been a significant change in wildfire activity since 1990 (Wakelin et al, 2009). Natural disturbance (lightning) induced wildfires are estimated to account for only 0.1 per cent of burning in grassland and forest land in New Zealand (Wakelin, 2006; Doherty et al, 2008). Emissions from these events are not reported because the subsequent regrowth is not captured in the inventory. In this situation, GPG-LULUCF (3.2.1.4.2) states that "if methods are applied that do not capture removals by regrowth after natural disturbances, then it is not necessary to report the CO_2 emissions associated with natural disturbance events". The emission of CO_2 from the combustion of biomass due to wildfires in forest land is not estimated (NE) at the time of burning. In planted forest, burnt stands are ether harvested or left to grow on at reduced stocking. CO_2 emissions are reported when the stand is harvested or deforested (with no reduction in stock when compared to an un-burnt stand). CO_2 lost in natural forest wildfires can be ignored since these fires do not result in land-use change and regrowth is not reported. 87.5 per cent of forests burnt in wildfires are planted forest. This means emissions may be underestimated where a mature stand is damaged during a wildfire event without a subsequent reduction in its net stocked area. However, this will be reported at the time of harvest. Given the few incidences of wildfire in New Zealand's planted forest lands, this is not regarded as a significant source of error (Wakelin, 2008).

In New Zealand, it is assumed that 25 per cent of grassland with woody biomass converted to forest land is cleared by controlled burning. Different biomass-density values for wildfire and controlled burning on grassland with woody biomass are used in the inventory. The differences are due to vegetation that is converted to forest, which is generally of a lesser stature when compared with other shrubland (Wakelin, 2008). The inventory does not report on-site preparation burning activities on forest land remaining forest. Although this practice is not thought to be significant, New Zealand is investigating a data source for this activity. Controlled burning of grassland with woody biomass for the establishment or re-establishment of pasture has also not been included. Conversions of planted forest land to grassland (pasture) have increased between 2004 and 2008; New Zealand is investigating sources of information to quantify emissions from this activity for possible reporting in future submissions (Wakelin, 2008).

Uncertainties and time-series consistency

Uncertainties arise from relatively coarse activity data for wildfires and a paucity of data for most controlled burning activities in New Zealand. Both liming and biomass burning statistics have gaps in the time-series where data collection did not occur or survey methodologies changed. Assumptions are made for some emission factors and burning fractions where insufficient data exists.

Table 7.9.3 Uncertainty in New Zealand's 2009 estimates for CH_4

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	7.6%
Emission factor uncertainty	40.0%
Uncertainty introduced into net CH_4 emissions for LULUCF	*30.2%*

Source-specific QA/QC and verification

Quality-control and quality-assurance measures are applied to the biomass burning and liming section of the inventory. The biomass burning dataset is scientifically verified whenever new data is supplied. In 2006 and 2009, the biomass burning parameters (emission factors, burning and emissions factors), assumptions and dataset were scientifically reviewed and updated. Data validation rules and plausibility tests were then applied to the dataset (Wakelin et al, 2009).

Category-specific recalculations

New Zealand has updated the country-specific emission factor for wildfire in forest land remaining forest land to better reflect the nature of the forest burnt. The quantity of biomass burned and the percentage of live biomass oxidised during wildfire in the grassland remaining grassland category has been refined to reflect New Zealand's specific conditions. The affect of the changes in this category are small due to the relatively minor incidences of wildfire in New Zealand.

Source-specific planned improvements

Emissions from controlled burning of planted forest harvesting residues, including those associated with planted forest land converted to grassland (pasture), are not reported in the inventory. New Zealand is investigating sources of information to quantify emissions from this activity for possible reporting in future submissions.

New Zealand is investigating attributing a proportion of wildfire activity into the land converted to forest land category.

The LUCAS plot network is currently being analysed to develop a better emission factor estimate for the grassland with woody biomass category.

Chapter 8: Waste

8.1 Sector overview

In 2009, the waste sector contributed 2,018.4 Gg carbon dioxide equivalent (CO_2-e) (2.9 per cent) of New Zealand's total greenhouse gas emissions. The largest source of waste sector emissions in 2009 was the solid waste disposal on land category, which contributed 1,398.6 Gg CO_2-e (or 69.3 per cent of waste sector emissions). The wastewater handling category contributed 617.7 Gg CO_2-e (30.6 per cent) of waste sector emissions and the waste incineration category contributed the remaining 2.2 Gg CO_2-e (0.1 per cent).

Emissions from the waste sector were 32.9 Gg CO_2-e (1.6 per cent) below the 1990 baseline value of 2,051.3 Gg CO_2-e (Figure 8.1.1). This reduction, despite an increase in New Zealand's economic activity – which is generally coupled with an increase in waste generation – occurred in the solid waste disposal on land category as a result of initiatives to improve solid waste management practices.

Methane (CH_4) emissions from solid waste disposal were identified as a key category in the 2009 level assessment and in the 1990–2009 trend assessment. Methane emissions from wastewater handling were also identified as a key category in the 2009 level assessment, but only in the analysis of total emissions.

Figure 8.1.1 New Zealand's waste sector emissions from 1990 to 2009

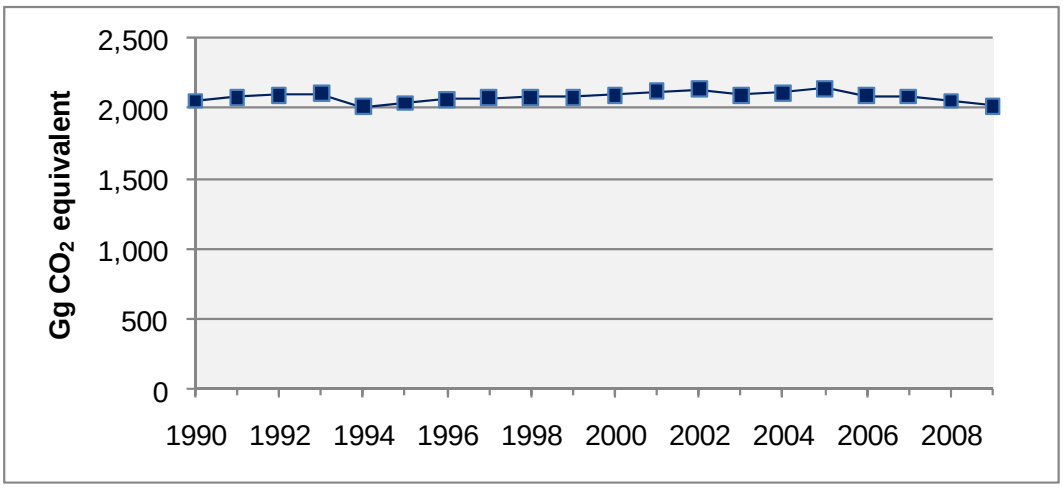
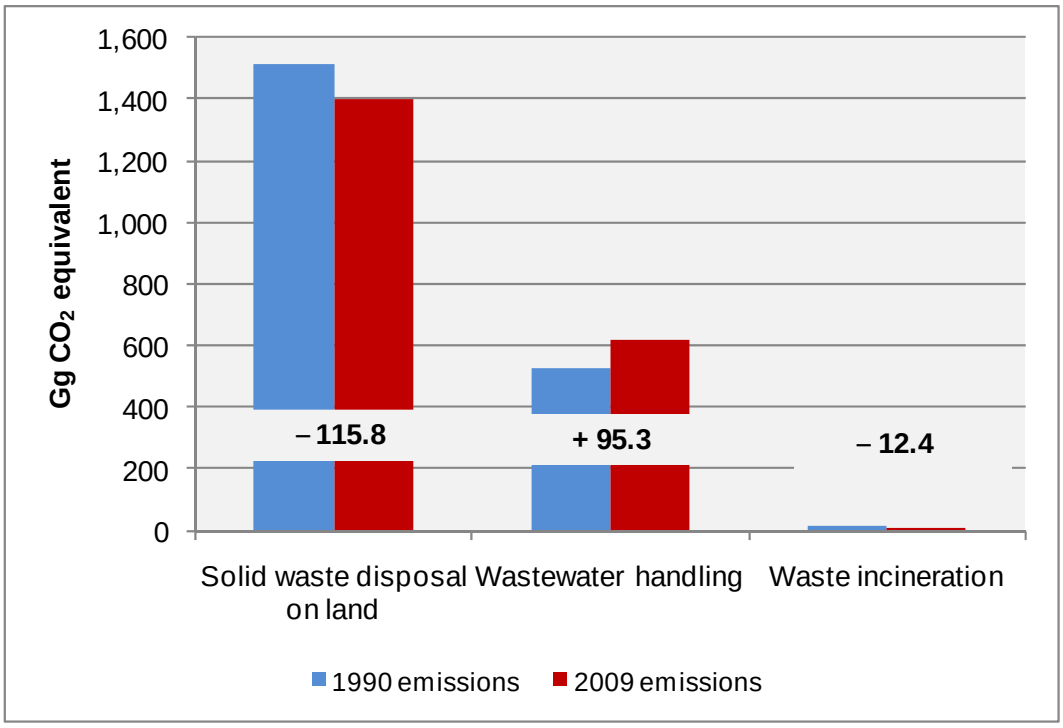


Figure 8.1.2 Change in New Zealand's emissions from the waste sector from 1990 to 2009



The disposal and treatment of industrial and municipal waste can produce methane and carbon dioxide emissions. Methane (CH_4) is produced as a by-product of anaerobic decomposition, while carbon dioxide is produced from the aerobic decomposition of organic material. Carbon dioxide (CO_2) emissions from the waste sector are not reported in the inventory because they are considered to be reabsorbed by growing organic matter in the following year.

8.1.1 Summary of improvements

The estimates for the waste sector have been recalculated. This is largely due to improved methodologies for calculating emissions and recovery of emissions from solid waste disposed to land. These improvements have come from:

- a better understanding of the management and design of landfills with operational CH_4 recovery systems
- the application of nationally consistent assumptions on the composition of solid waste.

The recalculations to the sector have also been influenced by the inclusion of new emission sources in the wastewater handling category. These improvements are the result of improved data for:

- treatment practices and sludge disposal methods of wastewater treatment plants
- the population serviced by each wastewater treatment plant.

8.2 Solid waste disposal on land (CRF 6A)

8.2.1 Description

In 2009, solid waste disposal on land contributed 1,398.6 Gg CO_2-e (69.3 per cent) of total emissions from the waste sector. Solid waste disposal emissions in 2009 were 115.8 Gg CO_2-e (7.6 per cent) below the 1990 level of 1,514.4 Gg CO_2-e.

Methane (CH_4) emissions from solid waste disposal were identified as a key category in the 2009 level assessment and in the 1990–2009 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 reported in the inventory as it is assumed to be reabsorbed in the following year. 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. In 1995, a national landfill census showed there were 327 legally operating landfills or solid waste disposal sites in New Zealand that accepted approximately 3.18 million tonnes of solid waste (Ministry for the Environment, 1997).

Since 1995, there have been a number of initiatives to improve solid waste management practices in New Zealand. These include the release of guidelines for:

- the development and operation of landfills
- the management of closing and closed landfills
- landfill resource consent conditions under New Zealand's Resource Management Act 1991.

As a result of these initiatives, a number of poorly located and substandard landfills have been closed and communities are relying increasingly on modern regional disposal facilities for disposal of their solid waste. The *National 2006/07 Landfill Census* reported that there were 60 legally operating municipal landfills in New Zealand, a reduction of 82 per cent from 1995 (Ministry for the Environment, 2007). The same census reported that 3.156 million tonnes of solid waste were disposed of to landfill in 2006.

In March 2002, the Government released the *New Zealand Waste Strategy* (Ministry for the Environment, 2002a). The Strategy, which was revised in 2010, sets out the Government's long-term priorities for waste management and minimisation (Ministry for the Environment, 2010). The Strategy's two goals provide direction to local government, businesses (including the waste industry), and communities on where to focus their efforts to deliver environmental, social and economic benefits to all New Zealanders. The goals are:

- reducing the harmful effects of waste
- improving the efficiency of resource use.

As part of the implementation and monitoring of the waste strategy, the Government developed the *Solid Waste Analysis Protocol*, which provided a classification system, sampling regimes and survey procedures to measure the composition of solid waste streams (Ministry for the Environment, 2002b). In 2008, the Government passed the Waste Minimisation Act, which imposes a levy of $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.

8.2.2 Methodological issues

Method

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, 2006c).

Twenty-four landfill-specific first order decay models, based on the model contained within the IPCC 2006 guidance, were used to develop estimates of net CH_4 emissions from waste disposed to landfills with CH_4 recovery systems. An additional first order decay model was used to estimate net CH_4 emissions from waste disposed to landfills without CH_4 recovery systems.

Activity data

Waste placement for landfills with CH_4 recovery systems

Landfill-specific information on annual solid waste placement was developed for the 24 landfills with CH_4 recovery systems through direct contact with landfill operators (SKM, Unpublished (b)).

Waste placement for landfills without CH_4 recovery systems

Annual total waste placement to all landfills has been estimated based on national surveys for the years 1995, 1998, 2002 and 2006. For those years that data is not available, solid waste placement per person is estimated by either interpolation between surveyed data, dividing waste placement data from the most recently surveyed year with annual population data, or by applying the most recent survey data (Table 8.2.1).

The annual solid waste placement for landfills without CH_4 recovery systems was calculated by subtracting the sum of the known annual solid waste placement for the 24 landfills with CH_4 recovery systems (SKM, Unpublished (b)) from the calculated total annual solid waste placement discussed above.

The quantity of solid waste going to landfills in New Zealand in 2006 was equivalent to 749.4 kilograms per person per year. This is a 12.6 per cent reduction in waste generation from 1995, when waste generation was estimated to be 858.0 kilograms per person per year. The reduction in solid waste per person per day since 1995 is due to waste minimisation initiatives from central and local government and increased recycling, which are programmes encouraged through New Zealand's waste strategy (see section 8.2.1).

Table 8.2.1 New Zealand's generation rate of solid waste to landfill

Year	Generation rate (kilograms per person per year)	Source
1950–1994	857.9	1995 figure applied retrospectively
1995	857.9	Ministry for the Environment (1997)
1996	812.6	Interpolation
1997	767.4	Interpolation
1998	722.1	Ministry for the Environment (2000)
1999	730.9	Interpolation
2000	739.8	Interpolation
2001	748.6	Interpolation
2002	757.5	Ministry for the Environment (2003)
2003	757.1	Estimated using population growth and waste composition analysis
2004	774.4	Estimated using population growth and waste composition analysis
2005	761.9	Interpolation
2006	749.4	Ministry for the Environment (2007) and Waste Not Consulting (Unpublished)
2007–2009	749.4	2006 figure applied

Waste class

New Zealand has insufficient data to categorise solid waste as either municipal solid waste or industrial solid waste, because many municipal landfills accept industrial waste. All national data is therefore reported in the municipal solid waste class and industrial waste is included in the composition estimates for this class.

Waste composition

Activity data on solid waste composition was estimated in the national surveys for 1995 and 2004 (Ministry for the Environment, 1997; Waste Not Consulting, Unpublished). Linear interpolations were used to provide estimates for the years between the two national surveys. The 1995 estimate is used for preceding years, and the 2004 estimate is used for subsequent years, including 2009.

The New Zealand waste composition categories from the unpublished Waste Not Consulting report do not exactly match the definition categories required for the IPCC degradable organic carbon calculation (IPCC, 2006c). The difference is that New Zealand's putrescibles category combines the food waste stream and the garden waste stream for the degradable organic carbon calculation and methane generation rate. A separation of the combined waste stream into the two IPCC categories was not possible given the available data. To maintain consistency, New Zealand has estimated food waste and garden waste as a combined waste stream for the entire time period.

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 (DOCf), and the fraction of CH_4 in landfill gas (F) (Table 8.2.2) (IPCC, 2006c).

New Zealand applies the IPCC default CH_4 generation rate (referred to as the half-life value (k)) for a wet temperate climate (IPCC, 2006c) for waste disposed to landfills without CH_4 recovery systems. Default half-life values are applied to these landfills as there is no New Zealand-specific data on the half-life values of that solid waste. This climate type is considered the best fit for New Zealand's complex climate systems and geography.[27] The half-life values are consistent across the time-series.

New Zealand applies a conservative approach for estimating the combined food and garden stream by applying the half-life for food waste to the combined food and garden waste category. For consistency, the degradable organic carbon content for food waste has also been applied to the combined category.

New Zealand-specific parameters

Degradable organic carbon (DOC) – all landfills

The degradable organic carbon (DOC) varies across the time-series according to the New Zealand-specific composition data. The value for degradable organic carbon content per Gg of waste has remained constant since 2004, as there is no new data available for solid waste composition. The estimate of degradable organic carbon content in 1995 was 0.15 Gg C/Gg waste. This estimate has been applied to preceding years. The estimate increased over time to 0.17 Gg C/Gg waste in 2004, and this has been applied to subsequent years, including 2009). This increase was mainly due to an increase in the proportion of wood waste going to landfills.

Methane correction factor (MCF) for landfills with CH_4 recovery systems

A methane correction factor (MCF) of 1.0 is applied to all landfills with CH_4 recovery systems.

Methane correction factor (MCF) for landfills without CH_4 recovery systems

In 1997, it was estimated that 90 per cent of New Zealand's waste in 1995 was disposed to managed solid waste disposal sites and 10 per cent disposed to uncategorised sites (Ministry for the Environment, 1997). However, it was estimated that 100 per cent of solid waste would be disposed to managed sites by 2010, due to the closure of unmanaged landfills. Consequently, the CH_4 correction factor will increase to a value of 1.00 from 2010. These methane correction factors (MCF) are only applied to waste disposed at landfills without CH_4 recovery systems.

Methane generation rate/half-life (k) for landfills with CH_4 recovery systems

Methane generation rates/half-life values for waste disposed of to the 24 landfills with CH_4 recovery systems were determined based on rainfall and the values used in the Inventory of US Greenhouse Gas Emissions and Sinks 1990–2007 (SKM,Unpublished (b)). These values were then amended based on the management practices at each landfill. The practices considered were leachate collection, leachate recirculation, leachate treatment and quality of capping (SKM,Unpublished (b)).

[27] Mean average temperatures vary from 10 degrees Celsius in the south to 16 degrees in the north. Mean annual precipitation ranges from 600 to 1,600 mm (National Institute of Water and Atmospheric Research, NIWA 2010). Mean annual potential evapo-transpiration ranges from 200 mm to 1,100 mm.

Oxidation factor (OX)

An oxidation factor of 0.1 is applied to all landfills as landfills in New Zealand are capped and are categorised as well managed (IPCC, 2006c). The small proportion that are not well managed are considered through the adjusted methane correction factor, discussed above.

Table 8.2.2 Parameter values applied by New Zealand for estimating solid waste disposal to land

Parameter	Value	Source
All landfills		
Starting year	1950	IPCC default
Delay time	6 months	IPCC default
Fraction of DOC that decomposes (DOCf)	0.50	IPCC default
Fraction of CH_4 in landfill gas (F)	0.50	IPCC default
Oxidation correction factor (OX)	0.10	New Zealand specific
Degradable organic carbon (DOC)	Varies according to composition	New Zealand specific
Landfills with CH_4 recovery systems		
Methane generation rate / half-life (k)	Range of 0.038–0.090	New Zealand/landfill specific
Methane correction factor (MCF)	1.0	New Zealand specific
Landfills without CH_4 recovery systems		
Methane generation rate / half-life (k):		
Food and garden	0.185	IPCC default for food
Paper	0.060	IPCC default
Wood and straw	0.030	IPCC default
Textiles	0.060	IPCC default
Disposable nappies	0.100	IPCC default
Sewage sludge	0.185	IPCC default
Methane correction factor (MCF)	Range of 0.96000 – 0.99733	New Zealand specific

Recovery

In the 24 landfills identified by SKM as having CH_4 recovery systems, 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 (b)). The estimates of efficiencies modelled using landfill characteristics were validated by applying this method to the landfills that had metered data. The results and the data were, on average, very similar, although the method had a very slight tendency to underestimate recovery efficiency (by approximately 3 per cent).

Efficiencies ranged from 7 per cent to 90 per cent, with an average efficiency of 61.1 per cent.

8.2.3 Uncertainties and time-series consistency

The overall level of uncertainty is estimated at ±40 per cent. The uncertainty has been reassessed to consider the new information introduced and is based on the uncertainty provided for the recovery modelling (SKM, Unpublished (b)), and sits within the IPCC default uncertainty range for methane recovery, as some metered data is used.

8.2.4 Source-specific QA/QC and verification

In preparation for this inventory submission, the data for 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.

As part of New Zealand's national greenhouse gas inventory system, the data provided by SKM (Unpublished (b)) was peer reviewed by independent experts, Tonkin and Taylor Ltd (Unpublished (a)). Errors identified were corrected by SKM and Tonkin and Taylor (Unpublished (a)) recommended that the improvements and methodology were acceptable for inclusion in this submission.

8.2.5 Source-specific recalculations

In previous submissions, separate degradable organic carbon values were used for waste disposed at landfills with CH_4 recovery systems and waste disposed at landfills without CH_4 recovery systems. This submission uses consistent degradable organic carbon values for waste disposed to all landfills.

The waste placement, decay values and collection efficiencies of landfills that have CH_4 recovery systems were recalculated based on surveys of these landfills and the review of previous Ministry for the Environment documents (SKM, Unpublished (b)). This updates the approach taken by Waste Management New Zealand (2005) that was applied to previous submissions.

The waste placement into landfills without CH_4 recovery systems was recalculated by considering the difference between the annual total waste placement value, and the summed placement values for those landfills with CH_4 recovery systems (or plans to install them). As placement values to landfills with CH_4 recovery systems were updated from previous estimates (SKM, 2009), this has resulted in a recalculation of the waste placement into landfills without CH_4 recovery systems.

New activity data on untreated sludge to landfills has been included in the estimates for solid waste disposal sites. This information was obtained by determining the amount of wastewater treated by each wastewater treatment plant and each plant's sludge disposal methods for 1990 to 2008 (Tonkin and Taylor, 2011b). These estimates were extrapolated back to 1950 and forward to 2009 using linear regression.

8.2.7 Source-specific planned improvements

In 2010, a complete year of waste placement information was collected under the Waste Minimisation Act 2008. This information will be assessed and work will be undertaken to incorporate the total annual solid waste placement in future inventory submissions.

The next submission will remove the methodological inconsistency regarding solid waste half lives between landfills with CH_4 recovery systems, and those without. As noted in 8.2.2 *New Zealand-specific parameters*, emissions are estimated from landfills with CH_4 recovery systems using rainfall and leachate management information, applied to the 'bulk waste' categorisation of solid waste. In contrast, emissions from landfills without CH_4 recovery systems use IPCC 2006 default half-life values for specific waste classes. The effect of this inconsistency on net CH_4 emissions is expected to be small, as the large majority of solid waste is disposed to landfills with CH_4 recovery systems. Due to insufficient data currently it is not known if this inconsistency is an overestimate or underestimate of net emission. Rainfall data and leachate management data will be utilised for all solid waste disposal sites in the next submission.

8.3 Wastewater handling (CRF 6B)

8.3.1 Description

In 2009, wastewater handling produced 617.7 Gg CO_2-e (30.6 per cent) of emissions from the waste sector. This was an increase of 95.3 Gg CO_2-e (18.3 per cent) from the 1990 level of 522.3 Gg CO_2-e and is due to increases in emissions from both the industrial and domestic sectors.

Methane emissions from wastewater handling were identified as a key category in the 2009 level assessment, but only in the analysis of total emissions.

Domestic and commercial wastewater

Domestic and commercial wastewater contributed 268.41 Gg CO_2-e (43.5 per cent) of the emissions from the wastewater handling category.

Wastewater from almost every town in New Zealand with a population over 1000 is collected and treated in community wastewater treatment plants. There are approximately 317 municipal wastewater treatment plants in New Zealand and approximately a further 50 government or privately owned treatment plants serving more than 100 people.

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 349.26 Gg CO_2-e (56.5 per cent) of the emissions from the wastewater handling category. This includes the major sources of industrial wastewater from the wine production, wool scouring and meat industries. Most of the industrial wastewater treatment is aerobic and any 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 processing 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 a refinement of the IPCC Tier 1 method (IPCC, 2006c).

Activity data

The population using each municipal treatment plant in New Zealand has been determined (SCS Wetherill Environmental, 2002; Beca, Unpublished; Tonkin and Taylor, Unpublished (b)). In 2006, the total connected population was 3.89 million. This excludes an estimated 411,000 people connected to rural septic tanks. This is a minimal difference between the estimated 2009 population. The different is unlikely to be significant within the accuracy of the calculations (Tonkin and Taylor, 2011b).

Parameters

It is good practice to use country-specific data for the maximum CH_4 producing capacity factor (B_o). Where no data is available, the revised 1996 IPCC guidelines recommend using a B_o of 0.25 kg CH_4/kg COD (chemical oxygen demand) or 0.6 kg CH_4/kg BOD (biological oxygen demand). The IPCC biological oxygen demand value is based on a 2.5 scaling factor of the chemical oxygen demand value (IPCC, 2000). New Zealand uses these 1996 IPCC default factors.

New Zealand uses a value of 0.026 kg BOD/1000 person/year. This is equivalent to the IPCC high-range default value for the Oceania region of 70 g/person/day (IPCC, 1996). This value has been determined as a typical value for wastewater treatment methods adopted in New Zealand (Beca, Unpublished). This value has been further increased by 25 per cent to allow for commercial and industrial activity within a municipal area.

Recovery

Methane removal via flaring or for energy production is known to occur at eight plants in New Zealand, and consequently methane is not emitted. Although these plants use anaerobic digesters as a component of the treatment, they are categorised as "centralised aerobic treatment plant, well managed" according to the IPCC (2006c), and the default CH_4 emission factor is zero.

Methane emissions from industrial wastewater treatment

Method

The IPCC default method is used to calculate emissions from industrial wastewater treatment (IPCC, 2006c).

Activity data

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.

For each industry, an estimate is made of the total industrial wastewater output in tonnes per year. The meat industry livestock data (Ministry of Agriculture and Forestry, 2010; Deer Industry New Zealand, 2009) is divided into kills and rendering. This separation entails two different methods: emissions from kills are calculated based on a pro-rata of previous inventories and actual carcass numbers, whereas emissions from rendering are calculated based on wastewater volume (Beca, Unpublished).

An estimate of the pulp and paper wastewater output is based on the paper, paperboard and pulp production (tonnes) from the industry. This information is updated quarterly by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2010).

The dairy industry predominantly uses aerobic treatment. There is only one remaining factory that uses anaerobic treatment (Beca, Unpublished). The wastewater is covered and the majority of the captured biogas (consisting of 55 per cent CH_4) is used to operate the boilers. The remainder is flared (Beca, Unpublished). Consequently, there are no emissions from this industry.

Parameters

The IPCC (2006c) default values for wastewater generated and chemical oxygen demand are used to calculate emissions from meat processing wastewater.

Estimates from the pulp and paper industry are derived from the chemical oxygen demand (COD)/t product which is determined from industry data for biochemical oxygen demand (BOD)/t product, using a conversion factor of COD = 2.2 × BOD.

For meat processing (rendering), total organic wastewater is a function of the IPCC (2006c) default COD value (4.1 kg COD/m^3) and site-specific estimates of wastewater treatment activity.

Recovery

There is no recovery of emissions reported for this source.

Methane emissions from domestic sludge treatment

Method

The IPCC (1996) Tier 1 method is used to calculate emissions from domestic sludge treatment.

Activity data

Estimates are derived from applying information on the number of treatment plants in New Zealand, the population connected to each treatment plant and the treatment methods of each plant (Beca, Unpublished; Tonkin and Taylor, Unpublished (b)).

The amount of domestic sludge treated by each plant has been determined from the details provided for each of the treatment plants in New Zealand.

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 and Taylor, Unpublished (b)). Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds.

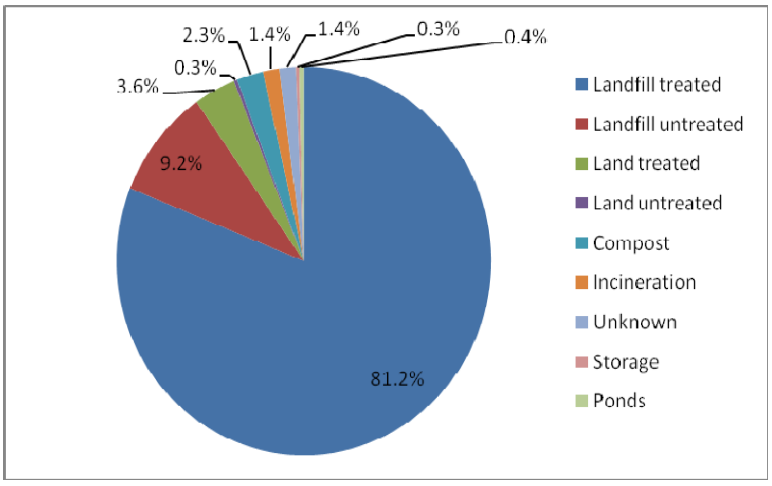
Oxidation ponds accumulate sludge on the pond floor. In New Zealand, these are typically only de-sludged every 20 years. The sludge produced is well stabilised with an average age of approximately 10 years. It has a low, biodegradable organic content and is considered unlikely to be a significant source of CH_4 (SCS Wetherill Environmental, 2002; Beca, Unpublished).

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.

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). The treated sludge sent to landfill is considered inert and therefore no emissions are produced, while untreated sludge emissions are included in the estimates for solid waste disposal to land (section 8.2).

Figure 8.3.1 Domestic sludge disposal in New Zealand, 2006



Parameters

New Zealand uses a value of 0.026 kg BOD/1000 persons/year. This is equivalent to the IPCC high-range default value for the Oceania region of 70 g/person/day (IPCC, 1996). This value has been determined as a typical value for wastewater treatment methods adopted in New Zealand (Beca, Unpublished). This value has been further increased by 25 per cent to include commercial and industrial activity within a municipal area.

The maximum producing capacity (B_o) has been calculated using the IPCC default value of 0.25 CH_4/kg COD (chemical oxygen demand) (IPCC, 1996).

A methane conversion factor of 1 has been used for anaerobic treatment systems, and a methane conversion factor of 0 used for aerobic treatment/handling systems.

Recovery

In 2008, anaerobic digestion treats 69 per cent of total domestic sludge in New Zealand. Of the sludge treated by anaerobic digestion, 96 per cent is treated by plants that utilise or flare methane.

A methane recovery value of 90 per cent is used for anaerobic digesters with known utilisation or flaring. This is a conservative method as a much higher destruction efficiency is expected. In accordance with the IPCC method, where the fate of the gas from an anaerobic digester is unknown, no CH_4 recovery is assumed.

Methane emissions from industrial sludge treatment

Method

The IPCC (1996) Tier 1 method is used to calculate emissions from industrial sludge treatment.

Activity data

In New Zealand, the pulp and paper industry has been determined as the only industry to produce a source of CH_4 from sludge treatment (Tonkin and Taylor, Unpublished (b)). An estimate of the pulp and paper wastewater output, is based on the paper, paperboard, and pulp production (tonnes) from the industry. This information is updated quarterly by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2010).

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.

Parameters

An 80 per cent chemical oxygen demand removal as sludge has been assumed (Tonkin and Taylor, Unpublished (b)).

The maximum producing capacity (B_o) has been calculated using the IPCC default value of 0.25 kilograms CH_4/kilograms chemical oxygen demand (IPCC, 1996).

A CH_4 conversion factor of 0.6 has been used for the pulp and paper industry as not all pulp and paper plants in New Zealand treat their sludge anaerobically This figure is likely to be conservative (ie, overestimate emissions) (Tonkin and Taylor, Unpublished (b)).

Nitrous oxide emissions from domestic wastewater

There are no methodologies to estimate these nitrous oxide emissions from domestic wastewater within New Zealand.

Nitrous oxide emissions from industrial wastewater treatment

The IPCC states that compared with domestic wastewater, the N_2O emissions from industrial wastewater are insignificant and can therefore be ignored (IPCC, 2006c). 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 industry.

Activity data

The activity is consistent with the activity data used for calculating CH_4 emissions from the meat industry under industrial wastewater treatment.

Parameters

Emissions are calculated using an emission factor of 0.02 kg N_2O-N/kg wastewater N (SCS Wetherill Environmental, 2002) to give the proportion of total nitrogen in the wastewater converted to N_2O.

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, 2006c).

Activity data

Nitrous oxide emissions from domestic wastewater sludge/human sewage treatment are updated based on population data from Statistics New Zealand.

Parameters

A value of 36.135 kg N/person/year is assumed for 1990 to 2009. This is the maximum value as reported to the Food and Agriculture Organization of the United Nations by New Zealand, and was used as there was no discernable trend between 1990 and 2009. Default IPCC values are used for the fraction of nitrogen in protein, the fraction of non-consumption protein, the fraction of industrial and commercial co-discharged protein, and nitrogen removed with sludge (IPCC, 2006c). The IPCC default emission factor of 0.005 kg N_2O-N/kg N is used (IPCC, 2006c).

Nitrous oxide emissions from industrial sludge

There are no methodologies to estimate these emissions within New Zealand.

8.3.3 Uncertainties and time-series consistency

Methane emissions from domestic sludge

The uncertainty of CH_4 from domestic sludge is assessed as being ±50 per cent. This uncertainty stems from:

- uncertainties in the method and factors used to calculate emissions from the sludge
- uncertainties in the quantities of sludge produced 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

The uncertainty is assessed as being +100 per cent to –50 per cent. This uncertainty stems from:

- uncertainties in the method and factors used to calculate emissions from the sludge
- uncertainties in the quantities of sludge produced
- the use of average removal efficiencies.

Methane emissions from domestic wastewater

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). The uncertainty reported for domestic wastewater values is based on an assessment of the reliability of the data and the potential for important sources to have been missed from the data. It is estimated that domestic wastewater CH_4 emissions have an accuracy of ±40 per cent (SCS Wetherill Environmental, 2002; Beca, Unpublished).

Methane emissions from industrial wastewater

Total CH_4 production from industrial wastewater has an estimated accuracy of ±70 per cent based on assessed levels of uncertainty in the input data (SCS Wetherill Environmental, 2002; Beca, Unpublished).

Nitrous oxide emissions from domestic sludge and industrial wastewater

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

As part of New Zealand's national system, the sludge data provided by Tonkin and Taylor (Unpublished (b)) was peer reviewed by independent experts, SKM (Unpublished (c)). Errors identified were corrected by Tonkin and Taylor, and SKM recommended that the methodology and improvements were acceptable for inclusion in this submission.

In 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

During the review of the 2010 submission, New Zealand provided estimates that largely improved the completeness of the wastewater inventory. This included revised estimates for estimating CH_4 emissions from sludge, and including CH_4 emissions from wool scouring and wine production wastewater.

The following section only addresses the minor recalculations made since the review of the 2010 submission.

Methane emissions from domestic wastewater

Methane emissions from domestic wastewater were recalculated using the population method provided by Tonkin and Taylor (Unpublished (b)). This has improved the consistency of datasets within the waste inventory.

Methane emissions from industrial wastewater

The 2008 value for CH_4 emissions from industrial wastewater handling has been recalculated using revised figures relating to the meat industry.

Methane emissions from industrial sludge

In the 2010 submission, the total degradable material figures were incorrectly entered as the organic sludge figures. These figures have been corrected in this submission.

8.3.7 Source-specific planned improvements

Further work is planned to refine the CH_4 emissions estimates from industrial sludge. This will potentially involve refining the actual production rates and disposal methods for each of the producers and potentially result in New Zealand-specific factors for methane producing capacity (B_o) and a refined New Zealand-specific fraction of industrial degradable organic component removed as sludge.

8.4 Waste incineration (CRF 6C)

8.4.1 Description

In 2009, waste incineration accounted for 2.2 Gg CO_2-e (0.1 per cent) of waste emissions. This was a decrease of 12.4 Gg CO_2-e (84.9 per cent) from the 1990 level of 14.6 Gg CO_2-e.

Waste incineration management in New Zealand

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

The 2006 IPCC guidelines (IPCC, 2006c) are used to calculate emissions from the incineration of waste because the revised 1996 IPCC guidelines (IPCC, 1996) and the IPCC Good Practice Guidance (IPCC, 2000) do not contain methods for estimating emissions from waste incineration. New Zealand considers the 2006 IPCC 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. This meant activity data had to be interpolated and 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.

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, 2006c). 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, 2006c). Biogenic CO_2, such as that from paper, cardboard and food, is excluded in accordance with the IPCC (IPCC, 2006c). Also excluded are emissions from waste to energy incineration facilities, as they are reported within the energy sector of the inventory.

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.

Parameters

Quarantine waste

Many incinerators in New Zealand are quarantine waste incinerators. The IPCC does not have a default category for quarantine incinerators. Only three default classifications are available: clinical waste, hazardous waste, and sewage sludge. None of these categories appropriately represent New Zealand quarantine waste, which contains paper, plastics, food and dunnage. 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. This is because clinical waste may also contain paper, plastics and biological matter (SKM, Unpublished (a)).

Estimates of direct emissions are made using the default Tier 1 methodology (IPCC, 2006c). Default emission factors for CO_2, CH_4 and N_2O are taken from the 2006 IPCC guidelines. New Zealand uses the mid-point where these emission factors are presented as a range.

Hazardous and clinical waste

Default IPCC compositional values are used to estimate the fossil fuel-derived carbon content of hazardous and clinical waste (IPCC, 2006c). These values are 27.5 per cent for hazardous waste (being the mean of the recommended range) and 25 per cent for clinical waste.

The default emission factor for industrial waste is used for hazardous waste, and the default emission factor for municipal/industrial waste is used for clinical waste. 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* (Eng et al, 2008). 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, 2006c).

