Ministry for the Environment
Manatū Mō Te Taiao

New Zealand's Greenhouse Gas Inventory 1990–2008

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.

Submitted to the United Nations
Framework Convention on Climate Change
15 April 2010

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PO Box 10-362, Wellington, New Zealand

ISSN: 1179-223X
Publication number: ME 1009

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The Ministry for the Environment acknowledges the many valuable contributions provided by experts from industry, central and local government and science organisations in the development of this inventory.

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 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 in the inventory. Only emissions and removals of the direct greenhouse gases, CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, are reported in New Zealand's total emissions under the Climate Change Convention and are 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 2008 (the current inventory year) and supplementary information required for the Kyoto Protocol. Each inventory report is 15 months in arrears allowing time for data to be collected and analysed.

Reporting afforestation, reforestation and deforestation activities since 1990 (Article 3.3 activities under the Kyoto Protocol) is mandatory in 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 emissions from energy, industrial processes, solvent and other product use, and the waste sector, but do not include emissions and removals from the LULUCF sector. Reporting total emissions excluding the LULUCF sector is consistent with the reporting requirements of the Climate Change Convention (UNFCCC, 2006).

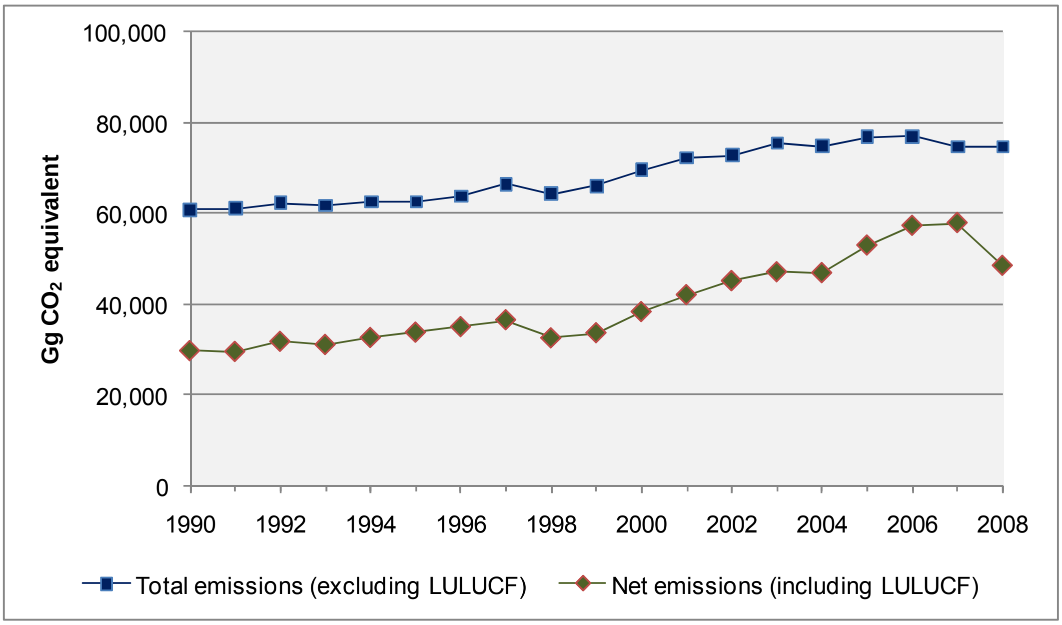
In 1990, New Zealand's total greenhouse gas emissions were 60,773.6 Gg carbon dioxide equivalent (CO_2-e). In 2008, total greenhouse gas emissions had increased by 13,885.1 Gg CO_2-e (22.8 per cent) to 74,658.7 Gg CO_2-e (Figure ES.2.1). Between 1990 and 2008, the average annual growth in total emissions was 1.3 per cent per year.

New Zealand's total emissions trend is different from many other countries. Instead of a predictable increase or decline in emissions, the trend for New Zealand consists of year-to-year fluctuations (Figure ES.2.1). These fluctuations are due to two main factors. The first is the change in proportion of non-renewable energy used in electricity and heat production affecting CO_2 emissions. The second factor is the effect of droughts on agriculture productivity and livestock numbers affecting N_2O and CH_4 emissions.

Net emissions

Net emissions include emissions from the energy, industrial processes, solvent and other product use, waste sector, and emissions and removals from the LULUCF sector. In 1990, New Zealand's net greenhouse gas emissions were 29,707.3 Gg CO_2-e. In 2008, net greenhouse gas emissions had increased by 18,774.6 Gg CO_2-e (63.2 per cent) to 48,482.0 Gg CO_2-e (Figure ES.2.1.1). The increase in net emissions between 1990 and 2008 is larger than for total emissions because the net removals from LULUCF were greater in 1990 than in 2008.

Figure ES.2.1.1New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2008



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. The initial assigned amount is five times the total emissions reported in the 1990 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 is different (1.8 per cent) from the 1990 level of 61,893.0 Gg CO_2-e used in the initial assigned amount calculation.

In 2008, net removals from land subject to afforestation, reforestation and deforestation were –14,416.8 Gg CO_2-e. Removals from afforestation and reforestation were –17,327.4 Gg CO_2-e. Deforestation emissions were 2,910.6 Gg CO_2-e.

ES.3 Gas trends

The predominant greenhouse gases emitted by New Zealand have changed since 1990. Whereas CH_4 and CO_2 contributed equally to New Zealand's emissions in 1990, in 2008, 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 indicates the growth in emissions from the energy sector.

Table ES.3.1.1 New Zealand's greenhouse gas emissions by gas in 1990 and 2008

Direct greenhouse gas emissions	Gg CO_2-equivalent		Change from 1990 (Gg CO_2-equivalent)	Change from 1990 (%)
	1990	2008		
CO_2	24,893.3	36,063.2	+11,169.9	+44.9
CH_4	25,456.4	25,816.2	+359.8	+1.4
N_2O	9,778.9	11,913.4	+2,134.6	+21.8
HFCs	NO	812.5	+812.5	NA
PFCs	629.9	38.8	–591.0	–93.8
SF_6	15.2	14.5	–0.7	–4.3
Total	**60,773.6**	**74,658.7**	**+13,885.1**	**+22.8**

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). Although there may be rounding errors in this table, the figures are consistent with estimates reported in the common reporting format tables.

ES.4 Sector trends

ES.4.1 Reporting under the Climate Change Convention

Energy (chapter 3)

The energy sector was the source of 33,838.8 Gg CO_2-e (45.3 per cent) of total emissions in 2008. In 2008, energy emissions had increased by 10,796.1 Gg CO_2-e (46.9 per cent) from the 1990 level of 23,042.7 Gg CO_2-e. This growth in emissions is primarily from the electricity generation, heat production and transport categories.

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2008 calendar year, hydro generation provided 52 per cent of New Zealand's electricity generation. Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990 and 2008. The fluctuations are caused by switching between thermal and hydro generation. Drought years increase the reliance on thermal electricity generation.

Between 2007 and 2008, emissions from the energy sector increased by 1,185.2 Gg CO_2-e (3.6 per cent). This is primarily due to a 987.3 Gg CO_2-e (14.8 per cent) increase in emissions from public electricity and heat production due to low hydro inflows for 2008. Public electricity and heat production emissions also rose in 2008 due to the increased use of coal in electricity generation.

An increase of 368.2 Gg CO_2-e (6.9 per cent) in the manufacturing industries and construction category between 2007 and 2008 also contributed to the increase in energy emissions. However, these increases were in part offset by a 623.7 Gg CO_2-e

(4.2 per cent) decrease in the transport category due to the high petrol and diesel prices in 2008 and the beginning of the global recession.

Industrial processes (chapter 4)

The industrial processes sector accounted for 4,292.0 Gg CO_2-e (5.7 per cent) of total emissions in 2008. Emissions from the industrial processes sector increased 906.2 Gg CO_2-e (26.8 per cent) from the 1990 level of 3,385.8 Gg CO_2-e. This increase was mainly caused by growth in emissions from the consumption of hydrofluorocarbons.

Between 2007 and 2008, emissions from the industrial processes sector decreased by 344.6 Gg CO_2-e (7.4 per cent). The largest decrease of 183.3 Gg CO_2-e (8.1 per cent) was due to a reduction in emissions from steel and aluminium production.

Between 2007 and 2008, emissions from the consumption of halocarbons and SF_6 category decreased by 105.3 Gg CO_2-e (11.3 per cent.) This was caused by reduced sales of new refrigerant (including halocarbons imported in bulk and in equipment, excluding exports). There was also a reduction in the amount of HFC-134a sold to the mobile air conditioning industry.

Solvent and other product use (chapter 5)

In 2008, the solvent and other product use sector was responsible for 31.0 Gg CO_2-e (0.04 per cent) of total emissions.

Agriculture (chapter 6)

The agriculture sector was the largest source of emissions in 2008, contributing 34,826.3 Gg CO_2-e (46.6 per cent) of total emissions (Table ES.4.1.1 and Figure ES.4.1.1). Consequently, New Zealand has a unique emissions profile. In other developed countries, agricultural emissions are typically less than 10 per cent of total emissions. In 2008, New Zealand's agricultural emissions increased by 2,960.9 Gg CO_2-e (9.3 per cent) from the 1990 level of 31,865.4 Gg CO_2-e (Figure ES.4.1.2). The change in emissions since 1990 is shown in Figure 2.3.3. The agriculture sector contributed 11,434.1GgCO_2-e (96.0 per cent) of New Zealand's total N_2O emissions and 23,392.2 Gg CO_2-e (90.6 per cent) of total CH_4 emissions in 2008.

Between 2007 and 2008, emissions from the agriculture sector decreased 737.1 Gg CO_2-e (2.1 per cent) (Figure 2.3.3). This was largely due to a decrease in the population of sheep (4,372,613 head or 11.4 per cent), deer (172,699 head or 12.4 per cent) and non-dairy cattle (256,745 head or 5.8 per cent). The drought that affected most of New Zealand throughout 2008 was the main cause for these decreases in animal numbers (Ministry of Agriculture and Forestry, 2009). This was the second year in a row drought affected some regions of New Zealand.

LULUCF (chapter 7)

Net removals from the LULUCF sector were estimated to be –26,176.8 Gg CO_2-e in 2008, and have decreased by 4,889.5 Gg CO_2-e (15.7 per cent) from the 1990 level of –31,066.3 Gg CO_2-e. This decrease is largely due to the harvesting and replanting of plantation forests in the five years prior to 2008 as this lowered the average age and therefore the CO_2 absorption capacity of planted forests in 2008. The decrease is also due to an increase in emissions from deforestation.

Waste (chapter 8)

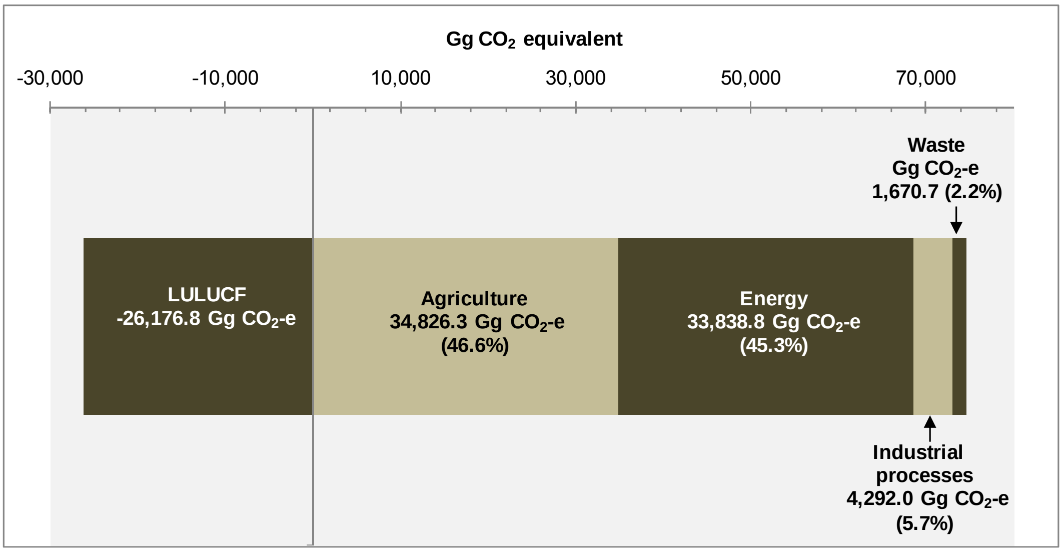
The waste sector accounted for 1,670.7 Gg CO_2-e (2.2 per cent) of total emissions in 2008. Emissions from the waste sector had decreased by 767.5 Gg CO_2-e (31.5 per cent) from the 1990 level of 2,438.2 Gg CO_2-e. This decrease was largely due to initiatives to improve solid waste management practices.

Table ES.4.1.1 New Zealand's emissions by sector in 1990 and 2008

Sector	Gg CO_2-equivalent 1990	Gg CO_2-equivalent 2008	Change from 1990 (Gg CO_2-equivalent)	Change from 1990 (%)
Energy	23,042.7	33,838.8	+10,796.1	+46.9
Industrial processes	3,385.8	4,292.0	+906.2	+26.8
Solvent and other product use	41.5	31.0	–10.5	–25.4
Agriculture	31,865.4	34,826.3	+2,960.9	+9.3
Waste	2,438.2	1,670.7	–767.5	–31.5
Total (excluding LULUCF)	**60,773.6**	**74,658.7**	**+13,885.1**	**+22.8**
LULUCF	–31,066.3	–26,176.8	+4,889.5	+15.7
Net Total (including LULUCF)	**29,707.3**	**48,482.0**	**+18,774.6**	**+63.2**

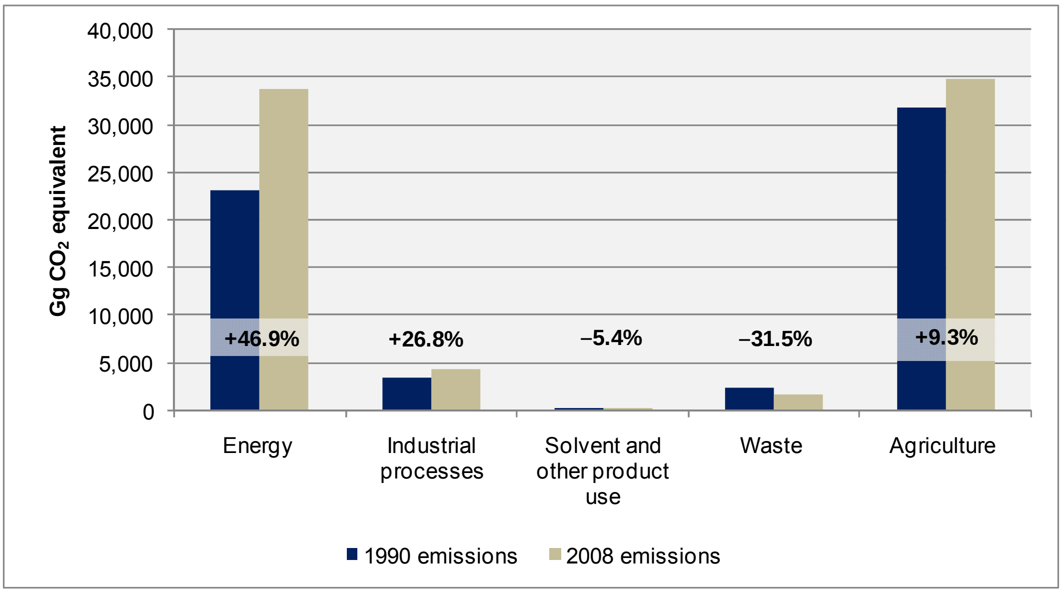
Note: LULUCF includes CO_2 removals and emissions of CO_2, CH_4 and N_2O. Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Although there may be rounding errors in this table, the figures are consistent with estimates reported in the common reporting format tables.

Figure ES.4.1.1 New Zealand's emissions by sector in 2008



Note: Emissions from the solvent and other product use sector are not represented in this figure. Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Although there may be rounding errors, the figures are consistent with estimates reported in the common reporting format tables.

Figure ES.4.1.2 Change in New Zealand's emissions by sector from 1990 to 2008



ES.4.2 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 2008 inventory (Table ES.4.2.1).

Afforestation and reforestation

During 2008, a gross area of 1,000 hectares of post-1989 forest was established. Between 1990 and 2008, it is estimated that a gross area of 580,524 hectares of post-1989 forest was established as a result of afforestation and reforestation activities. The gross area includes 11,749 hectares of land in transition to post-1989 forest that has subsequently been deforested. The net area of post-1989 forest as at 31 December 2008 was 568,775 hectares. The net area is the total area of post-1989 forest minus deforestation since 1 January 1990.

Deforestation

During 2008, 4,818 hectares of all forest (natural forest, pre-1990 planted forest and post-1989 forest), equivalent to emissions of 2,910.6 Gg CO_2-e, was deforested. Deforestation of all forests in 2008 has decreased from the 2007 level of 18,151 hectares, equivalent to 13,115.6 Gg of CO_2.

Table ES.4.2.1 New Zealand's net emissions and removals from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2008

Source	Gross area (ha) 1990–2008	Net area (ha) 2008	Emissions in 2008 (Gg CO_2-e)
Afforestation/reforestation	580,524	568,775	–17,327.4
Forest land not harvested since the beginning of the commitment period	–	568,274	–17,395.1
Forest land harvested since the beginning of the commitment period	–	500	67.8
Deforestation	96,355	4,818	2,910.6
Total	–	–	**–14,416.8**

Notes: Afforestation/reforestation refers to new forest established since 1 January 1990. The gross afforestation/reforestation area includes 11,749 hectares of land in transition to post-1989 forest that has subsequently been deforested. The net afforestation/reforestation area includes 1,000 hectares of new forest plantings in 2008. The 2008 areas are as at 31 December 2008. Columns may not total due to rounding.

ES.5 Improvements

In this submission, the most recent year (2008) had an estimated uncertainty for net emissions of ±9.5 per cent and ±3.8 per cent for the trend (1990–2008). This is an improvement from the 2009 submission, when the most recent year (2007) had an estimated uncertainty for net emissions of ±16.7 per cent and ±4.5 in the trend (1990–2007). The decrease in the uncertainties is largely because of improved data from the Land Use and Carbon Analysis System (LUCAS) and improved uncertainty analysis for enteric fermentation from cattle and sheep. Development of the LUCAS has reduced uncertainty for the LULUCF sector by using New Zealand-specific emission and removal factors, and has used spatial data mapped specifically for the Climate Change Convention and Kyoto Protocol reporting. Details of LUCAS are included in chapter 7.

Further improvements made to the estimates reported in this inventory since the 2009 submission are summarised in chapter 10. 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.

ES.6 National registry

At the beginning of the calendar year 2009, New Zealand's national registry held 309,444,733 assigned amount units, 120,000 emissions reduction units and 10,108 certified emission reduction units. At the end of 2009, there were 308,377,715 assigned amount units, 48,098 emission reduction units and 10,108 certified emission reduction units.

New Zealand's national registry did not hold any temporary certified emission reduction units and long-term certified emissions reduction units during 2009.

The transactions made to New Zealand's national registry during 2009 are summarised below:

- 1,000 assigned amount units were added to New Zealand's national registry and 1,068,018 were subtracted. The only addition was acquired from the United

Kingdom of Great Britain and Northern Ireland and the greatest subtraction was 540,281 units to Norway.

- 496,567 emission reduction units were added to New Zealand's national registry and 568,469 were subtracted. The only addition was a New Zealand verified project under Article 6 of the Kyoto Protocol. There were no external additions. The greatest subtraction was 240,000 emission reduction units to the Netherlands and 5,000 emission reduction units were transferred internally within New Zealand's national registry.
- 401,000 certified emission reduction units were added to New Zealand's national registry and 401,000 were subtracted. The greatest addition was 400,500 certified emission reduction units from Switzerland. The only subtraction was made to the United Kingdom of Great Britain and Northern Ireland. There were no internal transactions.
- There were no transactions of removal units, temporary certified emission reduction units and long-term certified emissions reduction units.

During 2009, no Kyoto Protocol units were expired, replaced or cancelled.

Contents

Tables

Figures

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 (human activities), 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 took effect on 21 March 1994 and has been signed and ratified by 188 nations, including New Zealand.

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. The Climate Change Convention requires Parties to monitor 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, 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[1] (developed countries) commit to providing financial assistance to non-Annex I Parties.

[1] 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[2] Parties that ratified the Climate Change Convention also agreed to non-binding targets to reduce greenhouse gas emissions to 1990 levels by the year 2000.

Only a few Annex I Parties made appreciable progress towards achieving their targets. The international community recognised that the Climate Change Convention alone was 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.

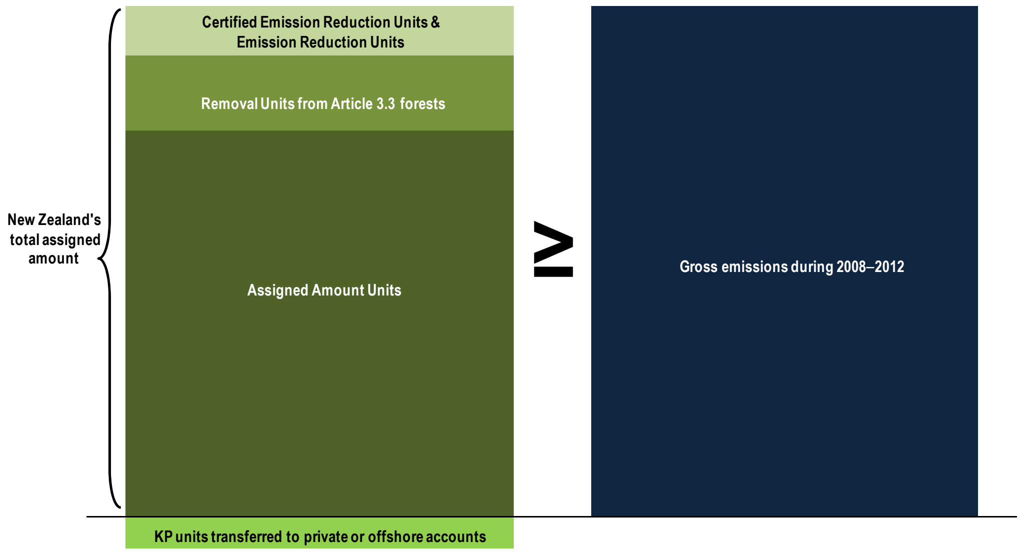
1.1.2 The Kyoto Protocol

The Kyoto Protocol shares and strengthens 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 that average annual emissions over the first commitment period are less than or equal to emissions in 1990.

A Party with a commitment under the Kyoto Protocol (as listed in Annex B of the Kyoto Protocol) must hold sufficient assigned amount to cover the total emissions during the first commitment period. A Party's assigned amount comprises assigned amount units, removal units from Article 3.3 or 3.4 activities under 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). Parties incur a 130 per cent penalty during any future commitment period if, during the first commitment period, they do not hold enough assigned amount to cover their total emissions. The Kyoto Protocol compliance equation for the first commitment period is simplified in Figure 1.1.1.

[2] 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).

Figure 1.1.1 The compliance equation under Article 3.1 of the Kyoto Protocol for the first commitment period (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 emitted in 1990 multiplied by five. These units are assigned amount units. 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. Removal units must be cancelled for any harvesting and deforestation emissions.

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

- Afforestation is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of seed sources.
- Reforestation is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that 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.
- Deforestation is the direct human-induced conversion of forested land to non-forested land.

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

1.1.3 The inventory

New Zealand's greenhouse gas inventory is the official annual report of all anthropogenic emissions and removals of greenhouse gases in New Zealand. The inventory measures progress against New Zealand's obligations under the Climate Change Convention and Kyoto Protocol.

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 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 New Zealand's total emissions under the Climate Change Convention and are accounted for under the Kyoto Protocol. The gases are reported under six sectors: energy, industrial processes, solvent and other product use, agriculture, 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 with the annual greenhouse gas inventory submission. The supplementary information is included in Part II of this submission.

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 14).

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'. The Climate Change Response Act 2002 specifies the primary functions of the inventory agency, are to:

- estimate annually New Zealand's anthropogenic emissions by sources and removals by sinks of greenhouse gases
- prepare the following reports for the purpose of discharging New Zealand's obligations:
  - 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
  - New Zealand's national communication (or periodic report) under Article 7.2 of the Kyoto Protocol and Article 12 of the Climate Change Convention
  - 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.

In carrying out its functions, the inventory agency must:

- identify source categories
- collect data by means of:
  - voluntary collection
  - collection from government agencies and other agencies that hold relevant information
  - collection in accordance with regulations made under this Part (if any)
- estimate the emissions and removals by sinks for each source category
- undertake assessments on uncertainties
- undertake procedures to verify the data
- retain information and documents to show how the estimates were determined.

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

1.2.2 Inventory agency and the national system

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.

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 Economic Development now also conducts the *Delivery of Petroleum Fuels by Industry*

Survey, previously administrated by Statistics New Zealand. 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 Agriculture and Forestry compiles the agriculture sector. Estimates are underpinned by the research and modelling of researchers 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 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 census and surveys. Statistics New Zealand also provides statistics on fuel consumption through the *Quarterly Statistical Return of Coal Production and Sales*. Population census data from Statistics New Zealand is used in the waste, and solvent and other product use sectors.

The Climate Change Response Act 2002 (updated 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 supplementary 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 15 months in arrears 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 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 on the Ministry for the Environment's central computer network in a controlled file system. The inventory is available from the websites of the Ministry for the Environment and the Climate Change Convention.

New Zealand is required to have a national system in place for its greenhouse gas inventory under Article 5.1 of the Kyoto Protocol. 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.

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.

Energy (chapter 3): Emissions from the energy sector are calculated using the IPCC Tier 1 approach. Activity data is compiled from industry-supplied information by the Ministry of Economic Development and Statistics New Zealand. 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 assessed via 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 insignificant 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.

New Zealand has established a data collection and modelling programme for the LULUCF sector called the Land Use and Carbon Analysis System (LUCAS) (see www.mfe.govt.nz/issues/climate/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, 2008); wall-to-wall land-use mapping for 1990 and 2008 using satellite and aircraft remotely sensed imagery; 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 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 from 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.

The key categories identified in the 2008 year are summarised in Table 1.5.1. The major contributions to the level analysis including LULUCF (Table 1.5.2(a)) were CH_4 emissions from enteric fermentation (21.0 per cent), CO_2 removals from conversion to forest land (16.1 per cent) and CO_2 emissions from road transportation (11.8 per cent).

The key categories that were identified as having the largest relative influence on New Zealand's emissions trend from 1990 to 2008, including LULUCF (Table 1.5.3), were CO_2 emissions from forest land remaining forest land (42.2 per cent), CO_2 removals from conversion to forest land (29.2 per cent) and CO_2 emissions from road transportation (7.2 per cent).

Table 1.5.1 Summary of New Zealand's key categories for 2008 (including and excluding LULUCF activities)

Quantitative method used: IPCC Tier 1		
IPCC categories	**Gas**	**Criteria for identification**
Energy		
Stationary combustion - solid	CO_2	level, trend
Stationary combustion - liquid	CO_2	level
Stationary combustion - gas	CO_2	level, trend
Transport – road transportation	CO_2	level, trend
Transport – civil aviation	CO_2	level
Fugitive emissions from oil and gas operations	CO_2	level, trend
Industrial processes		
Mineral products - cement production	CO_2	level
Metal production - iron and steel production	CO_2	level
Metal production - aluminium production	PFCs	trend
Chemical industry - ammonia production	CO_2	qualitative
Consumption of halocarbons and SF_6 - refrigeration & air conditioning	HFCs & PFCs	level, trend
Agriculture		
Enteric fermentation	CH_4	level, trend
Manure management	CH_4	level
Agricultural soils - direct emissions	N_2O	level, trend
Agricultural soils – pasture, range and paddock	N_2O	level, trend
Agricultural soils – indirect emissions	N_2O	level
LULUCF		
Forest land remaining forest land	CO_2	level, trend
Conversion to forest land	CO_2	level, trend
Conversion to grassland	CO_2	level, trend
Waste		
Solid waste disposal on land	CH_4	level, trend

Table 1.5.2 (a & b) New Zealand's key category analysis for 2008 – IPCC Tier 1 level assessment including LULUCF (a) and excluding LULUCF (b)

(a) IPCC Tier 1 category level assessment - including LULUCF (net emissions)				
IPCC categories	**Gas**	**2008 estimate ($Gg\ CO_2$-e)**	**Level assessment (%)**	**Cumulative total (%)**
Enteric fermentation	CH_4	22,657.5	21.0	21.0
Conversion to forest land	CO_2	17,327.7	16.1	37.1
Transport – road transportation	CO_2	12,670.2	11.8	48.8
Forest land remaining forest land	CO_2	12,441.1	11.5	60.4
Stationary combustion – gas	CO_2	8,033.0	7.5	67.8
Agricultural soils – pasture, range and paddock	N_2O	7,125.9	6.6	74.5
Stationary combustion – solid	CO_2	6,148.4	5.7	80.2
Stationary combustion – liquid	CO_2	3,144.1	2.9	83.1
Conversion to grassland	CO_2	2,849.6	2.6	85.7
Agricultural soils – indirect emissions	N_2O	2,468.8	2.3	88.0
Agricultural soils - direct emissions	N_2O	1,777.7	1.6	89.7
Metal production - iron and steel production	CO_2	1,539.2	1.4	91.1
Solid waste disposal on land	CH_4	1,278.4	1.2	92.3
Transport – civil aviation	CO_2	942.9	0.9	93.1
Fugitive emissions from oil and gas operations	CO_2	796.4	0.7	93.9
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	727.7	0.7	94.6
Manure management	CH_4	719.5	0.7	95.2

(b) IPCC Tier 1 category level assessment - excluding LULUCF (total emissions)				
IPCC categories	**Gas**	**2008 estimate ($Gg\ CO_2$-e)**	**Level assessment (%)**	**Cumulative total (%)**
Enteric fermentation	CH_4	22,657.5	30.5	30.5
Transport – road transportation	CO_2	12,670.2	17.0	47.5
Stationary combustion – gas	CO_2	8,033.0	10.8	58.3
Agricultural soils – pasture, range and paddock	N_2O	7,125.9	9.6	67.9
Stationary combustion – solid	CO_2	6,148.4	8.3	76.1
Stationary combustion – liquid	CO_2	3,144.1	4.2	80.4
Agricultural soils – indirect emissions	N_2O	2,468.8	3.3	83.7
Agricultural soils - direct emissions	N_2O	1,777.7	2.4	86.1
Metal production - iron and steel production	CO_2	1,539.2	2.1	88.2
Solid waste disposal on land	CH_4	1,278.4	1.7	89.9
Transport – civil aviation	CO_2	942.9	1.3	91.1
Fugitive emissions from oil and gas operations	CO_2	796.4	1.1	92.2
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	727.7	1.0	93.2
Manure management	CH_4	719.5	1.0	94.2
Mineral products - cement production	CO_2	634.2	0.9	95.0

Table 1.5.3 New Zealand's key category analysis for 2008 – IPCC Tier 1 trend assessment including LULUCF (a) and excluding LULUCF (b)

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

IPCC categories	Gas	Base year estimate (Gg CO_2-e)	2008 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Forest land remaining forest land	CO_2	33034.12	12441.13	0.204	42.2	42.2
Conversion to forest land	CO_2	166.24	17327.74	0.141	29.2	71.4
Transport – road transportation	CO_2	7500.22	12670.17	0.035	7.2	78.6
Stationary combustion – solid	CO_2	3139.65	6148.38	0.022	4.5	83.0
Enteric fermentation	CH_4	21837.22	22657.49	0.016	3.3	86.3
Conversion to grassland	CO_2	1114.80	2849.61	0.013	2.7	89.0
Solid waste disposal on land	CH_4	2063.21	1278.45	0.009	1.8	90.8
Agricultural soils - direct emissions	N_2O	515.17	1777.67	0.010	2.0	92.9
Consumption of halocarbons and SF_6 - refrigeration and air conditioning	HFCs & PFCs	0.00	727.74	0.006	1.2	94.1
Metal production - aluminium production	PFCs	629.87	36.47	0.006	1.1	95.2

(b) IPCC Tier 1 category trend assessment - excluding LULUCF (total emissions)

IPCC categories	Gas	Base year estimate (Gg CO_2-e)	2008 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation	CH_4	21837.22	22657.49	0.045	23.7	23.7
Transport – road transportation	CO_2	7500.22	12670.17	0.038	20.3	44.0
Stationary combustion – solid	CO_2	3139.65	6148.38	0.025	13.4	57.5
Agricultural soils – pasture, range and paddock	N_2O	6858.75	7125.90	0.014	7.4	64.9
Solid waste disposal on land	CH_4	2063.21	1278.45	0.014	7.3	72.1
Agricultural soils - direct emissions	N_2O	515.17	1777.67	0.013	6.7	78.8
Stationary combustion – gas	CO_2	7306.82	8033.04	0.010	5.3	84.1
Metal production - aluminium production	PFCs	629.87	36.47	0.008	4.3	88.4
Consumption of halocarbons and SF_6 - refrigeration and air conditioning	HFCs & PFCs	0.00	727.74	0.008	4.2	92.6
Fugitive emissions from oil and gas operations	CO_2	230.14	796.37	0.006	3.0	95.6

1.5.2 KP-LULUCF activities

The LULUCF categories identified as key (level assessment) under the Climate Change Convention in the 2008 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 2010 inventory submission are discussed in sections 1.6.1 and 1.6.2 below.

1.6.1 Quality control

For this submission, the completion of the IPCC (2000) Tier 1 quality-control check sheets for each sector was the responsibilities of the leading agency. The national inventory complier was provided with common reporting format databases 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 2008 inventory year were checked.

All sector-level data was entered into the common reporting format database by February 2009. This deadline allowed two months for the agencies leading each sector to complete their own quality-control activities.

Data in the common reporting format database was 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 inventory system is progressively improving its quality-assurance system to ensure risks are lowered at all stages of the inventory compilation process. In 2008, KMPG, a professional services firm, developed a risk register to highlight potential risks in the inventory data compilation process. The Ministry for the Environment will continue to use the risk register to assist in prioritising further improvements to the inventory.

A cross-government reporting governance group has been established to provide leadership over reporting and projections of greenhouse gas emissions and removals. The reporting governance group will enhance consistency, coordination, timeliness and risk management of reporting information and processes. The scope of the group includes New Zealand's national greenhouse gas inventory, projections reporting for the Kyoto Protocol and beyond, New Zealand's national system for reporting under the Kyoto Protocol and quantitative analysis of emissions and removals supporting policy formation. Meetings are held monthly. Further information is included in chapter 13.

For this submission, other improvements to quality assurance were made, particularly to the agriculture and LULUCF sectors. New Zealand established an independent agricultural inventory advisory panel to assess whether proposed changes to the agriculture sector can be accepted. Reports and/or papers on proposed changes must be independently peer reviewed before they are presented to the panel. The panel assesses if the proposed changes have been rigorously tested and if there is sufficient scientific evidence to support the change. The panel advises the Ministry of Agriculture and Forestry of their recommendations. Refer to section 6.1.1 for further details.

In 2009, New Zealand contracted a LULUCF expert reviewer to perform an independent peer review of the LULUCF sector and Article 3.3 activities under the Kyoto Protocol for this submission. The review found that New Zealand's LULUCF sector reporting is on track to meet the Climate Change Convention requirements in relation to the five key inventory principles (transparency, comparability, completeness, consistency and accuracy), and confirmed that the LUCAS methodology and general approach are consistent with IPCC good practice guidance. The review made a number of suggestions for improvements to the 2010 submission, and highlighted areas for future improvement to further enhance the accuracy and completeness of the LULUCF sector. These recommendations were either addressed, or have been identified as future improvements to the LUCAS programme.

The technical competence of key contributors to the inventory has been increased. Four government officials have passed their expert review exams under the Climate Change

Convention for the energy, agriculture, waste, and land use, land-use change and forestry sectors. Three other government officials, already expert reviewers under the Climate Change Convention, passed their mandatory Kyoto Protocol exams.

A list of previous quality-assurance reviews, their major conclusions and follow up 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 energy and agriculture activity data provided by Statistics New Zealand is subject to its own rigorous quality-assurance and control procedures on the data.

1.6.3 Verification activities

Where relevant in a sector, verification activities are discussed under the appropriate section.

1.6.4 Treatment of confidentiality issues

Confidential issues largely apply to sources of emissions in the energy and industrial processes sectors and are therefore discussed under the relevant sections of chapters 3 and 4.

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. This was an in-country review held from 19–24 February 2007. The 2007 and 2008 inventory submissions were reviewed during a centralised review in September 2008. The 2009 inventory submission was reviewed in September 2009. In all instances, the reviews were conducted by an international team of experts review team 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:

- "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.
- 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.
- 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.

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 following 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 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 by expert judgement from sectoral or industry experts, or by referring to uncertainty ranges quoted in the IPCC documentation. 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 2008 inventory.

Total emissions

Uncertainty in 2008

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) is ±12.9 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 11.3 per cent and 4.9 per cent respectively of New Zealand's total emissions and removals uncertainty in 2008. 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 CH_4 emissions per unit of dry-matter.

The improved uncertainty analysis for enteric fermentation from cattle and sheep was based on Kelliher et al (2009). Previous analysis expressed the coefficient of variation according to the standard deviation of the methane yield. Kelliher et al (2009) calculated the uncertainty by expressing the coefficient of variation according to the standard error of the methane yield (section 6.2.3).

Uncertainty in the trend

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) in the trend is ±4.1 per cent. In the 2009 submission, the most recent year (2007) had an estimated uncertainty for total emissions of ±20.6 per cent and ±5.5 in the trend (1990–2007). The decrease in the uncertainties is largely due to the improved uncertainty analysis for enteric fermentation (section 6.2.3).

Net emissions

Uncertainty in 2008

The calculated uncertainty for New Zealand's net inventory (including emissions and removals from the LULUCF sector) in 2008 is ±9.5 per cent. Removals of CO_2 from forest land were a major contribution to the uncertainty for 2008 at 3.0 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 2008 is ±3.8 per cent. The greatest contributor to the uncertainty in the trend for the net inventory is CO_2 removals from forest land accounting for 2.6 per cent. Carbon dioxide emissions from the energy sector contributed 2.4 per cent to the uncertainty in the trend for the net inventory. The large uncertainty in energy is due to the activity data having greater uncertainty than the energy emission factors.

In the 2009 submission, the most recent year (2007) had an estimated uncertainty for net emissions of ±16.7 per cent and ±4.5 in the trend (1990–2007). The decrease in the uncertainties is largely due to improved data from LUCAS and improved uncertainty analysis for enteric fermentation from cattle and sheep. Development of the LUCAS has reduced uncertainty for the LULUCF sector by using New Zealand-specific emission and removal factors, and has used spatial data mapped specifically for the Climate Change Convention and Kyoto Protocol reporting. Details of LUCAS are included in chapter 7.

1.7.2 KP-LULUCF

The combined uncertainty for emissions from afforestation and reforestation activities in 2008 was ±12.0 per cent. In 2008, the combined uncertainty for natural forest deforestation was ±6.8 per cent, ±19.5 for deforestation of pre-1990 forests and ±12.0 per cent for the deforestation of post-1989 forests.

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 1990–2008 is complete. In accordance with good practice guidance (IPCC, 2000), New Zealand has focused its resources for inventory development on 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).

1.8.2 KP-LULUCF

New Zealand has accounted for all carbon pools for Article 3.3 activities under the Kyoto Protocol. The carbon in organic soils, however, has been calculated as for mineral soils.

The reasons for this are that New Zealand uses a Tier 2 methodology to estimate soil carbon stock, using New Zealand-specific land-use and soil pedon data (Scott et al, 2002). The resulting peer-reviewed Soil Carbon Monitoring System does not estimate carbon stock or carbon changes for organic soils, as it calculates concentration within a fixed depth rather than total organic carbon mass (Tate et al, 2005).

Approximately 0.9 per cent of New Zealand's land area has organic soils, and between 1 January 1990 and 1 January 2008, 2,560 hectares of land with organic soils underwent land-use change. This represents 0.3 per cent of the total area of land-use change. New Zealand has reported organic soils as mineral soils in the reporting of soil carbon, and has used the notation key IE ('included elsewhere') for organic soils in the common reporting format tables. See section 7.1.2 for further detail.

Chapter 2: Trends in greenhouse gas emissions

2.1 Emission trends for aggregated greenhouse gas emissions

Total (gross) emissions

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

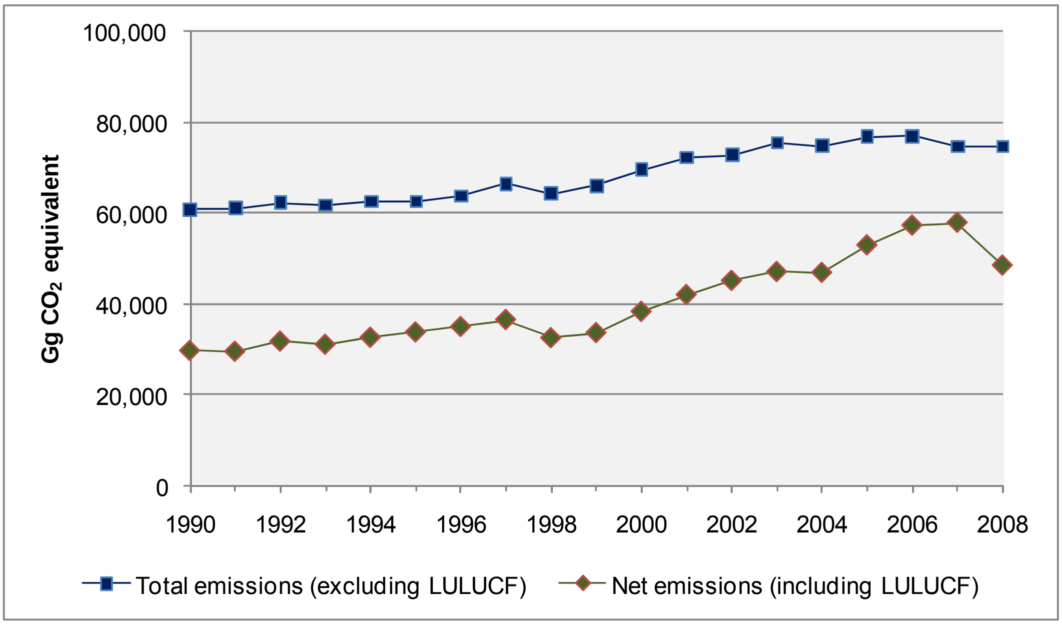
In 1990, New Zealand's total greenhouse gas emissions were 60,773.6 Gg carbon dioxide equivalent (CO_2-e). In 2008, total greenhouse gas emissions had increased by 13,885.1 Gg CO_2-e (22.8 per cent) to 74,658.7 Gg CO_2-e (Figure 2.1.1). Between 1990 and 2008, the average annual growth in total emissions was 1.3 per cent per year.

New Zealand's total emissions trend is different from many other countries. Instead of a predictable increase or decline in emissions, the trend for New Zealand consists of year-to-year fluctuations (Figure 2.1.1). These fluctuations are due to two main factors. The first is the change in proportion of non-renewable energy used in electricity and heat production affecting CO_2 emissions. The second factor is the effect of droughts on agriculture productivity and livestock numbers affecting nitrous oxide (N_2O) and methane (CH_4) emissions.

Net emissions

Net emissions include those from the energy, industrial processes, solvent and other product use, and waste sectors and emissions and removals from the LULUCF sector. In 1990, New Zealand's net greenhouse gas emissions were 29,707.3 Gg CO_2-e. In 2008, net greenhouse gas emissions had increased by 18,774.6 Gg CO_2-e (63.2 per cent) to 48,482.0 Gg CO_2-e (Figure 2.1.1). The increase in net emissions between 1990 and 2008 is larger than for total emissions because the net removals from LULUCF were greater in 1990 than in 2008.

Figure 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2008



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. The initial assigned amount is five times the total emissions reported in the 1990 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 different (1.8 per cent) from the 1990 level of 61,893.0 Gg CO_2-e used in the initial assigned amount calculation.

In 2008, net removals from land subject to afforestation, reforestation and deforestation were –14,416.8[3] Gg CO_2-e. Removals from afforestation and reforestation were –17,327.4 Gg CO_2-e. Deforestation emissions were 2,910.6 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 2008. Figure 2.2.1 shows New Zealand's 2008 total emissions profile by gas. The change in the six gases between 1990 and 2008 is shown in Figure 2.2.2. The change in CO_2, CH_4 and N_2O emissions since 1990 over the period 1990–2008 is shown in Figure 2.2.3.

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

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

dioxide (SO_2), oxides of nitrogen (NO_X), and non-methane volatile organic compounds (NMVOCs).

Carbon dioxide

Carbon dioxide contributed the largest share to total emissions in 2008 at 36,063.2 Gg CO_2 (48.3 per cent). Carbon dioxide emissions increased 11,169.9 Gg CO_2 (44.9 per cent) from the 1990 level of 24,893.3 Gg CO_2. The growth in CO_2 emissions from 1990 and 2008 represented the increased emissions from the energy and industrial processes sectors, particularly in road transport and electricity and heat production.