Sewage sludge

The Japanese emission factor is used for sewage sludge. The IPCC guidelines note that the most detailed observations of CH_4 emissions from waste incineration have been made in Japan (IPCC, 2006c, Volume 5, section 5.4.2).

8.4.3 Uncertainties and time-series consistency

As per the IPCC recommendation for uncertainties relating to activity data (IPCC, 2006c, Volume 5, section 5.7.2), the conservative estimated uncertainty for the amount of wet waste incinerated is ±10 per cent. The uncertainty for the data is likely to be greater than this, particularly where projections are based on a mass burn rate and assumed operating hours (SKM, Unpublished (a)).

The data collected for the composition of waste is not detailed. Therefore, as per the recommendation for uncertainties relating to emission factors (IPCC, 2006c Volume 5, section 5.7.1), 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, 2006c Volume 5, section 5.7.1); hence, the estimated uncertainty for default CH_4 and N_2O factors is ±100 per cent (SKM, Unpublished (a)).

8.4.4 Source-specific QA/QC and verification

As there were no 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 were no recalculations carried out for this category.

8.4.6 Source-specific planned improvements

No improvements are planned for this category.

Chapter 9: Other

New Zealand does not report any emissions under the UNFCCC category 7, ‘Other’.

Chapter 10: Recalculations and improvements

This chapter summarises the recalculations and improvements made to the New Zealand Greenhouse Gas Inventory following the 2010 submission common reporting format (CRF) version 1.2. 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 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 in a given year may differ from emissions 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.

The recalculation database

As part of the review process for the 2010 inventory submission, New Zealand resubmitted the common report format tables in October 2010 in response to expert review recommendations (common report format ver 1.2). This resulted in a 461.2 Gg CO_2-e (0.6 per cent) increase to total emissions in the 2008 year. The revised estimates were in the energy and waste sectors and were largely matters of completeness.

Following this resubmission, the expert review team requested clarification of the revised energy numbers in December 2010. This resulted in a 32.8 Gg CO_2-e (0.0004 per cent) increase to New Zealand's total emissions (common report format ver. 1.2) in 2008. This clarification was provided in December 2010 when the expert review team requested the information. Given the advanced stage of compilation for the 2011 submission, it was not practical for New Zealand to make an official resubmission of the CRF tables. Consequently, the updated emissions data provided in December 2010 do not appear in the CRF recalculation database.

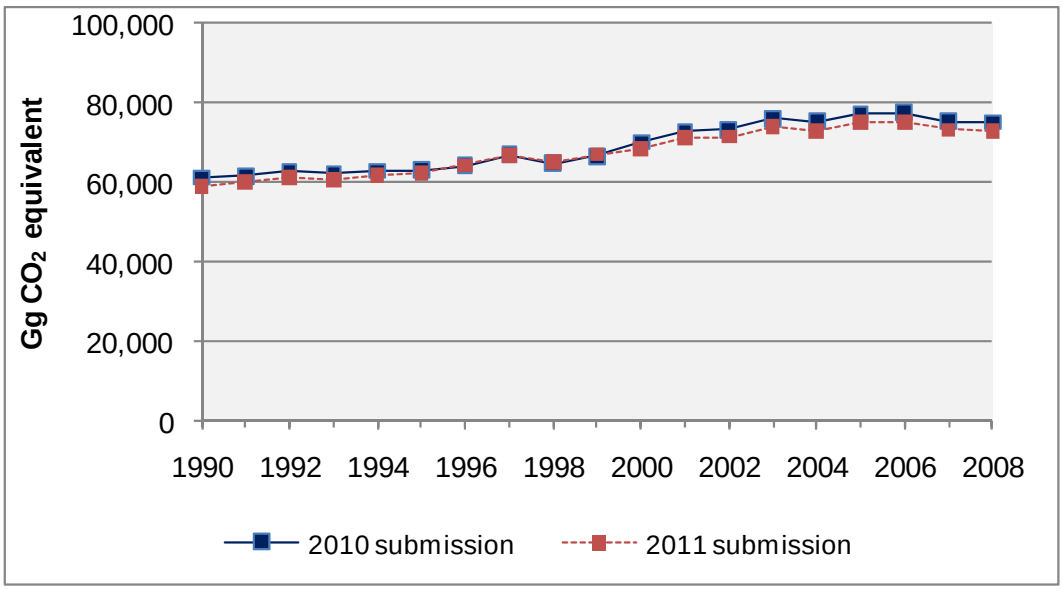
10.1 Implications and justifications

The overall effect of all recalculations in the 2010 inventory submission is shown in Figure 10.1.1. There was a 3.4 per cent (2,086.9 Gg CO_2-e) decrease in total (gross) emissions for the base year, 1990, and a 3.0 per cent (2,274.7 Gg CO_2-e) decrease in total emissions for the 2008 year. In New Zealand's 2010 inventory submission (1990–2008),

emissions were 22.8 per cent above the level reported in 1990. As a result of the recalculations in the 2011 inventory submission, total emissions for 2008 were 23.2 per cent above 1990. The greatest influence for recalculations of total emissions was the improvements made in the agriculture sector with the disaggregation of nitrogen excreted from cattle, sheep and deer into urine and dung fractions.

The following section details the effect of recalculations for each sector (excluding the solvent and other product use sector) and summarises the improvements that resulted in the recalculations.

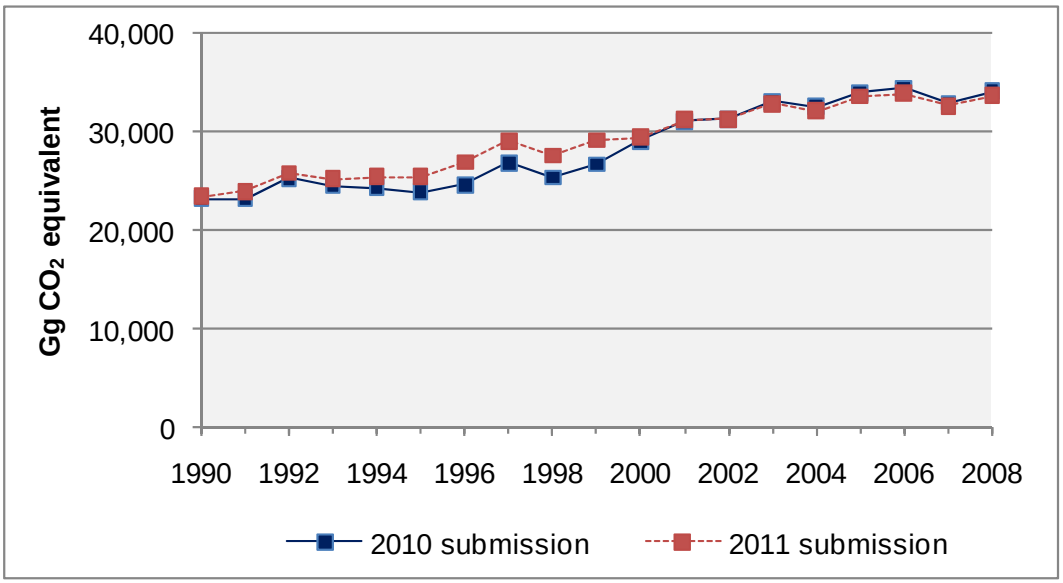
Figure 10.1.1 Effect of recalculations on New Zealand's total (gross) greenhouse gas emissions from 1990 to 2008



10.1.1 Energy

The improvements made in the energy sector have resulted in a 0.7 per cent (161.8 Gg CO_2-e) increase in energy emissions in 1990, and a 1.2 per cent (410.5 Gg CO_2-e) decrease in energy emissions in 2008 (Figure 10.1.2). The largest improvement was the completion and allocation of energy subcategories arising from the new *Annual Liquid Fuel Survey* (see section 3.3 for more detail on this survey). The recalculations made within the energy sector are summarised below.

Figure 10.1.2 Effect of recalculations on New Zealand's energy sector from 1990 to 2008



Fuel combustion: energy industries (section 3.3.1)

- Some cogeneration plants are now assigned to the public electricity and heat production subcategory rather than the manufacturing industries and construction subcategory. This has resulted in recalculations for the public electricity and heat production subcategory.
- Activity data for liquid fuels under the public electricity and heat production subcategory is now split between diesel and fuel oil and different emission factors applied. This improvement may not change the activity data total but will change the corresponding emissions.
- The reporting of the own use of natural gas at gas fields has been improved. This has resulted in slight revisions in activity data (and corresponding emissions for the manufacture of solid fuels and other energy industries subcategory. This subcategory now also includes natural gas liquids that were previously incorrectly included under liquefied petroleum gas for road transport.
- There have been small activity data revisions in some categories due to revisions in solid fuels data sources.

Fuel combustion: manufacturing industries and construction (section 3.3.2)

- This inventory submission includes the results of a new *Annual Liquid Fuel Survey*. With this new information, some liquid fuel demand that was previously allocated to the transport category has now been reallocated to the appropriate energy categories. This has resulted in revisions for activity data and corresponding emissions for liquid fuels in most subcategories.
- In previous inventory submissions biomass activity data was being overestimated. A more accurate activity data source based on the Bioassociation of New Zealand Heat Plant Database is now used.
- There have been small activity data revisions in some categories due to revisions in liquid fuels, natural gas and solid fuels data sources.

Fuel combustion: transport (section 3.3.3)

- This inventory includes the results of a new *Annual Liquid Fuel Survey*. With this new information, some liquid fuel demand that was previously allocated to the transport category has now been reallocated to the appropriate energy categories. This has resulted in revisions for activity data and corresponding emissions for gasoline and diesel oil in the road transport subcategory.
- Natural gas liquids were previously incorrectly assigned to the liquefied petroleum gas for the road transport subcategory. These natural gas liquids are now included in category manufacture of solid fuels and other energy industries (common reporting format category 1.AA.1.C).
- There have been small activity data revisions in some categories due to revisions in liquid fuels activity data provided by companies.
- The emission factor for natural gas has been slightly revised across the whole time-series. As this emission factor is a weighted average emission factor, small historical revisions in gas field production data means the historical emission factor will change.

Fuel combustion: other sectors (section 3.3.4)

- This submission includes the results of a new *Annual Liquid Fuel Survey*. With this new information, some liquid fuel previously allocated to the transport category has now been reallocated to the appropriate energy categories. This has resulted in revisions for activity data and corresponding emissions for liquid fuels in the commercial, residential and agriculture/forestry/fisheries subcategories.
- Natural gas activity data for one retailer that was previously unavailable is now reported. This has resulted in revisions across the whole time-series for the commercial and agriculture/forestry/fisheries subcategories.
- The emission factor for natural gas has been revised across the whole time-series. As this emission factor is a weighted average emission factor, small historical revisions in gas field production data means the historical emission factor will change.
- There have been small activity data revisions in some categories due to revisions in liquid, solid and gaseous fuels data sources.
- Activity data for residential use of biomass has been revised due to a revision in New Zealand household numbers provided by Statistics New Zealand. These numbers contribute to the calculation of the activity data.

Fugitive emissions (section 3.4)

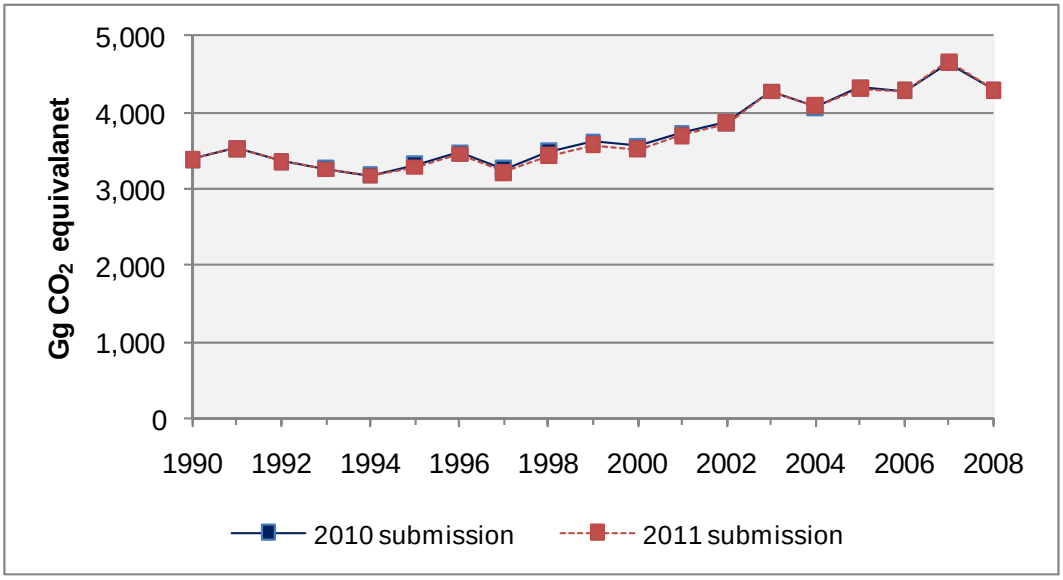
- Historical coal production data has been revised due to revisions provided by companies. This has resulted in revisions in activity data and corresponding emissions for some years.
- Activity data for oil transport has been revised due to a revision in crude oil production data provided by the New Zealand Refinery Company. Carbon dioxide emissions for oil transport are also included for the first time (they were previously not estimated).
- Methane emissions from natural gas other leakage are included for the first time in this inventory submission. In previous inventory submissions this category was not estimated.

- Historical venting and flaring activity data has been revised due to historical data revisions provided by companies.
- Activity data for gas distribution emissions has been revised due to a more accurate estimate of natural gas used in distribution pipelines becoming available.
- Fugitive emissions from geothermal between 1990 and 1998 have been revised. Because there is very little data around geothermal emissions in this period, emissions were estimated using a fixed amount each year. An implied emission factor based on the average activity data to emission ratio between 1999 and 2008 is now used which has resulted in revisions. Activity data from 2000 to 2008 has also been revised due to improved data becoming available from the Geothermal Association of New Zealand.

10.1.2 Industrial processes

The improvements made in the industrial processes sector have resulted in a 0.1 per cent (3.2 Gg CO_2-e) decrease in industrial processes emissions in 1990, and a 0.2 per cent (7.3 Gg CO_2-e) decrease in industrial processes emissions in 2008 (Figure 10.1.3). The improvements that resulted in the largest recalculation were for the estimates for mobile air conditioning. The recalculations made within the industrial processes sector are summarised below.

Figure 10.1.3 Effect of recalculations on New Zealand's industrial processes sector from 1990 to 2008



Mineral products (section 4.2.5)

The plant specific emission factors applied for lime production could not be verified in time for this submission. Consequently, the IPCC (2000) default emission factor for high calcium lime and the correction factor for hydrated lime have been applied for the whole time-series.

Chemical industry (section 4.3.5)

The emission factor for natural gas for the ammonia/urea subcategory has been revised across the entire time-series. This is because the emission factor is a weighted average emission factor and small historical revisions in gas field production data causes the historical emission factor to change.

Metal production (section 4.4.5)

Improvements were made to the time-series 1990–1999 for iron and steel production as a result of correcting the emission factor applied to the estimates for Pacific Steel. The emission factor now reflects the average of the implied emission factors for the period 2000–2008. While the 2010 submission improved the accuracy of the emission estimates for 2000–2008, the implied emission factor was not updated to reflect these improvements. This has now been corrected.

Consumption of halocarbons and SF_6 (section 4.7.5)

While there were many improvements made to this category, the largest improvement was in mobile air conditioning. The accuracy of emission estimates from mobile air conditioning has improved due to three factors.

- Vehicle fleet calculations are now based on Statistics New Zealand net import figures for each vehicle class to account for the changes in stocks of unregistered vehicles.
- More realistic mobile air conditioning HFC phase-in periods and refrigerant charges have been developed for new, used, assembled and retrofitted vehicles in the separate car, bus, light and heavy truck classes.
- Improved statistics from the New Zealand Transport Agency on the detailed age distribution of deregistered vehicles have been obtained from 1999 and this has improved the calculation of consequent emissions assumed from scrapping those vehicles containing HFC mobile air conditioning systems (with similar distributions interpolated for 1994 to 1998).

The improvements made to mobile air conditioning had an impact on the stationary refrigeration and air conditioning supply. In addition, the following improvements in completeness and accuracy were made to stationary refrigeration and air conditioning:

- air conditioning gas supply and equipment retirement rates
- eliminating likely double counting of R410A imported in 2008
- reassessing commercial air conditioning sales numbers, sizes and refrigerant charges
- equipment retirement scheme improvements
- dehumidifier exports, refrigerant charges and HFC proportions
- earlier commercial refrigeration transition to R404A
- earlier dairy refrigeration transition to R404A
- transport refrigeration a more complex mix of pre-charged and locally filled units
- historical gas supply for filling new equipment
- reassessment of imported gas shipment timing
- correcting omissions of small bulk gas exports.

Improvements made to other subcategories include:

- revised activity data for metered dose inhalers
- the completeness of the estimates where electricity providers corrected for previous omissions
- checking for consistency in calculations revealing two errors in previous calculations. The corrections have resulted in minor emission increases for 2008 and 2006 respectively.

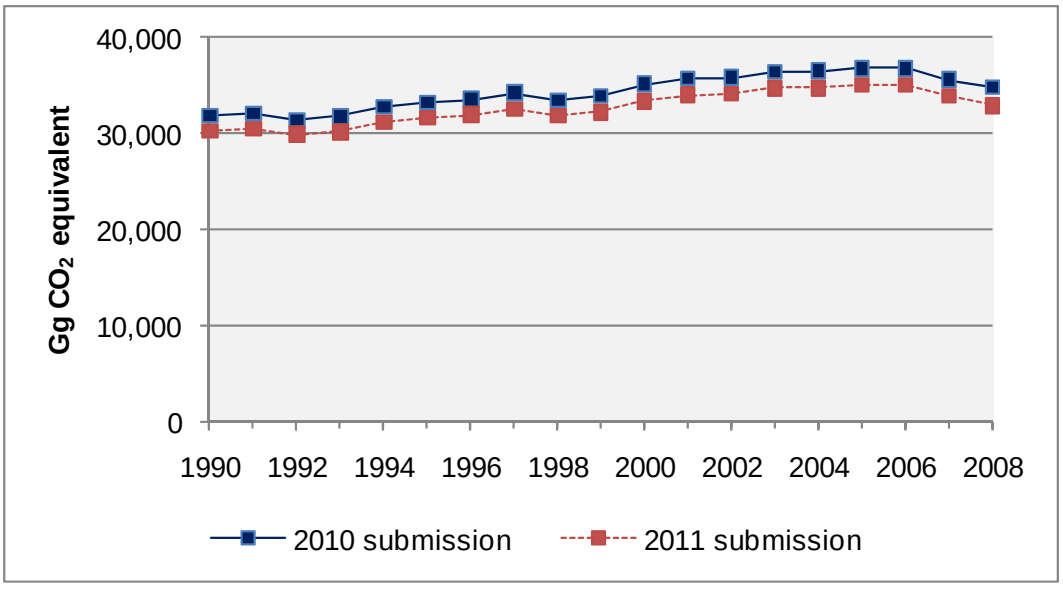
10.1.3 Solvent and other product use

There have been no recalculations made to this sector.

10.1.4 Agriculture

The improvements made in the agriculture sector have resulted in a 5.0 per cent (1,587.9 Gg CO_2-e) decrease in agriculture emissions in 1990, and a 5.6 per cent (1,959.4 Gg CO_2-e) decrease in agriculture emissions in 2008 (Figure 10.1.4). The largest improvement made in the agriculture sector is the disaggregation of nitrogen excreted from cattle, sheep and deer into urine and dung fractions. The recalculations made within the agriculture sector are summarised below.

Figure 10.1.4 Effect of recalculations on New Zealand's agriculture sector from 1990 to 2008



Agriculture soils

Two country specific EF's are now used in the calculation of emissions from animal production, namely $EF_{3(PR\&P)}$ = 0.01 for cattle, sheep and deer urine, and all manure from other species, and $EF_{3(PR\&P\ DUNG)}$ = 0.0025 for cattle, sheep and deer dung. As this is a change in methodology which has been applied to all years back to 1990, recalculations have been carried out for all years from 1990. This disaggregation has reduced emissions from the agriculture sector by 1,637.9 Gg CO_2-e in 1990 and 1,470.8 Gg CO_2-e in 2008.

Activity data

All activity data for enteric fermentation, manure management, agriculture soils and the field burning of agriculture residues was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2010), Livestock Improvement Corporation statistics (2010)). Activity data for the time-series of potato production and alpaca population were reviewed in 2010 and updated values have been used (Thomas 2010; Henderson and Cameron, 2010).

Tier 2 model

Enhancements of New Zealand's Tier 2 inventory model has resulted in recalculations of dairy, non-dairy and deer in enteric fermentation, manure management and agricultural soils.

10.1.5 Land use, land-use change and forestry (LULUCF)

The improvements made in the LULUCF sector have resulted in a 24.5 per cent (7,615.2 Gg CO_2-e) decrease in net LULUCF removals in 1990, and a 12.2 per cent (3,183.4 Gg CO_2-e) increase in net LULUCF removals in 2008 (Figure 10.1.5). The 2011 submission improvements comprise a second year of significant enhancements to the LULUCF inventory, following the introduction in the last submission of a new data collection and modelling programme for the New Zealand LULUCF sector – the Land Use and Carbon Analysis System (LUCAS). Further improvements and recalculations are expected to be introduced into the reporting in the LULUCF sector for the remainder of the first commitment period (see chapter 7 for details).

The recalculations of the LULUCF greenhouse gas estimates are largely the result of new information on historical land-use changes before 1990. This new information has enabled improved accuracy in the identification of land in a conversion state at 1990, and also the inclusion of lagged emissions and removals from land-use changes before 1990, which continue to have a carbon effect in the inventory period. Further detail is provided in section 7.1.5.

Other significant improvements include new mapping of deforestation, incorporation of emissions from the decay of historical harvesting residues, and the new reporting of emissions from organic soils. The effect of recalculations to the forest land and grassland categories is shown in Figures 10.1.6 and 10.1.7. The explanations and justifications for the recalculations of New Zealand's LULUCF estimates in the 2011 submission are summarised in Table 10.2.1

Figure 10.1.5 Effect of recalculations on net removals from New Zealand's LULUCF sector from 1990 to 2008

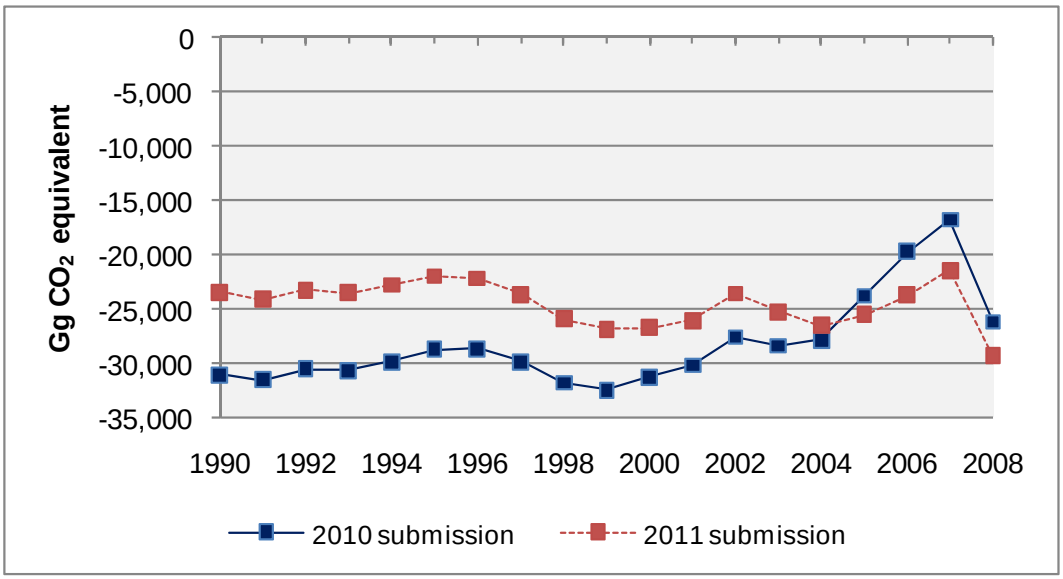


Figure 10.1.6 Effect of recalculations on net removals from New Zealand's forest land category from 1990 to 2008

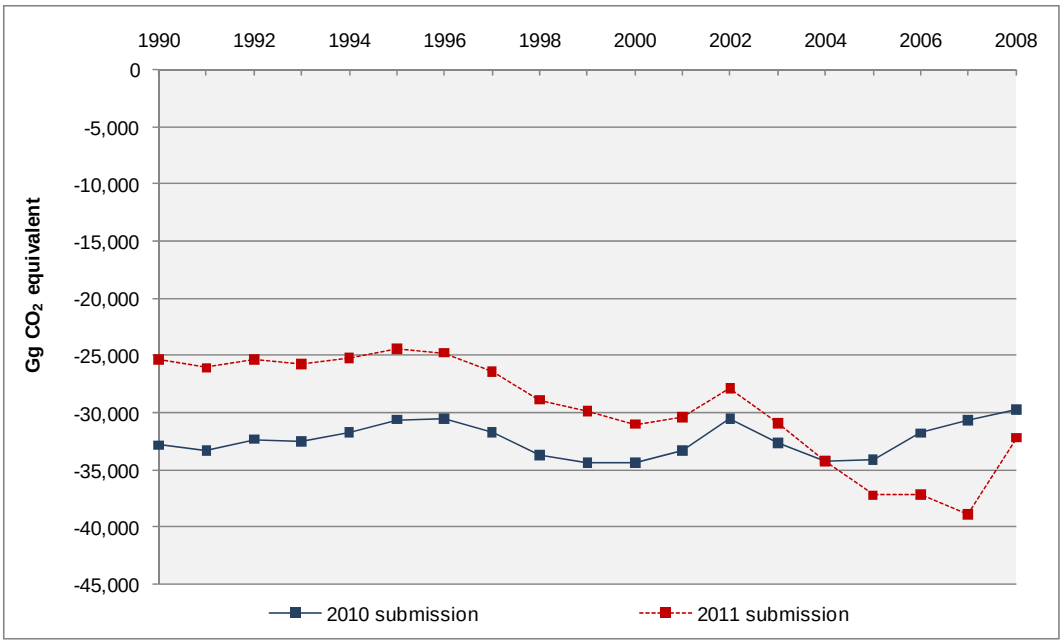


Figure 10.1.7 Effect of recalculations on net removals from New Zealand's grassland category from 1990 to 2008

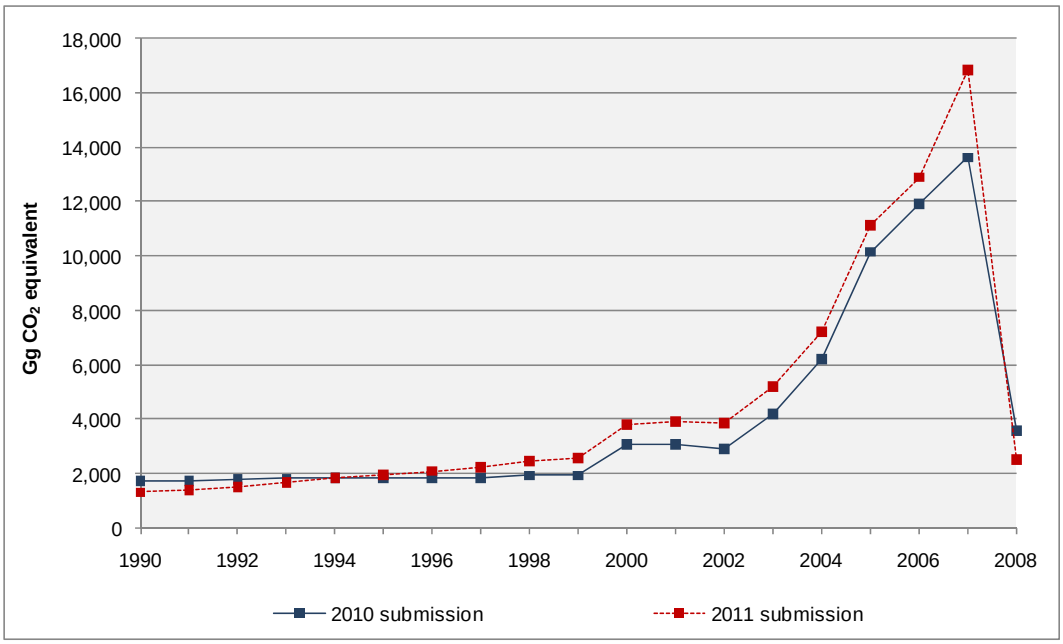


Table 10.1.1 Explanations and justifications for recalculations of New Zealand's previous LULUCF estimates

Explanation of recalculation	Good practice principal that was improved	Additional justification
Introduction of polygon-specific mapping (IPCC Approach 2) of deforestation from the start of the first commitment period (1 January 2008) onwards, to improve the measurement of deforestation. The mapping of deforestation up until to 1 January 2008 has also been improved, based on land-use change mapping rather than relying as previously on a range of information sources. See chapter 7.2.2 for further detail.	Accuracy	Key category improvement (*Land converted to grassland*)
Revised emission factors for natural forest deforestation, based on species composition determined using the ECOSAT spatial layer. See chapter 7.3.5 for further detail.	Accuracy	Key category improvement (*Land converted to grassland*)
Updated activity data on the total area of New Zealand to incorporate the remote and uninhabited sub-Antarctic islands, the Campbell and Auckland islands, equivalent to approximately 1 per cent of New Zealand's land area. See chapter 7.2.4 for further detail.	Completeness	Expert review team recommendation
The introduction of historical land-use data (backcasting) to model land-use change since 1962, to identify land in transition in the inventory base year of 1990. See chapter 7.2.4 for further detail.	Completeness Consistency	Expert review team recommendation
Revision of the estimates of emissions and removals from pre-1990 planted forest to include harvesting residue decay emissions resulting from historical (pre-1990) harvesting events. See chapter 7.3.5 for further detail.	Accuracy Completeness	Key category Tier 2 method refinement
Adjustment of the area of pre-1990 forest harvested. In the 2010 submission it was assumed all area harvested was forest remaining forest when some of this area is harvested as part of a deforestation event. This has been corrected. See chapter 7.1.5 for further detail.	Accuracy	Correction identified through quality assurance and quality control processes

Explanation of recalculation	Good practice principal that was improved	Additional justification
Introduction of a New Zealand-specific emission factor for perennial croplands, replacing the previous IPCC default emission factor, to better reflect actual carbon stock values and stock changes for this land-use category. See chapter 7.4.5 for further detail.	Accuracy	Expert review team recommendation to use New Zealand-specific emission factors and previous key category
Inclusion of activity data on organic soils areas, by land-use subcategory, reported in the inventory for the first time. See chapter 7.1.3 for further detail.	Completeness	Expert review team recommendation
Introduction of reporting of emissions from organic soils using IPCC default emission factors. See chapter 7.1.3 for further detail.	Accuracy Completeness	Expert review team recommendation
Introduction of reporting of N_2O emissions associated with land-use conversion to cropland on mineral soils. See chapter 7.9.3 for further detail.	Completeness	Expert review team recommendation
Improved soil stock density estimates in the Soils Carbon Monitoring System, for all land-use categories, resulting from the application of a bulk density correction factor, and the incorporation of additional soil datasets for annual cropland, grasslands and natural forest. See chapter 7.1.3 for further detail.	Accuracy	Tier 2 method refinement
Updated activity data on dolomite and liming emissions, sourced from Statistics New Zealand. See chapter 7.9.4 for further detail.	Accuracy	Use of latest data
The country-specific emission factor for wildfire in forest land remaining forest land has been updated to better reflect the nature of the forest burnt. See chapter 7.9.5 for further detail.	Accuracy	Key category Tier 2 method refinement
The quantity of biomass burned and the percentage of live biomass oxidised during wildfire in the grassland remaining grassland category has been to refined to reflect New Zealand's specific conditions. See chapter 7.9.5 for further detail.	Accuracy	Key category Tier 2 method refinement
Subdivision of the Wetlands land-use category into 'Wetlands – open water' and 'Wetlands – vegetative non-forest' in the calculation of New Zealand's LULUCF estimates. This split will be reflected in the CRF tables in the 2012 submission. See chapter 7.6.1 for further detail.	Comparability Transparency	Consistency between mapped and reported categories
Corrected reporting of emissions from the decay of below-ground biomass following harvesting events in the dead organic matter pool, instead of in the previously reported below-ground biomass pool. See chapter 7.3.5 for further detail.	Accuracy Consistency Comparability	Expert review team recommendation
Introduction of reporting of carbon stock changes from land-use change within the forest remaining forest category resulting from the clearing of natural forest and re-planting with exotic plantation forest, which has been classified as pre-1990 planted forest to distinguish it from post-1989, 'Kyoto' forest. See chapter 7.3.2 for further detail.	Accuracy Completeness	Correction identified through quality assurance and quality control processes
Mapping improvements to better distinguish pre 1990-planted forest from post-1989 forest, identify young newly planted post-1989 forest and update areas of perennial cropland. See chapter 7.2.6 for further detail.	Accuracy	Key category improvement

10.1.6 Waste

The methodological improvements made in the waste sector have resulted in a 24.3 per cent (657.6 Gg CO_2-e) decrease in calculated waste emissions in 1990, and a 12.2 per cent (102.5 Gg CO_2-e) decrease in waste emissions in 2008 (Figure 10.1.8). This

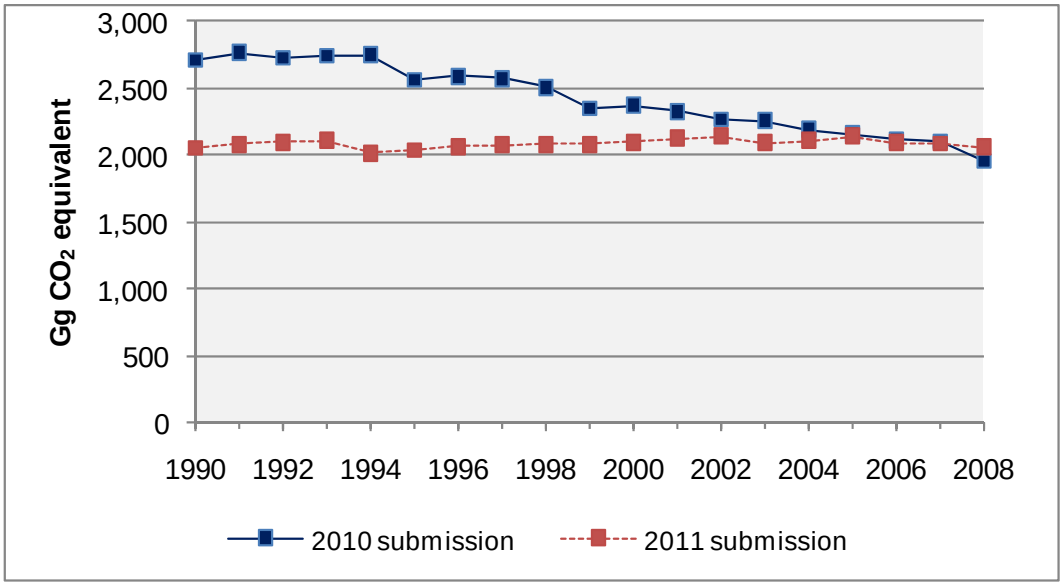
is largely due to improved methodologies for calculating emissions and recovery of emissions from solid waste disposed to land (see section 8.2.5), namely:

- a better understanding of the management and design of landfills with operational CH_4 recovery systems
- the application of nationally consistent assumptions on the composition of solid waste.

Recalculations were also due to the following improvements:

- use of landfill-specific decay values, collection efficiencies and waste placement for landfills with CH_4 recovery systems (section 8.2.5)
- inclusion of untreated sludge disposed to landfills, based on new data (section 8.2.5)
- revision of provisional 2008 activity data for calculating wastewater emissions from the meat industry (8.3.5)
- corrections made to the population serviced by each wastewater treatment plant (section 8.3.5)
- corrections made to the total degradable material figures were incorrectly entered as the organic sludge figures for industrial sludge emissions.

Figure 10.1.8 Effect of recalculations on New Zealand's waste sector from 1990 to 2008



10.1.7 Article 3.3 activities under the Kyoto Protocol

New Zealand's greenhouse gas estimates for activities under Article 3.3 of the Kyoto Protocol have been recalculated since the previous submission (Table 10.1.2 and Table 10.1.3). The recalculations incorporate improved New Zealand-specific methods, activity data and emission factors, as detailed in sections 7.1 and 7.2 and chapter 10.

The largest factor in the recalculations has been the revision of activity data, and in particular of deforestation areas. This is because deforestation areas were estimated in the 2010 submission, whereas they have now been mapped from satellite imagery.

Table 10.1.2 Impact of the recalculations of New Zealand's net emissions and removals under Article 3.3 of the Kyoto Protocol in 2008

Activity under Article 3.3 of the Kyoto Protocol	2008 net emissions and removals (Gg CO_2-e)		Change from 2010 submission
	2010 submission	2011 submission	
Afforestation/reforestation	–17,327.4	–17,525.1	–1.1%
Forest land not harvested since the beginning of the commitment period	–17,395.1	–17,593.4	–1.1%
Forest land harvested since the beginning of the commitment period	67.8	68.3	0.7%
Deforestation since the beginning of the commitment period	2,910.6	432.4	–85.1%
Total	**–14,416.8**	**–17,092.6**	**–18.6%**

Table 10.1.3 Recalculations to New Zealand's 2008 activity data under Article 3.3 of the Kyoto Protocol

Activity under Article 3.3 of the Kyoto Protocol	2008 areas (hectares)		Change from 2010 submission
	2010 submission	2011 submission	
Afforestation/reforestation	**568,775**	**587,936**	**+3.4%**
Forest land not harvested since the beginning of the commitment period	568,274	587,436	+3.4%
New planting	1000	1900	+90.0%
Forest land harvested since the beginning of the commitment period	500	500	NA
Deforestation	**4,818**	**1,472**	**–69.4%**
Natural forest	1,818	535	–70.6%
Pre-1990 planted forest	2,114	552	–73.9%
Post-1989 forest	886	385	–56.5%

Note: Forest land harvested since the beginning of the commitment period is NA (not applicable) as there were no recalculations applied.