Between 2007 and 2008, CO_2 emissions increased 829.7 Gg CO_2 (2.4 per cent). This increase is primarily due to an increase in emissions from public electricity and heat production due to low hydro inflows for 2008, that is, 2008 was a low rainfall year. Low hydro inflows increase thermal electricity generation. Public electricity and heat production emissions also rose in 2008 due to increased use of coal in electricity generation.

Removals of CO_2 by forest sinks are reported in the LULUCF sector under the Climate Change Convention (chapter 7). Kyoto Protocol Article 3.3 activities (afforestation, reforestation and deforestation) are reported in the supplementary Kyoto Protocol tables (chapter 11).

Methane

Methane contributed 25,816.2 Gg CO_2-e (34.6 per cent) to total emissions in 2008. Methane emissions have increased by 359.8 Gg CO_2-e (1.4 per cent) from the 1990 level of 25,456.4 Gg CO_2-e. Between 2007 and 2008, CH_4 emissions decreased 618.6 Gg CO_2-e (2.3 per cent). This was largely due to a decrease in the population of sheep, deer and non-dairy cattle as a result of the drought that affected most of New Zealand throughout 2008 (Ministry of Agriculture and Forestry, 2009).

Nitrous oxide

Nitrous oxide contributed 11,913.4 Gg CO_2-e (16.0 per cent) to total emissions in 2008. Emissions increased by 2,134.6 Gg CO_2-e (21.8 per cent) from the 1990 level of 9,778.9 Gg CO_2-e. The growth in N_2O is from the increase in emissions from animal excreta and an increase in the use of nitrogenous fertilisers in the agriculture sector. There has been a five-fold increase in the amount of synthetic fertiliser nitrogen applied to soils from 1990 to 2008.

Between 2007 and 2008, emissions of nitrous oxide decreased 162.0 Gg CO_2-e (1.3 per cent). This decrease can also be attributed to the widespread drought through 2008 affecting livestock numbers. Nitrous oxide emissions from the agriculture sector decreased 156.3 Gg CO_2-e (1.3 per cent).

Hydrofluorocarbons, PFCs and SF_6

Hydrofluorocarbons, PFCs and SF_6 contributed the remaining 865.9 Gg CO_2-e (1.2 per cent) to total emissions in 2008.

In 1990, no HFCs were used in New Zealand and therefore no percentage is shown in Table 2.2.1 and Figure 2.2.1. In 2008, 812.5 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 591.1Gg CO_2-e (93.8 per cent) from the 629.9 Gg CO_2-e in 1990, to 38.8 Gg CO_2-e in 2008. This decrease is due to improvements in the aluminium smelting process.

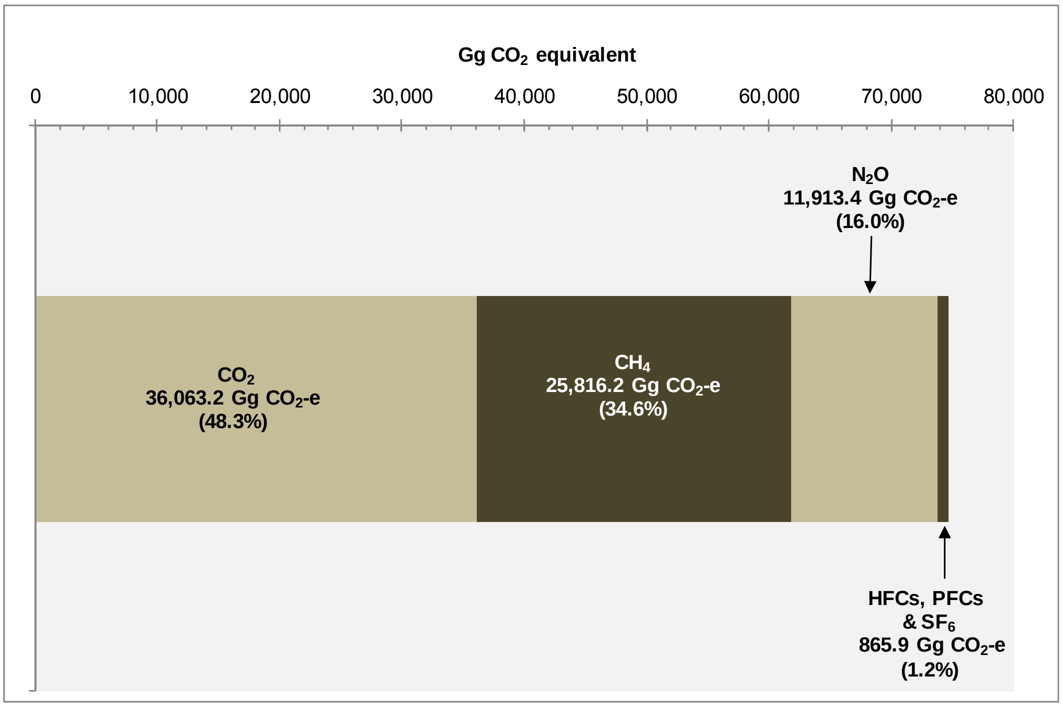
Emissions of SF_6 have decreased 0.7 Gg CO_2-e (4.3 per cent), from the 1990 level of 15.2 Gg CO_2-e to the 2008 level of 14.5 Gg CO_2-e.

Table 2.2.1 New Zealand's greenhouse gas emissions by gas in 1990 and 2008

Direct greenhouse gas emissions	Gg CO_2-equivalent 1990	Gg CO_2-equivalent 2008	Change from 1990 (Gg CO_2-equivalent)	Change from 1990 (%)
CO_2	24,893.3	36,063.2	+11,169.9	+44.9
CH_4	25,456.4	25,816.2	+359.8	+1.4
N_2O	9,778.9	11,913.4	+2,134.6	+21.8
HFCs	NO	812.5	+812.5	NA
PFCs	629.9	38.8	–591.0	–93.8
SF_6	15.2	14.5	–0.7	–4.3
Total	**60,773.6**	**74,658.7**	**+13,885.1**	**+22.8**

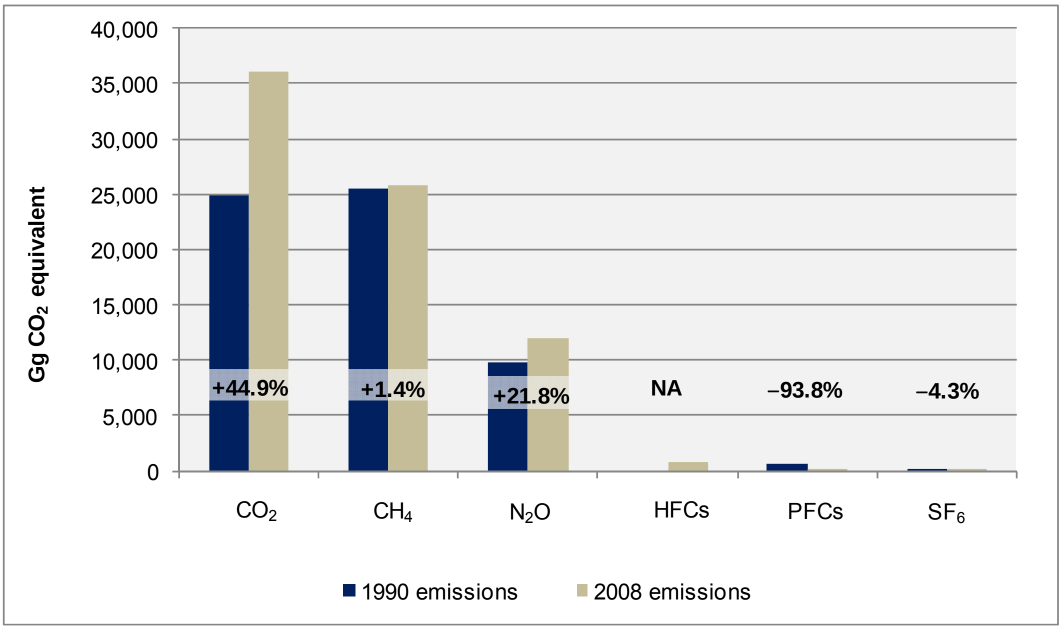
Notes: Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF. The per cent change for hydrofluorocarbons is not applicable (NA) as production of hydrofluorocarbons in 1990 was not occurring (NO). Although there may be rounding errors in this table, the figures are consistent with estimates reported in the common reporting format tables.

Figure 2.2.1 New Zealand's total emissions by gas in 2008



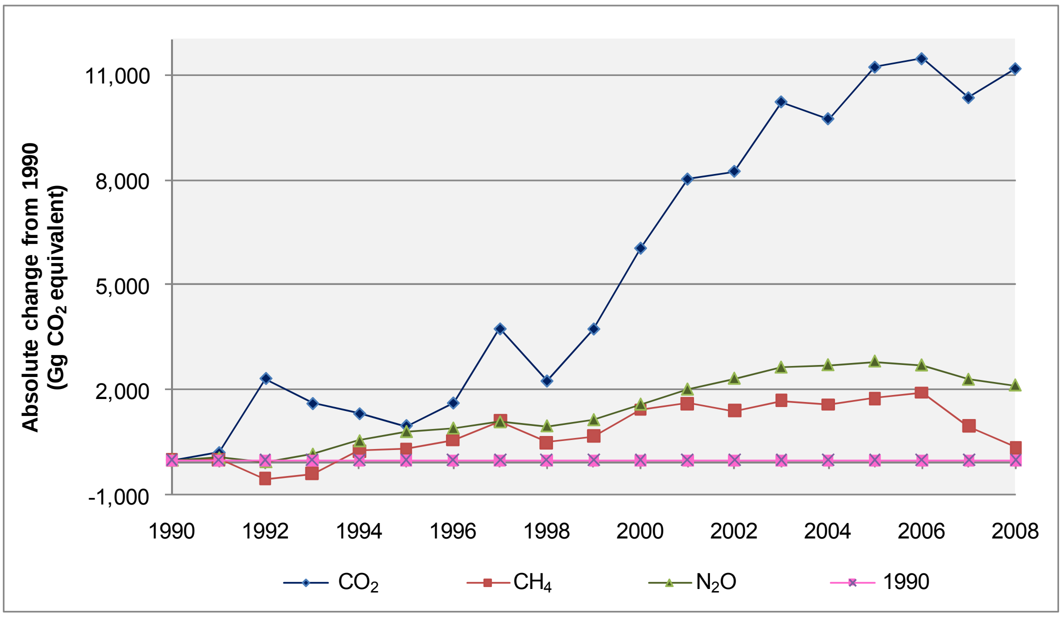
Note: Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF.

Figure 2.2.2 Change in New Zealand's emissions by gas from 1990 to 2008



Notes: The per cent change for hydrofluorocarbons is not applicable (NA) as there was no production of hydrofluorocarbons in 1990. Carbon dioxide, CH_4 and N_2O values exclude emissions and removals from LULUCF.

Figure 2.2.3 Change from 1990 in New Zealand's emissions of CO_2, CH_4 and N_2O from 1990 to 2008



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

2.3 Emission trends by source

Energy (chapter 3)

The energy sector was the source of 33,838.8 Gg CO_2-e (45.3 per cent) of total emissions in 2008. In 2008, energy emissions had increased by 10,796.1 Gg CO_2-e (46.9 per cent) from the 1990 level of 23,042.7 Gg CO_2-e. This growth in emissions is primarily from the electricity generation, heat production and transport categories.

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2008 calendar year, hydro generation provided 52 per cent of New Zealand's electricity generation. Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990–2008. These fluctuations can also be seen over the time series for New Zealand's total emissions. The fluctuations are caused by switching between thermal and hydro generation (Figure 3.3.2). Drought years increase the reliance on thermal electricity generation.

Between 2007 and 2008, emissions from the energy sector increased by 1,185.2 Gg CO_2-e (3.6 per cent). This is primarily due to a 987.3 Gg CO_2-e (14.8 per cent) increase in emissions from public electricity and heat production due to low hydro inflows for 2008. Public electricity and heat production emissions also rose in 2008 due to the increased use of coal in electricity generation.

An increase of 368.2 Gg CO_2-e (6.9 per cent) in the manufacturing industries and construction category between 2007 and 2008, also contributed to the increase in energy emissions. However, these increases were in part offset by a 623.7 Gg CO_2-e (4.2 per cent) decrease in the transport category due to the high petrol and diesel prices in 2008, and the beginning of the global recession.

Industrial processes (chapter 4)

The industrial processes sector accounted for 4,292.0 Gg CO_2-e (5.7 per cent) of total emissions in 2008. Emissions from the industrial processes sector increased 906.2 Gg CO_2-e (26.8 per cent) from the 1990 level of 3,385.8 Gg CO_2-e. This increase was mainly caused by growth in emissions from the consumption of hydrofluorocarbons.

Between 2007 and 2008, emissions from the industrial processes sector decreased by 344.6 Gg CO_2-e (7.4 per cent). The largest decrease of 183.3 Gg CO_2-e (8.1 per cent) was due to a reduction in emissions from steel and aluminium production.

Between 2007 and 2008, emissions from the consumption of halocarbons and SF_6 category decreased by 105.3 Gg CO_2-e (11.3 per cent.) This was caused by reduced sales of new refrigerant (including halocarbons imported in bulk and in equipment, excluding exports). There was also a reduction in the amount of HFC-134a sold to the mobile air conditioning industry.

Solvent and other product use (chapter 5)

In 2008, the solvent and other product use sector was responsible for 31.0 Gg CO_2-e (0.04 per cent) of total emissions.

Agriculture (chapter 6)

The agriculture sector was the largest source of emissions in 2008, contributing 34,826.3 Gg CO_2-e (46.6 per cent) of total emissions (Table 2.3.1 and Figure 2.3.1). Consequently, New Zealand has a unique emissions profile. In other developed countries, agricultural emissions are typically less than 10 per cent of total emissions. In 2008, New Zealand's agricultural emissions increased by 2,960.9 Gg CO_2-e (9.3 per cent) from the 1990 level of 31,865.4 Gg CO_2-e (Figure 2.3.2). The change in emissions since 1990 is shown in Figure 2.3.3. The agriculture sector contributed 11,434.1 Gg CO_2-e (96.0 per cent) of New Zealand's total N_2O emissions and 23,392.2 Gg CO_2-e (90.6 per cent) of total CH_4 emissions in 2008.

Between 2007 and 2008, emissions from the agriculture sector decreased 737.1 Gg CO_2-e (2.1 per cent) (Figure 2.3.3). This was largely due to a decrease in the population of sheep (4,372,613 head or 11.4 per cent), deer (172,699 head or 12.4 per cent) and non-dairy cattle (256,745 head or 5.8 per cent). The drought that affected most of New Zealand throughout 2008 was the main cause for these decreases in animal numbers (Ministry of Agriculture and Forestry, 2009). This was the second year in a row drought affected some regions of New Zealand.

LULUCF (chapter 7)

Net removals from the LULUCF sector under the Climate Change Convention were estimated to be –26,176.8 Gg CO_2-e in 2008, and have decreased by 4,889.5 Gg CO_2-e (15.7 per cent) from the 1990 level of –31,066.3 Gg CO_2-e. This decrease is largely due to the harvesting and replanting of plantation forests in the five years prior to 2008 as this lowered the average age and therefore the CO_2 absorption capacity of planted forests in 2008. The decrease is also due to an increase in emissions from deforestation.

Waste (chapter 8)

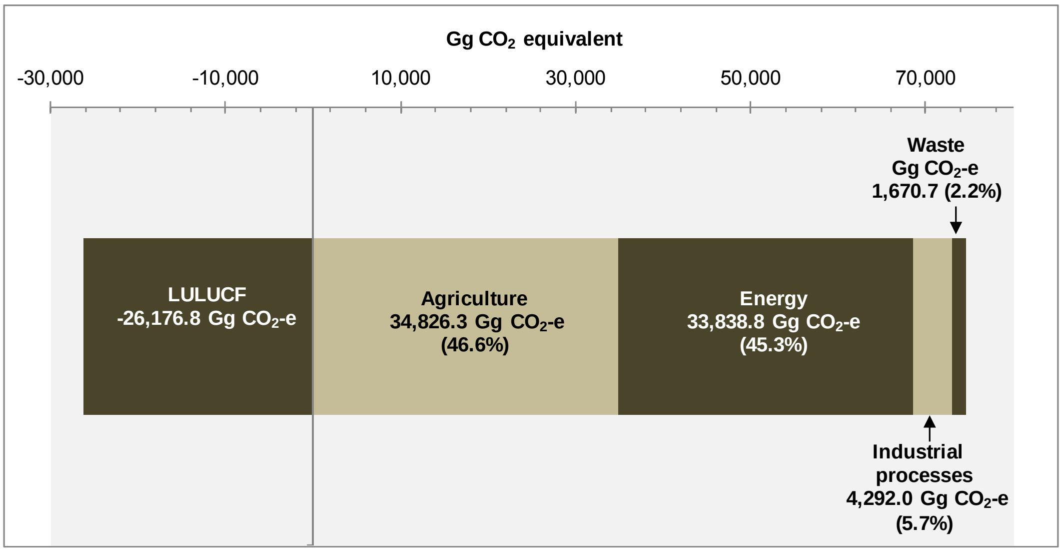
The waste sector accounted for 1,670.7 Gg CO_2-e (2.2 per cent) of total emissions in 2008. Emissions from the waste sector had decreased by 767.5 Gg CO_2-e (31.5 per cent) from the 1990 level of 2,438.2 Gg CO_2-e. This decrease was largely due to initiatives to improve solid waste management practices.

Table 2.3.1 New Zealand's emissions by sector in 1990 and 2008

	Gg CO_2-equivalent		Change from 1990 (Gg CO_2-equivalent)	Change from 1990 (%)
Sector	**1990**	**2008**		
Energy	23,042.7	33,838.8	+10,796.1	+46.9
Industrial processes	3,385.8	4,292.0	+906.2	+26.8
Solvent and other product use	41.5	31.0	–10.5	–25.4
Agriculture	31,865.4	34,826.3	+2,960.9	+9.3
Waste	2,438.2	1,670.7	–767.5	–31.5
Total (excluding LULUCF)	**60,773.6**	**74,658.7**	**+13,885.1**	**+22.8**
LULUCF	–31,066.3	–26,176.8	+4,889.5	+15.7
Net Total (including LULUCF)	**29,707.3**	**48,482.0**	**+18,774.6**	**+63.2**

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). Although there may be rounding errors in this table, the figures are consistent with estimates reported in the common reporting format tables.

Figure 2.3.1 New Zealand's emissions by sector in 2008



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). Although there may be rounding errors, the figures are consistent with estimates reported in the common reporting format tables.

Figure 2.3.2 Change in New Zealand's emissions by sector from 1990 to 2008

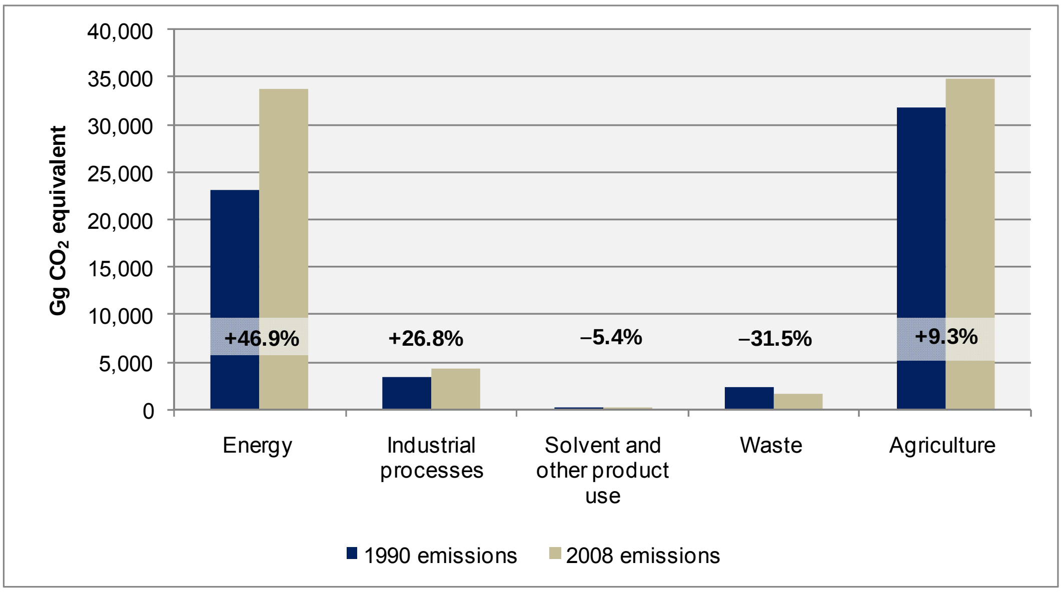
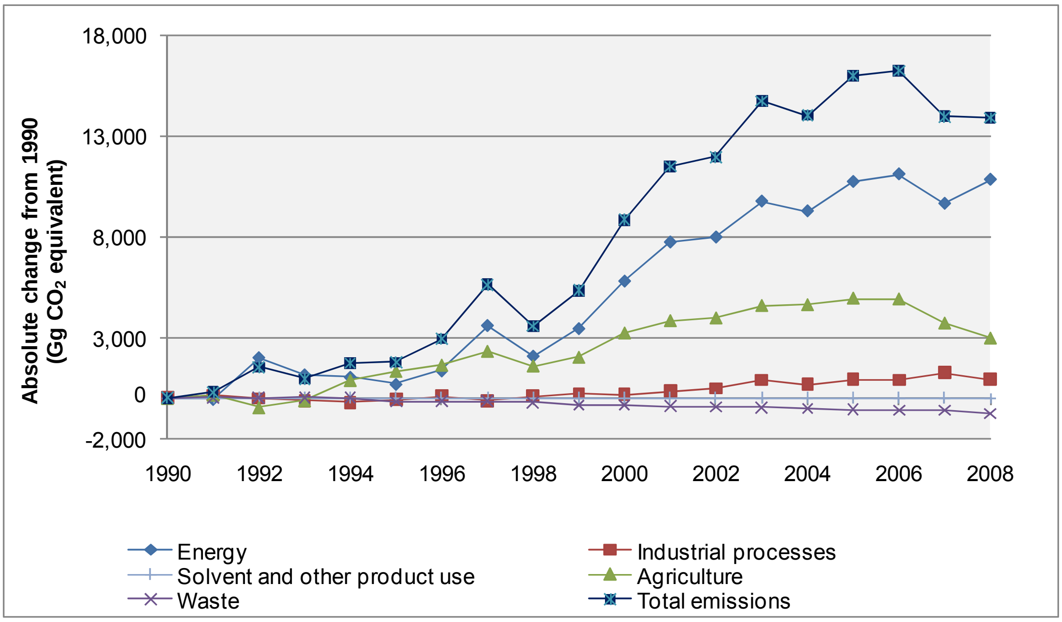


Figure 2.3.3 **Change from 1990 in New Zealand's emissions by sector from 1990 to 2008**



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

2.4 Emission trends for indirect greenhouse gases and SO_2

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 2008 are shown in Table 2.4.1. 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 2008

Indirect gas	Gg of gas(es) 1990	Gg of gas(es) 2008	Change from 1990 (Gg)	Change from 1990 (%)
NO_x	102.0	162.1	+60.1	+58.9
CO	628.2	717.5	+89.3	+14.2
NMVOCs	134.2	171.3	+37.1	+27.6
SO_2	56.4	79.9	+23.5	+41.7
Total	**920.7**	**1,130.7**	**+209.9**	**+22.8**

Note: Although there may be rounding errors in this table, the figures are consistent with estimates reported in the common reporting format tables.

Emissions of CO and NO_x are largely from the energy sector. The energy sector produced 90.5 per cent of total CO emissions in 2008. 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 (98.4 per cent), with the road transportation subcategory dominating. Other large sources of NO_x emissions were from the manufacturing industries, construction and energy industries subcategories.

The energy sector was also the largest producer of NMVOCs, producing 72.8 per cent of NMVOC emissions in 2008. Emissions from road transportation comprised 60.2 per cent of total NMVOC emissions. Other major sources of NMVOCs were in the solvent and other product use sector (20.3 per cent) and the industrial processes sector (6.9 per cent).

In 2008, emissions of SO_2 from the energy sector comprised 86.5 per cent of total SO_2 emissions. The energy industries category contributed 24.7 per cent, manufacturing industries and construction 28.3 per cent, and the transport category 15.7 per cent, of total SO_2 emissions. The industrial processes sector contributed 13.5 per cent of total SO_2 emissions. Aluminium production accounted for 7.9 per cent of SO_2 emissions.

2.5 Article 3.3 activities under the Kyoto Protocol

For reporting under Article 3.3 of the Kyoto Protocol, New Zealand has chosen to categorise its forests into three subcategories: natural forest, pre-1990 planted forest and post-1989 forest. These three subcategories are also used for reporting the LULUCF sector under the Climate Change Convention (chapter 7). All forest land that existed at 31 December 1989 is included as either natural forest or pre-1990 planted forest. For these forests, only emissions from deforestation activities are reported. For the post-1989 forests, emissions and removals from carbon losses and gains due to afforestation, reforestation and deforestation are reported for the first year of the commitment period.

Carbon dioxide emissions associated with biomass burning are captured by, and reported under, the general carbon stock change calculation for forests. This is because there is no reduction in the carbon stock made for areas burnt prior to forest harvesting or deforestation.

New Zealand's afforestation, reforestation and deforestation estimates do not include:

- liming of afforested and reforested land because this activity does not occur
- 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 fertiliser use on deforested land because these are reported in the agriculture sector.

Total emissions and removals from Article 3.3 activities (section 11.1)

For 2008, net removals from land subject to afforestation, reforestation and deforestation were –14,416.8 Gg CO_2-e (Table 2.5.1). This value includes removals from the growth of post-1989 forests and emissions from the conversion of land to post-1989 forest, harvesting of post-1989 forests, deforestation of all forest, and emissions from the disturbance associated with land-use conversion to cropland, liming and biomass burning. A detailed analysis of 2008 emissions and removals shows:

- the total net CO_2 removals based on carbon stock change were –14,417.3 Gg CO_2
- nitrous oxide emissions from disturbance associated with land-use conversion to cropland were 0.3 Gg CO_2-e
- carbon dioxide emissions from lime application of deforested land are estimated at 0.7 Gg CO_2
- methane emissions from the burning of biomass on afforestation/reforestation land were 0.3 Gg CO_2-e and N_2O emissions were 0.02 Gg CO_2-e.

Afforestation and reforestation

During 2008, a gross area of 1,000 hectares of post-1989 forest was established. Between 1990 and 2008, it is estimated that a gross area of 580,524 hectares of post-1989 forest was established as a result of afforestation and reforestation activities. The gross area includes 11,749 hectares of land in transition to post-1989 forest that has subsequently been deforested. The net area of post-1989 forest as at 31 December 2008 was 568,775 hectares. The net area is the total area of post-1989 forest minus deforestation since 1 January 1990.

Deforestation

During 2008, 4,818 hectares of all forest (natural forest, pre-1990 planted forest and post-1989 forest), equivalent to emissions of 2,910.6 Gg CO_2-e, was deforested. Deforestation of all forests in 2008 has decreased from the 2007 level of 18,151 hectares, equivalent to 13,115.6 Gg of CO_2.

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

Source	Gross area (ha) 1990–2008	Net area (ha) 2008	Emissions in 2008 (Gg CO_2-e)
Afforestation/reforestation	580,524	568,775	–17,327.4
Forest land not harvested since the beginning of the commitment period	–	568,274	–17,395.1
Forest land harvested since the beginning of the commitment period	–	500	67.8
Deforestation	96,355	4,818	2,910.6
Total	–	–	**–14,416.8**

Notes: Afforestation/reforestation refers to new forest established since 1 January 1990. The gross afforestation/reforestation area includes 11,749 hectares of land in transition to post-1989 forest that has subsequently been deforested. The net afforestation/reforestation area includes 1,000 hectares of new forest plantings in 2008. The 2008 areas are as at 31 December 2008. Columns may not total due to rounding.

Chapter 3: Energy

3.1 Sector overview

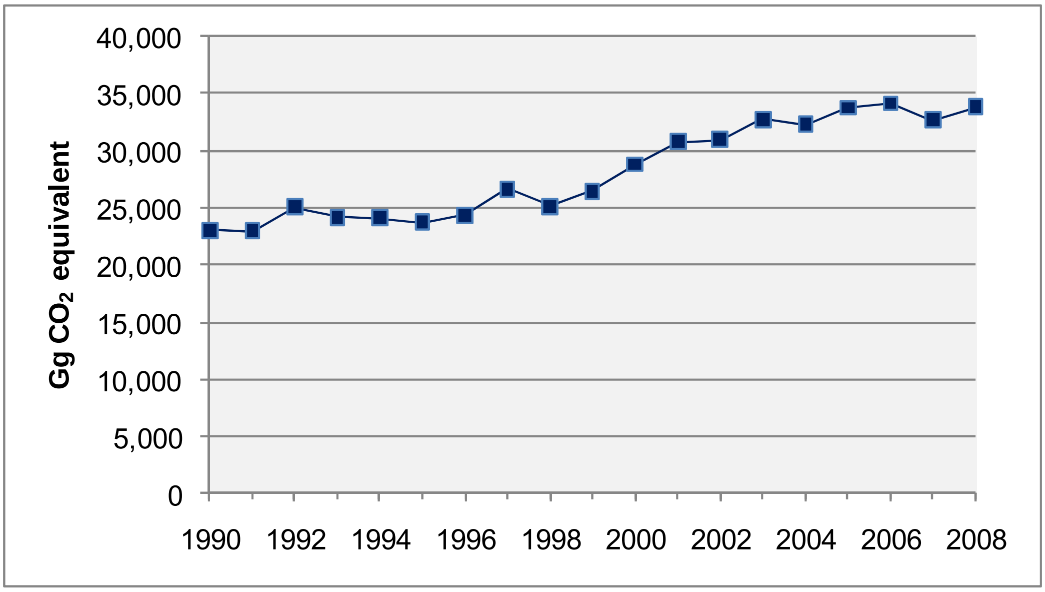
The energy sector produced 33,838.8 Gg carbon dioxide equivalent (CO_2-e) in 2008, representing 45.3 per cent of New Zealand's total greenhouse gas emissions. Emissions from the energy sector were 46.9 per cent (10,796.1 Gg CO_2-e) above the 1990 level of 23,042.7 Gg CO_2-e (Figure 3.1.1). The sources contributing most to this increase were emissions from the public electricity and heat production subcategory, an increase of 4,217.4 Gg CO_2-e (122.4 per cent), and the road transportation subcategory, an increase of 5,227.1 Gg CO_2-e (68.5 per cent). Emissions from the manufacture of solid fuels and the other energy industries subcategory have decreased by 1,429.7 Gg CO_2-e (81.3 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997. Carbon dioxide emissions from the stationary combustion of solid, liquid and gaseous fuels were identified as key categories in 2008.

Changes in emissions between 2007 and 2008

Between 2007 and 2008, emissions from the energy sector increased by 1,185.2 Gg CO_2-e (3.6 per cent). This is primarily due to a 987.3 Gg CO_2-e (14.8 per cent) increase in emissions from public electricity and heat production due to low hydro inflows for 2008. Public electricity and heat production emissions also rose in 2008 due to the increased use of coal in electricity generation.

An increase of 368.2 Gg CO_2-e (6.9 per cent) between 2007 and 2008, in the manufacturing industries and construction category also contributed to the increase in energy emissions. However, these increases were in part offset by a 623.7 Gg CO_2-e (4.2 per cent) decrease in the transport category due to the high petrol and diesel prices in 2008 and the beginning of the global recession.

Figure 3.1.1 New Zealand's energy sector emissions from 1990 to 2008



Energy flows

This inventory submission includes energy flow diagrams (Annex 2). The purpose of these diagrams is to provide a snapshot of the flow of various fuels from the suppliers to the end users within New Zealand for the 2008 calendar year and to provide greater transparency of the energy sector.

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. For verification, New Zealand has also applied a reference approach to estimate CO_2 emissions from fuel combustion for the time series (UNFCCC, 2006). This verifies that all carbon in fuels is accounted for.

The reference approach applies a country's energy supply data to calculate the CO_2 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).

The majority of the CO_2 emission factors for the reference approach are New Zealand-specific. Most emissions factors for liquid fuels are based on annual carbon content and the gross calorific value data provided by New Zealand's 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 emission factors for solid fuels are sourced from the *New Zealand Energy Information Handbook* (Eng et al, 2008).

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 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. 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, 2009).

Comparison of the two approaches in 2008 shows the sectoral total of CO_2 emissions is 1 per cent less than the reference total (Figure 3.2.1).

The energy-use and calculated emissions for the major fuel categories are not directly comparable between the reference and sectoral approaches. This is, first, 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.

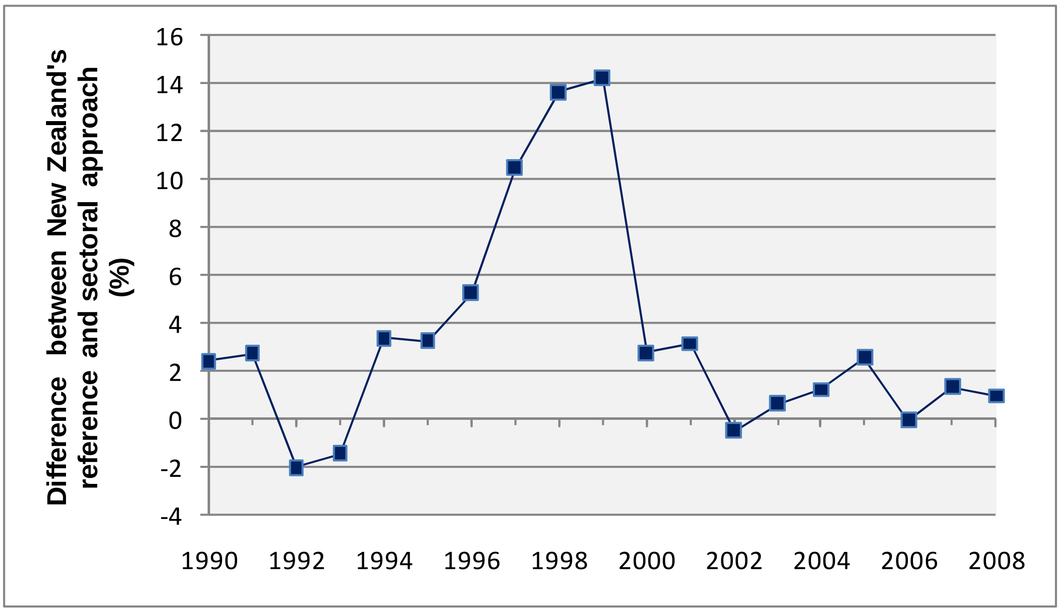
Secondly, combustion of refinery gas is included under gaseous fuels consumption in the sectoral approach and under liquid fuels consumption in the reference approach. This is because refinery gas is a by-product of the refining process derived from crude oil inputs. Consequently, emissions from the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

The Ministry of Economic Development will investigate the large differences between the reference and sectoral approaches in earlier years, particularly from the mid-1990s to the year 2000, for future inventory submissions. This will involve a review of the historical data and statistical differences in the supply and demand tables.

From previous inventory submissions the expert review team suggested more evidence was required to provide how the crude oil emission factor used in the reference approach was derived. After discussions with the New Zealand Refinery Company it was agreed that New Zealand should be using the IPCC default emission of 19.05 t C/TJ for the whole time series. In the previous inventory submission, the emission factor for crude oil was 17.8 t C/TJ.

Some notation keys for the reference approach category have also been updated as they were previously incorrect.

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



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, 2009). This report uses information from oil company monthly survey returns provided to the Ministry for Economic Development.

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. Due to further disaggregation of the marine liquid fuels data, this inventory submission has included the gasoline used in the marine international bunkers category for the first time (refer to the common reporting format Table 1.C1.B).

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 were calculated by taking the fraction of carbon stored or sequestered in the final product (this is based on industry production and chemical composition of the products) and subtracting this from the total fuel supplied. This difference is assumed to be the amount of carbon emitted as CO_2 and is reported in the common reporting format Table 1.A(d).

3.2.4 Carbon dioxide capture from flue gases and subsequent CO_2 storage

There was no CO_2 capture from flue gases and subsequent CO_2 storage occurring in New Zealand between 1990 and 2008.

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.

- A detailed subdivision of the manufacturing and construction category as set out in the 1996 IPCC guidelines is not available before 2000. This is due to historical needs and practices of energy statistics collection in New Zealand. The Ministry of Economic Development is investigating the extrapolation of data back to 1990.
- 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 Ozone precursors and SO_2 from oil refining

New Zealand's only oil refinery does not have a catalytic cracker. The emission factors used are the IPCC default values. The amounts of SO_2 recovered at the refinery are provided by the New Zealand Refining Company. All storage tanks at the refinery are equipped with floating roofs and all but two have primary seals installed.

3.2.7 Energy balance

The *New Zealand Energy Data File* 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 A2.5 (Annex 2) provides an overview of the 2008 energy supply and demand balance for New Zealand. This supply and demand balance table is slightly different from that published previously in the *New Zealand Energy Data File* (Ministry of Economic

Development, 2009). This is due to improvements made to the supply and demand balance post-publication.

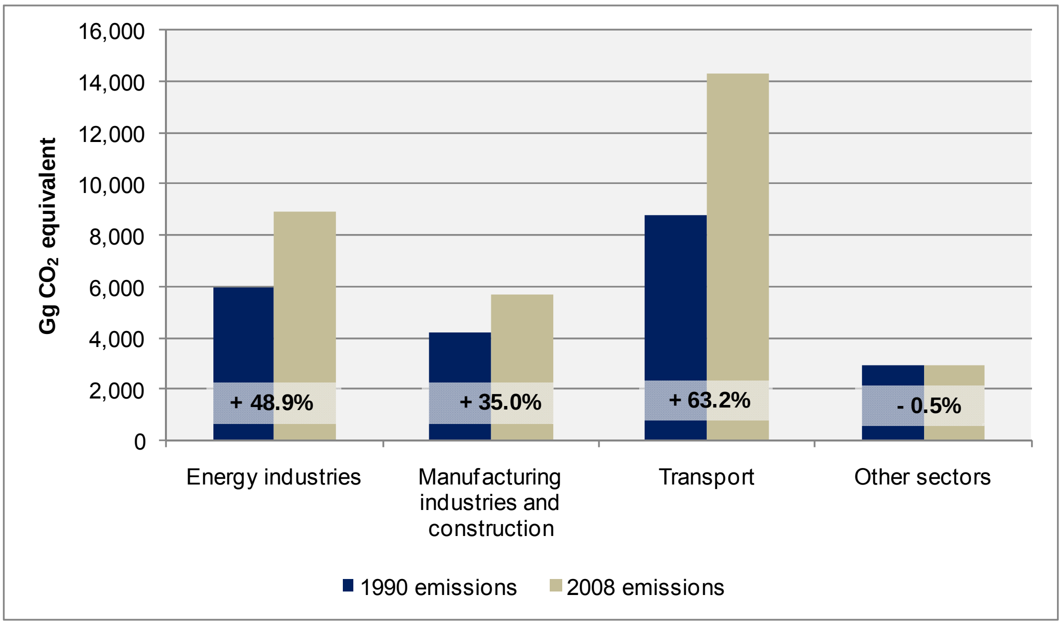
3.3 Fuel combustion (CRF 1A)

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, 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 to 2008



Note: The other sectors category includes fuel combustion emissions from the commercial, institutional, agricultural, forestry, fisheries and residential sectors.

Methodological issues

Energy emissions are compiled using the Ministry of Economic Development's energy database 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.

The fuel combustion category is separated into stationary combustion and mobile combustion. New Zealand has data on fuel combustion detailed by fuel type and subcategory. The methodologies used to calculate emissions for the energy sector are based on the IPCC Tier 1 approach, as data is not available for every individual energy facility.

Activity data – liquid fuels

The Ministry of Economic Development conducted the *Delivery of Petroleum Fuels by Industry Survey* in 2009. Before this, the survey was conducted by Statistics New Zealand. The 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).

The following fuels contribute to emissions from the transport category: compressed natural gas, premium and regular petrol, diesel, fuel oil (heavy and light), aviation fuels, liquefied petroleum gas and coal. In this submission, emissions from transport are calculated as those from the transport industry (ie, commercial enterprises engaged in providing transport services) including those from petroleum fuels sold via resellers (eg, service stations). This is likely to result in an overstatement of emissions attributed to the transport category, as resellers also on-sell petroleum fuels for non-transport uses (eg, diesel sold for powering stationary farm machinery). However, there is insufficient information available to estimate and reallocate the fuel on-sold for non-transport uses. Emissions attributed to the other sectors category will also include some transport-related emissions (eg, emissions from the operation of a commercial vehicle fleet). The Ministry of Economic Development has started working on an annual survey of independent distributor companies to improve the allocation of petroleum sales to the appropriate sectors. This improvement will be implemented in future inventory submissions.

Activity data has been revised for certain fuels and categories due to improvements in the datasets from the *Monthly Oil Submission* and the *Delivery of Petroleum Fuels by Industry Survey*. This has resulted in recalculations for a large number of categories in this inventory submission.

Activity data – solid fuels

The Ministry of Economic Development now conducts the *New Zealand Quarterly Statistical Return of Coal Production and Sales*, previously conducted by Statistics New Zealand. The survey covers coal produced and sold by coal producers in New Zealand. The three grades of coal 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 (2006). Prior to 2009, when Statistics New Zealand ran the survey, coal sold was attributed to seven sectors. Between 1990 and 1995, the sectoral shares of coal use are based on CRL Energy Ltd's survey of sectoral coal use for 1990 and 1995. Data was interpolated between 1990 and 1995. The exceptions to the consumption of coal that are received directly from the companies include: coal used for iron and steel, residential household and the public electricity and heat production subcategories.

Sectoral shares of coal were calculated by the following:

- the four calendar year quarters of coal sales data from the *Quarterly Statistical Return of Coal Production and Sales* was summed

- coal exports, coal used by the residential sector, coal used for iron and steel production, and coal used for public electricity and heat production were subtracted. CRL Energy's annual coal tonnage for each sector was divided by the total (excluding exports, steel, electricity and residential coal use), to provide sectoral shares of coal use for 1990 and 1995
- sectoral shares between 1990 and 1995 were interpolated
- the year-specific calorific values for the different grades of coal were provided by CRL Energy Ltd between 1995 and 2008
- the 1995 calorific value was adopted for the years 1990–1994 in the absence of other data
- this updated data has been incorporated in this inventory submission. To achieve better alignment between the reference and sectoral approaches peat/coke coal is included under the bituminous grade.

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. Vector Ltd provides data on processed gas, including the Kapuni gas field, and information on gas transmission and distribution throughout New Zealand. Large users of gas, including electricity generation companies, provide their activity data directly to the Ministry of Economic Development. Finally, the Ministry of Economic Development 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 co-generation 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 received by the Ministry of Economic Development from companies involved with combusting wood residues to provide process heat in the wood processing industry (ie, kiln drying).

Emission factors

New Zealand emission factors are based on gross calorific values. A list of emission factors for CO_2, methane (CH_4) and nitrous oxide (N_2O) for all fuel types is listed in Annex 2. 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 CO_2 emission factors for oil products are from the New Zealand Refining Company data, import data from industry and from Eng et al (2008). There is a direct relationship between each fuel's carbon content and the corresponding CO_2 emissions during combustion. However, the carbon composition of oil products is not closely monitored and there will be variation over time, depending on the crude oil used in production.

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.

Emission factors – solid fuels

In previous inventory submissions, New Zealand's emissions from coal combustion in the public electricity and heat production subcategory were calculated using the emission factor for sub-bituminous coal of 92.99 kt CO_2/PJ (Eng et al, 2008). This inventory submission has used 91.20 kt CO_2/PJ as the emission factor for sub-bituminous coal. This new emission factor is based on the assumption that applying the overall sub-bituminous value for the public electricity and heat production subcategory is consistent with other coal burning activities in New Zealand. This updated emission factor is included for the whole time series for the public electricity and heat production subcategory.

Emission factors – gaseous fuels

The gaseous fuels emission factor is the calculated average for all of the gas production fields (Ministry of Economic Development, 2009). 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, Pohukura) coming on stream.

The Kapuni gas field has a particularly high CO_2 content. Historically, this field has been valued by the petrochemicals industry as a feedstock. However, most of the gas from this field is now treated and the excess CO_2 removed at the Kapuni Gas Treatment Plant. Consequently, separate emission factors were used to calculate emissions from Kapuni treated and un-treated gas due to the difference in carbon content (refer to Annex 2). The emissions from this removal of CO_2 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).

Sector-wide planned improvements

All source-specific planned improvements will be discussed in their corresponding sections. However, the Ministry of Economic Development will collect further information on calorific values for imported coal and coal produced within New Zealand.

Uncertainties and time-series consistency

Uncertainty in greenhouse gas emissions from fuel combustion varies depending on the gas (Table 3.3.1). The uncertainty of CO_2 emissions is relatively low at ±5 per cent and is primarily due to uncertainty in activity data rather than emission factors. This is because of the direct relationship between the carbon content of the fuel and the corresponding CO_2 emissions during combustion. The low level of uncertainty in CO_2 emissions is important as CO_2 emissions comprised 96.4 per cent of energy sector emissions in 2008.