10.2 Recalculations in response to the review process and planned improvements

10.2.1 Response to the review process

Many of the recommendations made by the expert review team during the centralised review of New Zealand's greenhouse gas inventories submitted in 2007 and 2008 have been implemented. Due to prioritisation and limited resourcing, some of the recommendations have been partially implemented and some are ongoing. However, New Zealand does have the full implementation of the recommendations planned for in the risk register (see section 1.6.2 for further detail on the risk register). The recommendations made in UNFCCC (2010) and New Zealand's responses are included below in Table 10.2.1. There were no recommendations made for solvent and other product use sectors.

Table 10.2.1 New Zealand's response to expert review team recommendations from the individual review of the greenhouse gas inventories of New Zealand submitted 2009

Sector	Expert review team recommendation	New Zealand response
General	Expand methodological description for the estimation and provide a rationale for the selection of country-specific emission factors in the national inventory report.	**Partially implemented.**
General	Ensure, to the extent possible, the inclusion in its next annual submission, of emissions for categories currently reported as 'not estimated' and for which methods exist for these categories in the Revised 1996 IPCC guidelines and/or the IPCC good practice guidance, and if emissions for a given category cannot be estimated then the Party is to provide sufficient explanation in the national inventory report as to why it cannot be estimated.	**Partially implemented.** Work on-going for the LULUCF sector. For the 2010 submission, New Zealand introduced the new Land Use and Carbon Analysis System (LUCAS), which enabled new, New Zealand-specific Tier 2 approaches to be employed in producing the LULUCF estimates. For this submission, New Zealand has reported emissions from organic soils, and N_2O emissions associated with land-use conversion to cropland for the first time. Emissions from biomass burning were reported in the 2010 submission, under grassland and forest land, and New Zealand will investigate obtaining further activity data to report these emissions for additional land-use categories in future.
Registry	Report whether or not any changes have been made to the national registry test procedures.	**Implemented.**
Energy	Improve the transparency by providing in the national inventory report a carbon flow cycle (eg, carbon mass balance for natural gas from the well to the end consumer and associated products) and by clearly indicating where and how CO_2 is accounted for in the common reporting format tables to avoid double counting or the possible underestimation of emissions from fuel combustion.	**Resolved.** Energy fuel flow diagrams were included in the 2010 inventory submission (they are also included in this inventory submission).
Energy	Evaluate estimate of emissions that are currently reported as 'not estimated' as far as is practicable (eg, by using the IPCC default methodology) and limit the number of estimates 'included elsewhere' and improve its existing approach to data collection to report emissions at a sufficient level of detail and increase transparency.	**Resolved.** The use of notation keys in the fugitive sector has been improved. This includes the addition of fugitive emissions under category 1.B.2.B.5 (other leakage). There are now no 'not estimated' entries for this category.
Energy: Reference and sectoral approaches	Revise the method of comparing the reference and sectoral approaches by taking into account all relevant feedstocks and non-energy fuels.	**Resolved.** The addition of energy fuel flow diagrams in the 2010 submission and in this submission. More information on feedstocks and non-energy use has also been provided in this inventory submission.
Energy: Reference and sectoral approaches	Improve the transparency by providing flow charts for carbon and a carbon balance, most importantly the carbon balance for natural gas (from the well to the end consumer, including relevant products), and by indicating where and how CO_2 is accounted for in the common reporting format tables to avoid a potential double counting or underestimation of emissions from fuel combustion.	**Resolved.** Energy fuel flow diagrams were included in the 2010 inventory submission and in this submission.
Energy: Reference and sectoral approaches	Improve the transparency by providing a description of the relevant geothermal methodology in the national inventory report.	**Resolved.** This inventory submission includes more detail for the methodology on how geothermal emissions are measured in New Zealand.

Sector	Expert review team recommendation	New Zealand response
Energy: Stationary combustion: liquid, solid and gaseous fuels – CO_2	Provide all values used for calculating CO_2 from liquid fuels in stationary combustion in the national inventory report of its next annual submission.	**Resolved.** More information on the calculation of liquid fuels emission factors, including a complete time-series of gross calorific values and carbon content and uncertainties has been included in this inventory submission.
Energy: Stationary combustion: liquid, solid and gaseous fuels – CO_2	Give a proper explanation for why emissions from coal combustion in the public electricity and heat production subcategory were calculated using the emission factor for sub-bituminous coal (92.99 t CO_2/TJ), while for all other coal combustion activities, a lower emission factor (91.20 t CO_2/TJ) was used.	**Partially implemented.** This inventory submission has improved the explanation for which emissions factors are used where and the justification for their use. The Ministry of Economic Development is also examining the use of more specific solid fuel CO_2 emission factors. See section 3.3 for more information.
Energy: Stationary combustion: liquid, solid and gaseous fuels – CO_2	Provide an explanation in the national inventory report of its next annual submission, including relevant information on methods used, data processing, etc for calculating emissions from the gas field, Kapuni.	**Resolved.** This information was included in the 2010 inventory submission and in this submission.
Energy: Fugitive emissions: gaseous fuels – CH_4	Provide disaggregated estimates of fugitive emissions from natural gas, including estimates for the gas production category (previously reported as "not estimated", currently as "included elsewhere"), and include a transparent description of the relevant methodology.	**Resolved.** Transmission and distribution data was reported separately in the 2010 submission and explanatory text is included in this inventory submission.
Energy: Non-key categories Road transportation: liquid fuels – N_2O	Revise its approach to estimating non-CO_2 emissions (mainly N_2O), taking into consideration advances in vehicle technology since 1990.	**Work in progress.** An improved methodology for calculating emissions from road transport is currently being developed. More information can be found in section 3.3.3.
Industrial processes and solvent and other product use	Provide more information on how recalculations affect the time-series in the category-specific sections of the national inventory report and how recalculations improve the accuracy of emission estimates, time-series consistency and completeness of the inventory in its next annual submission.	**Implemented.**
Industrial processes and solvent and other product use	Reassess the uncertainty estimates for activity data, report uncertainty estimates for each emission factor and provide a more detailed description of the uncertainty estimates used at least for every key category.	**Implemented.**
Cement production – CO_2	Provide a description of the quality control procedures that have been performed on the reported data by cement plants or the inventory team.	**Work in progress.**
Cement production – CO_2	Demonstrate in the national inventory report that this method is in line with the IPCC good practice guidance.	**Implemented.**
Ammonia production – CO_2	Provide a more thorough explanation on consumption of natural gas as raw material and that there is no double counting in the national inventory report of its next annual submission, including information demonstrating that the amount of natural gas used in NH_3 production has been subtracted from total natural gas used, preventing double counting.	**Implemented.**

Sector	Expert review team recommendation	New Zealand response
Iron and steel production – CO_2	Provide more information on which flux elements are included in the mass balance calculation and how their emissions are reported in the common reporting format tables.	**Implemented.**
Iron and steel production – CO_2	Explain the methodology used in more detail, including the emission factors used and the carbon content of the raw materials.	**Implemented.**
Consumption of halocarbons and SF_6 – HFCs	Continue to improve the description of the method for the estimation of emissions from this category in the national inventory report and the quality of estimates where possible.	**Implemented.**
Non-key categories: Limestone and dolomite use – CO_2	Provide a more thorough description of the original calculation and recalculation methods used in its next annual submission.	**Implemented.**
Agriculture	Revise the list of crops and improve the coverage of crop data in its next annual submission.	**Work in progress.**
LULUCF	Implement plans to introduce additional, country-specific data on carbon stocks for the pools in the different land-use categories in future submissions, as part of a process of ongoing improvement which is prioritised according to LULUCF key categories.	**Partially implemented.** The Land Use and Carbon Analysis System (LUCAS) introduced for the 2010 submission enabled new country-specific emission factors to be applied, including Tier 2 approaches to estimating the carbon stocks in forest and woody subcategories, as well as in mineral soils. In this submission, New Zealand has introduced a New Zealand-specific emission factor for perennial croplands, and updated the existing emission factors for mineral soils and biomass burning. Forest carbon inventory work is ongoing, and additional or improved country-specific emission factors will continue to be introduced on an ongoing basis as part of New Zealand's programme of continuous improvement for LULUCF sector reporting.
LULUCF: Key categories: Cropland remaining cropland	Use country-specific parameters, including carbon loss from perennial crops, and estimate changes in soil carbon stock, including cultivated organic soils, in future submissions. New Zealand has indicated that it intends to introduce additional country-specific methods and data in its 2010 submission, and the expert review team recommends it continue to develop country-specific data for all relevant carbon stocks.	**Implemented.** New Zealand has introduced a New Zealand-specific emission factor for perennial croplands above-ground biomass in its 2009 estimates. For its 2008 estimates, a Tier 2 soil carbon monitoring system was introduced to estimate soil carbon stock changes. The implementation of the LUCAS system in the 2010 submission has also been accompanied by the introduction of additional New Zealand-specific emission factors and activity data in 2008. The introduction of further New Zealand-specific data on carbon stocks for the pools in the different land-use categories will continue to be investigated as part of New Zealand's programme of continuous improvement for LULUCF sector reporting.
LULUCF: Key categories: Land converted to grassland	Continue to develop country-specific data for all carbon stocks concerned.	**Implemented.** In this submission, New Zealand introduced backcasting to 1962 (28 years before 1990) for the LULUCF estimates, to identify land in a conversion state at 1990. The LUCAS system has also introduced a

Sector	Expert review team recommendation	New Zealand response
		Tier 2 modelling approach to estimate carbon in the mineral soil component of the soil organic matter pool for all land-use categories. This later improvement was implemented for the 2010 submission.
Waste: Sector overview	Report the reason for the recalculations in common reporting format table 8(b).	**Implemented.**
Solid waste disposal on land – CH_4	Validate the model using metered values from selected sites, and reiterates the recommendation made during the previous review that New Zealand provide more detailed justification for the use the current methodology, demonstrating that estimated emissions from recovered CH_4 are not overestimated.	**Implemented.**
Non-key categories: Wastewater handling – CH_4 and N_2O	Include these estimated emissions from industrial wastewater and sludge handling included emissions from wool scouring and wine processing. since the data are readily available, and since the Climate Change Convention reporting guidelines require that Parties submit a complete inventory	**Implemented.**
Non-key categories: wastewater handling – CH_4 and N_2O	Investigate and verify the wastewater treatment systems and report on this to ensure transparency of its reporting in its next annual submission.	**Implemented.**

10.2.2 Planned improvements

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

Planned improvements to methodologies and emission factors are discussed under each sector as appropriate.

PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7.1

Chapter 11: KP-LULUCF

11.1 General information

In 2009, net removals from land subject to afforestation, reforestation and deforestation were 17,268.4 Gg CO_2-e (Table 11.1.1). This value is the net total of all emissions and removals from activities under Article 3.3 of the Kyoto Protocol, and includes removals from the growth of post-1989 forest, and emissions from the conversion of land to post-1989 forest, the harvesting of forests planted on non-forest land after 31 December 1989 and the deforestation of all forest types, as well as emissions from liming, biomass burning and soil disturbance associated with land-use conversion to cropland.

These net emissions and removals are reported separately for the North and South Islands for the five carbon pools (Figure 11.1.1). Afforestation, reforestation and deforestation are key categories for New Zealand (Table 1.5.4).

For reporting under Article 3.3 of the Kyoto Protocol, New Zealand has categorised its forests into three subcategories: natural forest, pre-1990 planted forest, and post-1989 forest. These subcategories are also used for greenhouse gas inventory reporting on the land use, land-use change and forestry (LULUCF) sector under the Climate Change Convention (see chapter 7). For the first commitment period, New Zealand has not elected any of the activities under Article 3.4 of the Kyoto Protocol.

All forest land that existed on 31 December 1989 has been categorised as either natural forest or pre-1990 planted forest. For these forests, only emissions from deforestation activities are reported in this chapter. For the post-1989 forests, emissions and removals from carbon losses and gains due to afforestation, reforestation and deforestation are reported for the first two years of the commitment period, 2008 and 2009.

Table 11.1.1 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 2009

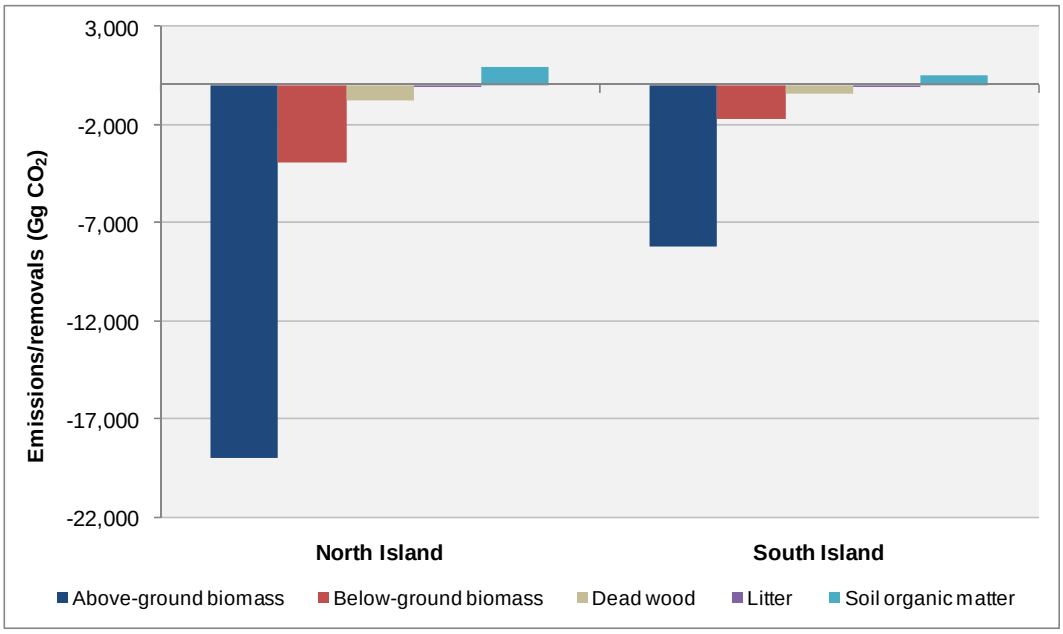
Source	Gross area (ha) 1990–2009	Net area (ha) 2009	Emissions in 2009 (Gg CO_2-e)
Afforestation/reforestation	606,706	591,202	–17,624.3
Forest land not harvested since the beginning of the commitment period	–	590,752	–17,701.3
Forest land harvested since the beginning of the commitment period	–	450	77.0
Deforestation	98,668	1,644	355.9
Total	–	–	–17,268.4

Notes: Afforestation/reforestation refers to new forest established since 1 January 1990. The gross afforestation/reforestation area includes 15,503 hectares of land in transition to post-1989 forest that has subsequently been deforested. The 2009 areas are as at 31 December 2009. Columns may not total due to rounding.

Between 1990 and 2009, 606,706 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities – an average of 30,000 hectares per year (refer to Figure 7.3.1 and Table 11.1.2).

During 2009 there were 4000 hectares of new forest planting, up from 1900 hectares planted in 2008. Deforestation of all subcategories of forest land (post-1989, pre-1990 planted and natural forest) during 2009 was mapped at 1644 hectares (equivalent to emissions of 355.9 Gg CO_2-e).

Figure 11.1.1 New Zealand's net CO_2 emissions and removals by carbon pool associated with afforestation, reforestation and deforestation activities in 2009



Note: Emissions and removals shown are the result of changes in carbon stock only and do not include non-CO_2 emissions.

A breakdown of New Zealand's net removals under Article 3.3 of the Kyoto Protocol by greenhouse gas source category is provided in Table 11.1.2.

Table 11.1.2 New Zealand's net removals under Article 3.3 of the Kyoto Protocol by greenhouse gas source category

	Net emissions and removals in 2009 (Gg)		
Greenhouse gas source category	**Source form**	**Source emission**	**CO_2-equivalent**
Carbon stock change	CO_2	–17,270.0	–17,270.0
Disturbance associated with forest conversion to cropland	N_2O	0.0002	0.05
Agricultural lime application on deforested land	C	4.6	17.0
Biomass burning of afforestation/reforestation land	CH_4	0.07	1.4
Biomass burning of afforestation/reforestation land	N_2O	0.0005	0.14
Total			**–17,268.4**

There is no reduction in the carbon stock of areas burnt prior to forest harvesting or deforestation. Consequently, CO_2 emissions associated with biomass burning are captured by, and reported under, the general carbon stock change calculation for forests.

New Zealand is not reporting:

- liming of afforested and reforested land, as this activity does not occur

- non-CO_2 emissions from controlled burning on deforested land, as there is currently insufficient data to quantify the emissions from this activity. The notation NE ('not estimated') is reported in the common reporting format tables for controlled burning associated with deforestation. New Zealand is investigating sources of information to quantify emissions from controlled burning for possible reporting in future submissions
- emissions associated with nitrogen fertiliser use on deforested land, as these are reported in the agriculture sector.

Afforestation and reforestation

Between 1990 and 2009, it is estimated that 606,706 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities (Table 11.1.3). The net area of post-1989 forest as at the end of 2009 was 591,202 hectares. The net area is the total area of new forest planted since 31 December 1989 minus the deforestation of post-1989 forest since 1 January 1990.

The new planting rate (land reforested or afforested) between 1990 and 2009 was, on average, 30,000 hectares per year. While new planting rates were high from 1992 to 1998 (averaging 61,000 hectares per year), the rate of new planting declined rapidly from 1998 and reached a low of 1900 hectares in 2008.

In the 2009 calendar year, the new planting rate increased, and it is currently estimated that 4000 hectares of new plantation forest were established.

Table 11.1.3 New Zealand's annual net area of afforestation/reforestation since 1990

Year	Annual area of post-1989 forest (ha)			
	New forest planting	Harvesting	Deforestation	Net cumulative area
1990	13,955	0	0	13,955
1991	13,602	0	0	27,557
1992	44,339	0	0	71,896
1993	54,408	0	0	126,305
1994	86,742	0	0	213,047
1995	65,215	0	0	278,262
1996	73,926	0	0	352,187
1997	56,297	0	0	408,484
1998	45,178	0	0	453,662
1999	35,243	0	0	488,905
2000	29,570	0	0	518,474
2001	26,513	0	0	544,988
2002	19,436	0	721	563,702
2003	17,496	0	2,273	578,925
2004	9,282	0	2,089	586,119
2005	5,251	200	2,376	588,994
2006	2,276	500	2,037	589,233
2007	2,077	500	4,889	586,421
2008	1,900	500	385	587,936
2009	4,000	450	734	591,202
Total	**606,706**	**2,150**	**15,503**	**591,202**

The New Zealand Government has recently introduced legislation and government initiatives to encourage forest establishment and discourage deforestation of planted forests. These include:

- Climate Change Response Act 2002 (amended 8 December 2009)
- Permanent Forest Sink Initiative (Ministry of Agriculture and Forestry, 2008b)
- Afforestation Grant Scheme (Ministry of Agriculture and Forestry, 2009b).

The New Zealand Emissions Trading Scheme (NZ ETS) has been introduced under the Climate Change Response Act 2002. Forest land was introduced into the scheme on 1 January 2008. Under the scheme, owners of post-1989 forest land may voluntarily participate in the NZ ETS and receive emission units for any increase in carbon stocks in their forests from 1 January 2008. The annual area of new planting is expected to increase with the implementation of the NZ ETS, Permanent Forest Sinks Initiative and Afforestation Grant Scheme.

New Zealand's post-1989 forests are described in further detail in section 7.2.

Deforestation

In 2009, deforestation emissions were 355.9 Gg CO_2-e, compared with 432.4 Gg CO_2-e in 2008 (a 13.7 per cent reduction). These emissions are mainly from the carbon stock loss caused by deforestation in 2009. However, they also include non-carbon emissions and lagged emissions that occurred in 2009 as a result of deforestation since 1990, including from the liming of forest land converted to grassland and disturbance associated with forest land conversion to cropland.

The area of deforestation in 2009 was 1644 hectares, slightly higher (11.7 per cent) than the 1472 hectares deforested in 2008. The lower emissions in 2009 are a result of the higher proportion of the deforested area that was post-1989 forest (44.6 per cent of the total, compared with 9.2 per cent in 2008), which is on average younger and has a lower carbon stock than pre-1990 planted or natural forest. The higher proportion of post-1989 forest deforestation in 2009 compared with pre-1990 planted forest may reflect the deforestation liabilities that have been imposed on pre-1990 forest land since the introduction of the NZ ETS on 1 January 2008.

Table 11.1.4 shows the areas of forest land subject to deforestation since 1990, by forest subcategory, and the associated emissions from carbon stock change in 2009.

Table 11.1.4 New Zealand's forest land subject to deforestation in 2009, and associated emissions from carbon stock change

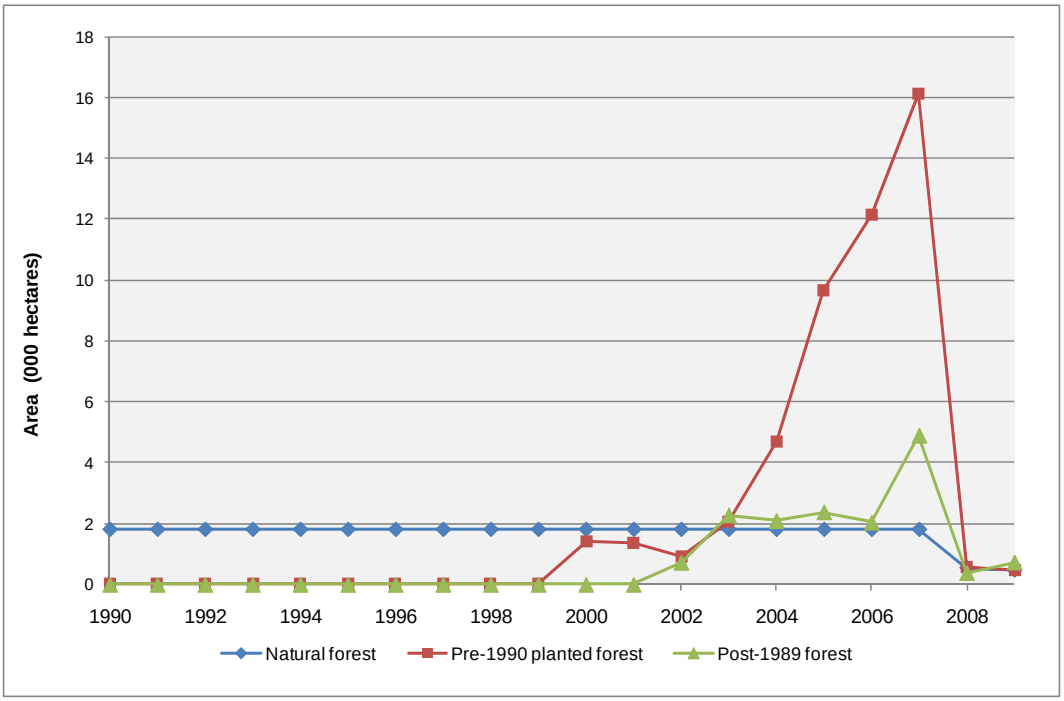
	Area of deforestation (ha)			Emissions from carbon stock change in 2009 (Gg CO_2)
Forest land subcategory	**Since 1990**	**2008**	**2009**	
Natural forest	33,715	535	462	38.4
Pre-1990 planted forest	49,450	552	449	103.3
Post-1989 forest	15,503	385	734	210.8
Total	98,668	1472	1,644	352.5

Note: 2008 and 2009 areas as at 31 December. Only emissions from carbon stock change, does not include emissions associated with fertilisation, liming or disturbance with conversion to cropland.

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 2009



No emissions from deforestation of pre-1990 planted forest or post-1989 forest before 2000 are estimated 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 only two hectares in any five-year period without having to surrender emission units. Above this level of deforestation they are required to surrender units equal to the reported emissions, with some exemptions for smaller forest owners (Ministry of Agriculture and Forestry, 2009b). This has 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 that 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).

The area of deforestation of natural forests prior to 2008 has been estimated by linear interpolation from the average land-use change mapped between 1 January 1990 and 1 January 2008. As there was no quantitative information on the annual rate of natural forest deforestation between 1990 and 2007, the same annual rate of change was assumed for the entire period (1818 hectares per year). However, a number of factors suggest that

the rate of natural forest deforestation is unlikely to have been constant over the 18-year period between 1990 and 2007, but instead mostly occurred prior to 2002. The area available for harvesting (and potentially deforestation) was higher before amendments were made to the Forests Act 1949 in 1993. Further restrictions to the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand in 2002. Both of these developments are likely to have reduced natural forest deforestation since 2002.

The estimated rate of natural forest deforestation has decreased since the start of the commitment period. This reduced rate of natural forest deforestation has been confirmed in 2008 and 2009 through satellite image mapping of deforestation (see Figure 7.2.4 under land-use mapping for details of the mapping process).

Deforestation in New Zealand is described more fully in sections 7.2.1, 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 11.1.5 provides the defining parameters for forest land.

Table 11.1.5 Parameters defining forest in New Zealand

Forest parameter	Kyoto Protocol range	New Zealand selected value
Minimum land area (ha)	0.05–1	1
Minimum crown cover (%)	10–30	30
Minimum height (m)	2–5	5

Note: The range values represent the minimum forest definition values as defined under the Kyoto Protocol, decision 16/CMP.1.

New Zealand also uses a minimum forest width of 30 metres, which removes linear shelterbelts from the forest category. The width and height of linear shelterbelts can vary as 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" (UN-ECE/FAO, 2000). For reporting to the Food and Agriculture Organization, New Zealand subdivided forests into two estates based on their biological characteristics, the management regimes applied to the forests and their respective roles and national objectives (Ministry of Agriculture and Forestry, 2002). The two estates are indigenous and planted production forest. The former estate largely equates to natural forest as reported in this submission, and the latter largely equates to pre-1990 planted forest and post-1989 forest. There is an overlap where post-1989 forest has been established with native species or is the result of growth of native species following a change in management regime eg, retirement of pasture land.

11.1.2 Elected activities under Article 3.4

As stated in *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006), New Zealand has not elected any of the activities under Article 3.4 of the Kyoto Protocol for the first commitment period.

11.1.3 Implementation and application of activities under Article 3.3

The area of afforestation/reforestation reported under the Kyoto Protocol is equal to the net area of post-1989 forest reported for land-use change to forest land reported in the LULUCF sector. Between 1990 and 2009, 606,706 hectares were reforested and 4000 hectares of this occurred in 2009. Of the total area afforested or reforested between 1990 and 2009, an estimated 15,503 hectares were deforested between 1990 and 2009. Once an area has been tagged 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 in the Land Use and Carbon Analysis System (LUCAS) Calculation and Reporting Application (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's intention is to account for all activities under Article 3.3 of the Kyoto Protocol at the end of the commitment period (Ministry for the Environment, 2006).

11.2 Land-related information

11.2.1 Spatial assessment unit

New Zealand is mapping land use to 1 hectare.

11.2.2 Methodology for land transition matrix

Mapping of land use as at the start of 1990 and of 2008 focused on the classes containing woody biomass (natural forest, pre-1990 planted forest, post-1989 forest and grassland with woody biomass). Satellite imagery was used to map woody classes as at 1 January 1990 and 1 January 2008. The mapping of land-use change prior to 2008 was based on these maps, high-resolution photography and field visits.

For the 2008 and 2009 years, deforestation was mapped from satellite imagery, and afforestation was estimated from the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2010), the Afforestation Grants Scheme and the New Zealand Emissions Trading Scheme (both Ministry of Agriculture and Forestry, 2008). For the non-forest land uses, change was estimated based on the average annual change between 1 January 1990 and 1 January 2008. This is further explained in section 7.2.

The 1990 land-use map was derived from 30-metre spatial resolution Landsat 4 and Landsat 5 satellite imagery taken in, or close to, 1990. The 2008 land-use map (land use as at 1 January 2008) was derived from 10-metre spatial resolution SPOT 5 satellite

imagery and was processed into standardised reflectance images, using the same approach as for the 1990 imagery. Refer to section 7.2 for further explanation of the land-use mapping methodology.

The remaining land-use categories were mapped based on existing information from two land cover databases, LCDB1 (1996) and LCDB2 (2001) (Thompson et al, 2004), the New Zealand Land Resource Inventory (NZLRI) (Eyles, 1977) and hydrological data from Land Information New Zealand (Shepherd and Newsome, 2009a, b).

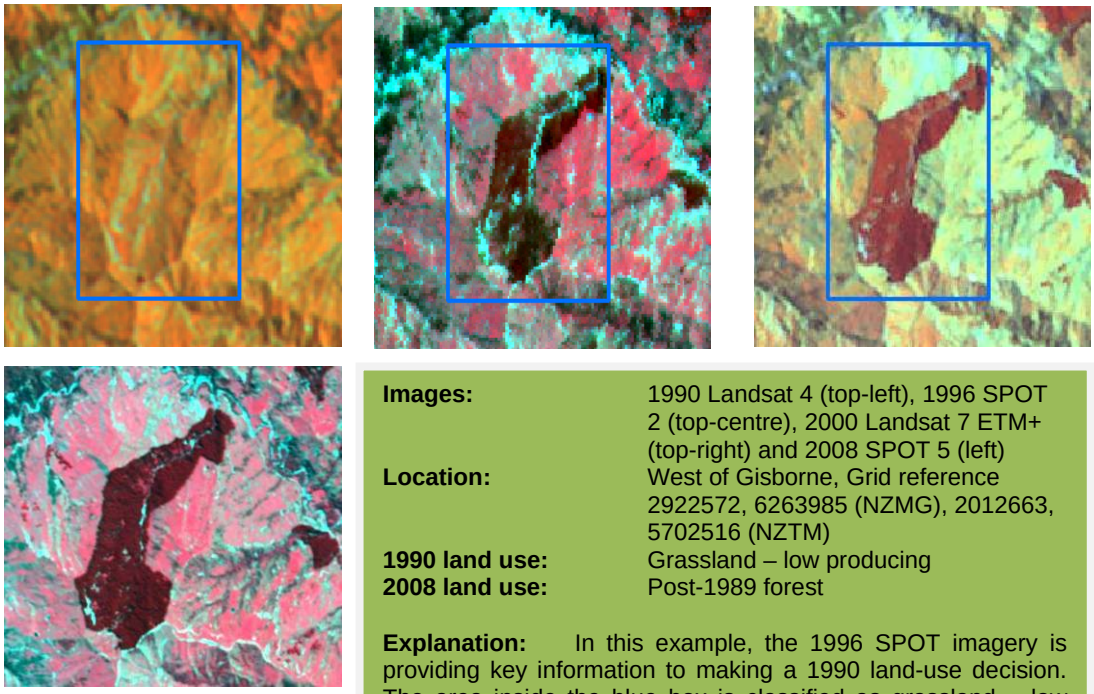
Decision process for mapping post-1989 forests

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 to support land-use classification decisions.

To aid the decision-making process, the LUCAS mapping also used nationwide and cloud-free 1996 SPOT and 2001 Landsat 7 satellite imagery to determine the age of forest that might have been planted between 1990 and 1993. This process is designed to reduce errors of omission and ensures all forests are mapped. Figure 11.2.1 illustrates how mapping operators determined the status of an area of planted forest established between 1990 and 1993, with a situation where an area was classified as post-1989 forest by assessing the 1990, 1996 and 2001 satellite imagery. The 1990 image shows no obvious spectral signature of any forest vegetation within the blue box. However, the 1996 and 2001 images show strong forestry spectral signatures. If the 1990 imagery had shown some spectral signature that corresponded to the forest boundary in 1996, the mapping operators would have classified the area as pre-1990 planted forest. By applying this method, the later date imagery is used to confirm subtle variations in spectral signature in the 1990 imagery that correspond with young planted forest.

Where possible, information obtained directly from forest owners is also used to improve the accuracy of the pre-1990/post-1989 forest classification.

Figure 11.2.1 Identification of post-1989 forest in New Zealand (Dougherty et al, 2009)



Images:	1990 Landsat 4 (top-left), 1996 SPOT 2 (top-centre), 2000 Landsat 7 ETM+ (top-right) and 2008 SPOT 5 (left)
Location:	West of Gisborne, Grid reference 2922572, 6263985 (NZMG), 2012663, 5702516 (NZTM)
1990 land use:	Grassland – low producing
2008 land use:	Post-1989 forest

Explanation: In this example, the 1996 SPOT imagery is providing key information to making a 1990 land-use decision. The area inside the blue box is classified as grassland – low producing in the 1990 land-use mapping data. The area inside the box can then be seen using the 1996 SPOT imagery, 2000 Landsat imagery and 2008 SPOT imagery as forest that was planted after 1989. From the imagery sequence above, it can be determined that the area inside the box is correctly classified as post-1989 forest in the 2008 land-use mapping data.

Where information on the timing of planting and harvesting was not available, ancillary data from the *National Exotic Forest Description* was used (Ministry of Agriculture and Forestry, 2010). This process is described in section 7.2.

Land-use change during the first commitment period will be confirmed following mapping at the end of 2012.

11.2.3 Identifying geographical locations

New Zealand has used Reporting Method 1 for preparing estimates of emissions and removals from afforestation, reforestation and deforestation, and has used a combination of Approaches 2 and 3 to map land-use change.

The geographic units chosen by New Zealand to report by are: the North Island, including Great Barrier and Little Barrier Islands; and the South Island, including Stewart Island, the Chatham Islands and New Zealand's offshore islands.

New Zealand's uninhabited offshore islands include the Kermadec Islands, Three Kings Islands and the sub-Antarctic Islands (Auckland Islands, Campbell Island, Antipodes Islands, Bounty Islands and Snares Islands) and are reported in a steady state of land use. These protected conservation areas total 74,052 hectares, and are not subject to land-use change.

11.3 Activity-specific information

11.3.1 Carbon stock change and methods

Description of the methodologies and the underlying assumptions used

The methodologies and assumptions used for reporting under the Kyoto Protocol Article 3.3 activities are the same as those used for Climate Change Convention reporting and are described fully in chapter 7.

Emissions and removals from afforestation and reforestation are determined at the national scale. Carbon analyses based on a national forest plot network are performed to estimate the average amount of carbon per hectare per pool.

For the 2011 submission, emissions from deforestation have been calculated based on mapped polygons of deforestation using satellite imagery and average carbon yield tables for each subcategory of forest (natural forest, pre-1990 planted forest and post-1989 forest).

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 shrubland areas (Table 11.3.1). This has been determined using the ECOSAT spatial layer, which enables more accurate reporting of the dominant natural forest species within the deforested area, resulting in more accurate emission factors. For more information on the ECOSAT layer refer to:
http://www.landcareresearch.co.nz/services/informatics/ecosat/about.asp

Table 11.3.1 New Zealand's areas of natural forest deforestation by sub-classification in 2008 and 2009

	Area of deforestation since 2008 (ha)		
Natural forest sub-classification	**2008**	**2009**	**Total**
Shrub	477	411	889
Tall forest	57	50	108
Total	535	462	996
% tall forest	12.0%	12.2%	12.1%

A future planned improvement is to use specific carbon stock estimates for emissions from deforestation based on the locality of the deforested area. This will be carried out for individual deforestation polygons where the tree age (from time-sequential, remotely-sensed imagery) and land productivity (from a productivity spatial layer) have been determined. The carbon yield tables for all three subcategories of forest will also be updated following measurement of these forests.

Following deforestation, carbon on the new land use then accumulates at rates given in Table 7.1.4.

Justification when omitting any carbon pool or GHG emissions/ removals from activities under Article 3.3 and elected activities under Article 3.4

New Zealand has accounted for all carbon pools from activities under Article 3.3. New Zealand has not elected any activities under Article 3.4 for the first commitment period.

New Zealand has not estimated methane or nitrous oxide emissions from controlled burning on land subject to deforestation under Article 3.3, as there is currently no data on this activity. New Zealand is investigating sources of information to quantify emissions from this activity for possible reporting in future submissions.

Methane and nitrous oxide emissions from wildfires on afforestation and deforestation land are reported as NO ('not occurring') in the common reporting format tables, as wildfires do not occur in New Zealand at significant levels, due to its temperate climate and rainfall. New Zealand is investigating attributing a proportion of wildfire activity into the land converted to forest land category. See section 7.9.6 for further detail.

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 soil emissions.

Factoring out information

New Zealand does not factor out emissions or removals from:

(a) elevated carbon dioxide concentrations above pre-industrial levels

(b) indirect nitrogen deposition

(c) the dynamic effects of age structure resulting from activities prior to 1 January 1990.

Recalculations

New Zealand's greenhouse gas estimates for activities under Article 3.3 of the Kyoto Protocol have been recalculated since the previous submission to incorporate improved New Zealand-specific methods, activity data and emission factors, as detailed in sections 7.1, 7.2 and chapter 10. The impact of the recalculations on New Zealand's 2008 Kyoto Protocol estimates is shown in Table 11.3.2.

Table 11.3.2 Impact of the recalculations of New Zealand's net emissions and removals under Article 3.3 of the Kyoto Protocol in 2008

	2008 net emissions and removals (Gg CO2-e)	
Activity under Article 3.3 of the Kyoto Protocol	**2010 submission**	**2011 submission**
Afforestation/reforestation	–17,327.4	–17,525.1
Forest land not harvested since the beginning of the commitment period	–17,395.1	–17,593.4
Forest land harvested since the beginning of the commitment period	67.8	68.3
Deforestation	2,910.6	432.4
Total	**–14,416.8**	**–17,092.6**

The largest factor in the recalculations has been the revision of activity data and, in particular, of deforestation areas (Table 11.3.3). This is because deforestation areas

were estimated in the 2010 submission, whereas they have now been mapped from satellite imagery.