In comparison, emissions of the non-CO_2 gases are much less certain as emissions vary with combustion conditions. Many of the non-CO_2 emission factors used by New Zealand are the IPCC default values. The uncertainty of all the default emission factors has not been quantified in the IPCC guidelines (IPCC, 1996). The uncertainties proposed in Table 3.3.1 are best estimates derived for New Zealand conditions (Ministry of Economic Development, 2006).

Table 3.3.1 General uncertainty for New Zealand's emission estimates from fuel combustion (Ministry of Economic Development, 2006)

Gas	Uncertainty (%)
CO_2	±5
CH_4	±50
N_2O	±50
NO_x	±33
CO	±50
NMVOCs	±50

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 CO_2 removed from Kapuni gas at the Kapuni Gas Treatment Plant has also been reported under the manufacture of solid fuels and other energy industries subcategory because of confidentiality concerns.

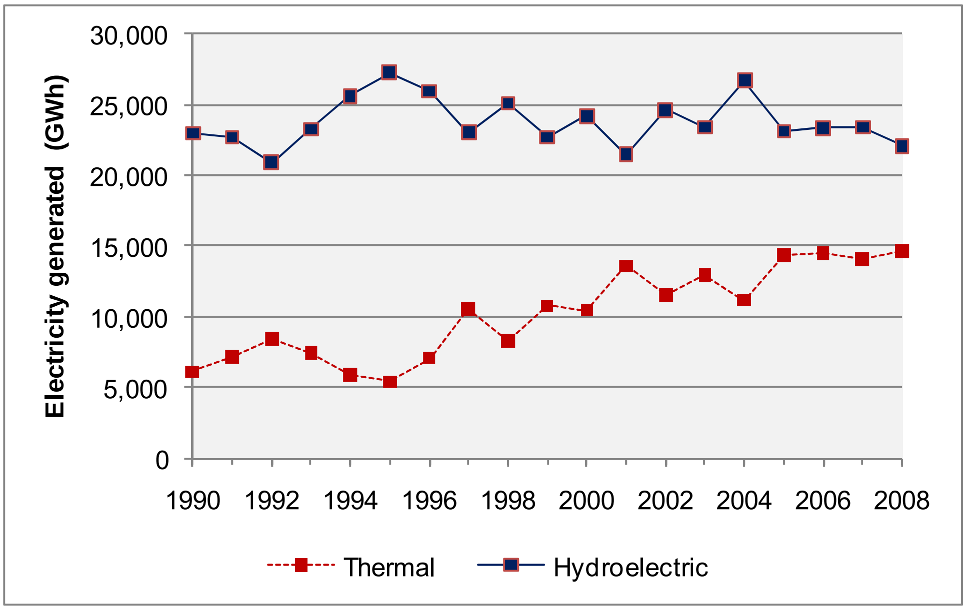
In 2008, emissions in the energy industries category totalled 8,900.7 Gg CO_2-e (26.3 per cent) of the energy sector. Emissions from energy industries have increased 2,923.4 Gg CO_2-e (48.9 per cent) since the 1990 level of 5,977.3 Gg CO_2-e. The public electricity and heat production subcategory accounted for 7,661.7 Gg CO_2-e (86.1 per cent) of the emissions from the energy industries category in 2008. This is an increase of 4,217.4 Gg CO_2-e (122.4 per cent) from the 1990 level of 3,444.3 Gg CO_2-e.

Between 2007 and 2008, there was an increase of 987.3 Gg CO_2-e (14.8 per cent) in emissions from public electricity and heat production. This increase is largely due to low hydro inflows for 2008 (ie, 2008 was a dry year). Subsequently, there was an increased reliance on thermal electricity generation. Public electricity and heat production emissions also rose in 2008 due to an increased use of coal compared with gas in the production of thermal electricity.

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2008 calendar year, hydro generation provided 52 per cent of New Zealand's electricity generation. A further 13 per cent came from other renewable sources (such as geothermal, wind and biomass) and waste heat sources. The remaining 35 per cent was provided by fossil fuel thermal generation plants using oil, gas and coal (Ministry of Economic Development, 2009).

Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990–2008. 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 affects the majority of New Zealand's hydroelectric lake levels, the shortfall is made up by thermal electricity generation. New Zealand's hydro resources have limited storage capacity, with around 10 per cent of New Zealand's annual demand of reservoir storage (Electricity Technical Advisory Group and the Ministry of Economic Development, 2009). Electricity generation in a "normal" hydro year requires lower gas and coal use, while a "dry" hydro year requires higher gas and coal use.

Figure 3.3.2 New Zealand's hydroelectric and thermal generation from 1990 to 2008 (Ministry of Economic Development, 2009)



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

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 7 per cent of New Zealand's electricity is supplied by co-generation (also known as combined heat and power) (Ministry of Economic Development, 2009). Most of the major co-generation plants are attached to large industrial facilities that consume most of the electricity and heat generated. According to the IPCC (1996) definition of public electricity and heat production, there is only one co-generation plant in New Zealand producing electricity as its primary purpose. The emissions from this plant are included under the public electricity and heat production subcategory, while emissions from other co-generation plants are included within the manufacturing industries and construction category (section 3.2.2). A Tier 2 method is used to calculate emissions for this co-generation plant. This uses activity data from the Ministry of Economic Development's *Monthly Survey of Electricity Generation* supplemented by the Ministry of Economic Development's annual statistical returns for electricity generators and the weighted average gas emission factor.

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-CO_2 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 oil and gas extraction is provided to the Ministry of Economic Development by each individual gas field operator. 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 2 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.

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 3.3.1).

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

Gaseous fuels activity data for the public electricity and heat production subcategory has now been replaced by annual data rather than quarterly data. The annual data is more accurate because it is subject to better quality-assurance and quality-control checks and verification methods carried out by both electricity suppliers and the Ministry of Economic Development. Pre-1996 monthly activity data has not changed because it came directly from the Electricity Corporation of New Zealand (a New Zealand state-owned enterprise prior to the deregulation of the entire New Zealand electricity market in 1996), although there is no visible step change in the activity data.

Biomass activity data for the public electricity and heat production subcategory is now reported back to 1990, as new electricity and co-generation data became available to the Ministry of Economic Development from electricity generator returns for the years 1990–1993.

The accuracy of gaseous fuels activity data for the manufacture of solid fuels and other energy industries subcategory has been revised because of improvements in data collection methods. This data was previously manually entered and contained many errors. This has now been corrected and quality-assurance and control procedures put in place.

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

The emission factors for liquid fuels and gaseous fuels have been improved (refer to section 3.3).

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

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, emissions from methanol production are reported under the manufacturing industries and construction subcategory for all years because of confidentiality concerns.

In 2008, emissions from the manufacturing industries and construction subcategory accounted for 5,706.8 Gg CO_2-e (16.9 per cent) emissions from the energy sector. Emissions were 1,478.6 Gg CO_2-e (35.0 per cent) above the 1990 level of 4,228.1 Gg CO_2-e. A decline in methanol production between 2003 and 2004 caused a significant reduction in emissions from this category. Methanol production is the largest source of emissions in the chemical subcategory.

Methodological issues

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 as shown in Box 3.1.

Box 3.1 New Zealand's calculation of CO_2 emissions from methanol production

Assumptions:

- Synthetic petrol is 85.8 per cent carbon by weight.
- Methanol is 37.5 per cent carbon by weight.
- CO_2 emissions factor for Maui gas is 52.37 kt/PJ (2008) (refer Annex 2).
- CO_2 emissions factor for Kapuni low temperature separator gas is 84.10 kt/PJ (2008) (refer Annex 2).
- CO_2 weighted average emissions factor for distributed gas is 53.59 (2008) (refer Annex 2).

The resulting calculations are:

Weight of carbon in gas to Methanex = [(PJ Maui)*52.37 + (PJ Kapuni)*84.10 + (PJ distributed)*53.59] *12/44 kilotonnes.

- Weight of carbon in synthetic petrol = [amount of petrol produced *0.858] kilotonnes.
- Weight of carbon in methanol = [amount of methanol produced *0.375] kilotonnes.
- Weight of carbon sequestered in the products = [weight of carbon in petrol + weight of carbon in methanol] kilotonnes.
- Total emissions of CO_2 = [(weight of carbon in gas to Methanex) – (weight of carbon sequestered)] *44/12 kilotonnes.

The major non-fuel related emissions from the methanol process are CH_4 and NMVOCs.

As mentioned under section 3.2.5, disaggregated data by industry type is unavailable pre-2000. Therefore, activity data and related emissions are reported as aggregate values under the 'other' subcategory.

Uncertainties and time-series consistency

Uncertainties in emission and activity data estimates are those relevant to the entire energy sector (Table 3.3.1 and Annex 2).

Source-specific QA/QC and verification

In preparation of this inventory, the data for CO_2 estimates for this category underwent IPCC Tier 1 quality checks.

Source-specific recalculations

The data reported in this category has been further disaggregated. Gaseous fuels activity data is now reported for all subcategories for 2000 onwards. Data prior to 2000 is not reported because the Ministry of Economic Development's *Gas Retailers and Wholesalers Survey* only began in 2000.

Liquid fuels data is also now reported for the food processing, beverages and tobacco subcategory.

Gaseous fuels activity data for co-generation has been reported back to 1990 resulting in recalculations to the 'other' subcategory. Previously, this data was only available back to 1994. The data has become available based on a collaboration with Statistics New Zealand and the Electricity Commission and has greatly improved the accuracy of the published data.

Biomass activity data for co-generation is now received by the Ministry of Economic Development on a quarterly basis from companies involved with combusting wood residues to provide process heat in the wood processing industry (ie, kiln drying). This has resulted in recalculations to the 'other' subcategory. Previously, this data was estimated based on plant capacity.

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

The emission factors for liquid fuels and gaseous fuels have been improved (refer to section 3.3).

Source-specific planned improvements

The Ministry of Economic Development will investigate the extrapolation of gaseous fuels data back to 1990 for the manufacturing industries and construction category for future inventory submissions.

The Ministry of Economic Development is reviewing emission factors used for estimating non-CO_2 emissions for methanol production.

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 2008, the transport category was responsible for 14,273.9 Gg CO_2-e (42.2 per cent) of emissions from the energy sector, or 19.2 per cent of total emissions. Emissions increased 5,525.2 Gg CO_2-e (63.2 per cent) from the 8,748.7 Gg CO_2-e emitted in 1990. The transport emissions profile in 2008 was dominated by emissions from the road transportation subcategory. In 2008, road transport accounted for 12,860.8 Gg CO_2-e (90.1 per cent) of total transport emissions. This was an increase of 5,227.1 Gg CO_2-e (68.5 per cent) from the 1990 level of 7,633.6 Gg CO_2-e. Carbon dioxide emissions from road transport were identified as a key category (trend and level) in 2008. Carbon dioxide emissions from aviation were also identified as a key category (level) in 2008.

Between 2007 and 2008, emissions from transport decreased by 623.7 Gg CO_2-e (4.2 per cent). This was due to the high petrol and diesel prices in 2008 and the beginning of the global recession.

Methodological issues

Emissions from transport were compiled from the Ministry for Economic Development's energy database using an IPCC (2000) Tier 1 approach.

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, 2009).

Road transportation

The IPCC (2000) Tier 1 approach was used to calculate CO_2 and non-CO_2 emissions from road transportation. New Zealand-specific emission factors have been used to estimate CO_2, while because of insufficient information, default emission factors have been used to estimate non-CO_2 emissions. The emission factors for CO_2 and non-CO_2 gases for the various fuel types used in the road transportation subcategory can be found in Annex 2.

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 CO_2 emissions and, because of insufficient data, the IPCC default emission factors were used to estimate CH_4 and N_2O emissions. The emission factors for CO_2 and non-CO_2 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). New Zealand-specific emission factors have been used to estimate CO_2 emissions and, because of insufficient data, the IPCC 1996 default emission factors have been used to estimate CH_4 and N_2O emissions.

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. New Zealand does not have the data to split the domestic and international components of fuel use for international flights with a domestic leg. This is because information on fuel use for civil aviation and navigation is only available from the oil companies rather than from the individual airlines or shipping companies.

Uncertainties and time-series consistency

Uncertainties in emission estimates from the transport category are relevant to the entire fuel combustion sector (Table 3.3.1).

Source-specific QA/QC and verification

In preparation of this inventory, data for CO_2 emissions from the transport category underwent IPCC Tier 1 quality checks.

Source-specific recalculations

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

The emission factors for liquid fuels and gaseous fuels have been improved (refer to section 3.3).

Source-specific planned improvements

In 2010, the Ministry of Economic Development will continue to work with the Ministry of Transport on developing a Tier 2 methodology for estimating road transportation emissions. The Ministry of Economic Development will also continue to focus on international bunker issues, including the improvement of both marine and aviation fuel data.

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 agriculture, forestry and fisheries subcategories.

In 2008, fuel combustion of the other sectors category accounted for 2,898.2 Gg CO_2-e (8.6 per cent) of the emissions from the energy sector. This is a decrease of 15.8 Gg CO_2-e (0.5 per cent) below the 1990 value of 2,914.0 Gg CO_2-e.

Emissions from the agricultural, forestry and fisheries subcategory were 1,243.4 Gg CO_2-e (42.9 per cent) of the other sectors category in 2008. This is an increase of 134.4 Gg CO_2-e (12.1 per cent) from the 1990 level of 1,109.0 Gg CO_2-e.

Emissions from the commercial and institutional subcategory were 1,122.1 Gg CO_2-e (38.7 per cent) of the other sectors category in 2008. This is a decrease of 40.8 Gg CO_2-e (3.5 per cent) from the 1990 level of 1,162.9 Gg CO_2-e.

Emissions from the residential subcategory were 532.8 Gg CO_2-e (18.4 per cent) of the other sectors category in 2008. This is a decrease of 109.4 Gg CO_2-e (17.0 per cent) from the 1990 level of 642.2 Gg CO_2-e.

Methodological issues

Accurately partitioning energy use between categories is difficult. An example is the allocating of diesel consumption between the road transport and commercial and institutional subcategories. As mentioned under section 3.3, some transport-related emissions, particularly from commercial enterprises, may be captured under the commercial and institutional subcategory. The Ministry of Economic Development has started working on an annual survey of independent distributor companies to correctly allocate their petroleum sales to the appropriate sectors.

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

There was no specific IPCC Tier 1 quality checks applied to this category as it was not identified as a key category. However, the data was checked by the Ministry of Economic Development as part of its quality-control programme.

Source-specific recalculations

Biomass activity data for the commercial and residential sectors has been improved. Commercial biomass data is now available from the Cogeneration Association of New Zealand. Further information on commercial biomass data can be found at: www.cogeneration.co.nz). Improved residential biomass data is now based on

New Zealand census results and wood consumption from a household energy end-use project (Building Research Association of New Zealand, 2002). Previously, this data was estimated based on plant capacity.

Activity data for liquid fuels in this category is now more accurate. This is due to the further disaggregation of liquid fuels using the *Delivery of Petroleum Fuel Industries Survey* (eg, premium petrol, regular petrol, heavy fuel oil, light fuel oil) and individual emission factors applied to each type of liquid fuel. The data has been aggregated to calculate the liquid fuels total for the commercial, residential and agriculture subcategories.

The stationary and mobile splits for the agriculture subcategory have been improved. The Statistics New Zealand *Energy Use Survey: Primary industries 2008* (Statistics New Zealand, 2008) is now used. Consequently, the stationary and mobile splits are more accurate and detailed for the whole time series.

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

The emission factors for liquid fuels and gaseous fuels have been improved (refer to section 3.3).

Source-specific planned improvements

In 2008, a study conducted by an external consultant investigated the disproportionate growth of the 'resellers' category of the *Delivery of Petroleum Fuels by Industry Survey*. The study reviewed the fuel supply chain in New Zealand and tested the theory that the *Delivery of Petroleum Fuels by Industry Survey* was not accurately describing the consumption of petroleum fuels. The report can be found on the Ministry of Economic Development's website at:
www.med.govt.nz/templates/MultipageDocumentTOC____40472.aspx.

The key finding of this study was that the approach of surveying New Zealand's five major oil companies is inadequate as there are now many more independent distributors involved in direct fuel deliveries to larger consumers. The major oil companies have moved into a wholesale role and withdrawn from their direct delivery operations.

The Ministry of Economic Development will develop an annual survey of independent distributor companies to capture their fuel deliveries, and allocate these to the appropriate economic sector. Initial work on this survey has started and will continue throughout 2010.

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 2008, fugitive emissions from fuels accounted for 2,059.1 Gg CO_2-e (6.1 per cent) of emissions from the energy sector. This is an increase of 884.6 Gg CO_2-e (75.3 per cent) from the 1990 level of 1,174.5 Gg CO_2-e.

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

Description

In 2008, fugitive emissions from the solid fuels subcategory produced 342.6 Gg CO_2-e (16.6 per cent) of emissions from the fugitive emissions category. This is an increase of 70.5 Gg CO_2-e (25.9 per cent) from the 272.1 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 CH_4 released during coalmining is dependent on the coal grade and the depth of the coal seam. In 2008, 79.2 per cent of the CH_4 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 CH_4 at coalmines, and CH_4 captured for industrial use is negligible. In 2008, New Zealand coal production was 4.9 million tonnes, a 1.5 per cent increase from the 2007 production level of 4.8 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 CH_4 emissions (Beamish and Vance, 1992). Emission factors for the other subcategories, for example, surface mining, are sourced from the revised IPCC 1996 as shown in Table 3.4.1.

Table 3.4.1 Methane release factors for New Zealand coal

Activity	Release factors (t CH_4/kt coal)	Source of release factors
Surface mining	0.77	Mid-point IPCC (1996) default range (0.2–1.34 t/kt coal)
Underground: bituminous mining	16.75	Top end of IPCC (1996) default range (6.7–16.75 t/kt coal)
Underground: sub-bituminous mining	12.1	Beamish and Vance, 1992
Surface post mining	0.067	Mid-point IPCC (1996) default range (0.0–0.134 t/kt coal)
Underground post mining	1.6	Mid-point IPCC (1996) default range (0.6–2.7 t/kt coal)

Note: There is no release factor for lignite from underground mining as all lignite is taken from surface mining.

Uncertainties and time-series consistency

Uncertainties in fugitive emissions are relevant to the entire energy sector (Table 3.3.1).

Source-specific QA/QC and verification

There was no specific IPCC Tier 1 quality checks applied to this category because it was not identified as a key category. However, the data was checked by the Ministry of Economic Development as part of its quality-control programme.

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

Description

In 2008, fugitive emissions from the oil and natural gas subcategory contributed 1,716.5 Gg CO_2-e (83.4 per cent) of emissions from the fugitive emissions category. This is an increase of 814.1 Gg CO_2-e (90.2 per cent) from 902.4 Gg CO_2-e in 1990. Fugitive emissions from oil and gas operations (CO_2) were identified as a key category (level and trend) in 2008.

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

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

Carbon dioxide is also produced when natural gas is flared at the wellheads of other fields. The combustion efficiency of flaring is 95–99 per cent, leaving some fugitive emissions as a result of incomplete combustion. There was a 9.6 per cent increase in emissions from processing and flaring between 2007 and 2008. This is largely due to the large increase in flaring from the Tui offshore oil field as it does not have pipeline facilities to on-sell any of the extracted gas.

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 2008, emissions from geothermal operations were 515.4 Gg CO_2-e, an increase of 105.6 Gg CO_2-e (25.8 per cent) since the 1990 level of 409.8 Gg CO_2-e.

Between 2007 and 2008, emissions from geothermal operations increased by 55.2 per cent. This was in part due to the commissioning of a new 100 MW geothermal electricity generation plant in Kawerau in 2008.

Methodological issues

Venting and flaring from oil and gas production

Data on the amount of CO_2 released through flaring was either supplied directly by the gas field operators or calculated from the supplied energy data using emission factors from Eng et al (2008). Vector Ltd, New Zealand’s gas transmission company, supplies estimates of CO_2 released during the processing of the natural gas.

Gas transmission and distribution

Carbon dioxide and CH_4 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 for the first time. 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 CO_2 and CH_4 emissions are based on gas composition data.

Oil transport, refining and storage

Fugitive emissions from the oil transport and oil refining and storage subcategories are calculated using an IPCC Tier 1 approach (IPCC, 1996). For the oil transport subcategory, the fuel activity data is New Zealand's total production of crude oil reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2009). The CH_4 emission factor is the mid-point of the IPCC (1996) default value range (0.745 tonnes of CH_4/PJ).

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

Geothermal

Estimates of CO_2 and CH_4 emissions for the geothermal subcategory are obtained directly from the geothermal field operators. There are two major geothermal operators in New Zealand. Quarterly gas sampling analysis is conducted to measure the amount of CO_2 and CH_4 in the steam for one of the main operators. For the other main operator, spot measurements are taken when the power stations are operating normally and the net mega watts of electricity generated that day is used to calculate the emission factors.

No fuel is burnt in the geothermal operations as the process harnesses the energy in tapped geothermal fluid. High-pressure steam (26 bar) is used to power the main electricity generating back-pressure turbines. In some plants, the low-pressure exhaust steam is then used to drive secondary (binary) turbines. The CO_2 and CH_4 dissolved in the geothermal fluid are released with the steam.

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

There was no specific IPCC Tier 1 quality checks applied to this category as it was not identified as a key category. However, the data was checked by the Ministry of Economic Development as part of its quality-control programme.

Source-specific recalculations

Venting, flaring and own-use activity data from gas and oil field operators has been revised. This is due to the correction of manual entry errors in the data set. This data has now been corrected and quality-control procedures have been established.

Geothermal activity data has been revised due to the removal of the Tarawera geothermal field. The field is a binary plant which does not release emissions.

Activity data provided by the New Zealand Refining Company of crude oil production in New Zealand has been revised.

Transmission and distribution data has been split out. The activity data for transmission and distribution has also been improved. Previously, the total amount of gas entering the pipelines was reported for activity data. Now, the actual amount lost in terajoules is reported.

Source-specific planned improvements

The Ministry of Economic Development has started investigating discrepancies between activity data, CO_2 and CH_4 emissions for some years (particularly estimates for the late 1990s). This work will continue through 2010. Geothermal and Energy Technical Services Ltd (2009) provides further detail on New Zealand's geothermal fields and will aid the Ministry of Economic Development in its investigations.

Chapter 4: Industrial processes

4.1 Sector overview

In 2008, New Zealand's industrial processes sector produced 4,292.0 Gg of carbon dioxide equivalent (CO_2-e), contributing 5.7 per cent of New Zealand's total greenhouse gas emissions. Emissions from industrial processes had increased by 906.2 Gg CO_2-e (26.8 per cent) above the 1990 level of 3,385.8 Gg CO_2-e (Figure 4.1.1). The largest source of industrial process emissions are from the metal production category (CO_2 and perfluorocarbons (PFCs)) contributing 48.5 per cent of emissions in 2008.