Table 11.3.3 Recalculations to New Zealand's 2008 activity data under Article 3.3 of the Kyoto Protocol

Activity under Article 3.3 of the Kyoto Protocol	2008 Areas (ha)		Change from 2010 submission (%)
	2010 submission	2011 submission	
Afforestation/reforestation	568,775	587,936	+3.4%
Forest land not harvested since the beginning of the commitment period	568,274	587,436	+3.4%
New planting	1000	1900	+90.0%
Forest land harvested since the beginning of the commitment period	500	500	0.0%
Deforestation	4,818	1472	–69.4%
Natural forest	1,818	535	–70.6%
Pre-1990 planted forest	2,114	552	–73.9%
Post-1989 forest	886	385	–56.5%

Uncertainty

The uncertainty in net emissions and removals from afforestation and reforestation is 13.8 per cent, based on the uncertainty in emissions and removals from post-1989 forest (refer to section 7.3.3 and Table 7.3.9 for further details). The uncertainty in emissions from deforestation units is determined by the type of forest land deforested. This may be natural forest, pre-1990 forest or post-1989 forest (Table 11.1.4). Further detail on the uncertainty in emissions and removals for natural forest and pre-1990 forest is provided in chapter 7, section 7.3.

Table 11.3.4 Uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2009

Source of emissions/ removals	Uncertainty with a 95% confidence interval (%)				
	Afforestation/ reforestation	Deforestation			
Land-use subcategory	Post-1989 forest	*Natural forest*	*Pre-1990 forest*	*Post-1989 forest*	Total
Activity data uncertainty	7.0%	*4.0%*	*6.0%*	*7.0%*	4.6%
Emission factor uncertainty	11.9%	*3.6%*	*16.9%*	*11.9%*	8.7%
Total uncertainty	**13.8%**				**9.8%**

Note: All land that has been afforested/reforested since 1 January 2008 is defined as post-1989 forest. Land deforested since 1 January 2008 may be natural forest, pre-1990 forest or post-1989 forest.

Other methodological issues

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses to be consistent with IPCC (2003) and New Zealand's inventory quality-control and quality-assurance plan. Data quality and data assurance plans were established for each type of data used to determine carbon stock and stock changes, as well as the areal extent and spatial location of land-use changes. All data was subject to an independent and documented quality-assurance process. Data validation rules and reports were established to ensure that all data is fit-for-purpose and are of

consistent and known quality, and that data quality continues to be improved over time. The data used to derive the country-specific yield tables and average carbon values has also undergone quality assurance as described in section 7.3.4.

Year of the onset of an activity

Paragraph 18 of the annex to 16/CMP.1 (land use, land-use change and forestry) requires that New Zealand account for emissions and removals from Article 3.3 activities beginning with the onset of the activity or the beginning of the commitment period, whichever is later. In practical terms, paragraph 18 means there is a need to differentiate activities that occurred between 1 January 1990 and 31 December 2007 from those after this period.

During 2009, 4000 hectares of post-1989 forest were established and 1644 hectares of forest (natural forest, pre-1990 planted forest and post-1989 forest) were deforested.

11.4 Article 3.3

11.4.1 Demonstration that activities apply

The UNFCCC reporting guidelines require that countries provide information which demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and that these activities are direct human-induced.

All land in New Zealand is under some form of management and management plan. Land is managed for a variety of reasons, including agriculture and/or forestry production, conservation, biodiversity, fire risk management (eg, fire breaks), and scenic and cultural values. Most land-use changes occur in agriculture and forestry landscapes. All land-use change, including deforestation, is therefore a result of human decisions to either change the vegetation cover and/or change the way land is managed. The only notable exception to this is the loss of natural forest due to erosion which can be a non-anthropogenic land-use change.

New Zealand has used satellite imagery collected around the start of 1990 and 2008 to detect changes in land use between these two periods.

To estimate land-use change in 2008 and 2009, LUCAS mapping was augmented with data from the Ministry of Agriculture and Forestry's Afforestation Grants Scheme, the NZ ETS and the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2010)). This was used to estimate afforestation and reforestation during 2009. Deforestation occurring during 2009 was mapped from DMC satellite imagery (see section 7.2).

Following the mapping of land use at the end of 2012, New Zealand will recalculate the area of land-use change due to afforestation, reforestation and deforestation during the first commitment period.

11.4.2 Distinction between harvesting and deforestation

The UNFCCC reporting guidelines require that countries provide information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation.

New Zealand has used the IPCC (2003) definition of deforestation: "Deforestation is the direct human-induced conversion of forested land to non-forested land". Deforestation is different from harvesting, in that harvesting is part of usual forest management practice and involves the removal of biomass from a site followed by reforestation (replanting or revegetation, ie, no change in land use).

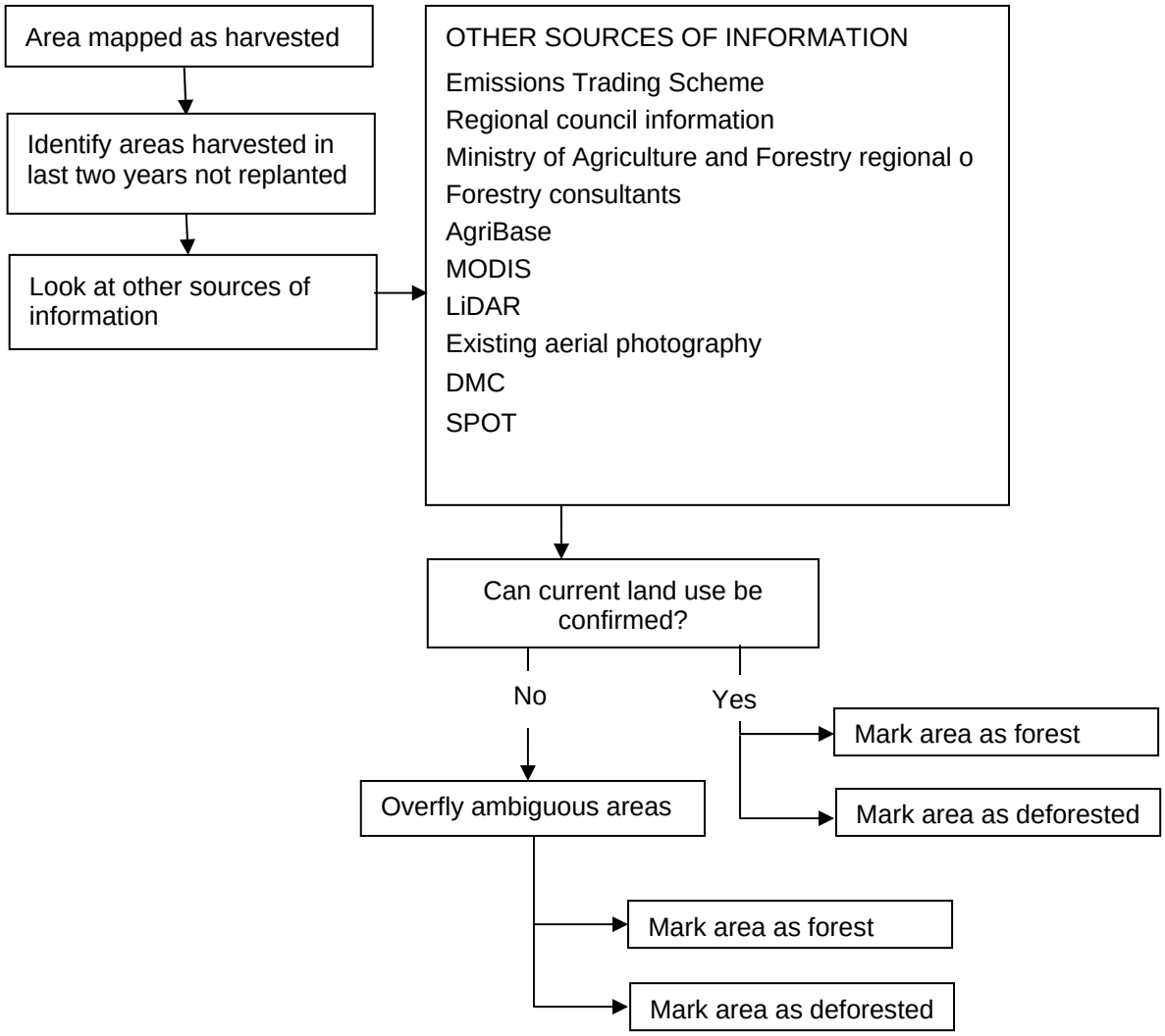
In New Zealand, temporarily unstocked or cleared areas of forest (eg, harvested areas and areas subject to disturbances) remain designated as forest land unless there is a confirmed change in land use or if, after four years, no reforestation (replanting or revegetation) has occurred. The four-year time period was selected because, in New Zealand, the tree grower and landowner are often different people. Forest land can be temporarily unstocked for a number of years while landowners decide what to do with land after harvesting.

Prior to the four-year time period, there are a number of activities that will be carried out to confirm if land-use change has occurred, including the analysis of satellite and aerial photography and airborne-scanning LiDAR imagery. These activities are detailed in section 7.2 – mapping of deforestation and harvesting.

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, 2009d). There is a data-sharing agreement that the Ministry of Agriculture and Forestry, the agency that administers the forestry aspects of the NZ ETS, will provide the Ministry for the Environment with regular updates of the area of confirmed deforestation.

To confirm that an area has not been reforested, an inspection of those areas mapped as harvested, based on satellite imagery, will occur two years after the harvesting was mapped. There are a number of approaches to this inspection including: aerial photography, airborne-scanning LiDAR and digital aerial photography, and searching for information held either by regional councils, Ministry of Agriculture and Forestry district offices, or forestry consultants. This process is shown in Figure 11.4.1.

Figure 11.4.1 Verification of deforestation in New Zealand



Following mapping at the end of 2012, the area of deforestation will be confirmed. It may take up to four years for deforestation to be confirmed where areas are harvested within four years of the end of the first commitment period. Where land-use change cannot be confirmed, New Zealand will use a combination of the ratio of area harvested to area deforested over the first part of the commitment period, and high-resolution SPOT 5 (or similar high-resolution optical imagery) acquired at the end of the commitment period to determine the area of deforestation and the likely localities.

Once a land-use change is mapped and confirmed, the deforestation emissions will be reported in the year of forest clearance. This is based on the assumption that, at the time of forest clearance, the intention was to deforest the land, and that associated emissions therefore occurred in that year.

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 which are not yet classified as deforested.

Harvested areas are tagged within the geospatial database and will be monitored over time using the method described above and allocated to a land-use change category if they are not replanted or reverting to forest within four years.

11.5 Article 3.4

New Zealand has not elected any activities under Article 3.4 of the Kyoto Protocol (Ministry for the Environment, 2006).

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities

Conversion to forest land (afforestation and reforestation) is a key category in both the level and trend analysis and conversion to grassland (deforestation) is a key category in the 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 12: Information on accounting of the Kyoto Protocol units

12.1 Background information

12.1.1 Assigned amount and commitment period reserve

In January 2007, 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 31 December 2010 the registry held 307,098,445 assigned amount units in its Party holding accounts.

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.

12.1.2 Holdings and transactions of Kyoto Protocol units

Please refer to the standard reporting format tables below (Table12.2.2). These tables are also provided in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/).

12.1.3 General note

Abbreviations used in this chapter include:

AAUs	Assigned amount units
ERUs	Emission reduction units
RMUs	Removal units
CERs	Certified emission reduction units
tCERs	Temporary certified emission reduction units
ICERs	Long-term certified emission reduction units
NZEUR	New Zealand Emission Unit Register
CDM	Clean development mechanism
NO	Not occurring

(for *Table 2b Annual external transactions* in Table 12.2.2 in the column 'Transfers and acquisitions')

AT	Austria
CH	Switzerland
DK	Denmark
FR	France
GB	United Kingdom of Great Britain and Northern Ireland
IE	Ireland
JP	Japan
NL	Netherlands
NO	Norway

12.2 Summary of the standard electronic format tables for reporting Kyoto Protocol units

At the beginning of the calendar year 2010, New Zealand's national registry held 308,377,715 assigned amount units, 48,098 emissions reduction units and 10,108 certified emission reduction units (Table 1 in Table 12.2.2). At the end of 2010, there were 307,259,426 assigned amount units, 20,328 emission reduction units and 531,020 certified emission reduction units.

New Zealand's national registry did not hold any temporary certified emission reduction units or long-term certified emissions reduction units during 2010 (Table 4 in Table 12.2.2).

The transactions made through New Zealand's national registry during 2010 (Tables 2 (a), (b), (c) in Table 12.2.2) are summarised below:

- 1 assigned amount unit was added to New Zealand's national registry and 1,120,979 were subtracted. The only addition was acquired from Japan and the greatest subtraction was 695,409 units to Norway.
- 419,880 emission reduction units were added to New Zealand's national registry and 447,650 were subtracted. The main additions were in respect to New Zealand verified projects under Article 6 of the Kyoto Protocol. There was one external addition of 20,000 units from Japan. The greatest subtractions were 120,000 and 110,246 emission reduction units to the Netherlands and Great Britain respectively. There were no internal subtractions.
- 621,002 certified emission reduction units were added to New Zealand's national registry and 100,090 were subtracted. The greatest addition was 619,002 certified emission reduction units from the Great Britain. The greatest subtraction was 100,002 certified emission reduction units made to Great Britain. There were no internal transactions.
- There were no transactions of removal units, temporary certified emission reduction units or long-term certified emissions reduction units.

During 2010, no Kyoto Protocol units were expired, replaced or cancelled.

Table 12.2.1 New Zealand's submission of the standard electronic format

Annual submission item	New Zealand's national registry response
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	The Standard Electronic Format report for 2010 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	2011
Reported year	2010
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	308329266	NO	NO	NO	NO	NO
Entity holding accounts	48449	48098	NO	9308	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	NO	NO	NO	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	308377715	48098	NO	10108	NO	NO

Party	New Zealand
Submission year	2011
Reported year	2010
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		399880					399880		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							2689	NO	NO	NO	NO	NO
Sub-total		399880	NO				402569	NO	NO	NO	NO	NO

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

Party	New Zealand
Submission year	2011
Reported year	2010
Commitment period	1

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	29586	NO	NO	NO	NO
CH	NO	NO	NO	NO	NO	NO	NO	80000	NO	NO	NO	NO
DK	NO	NO	NO	NO	NO	NO	22000	NO	NO	NO	NO	NO
FR	NO	NO	NO	2000	NO	NO	NO	47818	NO	NO	NO	NO
GB	NO	NO	NO	619002	NO	NO	1000	110246	NO	100002	NO	NO
IE	NO	NO	NO	NO	NO	NO	NO	NO	NO	88	NO	NO
JP	1	20000	NO	NO	NO	NO	1	60000	NO	NO	NO	NO
NL	NO	NO	NO	NO	NO	NO	NO	120000	NO	NO	NO	NO
NO	NO	NO	NO	NO	NO	NO	695409	NO	NO	NO	NO	NO
Sub-total	1	20000	NO	621002	NO	NO	718410	447650	NO	100090	NO	NO

Additional information

Independently verified ERUs								NO				

Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	1	419880	NO	621002	NO	NO	1120979	447650	NO	100090	NO	NO

Party	New Zealand
Submission year	2011
Reported year	2010
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	2011
Reported year	2010
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	307098445	NO	NO	NO	NO	NO
Entity holding accounts	158292	20328	NO	530220	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	2689	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	307259426	20328	NO	531020	NO	NO

Party	New Zealand
Submission year	2011
Reported year	2010
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)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	1001	1036447	NO	1047110	NO	NO	2308997	1016119	NO	516890	NO	NO
Total	309565734	1036447	NO	1047110	NO	NO	2308997	1016119	NO	516890	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**
Year 1 (2008)	NO	NO	NO	NO	NO
Year 2 (2009)	NO	NO	NO	NO	NO
Year 3 (2010)	NO	NO	NO	NO	NO
Year 4 (2011)	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO

Party	New Zealand
Submission year	2011
Reported year	2010
Commitment period	1

Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions

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

Table 6 (b). Memo item: Corrective transactions relating to replacement

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

Table 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 2010. 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 2010. 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 2010. For completeness, the report R-4 is included with 'Nil' non-replacement transactions during the reporting period.
15/CMP.1 annex I.E, paragraph 1 15: List of invalid units	No invalid units exist as at 31 December 2010. For completeness, the report R-5 is included with 'Nil' invalid units notification received during the reporting period.
15/CMP.1 annex I.E, paragraph 1 17: Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.

12.4 Publicly accessible information

New Zealand's national registry list of publicly accessible information is available at **www.eur.govt.nz**, Search the Register tab. A list of publicly accessible information is provided in Table 12.4.1.

Table 12.4.1 List of the publicly accessible information in New Zealand's national registry

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
44. Each national registry shall make non-confidential information publicly available and provide a publicly accessible user interface through the internet that allows interested persons to query and view it. 45. The information referred to in paragraph 44 above shall include up-to-date information for each account number in that registry on the following:			

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(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 cancellation or retirement account is associated.	Yes – (refer Search the Register: Accounts: Click on Account Number hyperlink to access Account Information Report).	Up to date (real-time).	n/a
(d) Representative identifier: the representative of the account holder, using the Party identifier (the two-letter country code defined by ISO 3166) and a number unique to that representative within the Party's registry.	No – the representative identifiers for primary representatives are not publicly available as it is classified as confidential.	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.	Yes, available during the reporting period. Partial from 12 February 2011 – the publication of the personal email addresses of the representatives has been withdrawn given the recent security issues encountered by some overseas registries. (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 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 Conversions tab or through the Ministers' Directions menu item. This	Joint Implementation (JI) Projects annually by 31 January for the previous calendar year.	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
	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 ERUs converted from AAUs by year).	Ministers' directions – Up to date (real-time).	
(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's website for Joint Implementation Projects at http://www.mfe.govt.nz/issues/climate/policies-initiatives/joint-implementation/notice.html and is not replicated on the New Zealand's national registry website (www.eur.govt.nz). The following information for each JI project is published on the Ministry for the Environment website: • project description • non-host party project approval • annual reports • verification reports Project proposals are not included as they contain financial information which 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).	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).

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
	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 are 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.
(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 1January 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).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	n/a
	The identity of the individual transferring accounts is not available as it is considered to be confidential information.		section 27(j) of the Climate Change Response Act 2002 requires that only the following be made publicly available: • total quantity of units transferred • total quantity and type of unit transferred • the identity of the transferring overseas registries including the total quantity of units transferred from

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
			each overseas registry and each type of unit transferred from each overseas registry.
(e) The total quantity of RMUs issued on the basis of each activity under Article 3, paragraphs 3 and 4.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	n/a
(f) The total quantity of ERUs, CERs, AAUs and RMUs transferred to other registries and the identity of the acquiring accounts and registries.	Partial – the total quantity of ERUs, CERs, AAUs and RMUs transferred to other registries, and the identity of the registries is publicly available by 31 January for the previous calendar year.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	n/a
	The identity of the individual acquiring accounts is not available as it is considered to be confidential information.		section 27(k) of the Climate Change Response Act 2002 requires that only the following be publicly available: • total quantity of units transferred • total quantity and type of unit transferred • the identity of the acquiring overseas registries including the total quantity of units transferred to each overseas registry and each type of unit transferred to each overseas registry.
(g) The total quantity of ERUs, CERs, AAUs and RMUs cancelled on the basis of activities under Article 3, paragraphs 3 and 4.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(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). 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
(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 are only those completed 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.

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
	(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).		
48. The information referred to in paragraph 44 shall include a list of legal entities authorised by the Party to hold ERUs, CERs, AAUs and/or RMUs under its responsibility.	Yes (refer Search the Register: Account Holders for list of authorised entities).	Up-to-date (real time).	n/a

12.5 Calculation of the commitment period reserve

New Zealand's commitment period reserve calculation is based on the assigned amount and therefore fixed. The commitment period reserve is 278,608,260 metric tonnes of CO_2-e), 90 per cent of the assigned amount of 309,564,733, fixed after the review of *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006).

The commitment period reserve level as at 31 December 2010 is:

Commitment period reserve limit:	278,608,260
Units held:	307,807,285
Commitment period reserve level:	307,807,285
Commitment period reserve level = (% of assigned amount):	99.43%

CPR level comprises of the following units:

AAUs	307,256,737
ERUs (converted from AAUs)	20,328
CERs	530,220
Total units	307,807,285

New Zealand's commitment period reserve level is also available at: www.eur,govt.nz, and is updated daily.

Chapter 13: Information on changes to the national system

New Zealand efforts in the national system were focused on the preparation and the response for the in-country review of the 2010 inventory submission. However, improvements were made to the documentation of compiling and the expertise of some of the key inventory contributors was increased. The manual for the national inventory compiler was updated and elaborated to include more detail on the inventory preparation process. Two government officials have passed their expert review exams under the Climate Change Convention for the land use, land-use change and forestry sector. Four other government officials, already expert reviewers under the Climate Change Convention, passed their mandatory Kyoto Protocol exams.

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 2010 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 'Recertification' 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	No change in the name or contact information of the registry administrator occurred during the reported period.
15/CMP.1 Annex II.E, paragraph 32.(b): Change in cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
1/CMP.1 Annex II.E, paragraph 32.(c): Change to the database or the capacity of the national registry	No change to the database or to the capacity of the national registry occurred during the reported period.
15/CMP.1 Annex II.E, paragraph 32.(d): Change in the conformance to technical standards	During first half of 2010 New Zealand has introduced functionality to enable the support of Method 2 Two man rule/additional authorised representative. The change was a system code release only. The only changes made were to the test plan and test report areas. There were no changes made to the other areas under the Readiness Documentation. There were no changes made to the Database and Application Backup (no changes to the content of the backup procedures, no changes to the backup retention periods, no changes to the frequency of the database backups), no changes made to the Disaster Recovery Plan, no changes made to the Security Plan, no changes made to the Application Logging Documentation, no changes made to the Time Validation Plan, no changes made to the Version Change Management and no changes made to the Operational Plan.
15/CMP.1 Annex II.E, paragraph 32.(e): Change in the discrepancy procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 Annex II.E, paragraph 32.(f): Change in security	During first half of 2010 New Zealand implemented functionality to enable account holders to optionally add an extra level of protection when conducting transactions by separating their duties of their authorised representatives. This enables the account holder to appoint some representatives as 'preparers' and some representatives as 'approvers' and by doing this to have two people involved in all transactions (Method 2: Two man-rule/additional authorised representatives). This functionality was released into the New Zealand national registry on 10 June 2010.
15/CMP.1 Annex II.E, paragraph 32.(g): Change in the list of publicly available information	No change to the list of publicly available information occurred during the reporting period. Subsequently, in February 2011, in response to the recent security issues encountered by certain overseas registries, the Registrar has invoked the powers under section 13 of the Climate Change Response Act 2002 to remove the publication of the email addresses of primary representatives to ensure the security of the registry.

Section subheading	New Zealand's response
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	During first half of 2010 New Zealand has introduced functionality to enable the support of Method 2: Two man rule/additional authorised representative. For this change the New Zealand national registry updated the business acceptance test plan, the test scripts (by creating additional tests for the additional representative 'types') and business acceptance test completion report. These documents (including a sample test script and the test log) are attached (items 1 to 5 in Table 14.3 below).

Table 14.2 Previous recommendations for New Zealand from the expert review team

Previous annual review recommendations	New Zealand addressed the recommendation as follows
2010 Report of the individual review of the annual submission of New Zealand	At the time of writing, the 2010 report of the individual review of the annual submission of New Zealand had not yet been finalised for issue and publication.
2010 Standard Independent Assessment Report (SIAR)	No recommendations were made that require a response from the New Zealand national registry.

Table 14.3 New Zealand's reference document list (zipped under the folder submitted as 'Recertification.zip')

ID	Document name	Document description
1	NZEUR Business Acceptance Test Plan – SOW6 Phase 2.doc	NZEUR test plan for testing the preparer/approver functionality
2	NZEUR Business Acceptance Test Completion Report – SOW6 Phase 2.doc	NZEUR Business Acceptance test report at the end of testing the preparer/approver functionality
3	NZEUR General Information.doc	NZEUR testing general guidance
4	TS-00571.doc	NZEUR test script sample
5	SOW6 MED 14 May.xls	NZEUR test results log

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.

15.1 Overview

New Zealand's Cabinet and legislative processes to establish and implement climate change response measures include consultation with the Ministry of Foreign Affairs and Trade and with the public. The Ministry of Foreign Affairs and Trade provides advice to the Government on international aspects of proposed policies. During the public consultation phase, concerns and issues about the proposed measure can be raised by any person or organisation.

Through the New Zealand Government's regular trade, economic and political consultations with other governments, including some non-Annex I Parties, there are opportunities for those who may be concerned about the possible or actual impacts of New Zealand policies to raise concerns and have them resolved within the bilateral relationship. To date, there have been no specific concerns raised about any negative impact of New Zealand's climate change response policies.

The New Zealand Government, through the New Zealand Aid Programme (www.aid.govt.nz), has regular Official Development Assistance programming talks with partner country governments, where partners have the opportunity to raise concerns about any impacts and to ask for or prioritise assistance to deal with those impacts. From these discussions, New Zealand works closely with the partner country to prepare a country strategic framework for development. These engagement frameworks are relatively long term (five or ten 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 developing countries to strengthen governance and enabling environments. This improves their ability to respond to changing circumstances. As a member of the Pacific Islands Forum, New Zealand works closely with non-Annex I Parties in the Pacific in a wide range of technical, economic and political fields, addressing concerns that are raised in the regional context.

New Zealand maintains a liberalised and open trading environment, consistent with the principles of free trade and investment, ensuring that both developed and developing countries can maximise opportunities in New Zealand's market regardless of the response measures undertaken.

15.2 Market imperfections, fiscal incentives, tax and duty exemptions and subsidies

Annex I Parties are required to report any progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities.

New Zealand does not have any significant market imperfections, fiscal incentives, tax and duty exemptions or subsidies in greenhouse-gas-emitting sectors of this nature.

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. To support international efforts, New Zealand is a member of "the Friends of Fossil Fuel Subsidy Reform", an informal group of non-G20 countries which encourages and supports the G20 countries to meet their commitments. The group is committed to supporting the reform of inefficient fossil-fuel subsidies, 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.

15.4 Technological development of non-energy uses of fossil fuels

Annex I Parties are required to report on cooperation in the technological development of non-energy use of fossil fuels and support provided to non-Annex I Parties. The New Zealand Government has not actively participated in activities of this nature as yet.

15.5 Carbon capture and storage technology development

Annex I Parties are required to report on cooperation in the development, diffusion and transfer of less-greenhouse-gas-emitting advanced fossil fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouragement of their wider use; and facilitating the participation of non-Annex I Parties.

New Zealand is a member of the United States-led Carbon Sequestration Leadership Forum (www.cslforum.org), the Australian-led Global Carbon Capture and Storage Institute (www.globalccsinstitute.com) and the International Energy Agency Greenhouse Gas Research and Development Programme (www.ieaghg.org).

15.6 Improvements in fossil fuel efficiencies

Annex I Parties are required to report how they have strengthened the capacity of non-Annex I Parties identified in Article 4.8 and 4.9 of the Climate Change Convention, by improving the efficiency in upstream and downstream activities related to fossil fuels and by taking into consideration the need to improve the environmental efficiency of these activities.

An example is the successfully completed refurbishment of the diesel-fired Aitutaki Power Station in the Cook Islands, with funding of NZ $1.1 million by the New Zealand Aid Programme. This was identified as a government priority under the Cook Islands National Sustainable Plan 2007–2010. The key outputs were a more efficient, reliable and continuous electricity supply for residential and commercial users. It also provided more environmentally friendly operations including significant reduction in noise pollution, diesel fuel and oil spillage, and contamination.

There is now capacity to meet not only current demand but also demand for years to come. There is also capacity to integrate alternative renewable energies such as wind and/or solar into the network at significantly less cost.

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. This is one of the objectives of the International Partnership for Energy Development in Island Nations (www.edinenergy.org). New Zealand is a member of the International Partnership for Energy Development in Island Nations alongside the United States of America and Iceland.

The International Partnership for Energy Development in Island Nations provides:

- sound policies to help remove barriers to clean energy development and create incentives for growth
- financing resources to attract private capital and project developers to islands for renewable energy and energy-efficiency projects
- clean energy technologies by helping to develop a knowledge base through technical assistance and training, and by promoting the transfer of new renewable energy and energy efficiency technologies into the marketplace.

References

General references

Beets PN, Kimberley MO, Goulding CJ, Garrett LG, Oliver GR, Paul TSH. 2009. Natural Forest plot data analysis: carbon stock analyses and re-measurement strategy.

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

IPCC. 1996. Houghton JT, Meira Filho LG, Lim B, Treanton K, Mamaty I, Bonduki Y, Griggs DJ, Callender BA (eds). IPCC/OECD/IEA. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.* United Kingdom Meteorological Office: Bracknell.

IPCC. 2000. Penman J, Kruger D, Galbally I, Hiraishi T, Nyenzi B, Emmanul S, Buendia L, Hoppaus R, Martinsen T, Meijer J, Miwa K, Tanabe K (eds). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2003. Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Tanabe K, Wagner F (eds). *Good Practice Guidance for Land Use, Land-use Change and Forestry*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2006a. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3. Industrial Processes and Product Use*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2006b. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2006c. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

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

Kimberley MO, Beets PN. 2008: Forest Carbon Predictor Version 2.1. Contract report prepared by New Zealand Forest Research Institute (trading as Scion) for the Ministry for the Environment. Ministry for the Environment: Wellington.

Manley B. 2009. *2008 Deforestation Intentions Survey*. Contract report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Ministry of Agriculture and Forestry. 2008. *National Exotic Forest Description as at 1 April 2007*. Edition 24. Wellington: Ministry of Agriculture and Forestry.

Ministry of Agriculture and Forestry. 2010. *Situation and Outlook for New Zealand Agriculture and Forestry (SONZAF).* Available at http://www.maf.govt.nz/news-resources/publications.aspx?title=SONZAF

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.

Stephens PR, Watt PJ, Loubser D, Haywood A, Kimberley MO. 2007. Estimation of carbon stocks in New Zealand planted forests using airborne scanning LiDAR. Workshop on Laser Scanning. 12–14 September 2007. Finland. pp 389–394, IAPRS XXXVI, Part 3/W52.

Stephens PR, McGaughey RJ, Dougherty T, Farrier T, Geard BV, Loubser D. 2008. Quality assurance and quality control procedures of airborne scanning LiDAR for a nation-wide carbon inventory of planted forests. In: *Proceedings of SilviLaser 2008: 8th international conference on LiDAR applications in forest assessment and inventory*. Hill RA, Rosette J, Suárez J (eds). September 2008. Edinburgh, United Kingdom. pp 563–571.

UNFCCC. 2001a. FCCC/WEB/IRI (1)/2000/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2000.* Desk Review (20 June 2001).

UNFCCC. 2001b. FCCC/WEB/IRI (2)/2000/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2000*. In-country Review (20 July 2001).

UNFCCC. 2001c. FCCC/WEB/IRI (3)/2000/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2000.* Centralised Review (30 May 2001).

UNFCCC. 2003. FCCC/WEB/IRI (1)/2002/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2002*. Desk Review (13 October 2003).

UNFCCC. 2005. FCCC/KP/CMP/2005/8/Add.3. *Land use, land-use change and forestry*.

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)*.

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).

UNFCCC. 2009. FCCC/ARR/2008/NZL. *Report of the individual review of the greenhouse gas inventories of New Zealand submitted in 2007 and 2008*. Centralised Review.

UNFCCC. 2010. FCCC/ARR/2009/NZL. *Report of the individual review of the annual submission of New Zealand submitted in 2009*. Centralised Review.

United Nations. 1992. United Nations Framework Convention on Climate Change.

Specific references for Chapter 3: Energy

Australian Bureau of Statistics and Statistics New Zealand. 2006. *Australian and New Zealand Standard Industrial Classification Revision 1.0.* Australian Bureau of Statistics: Canberra.

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

Beamish BB, Vance WE. 1992. Greenhouse Gas Contributions from Coal Mining in Australia and New Zealand. *Journal of the Royal Society of New Zealand* 22(2).

Building Research Association of New Zealand. 2002. *Energy Use in New Zealand Households*. Building Research Association of New Zealand: New Zealand.

Eng G, Bywater I, and Hendtlass C. 2008. *New Zealand Energy Information Handbook: Energy data conversion factors and definitions*. Christchurch: New Zealand Centre for Advanced Engineering.

Hale and Twomey Ltd. 2009. *Reviewing default emission factors for liquid fossil fuels adopted by the New Zealand Emissions Trading Scheme*. Contract report prepared for the Ministry for the Environment. Wellington: Ministry for the Environment.

Ministry for the Environment. 2009. *Projects to Reduce Emissions (PRE)* www.mfe.govt.nz/issues/climate/policies-initiatives/projects.

Ministry of Economic Development. 2008. *Liquid Fuel Use in New Zealand*. www.med.govt.nz/energy/liquid-fuel-demand/.

Ministry of Economic Development. 2010. *Delivering the Diesel: Liquid Fuel Deliveries in New Zealand 1990–2008*. www.med.govt.nz/energy/delivering-the-diesel/.

Ministry of Economic Development. 2010b. *New Zealand Energy Data File*. Wellington: Ministry of Economic Development.

New Zealand Institute of Chemistry. 1998. *Chemical Processes in New Zealand (2nd Edition)*. Auckland: New Zealand Institute of Chemistry.

Statistics New Zealand. 2007. *Manufacturing Energy Use Survey: Year ended March 2006*. Wellington: Statistics New Zealand.

Specific references for Chapter 4: Industrial processes

Cement and Concrete Association of New Zealand. 1995. The State of the Standards. *New Zealand Concrete Construction* October/November 1995. p40.

CRL Energy Ltd. 2006. Hennessy W, Maxwell D. *Inventory of Non-CO_2 Greenhouse Gas Emissions from Industrial Sources and Solvents for New Zealand 2004–2005*. A report by CRL Energy Ltd to the Ministry for the Environment. Wellington: Ministry for the Environment.

CRL Energy Ltd. 2009. Hennessy W. *Inventory of HFC, PFC & SF_6 Emissions for New Zealand 2008*. A report by CRL Energy Ltd to the Ministry for the Environment. Wellington: Ministry for the Environment.

CRL Energy Ltd. 2010. Hennessy W. *Inventory of HFC, PFC & SF_6 Emissions for New Zealand 2009*. A report by CRL Energy Ltd to the Ministry for the Environment. Wellington: Ministry for the Environment.

International Aluminium Institute. 2006. *The Aluminium Sector Greenhouse Gas Protocol*. London: International Aluminium Institute.

Ministry of Economic Development. 2010. *New Zealand Energy Greenhouse Gas Emissions 1990–2009*. Wellington: Ministry of Economic Development.

MWH (2002) Inventory of Halocarbon Emissions for New Zealand, report to the Ministry for the Environment, Wellington.

Ure CR. 2000. Alternative Iron-making at BHP New Zealand Steel. *58th Electric Furnace Conference and 17th Process Technology Conference*. Orlando, FL, United States of America: 12–15 November 2000. pp 535–546.

World Business Council for Sustainable Development. 2005. *The Cement CO_2 Protocol: CO_2 Accounting and Reporting Standard for the Cement Industry*. Switzerland: World Business Council for Sustainable Development.

Specific references for Chapter 5: Solvent and other product use

Auckland Regional Council. 1997. *Auckland Air Emissions Inventory*. Report by the Victorian Environmental Protection Agency. Auckland: Auckland Regional Council.

CRL Energy Ltd. 2006. Hennessy W, Maxwell D. *Inventory of Non-CO_2 Greenhouse Gas Emissions from Industrial Sources and Solvents for New Zealand 2004–2005*. A report by CRL Energy Ltd to the Ministry for the Environment. Wellington: Ministry for the Environment.

Nelson, P. 1992. Waste Control and Pollution Prevention in the Paint Industry. *Surface Coatings Australia* (July).

United States EPA. 1985. *Compilation of Air Pollutant Emission Factors, Vol. 1: Stationary Point and Area Sources* (5th edn) (commonly known as AP-42). Washington, DC: United States Environmental Protection Agency.

Specific references for Chapter 6: Agriculture

Carran RA, Dewar D, Theobald PW. 2003. *Methane and Nitrous Oxide Emissions from Sheep Dung*. Report prepared for the Ministry of Agriculture and Forestry by the New Zealand Pastoral Agricultural Research Institute. Wellington: Ministry of Agriculture and Forestry.

Carran RA, Theobold PW, Evans JP. 1995. Emissions of nitrous oxide from some grazed pasture soils. *New Zealand and Australian Journal of Soil Research* 33: 341–352.

Clark H. 2008. *Guidelines to Accompany Computerised Inventory.* Report to the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Clark H, Brookes I, Walcroft A. 2003. *Enteric Methane Emissions from New Zealand Ruminants 1990–2001 Calculated Using an IPCC Tier 2 Approach.* Report prepared for the Ministry of Agriculture and Forestry (March 2003). Wellington: Ministry of Agriculture and Forestry.

Clough TJ, Kelliher FM, Clark H, van der Weerden TJ. 2008. *Incorporation of the Nitrification Inhibitor DCD into New Zealand's 2009 National Inventory.* Report to the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

CSIRO. 2007. *Feeding Standards for Australian Livestock: Ruminants*. Victoria, Australia: Commonwealth Scientific and Industrial Research Organisation.

de Klein CAM, Barton L, Sherlock RR, Li Z, Littlejohn RP. 2003. Estimating a nitrous oxide emission factor for animal urine from some New Zealand pastoral soils. *Australian Journal of Soil Research* 41: 381–399.

Fennessy PF, Moore GH, Corson ID. 1981. Energy Requirements of Red Deer. *Proceedings of the New Zealand Society of Animal Production, 41:* 167–173.

Grainger C, Clarke T, McGinn SM, Auldist MJ, Beauchemin KA, Hannah MC, Waghorn GC, Clark H, Eckard RJ. 2007. Methane emissions from dairy cows measured with sulphur hexafluoride (SF_6) tracer and chamber techniques. *Journal of Dairy Science* 90:6 2755–2766.

Henderson H, Cameron C. 2010. Review of the Methodology for Alpaca Population Estimations used in the National Greenhouse Gas Inventory. Report for the Ministry of Agriculture and Forestry (December 2010). Wellington: Ministry of Agriculture and Forestry.

Heatley P. 2001. *Dairying and the Environment: Managing Farm Dairy Effluent*. Palmerston North: New Zealand Dairy Research Institute.

Kay RNB. 1995. Body Size, Patterns of Growth, and Efficiency of Production in Red Deer. In: *Biology of Deer Production*. Fennessey PF, Drew KR (eds). *Royal Society of New Zealand Bulletin* 22: 411–421.

Kelliher FM, Clough T, Newsome P, Pitcher-Campbell S, Shephard G. 2002. *N_2O Emissions from Organic Soils*. Report for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Kelliher FM, Ledgard SF, Clark H, Walcroft AS, Buchan M, Sherlock RR. 2003. *A Revised Nitrous Oxide Emissions Inventory for New Zealand 1990–2001*. Report for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Kelliher FM, de Klein CAM, Li Z; Sherlock RR. 2005. *Review of nitrous oxide emission factor (EF_3) data*. Report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Kelliher FM, de Klein CAM. 2006. *Review of New Zealand's Fertiliser Nitrous Oxide Emission Factor (EF_1) Data.* A Report for the Ministry for the Environment. Wellington: Ministry for the Environment.

Kelliher FM, Clark H, Smith MH, Lassey KR, Sedcole R. 2009. *Reducing Uncertainty of the Enteric Methane Emissions Inventory*. Report for the Ministry of Agriculture and Forestry (June 2009). Wellington: Ministry of Agriculture and Forestry.

Lassey KR, Ulyatt MJ, Martin RJ, Walker CF, Shelton ID. 1997. Methane Emissions Measured Directly from Grazing Livestock in New Zealand. *Atmospheric Environment* 31: 2905–2914.

Laubach J, Kelliher FM. 2004. Measuring Methane Emission Rates of a Dairy Cow Herd by Two Micrometeorological Techniques. *Agricultural and Forest Meteorology* 125: 279–303.

Ledgard S, Brier G. 2004. *Estimation of the Proportion of Animal Excreta Transferred to the Farm Dairy Effluent System*. Report prepared for Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Ledgard SF, Webby R, Hawke M. 2003. *Improved Estimation of N Excretion by Grazing Animals to Improve N_2O Emission Inventories*. Report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Livestock Improvement Corporation Limited. 2010. New Zealand *Dairy Statistics 2009–2010*. Hamilton: Livestock Improvement Corporation Limited. www.lic.co.nz or www.dairynz.co.nz/dairystatisitcs.

Luo J, van der Weerden T, Hoogendoorn C, de Klein C. 2009. *Determination of the N_2O emission factor for animal dung applied in spring in three regions of New Zealand* . Report for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

McGrath RJ, Mason IG. 2002. An observational method for assessment of biogas production from an anaerobic waste stabilisation pond treating farm dairy wastewater. Presented IWA Specialised Conference on Waste Stabilisation Ponds (April 2002): Auckland, New Zealand.

Ministry of Agriculture and Forestry. 2009. *Situation and Outlook for New Zealand Agriculture and Forestry (SONZAF).* Available at http://www.maf.govt.nz/news-resources/publications.aspx?title=SONZAF

Muller C, Sherlock RR, Williams PH. 1995. Direct field measurements of nitrous oxide emissions from urine-affected and urine-unaffected pasture in Canterbury. In: *Proceedings of the Workshop on Fertilizer Requirements of Grazed Pasture and Field Crops: Macro and Micronutrients.* Currie LD, Loganathan P (eds). *Occasional Report No. 8*, ISSN 0112–9902: 7. Palmerston North: Massey University. pp 243–34.

Pinares-Patino CS, Ulyatt MJ, Waghorn GC, Lassey KR, Barry TN, Holmes CW, Johnson DE. 2003. Methane Emission by Alpaca and Sheep Fed on Lucerne Hay or Grazed on Pastures of Perennial Ryegrass/White Clover or Birdsfoot Trefoil. *Journal of Agricultural Science* 140: 215–226.

Payton IJ, Pearce G. 2001. *Does Fire Deplete Physical and Biological Resources of Tall-tussock (Chionochloa) Grasslands? The Latest Attempt at Some Answers.* Bushfire 2001. Australasian Bushfire Conference, 3–6 July 2001, Christchurch, New Zealand. pp 243–249.

Saggar S, Clark H, Hedley C, Tate K, Carran A, Cosgrove G. 2003. *Methane Emissions from Animal Dung and Waste Management Systems, and its Contribution to National Budget.* Landcare Research Contract Report: LC0301/02. Prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Sherlock RR, Johnston G, Kelliher F, Newsome P, Walcroft A, de Klein CAM, Ledgard S. 2001. *A Desktop Study of Regional Variations in Nitrous Oxide Emissions.* Report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Sherlock RR, de Klein C, Li Z. 2003. *Determination of N_2O and CH_4 Emission Factors from Animal Excreta, Following a Summer Application in Three Regions of New Zealand.* A final report of an NzOnet study prepared for Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Sherlock RR, Jewell P, Clough T. 2009. *Review of New Zealand Specific $Frac_{GASM}$ and $Frac_{GASF}$ Emissions Factors.* Report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Statistics New Zealand. 2010. Agriculture Statistics table builder and Infoshare database. Available at: www.stats.govt.nz/methods_and_services/access-data/TableBuilder.aspx and www.stats.govt.nz/infoshare.

Thomas S. 2010. *Assessment of the methodology of potato area and yield activity estimations used in the NZ national GHG Inventory*. Report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Thomas SM, Ledgard SF, Francis GS. 2005. Improving Estimates of Nitrate Leaching for Quantifying New Zealand's Indirect Nitrous Oxide Emissions. *Nutrient Cycling in Agroecosystems* 73: 213–226.

Thomas SM, Fraser T, Curtin D, Brown H, Lawrence E. 2008. *Review of Nitrous Oxide Emission Factors and Activity Data for Crops.* Report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Ulyatt MJ, Baker SK, McCrabb GJ, Lassey KR. 1999. Accuracy of the SF_6 Tracer Technology and Alternatives for Field Measurements. *Australian Journal of Agricultural Research* 50: 1329–1334.

Waghorn G, Molano G, Cavanagh A. 2003. *An Estimate of Whole Herd Methane Production from Cows at the Lincoln University Dairy Farm in October 2003.* Final report prepared for Landcare Research NZ Ltd, Palmerston North: AgResearch.

Waghorn G, Molano G, Lassey K. Unpublished. Estimates of Whole Herd Methane Production from Cows at the Lincoln University Dairy Farm in January and March 2002. A preliminary report to Landcare Research NZ Ltd. Lincoln, Christchurch: Landcare Research NZ Ltd.

Wheeler DM, Ledgard SF, De Klein CAM, Monaghan PL, Carey PL, McDowell RW, Johns KL. 2003. OVERSEER® Nutrient budgets – moving towards on-farm resource accounting. *Proceedings of the New Zealand Grassland Association 2003*. Palmerston North: NZ Grassland Association Inc.

Specific references for Chapter 7: Land use, land-use change and forestry

Baisden WT, Beets PN, Davis M, Wilde RH, Arnold G, Trotter CM. 2006a. *Changes in New Zealand's Soil Carbon Stocks Following Afforestation of Pastures*. Landcare Research Contract Report: LC0506/105. Wellington: Ministry for the Environment.

Baisden WT, Wilde RH, Arnold G, Trotter C.M. 2006b. *Operating the New Zealand Soil Carbon Monitoring System*. Landcare Research Contract Report: LC0506/107. Wellington: Ministry for the Environment.

Beets PN, Robertson K, Ford-Robertson JB, Gordon J, Maclaren JP. 1999. Description and Validation of C_Change: A Model for Simulating Carbon Content in Managed *Pinus Radiata* Stands. *New Zealand Journal of Forestry Science* 29(3): 409–427.

Beets PN, Kimberley MO, McKinley RB. 2007a. Predicting Wood Density of *Pinus radiata* Annual Growth Increments. *New Zealand Journal of Forestry Science* 37: 241–266.

Beets PN, Pearce SH, Oliver GR, Clinton P. 2007b. Root/shoot Ratios for Deriving the Below Ground Biomass of *Pinus radiata* Stands. *New Zealand Journal of Forestry Science* 37: 267–288.

Beets PN, Oliver GR, Kimberley MO, Hodgkiss PD, Cown DJ. 2008a. *Wood Density of Exotic and Native Species in New Zealand's Planted and Natural Forests*. Contract report prepared for the Ministry for the Environment. Contract No. 11407. Wellington: Ministry for the Environment.

Beets, PN, Oliver, GR, Kimberley, MO, Pearce, SH. 2008b. Allometric Functions for Estimating Above Ground Carbon in Native Forest Trees, Shrubs and Tree Ferns. Contract report prepared for the Ministry for the Environment. Contract No. 10048. Wellington: Ministry for the Environment.

Beets PN, Kimberley MO, Goulding CJ, Garrett LG, Oliver GR, Paul TSH. 2009. Natural Forest plot data analysis: carbon stock analyses and re-measurement strategy. Contract report 11455 prepared by New Zealand Forest Research Institute (Trading as Scion) for the Ministry for the Environment. Ministry for the Environment: Wellington.

Beets PN, Brandon AM, Fraser BV, Goulding CJ, Lane P, Stephens PR. 2010. National Forest Inventory Country Report: New Zealand. In E Tomppo, T Gschwantner, M Lawrence and RE McRoberts (eds) *National Forest Inventories: Pathways for Common Reporting*. Managing Forest Ecosystems Series. Springer.

Beets PN, Kimberley MO, Paul TSH. In press (a). Planted Forest Carbon Monitoring System – Forest Carbon Model Validation Study for *Pinus radiata*. *New Zealand Journal of Forest Research*.

Beets PN, Reutebuch S, McGaughey RJ, Kimberley MO, Oliver GR, Pearce SH. In press (b). Use of LiDAR to estimate biomass carbon, leaf area index, and carbon sequestration in radiata pine. Submitted to *Remote Sensing of Environment*. October 2009.

Brack C. 2009. *2009: Planted Forest Inventory Design: Post-1989 exotic*. Contract Report: 12479. Wellington: Ministry for the Environment.

Brack C and Broadley J. 2010. *Co-location of LiDAR and Post-1989 Forest Plots*. Contract Report: 13117. Wellington: Ministry for the Environment.

Coomes DA, Allen RB, Scott NA, Goulding CJ, Beets PN. 2002. Designing Systems to Monitor Carbon Stocks in Forests and Shrublands. *Forest Ecology and Management* 164: 89–108.

Corona P, Fattorini L. 2008: Area-based LiDAR-assisted Estimation of Forest Standing Volume. *Canadian Journal of Forest Research* 38: 2911–2916.

Daly BK and Wilde RH. 1997. *Contribution of Soil Carbon to New Zealand's CO_2 Emissions: I Reclassification of New Zealand Soil Series to IPCC Categories*. Landcare Research Contract Report: LC9697/096. Ministry for the Environment, Wellington.

Davis MR and Wakelin SJ. 2010. *Perennial Cropland Biomass: Sampling Requirements*. New Zealand Forest Research Institute Limited (trading as Scion. Contract report: 11407. Wellington: Ministry for the Environment.

Doherty JJ, Anderson SAJ, Pearce HG. 2008. *An Analysis of Wildfire Records in New Zealand: 1991–2007*. Scion client report no 12796. Christchurch: Scion.

Dougherty T, Gapare N, Stephens PR. 2009. *Guide to Mapping Woody Land-use classes Using Satellite Imagery*. Wellington: Ministry for the Environment Internal Document.

Dymond JR, Shepherd JD, Qi J. 2001. A Simple Physical Model of Vegetation Reflectance for Standardising Optical Satellite Imagery. *Remote Sensing of Environment*. 37: 230–239.

Dymond JR, Shepherd JD. 2004. The spatial distribution of indigenous forest and its composition in the Wellington region, New Zealand, from ETM+ satellite imagery. *Remote Sensing of Environment* 90: 116–125.

Dymond JR, Shepherd JD, Arnold GC, Trotter CM. 2008. Estimating area of forest change by random sampling of change strata mapped using satellite imagery. *Forest Science* 54(5): 475–480.

Eyles, GO. 1977. NZLRI worksheets and their applications to rural planning. *Town Planning Quarterly* 47: 38–44.

Fraser S, Wilde H, Payton I, Scott J. 2009. *Historic Soils Dataset – Land-use Reclassification*. Landcare Research Contract Report: LC0809/131. Wellington: Ministry for the Environment.

Garrett G, Oliver GO, Pearce SH, Kimberley MO. 2009. *Decomposition of woody roots and branches in managed Pinus radiata forests – time series approach*. Scion contract report number 45653 to Ministry for the Environment. Wellington: Ministry for the Environment.

GNS Science. 2009. LUM 2008 AQC Regional Reports. Contract deliverables prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Goulding CJ, Beets PN, Duigan A, Davis M, Allen RB, Payton IJ, Tate KR, Wilde H. 2001. *Development of a carbon monitoring system for the indigenous forest, shrubland and soils of New Zealand*. Contract report prepared for the Ministry for the Environment. Wellington: Ministry for the Environment.

Hedley CB, Payton IJ, Lynn IH, Carrick, ST, Webb TH. Submitted. Random Sampling of Stony and Non-stony Soils for Validating a Soil Carbon Monitoring System. Paper submitted to *Journal of Soil Use and Management*.

Hewitt AE. 1998. *New Zealand Soil Classification*. 2nd ed. Landcare Research Science Series No. 1, Manaaki Whenua Press, Lincoln.

Hollinger DY, Maclaren JP, Beets PN, Turland J. 1993. Carbon sequestration by New Zealand's plantation forests. *New Zealand Journal of Forest Science* 23: (2).

Hunter G and McNeill S. 2010. *Review of LUCAS land-use backcasting 1962–1989*. Landcare Research Limited. Contract report number LC70 prepared for the Ministry for the Environment. Wellington: Ministry for the Environment.

Jaakko Poyry Consulting. 2003. *Small Forest Owners Yield Table Evaluation.* Contract report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Kimberley MO, West GG, Dean MG, Knowles LR. 2005. The 300 Index – a volume productivity index for radiata pine. *New Zealand Journal of Forestry* 50, pp 13–18.

Kimberley MO, Dean MG. 2005. A validation of the 300 index growth model. *Plantation Management Cooperative Report No. 98*.

Kimberley MO, Beets PN. 2008: Forest Carbon Predictor Version 2.1. Contract report prepared by New Zealand Forestry Research Institute (trading as Scion) for the Ministry for the Environment. Ministry for the Environment: Wellington.

Kimberley MO, Beets PN, Wakelin SJ. 2009. Revised regression models for estimating forest carbon stocks in New Zealand post-1989 forests using LiDAR. Scion contract report number 45478 to Ministry for the Environment. Wellington: Ministry for the Environment.

Kirschbaum M, Trotter C, Wakelin S, Baisden T, Curtin D, Dymond J, Ghani A, Jones HS, Deurer M, Arnold G, Beets PN, Davis MR, Hedley C, Peltzer D, Ross C, Schipper L, Sutherland A, Wang H, Beare M, Clothier B, Mason N, Ward M. 2009. *Carbon Stocks and Changes in New Zealand's Soils and Forests, and Implications of Post-2012 Accounting Options for Land-Based Emissions Offsets and Mitigation Opportunities*. Landcare Research Contract Report: LC0708/174, 1–457. Lincoln: Landcare Research New Zealand Ltd.

Kelliher FM, de Klein, CAM. 2006. *Review of New Zealand's Fertiliser Nitrous Oxide Emission Factor (EF_1) Data.* A Report for the Ministry for the Environment (April 2006). Wellington: Ministry for the Environment.

Lawrence-Smith EJ, Tregurtha CS, Beare MH. 2010. *Land Management Index data for use in New Zealand's Soil Carbon Monitoring System*. Plant and Food Research Contract Report: SPTS 4612. Ministry for the Environment, Wellington.

MacLaren JP, Knowles RL. 2005. Version 2 Calculators. Upgrading the business of farm forestry. *New Zealand Tree Grower*. May 2005:24.

McNeill SJ, Forester G, Giltrap D. 2009. *Spatial Autocorrelation Analysis of Data for the Soils CMS Model*. Landcare Research Contract Report: LC0910/003. Wellington: Ministry for the Environment.

McNeill SJ. 2010. *Soil CMS model recalibration and uncertainty analysis*. Landcare Research Contract Report: LC93. Ministry for the Environment, Wellington.

McNeill SJ, Campbell S, Hewitt A, Webb T. 2010. *Soil Carbon Monitoring System: Bulk density and soil carbon correction, re-extraction from National Soils Database, and documentation*. Landcare Research Contract Report: LC0910/124. Ministry for the Environment, Wellington.

McGaughey RJ, Carson WW, Reutebuch SE, Andersen HE. 2004. Direct measurement of individual tree characteristics from LiDAR data. In: *Proceedings of the 2004 Annual ASPRS Conference*, 23–28 May 2004; Denver, Colorado: Bethesda, MD. American Society of Photogrammetry and Remote Sensing. Unpaginated CD-ROM.

McGlone MS. 2009. Postglacial history of New Zealand wetlands and implications for their conservation. *New Zealand Journal of Ecology* 33(1):1–23.

Manley B. 2004. *Review of NEFD Yield Table Structure.* Contract report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Manley B. 2009. *2008 Deforestation Intentions Survey*. Contract report prepared for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

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.

Ministry of Agriculture and Forestry. 2008a. *National Exotic Forest Description as at 1 April 2007*. Edition 24. Wellington: Ministry of Agriculture and Forestry.

Ministry of Agriculture and Forestry. 2008b. Permanent Forest Sink Initiative – see www.maf.govt.nz/forestry/pfsi.

Ministry of Agriculture and Forestry. 2009a. *National Exotic Forest Description as at 1 April 2008*. Edition 25. Wellington: Ministry of Agriculture and Forestry.

Ministry of Agriculture and Forestry. 2009b. Afforestation Grants Scheme. Retrieved 16 December 2009 from www.maf.govt.nz/climatechange/forestry/initiatives/ags.

Ministry of Agriculture and Forestry. 2009c. Forestry Production and Trade for the June 2009 Quarter. *Forestry Statistical Release 04/09*.

Ministry of Agriculture and Forestry. 2010. *National Exotic Forest Description as at 1 April 2009*. Edition 26. Wellington: Ministry of Agriculture and Forestry.

Ministry of Agriculture and Forestry. 2011. South Island Landless Natives Act 1906 (SILNA) Forests. Retrieved 3 February 2011 from http://www.maf.govt.nz/forestry/forestry-in-nz/indigenous-forestry/south-island-landless-natives-act-silna.aspx.

Moore JR, Goulding CJ. 2005. *Sampling Methods and Associated Levels of Precision for a National Carbon Inventory in Planted Forests*. Contract report prepared for Ministry for the Environment, June 2005. Wellington: Ministry for the Environment.

Newsome PFJ, Wilde RH, Willoughby EJ. 2000. *Land Resource Information System Spatial Data Layers*. Landcare Research New Zealand Limited, Palmerston North.

Palmer DJ, Hock BK, Kimberley MO, Watt MS, Lowe DJ, Payn TW. In press. A comparison of spatial prediction techniques for developing Pinus radiata productivity surfaces across New Zealand. *Forest Ecology and Management*.

Parfitt RL, Ross C, Schipper LA, Claydon JJ, Baisden WT, Arnold G. 2010. Correcting bulk density measurements made with driving hammer equipment. *Geoderma* 157: 46–50.

Parker RC, Evans DL. 2004. An application of LIDAR in a Double-Sample Forest Inventory. *Western Journal of Applied Forestry* April, 19(2): 95–101.

Paul TSH, Andersen C, Kimberley MO, Goulding CJ. 2009. *Revised Calculations of Carbon Stocks and Sequestration in New Zealand Post-1989 Forest*. Scion contract report 45491 to the Ministry for the Environment, October 2009. Wellington: Ministry for the Environment.

Paul TSH, Kimberley MO. 2009. *Carbon Stock Estimates for Minor Plantation Species in New Zealand Post-1989 Forest*. Scion Contract report 45611 to the Ministry for the Environment, November 2009. Wellington: Ministry for the Environment.

Payton IJ, Brandon AM. 2010. *Land Use and Carbon Analysis System Natural Forest Data Collection Manual*. Ministry for the Environment, Wellington.

Payton IJ, Moore JR, Burrows, LE, Goulding CJ, Beets PN, Dean MG. 2008. *New Zealand carbon monitoring system: planted forest data collection manual*. Contract report to the Ministry of Agriculture and Forestry: New Zealand.

Payton IJ, Moss KA. 2001. Sequester: A National Carbon Monitoring System for New Zealand's Indigenous Forest and Shrublands and Soils – Part II Forest and Shrubland data collection. Report to the Ministry for the Environment. Wellington: Ministry for the Environment.

Payton IJ, Newell CL, Beets PN. 2004. *New Zealand Carbon Monitoring System indigenous forest and shrubland data collection manual*. Christchurch: The Caxton Press.

PricewaterhouseCoopers. 2008. *LUCAS Data Quality Framework*. Report prepared for the Ministry for the Environment. Wellington: Ministry for the Environment.

Rhodes D, Novis J. 2002. The Impact of Incentives on the Development of Plantation Forest Resources in New Zealand. MAF Information Paper No: 45. MAF Policy Division. ISSN no: 1171-4654 ISBN no: 0-478-07681-9. August 2002.

Scott NA, Tate KR, Giltrap DJ, Tattersall Smith C, Wilde RH, Newsome PFJ, Davis MR. 2002. Monitoring land-use change effects on soil carbon in New Zealand: Quantifying baseline soil carbon stocks. *Environmental Pollution* 116: S167–S186.

Shepherd JD, Dymond JR. 2003. Correcting satellite imagery for the variance of reflectance and illumination with topography. *International Journal of Remote Sensing* 24: 3503–3514.

Shepherd JD, Newsome P. 2009a. *Establishing New Zealand's Kyoto Land Use and Land-use Change and Forestry 1990 Map*. Contract report prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Shepherd JD, Newsome P. 2009b. *Establishing New Zealand's Kyoto Land Use and Land-use Change and Forestry 2008 Map*. Contract report prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Stephens PR, Watt PJ, Loubser D, Haywood A, Kimberley MO. 2007. Estimation of carbon stocks in New Zealand planted forests using airborne scanning LiDAR. Workshop on Laser Scanning. 12–14 September 2007. Finland. pp 389–394, IAPRS XXXVI, Part 3/W52.

Stephens PR, McGaughey RJ, Dougherty T, Farrier T, Geard BV, Loubser D. 2008. Quality assurance and quality control procedures of airborne scanning LiDAR for a nation-wide carbon inventory of planted forests. In: *Proceedings of SilviLaser 2008: 8th international conference on LiDAR applications in forest assessment and inventory*. Hill RA, Rosette J, Suárez J (eds). September 2008. Edinburgh, United Kingdom. pp 563–571.

Tate KR, Giltrap DJ, Claydon JJ, Newsome PF, Atkinson IAE, Taylor MD, Lee R. 1997. Organic carbon stocks in New Zealand's terrestrial ecosystems. *Journal of the Royal Society of New Zealand* 27(3): 315–335.

Tate KR, Scott NA, Newsome PF, Betts H, Davis MR, Beets PN, Ford-Robertson JB, Giltrap DJ. 1999. Design and testing of national soil system. Palmerston North: Landcare Research New Zealand Ltd and New Zealand Forest Research Institute Ltd. Contribution of soil carbon to New Zealand's CO_2 emissions.

Tate KR, Barton JP, Trustrum NA, Baisden WT, Saggar S, Wilde RH, Giltrap DJ, and Scott NA. 2002. Monitoring and modelling soil organic carbon stocks and flows: a New Zealand perspective, presented at: OECD Expert Meeting on Soil Organic Carbon Indicators for Agricultural Land, Ottawa, Canada, 15–18 October 2002. p 17.

Tate KR, Scott NA, Saggar S, Giltrap DJ, Baisden WT, Newsome PF, Trotter CM, Wilde RH. 2003a. Land-use change alters New Zealand's terrestrial carbon budget: Uncertainties associated with estimates of soil carbon change between 1990–2000. *Tellus, Series B: Chemical and Physical Meteorology* 55(2): 364–377.

Tate KR, Barton JP, Trustrum NA, Baisden WT, Saggar S, Wilde RH, Giltrap DJ, and Scott NA. 2003b. Monitoring and modelling soil organic carbon stocks and flows in New Zealand. In CA Scott-Smith (ed.) *Soil Organic Carbon and Agriculture: Developing Indicators for Policy Analysis*. *Proceedings of an OECD Expert Meeting, Ottawa, ON*. October 2002. Paris, France: Agriculture and Agri-Food Canada and Organisation for Economic Co-operation and Development. pp 253–268.

Tate, KR, Wilde, RH, Giltrap, DJ, Baisden, WT, Saggar, S, Trustrum, NA, Scott, NA. 2003c. Current Approaches to Soil Carbon Monitoring in New Zealand. In: *Proceedings of Carbon Measurement and Monitoring Forum (CASGMS)*. Manhattan: Kansas. 15–17 October 2003.

Tate KR, Wilde RH, Giltrap DJ, Baisden WT, Saggar S, Trustrum NA, Scott, NA. 2004. Soil carbon changes and uncertainties with New Zealand land-use change. In: *SuperSoil 2004*: *Proceedings of the 3rd Australian New Zealand Soils Conference*. Sydney: University of Sydney, Australia. 5–9 December 2004. www.regional.org.au/au/asssi/supersoil2004.

Tate KR, Wilde RH, Giltrap DJ, Baisden WT, Saggar S, Trustrum NA, Scott NA, Barton JP. 2005. Soil organic carbon stocks and flows in New Zealand: System development, measurement and modelling. *Canadian Journal of Soil Science* 85(4): 481–489.

Thompson S, Gruner I, Gapare N. 2004. *New Zealand Land Cover Database Version 2. Illustrated Guide to Target Classes.* Report for the Ministry for the Environment. Wellington: Ministry for the Environment.

Trotter C, MacKay A. 2005. Potential Forest Land. Landcare Research Contract Report: 04/05-0410-L. Wellington: Ministry for the Environment.

Wakelin SJ. 2004. *Review of Shrubland Clearance Assumptions in the National Carbon Inventory*. Contract report prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Wakelin SJ. 2006. *Review of LULUCF Biomass Burning Assumptions in New Zealand's Greenhouse Gas Inventory*. Report for the Ministry for the Environment. Wellington: Ministry for the Environment.

Wakelin SJ. 2008. *Carbon Inventory of New Zealand's Planted Forests – Calculations revised in October 2008 for New Zealand's 2007 Greenhouse Gas Inventory*. Report for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

Wakelin SJ, Clifford VR, Anderson SAJ, Pearce HG. 2009. *Review of LULUCF Non-Carbon Emissions in New Zealand's Greenhouse Gas Inventory*. Contract report prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Wakelin SJ, Garrett LG. 2010. *Biomass Carbon Loss from Forest Harvesting*. Contract report prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Wilde RH (ed.). 2003. *Manual for National Soils Database*. Palmerston North: Landcare Research New Zealand Ltd. Retrieved from www.landcareresearch.co.nz/databases/nsd_manual_v1.pdf (5 April 2010).

Wilde H, Davis M, Tate K, Giltrap D. 2004. Testing the representativeness of soil carbon data held in databases underpinning the New Zealand Soil Carbon Monitoring System. *SuperSoil* 2004: 3rd Australian New Zealand Soils Conference, 5–9 December 2004, University of Sydney, Australia.

Woollons, R. 2009. Analysis of the 2007–2008 planted forest carbon monitoring system inventory data of Post-1989 forests by Thomas Paul, Carolyn Andersen, Mark Kimberley, Chris Goulding. Report 11448 prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Specific references for Chapter 8: Waste

Beca. Unpublished. National Greenhouse Gas Inventory from Wastewater Treatment and Discharge.

Deer Industry New Zealand. 2009. Annual Report 2008/2009. Retrieved from http://www.deernz.org/upload/notion/sectionimages/2668_Annual_Report_Online_Copy_FINAL.pdf.

Eng G, Bywater I, and Hendtlass C. 2008. *New Zealand Energy Information Handbook: Energy data conversion factors and definitions*. Christchurch: New Zealand Centre for Advanced Engineering.

Ministry for the Environment. 1997. *National Waste Data Report*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2000. *The 1998/99 National Landfill Census Report*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2002a. *The New Zealand Waste Strategy*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2002b. *Solid Waste Analysis Protocol*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2003. *The 2002 Landfill Review and Audit*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2007. The 2006/07 National Landfill Census. Wellington: Ministry for the Environment.

Ministry for the Environment. 2010. *The New Zealand Waste Strategy: Reducing Harm, Improving Efficiency*. Wellington: Ministry for the Environment.

Ministry of Agriculture and Forestry. 2010. Annual Pulp Paper and Paperboard Statistics. Retrieved from http://www.maf.govt.nz/news-resources/statistics-forecasting/forestry/annual-pulp-paper-and-paperboard-statistics.aspx.

National Institute of Water and Atmospheric Research. 2010. Overview of New Zealand Climate. Retrieved from http://www.niwa.co.nz/education-and-training/schools/resources/climate/overview (November 2010).

Resource Management Act, No. 69. (1991). Retrieved from http://www.legislation.govt.nz/act/public/1991/0069/latest/whole.html.

SCS Wetherill Environmental. 2002. *National Greenhouse Gas Inventory from the Waste Sector 1990–2020*. A report for the Ministry for the Environment. Wellington: Ministry for the Environment.

SKM. Unpublished (a). Greenhouse Gases from the Waste Incineration Sector.

SKM. Unpublished (b). Estimates of landfill methane recovered in New Zealand 1990-2012. Report commissioned by the Ministry for the Environment.

SKM. Unpublished (c). Peer Review: National Greenhouse Gas Emissions from Wastewater Sludge. Report commissioned by the Ministry for the Environment.

Tonkin and Taylor. Unpublished (a). Peer review and quality check of landfill gas capture rate. Report commissioned by the Ministry for the Environment.

Tonkin and Taylor. Unpublished (b). National Greenhouse Gas Emissions from Wastewater Sludge. Report commissioned by the Ministry for the Environment.

Waste Management New Zealand. 2005. *Landfill Methane Recovery Estimate and National Greenhouse Gas Inventory from the Waste Sector*. Report commissioned by the Ministry for the Environment. Wellington: Ministry for the Environment.

Waste Minimisation Act, No. 89 (2008). Retrieved from http://www.legislation.govt.nz/act/public/2008/0089/latest/DLM999802.html.

Waste Not Consulting. Unpublished. Waste Composition and Construction Waste Data.

Specific references for Chapter 11: KP-LULUCF

Dougherty T, Gapare N, Stephens PR. 2009. *Guide to Mapping Woody Land Use Classes Using Satellite Imagery*. Wellington: Ministry for the Environment Internal Document.

Eyles, GO. 1977. NZLRI worksheets and their applications to rural planning. *Town Planning Quarterly* 47: 38–44.

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.

Ministry of Agriculture and Forestry. 2002. *New Zealand Country Report*. Montreal Process Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests 2003. Ministry of Agriculture and Forestry Technical Paper No: 2002/21, December.

Ministry of Agriculture and Forestry. 2008b. Permanent Forest Sink Initiative – see www.maf.govt.nz/forestry/pfsi.

Ministry of Agriculture and Forestry. 2009b. Afforestation Grants Scheme. Retrieved 16 December 2009 from www.maf.govt.nz/climatechange/forestry/initiatives/ags.

Ministry of Agriculture and Forestry. 2009d. *A guide to forestry in the emissions trading scheme*. Retrieved from www.maf.govt.nz/sustainable-forestry/ets/guide/page-02.htm (5 April 2010).

Ministry of Agriculture and Forestry. 2010. *National Exotic Forest Description as at 1 April 2009*. Edition 26. Wellington: Ministry of Agriculture and Forestry.

Shepherd JD, Newsome P. 2009a. *Establishing New Zealand's Kyoto Land Use and Land-use Change and Forestry 1990 Map*. Contract report prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Shepherd JD, Newsome P. 2009b. *Establishing New Zealand's Kyoto Land Use and Land-use Change and Forestry 2008 Map*. Contract report prepared for Ministry for the Environment. Wellington: Ministry for the Environment.

Thompson S, Gruner I, Gapare N. 2004. *New Zealand Land Cover Database Version 2. Illustrated Guide to Target Classes.* Report for the Ministry for the Environment. Wellington: Ministry for the Environment.

UNECE/FAO. 2000. *Temperate and Boreal Forest Resources Assessment (TBFRA 2000)*. Main report. UNECE/FAO Contribution to the Global Forest Resources. United Nations, New York and Geneva.

Wakelin SJ. 2008. Carbon Inventory of New Zealand's Planted Forests – Calculations Revised in October 2008 for New Zealand's 2007 Greenhouse Gas Inventory. Report for the Ministry of Agriculture and Forestry. Wellington: Ministry of Agriculture and Forestry.

General notes

Units

Standard metric prefixes used in this inventory are:

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

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

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

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

Gases

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

Global warming potentials

The global warming potential is an index, representing the combined effect of the differing times greenhouse gases remain in the atmosphere, and their relative effectiveness in absorbing thermal infrared radiation (IPCC, 2007).

The Climate Change Convention reporting requirements (UNFCCC, 2006) stipulate that the 100-year global warming potentials contained in the IPCC Second Assessment Report (IPCC, 1995) are used in national inventories. The indirect effects on global warming of a number of gases (CO, NO_x, SO_2 and NMVOCs) cannot currently be quantified, and, consequently, these gases do not have global warming potentials. In accordance with the Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases that do not have global warming potentials are reported in the inventory but are not included in the inventory emissions total.

Common global warming potentials (100-year time period)

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

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

Conversion factors

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

Notation keys

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

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

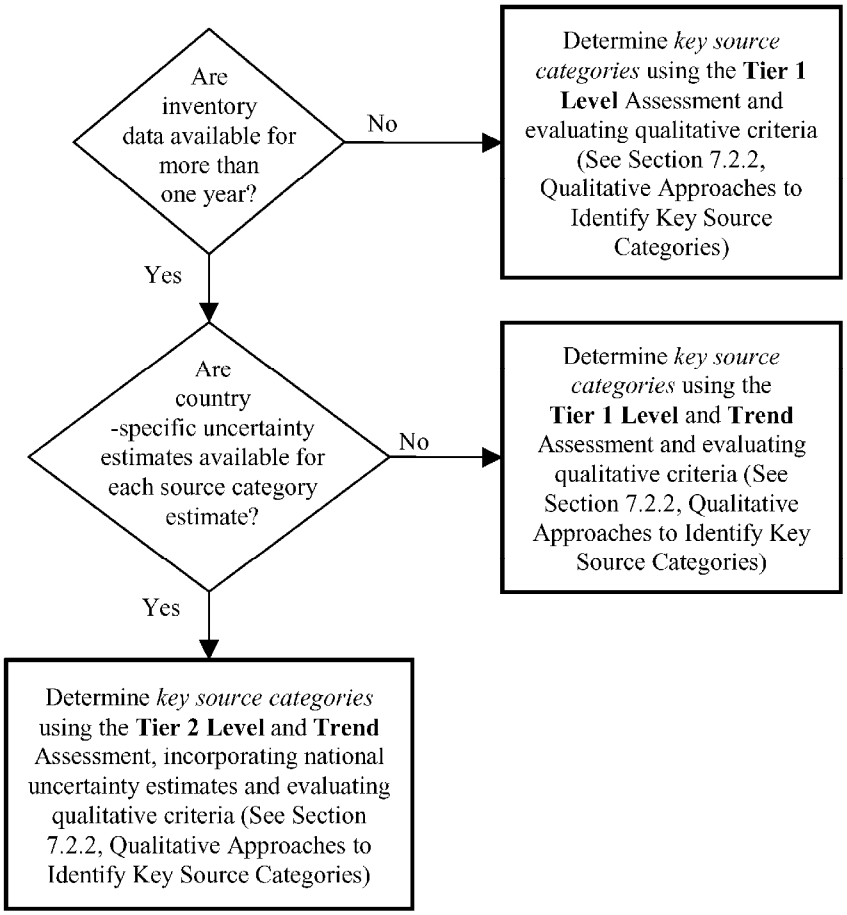
Annexes to New Zealand's National Inventory Report for 2009

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 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 assessment 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). 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 IPCC categories using 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-ULUCF Table 5.4.1.

There was one modification to the suggested categories to reflect New Zealand's national circumstances. The 'fugitive emissions from the oil and natural gas category' was divided into two categories: fugitive emissions from oil and gas operations and fugitive emissions from geothermal operations. This is to reflect that New Zealand generates a significant amount of energy from geothermal sources that cannot be included as oil or gas operations.