Figure 4.1.1 New Zealand's industrial processes sector emissions from 1990 to 2008

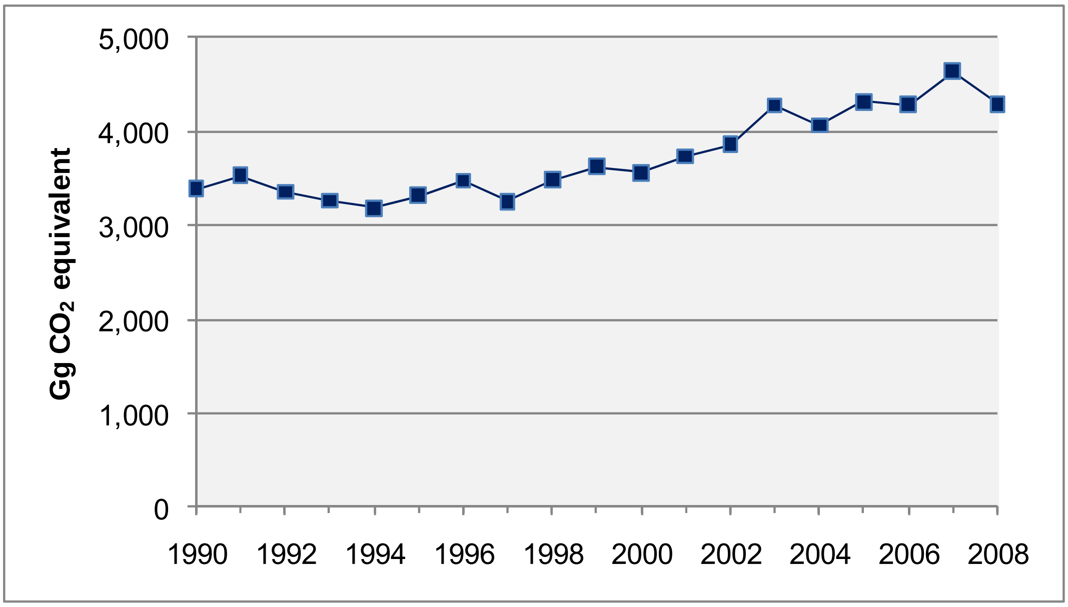
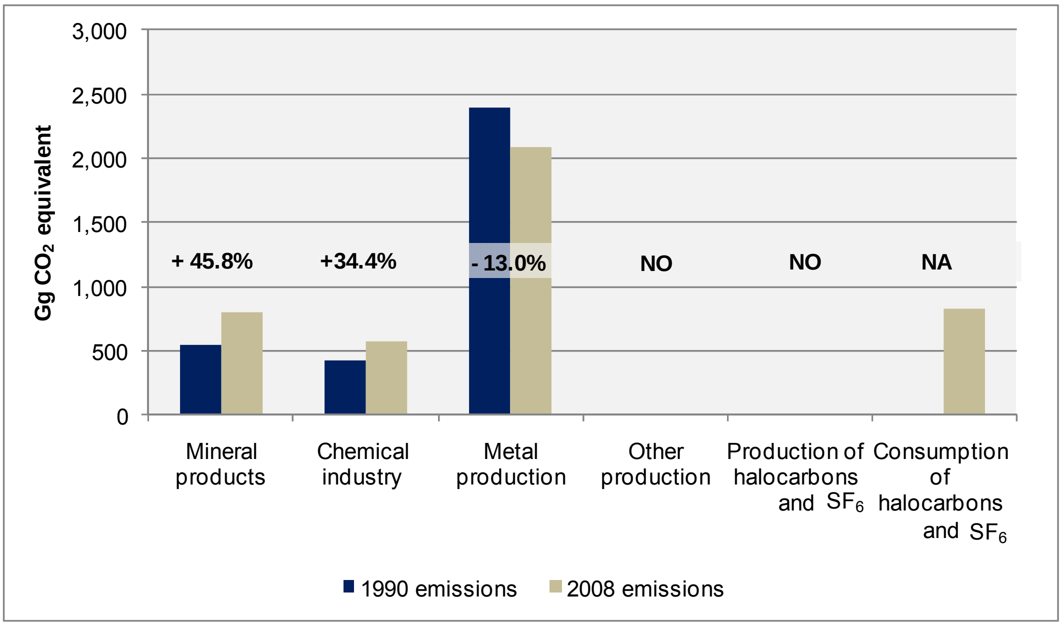


Figure 4.1.2 Change in New Zealand's industrial processes sector emissions from 1990 to 2008



Notes: The per cent change for 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 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 of ammonia for use in the production of urea
- production of hydrogen.

Changes in emissions between 2007 and 2008

Between 2007 and 2008, emissions from the industrial processes sector decreased by 344.6 Gg CO_2-e (7.4 per cent). The largest decrease of 183.3 Gg CO_2-e (8.1 per cent) was due to a reduction in emissions from steel and aluminium production.

Between 2007 and 2008, emissions from the consumption of halocarbons and sulphur hexafluoride (SF_6) category decreased by 105.3 Gg CO_2-e (11.3 per cent.) This was largely due to a reduction in annual sales of new refrigerant (including halocarbons imported in bulk and in equipment, excluding exports). There was also a reduction in the amount of HFC-134a sold to the mobile air conditioning industry.

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 1990–2008* (Ministry of Economic Development, 2009).

Most of the activity data for the non-CO_2 gases is collated via an industry survey. Between 1990 and 2008, the only known methane (CH_4) emissions from the industrial processes sector came from methanol production. Emissions of hydrofluorocarbons (HFCs) and 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).

4.1.2 Uncertainties

The number of companies in New Zealand producing CO_2 from industrial processes is small and the emissions of CO_2 supplied by the companies are considered to be accurate to ± 5 per cent (Ministry of Economic Development, 2006). 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. Uncertainty of non-CO_2 emissions is discussed under each category.

4.2 Mineral products (CRF 2A)

4.2.1 Description

In 2008, the mineral products category accounted for 802.6 Gg CO_2-e (18.6 per cent) of total emissions from the industrial processes sector. Emissions in this category have increased by 252.0 Gg CO_2-e (45.8 per cent) from the 1990 level of 550.6 Gg CO_2-e. 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, asphalt roofing, limestone and dolomite use, road paving with asphalt, and glass production. In 2008, cement production accounted for 634.2 Gg CO_2-e (79.0 per cent) of emissions from the mineral products category. In the same year, lime production accounted for 119.1 Gg CO_2-e (14.8 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.

4.2.2 Methodological issues

Cement production

In 2008, CO_2 emissions from cement production were a key category in the level assessment (Table 1.5.1). In 2008, 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.

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.

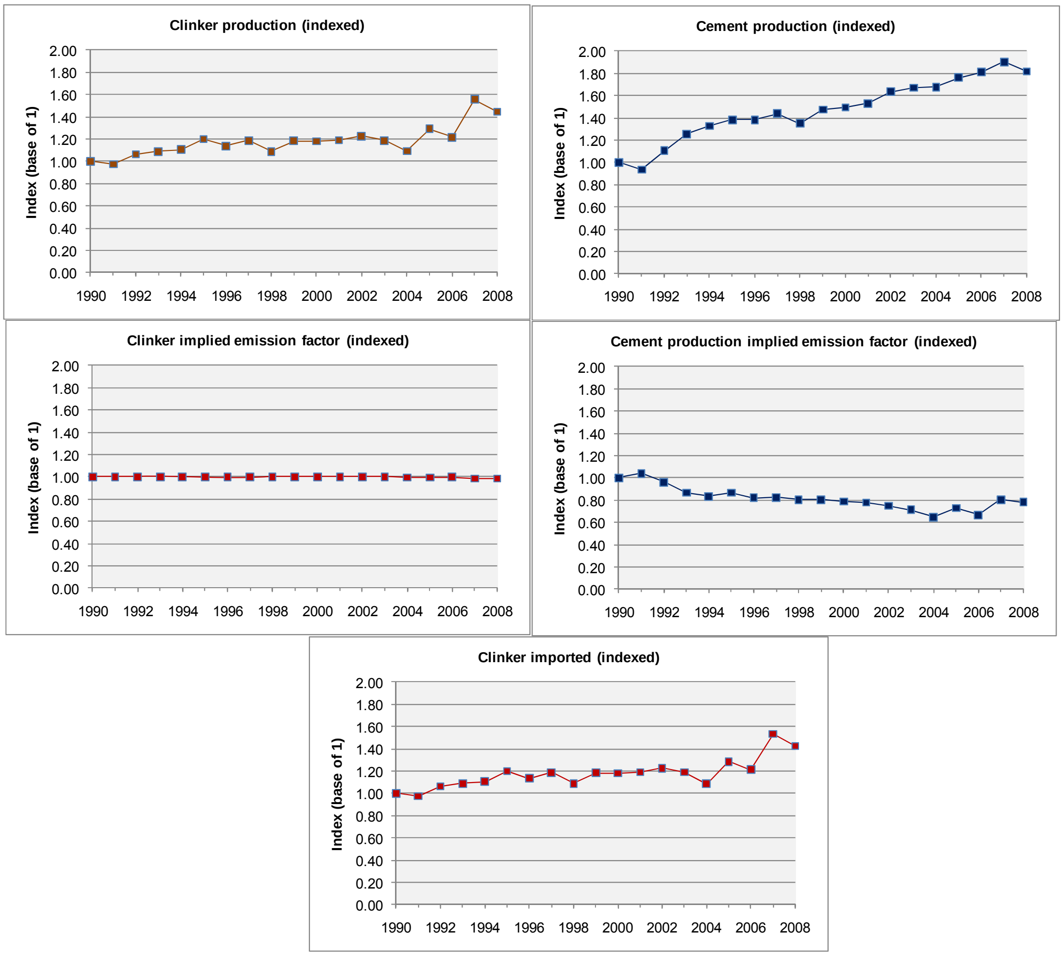
The cement companies supply their emission data to the Ministry of Economic Development during an annual survey. The IPCC (2000) default cement-kiln dust correction factor, 1.02, is included in Holcim New Zealand Ltd's CO_2 emissions calculation. Cement-kiln dust is a mix of calcined and uncalcined raw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

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 1990–2008 time series. In general, the figure shows clinker and cement production increasing over the time series 1990–2008. 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. The increase in clinker production from 2006 to 2007 is due to one of New Zealand's cement companies running at full production in 2007.

Sulphur dioxide (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 factor (indexed) from 1990 to 2008



Lime production

In 2008, lime production in New Zealand was not a key category. 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.

Carbon dioxide and SO_2 emission data from lime production are supplied to the Ministry of Economic Development by the lime production companies. Emissions are calculated by multiplying lime activity data by an emission factor (IPCC, 2000). Given the limited data availability before 2002, a single New Zealand-specific emission factor based on the typical levels of impurities in the lime produced in New Zealand was applied for 1990–2002. Since 2002, plant-specific emission factors have been used. In alignment with good practice, a correction factor is applied to the hydraulic lime produced. There has been little change in the implied emission factor varying from 0.72 t CO_2/t lime to 0.73 t CO_2/t lime from 1990 to 2008.

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 as 0.5 kg SO_2/t 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 the company, 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 (2A.3). This data 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.

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 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/t 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.

Asphalt roofing

There is one company manufacturing asphalt roofing in New Zealand, Bitumen Supply Ltd. 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 2006–2008.

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.

In New Zealand, solvents are rarely added to asphalt. This means that asphalt paving is not considered a significant source of 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 (NO_x), CO and NMVOC emissions that arise from an asphalt plant. The IPCC default road-surface emissions factor of 320 kg NMVOC/t 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 2006–2008.

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, 2009) and are reported with limestone and dolomite use (2.A.3) because of confidentiality concerns.

Non-methane volatile organic compounds may be emitted from the manufacture of glass and 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.

Due to confidentiality concerns, the NMVOCs and SO_2 emissions are now reported under the limestone and dolomite use subcategory as confidential.

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

Uncertainties in CO_2 emissions are assessed as ±5 per cent (section 4.1.2). Uncertainties in non-CO_2 emissions (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 non-CO_2 emissions from the mineral products category

Mineral product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Cement	0	±40
Lime	±1	±80
Asphalt roofing	±30 (+50 for 1990–2000)	±40
Road paving with asphalt	±10	±15 (chip-seal fraction and solvent emission fraction) to ±25 (solvent dilution)
Glass	0	NMVOC: ±50 SO_2: ±10

4.2.4 Source-specific QA/QC and verification

In 2008, CO_2 emissions from cement production were a key category (level and trend assessment). In the preparation of this inventory, the data for these emissions underwent IPCC Tier 1 quality checks. The estimates for lime production were also subject to IPCC Tier 1 quality checks.

4.2.5 Source-specific recalculations

Cement production

The plant-specific cement-kiln dust correction factor applied by Holcim New Zealand was not able to be verified in time for the 2010 submission. Consequently, the IPCC (2000) default factor of 1.02 has been applied to the whole time series for that company.

Lime production

One company had provided incorrect data for the 2007 calendar year for the 2009 submission and this has subsequently been corrected for the 2010 submission.

Limestone and dolomite use

Emissions from soda ash are now included in this subcategory because of confidentiality concerns for the glass manufacturer.

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 2008, emissions from the chemical industry category comprised 578.3 Gg CO_2-e (13.4 per cent) of total emissions from the industrial processes sector. Emissions have increased by 148.0 Gg CO_2-e (34.4 per cent) from the 1990 level of 430.2 Gg CO_2-e. In 2008, CO_2 emissions from ammonia production accounted for 331.6 Gg CO_2-e (57.3 per cent) of emissions in the chemical industry category. In 2008, ammonia production was a qualitative key category (Table 1.5.1). Hydrogen production contributed the remaining 246.7 Gg CO_2-e (42.7 per cent) of emissions from the chemical industry in 2008.

Emissions from methanol production should be included in this category, however, because of confidentiality concerns, methanol emissions are reported in the energy sector.

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 production plant.

Only 20 per cent of the carbon is assumed to be sequestered in the urea product and this is eventually released after it is applied to the land. The remaining 80 per cent is assumed to be combusted and these emissions are consequently reported in the energy sector. 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 1990–2008 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 covered in the energy sector.

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.

Methanol

Emissions estimated from the production of methanol are reported under the energy sector (see section 3.3.2) because of confidentiality concerns.

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 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 2006–2008. Plant-specific emission factors used in previous years were applied to the 2008 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 2008, the combined implied emission factor is 1.5 kg SO_2.

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 2008, the implied emission factor was 6.1 tonnes of CO_2 per tonne of hydrogen produced.

4.3.3 Uncertainties and time-series consistency

Uncertainties in CO_2 emissions are assessed as ±5 per cent (section 4.1.2). 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	±0	±30
Formaldehyde	±2	±50 (NMVOCs)
Methanol	±0	±50 (NO_x and CO) ±30 (NMVOCs) ±80 (CH_4)
Fertiliser	±10 sulphuric acid ±10 superphosphate	±15 sulphuric acid ±25 to ±60 superphosphate (varies per plant)

4.3.4 Source-specific QA/QC and verification

New Zealand has specified CO_2 from ammonia production as a qualitative key category due to the large increase in nitrogenous fertiliser use observed in the agriculture sector since 1990. The ammonia produced in New Zealand is used in the production of urea fertiliser. In the preparation of this inventory, the data for these emissions underwent IPCC Tier 1 quality checks.

4.3.5 Source-specific recalculations

Ammonia

The accuracy and comparability of the ammonia emissions estimates has improved for the whole time series due to using daily emissions factor data for the three main gas fields in New Zealand to derive a weighted average emission factor.

Methanol and hydrogen

The accuracy of the methanol CH_4 and the hydrogen CO_2 emission estimates has improved since the 2009 submission. Corrections were made to errors identified by the Ministry of Economic Developing during the improvements made to its database during 2009. All methanol emission estimates are now reported in the energy sector because of confidentiality concerns.

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 2008, perfluorocarbon emissions from the aluminium production subcategory were a key category in the trend analysis.

In 2008, emissions from the metal production category were 2,081.7 Gg CO_2-e (48.2 per cent) of emissions from the industrial processes sector. Emissions from this category decreased 310.9 Gg CO_2-e (13.0 per cent) from the 1990 level of 2,392.6 Gg CO_2-e. Carbon dioxide emissions accounted for 98.2 per cent of emissions in this category with another 1.8 per cent from PFCs. In 2008, the level of CO_2 emissions increased by 285.3 Gg CO_2-e (16.2 per cent) above the 1990 level. Perfluorocarbon emissions have decreased from the 629.9 Gg CO_2-e in 1990 to 36.5 Gg CO_2-e in 2008, a decrease of 593.4 Gg CO_2-e (94.2 per cent). This decrease is due to improvements made by the aluminium smelter. These improvements are discussed further in the following section.

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 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. The carbon content of the ironsand is negligible with iron, in the form of magnetite, the predominant chemical in the sand (Ure, 2000), and has therefore not been counted.

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 is applied to the sub-bituminous coal used as a reducing agent. The emission factor is calculated based on the specific characteristics of the coal used.

Care has been taken not to double-count coal use for iron and steel making. New Zealand energy statistics for coal are disaggregated into coal used in steel making and coal used in other industries and sectors. The coal used in the iron-making process 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).

All emissions from limestone use at New Zealand Steel Ltd are reported in the limestone use subcategory.

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 and are acknowledged as contributing a negligible amount to the final carbon content of the billet steel.

Due to limited process data at Pacific Steel, emissions between 1990 and 1999 are calculated using a default emission factor (IPCC, 1996) 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.

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).

Aluminium

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 2008, aluminium emissions were 542.5 Gg CO_2-e, a decrease of 536.4 Gg

CO_2-e (49.7 per cent) from the 1990 level of 1,078.9 Gg CO_2-e. In 2008, both CO_2 and PFC emissions from aluminium production were key categories for New Zealand (level and trend respectively).

Aluminium production is a source for CO_2 and PFC emissions. 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.

NZAS calculates the process CO_2 emissions using the International Aluminium Institute (2006) Tier 3 method. This method breaks the prebake anode process into three stages (baked anode consumption, pitch volatiles consumption and packing coke consumption).

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

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.

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 4.4.1.

Figure 4.4.1 New Zealand's implied emission factors for aluminium production from 1990 to 2008

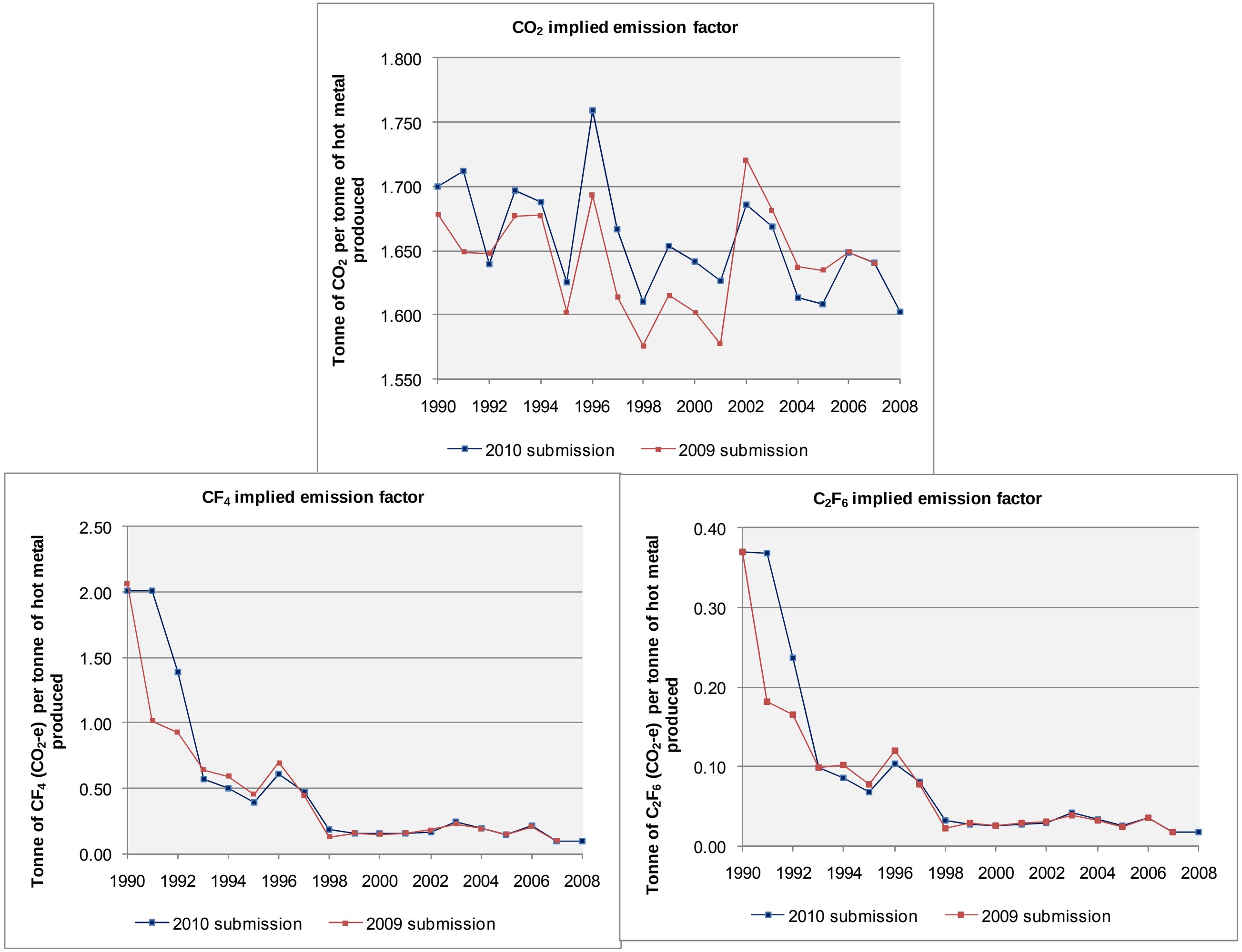


Table 4.4.1 Explanation of variations in New Zealand's aluminium emissions

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.

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 (IPCC range 135–400 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

Uncertainty in CO_2 emissions is assessed as ±5 per cent as discussed in section 4.1.2. 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 4.4.2.

Table 4.4.2 Uncertainty in New Zealand's non-CO_2 emissions from the metal production category

Metal product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Iron and steel	0	±20–30 (CO) ±70 (NO_x)
Aluminium	0	±5 (SO_2) ±40 (CO) ±50 (NO_x) ±30 (PFCs)[1]

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 the iron and steel production and PFC emissions from aluminium production (trend assessment) were key categories in 2008. In the preparation of this inventory, the data for these subcategories underwent IPCC Tier 1 quality checks. Given the recalculations for CO_2 emissions from aluminium production, this subcategory was also subject to IPCC quality checks.