A1.3 Tables 7.A1–7.A3 of the IPCC Good Practice Guidance

Table A1.3.1 Results of the key category level analysis for 99 per cent of the net emissions and removals for New Zealand in 2009. Key categories are those that comprise 95 per cent of the total

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2009				
IPCC categories	**Gas**	**2009 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	31594.35	29.5	29.5
Enteric fermentation – dairy cattle	CH_4	9,462.8	8.8	38.3
Enteric fermentation – sheep	CH_4	7,615.8	7.1	45.5
Transport – road transport – gasoline	CO_2	7,115.3	6.6	52.1
Agricultural soils – pasture, range and paddock	N_2O	5514.38	5.1	57.3
Enteric fermentation – other	CH_4	5,427.6	5.1	62.3
Transport – road transport – diesel oil	CO_2	5,008.0	4.7	67.0
Energy industries – public electricity and heat production – gaseous fuels	CO_2	3,458.7	3.2	70.2
Energy industries – public electricity and heat production – solid fuels	CO_2	2,469.4	2.3	72.5
Agricultural soils – indirect emissions	N_2O	2411.69	2.3	74.8
Manufacturing industries and construction – gaseous fuels	CO_2	2,334.47	2.2	77.0
Grassland remaining grassland	CO_2	2152.98	2.0	79.0
Other sectors – liquid fuels	CO_2	2,042.9	1.9	80.9
Forest land remaining forest land	CO_2	2016.01	1.9	82.8
Manufacturing industries and construction – solid fuels	CO_2	1,601.44	1.5	84.3
Agricultural soils – direct emissions	N_2O	1572.32	1.5	85.7
Metal production – iron and steel production	CO_2	1563.07	1.5	87.2
Solid waste disposal on land	CH_4	1398.56	1.3	88.5

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2009				
IPCC categories	**Gas**	**2009 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Transport – civil aviation – jet kerosene	CO_2	890.5	0.8	89.3
Manufacturing industries and construction – liquid fuels	CO_2	848.54	0.8	90.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	796.56	0.7	90.9
Manure management	CH_4	783.4	0.7	91.6
Other sectors – gaseous fuels	CO_2	776.7	0.7	92.3
Fugitive emissions – flaring – combined	CO_2	762.7	0.7	93.0
Energy industries – Petroleum refining – gaseous fuels	CO_2	762.16	0.7	93.7
Fugitive emissions – geothermal	CO_2	610.0	0.6	94.3
Mineral products – cement production	CO_2	593.75	0.6	94.9
Metal production – aluminium production	CO_2	451.51	0.4	95.3
Waste-water handling	CH_4	437.99	0.4	95.7
Chemical industry – ammonia production	CO_2	386.58	0.4	96.1
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	369.00	0.3	96.4
Fugitive emissions – natural gas	CH_4	361.37	0.3	96.7
Fugitive emissions – coal mining and handling	CH_4	348.93	0.3	97.1
Cropland remaining cropland	CO_2	339.23	0.3	97.4
Conversion to grassland	CO_2	334.66	0.3	97.7
Transport – navigation – residual oil	CO_2	297.34	0.3	98.0
Other sectors – solid fuels	CO_2	263.96	0.2	98.2
Chemical industry – hydrogen production	CO_2	238.76	0.2	98.4
Wastewater handling	N_2O	179.68	0.2	98.6
Transport – railways – liquid fuels	CO_2	161.47	0.2	98.8
Energy industries – Petroleum refining – liquid fuels	CO_2	135.31	0.1	98.9
Mineral products – lime production	CO_2	121.05	0.1	99.0

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. Key categories are those that comprise 95 per cent of the total

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990				
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	20,910.8	24.2	24.2
Enteric fermentation – sheep	CH_4	11,280.0	13.1	37.3
Transport – road transport – gasoline	CO_2	5,570.7	6.4	43.7
Enteric fermentation – other	CH_4	5,527.3	6.4	50.1
Agricultural soils – pasture, range and paddock	N_2O	5,235.8	6.1	56.2
Enteric fermentation – dairy cattle	CH_4	5,057.4	5.9	62.0
Forest land remaining forest land	CO_2	4,446.9	5.1	67.2

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990				
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,969.7	3.4	70.6
Agricultural soils – indirect emissions	N_2O	2,009.5	2.3	72.9
Manufacturing industries and construction – solid fuels	CO_2	1,895.3	2.2	75.1
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,756.4	2.0	77.2
Other sectors – liquid fuels	CO_2	1,713.7	2.0	79.1
Manufacturing industries and construction – gaseous fuels	CO_2	1,649.0	1.9	81.1
Solid waste disposal on land	CH_4	1,514.4	1.8	82.8
Transport – road transport – diesel oil	CO_2	1,416.9	1.6	84.4
Metal production – iron and steel production	CO_2	1,306.7	1.5	86.0
Transport – civil aviation – jet kerosene	CO_2	842.5	1.0	86.9
Grassland remaining grassland	CO_2	801.7	0.9	87.9
Other sectors – solid fuels	CO_2	778.3	0.9	88.8
Manufacturing industries and construction – liquid fuels	CO_2	763.6	0.9	89.6
Metal production – aluminium production	PFCs	629.9	0.7	90.4
Manure management	CH_4	618.5	0.7	91.1
Energy industries – Petroleum refining – gaseous fuels	CO_2	562.6	0.7	91.7
Agricultural soils – direct emissions	N_2O	517.1	0.6	92.3
Other sectors – gaseous fuels	CO_2	471.4	0.5	92.9
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	0.5	93.4
Conversion to grassland	CO_2	464.8	0.5	94.0
Metal production – aluminium production	CO_2	449.0	0.5	94.5
Mineral products – cement production	CO_2	444.7	0.5	95.0
Fugitive emissions – natural gas	CH_4	391.5	0.5	95.5
Waste-water handling	CH_4	368.9	0.4	95.9
Cropland remaining cropland	CO_2	334.8	0.4	96.3
Chemical industry – ammonia production	CO_2	277.9	0.3	96.6
Fugitive emissions – coal mining and handling	CH_4	274.5	0.3	96.9
Transport – navigation – residual oil	CO_2	235.8	0.3	97.2
Fugitive emissions – flaring – combined	CO_2	228.9	0.3	97.4
Fugitive emissions – geothermal	CO_2	228.6	0.3	97.7
Energy industries – Petroleum refining – liquid fuels	CO_2	211.3	0.2	98.0
Transport – road transport – liquefied petroleum gases	CO_2	196.7	0.2	98.2
Conversion to wetland	CO_2	164.7	0.2	98.4
Wastewater handling	N_2O	153.5	0.2	98.5
Chemical industry – hydrogen production	CO_2	152.3	0.2	98.7
Transport – road transport – gaseous fuels	CO_2	139.6	0.2	98.9
Mineral products – lime production	CO_2	82.6	0.1	99.0

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 2009. Key categories are those that comprise 95 per cent of the total

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

IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2009 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation – sheep	CH_4	11,280.0	7,615.8	0.048	16.7	16.7
Conversion to forest land	CO_2	20,910.8	31594.35	0.043	14.9	31.7
Forest land remaining forest land	CO_2	4,446.9	2016.01	0.026	9.2	40.9
Transport – road transport – diesel oil	CO_2	1,416.9	5,008.0	0.025	8.6	49.4
Enteric fermentation – dairy cattle	CH_4	5,057.4	9,462.8	0.024	8.4	57.8
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	2,469.4	0.014	5.0	62.8
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,756.4	369.00	0.014	4.8	67.6
Enteric fermentation – other	CH_4	5,527.3	5,427.6	0.011	3.7	71.3
Grassland remaining grassland	CO_2	801.7	2152.98	0.009	3.1	74.4
Agricultural soils – pasture, range and paddock	N_2O	5,235.8	5514.38	0.007	2.6	76.9
Agricultural soils – direct emissions	N_2O	517.1	1572.32	0.007	2.5	79.4
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	796.56	0.006	2.1	81.5
Manufacturing industries and construction – solid fuels	CO_2	1,895.3	1,601.44	0.006	2.0	83.5
Metal production – aluminium production	PFCs	629.9	44.82	0.006	1.9	85.4
Other sectors – solid fuels	CO_2	778.3	264.0	0.005	1.8	87.2
Fugitive emissions – flaring – combined	CO_2	228.9	762.7	0.004	1.3	88.5
Solid waste disposal on land	CH_4	1,514.4	1398.56	0.004	1.3	89.8
Fugitive emissions – geothermal	CO_2	228.6	610.0	0.002	0.9	90.6
Manufacturing industries and construction – gaseous fuels	CO_2	1,649.0	2,334.47	0.002	0.8	91.4
Conversion to grassland	CO_2	464.8	334.66	0.002	0.6	92.0

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

IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2009 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,969.7	3,458.7	0.002	0.6	92.6
Transport – road transport – gasoline	CO_2	5,570.7	7,115.3	0.002	0.6	93.2
Conversion to wetland	CO_2	164.7	0.00	0.002	0.5	93.7
Other sectors – gaseous fuels	CO_2	471.4	776.7	0.001	0.5	94.2
Transport – road transport – gaseous fuels	CO_2	139.6	2.0	0.001	0.5	94.7
Transport – road transport – liquefied petroleum gases	CO_2	196.7	80.3	0.001	0.4	95.1
Transport – civil aviation – jet kerosene	CO_2	842.5	890.5	0.001	0.4	95.5
Energy industries – Petroleum refining – liquid fuels	CO_2	211.3	135.31	0.001	0.3	95.8
Fugitive emissions – natural gas	CH_4	391.5	361.4	0.001	0.3	96.1
Metal production – aluminium production	CO_2	449.0	451.51	0.001	0.3	96.4
Manufacturing industries and construction – liquid fuels	CO_2	763.6	848.54	0.001	0.3	96.7
Consumption of halocarbons and SF_6 – foam blowing	HFCs & PFCs	0.0	82.43	0.001	0.2	96.9
Other sectors – liquid fuels	CO_2	1,713.7	2,042.9	0.001	0.2	97.1
Agricultural soils – indirect emissions	N_2O	2,009.5	2411.69	0.001	0.2	97.3
Cropland remaining cropland	CO_2	334.8	339.23	0.001	0.2	97.5
Conversion to cropland	CO_2	55.9	3.72	0.000	0.2	97.7
Transport – railways – liquid fuels	CO_2	77.6	161.5	0.000	0.2	97.9
Energy industries – Petroleum refining – gaseous fuels	CO_2	562.6	762.16	0.000	0.2	98.0
Metal production – iron and steel production	CO_2	1,306.7	1563.07	0.000	0.1	98.2
Fugitive emissions – geothermal	CH_4	46.0	113.2	0.000	0.1	98.3
Transport – road transport – diesel oil	N_2O	23.8	83.5	0.000	0.1	98.5
Chemical industry – hydrogen production	CO_2	152.3	238.76	0.000	0.1	98.6

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)						
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**2009 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Mineral products – cement production	CO_2	444.7	593.75	0.000	0.1	98.7
Chemical industry – ammonia production	CO_2	277.9	386.58	0.000	0.1	98.8
Transport – road transport – gaseous fuels	CH_4	31.6	0.5	0.000	0.1	98.9
Conversion to other land	CO_2	31.9	7.24	0.000	0.1	99.0

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:

- net calorific value = 0.95 × gross calorific value for coal and liquid fuels
- net calorific value = 0.90 × gross calorific value for gas.

Emission factors for gas, coal, biomass and liquid fuels used by New Zealand are shown in Tables A2.1–A2.3.

Table A2.1 Gross carbon dioxide emission factors used for New Zealand's energy sector in 2009 (before oxidation)

	Emission factor ($t CO_2/TJ$)	Emission factor (t C/TJ)	Source
Gas			
Maui	52.79	14.40	1
Kapuni treated	52.96	14.44	1
Kapuni low temperature separator	84.10	22.94	1
Weighted average for distributed gas	53.18	14.50	
Methanol – mixed feed (1990–1994)	62.44	17.03	3
Methanol – low temperature separator (1990–1994)	83.97	22.90	3
Kaimiro	55.90	15.25	3
Ngatoro	55.67	15.18	3
Rimu/Kauri	51.91	14.16	3
Waihapa/Ngaere + Tariki/Ahuroa	52.72	14.38	3
McKee	52.61	14.35	3
Mangahewa	54.05	14.74	3
Turangi	54.11	14.76	3
Maari	51.25	13.98	3
Pohokura	53.98	14.72	1
Liquid fuels			
Crude oil	69.85	19.05	5
Regular petrol	66.57	18.15	4
Petrol – premium	66.82	18.22	4
Diesel (10 ppm)	69.55	18.97	4
Jet kerosene	68.59	18.71	4
Av gas	65.89	17.97	4
LPG	60.43	16.48	2
Heavy fuel oil	73.84	20.14	4
Light fuel oil	72.78	19.85	4
Power station fuel oil	74.23	20.24	4
Bitumen (asphalt)	76.90	20.97	4

	Emission factor ($t CO_2/TJ$)	Emission factor (t C/TJ)	Source
Biomass			
Biogas	100.98	27.54	5
Wood (industrial)	104.15	28.41	5
Bioethanol	64.20	17.33	6
Biodiesel	62.40	16.85	6
Wood (residential)	104.15	28.41	5
Coal			
All sectors (sub bit)	91.20	24.87	2
All sectors (bit)	88.80	24.22	2
All sectors (lignite)	95.20	25.96	2

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).

Table A2.2 IPCC (1996) methane emission factors used for New Zealand's energy sector for 1990 to 2009

	Emission factor t CH_4/PJ	Source
Natural gas		
Electricity – boilers	.09	IPCC Tier 2 (Table 1–15) natural gas boilers
Electricity – large turbines	5.40	IPCC Tier 2 (Table 1–15) large gas-fired turbines > 3MW
Commercial	1.08	IPCC Tier 2 (Table 1–19) natural gas boilers
Residential	0.90	IPCC Tier 2 (Table 1–18) gas heaters
Domestic transport (CNG)	567.00	IPCC Tier 2 (Table 1–43) passenger cars (uncontrolled)
Other stationary (mainly industrial)	1.26	IPCC Tier 2 (Table 1–16) small natural gas boilers
Liquid fuels		
Stationary sources		
Electricity – residual oil	0.86	IPCC Tier 2 (Table 1–15) residual oil boilers – normal firing
Electricity – distillate oil	0.86	IPCC Tier 2 (Table 1–15) distillate oil boilers – normal firing
Industrial (including refining) – residual oil	2.85	IPCC Tier 2 (Table 1–16) residual oil boilers
Industrial – distillate oil	0.19	IPCC Tier 2 (Table 1–16) distillate oil boilers
Industrial – LPG	1.05	IPCC Tier 2 (Table 1–18) propane/butane furnaces
Commercial – residual oil	1.33	IPCC Tier 2 (Table 1–19) residual oil boilers
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	1.90	IPCC Tier 2 (Table 1–48) jet and turboprop aircraft
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 A2.3 IPCC (1996) nitrous oxide emission factors used for New Zealand's energy sector for 1990 to 2009

	Emission factor t N_2O/PJ	Source
Natural gas		
Electricity generation	0.09	IPCC Tier 1 (Table 1–8) natural gas – all uses
Commercial	2.07	IPCC Tier 2 (Table 1–19) natural gas boilers
Residential	0.09	IPCC Tier 1 (Table 1–8) natural gas – all uses
Domestic transport (CNG)	0.09	IPCC Tier 1 (Table 1–8) natural gas – all uses
Other stationary (mainly industrial)	0.09	IPCC Tier 1 (Table 1–8) natural gas – all uses
Liquid fuels		
Stationary sources		
Electricity – residual oil	0.29	IPCC Tier 2 (Table 1–15) residual oil boilers – normal firing
Electricity – distillate oil	0.38	IPCC Tier 2 (Table 1–15) distillate oil boilers – normal firing
Industrial (including refining) – residual oil	0.29	IPCC Tier 2 (Table 1–16) residual oil boilers
Industrial – distillate oil	0.38	IPCC Tier 2 (Table 1–16) distillate oil boilers
Commercial – residual oil	0.29	IPCC Tier 2 (Table 1–19) residual oil boilers
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 Economic Development is run as a census meaning there is no sampling error. The only possible sources or error are non-sample error (such as respondent error and processing error). The 2009 statistical difference for liquid fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b) was 2.9 per cent. This is used as the activity data uncertainty for liquid fuels in 2009.

A2.1.2 Emission factors and uncertainties

2009 carbon dioxide emission factors are described in Table A2.1. Table A2.1.1 shows a complete time-series of gross calorific values while table A2.1.2 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.

The Hale and Twomey Ltd (2009) consultant report to the Ministry for the Environment estimates the uncertainty of carbon dioxide emission factors for liquid fuels at ±0.5 per cent. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

Table A2.1.1 Gross Calorific Values (MJ/kg) for liquid fuels for 1990 to 2009

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Aviation 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

Table A2.1.2 Carbon Content (% mass) for liquid fuels for 1990 to 2009

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Aviation 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	85.85	86.36	85.00	86.37	86.83	86.16	86.60

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 Economic Development 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 2009 statistical difference for solid fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b) was 11.3 per cent. This is used as the activity data uncertainty for solid fuels in 2009.

A2.2.2 Emission factors and uncertainties

The estimated uncertainty in carbon dioxide emission factors for solid fuels is ±3.5 per cent. This is based on the difference between the range of 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 Economic Development, they have 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 2009 statistical difference for gaseous fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2010b) was 2.6 per cent. This is used as the activity data uncertainty for gaseous fuels in 2009.

A2.3.2 Emission factors

The estimated uncertainty in carbon dioxide emission factors for gaseous fuels is ±2.7 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 85 per cent of New Zealand's total gas supply in 2009. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

A2.4 Energy balance for year ended December 2009

Table A2.4.1 New Zealand energy balance for year ended December 2009 (Ministry of Economic Development, 2010b)

Converted into Petajoules using Gross Calorific Values		Coal			Oil							Natural Gas	Renewables								Electricity	Waste Heat	
		Bituminous & Sub-bitum.	Lignite	Total	Crudes/ Feedstocks/ NGL	LPG	Petrol	Diesel	Fuel Oil	Av. Fuel/ Kero	Others	Total	Total	Hydro	Geothermal	Solar	Wind	Liquid Biofuels	Biogas	Wood	Total	Total	Total	TOTAL
SUPPLY	Indigenous Production	112.57	3.97	116.54	118.62	3.56						122.17	165.06	87.12	122.94	0.34	5.30	0.09	2.79	55.10	273.68		1.52	678.97
	+ Imports	15.90	-	15.90	219.26	4.73	50.32	33.13	0.13	9.24	4.79	321.59												337.49
	- Exports	65.25	-	65.25	106.46	0.00	-	0.24	7.72	-	-	114.43												179.68
	- Stock Change	4.12		4.12	4.73	0.17	2.13	-1.10	0.48	-0.43	-1.00	4.98	4.09					-0.02			-0.02			13.17
	- International Transport						0.06	1.26	13.56	32.12	-	47.01												47.01
	TOTAL PRIMARY ENERGY	59.10	3.97	63.07	226.68	8.12	48.12	32.72	-21.63	-22.45	5.79	277.34	160.97	87.12	122.94	0.34	5.30	0.11	2.79	55.10	273.70		1.52	776.60
	ENERGY TRANSFORMATION	-44.36	-0.29	-44.65	-227.71	-0.60	65.66	72.90	31.02	39.22	5.37	-14.15	-78.57	-87.12	-113.10		-5.30	-0.11	-2.51	-4.61	-212.75	139.95	-1.52	-211.69
	Electricity Generation	-27.63	-	-27.63				-0.08	-0.02			-0.10	-53.71	-87.12	-111.85		-5.30		-1.76		-206.03	146.78		-140.68
	Cogeneration	-6.35	-0.29	-6.64									-18.02		-1.25				-0.75	-4.61	-6.61	9.39	-1.52	-23.40
	Oil Production				-227.09		66.53	72.41	31.19	40.28	13.67	-3.01	-					-0.11			-0.11			-3.12
	Other Transformation	-10.14	-	-10.14																				-10.14
	Losses and Own Use	-0.25	-	-0.25	-0.62	-0.60	-0.87	0.57	-0.16	-1.06	-8.30	-11.04	-6.85									-16.22		-34.35
Non-energy Use											-11.16	-11.16	-24.47											-35.63
CONSUMER ENERGY (calculated)		14.73	3.68	18.41	-1.03	7.52	113.78	105.61	9.39	16.77	-	252.04	57.93		9.84	0.34	-	-	0.28	50.49	60.95	139.95	-	529.27
DEMAND	Agriculture, Forestry and Fishing	0.77	0.00	0.78			1.75	13.94	2.51	0.12		18.31	1.82		0.73						0.73	6.56		28.20
	Agriculture	0.77	0.00	0.78			1.72	10.20	-	0.09		12.01	1.82		0.73						0.73	5.87		21.22
	Forestry and Logging	-	-	-			0.02	1.73	-	0.00		1.76	0.00									0.20		1.95
	Fishing	-	-	-			0.02	2.00	2.51	0.02		4.54	-									0.49		5.03
	Industrial	14.33	3.23	17.56		2.49	0.28	13.45	0.91	0.10		17.24	44.34		6.31					42.85	49.16	50.68		178.97
	Mining	0.12	0.01	0.14			0.00	4.63	-	-		4.64	0.10									1.57		6.44
	Food Processing	8.03	3.07	11.10			-	0.01	0.02	-		0.03	11.26									7.67		30.06
	Textiles	0.12	-	0.12									0.46									0.48		1.06
	Wood, Pulp, Paper and Printing	0.72	0.08	0.80									5.13									11.88		17.81
	Chemicals	-	-	-									20.55									2.64		23.18
	Non-metallic Minerals	1.63	-	1.63									1.58									0.93		4.14
	Basic Metals	0.01	-	0.01			-	-	-	-		-	2.92									19.60		22.53
	Mechanical/Electrical Equipment	0.01	-	0.01									0.42									0.86		1.29
	Building and Construction	0.01	-	0.01			0.02	4.37	0.02	0.09		4.51	0.04									0.70		5.26
	Unallocated	3.68	0.07	3.74		2.49	0.25	4.44	0.87	0.01		8.06	1.88		6.31					42.85	49.16	4.36		67.21
	Commercial	1.09	0.20	1.30		1.48	0.20	2.41	0.05	0.52		4.67	6.07		2.52				0.28		2.80	33.56		48.40
	Transport	0.02	-	0.02		1.34	107.89	75.11	4.10	13.59		202.04	0.04						-		-	0.36		202.45
	Residential	0.56	0.30	0.86		2.20	-	0.31	-	-		2.51	6.79		0.28	0.34				7.64	8.26	46.62		65.03
CONSUMER ENERGY (observed)		16.78	3.73	20.51	-	7.52	110.12	105.22	7.57	14.33	-	244.76	59.06	-	9.84	0.34	-		0.28	50.49	60.95	137.78	-	523.06
Statistical Differences		-2.04	-0.05	-2.09	-1.03	-	3.66	0.39	1.82	2.44	-	7.27	-1.13		0.00	-	-		-	-	-	2.17	-	6.22

A2.5 Fuel flow diagrams for year ended December 2009

Figure A2.5.1 New Zealand coal energy flow summary for 2009

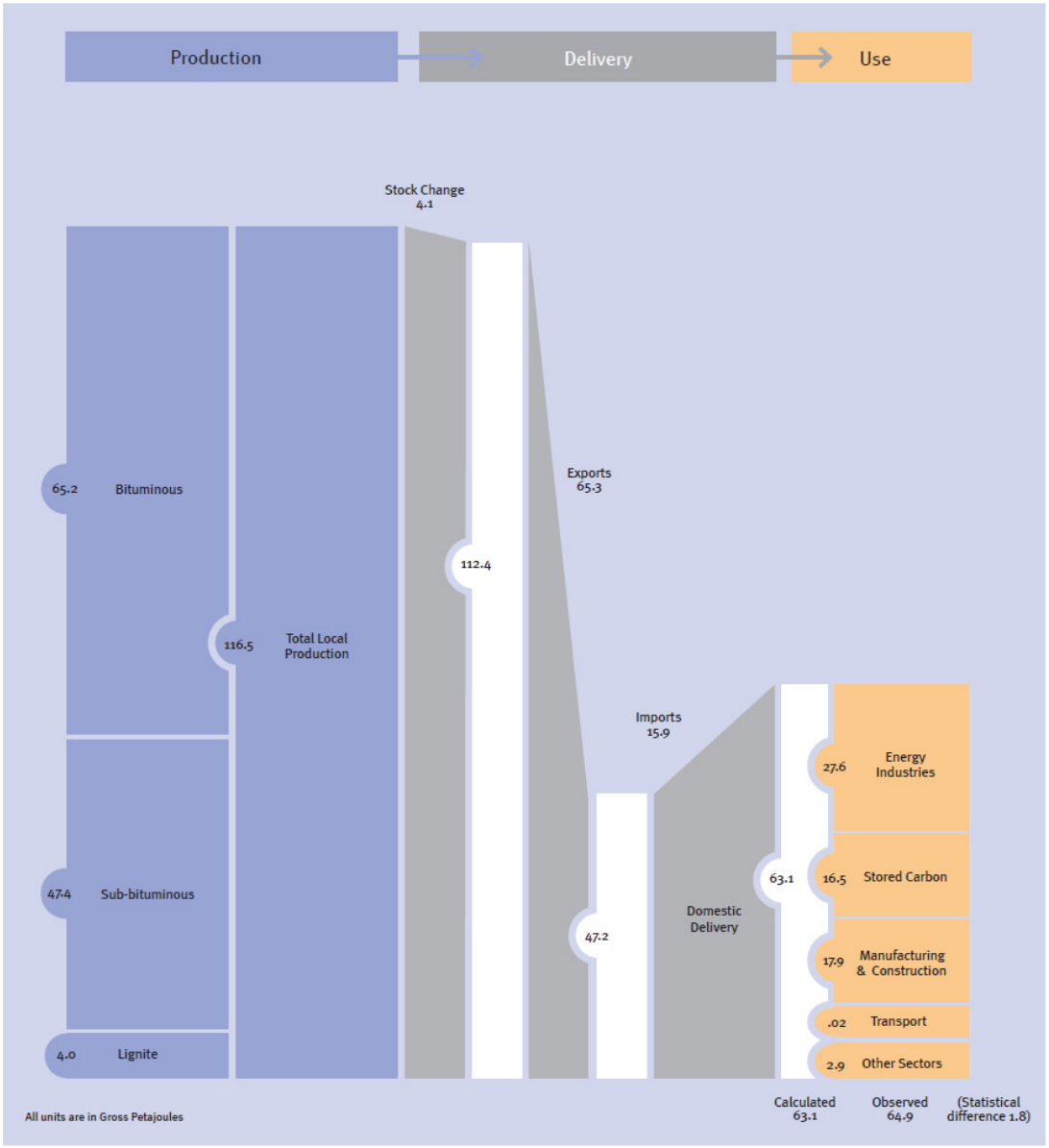
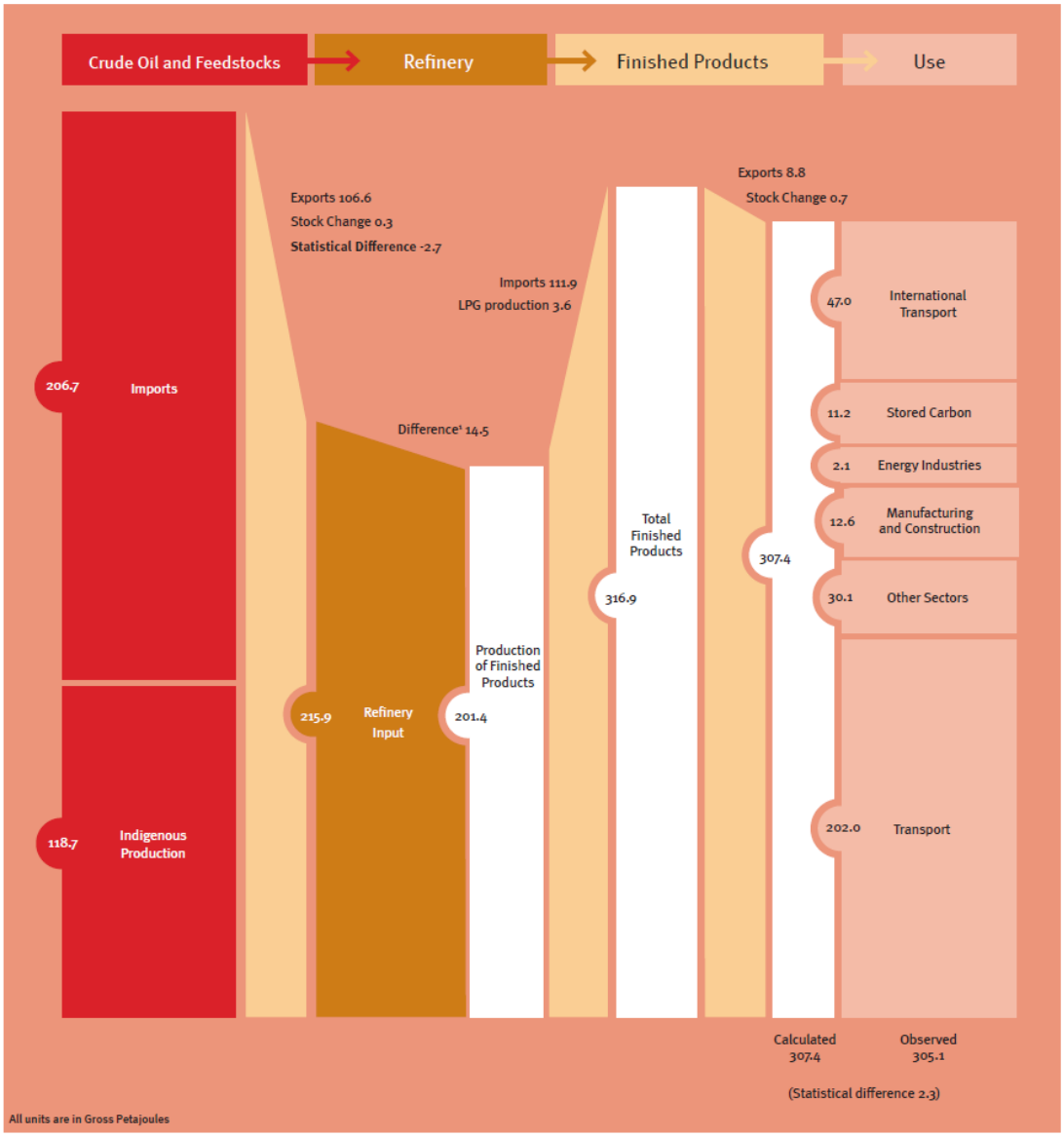
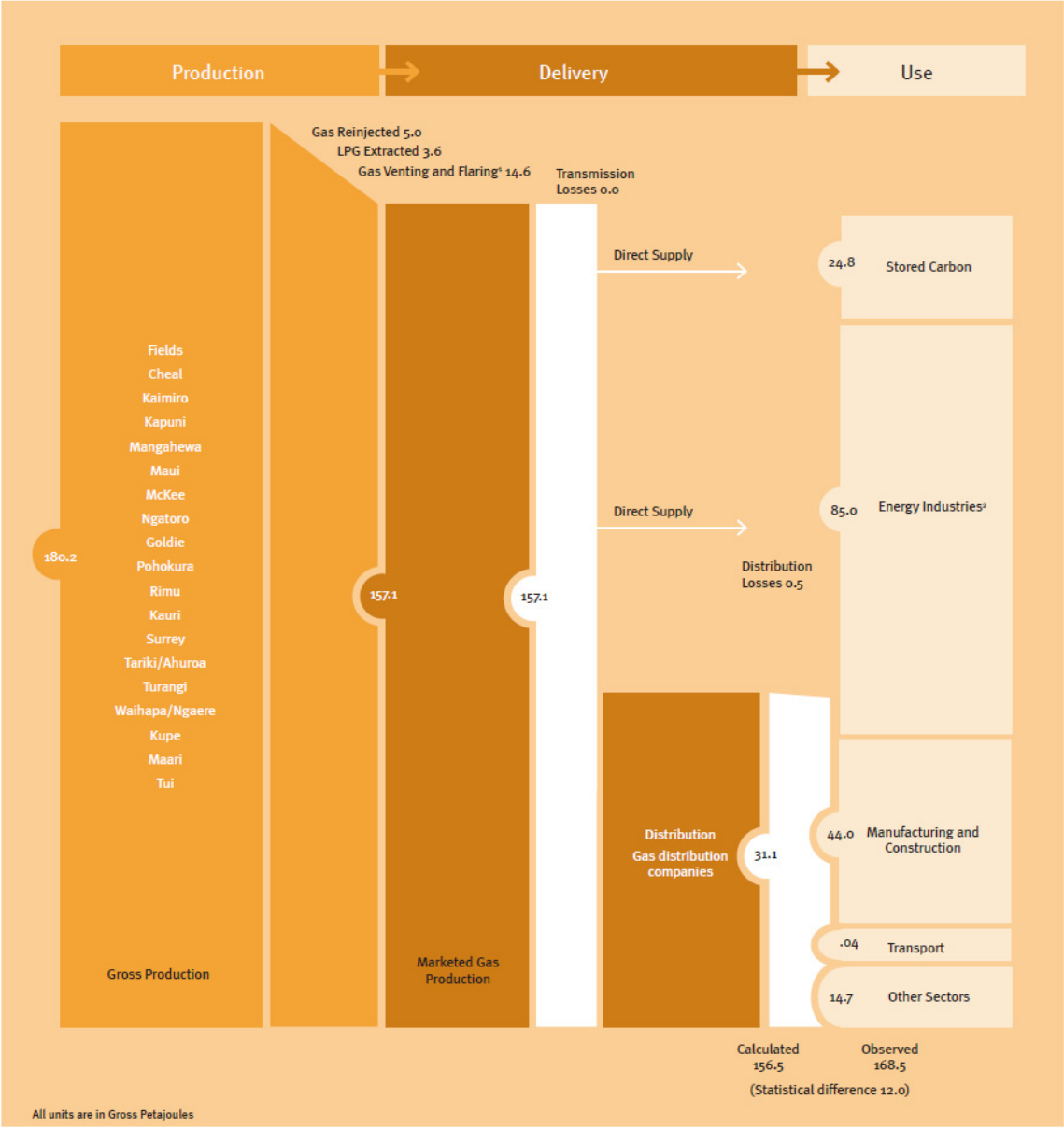


Figure A2.5.2 New Zealand oil energy flow summary for 2009



Note: The difference is the own use of fuels at the Refinery. These fuels (asphalt, fuel oil, refinery gas and natural gas) are accounted for under the category 'Energy industries' for liquid fuels and natural gas. This will consequently lead to the statistical difference for liquid fuels and natural gas being larger than they actually are.

Figure A2.5.3 New Zealand natural gas energy flow summary for 2009



Note:

1. 'Gas Venting and Flaring' consists of venting and flaring at gas and oil fields, flaring at the New Zealand Refining Company (NZRC), and venting at the Kapuni Gas Treatment Plant (KGTP). These numbers are combined to protect the confidentiality of the companies involved. The data from the two later of these three, does not originate from the 'Gross Production' number. This will therefore lead to the statistical difference between calculated and observed gas being larger than it actually is.
2. This category also consists of the combustion of 'refinery gas'. This is a synthetic gas produced by the NZRC through cracking, reforming and other processes. This 'refinery gas' is not a natural gas but is placed within the 'natural gas category'. It does not originate from the gross production figure and will therefore lead to the statistical difference between calculated and observed gas being larger than it actually is.

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 Statistics New Zealand's website. For information about surveys and census see: **http://search.stats.govt.nz/nav/ct2/industrysectors_agriculture/ct1/industrysectors/0**.

Agricultural production surveys

The target population for the *2009 Agricultural Production Survey* were all units 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 2009. The response rate was 84 per cent. These businesses represent 86 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 *2009 Agricultural Production Survey* are provided in Table A3.1.1.