4.4.5 Source-specific recalculations

Steel

The accuracy, completeness and consistency of the emission estimates for steel production have improved for 2000–2007. After significant research and discussion, an agreement was reached in 2009 between the inventory team and Pacific Steel over the scope and boundary of the emission source. Industrial processes CO_2 emissions from Pacific Steel are now only estimated from the oxidation of the electric arc furnace process. The minor carbon components of the additives that are subsequently added to the ladle are excluded. This exclusion is because the associated emissions are generally a contaminant of the vanadium, manganese or silicon additives and are acknowledged as contributing to the final carbon content of the billet steel.

All other CO_2 emissions from the steel-making process at Pacific Steel are estimated in the energy sector. This includes emissions from electricity, natural gas, diesel and liquefied petroleum gas.

Aluminium – CO_2

The accuracy, completeness and consistency of the entire time series have improved largely because of the following reasons:

- actual plant data has been provided for 1991 and 1992, replacing previously interpolated estimates
- estimates of soda ash have been included for the first time
- 1990–2001 now calculates CO_2 emitted from pitch volatile and packing coke combustion in the Carbon Baking Furnaces separately. This is consistent with the International Aluminium Institute (2006) method. Previously, a factor was applied

to the net carbon consumption (tonnes baked anode carbon per tonnes aluminium) to account for the other anode consumption derived sources of CO_2

- 1996–1998 now estimates CO_2 from pitch volatile combustion. During these years, a new furnace was commissioned and another decommissioned, providing for greater uncertainty for the required inputs to the calculation using the International Aluminium Institute (2006) method
- 2002–2007 includes improved input data following a review by NZAS of the inputs involved in the calculation. This includes packing coke consumption and the sulphur content of the baked anodes.

Aluminium – PFCs

The accuracy and consistency of the entire time series have improved because of the following reasons:

- the estimates for 1991 and 1992 were previously interpolated. This did not account for the reduction in production due to power shortage. The estimate for 1991 is now estimated using the Tier 1 IPCC (2000) method with default emission factors. The estimate assumes reduction cell operating conditions are similar to those in 1990
- the estimate for 1992 is now derived using the Tier 2 (International Aluminium Institute, 2006) method with the mid-point value for the extrapolated anode effect duration from the 1991 Tier 1 default emission rate and the 1993 plant specific anode effect duration
- the influence of the extended voltage operation during new cell start up has been eliminated to provide consistency with the International Aluminium Institute (2006) method
- other improvements are due to correcting database errors at NZAS.

4.4.6 Source-specific planned improvements

There are no planned improvements for this source.

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 2008, emissions from this category totalled 7.5 Gg NMVOC. This was an increase of 1.5 Gg NMVOC from the 1990 level of 5.9 Gg CO_2-e.

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 2008, 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) ±20 (wine) ±40 (spirits)	±80 (beer and wine) ±40 (spirits)
Food – food production	±5–20 (varies with food type)	±80 (IPCC factors)

4.5.4 Source-specific QA/QC and verification

Other production was not a key category and no specific quality-assurance or quality-control activities were performed. Where possible, activity data is cross referenced between companies and industry associations to verify the data.

4.5.5 Source-specific recalculations

There were no recalculations for this source.

4.5.6 Source-specific planned improvements

There are no planned improvements for this source.

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 2008, emissions from the consumption of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) totalled 814.9 Gg CO_2-e (19.0 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. In 2008, emissions from the consumption of HFCs and PFCs from refrigeration and air conditioning were identified as a key category (level and 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 2008, sulphur hexafluoride (SF_6) emissions were 14.5 Gg CO_2-e, this is an increase of 2.2 Gg CO_2-e (17.9 per cent) from the 1990 level of 12.3 Gg CO_2-e. The majority of SF_6 emissions are from the 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, 2009).

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	N/A
Fire protection	IPCC (2006a)	Top-down approach using 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. Emissions from aerosols contributed 32.0 Gg CO_2-e in 2008, an increase of 30.4 Gg CO_2-e from the 1996 level of 1.6 Gg CO_2-e. Aerosols were not widely used in New Zealand until 1994, and therefore emissions from aerosols are estimated from 1996 – the initial charge is expected to be emitted within the first two years of sale. In 2008, emissions from metered dose inhalers contributed 51.3 Gg CO_2-e, an increase of 50.8 Gg

CO_2-e from the 1995 level of 0.5 Gg CO_2-e. The consumption of HFCs in metered dose inhalers is not known to have occurred in New Zealand before 1995.

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.

Data on the total number of doses contained in metered dose inhalers used from 1999 to 2008 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, 2009).

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. The only sub-application that does have sufficient data is metered dose inhalers. Consequently, a Tier 2a method has been applied. 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.

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.

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, 2009).

Foam

In New Zealand, only emissions from closed-cell foam (hard foam) are known to have occurred between 2000 and 2008. In 2008, emissions from the use of HFC-134a in hard foam blowing were 0.10 Gg CO_2-e. This is an increase of 0.1 Gg CO_2-e (80.0 per cent) 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 2008. These emissions are estimated to have increased from 0.1 tonne in 2004 to 0.6 tonne in 2008. 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 2008, activity data was provided by the sole supplier of HFCs for foam blowing (CRL Energy, 2009). 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 574.3 Gg CO_2-e in 2008. This is an increase from the 1992 level of 1.3 Gg CO_2-e. In 2008, stationary refrigeration and air conditioning made up 69.2 per cent of the emissions from the halocarbon and SF_6 consumption category. The category has been identified as a key category (level and trend). In 1992, only HFC-134a was used, while in 2008 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 2008 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 a top-down Tier 2b approach (Box 4.2) and New Zealand-specific data to obtain actual emissions from stationary refrigeration and air conditioning.

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)

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, 2006). 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, 2009) 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 2008, HFC-134a emissions from mobile air conditioning were 155.9 Gg CO_2-e, an increase over the 1994 level of 4.6 Gg CO_2-e. Emissions from mobile air conditioning made up 18.9 per cent of total emissions from the halocarbon and SF_6 consumption category in 2008. There was no use of HFCs as refrigerants for mobile air conditioning in New Zealand before 1994. This increase 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 a 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.

Box 4.3 Equation 3.44 (IPCC, 2000)

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

First-fill emissions are calculated from vehicle fleet numbers provided by 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, 2009).

Fire protection

In 2008, 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 2008, SF_6 emissions from electrical equipment were 11.7 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, 2009).

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, 2009).

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 2008 shows potential SF_6 emissions are again greater than actual emissions.

Other SF_6 applications

Emissions from other SF_6 applications in 1990 and 2008 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 2008 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 4.7.2. For many sources, there is no statistical measure of uncertainty but a quantitative assessment is provided from expert opinion.

Table 4.7.2 New Zealand's uncertainties in the consumption of halocarbons and SF_6 category (CRL Energy, 2009)

HFC source	Uncertainty estimates (%)
Aerosols	Combined uncertainty ±49
Metered dose inhalers	Combined uncertainty ±10
Solvents	Not occurring
Foam	Combined uncertainty ±64
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 ±26
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 an accurate record of activity data.

4.7.5 Source-specific recalculations

The accuracy of emission estimates from halocarbon consumption has improved largely due to revised supply assumptions for the stationary refrigeration and air conditioning and mobile air-conditioning categories.

The most significant improvement is the revised assumption shift to reduced supply of HFC-134a for the mobile air-conditioning category compared with the stationary refrigeration and air-conditioning category. This is due to a significant reduction in supply of HFC-134a in 2008, showing that previous assumptions were significantly overestimated. Even with an assumption shift that mobile air conditioning HFC-134a supply (for leakage) was 5 per cent of the vehicle refrigerant bank in 2008 (instead of the previous 6.5 per cent). The 2008 estimates were so atypical compared with previous years that a further temporary reduction to 3.3 per cent was assumed for that year. This was necessary to avoid negative emissions from the stationary refrigeration and air-conditioning category.

Estimates now include improved household and commercial export and import data from Statistics New Zealand for equipment containing HFCs in the stationary refrigeration and air-conditioning category.

Improved assumptions for the cool store sector have resulted in a 50 per cent reduction in the estimates of the HFC refrigerant bank and annual additions. A detailed estimate of Canterbury stocks, together with reassessments of the previous surveys of Bay of Plenty, Hawke's Bay and Nelson led to the conclusion that Canterbury would be more typical (than those other three regions previously used) for pro rata estimates of all other regions. To build up a bank of 120 tonne (80 per cent R404A/20 per cent R134A), annual additions have been assumed of 5 tonne in 1999, 10 tonne in 2000 to 2003 and 15 tonne for 2004 onwards. This represented a 20 tonne annual decrease in HFC chemicals used to charge new equipment in recent years so calculated operation emissions have increased accordingly.

New information for the sales data for air-conditioning equipment has improved the understanding of sales and import data. Consequently, the model has been expanded to reflect the format for the household and commercial refrigeration sectors (with separate imports, exports and New Zealand manufacture estimates). Examples of the effects of the changed assumptions for imports, exports and New Zealand manufacture are that the estimates of HFCs imported in air-conditioning equipment in 2006 and 2007 have increased 4 per cent to 96 tonne and 16 per cent to 122 tonne respectively (compared with previous estimates).

Other changes to the commercial refrigeration sector were relatively minor. It was learned from equipment suppliers that the small number of refrigerated rail units had been included in refrigerated truck figures and that refrigerated shipping is likely to have been even smaller than the small quantities assumed previously. Consequently, new installations were assumed to have totalled 0.3 tonne R404A from 1997 to 2002 and 0.5 tonne from 2003 (rather than 0.5 tonne and 1.0 tonne respectively). Minor calculation errors were discovered and corrected for the proportion of R134A versus R404A versus R22 for the dairy farm sector from 1998 to 2003. To illustrate the size of the errors, the HFC-125 emission estimates were reduced by 0.4 tonne, 0.4 tonne, 0.3 tonne, 0.4 tonne, 0.3 tonne and 0.1 tonne respectively for 1998 to 2003.

The previous assumption that, on average, one-third of the refrigerant in retired commercial refrigeration equipment would be collected for recycling has been revised, as any reused or recycled refrigerant would simply replace bulk chemicals used for new equipment or for replacing leakage. Consistent with the mass-balance methodology, the total charge is now assumed to be lost on retirement as it is in other sectors and the only correction made to that assumption is captured in the refrigerant amounts collected for destruction. The result of this change is that the HFC amount retired from stationary refrigeration and air-conditioning equipment in 2007 was 4.7 tonnes rather than the previous estimate of 3.7 tonnes (a 0.6 tonne increase for 2006, 0.2 tonne for 2005 and negligible in earlier years).

Due to a review of the consistency of the approach for reporting exported bulk chemicals, it is now assumed that all HFC destruction occurs in Australia and is consequently reported under exported gases.

As explained for the stationary refrigeration and air-conditioning category above, the most significant improvement made to the mobile air-conditioning category is revised assumptions for the supply split of HFC-134a for the mobile air-conditioning and stationary refrigeration and air-conditioning sectors. Previous assumptions of mobile air-conditioning supply were overestimated. Even with an assumption shift that mobile air-conditioning HFC supply (for leakage) is now 5 per cent of the vehicle refrigerant bank (instead of the previous 6.5 per cent) the 2008 estimates are so atypical that a temporary reduction to 3.3 per cent has been assumed for that year. This translates to 60 tonnes of supply for 2008 instead of 90 tonnes for the 5 per cent assumption or 119 tonnes under the assumptions used for the last two studies.

Improved statistics from the New Zealand Transport Agency on the age distribution of deregistered vehicles and the consequent emissions assumed from scrapping those vehicles containing HFC mobile air-conditioning systems has improved the accuracy of the estimates from the mobile air-conditioning category. Due to the anomalies in the age distribution, the scrap rate was increased 14 per cent in 2005, 9 per cent in 2006 and only 1 per cent in 2007. Also minor errors (<1 per cent increases) in the calculation of mobile air-conditioning emissions for 2006 and 2007 were corrected.

Previous estimates of foam blowing emissions have been made more comprehensive by considering the three components separately. HFC-134a was reported to be used for foam blowing (0.5 tonne per year) from 2000–2003, so the total HFC-134a emissions (assuming 4.5 per cent annual loss) were about 0.1 tonne per year (and will be assumed to continue for about 15 years). Then HFC-245fa/365mfc was reported to be used from 2004 to 2008. Consequently, HFC-245fa and HFC-365mfc manufacturing emissions (assuming 4.5 per cent annual loss) have each steadily increased from about 0.05 tonne in 2004 to 0.36 tonne in 2008. An assessment of additional foam emissions from United States of America and Mexico refrigerator imports of 0.03 tonne of HFC-245fa emissions in 2004, rising to 0.10 tonne emissions in 2008 have been included for the first time.

Pharmac has amended its figures for total inhaler doses and for HFC doses for 1999–2007 compared with the estimates. The consequent relative increases in HFC-134a emissions compared with the 2008 survey ranged from 1 per cent to 4 per cent.

The accuracy of the entire time series of SF_6 emission estimates has improved because of the following reasons.

- A minor level of equipment manufacturing emissions was separated from operation emissions for 2001 to 2008. There was no information available to estimate any manufacturing emissions before 2001.
- Responses from major electrical users showed that their previous holdings were overestimated so there has been a slight reduction (<0.2 per cent) in assessed emissions for the last few years in line with those revisions.
- Potential SF_6 emissions have increased for 2002 because of new information that SF_6 was handled within New Zealand, rather than sent overseas for destruction.

There has been a review of the notation keys for consumption of halocarbons and SF_6. The notation key NO (‘not occurring’) has been applied in the common report format tables to HFC-23 and HFC-152a where exports of the minor gases for destruction are greater than negligible imports.

4.7.6 Source-specific planned improvements

For the 2011 submission, some estimates will be provided where no data has been available for manufacturing emissions (where the notation NE (‘not estimated’) has been applied). The estimates for refrigeration and air conditioning will be reported under domestic, commercial, transport and industrial processes in future inventory submissions.

4.8 Other production (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 2008 were 1.2 Gg. This is an increase of 0.3 Gg over the 1990 level of 0.9 Gg.

Chapter 5: Solvent and other product use

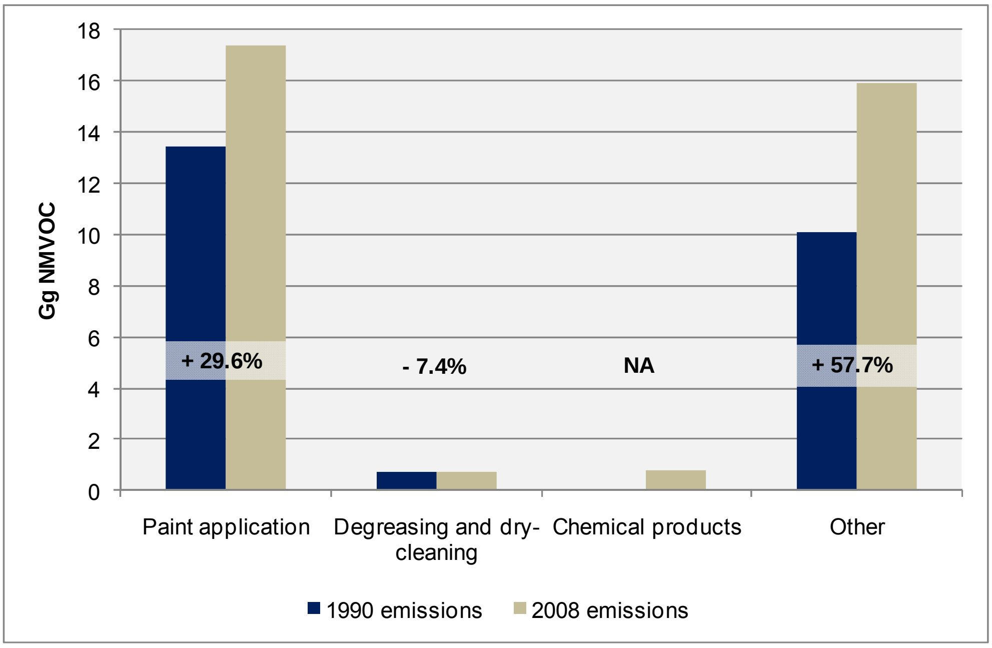
5.1 Sector overview (CRF 3)

This sector 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.

The only direct greenhouse gas reported in this category is nitrous oxide (N_2O) emissions from anaesthesia use. In 2008, N_2O emissions from anaesthesia use totalled 31.0 Gg carbon dioxide equivalent (CO_2-e). This was a decrease of 10.5 Gg CO_2-e (25.4 per cent) from the 1990 level of 41.5 Gg CO_2-e.

However, this sector is a significant source for non-methane volatile organic compound (NMVOC) emissions. In 2008, NMVOC emissions from the solvent and other product use sector were 34.8 Gg, or 20.3 per cent of total NMVOC emissions. This was a decrease of 10.5 Gg (43.3 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 (Figure 5.1.1) subcategories.

Figure 5.1.1 Change in New Zealand's emissions of NMVOC from the solvent and other product use sector from 1990 to 2008



Note: The per cent 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 and 2008 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.

Paint application

Activity and emissions data for 2006 and 2008 were extrapolated from the 2005 survey data. 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 for the 2006 and 2008 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 instance, 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. Degreasing is not estimated in 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.

The emissions for 2008 are the same as for 2006.

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 on 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. Total NMVOC emissions in 2008 were 1.68 Gg. This is based on the assumption that the units are fully discharged within two years of purchase.

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. As at December 2008, the population was estimated to be 4.25 million.

Nitrous oxide used for anaesthesia

The sole importer of bulk N_2O into New Zealand provided activity data for the 2008 calendar year. The importer supplies its competitor with its requirements so the figure 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.

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

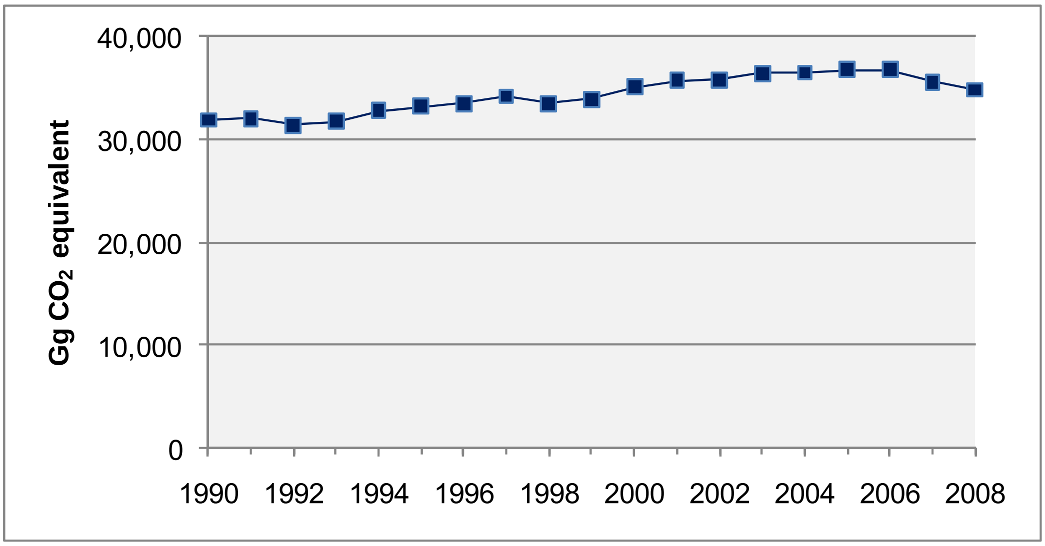
There are no planned improvements for this sector. There are large uncertainties; however, the emission levels from the solvent and other products sector are negligible compared with other sectors. In accordance with good practice, New Zealand will continue to focus its inventory development on key source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

Chapter 6: Agriculture

6.1 Sector overview

In 2008, the agriculture sector contributed 34,826.3 Gg of carbon dioxide equivalent (Gg CO_2-e) (46.6 per cent) of New Zealand's total greenhouse gas emissions. Emissions in this sector have increased by 2,960.9 Gg CO_2-e (9.3 per cent) from the 1990 level of 31,865.4 Gg CO_2-e (Figure 6.1.1). The increase since 1990 is primarily due to an 820.3 Gg CO_2-e (3.8 per cent) increase in methane (CH_4) emissions from the enteric fermentation category and a 1,993.3 Gg CO_2-e (21.3 per cent) increase in nitrous oxide (N_2O) emissions from the agricultural soils category.

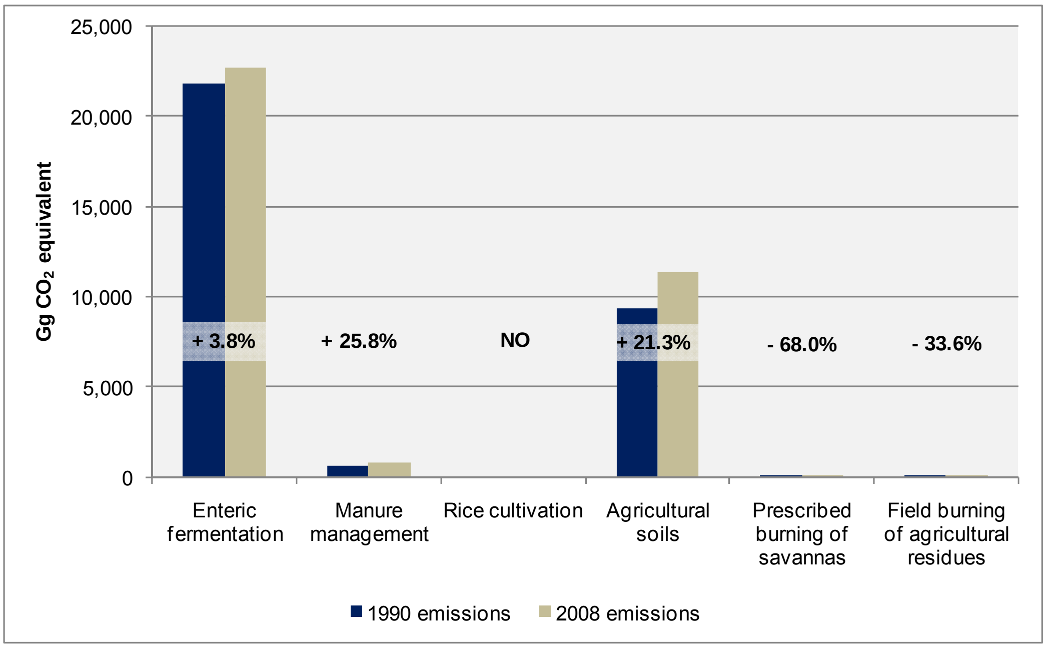
Figure 6.1.1 New Zealand agricultural sector emissions from 1990 to 2008



In 2008, CH_4 emissions from enteric fermentation were 65.1 per cent (22,657.5 Gg CO_2-e) of agricultural emissions and 30.3 per cent of New Zealand's total emissions. Nitrous oxide emissions from the agricultural soils category were 32.7 per cent (11,372.3 Gg CO_2-e) of agricultural emissions and 15.2 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.