The *2009 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 *2009 Agricultural Production Survey*

Statistic	Proportion of total estimate imputed (%)	Sample error (%)
Ewe hoggets put to ram	19	11
Breeding ewes, 2 tooth and over	19	4
Total number of sheep	18	4
Lamb born to ewe hoggets	21	24
Lambs born to ewes	19	4
Beef cows and heifers (in calf) 2 years and over	18	5
Beef cows and heifers (in calf) 1–2 years	18	12
Total number of beef cattle	18	3
Calves born alive to beef heifers/cows	18	5
Dairy cows and heifers, in milk or calf	21	5
Total number of dairy cattle	20	5
Calves born alive to dairy heifers/cows	21	6
Female deer mated	17	7
Total number of deer	16	6
Fawns born on farm and alive at 4 months	16	7
Area of wheat harvested	16	11
Area of barley harvested	19	10

A3.1.2 Key parameters and emission factors used in the agricultural sector

Table A3.1.2 Parameter values for New Zealand's agriculture N_2O emissions

Parameter (fraction)	Fraction of the parameter	Source	Parameter value
$Frac_{BURN}$ (kg N/kg crop-N)	Crop residue burned in fields	Ministry of Agriculture and Forestry (expert opinion)	0.3
$Frac_{BURNL}$ (kg N/kg legume-N)	Legume crop residue burned in fields	Ministry of Agriculture and Forestry (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
$Frac_{NCRBF}$ (kg N/kg of dry biomass)	Nitrogen in N-fixing crops	IPCC (1996) Reference Manual Table 4.19	0.03
$Frac_{NCR0}$ (kg N/kg of dry biomass)	Nitrogen in non-N-fixing crops	IPCC (1996) Reference Manual Table 4.19	0.015
$Frac_{R}$ (kg N/kg crop-N)	Crop residue removed from the field as crop	IPCC (1996) Reference Manual Table 4.19	0.45

Table A3.1.3 Emission factors for New Zealand's agriculture emissions N_2O 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_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 & runoff)	Indirect emissions from leaching nitrogen	IPCC (2000) Table 4.18	0.025

Table A3.1.4 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	New Zealand-specific	9
EF_{HORSES}	Enteric fermentation – horses	IPCC (1996) Table 4.3	18
EF_{SWINE}	Enteric fermentation – swine	IPCC (1996) Table 4.3	1.5
EF_{ALPACA}	Enteric fermentation – alpaca	IPCC (2006) Table 10.10	8
MM_{GOATS}	Manure management – goats	IPCC (1996) Table 4.5	0.18
MM_{HORSES}	Manure management – horses	IPCC (1996) Table 4.5	2.1
MM_{SWINE}	Manure management – swine	IPCC (1996) Table 4.6	20
$MM_{POULTRY}$	Manure management – poultry	IPCC (1996) Table 4.5	0.117
MM_{ALPACA}	Manure management – alpaca	New Zealand 1990 sheep value	0.091

A3.2 Supplementary information for the LULUCF sector: the Land Use and Carbon Analysis System (LUCAS)

A3.2.1 LUCAS Data Management System

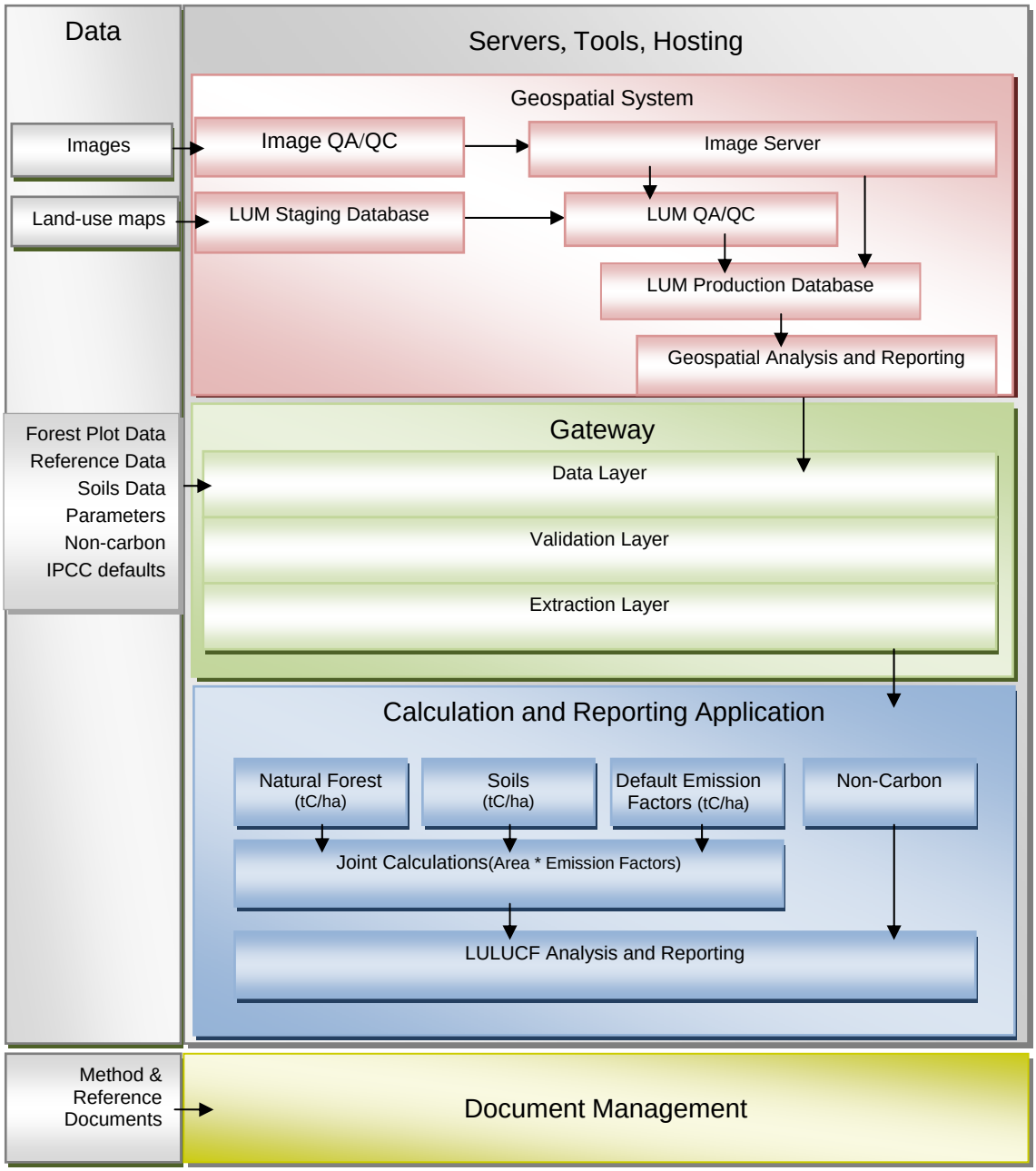
The LUCAS Data Management System stores, manages and archives data for international greenhouse gas reporting for the LULUCF sector. These systems are used for managing the land-use spatial databases, plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting (Figure A3.2.1).

The data collected is stored and manipulated within three systems: the Geospatial System, the Gateway and the Calculation and Reporting Application.

The key objectives of these systems are to:

- provide a transparent system for data storage and carbon calculations
- provide a repository for the versioning and validation of plot measurements and land-use data
- calculate carbon stocks, emissions and removals per hectare for land uses and carbon pools based on the plot and spatial data collected
- calculate biomass burning and liming emissions by land use based on spatial 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.

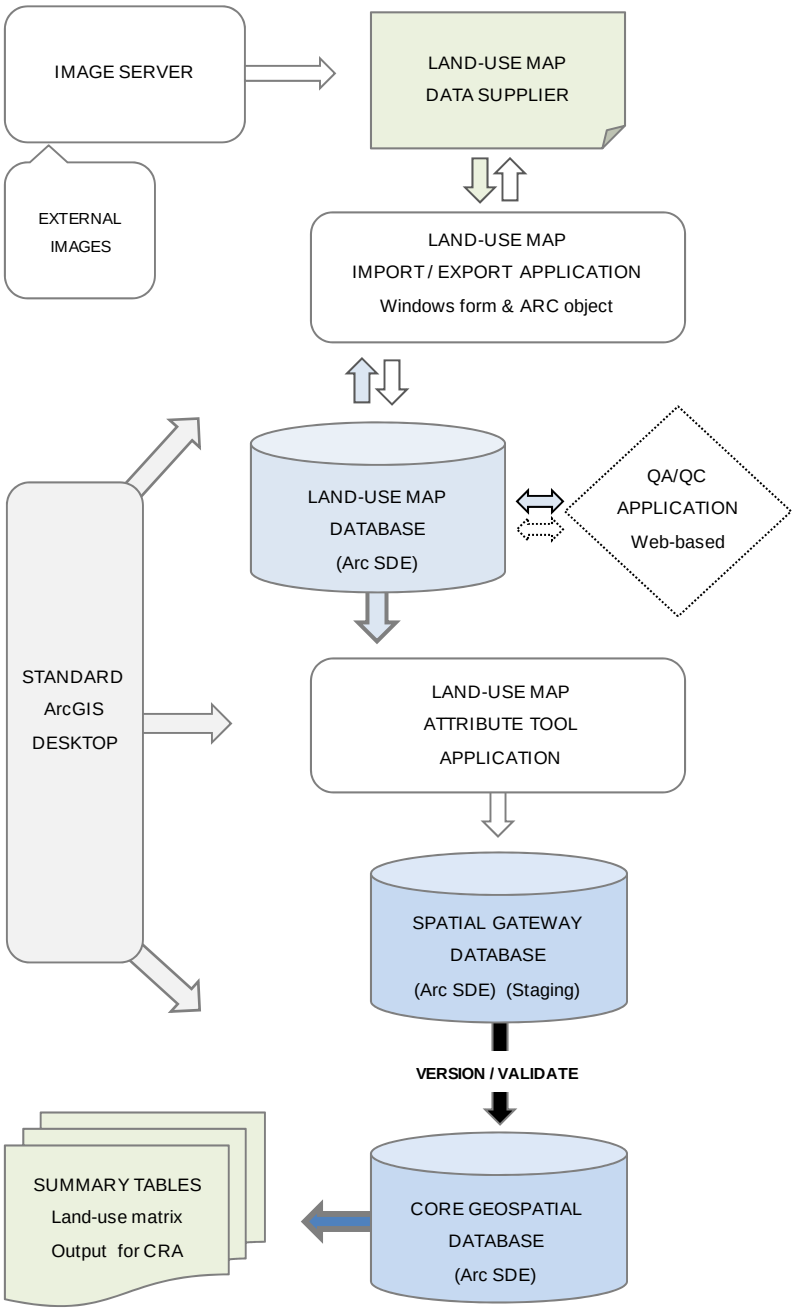
The Module Joint Calculations refers to the process New Zealand uses to estimate national average carbon values by carbon pool for each land-use category and subcategory.

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 or South Island.

The Geospatial System

The Geospatial System consists of hardware and specific applications designed to meet LULUCF reporting requirements. The hardware largely comprises servers for spatial database storage, management, versioning and running web mapping applications. The core components of the Geospatial System are outlined below.

Figure A3.2.2 New Zealand's Geospatial System components



Land-use mapping functionality

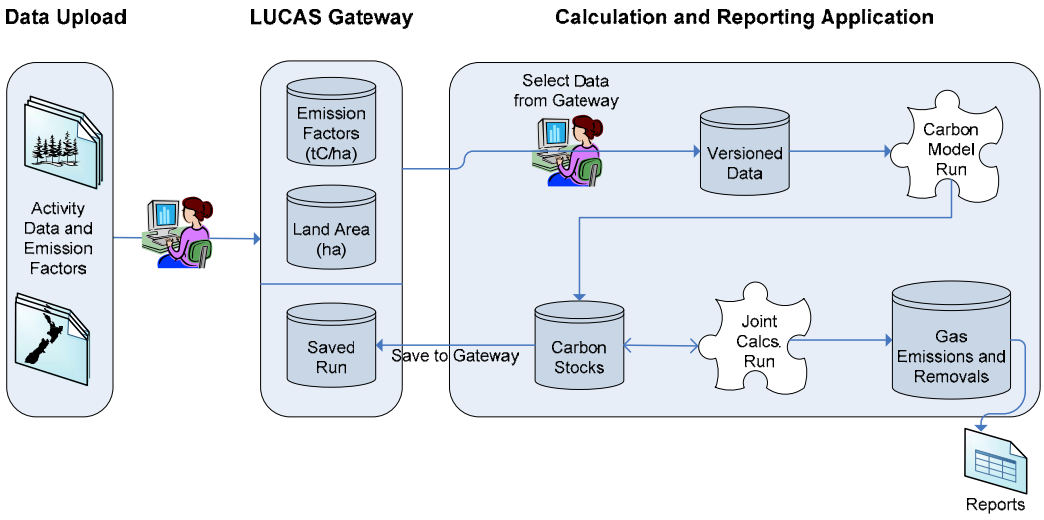
The land-use mapping (LUM) functionality of the Geospatial System largely involves the editing and maintenance of time-stamped land-use mapping data. There are five components within the LUM functionality, as described below:

- LUM Import/Export Application – provides functionality for managing the importing and exporting of land-use mapping information into and out of the database
- LUM Attribute Tool Application – an extension to the standard ArcGIS Desktop software that facilitates maintenance and updates to the land-use mapping data by external contractors
- LUM Database – a non-versioned GIS database for interim land-use mapping data and related quality assurance and control observation data
- Spatial Gateway Application – used to validate and version data from the LUM database prior to loading into the Core Geospatial Database. Spatial gateway rules are stored in the Spatial Gateway Database
- Core Geospatial Database – stores final versioned geospatial datasets which are used by the Summary Calculation application to generate land-use matrix data. It also stores the summary tables produced.

The LUCAS Management Studio

The LUCAS Management Studio is the package of applications used to store activity data, and calculate and report New Zealand's emission and removals for LULUCF. The LUCAS Gateway is a data warehouse with the purpose of storing, versioning and validating activity data and emissions factors. The Calculation and Reporting Application sources all data from the Gateway, and calculates and outputs New Zealand's emissions and removals for LULUCF for land remaining land and land converted to another land use, by pool and year.

Figure A3.2.3 LUCAS Management Studio



The LUCAS Gateway

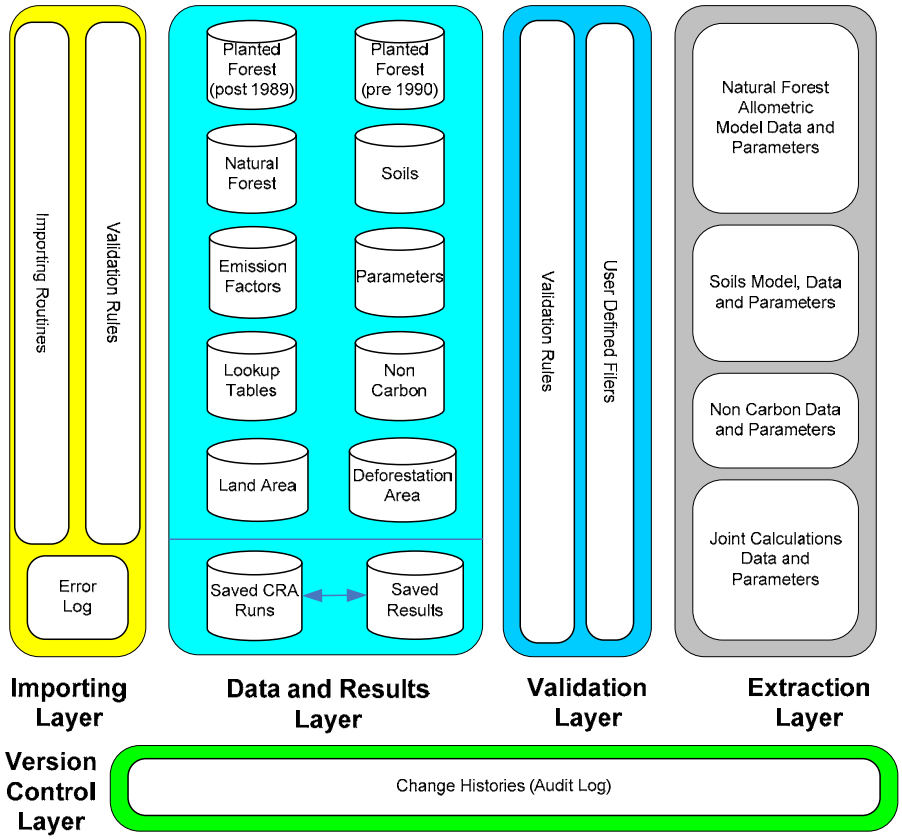
The LUCAS Gateway enables the storage of activity data such as: field plot data, land-use area, biomass burning, liming and other data, such as IPCC defaults, needed by the Calculation and Reporting Application.

The LUCAS Gateway provides a viewing, querying and editing interface to the source (plot, land-use area, carbon and non-carbon) data. The Gateway also stores any published or saved results from running the Calculation and Reporting Application.

All activity data and emission factors are stored within the Gateway database (Figure A3.2.4).

- A data and results layer contains all activity data (natural, planted forest, soils, default carbon, non-carbon, land-use areas, land-use change and reference tables). The user has the ability to create a 'snapshot' in time (a dataset archiving system) of the data held in the Gateway. This enables users of the Calculation and Reporting Application to select from a range of data snapshots and also ensures past results can be replicated over time.
- A validation layer allows users to judge the suitability of data for use in the Calculation and Reporting Application calculations, subsequent to passing primary validation. Where records are deemed not acceptable for use within published reports they are tagged as 'invalid' in the LUCAS Gateway database.
- An audit trail provides a history of any changes to the database tables within the Gateway.
- Versioning at a number of levels ensures any changes to data, schema or the database itself are logged and versioned, while providing the user with the ability to track what changes have been applied, and roll back to a previous version if required. The results of saved or published reports within the Calculation and Reporting Application are also stored within the Gateway for repeatability and reference.
- Primary data validation, both during data capture and during import of the data into the Gateway, ensures only data that has passed acceptability criteria are available for a publishable Calculation and Reporting Application run.
- Hosting and application support provides hosting services, system security, backup and restore, daily maintenance and monitoring for the Gateway and Calculation and Reporting Application.

Figure A3.2.4 LUCAS Gateway Database

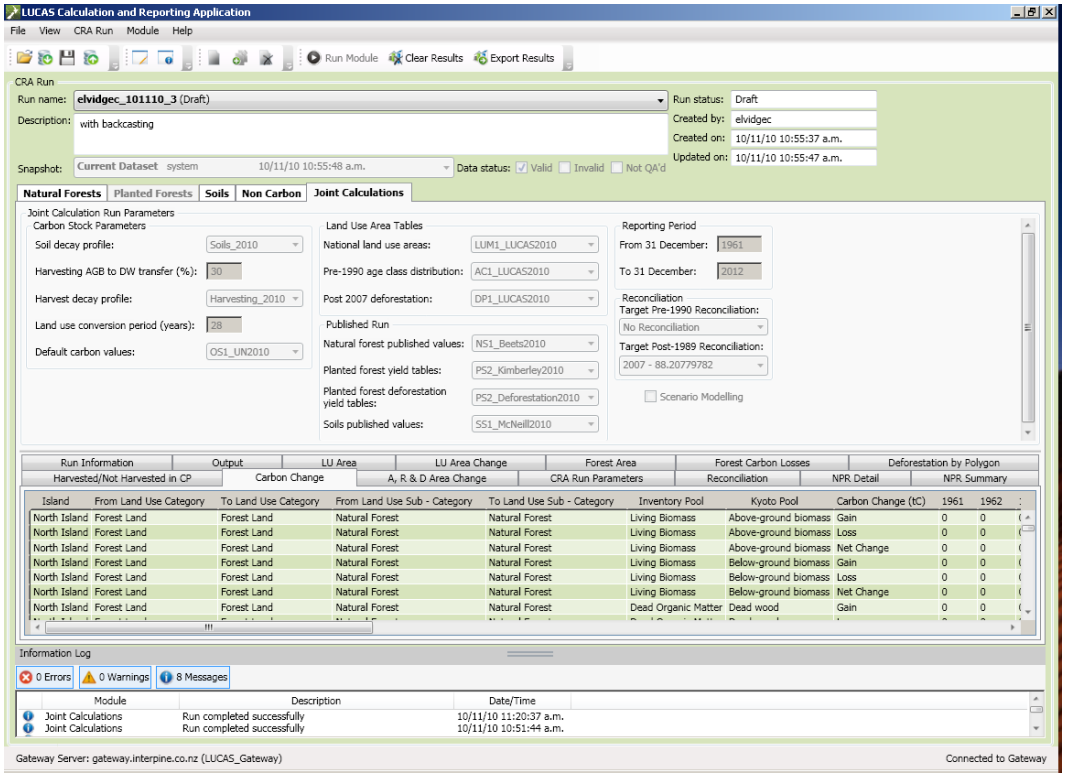


Calculation and Reporting Application

The Calculation and Reporting Application enables users to import carbon and non-carbon data from the Gateway and, by running the various modules, determine emissions and removals by New Zealand's forests, cropland, grassland and other land-use types. This information, combined with land-area data, enables New Zealand to meet its reporting requirements under the Climate Change Convention and Kyoto Protocol.

The Calculation and Reporting Application allows for the inclusion of other datasets, models and calculations without the complete redesign of the applications. All models, data and results are versioned, and the Calculation and Reporting Application allows the user to alter specific key values within a model or calculation (parameters) without the intervention of a programmer or technical support officer. The Calculation and Reporting Application is deployed as a client-based application that sources the required data from the Gateway.

Figure A3.2.5 Calculation and Reporting Application



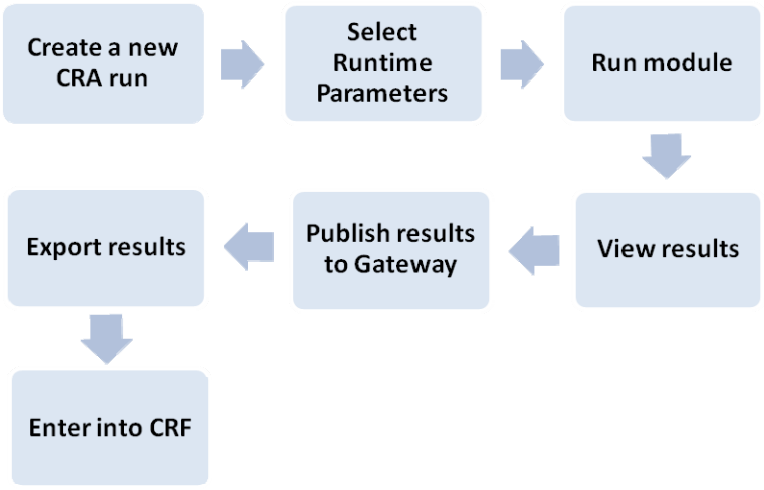
The Calculation and Reporting Application is comprised of four modules: natural forest, soils, non-carbon, and joint calculations. Any of these modules can be run independently or as a group. The results are provided as 'views' to the user at the completion of the run.

To activate the module, the user selects the module to run within the Calculation and Reporting Application, the version of the dataset to be used, the model version, and other calculation parameters. The natural forest and soil carbon modules use R statistical language as the base programme language, while the non-carbon module and joint calculations module are developed in C Sharp programming language (C#).

Within the joint calculations module, the user has the option of using the carbon results from running the modules, or using default carbon estimates (based on published reports) stored within the Gateway. The joint calculations module combines the carbon estimates with the land-use area to calculate carbon stock and change. The results represent carbon stock and change for every 'from' and 'to' land-use combination outlined by the IPCC since 1990.

On completion of running a module, the results can be saved or published back to the Gateway. This provides a versioned and auditable record of the results used for reporting. If the results are saved or published, other information such as the time created, the user's identification and the module-particular parameters that were used are also saved for tracking and audit control.

Figure A3.2.6 How New Zealand used the Calculation and Reporting Application for entry into the common reporting format database



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 IT 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 the 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.

Improvements

During the 2010 Calendar year, the Gateway and the Calculation and Reporting Application underwent the following improvements.

- As a result of the 'backcasting' project (to identify land in transition at 1990), the Gateway and the Calculation and Reporting Application required minor system changes. The benefit of this improvement enabled New Zealand to report land in a transition state as at the base line year 1990. Proving land in a transition state is an IPCC GPG requirement and was noted as a future improvement in the 2007 NIR review.
- The separation of the wetland category into two subcategories: 'Wetland open water' and 'Wetland vegetative non-forest'.
- A user interface to enable forecasting of emissions and removals beyond the reporting period was also developed. This improved functionality ensures New Zealand's LULUCF emissions and removals estimates are consistent in that one system is now used for Climate Change Convention and Kyoto reporting and for Net Position reporting.
- Providing a user friendly interface that allows the import emission factors and activity data into the Gateway with the need of a system expert.
- Allowing basic system administration functionality such as resetting passwords and assigning new users of the systems.

- In previous National Inventory Reports, New Zealand only reported total liming emissions. However, in 2008 Statistics New Zealand, via the annual Agriculture survey asked respondents for liming to be separated into the volume of dolomite and lime application. Given this new data availability additional data storage tables were created within the Gateway and additional calculations within the Calculation and Reporting Application were required. As a result, New Zealand's estimates of emissions from dolomite and lime application on grassland and cropland have increased.

A3.3 New Zealand Soil Carbon Monitoring System: Model Recalibration and Uncertainty Analysis

Prepared for the Ministry for the Environment by SJ McNeill, Landcare Research, New Zealand, December 2010. Landcare Research Contract Report: LC93.

A3.3.1 Introduction

The Ministry for the Environment (the Ministry) has created a Land Use and Carbon Analysis System (LUCAS) that is used to report on New Zealand's land use, land-use change and forestry (LULUCF) sector in the greenhouse gas inventory. The Soil Carbon Monitoring System (the 'Soil CMS') has been developed for inventory of the soil carbon pool. The Soil CMS comprises a regression model (the 'Soil CMS model'), and a calibration dataset (the 'Historic Soils dataset').

The Historic Soils dataset is derived primarily from the National Soils Database (NSD), with various supplementary datasets. Recently, a large amount of new data has been obtained to provide improved land-use and geographic representation, and the Soil CMS model needs to be recalibrated against the new data.

In addition, the recent in-country review highlighted issues of model estimate uncertainties and transparency in the explanation of stock and stock change uncertainties. Those aspects that can be addressed immediately will be incorporated into the 2009 National Inventory Report.

The purposes of this project are to:

- recalibrate the Soil CMS model with corrections for spatial autocorrelation for the 0–30 cm soil layer using supplied data that is a combination of the Historic, Annual Cropland, and Natural Forest Soils databases
- provide a transparent explanation of model estimate uncertainties in a report format for use within the 2009 National Inventory Report.

Scope of this report

This report describes the Soil CMS model as at November 2010 and is intended for Ministry for the Environment and other agencies concerned with the detailed technical operation of the Soil CMS. The aim is to provide sufficient detail to enable understanding of the key equations used to describe the model and the assumptions required to interpret the model results. It is assumed that those wanting to know more about the way the Soil

CMS model works can obtain this background information from documents such as Baisden et al (2006) and Kirschbaum et al (2009).

A3.3.2 The Soil CMS model

Model basis

A system for inventory of organic carbon in mineral soil horizons is required by the Ministry for the Environment to ensure New Zealand can meet reporting requirements under the United Nations Framework Convention on Climate Change (UNFCCC), and the Kyoto Protocol. The inventorying of organic carbon in mineral soil (hereafter referred to as soil C) in New Zealand has been performed under a system known as the soil Carbon Monitoring System (CMS), which was developed by Landcare Research for the Ministry for the Environment between 1996 and 2001 (Scott et al, 2002; Tate et al, 2003) and further refined through ongoing research funded by the Foundation for Research, Science and Technology (Tate et al, 2005).

The operation of the Soil CMS to produce soil C involves applying a linear statistical model to key factors of land use, climate, and soil class, which together regulate net soil C storage. The model also includes an additional environmental factor consisting of the product of slope and rainfall – a term used as a proxy for the potential for surface soil erosion to occur (erosivity) (Giltrap et al, 2001). The development of the soil C model is described by Baisden et al (2006), including its conceptual development, statistical basis, and how the model is used to calculate national soil C. Essentially, the Ministry for the Environment Soil CMS model is an empirical model developed from sound physical principles.

The key concept in the operation of the soil C model is that estimates must be reported grouped by specified land-use classes. The model allows for an explanatory effect by land-use class, so estimates grouped by land use are unbiased where a specific land-use class has an effect significantly different from the pooled soil carbon value. In addition, where some land-use classes have such an effect, incorporating land use as an explanatory effect reduces the overall residual standard error in soil carbon.

The uncertainty of the land-use effect from the soil C model depends on two factors. One component of uncertainty relates to the inherent uncertainty of soil C knowledge, whereas a second depends on the number of field samples available. The nature of the field data is such that this latter component of uncertainty is dominant.

Model statistical design

The linear statistical model that is the basis of the soil C model is fitted using a set of soil measurements from several different sources. The soil dataset is based on a number of different sampling efforts, and the overall statistical design does not represent simple random sampling in the classical sense (Lohr, 1999). As a result of the non-random sampling, some soil–climate and land-use factors may be under-represented and others over-represented. Since soil samples are correlated to some extent depending on the distance between them, application of the Soil CMS model to the Historic Soils dataset results in predictions of soil carbon stocks that are biased from their true values. The effect was noted in a preliminary analysis (Kirschbaum et al, 2009), and the methods for the correction are outlined in more detail elsewhere (McNeill et al, 2009).

The linear regression model for soil C in the 0–30 cm layer as a response variable uses explanatory variables of the soil–climate factor, the land-use class, and the slope–rainfall product. This model can be represented as an equation for the soil carbon $C_{i,j}^{0-30cm}$ in land-use class i and soil–climate class j as

$$C_{i,j}^{0-30cm} = M + L_i + S_j + b.SR \quad (1)$$

In equation (1), M is the mean soil carbon in the 0–30 cm layer for the combination of the reference level of land use (low-producing grassland), the reference level for soil climate (MstTempHAC, ie, '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 (MstTempHCA; t/ha). Finally, b is the additional soil carbon for each unit of SlopeRain (t (m deg × 10) − 1).

Equation (1) predicts a single value of soil carbon for one single site. If we denote C_{NZ}^{0-30cm} as the total New Zealand carbon stock, with A_{NZ}, A_{Li}, and A_{Sj} the area of New Zealand, the area in land use *i*, and the area in soil–climate class *j* respectively, then the total soil carbon for New Zealand is found using

$$C_{NZ}^{0-30cm} = A_{NZ}M + \sum_i L_i A_{Li} + \sum_j S_j A_{Sj} + b.A_{NZ}.\overline{SR} \quad . \quad (2)$$

In equation (2), $A_{NZ}M$ is the soil carbon for the 'Grassland – low producing' land-use class and 'MstTempHCA' soil–climate and flat land, $\sum L_i A_{Li}$ is the additive adjustment for the soil carbon in each land-use class other than 'Grassland – low producing', $\sum S_j A_S$ is the additive adjustment for the soil–climate relative to 'MstTempHCA', while $b.A_{NZ}\overline{SR}$ is the additive adjustment for rainfall and slope. All terms have units of tonnes (t). The quantities M, L_i, S_j, and b are obtained by fitting a statistical model to the Historic Soils dataset and are the subject of this report; all other quantities are obtained from other datasets or from separate analyses. For example, the mean value of the slope-times-rainfall must be obtained from national statistics of rainfall and a terrain slope map.

Using the soil C model correctly

As noted in Baisden et al (2006), the prevailing assumption in the adoption of the soil C model is that any change in soil carbon is defined by a change in land use. Therefore, the coefficients corresponding to the various land-use classes are of most interest when reporting soil carbon, since they represent the effects that will be reflected in changes in soil carbon as a result of changes in land use.

Given the above, the soil carbon model can be used in two quite distinct ways, depending on the precise circumstances in which it is employed. First, if an estimate is required of soil carbon at a specific site with land use L_i, soil–climate class S_j and slope–rainfall SR, then equation (1) is used. Second, if an estimate is required of New Zealand soil carbon for carbon accounting purposes, what is of interest eventually are the changes in

soil carbon as a result of different land-use conditions, so that equation (2) is used to extract the effect for the different land-use classes. As noted earlier, an explanatory effect of land use is incorporated in the soil model, 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.

A3.3.3 Methods

Data description

The data for the tasks presented in this report come from three sources. The first, the Historic Soils dataset, is derived primarily from the National Soils Database (NSD), with various supplementary datasets. The second, the Natural Forest Soils dataset, is gathered as part of the Natural Forest Survey, with samples taken on a sub-sample of a regular grid across the landscape, with some exceptions as a result of practical considerations. The third comprises a set of high-producing grassland and annual cropland records, referred to as the Annual Cropland dataset. Together, the combined datasets cover most of the land mass of New Zealand, as shown in Figure A3.3.1. The combined datasets were provided by the Ministry in a single spreadsheet, in which each row or record represents a site and the columns describe various attributes of the site.

The response variables of interest for deriving soil C are the amount of organic carbon in the 0–30 cm soil layer, normalised by unit area. Soil C units can be presented equivalently in either megagrams per hectare (Mg/ha) or tonnes per hectare (t/ha), but in this report t/ha C will be used.

Although there are many columns available in the supplied spreadsheet, the important variables and their meaning are shown in Table A3.3.1.

Table A3.3.1 Relevant data variables and their description

Column heading	Description
Ident	A unique identifier for each record. If the site is derived from a dataset or project, this field matches the unique site identifier in the dataset or project from which the data are derived
SurveyType	Indicates whether the record is from the Historic Soils (SH), Natural Forest (SN) or Annual Cropland (SA) source
IsValid	Indicates whether the record can (if value is TRUE) be used in the analysis for soil carbon
SoilClim	Soil–climate class
SlopeRain	An empirical estimate of erosivity, calculated as slope (degrees) multiplied by annual rainfall (mm) in units of (milli-degrees x 10)
SlopeSource	Indicates the source of the slope information for the site
TtlC0_30	Organic C stored in the 0–0.3 metre soil layer (t/ha C)
GPSE_NZTM	Easting position in New Zealand Transverse Mercator projection
GPSN_NZTM	Northing position in New Zealand Transverse Mercator projection
LucasSubCategoryName	Land use in one of 11 categories

Data importing

The combined dataset was supplied as an Excel spreadsheet, and was exported as a tab-separated-variable file. An R script was written to read this tab-separated-variable file and make the appropriate transformations of the various columns into variables. This was

necessary as some spreadsheet columns were invalid R variable names, and there were many superfluous data columns. The script to read and process the combined dataset is given in an electronic appendix to this report.

A single data-frame was generated in R that contained all the variables required for analysis of the task, defined in Table A3.3.1. The importing script excluded those records with values of 'ORG' for SoilClim, 'DEM' for SlopeSource, 'FALSE' for IsValid, and null TtlC0_30.

The LucasSubCategoryName field was converted from UTF-8-character encoding to standard ASCII-character encoding. This was necessary as the Excel spreadsheet stored hyphens in the extended UTF-8 character set, which are difficult to separate from the ASCII hyphens.

The soil–climate and land-use factor variables in the imported data frame were referenced to 'MstTmp_HAC' and 'Grassland – low producing' respectively. In addition, the soil–climate and land-use-factor levels were ordered the same way as for previous statistical analysis of the Soil CMS model (McNeill et al, 2009; McNeill et al, 2010), for reasons of consistency. Finally, the exotic-forest land-use classes ('Post-1989 forest' and 'Pre-1990 planted forest') were aggregated into a single 'Planted forest' land-use class.

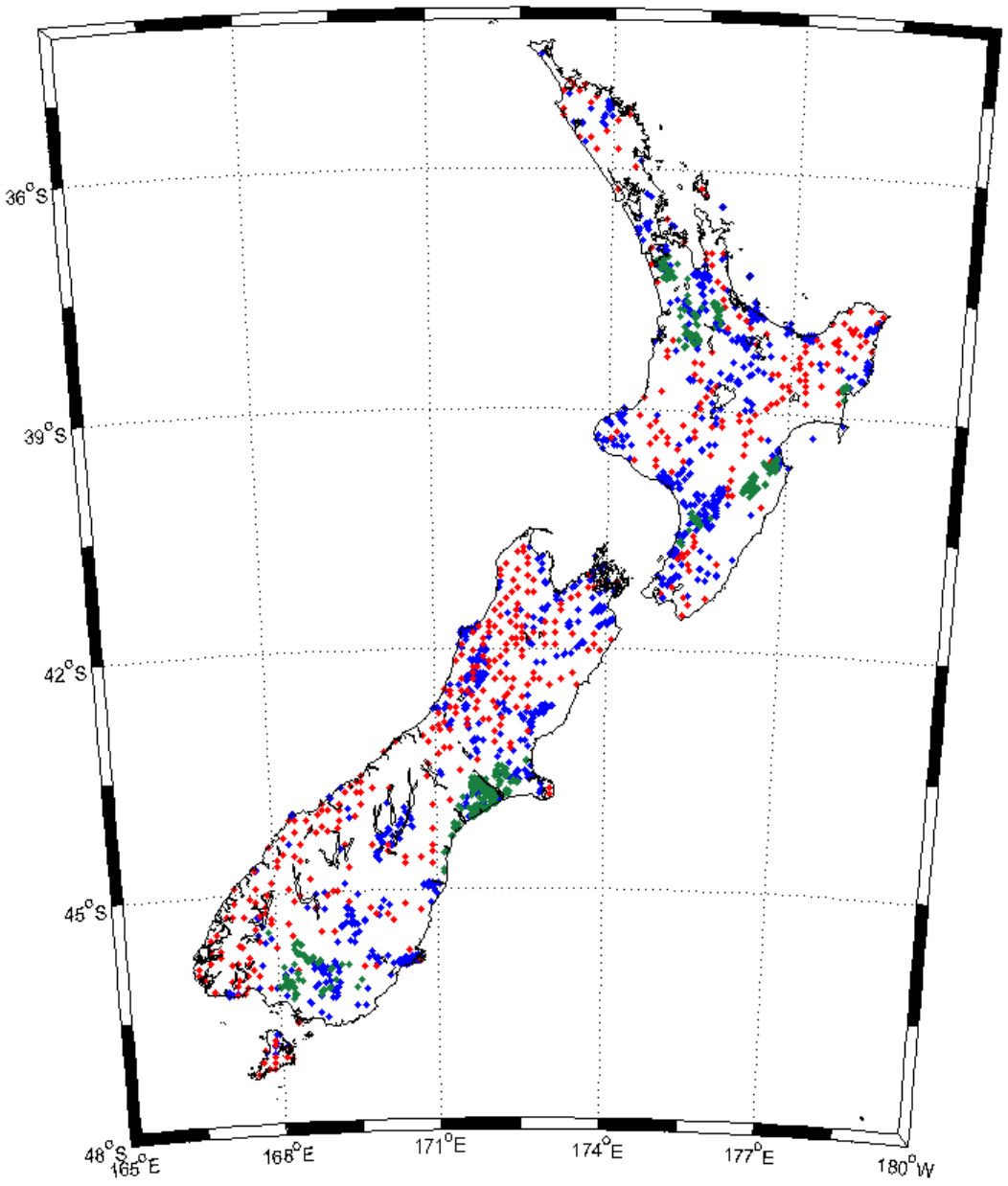
After importing and processing the data in the above manner, a total of 1959 valid records remain (1130 from Historic Soils, 521 from Annual Cropland Soils, and 308 from Natural Forest Soils). The number of soil C records in each of the land-use classes is shown in Table A3.3.2. It is clear from Table A3.3.2 that there is a wide variation in the number of records associated with the different land-use classes. It is therefore reasonable to expect that there will also be considerable variability in the uncertainty of the estimated land-use effect for the different land-use classes. For instance, it is clear that the uncertainty will be poor for land-use classes with few soil C records (eg, Wetlands – vegetative non forest), and better for cases where there are many soil C records (eg, Grassland – high producing), assuming all other things being equal.

Table A3.3.2 Tabulation of the number of soil CMS records by land-use class

Land-use class	Number of records
Grassland – low producing	276
Grassland – high producing	768
Grassland – with woody biomass	173
Cropland – perennial	10
Cropland – annual	252
Wetlands – vegetative non-forest	4
Planted forest	64
Natural forest	409
Other land	3
Total	**1959**

Figure A3.3.1 shows a plot of the distribution of the three different datasets; the Historic and Natural Forest soils together cover the landscape more or less uniformly, while the Cropland records provide intensive sampling in specific agricultural regions.

Figure A3.3.1 Map of soil plot locations in the Historic Soils dataset (blue points), the Natural Forest Soils dataset (red points), and Cropland soils (green points). Projection: Lambert Conformal Conic



Correction for repeated positions

A characteristic of the combined soil C dataset is that there are some groups of distinct records with the same recorded spatial location (ie, the same easting and northing). It is not clear why these records have the same location but some records may have only generalised positions recorded, and these generalised positions are not distinct from other positions. In addition, a number of soil C records have the same recorded position and have been measured at different times. Whatever the reason, it is important that the repeated positions are avoided, since the core fitting routine used in this analysis (the 'gls' function in the R 'nlme' module) does not tolerate distinct records with the same position.

There are several ways to avoid the repeated-position difficulty. One drastic method is to omit the records altogether, except for perhaps one randomly selected record at a given position. This approach is not desirable, as it removes records that may have some useful explanatory value. A preferred approach is to randomly displace the spatial positions so the records do not coincide, and retain all the soil C records. It is important that the selected method does not significantly affect the results of the subsequent statistical analysis. A complication is that repeated records may have different soil–climate and land-use classes.

Several methods for randomly displacing the records have been trialled. The selected method uses a random permutation of the integers $1 \cdots N$, where N is the number of repeated positions in a group. The easting coordinate is randomly displaced by an amount equal in metres to the random permutation. The northing coordinate is randomly displaced by an amount equal in metres to the circularly shifted version of the random permutation. The circular shift of the random permutation ensures that the combination in northing and easting never produces a co-linear set of spatial coordinates.

Statistical analysis

The analysis was performed using R version 2.10.1, 14 December 2009 (R Development Core Team, 2009). R modules used in the analysis include nlme (version 3.1-96) and MASS (7.3-5).

The method of statistical analysis is outlined in detail elsewhere (Baisden et al, 2006; McNeill et al, 2009). The model is a least-squares linear model fit, with corrections for spatial autocorrelation between points. The spatial autocorrelation between points is modelled as an exponential kernel, with a nugget effect (McNeill et al, 2009).

A3.3.4 Results

Model fitting

Model fitting with spatially correlated observations is very slow compared with linear-model-fitting procedures. This is because the procedure required to fit the model with corrections for spatial correlation must build a matrix of all point-to-point distances in the fitting dataset. On the Windows PC used for this work (dual-core 2.8GHz processor with Microsoft Windows-XP), fitting a linear model accounting for spatial correlation takes approximately 27 minutes.

The spatial autocorrelation analysis fits a negative-exponential model for the spatial semi-variogram, and includes a nugget effect. The analysis yields a nugget effect of 0.47, while the distance beyond which there is no correlation (the *scale* distance) is estimated to be 21.7 km. The residual standard error of the regression is 40.7 t/ha C.

The nugget effect of 0.47 is close to the estimate from McNeill et al (2009), which used a much smaller set of soil C records for fitting the soil model. The scale distance of 21.7 km is smaller than the value of 148 km from McNeill et al (2009); this reduction is evidently due to the increased spatial support available in the large set of soil C records in the current project.

The estimated residual standard error of 40.7 t/ha C is 16 per cent smaller than the estimate from McNeill et al (2009).

Table A3.3.3 provides a summary of the coefficients for the fitted model.

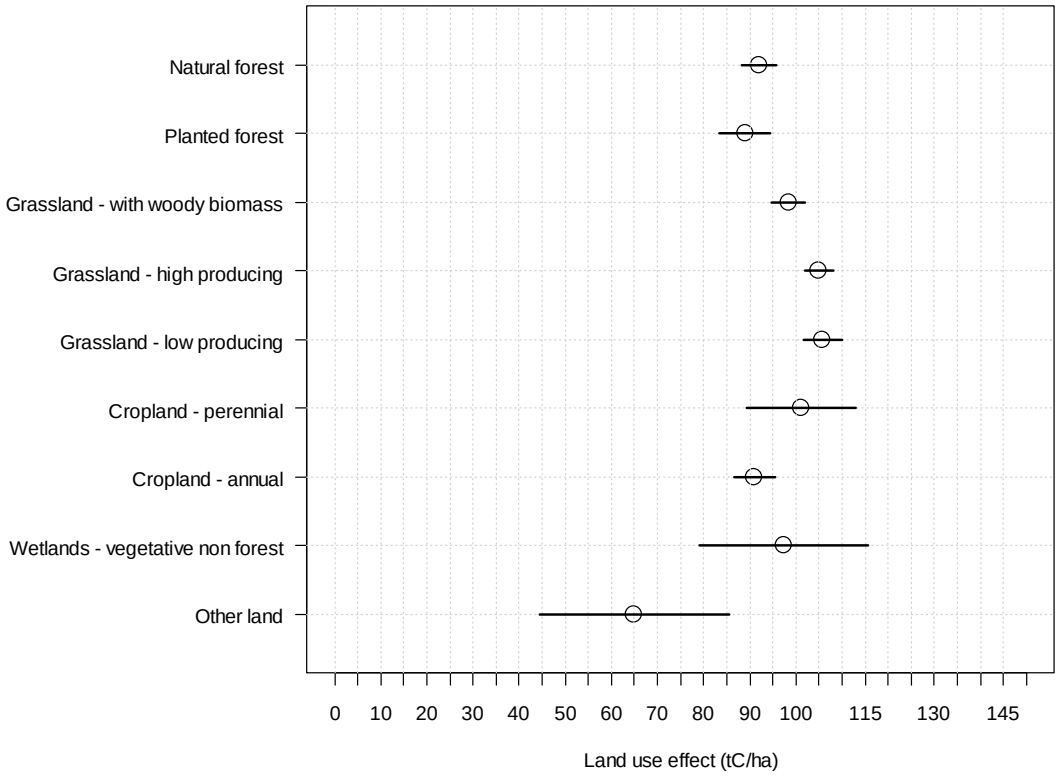
Table A3.3.3 Summary table of coefficients for the linear model for soil carbon in the 0–30 cm layer, incorporating corrections for spatial auto correlation

Coefficients	Value	Std error	*t*-value	*p*-value
Intercept	105.80299	4.152694	25.478155	0.0000
SoilClimAQU	5.55333	3.076308	1.805194	0.0712
SoilClimBor_HAC	–7.33987	7.442459	–0.986216	0.3242
SoilClimBor_POD	11.95150	9.606413	1.244117	0.2136
SoilClimBor_SAN	–26.63219	6.225813	–4.277706	0.0000
SoilClimBor_VOL	51.85607	31.412713	1.650799	0.0989
SoilClimDryTmp_HAC	–4.90190	3.861202	–1.269528	0.2044
SoilClimHumBor_HAC	8.48905	6.655164	1.275558	0.2023
SoilClimHumTmp_HAC	13.81623	3.743932	3.690301	0.0002
SoilClimHumTmp_POD	20.52015	4.900224	4.187595	0.0000
SoilClimHumTmp_SAN	–51.20907	9.032974	–5.669127	0.0000
SoilClimHumTmp_VOL	34.09744	5.438994	6.269071	0.0000
SoilClimLAC	30.35075	12.311825	2.465171	0.0138
SoilClimTmp_POD	20.53036	9.840740	2.086262	0.0371
SoilClimTmp_SAN	–61.45450	20.202088	–3.041987	0.0024
SoilClimTmp_VOL	26.80748	3.871049	6.925122	0.0000
SoilClimVDryTmp_HAC	–32.82881	10.233544	–3.207961	0.0014
SlopeRain	–0.02056	0.003542	–5.802615	0.0000
LucasSubCategoryNameGrassland – high producing	–0.81440	3.078461	–0.264547	0.7914
LucasSubCategoryNameGrassland – with woody biomass	–7.37829	3.594734	–2.052528	0.0403
LucasSubCategoryNameCropland – perennial	–4.56755	11.825592	–0.386242	0.6994
LucasSubCategoryNameCropland – annual	–14.80956	4.379605	–3.381483	0.0007
LucasSubCategoryNameWetlands – vegetative non forest	–8.45302	18.222202	–0.463886	0.6428
LucasSubCategoryNamePlanted forest	–16.84505	5.452016	–3.089692	0.0020
LucasSubCategoryNameNatural forest	–13.76612	3.655947	–3.765404	0.0002
LucasSubCategoryNameOther land	–40.86099	20.627175	–1.980930	0.0477

Land-use-effect uncertainty

Figure A3.3.2 shows point estimates for the land-use effect of the nine land-use classes, as well as lines indicating plus-and-minus one standard error from the point estimate. Note that in Figure A3.3.2 the land-use effect plotted is the gross effect for a given land-use class, not the marginal effect with respect to low-producing grassland. It can be noted from Figure A3.3.2 that the land-use classes with large standard errors are those with relatively small numbers of soil C records (eg, 'Cropland – perennial', 'Wetlands – vegetative non forest', and 'Other land').

Figure A3.3.2 Estimates of the land-use effect for the Soil CMS model. The markers indicate the point estimate of the land-use effect, while the horizontal lines through each marker indicate plus-and-minus one standard error



Land-use effect for a land-use transition

The land-use effect for a transition in land use from 'Grassland – low producing' to one of the other land-use classes can be obtained by inspection of the coefficients of the soil C model in Table A3.3.3. The land-use effect for a transition in land use from any arbitrary land-use class and a different land-use class can also be obtained by calculating the difference of the land-use effects from the origin and destination land use with respect to 'Grassland – low producing'.

The uncertainty of the land-use effect between two land-use classes is conceptually straightforward; two estimates of land-use effect in Figure A3.3.2 are more likely to be significantly separated if their point estimates are farther apart, and if their respective uncertainty limits are not overlapping. However, a complication to this straightforward assessment is that some account must be taken of the covariance between the two land-use classes.

For the transition from one land-use class to another, the significance of the change is determined from the size of the land-use change, and then calculating the standard error of the transition between the two classes from the variances of the two land-use classes and the covariance between them. The covariance between land-use classes is obtained during the linear-model-fitting process. The standard error $SE_{i,j}$ of the land-use-effect change for a transition between two land-use classes with effects LUE_i and LUE_i is then estimated by

$$SE_{i,j} = \sqrt{Var(LUE_i) + Var(LUE_j) - 2.Cov(LUE_i, LUE_j)}, \quad (3)$$

where $Var(LUE_i)$ is the variance of land-use effect i, and $Cov(LUE_i, LUE_j)$ is the covariance between land-use effects LUE_i and LUE_j. The covariance matrix $Cov(LUE_i, LUE_j)$ between land-use effects LUE_i and LUE_j is given in Table A3.3.4. The estimated standard errors for land-use effects calculated in this manner are shown in Table A3.3.5.

Table A3.3.4 Covariance matrix between land-use classes for the fitted model

i,j	Natural forest	Planted forest	Grassland – with woody biomass	Grassland – high producing	Grassland – low producing	Cropland – perennial	Cropland – annual	Wetlands – vegetative non-forest	Other land
Natural forest	13.37	7.73	6.49	5.00	−6.07	4.45	5.00	5.14	8.25
Planted forest	7.73	29.72	6.03	5.82	−6.74	4.97	5.81	4.30	7.33
Grassland – with woody biomass	6.49	6.03	12.92	4.64	−5.39	4.48	4.66	5.47	4.70
Grassland – high producing	5.00	5.82	4.64	9.48	−5.92	7.33	8.68	5.19	3.59
Grassland – low producing	−6.07	−6.74	−5.39	−5.92	17.24	−5.38	−6.34	−4.80	−4.80
Cropland – perennial	4.45	4.97	4.48	7.33	−5.38	139.84	10.55	5.04	3.09
Cropland – annual	5.00	5.81	4.66	8.68	−6.34	10.55	19.18	5.13	3.56
Wetlands – vegetative non forest	5.14	4.30	5.47	5.19	−4.80	5.04	5.13	332.05	2.77
Other land	8.25	7.33	4.70	3.59	−4.80	3.09	3.56	2.77	425.48

The values in Table A3.3.4 are applied in equation (3) to estimate the standard error of the land-use transition. Each shaded value in Table A3.3.4 corresponds to the variance of the corresponding land-use effect; the square-root of this variance is the standard error for the land-use effect in Table A3.3.5. For example, the square-root of the variance of the natural forest land use from Table A3.3.4 is $\sqrt{13.37} = 3.66$, which is the standard error for the natural forest land-use class in Table A3.3.3.

Table A3.3.5 Land-use effect (LUE) for transition between land-use classes (with estimated standard error)

Original land use	Land converted to	LUE	Std error
Planted forest	Natural forest	3.08	5.26
Grassland – with woody biomass	Natural forest	−6.39	3.65
Grassland – high producing	Natural forest	−12.95	3.58
Grassland – low producing	Natural forest	−13.77	6.54
Cropland – perennial	Natural forest	−9.2	12.01
Cropland – annual	Natural forest	1.04	4.75
Wetlands – vegetative non forest	Natural forest	−5.31	18.31
Other land	Natural forest	27.09	20.55
Grassland – with woody biomass	Planted forest	−9.47	5.53
Grassland – high producing	Planted forest	−16.03	5.25
Grassland – low producing	Planted forest	−16.85	7.78

Original land use	Land converted to	LUE	Std error
Cropland – perennial	Planted forest	−12.28	12.63
Cropland – annual	Planted forest	−2.04	6.11
Wetlands – vegetative non-forest	Planted forest	−8.39	18.79
Other land	Planted forest	24.02	20.99
Grassland – high producing	Grassland – with woody biomass	−6.56	3.62
Grassland – low producing	Grassland – with woody biomass	−7.38	6.4
Cropland – perennial	Grassland – with woody biomass	−2.81	11.99
Cropland – annual	Grassland – with woody biomass	7.43	4.77
Wetlands – vegetative non-forest	Grassland – with woody biomass	1.07	18.28
Other land	Grassland – with woody biomass	33.48	20.71
Grassland – low producing	Grassland – high producing	−0.81	6.21
Cropland – perennial	Grassland – high producing	3.75	11.6
Cropland – annual	Grassland – high producing	14	3.36
Wetlands – vegetative non-forest	Grassland – high producing	7.64	18.2
Other land	Grassland – high producing	40.05	20.68
Cropland – perennial	Grassland – low producing	4.57	12.96
Cropland – annual	Grassland – low producing	14.81	7.01
Wetlands – vegetative non-forest	Grassland – low producing	8.45	18.94
Other land	Grassland – low producing	40.86	21.27
Cropland – annual	Cropland – perennial	10.24	11.74
Wetlands – vegetative non-forest	Cropland – perennial	3.89	21.49
Other land	Cropland – perennial	36.29	23.65
Wetlands – vegetative non-forest	Cropland – annual	−6.36	18.47
Other land	Cropland – annual	26.05	20.92
Other land	Wetlands – vegetative non-forest	32.41	27.42

Interpretation of the land-use-effects table

As noted earlier, it is important that the coefficients from the soil C model are not fitted to determine the *significance* of the various land-use transitions and the *appropriateness* of including any given transition in subsequent assessment of change in soil carbon. Instead, the model is fitted to estimate the *size* of all the land-use effects, so estimates of soil carbon by land use or change in soil carbon by land-use transition are *unbiased with respect to land use*. Avoiding the bias in this manner also reduces the residual uncertainty of the soil C estimates. This approach is consistent with the physically based model (outlined in Scott et al, 2002; Tate et al, 2003, 2005; Baisden et al, 2006; Kirschbaum et al, 2009). For this reason, the effect of all land-use transitions ought to be included in calculations of soil C change.

It is important to note from the number of soil C records available in different land-use classes (see Table A3.3.2) that the standard error of the effect of many land-use transitions is directly related to the population of samples available to fit the soil C model. The number of records available in the present model-fitting effort is much larger than for previous efforts (compare with, for example, Baisden et al (2006) and McNeill et al (2009)). The standard error for these land-use effects is likely to change in the future if additional soil C records become available. For this reason, all land-use transitions ought to be retained, but their uncertainty noted.

Stability of regression results

An earlier section of this report ('Correction for repeated positions') described a method used to deal with groups of soil records that had the same spatial position. Since this method uses the R internal random number generator to modify the positions of specific records, a relevant question is: what is the stability of the regression coefficients over successive fitting procedures? To test this, an R script was written to repeatedly fit the linear model, using different random allocations of northing and easting for the repeated record positions for each fitting procedure.

Over 200 successive fitting procedures, the difference in the coefficient values for the linear model was zero. While the test was limited to 200 successive runs, the test took place over a sufficiently long period (6.5 days elapsed time) that it provides some confidence that the method is likely to be stable.

Annex 4: Carbon dioxide reference approach and comparison with sectoral approach, and relevant information on the national energy balance

Information on the CO_2 reference approach and a comparison with sectoral approach is provided in section 3.4.1. A table of the national energy balance for the 2008 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, varying from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable 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. LULUCF categories have been included using the absolute value of any removals of CO_2 (Table A7.1). Table A7.2 calculates the uncertainty only in emissions, that is, excluding LULUCF removals.

A7.1 Tier 1 uncertainty calculation

The uncertainty in activity data and emission/removal factors shown in Table A7.1 and A7.2 are equal to half the 95 per cent confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95 per cent confidence interval is that the value corresponds to the familiar plus or minus value when uncertainties are loosely quoted as ‘plus or minus x per cent’.

Where uncertainty is highly asymmetrical, the larger percentage difference between the mean and the confidence limit is entered. Where only the total uncertainty is known for a category, then:

- if uncertainty is correlated across years, the uncertainty is entered as the emission or the removal factor uncertainty and as zero in the activity data uncertainty
- if uncertainty is not correlated across years, the uncertainty is entered as the uncertainty in the activity data and as zero in the emission or the removal factor uncertainty.

In the Tier 1 method, uncertainties in the trend are estimated using two sensitivities.

- Type A sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and a greenhouse gas in both the base year and the current year.
- Type B sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and gas in the current year only.

Uncertainties that are fully correlated between years are associated with Type A sensitivities, and uncertainties that are not correlated between years are associated with Type B sensitivities.

In Tables A7.1.1 and A7.1.2, the figure labelled 'Uncertainty in the trend' is an estimate of the total uncertainty in the trend in emissions since the base year. This is expressed as the number of percentage points in the 95 per cent confidence interval in the per cent change in emissions since the base year. The total uncertainty in the trend is calculated by combining the contribution of emissions factor uncertainty and activity data uncertainty to the trend across all categories using equation 3.1 (IPCC, 2000).

The values for individual categories are an estimate of the uncertainty introduced into the trend by the category in question.

Table A7.1.1 The uncertainty calculation (including LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2009* (IPCC Tier 1)

IPCC source category	Gas	1990 emissions or absolute value of removals	2009 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	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	column H^2 (Year t)	column M^2 (Trend)
Energy – liquid fuels	CO_2	11096.10	16629.85	2.9	0.5	2.9	0.5	0.0393	0.1925	0.0196	0.7840	0.8	R	M	0.222535572	0.614977065
Energy – solid fuels	CO_2	3145.99	4336.53	11.3	3.5	11.8	0.5	0.0068	0.0502	0.0237	0.7993	0.8	M	M	0.246349708	0.639391237
Energy – gaseous fuels	CO_2	7548.74	7703.00	2.6	2.7	3.7	0.3	–0.0150	0.0892	–0.0406	0.3249	0.3	M	M	0.077739080	0.107197825
Energy – fugitive – geothermal	CO_2	228.58	610.01	5.0	5.0	7.1	0.0	0.0039	0.0071	0.0195	0.0499	0.1	D	D	0.001752455	0.002874159
Energy – fugitive – venting/flaring	CO_2	228.88	762.71	2.6	2.7	3.7	0.0	0.0057	0.0088	0.0153	0.0322	0.0	M	M	0.000762145	0.001268479
Energy – fugitive – oil transport	CO_2	0.01	0.01	5.0	50.0	50.2	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D	0.000000000	0.000000000
Energy – fugitive – transmission and distribution	CO_2	1.46	1.17	2.6	5.0	5.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	M	0.000000004	0.000000004
Industrial processes – mineral production	CO_2	551.56	760.50	100.0	5.0	100.1	0.7	0.0012	0.0088	0.0059	1.2449	1.2	D	D	0.546128781	1.549910088
Industrial processes – chemical industry	CO_2	430.21	625.34	2.0	6.0	6.3	0.0	0.0013	0.0072	0.0078	0.0205	0.0	D	D	0.001473318	0.000479916
Industrial processes – metal production	CO_2	1755.74	2014.58	5.0	7.0	8.6	0.2	–0.0009	0.0233	–0.0064	0.1649	0.2	D	D	0.028288424	0.027231062
LULUCF – forest land	CO_2	25,357.8	29,578.3	8.3	19.6	21.3	6.1	–0.0077	0.3424	–0.1506	4.0188	4.0	M	R	37.333705611	16.173587099
LULUCF – non-forested land	CO_2	1,861.1	2,832.9	4.1	50.3	50.5	1.4	0.0071	0.0328	0.3570	0.1901	0.4	M	R	1.925199830	0.163570800
Waste – waste incineration	CO_2	12.9	0.9	10.0	40.0	41.2	0.0	–0.0002	0.0000	–0.0067	0.0002	0.0	D	D	0.000000136	0.000044983
Energy – liquid fuels	CH_4	41.84	53.26	2.9	50.0	50.1	0.0	0.0000	0.0006	0.0019	0.0025	0.0	D	M	0.00067011	0.00001006
Energy – solid fuels	CH_4	24.35	6.20	11.3	50.0	51.3	0.0	–0.0003	0.0001	–0.0132	0.0011	0.0	D	M	0.00000951	0.00017605
Energy – gaseous	CH_4	56.88	40.42	2.6	50.0	50.1	0.0	–0.0003	0.0005	–0.0159	0.0017	0.0	D	M	0.00038568	0.00025474

IPCC source category	Gas	1990 emissions or absolute value of removals	2009 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	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	column H^2 (Year t)	column M^2 (Trend)
fuels																
Energy – biomass	CH_4	56.98	60.01	5.0	50.0	50.2	0.0	–0.0001	0.0007	–0.0046	0.0049	0.0	D	D	0.00085660	0.00004525
Energy – fugitive – geothermal	CH_4	46.02	113.23	5.0	5.0								D	D	0.00000000	0.00000000
Energy – fugitive – venting/flaring	CH_4	54.29	59.47	2.6	50.0	50.1	0.0	–0.0001	0.0007	–0.0031	0.0025	0.0	D	M	0.00083493	0.00001563
Energy – fugitive – coal mining	CH_4	274.47	348.93	11.3	50.0	51.3	0.2	0.0002	0.0040	0.0125	0.0643	0.1	D	M	0.03012415	0.00429201
Energy – fugitive – transmission and distribution	CH_4	235.16	162.56	2.6	5.0	5.6	0.0	–0.0014	0.0019	–0.0068	0.0069	0.0	D	M	0.00007875	0.00009358
Energy – fugitive – other leakages	CH_4	156.3	198.8	5.0	50.0	50.2	0.1	0.0001	0.0023	0.0072	0.0163	0.0	D	D	0.00940094	0.00031606
Energy – fugitive – oil transportation	CH_4	4.8	5.8	5.0	50.0								D	D	0.00000000	0.00000000
Agriculture – enteric fermentation	CH_4	21,864.7	22,506.2	0.0	16.0	16.0	3.5	–0.0412	0.2605	–0.6598	0.0000	0.7	M	M	12.21385747	0.43533133
Agriculture – manure management	CH_4	580.4	727.6	5.0	100.0	100.1	0.7	0.0004	0.0084	0.0410	0.0596	0.1	M	M	0.49992862	0.00522852
Agriculture – prescribed burning	CH_4	2.7	0.9	20.0	60.0	63.2	0.0	0.0000	0.0000	–0.0017	0.0003	0.0	D	R	0.00000029	0.00000283
Agriculture– burning of residues	CH_4	21.4	16.2	0.0	40.0	40.0	0.0	–0.0001	0.0002	–0.0043	0.0000	0.0	D	R	0.00003938	0.00001867
LUCLUF	CH_4	50.1	55.0	7.6	30.2										0.00000000	0.00000000
Waste – solid waste disposal	CH_4	1,514.4	1,398.6	0.0	40.0	40.0	0.5	–0.0047	0.0162	–0.1887	0.0000	0.2	M	R	0.29477564	0.03561153
Waste – wastewater handling	CH_4	368.9	438.0	0.0	100.0	100.0	0.4	0.0000	0.0051	–0.0023	0.0000	0.0	D	R	0.18068874	0.00000513
Waste – waste incineration	CH_4	0.0	0.0	10.0	100.0	100.5	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D	0.00000000	0.00000000
Energy – liquid fuels	N_2O	90.88	172.90	2.9	50.0	50.1	0.1	0.0007	0.0020	0.0373	0.0082	0.0	D	M	0.007062805	0.001460251

IPCC source category	Gas	1990 emissions or absolute value of removals	2009 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	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	column H^2 (Year t)	column M^2 (Trend)
Energy – solid fuels	N_2O	16.06	22.64	11.3	50.0	51.3	0.0	0.0000	0.0003	0.0020	0.0042	0.0	D	M	0.000126815	2.14781E-05
Energy – gaseous fuels	N_2O	6.71	7.38	2.6	50.0	50.1	0.0	0.0000	0.0001	–0.0004	0.0003	0.0	D	M	1.28521E-05	2.28741E-07
Energy – biomass	N_2O	44.66	66.48	5.0	50.0	50.2	0.0	0.0002	0.0008	0.0076	0.0054	0.0	D	D	0.001050971	8.80598E-05
Solvents – N_2O use	N_2O	41.5	27.9	10.0	0.0	10.0	0.0	–0.0003	0.0003	0.0000	0.0046	0.0	R		7.33189E-06	2.08594E-05
Agriculture – agricultural soils	N_2O	7,762.4	9,498.4	0.0	74.0	74.0	6.8	0.0028	0.1099	0.2056	0.0000	0.2	M	M	46.53405411	0.042274601
Agriculture – manure management	N_2O	38.2	55.7	5.0	100.0	100.1	0.1	0.0001	0.0006	0.0119	0.0046	0.0	R	R	0.002934723	0.000161465
Agriculture – prescribed burning	N_2O	0.5	0.2	20.0	60.0	63.2	0.0	0.0000	0.0000	–0.0003	0.0001	0.0	D	R	9.62965E-09	9.44083E-08
Agriculture – burning of residues	N_2O	7.4	5.3	6.0	50.0	50.4	0.0	0.0000	0.0001	–0.0020	0.0005	0.0	D	R	6.76763E-06	4.26669E-06
LULUCF	N_2O	9.9	7.7	5.5	24.7	25.3	0.0	0.0000	0.0001	–0.0012	0.0007	0.0	R	R	3.57401E-06	1.89812E-06
Waste – wastewater handling	N_2O	153.5	179.7	0.0	1200.0	1200.0	2.1	0.0000	0.0021	–0.0466	0.0000	0.0	D	R	4.37900136	0.002172524
Waste – waste incineration	N_2O	1.6	1.3	10.0	100.0	100.5	0.0	0.0000	0.0000	–0.0008	0.0002	0.0	D	D	1.54676E-06	6.43236E-07
Industrial processes	HFCs	0.0	879.23	21.0	21.0	29.7	0.3	0.0102	0.0102	0.2137	0.3023	0.4	R	R	0.064221843	0.137034512
Industrial processes – aluminium production	PFCs	629.9	44.82	5.0	30.0	30.4	0.0	–0.0082	0.0005	–0.2453	0.0037	0.2	M	M	0.000174999	0.060182425
Industrial processes – consumption of hydrofluorocarbons	PFCs	0	1.32	50.0	50.0	70.7	0.0	0.0000	0.0000	0.0008	0.0011	0.0	R	R	8.24322E-07	0.060182425
Industrial processes	SF_6	15.2	19.75	22.0	22.0	31.1	0.0	0.0000	0.0002	0.0004	0.0071	0.0	R	R	3.55655E-05	5.07618E-05
Total emissions/ removals		**86,391.0**	**103,037.7**		**Uncertainty in the year**		**10.2%**			**Uncertainty in the trend**		**4.5%**			**104.604281974**	**20.065590601**

Table A7.1.2 The uncertainty calculation (excluding LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2009* (IPCC Tier 1)

IPCC source category	Gas	1990 emissions or absolute value of removals	2009 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	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	column H^2 (Year t)	column M^2 (Trend)
Energy – liquid fuels	CO_2	11096.10	16629.85	2.9	0.5	2.9	0.7	0.0571	0.2813	0.0286	1.1457	1.1	R	R	0.474491105	1.313531548
Energy – solid fuels	CO_2	3145.99	4336.53	11.3	3.5	11.8	0.7	0.0098	0.0734	0.0345	1.1681	1.2	R	R	0.525267687	1.365670865
Energy – gaseous fuels	CO_2	7548.74	7703.00	2.6	2.7	3.7	0.4	–0.0221	0.1303	–0.0596	0.4748	0.5	R	R	0.165755531	0.229004896
Energy – fugitive – geothermal	CO_2	228.58	610.01	5.0	5.0	7.1	0.1	0.0057	0.0103	0.0285	0.0730	0.1	D	D	0.003736589	0.006137793
Energy – fugitive – venting/flaring	CO_2	228.88	762.71	2.6	2.7	3.7	0.0	0.0083	0.0129	0.0223	0.0470	0.1	R	R	0.001625048	0.002708865
Energy – fugitive – oil transport	CO_2	0.01	0.01	5.0	50.0	50.2	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D	0.000000000	0.000000000
Energy – fugitive – transmission and distribution	CO_2	1.46	1.17	2.6	5.0	5.6	0.0	0.0000	0.0000	0.0000	0.0001	0.0	R	R	0.000000009	0.000000008
Industrial processes – mineral production	CO_2	551.56	760.50	100.0	5.0	100.1	1.1	0.0017	0.0129	0.0086	1.8195	1.8	D	D	1.164457648	3.310473715
Industrial processes – chemical industry	CO_2	430.21	625.34	2.0	6.0	6.3	0.1	0.0019	0.0106	0.0113	0.0299	0.0	D	D	0.003141415	0.001024023
Industrial processes – metal production	CO_2	1755.74	2014.58	5.0	7.0	8.6	0.2	–0.0014	0.0341	–0.0096	0.2410	0.2	D	D	0.060316674	0.058167291
Waste – waste incineration	CO_2	12.9	0.9	10.0	40.0	41.2	0.0	–0.0002	0.0000	–0.0098	0.0002	0.0	D	D	0.000000289	0.000096256
Energy – liquid fuels	CH_4	41.84	53.26	2.9	50.0	50.1	0.0	0.0001	0.0009	0.0028	0.0037	0.0	D	D	0.00142881	0.00002129
Energy – solid fuels	CH_4	24.35	6.20	11.3	50.0	51.3	0.0	–0.0004	0.0001	–0.0193	0.0017	0.0	D	D	0.00002027	0.00037685
Energy – gaseous fuels	CH_4	56.88	40.42	2.6	50.0	50.1	0.0	–0.0005	0.0007	–0.0232	0.0025	0.0	D	D	0.00082235	0.00054642

IPCC source category	Gas	1990 emissions or absolute value of removals	2009 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	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	column H^2 (Year t)	column M^2 (Trend)
Energy – biomass	CH_4	56.98	60.01	5.0	50.0	50.2	0.0	–0.0001	0.0010	–0.0068	0.0072	0.0	D	D	0.00182645	0.00009732
Energy – fugitive – geothermal	CH_4	46.02	113.23	5.0	5.0								D	D	0.00000000	0.00000000
Energy – fugitive – venting/flaring	CH_4	54.29	59.47	2.6	50.0	50.1	0.0	–0.0001	0.0010	–0.0045	0.0037	0.0	R	R	0.00178025	0.00003381
Energy – fugitive – coal mining & handling	CH_4	274.47	348.93	11.3	50.0	51.3	0.3	0.0004	0.0059	0.0180	0.0940	0.1	R	R	0.06423081	0.00915862
Energy – fugitive – transmission and distribution	CH_4	235.16	162.56	2.6	5.0	5.6	0.0	–0.0020	0.0027	–0.0100	0.0100	0.0	R	R	0.00016791	0.00020030
Energy – fugitive – other leakages	CH_4	156.3	198.8	5.0	50.0	50.2	0.1	0.0002	0.0034	0.0103	0.0238	0.0	D	D	0.02004472	0.00067222
Energy – fugitive – oil	CH_4	4.8	5.8	5.0	50.0								D	D	0.00000000	0.00000000
Agriculture – enteric fermentation	CH_4	21,864.7	22,506.2	0.0	16.0	16.0	5.1	–0.0606	0.3807	–0.9693	0.0000	1.0	M	M	26.04242853	0.93948710
Agriculture – manure management	CH_4	580.4	727.6	5.0	100.0	100.1	1.0	0.0006	0.0123	0.0589	0.0870	0.1	M	M	1.06594951	0.01104642
Agriculture – prescribed burning	CH_4	2.7	0.9	20.0	60.0	63.2	0.0	0.0000	0.0000	–0.0024	0.0004	0.0	D	R	0.00000062	0.00000606
Agriculture– burning of residues	CH_4	21.4	16.2	0.0	40.0	40.0	0.0	–0.0002	0.0003	–0.0063	0.0000	0.0	D	R	0.00008398	0.00004007
Waste – solid waste disposal	CH_4	1,514.4	1,398.6	0.0	40.0	40.0	0.8	–0.0069	0.0237	–0.2768	0.0000	0.3	M	R	0.62852163	0.07663814
Waste – wastewater handling	CH_4	368.9	438.0	0.0	100.0	100.0	0.6	0.0000	0.0074	–0.0040	0.0000	0.0	D	R	0.38526514	0.00001566
Waste – waste incineration	CH_4	0.0	0.0	10.0	100.0	100.5	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D	0.00000000	0.00000000

IPCC source category	Gas	1990 emissions or absolute value of removals	2009 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	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	column H^2 (Year t)	column M^2 (Trend)
Energy – liquid fuels	N_2O	90.88	172.90	2.9	50.0	50.1	0.1	0.0011	0.0029	0.0545	0.0119	0.1	D	D	0.015059336	0.003110246
Energy – solid fuels	N_2O	16.06	22.64	11.3	50.0	51.3	0.0	0.0001	0.0004	0.0029	0.0061	0.0	D	D	0.000270396	4.57924E–05
Energy – gaseous fuels	N_2O	6.71	7.38	2.6	50.0	50.1	0.0	0.0000	0.0001	–0.0005	0.0005	0.0	D	D	2.74033E-05	4.94858E-07
Energy – biomass	N_2O	44.66	66.48	5.0	50.0	50.2	0.0	0.0002	0.0011	0.0111	0.0080	0.0	D	D	0.002240884	0.000187213
Solvents – N_2O use	N_2O	41.5	27.9	10.0	0.0	10.0	0.0	–0.0004	0.0005	0.0000	0.0067	0.0	R		1.56331E-05	4.45539E-05
Agriculture – agricultural soils	N_2O	7,762.4	9,498.4	0.0	74.0	74.0	10.0	0.0039	0.1607	0.2903	0.0000	0.3	M	M	99.22006879	0.084273941
Agriculture – manure management	N_2O	38.2	55.7	5.0	100.0	100.1	0.1	0.0002	0.0009	0.0173	0.0067	0.0	R	R	0.006257427	0.000342559
Agriculture – prescribed burning	N_2O	0.5	0.2	20.0	60.0	63.2	0.0	0.0000	0.0000	–0.0004	0.0001	0.0	D	R	2.05324E-08	2.02114E-07
Agriculture – burning of residues	N_2O	7.4	5.3	6.0	50.0	50.4	0.0	–0.0001	0.0001	–0.0029	0.0008	0.0	D	R	1.443E-05	9.15103E-06
Waste – wastewater handling	N_2O	153.5	179.7	0.0	1200.0	1200.0	3.1	–0.0001	0.0030	–0.0714	0.0000	0.1	D	R	9.336921626	0.005090963
Waste – waste incineration	N_2O	1.6	1.3	10.0	100.0	100.5	0.0	0.0000	0.0000	–0.0011	0.0003	0.0	D	D	3.298E-06	1.38038E-06
Industrial processes	HFCs	0.0	879.23	21.0	21.0	29.7	0.4	0.0149	0.0149	0.3124	0.4417	0.5	R	R	0.136934032	0.292693924
Industrial processes – aluminium production	PFCs	629.9	44.82	5.0	30.0	30.4	0.0	–0.0120	0.0008	–0.3588	0.0054	0.4	M	M	0.000373133	0.12877366
Industrial processes – consumption of hydrofluorocarbons	PFCs	0	1.32	50.0	50.0	70.7	0.0	0.0000	0.0000	0.0011	0.0016	0.0	R	R	1.75762E-06	3.75689E-06
Industrial processes	SF_6	15.2	19.75	22.0	22.0	31.1	0.0	0.0000	0.0003	0.0006	0.0104	0.0	R	R	7.58329E-05	0.000108416
Total emissions		**59,112.1**	**70,563.8**		**Uncertainty in the year**		**0.0%**			**Uncertainty in the trend**		**2.8%**			139.329626962	**7.839841789**