Figure 6.1.2 Change in New Zealand's emissions from the agricultural sector from 1990 to 2008



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. Due to the higher profitability of dairy in recent years, there has been an increase in dairy production. The extra land required to accommodate the extra dairy production has mainly come out of sheep farming due to the reduction in profitability of sheep products since 1990. Over the long term, 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, 2009).

There was a gradual increase in the implied emission factors for dairy cattle and beef cattle from 1990 to 2007 that reflects the increased levels of productivity achieved by New Zealand farmers since 1990. Increases in animal liveweight and productivity (milk yield and liveweight gain per animal) require an increased feed intake by the animal to meet higher energy demands. Increased feed intake results in increased CH_4 emissions per animal. The drop in implied emission factors in 2008 is due to a small reduction in productivity as a consequence of the nationwide drought in 2008.

The land area used for horticulture also increased by 50 per cent since 1990 and the types of produce grown have changed (Ministry of Agriculture and Forestry, 2009). There is now less cultivated land area for barley, wheat and fruit but more for grapes (for wine production) and vegetables 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 2007 and 2008

Total agricultural emissions in 2008 were 737.1 Gg CO_2-e (2.1 per cent) lower than the 2007 level. This was largely due to a decrease in the population of sheep (4,372,613 or 11.4 per cent), deer (172,699 or 12.4 per cent) and non-dairy cattle (256,745 or 5.8 per cent). The drought that affected most of New Zealand throughout 2008 was the main cause for these decreases in animal numbers (Ministry of Agriculture and Forestry, 2009). This was the second year in a row that some regions of New Zealand experienced drought.

6.1.1 Methodological issues for the agriculture sector

New Zealand uses a June year for all 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), 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.

To ensure consistency, a single livestock population characterisation and feed-intake estimate is used to estimate CH_4 emissions from the enteric fermentation category, CH_4 and N_2O emissions from the manure management category, and N_2O emissions from the pasture, range and paddock manure subcategory.

Information on livestock population census and survey procedures is included in Annex 3.1.

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 and has been formed to advise if changes to New Zealand's agricultural section of the national inventory are scientifically robust. Reports and papers on proposed changes must have been peer reviewed before they are presented to the panel. The panel then 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. The inaugural meeting of the panel was held on 27 November 2009 where three adjustments were presented. These were (1) calculating dairy emissions using regional data rather than national averages (2) changing how the uncertainty for enteric fermentation is calculated and (3) adopting a country-specific value of 0.1 for $Frac_{GASM}$ and $Frac_{GASF}$. All changes were approved and are detailed in the relevant sections of this report.

6.2 Enteric fermentation (CRF 4A)

6.2.1 Description

Methane is a by-product of digestion in ruminants, for example, cattle, and some non-ruminant animals, such as swine and horses. Within the agriculture sector, ruminants are the largest source of CH_4 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.

In 2008, CH_4 emissions from the enteric fermentation category were identified as the largest key category for New Zealand in the level assessment (excluding land use, land-use change and forestry (LULUCF)). In accordance with Intergovernmental Panel on Climate Change (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 2008, enteric fermentation contributed 22,657.5 Gg CO_2-e. This represented 30.3 per cent of New Zealand's total CO_2-e emissions and 65.1 per cent of agricultural emissions.

Cattle contributed 13,947.7 Gg CO_2-e (61.6 per cent) of emissions from the enteric fermentation category, and sheep contributed 8,079.9 Gg CO_2-e (35.7 per cent) of emissions from this category. Emissions from the enteric fermentation category in 2008 were 820.3 Gg CO_2-e (3.8 per cent) above the 1990 level of 21,837.2 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 2008, dairy cattle were responsible for 9,028.9 Gg CO_2-e, an increase of 3,999.6 Gg CO_2-e (79.5 per cent) from the 1990 level of 5,029.3 Gg CO_2-e. Meanwhile, there have been decreases in emissions from sheep and minor livestock populations, such as goats, horses and swine. In 2008, emissions from sheep were 8,079.9 Gg CO_2-e, a decrease of 3,200.1 Gg CO_2-e (28.4 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

New Zealand's Tier 2 method (Clark et al, 2003) uses a detailed livestock population characterisation and livestock productivity data to calculate feed intake for the four largest categories in the New Zealand ruminant population (dairy cattle, beef cattle, sheep and deer). The amount of CH_4 emitted per animal is calculated using CH_4 emissions per unit of feed intake (Figure 6.2.1).

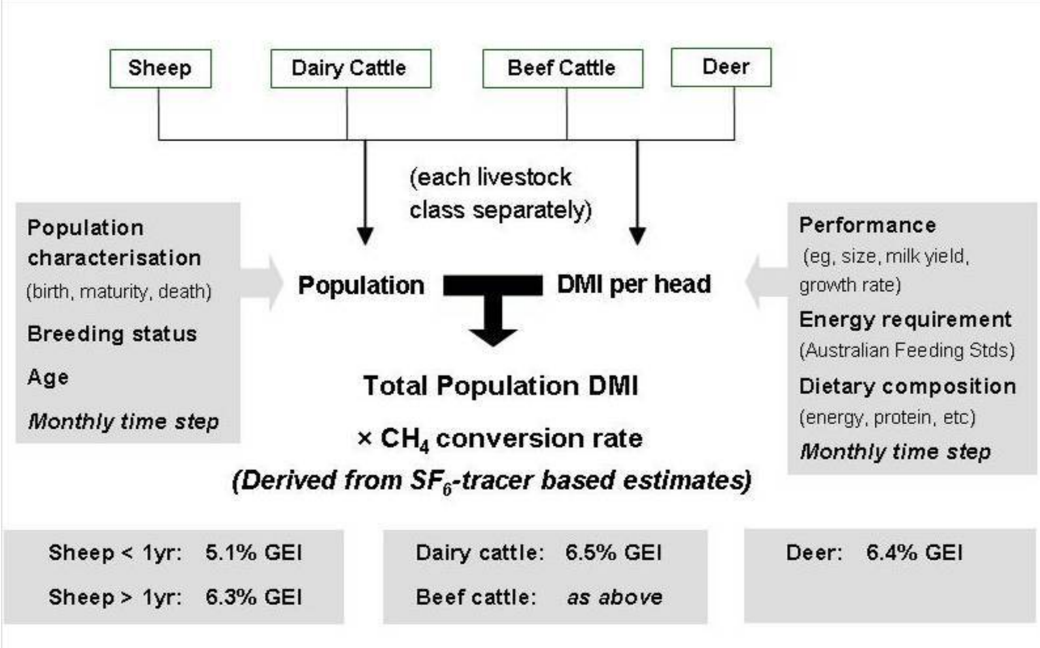
Livestock population data

The New Zealand ruminant population is separated into four main categories: dairy cattle, beef cattle, sheep and deer. Each livestock category is further subdivided by population models (Clark et al, 2003; Clark, 2008b). The populations within a year are adjusted on a monthly basis to account for births, deaths and transfers between age groups. This is necessary because the numbers present at one point in time may not accurately reflect the numbers present at other times of the year. For example, the majority of lambs are born and slaughtered between August and May and, therefore, do not appear in the June census or survey data.

Livestock numbers are provided by Statistics New Zealand from census and survey data conducted in June each year. 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.

Statistics New Zealand collects population data on a territorial authority basis. Territorial authorities are the lowest local political division in New Zealand. These territorial authorities are then aggregated up to regional council boundaries by Statistics New Zealand. In 1993, these 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.

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.

Livestock productivity data

Productivity data comes from Statistics New Zealand and industry statistics. 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 at all.

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).

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 (2009). 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 from 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. Prior to 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.

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

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 several regional councils. As there are 16 regional council regions, some regions use the same liveweight data as other regions. For years in the time series prior to 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 their average 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 per 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, for example, breeding dairy bulls contribute less than 0.1 per cent of emissions from the dairy sector.

Beef cattle: The principal source of information for estimating productivity for beef cattle is livestock slaughter statistics provided by the Ministry 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[4] are made in order 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[5] 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 per annum in mature sheep (ewes, rams and wethers) and 2.5 kg per annum in growing sheep and lambs.

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 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, 1990). These algorithms are chosen as they specifically include methods to estimate the energy requirements of grazing animals. This method estimates a maintenance requirement (a function of liveweight, the amount of energy expended on the grazing process), and a production energy requirement influenced by the level of productivity (eg, milk yield and liveweight gain), physiological state (eg, pregnant or lactating) and the stage of maturity of the animal. All calculations are performed on a monthly basis.

For deer, an approach similar to that used for cattle is adopted using algorithms derived from New Zealand studies on red deer. The algorithms take into account animal

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4 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.

5 Percentage of carcass weight in relation to live weight.

liveweight and production requirements based on the rate of liveweight gain, sex, milk yield and physiological state.

Monthly 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 farm surveys on commercial cattle and sheep farms.

Methane emissions per unit of feed intake

There are a number of published algorithms and models[6] 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 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 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.

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 old. 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 6.2.1 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

Note: GE is gross energy.

6 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 Clark et al, 2003.

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	69.6	50.7	9.3	18.8
1991	73.2	51.9	9.4	19.3
1992	73.1	52.4	9.4	20.2
1993	74.6	53.5	9.5	20.4
1994	72.8	54.2	9.6	19.7
1995	72.8	53.3	9.4	20.6
1996	75.1	54.6	9.8	20.9
1997	75.5	55.1	10.2	21.0
1998	73.0	55.1	10.2	21.2
1999	75.3	54.1	10.2	21.3
2000	76.9	56.1	10.7	21.8
2001	77.7	57.0	10.7	21.7
2002	77.1	56.6	10.7	21.6
2003	80.0	56.1	10.7	21.6
2004	78.2	57.0	11.0	21.7
2005	79.2	57.7	11.1	22.2
2006	78.9	58.6	10.9	22.2
2007	77.6	57.3	10.7	22.3
2008	77.1	56.6	11.3	22.4

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 2008.

Livestock population data

The populations of goats, horses and pigs 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.

Livestock emissions data

Horses and swine: Enteric CH_4 from these classes of livestock were not a key category in 2008 and, in the absence of data to develop New Zealand emissions' factors, IPCC default values were used.

Goats: Enteric CH_4 from goats was not a key category in 2008. 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/year. 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: Enteric CH_4 from alpaca was not a key category in 2008. 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 recalculating 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 according to the standard deviation of the methane yield. The recent report investigated calculating the uncertainty by expressing the coefficient of variation 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 is larger. 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 2008, 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	1,039.7	873.3	1,206.1
2008	1,078.9	906.3	1,251.5

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

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 coefficient of variation (standard error as a percent 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 2008, CH_4 from enteric fermentation was identified as a key category (level and trend assessment). In preparation for this inventory submission, the data for this category underwent Tier 1 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 with 365 (±61) g CH_4/day/cow for the scaled-up measurements reported by Waghorn et al (2002; 2003). 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 chambers or the SF_6 tracer technique respectively.

Table 6.2.4 shows a comparison of the New Zealand-specific 2008 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 (UNFCCC, 2009). New Zealand has a slightly higher implied emission factor than the IPCC Oceania default due to the higher productivity of the livestock compared with the Oceania average. The converse is true for the lower implied emission factor for dairy in comparison with Australia and the United Kingdom. Also, New Zealand livestock have a predominant diet of pasture with a higher digestibility than the value reported in Table A-1 of the revised 1996 IPCC guidelines (IPCC, 1996). New Zealand's emissions factor for sheep is higher than the Australian and United Kingdom emission factor 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.

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.

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[7] (kg CH_4/head/year)
IPCC (2006b) 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
New Zealand-specific 2008 value	77	57	10.9

Note: IEF is implied emission factor.

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

6.2.5 Source-specific recalculations

Previously, emissions from dairy animals were calculated using national averages of populations and productivity data. This data was used in the Tier 2 method. A report was commissioned by the Ministry of Agriculture and Forestry to determine if it was feasible to calculate dairy emissions at a regional level before being aggregated up into a national figure. By changing to this method of calculation, differences in animal performance and subsequent emissions efficiencies across the regions could be identified. The report found that data was available for this to occur and for recalculations back to 1990 (Clark 2008a). Data required for the Tier 2 method is now gathered at the regional level rather than using national averages. Details of how the activity data is sourced are outlined in section 6.2.2. This methodological change affects the enteric fermentation, manure management and agricultural soils sections and recalculations have been carried out for each section. The impact of the change is reported in chapter 10.

Alpacas have a very small population in New Zealand but are increasing in number and have therefore been included in the current submission. Although population estimations were required in order to calculate emissions back to 1990, the New Zealand Alpaca Association has begun to collate this data and therefore future population estimates will improve. The impact of this change to the inventory is reported in chapter 10.

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2009), Meat and Wool statistics (2009), Livestock Improvement Corporation statistics (2009)).

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 under way 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 eight 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 2008, emissions from the manure management category comprised 776.3 Gg CO_2-e (2.2 per cent) of emissions from the agriculture sector. Emissions from manure management had increased by 159.1 Gg CO_2-e (25.8 per cent) from the 1990 level of 617.2 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 2008.

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 of 56.9 Gg CO_2-e in 2008. In comparison, N_2O emissions from the agricultural soils category totalled 11,372.3 Gg CO_2-e in 2008.

In New Zealand, dairy cows only have a fraction (5 per cent) of their excreta stored in anaerobic lagoon waste systems. The remaining 95 per cent of excreta from dairy cattle is deposited directly onto pasture. These fractions relate to the proportion of time dairy cattle spend on pasture compared with the time they spend in the milking shed. All other ruminant species (sheep, beef cattle, goats, deer, alpaca and horses) graze outdoors all year round 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	–	3	–	97
Sheep	–	100	–	–
Swine	55	–	17	28
Goats	–	100	–	–
Deer	–	100	–	–
Horses	–	100	–	–
Alpaca	–	100	–	–

6.3.2 Methodological issues

Methane from manure management

The IPCC Tier 2 approach is used to calculate CH_4 emissions from ruminant animal wastes 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. Table 6.3.2 summarises the key variables in the calculation of CH_4 from manure management.

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

Livestock	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	0.05	90	4.6	3.27
Beef cattle	1.0	0.98	0.0	–	–	–
Sheep	1.0	0.69	0.0	–	–	–
Deer	1.0	0.92	0.0	–	–	–

Dairy cattle

Faecal material deposited directly onto pastures: The quantity of faecal dry-matter produced is obtained by multiplying the quantity of feed eaten by the dry-matter digestibility of the feed, minus the feed retained in product. These feed intake and dry-matter digestibility estimates are used in the enteric CH_4 and N_2O Tier 2 model calculations. 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 (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

The quantity of faecal dry-matter produced is obtained by multiplying the quantity of feed eaten by the dry-matter digestibility of the feed, minus the feed retained in product. These feed intake and dry-matter digestibility estimates are used in the enteric CH_4 and N_2O Tier 2 model calculations.

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 0.69 g CH_4/kg. This value is obtained from New Zealand studies on sheep (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 an N_2O emission factor for each animal waste management system.

The N_{ex} values are calculated from the nitrogen intake less the nitrogen 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 CH_4 emissions (Clark et al, 2003). The nitrogen content of feed is estimated from a review of over 6000 pasture samples of dairy, 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, wool and beef, and the nitrogen retained in deer velvet, are taken from New Zealand-based research.

Table 6.3.3 (overleaf) shows N_{ex} values increasing over time reflecting the increases in animal productivity in New Zealand since 1990.

Table 6.3.3 N_{ex} values for New Zealand's main livestock classes from 1990 to 2008

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	104.22	24.88
1991	12.83	66.98	109.06	25.64
1992	12.80	67.78	109.09	26.83
1993	12.93	69.26	110.81	27.06
1994	12.96	70.15	108.13	26.20
1995	12.81	68.95	108.05	27.42
1996	13.32	70.82	110.91	27.76
1997	13.89	71.48	111.29	27.84
1998	14.01	71.48	108.23	28.06
1999	13.97	70.00	111.23	28.24
2000	14.58	72.60	112.89	28.91
2001	14.72	73.71	113.79	28.85
2002	14.68	73.14	113.13	28.74
2003	14.66	72.38	117.48	28.67
2004	15.07	73.61	115.21	28.88
2005	15.19	74.60	116.45	29.47
2006	15.01	75.81	115.64	29.58
2007	14.75	73.91	113.95	29.69
2008	15.57	72.99	112.86	29.79

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 literature indicates that alpacas have an 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 greatly overestimating the true N_{ex} value for alpacas.

6.3.3 Uncertainties and time-series consistency

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 New Zealand-specific emission factor for $EF_{3(PR\&P)}$ is 0.01 kg N_2O-N/kg N (further details in 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 2008. In preparation for this inventory submission, the data for this category underwent Tier 1 quality checks.

Table 6.3.4 shows a comparison of the New Zealand-specific 2008 implied emission factor for methane from manure management with the IPCC Oceania default and the Australian and United Kingdom implied emission factor for dairy, beef cattle and sheep. New Zealand has a lower implied emission factor for 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 as Australia also has 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, that is, productivity of the animals and the use of different algorithms to determine energy intake as well as values used for nitrogen content of feed and digestibility.

Table 6.3.4 Comparison of IPCC default emission factors and country-specific implied emission factors for 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
New Zealand-specific 2008 value	3.31	0.7	0.11

Note: IEF is implied emission factor.

6.3.5 Source-specific recalculations

Due to improvements in how dairy emissions are calculated (ie, using regional data rather than a national average), N_{ex} and methane emissions from manure management have been recalculated for all years. Details of how activity data is sourced can be found in section 6.2.2. The impact of the change to the inventory is reported in chapter 10.

Estimates of emissions from alpacas have been incorporated into this submission and emissions have been recalculated back to 1990. See section 6.2 for further details. The impact of the change to the inventory is reported in chapter 10.

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2009), Meat and Wool statistics (2009), Livestock Improvement Corporation statistics (2009)).

6.3.6 Source-specific planned improvements

Both the Poultry Industry Association New Zealand and New Zealand Pork are currently working to improve knowledge on the distribution of each industry's manure into each of the manure management categories. This work will be assessed 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 2008, the agricultural soils category contributed 11,372.3 Gg CO_2-e (15.2 per cent) to New Zealand's total emissions and 95.5 per cent to total N_2O emissions. Emissions were 1,993.3 Gg CO_2-e (21.3 per cent) above the 1990 level of 9,379.0 Gg CO_2-e. This category comprises three subcategories. Each of these subcategories has been identified as a key category. The trend for each subcategory is provided below.

- 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 1,777.7 Gg CO_2-e (15.6 per cent) to emissions from the agricultural soils category in 2008. This was an increase of 1,262.5 Gg CO_2-e (245.1 per cent) from the 1990 level of 515.2 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. In 2008, indirect N_2O emissions from nitrogen used in agriculture contributed 2,468.8 Gg CO_2-e (21.7 per cent) to emissions from the agricultural soils category. This was an increase of 463.7 Gg CO_2-e (23.1 per cent) from the 1990 level of 2,005.1 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 7,125.9 Gg CO_2-e (62.7 per cent) to emissions from the agricultural soils category. This is an increase of 267.1 Gg CO_2-e (3.9 per cent) from the 1990 level of 6,858.7 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.

Five New Zealand-specific emission factors and parameters are used in the inventory: EF_1, $EF_{3(PR\&P)}$, $Frac_{LEACH}$, $Frac_{GASM}$ and $Frac_{GASF}$. The use of a country-specific emission factor for EF_1 (direct emissions from nitrogen input to soil) of 1 per cent, is based on work by Kelliher and de Klein (2006). The country-specific $EF_{3(PR\&P)}$ emission factor of 1 per cent and $Frac_{LEACH}$ of 0.07 are based on extensively reviewed literature and field studies (Carran et al, 1995; de Klein et al, 2003; Muller et al, 1995; Thomas et al, 2005). A new value of 0.1 has been adopted for the emission factor $Frac_{GASM}$ after an extensive review of scientific literature (Sherlock et al, 2009). Conversely, 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).

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.

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). 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), 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 three locations. The percentage of applied nitrogen (in urine or dung) emitted as N_2O, and relevant environmental variables, were measured in four separate trials that began 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 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).

The research and analysis to date indicates that, if excreta is separated into urine and dung components, EF_3 for urine and dung could be set to 0.007 and 0.003 respectively. However, it is recognised the dung EF_3 data is limited. By combining urine and dung EF_3 values, the dairy cattle total excreta EF_3 is 0.006. By conservatively rounding the total excreta, an EF_3 of 0.006 provides a New Zealand-specific value of 0.01 for $EF_{3(PR\&P)}$. The IPCC default value of $EF_{3(PR\&P)}$ is 0.02 (IPCC, 1996).

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 2008 calendar year, DCD mitigated 40.8 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 10 kg per hectare 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 are 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 nitrogen fertiliser use in New Zealand, it is currently not possible to apply these reductions to EF_1 in the inventory calculations.

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 0.0094 and $Frac_{LEACH}$ of 0.0658 for a dairy grazing area in the months that DCD is applied (May to September). The modified emission factors are based on information from the agricultural survey that 5.1 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	5.1	0.0094
$Frac_{LEACH}$	0.07	53	5.1	0.0658

All other emission factors and parameters relating to animal excreta and fertiliser use ($Frac_{GASM}$, $Frac_{GASF}$, EF_4 and EF_5) remain unchanged when DCD is used as an N_2O mitigation technology. Based on the physico-chemical reaction of DCD in the soil, DCD should 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 in 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.

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.

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 is then re-emitted as N_2O. This is calculated as an indirect emission of N_2O. The fraction of nitrogen that is deposited or spread on land that then indirectly becomes 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 have shown that the current 1996 IPCC default value for $Frac_{GASM}$ is too high for New Zealand conditions. In most European countries, ammonia emitted from pasture soils following grazing is just one of several sources contributing to 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 national papers covering 19 individual measurements were reported on. The report determined 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.

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. All of the nitrogen inputs are summed together and a New Zealand-specific emission factor 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.

Data on nitrogen fertiliser use is provided by the New Zealand Fertiliser Manufacturers' Research Association from sales records for 1990 to 2008. There has been a five-fold increase in the amount of synthetic fertiliser nitrogen applied to soils over the time series, from 59,265 tonnes in 1990 to 328,157 tonnes in 2008. These figures differ by 10 per cent from those reported in the common reporting format tables. This is because the values reported in the common format reporting tables are adjusted to account for the amount that volatises as NH_3 and NO_x (IPCC, 2000).

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. New Zealand uses a country-specific value for EF_1 of 0.01 kg N_2O-N/kg N (Kelliher and de Klein, 2006).

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). Kelliher et al (2002) estimated 5 per cent (ie, 10,109 hectares) of organic soils under agricultural pasture are cultivated on an annual basis. New Zealand uses the IPCC default emissions factor (EF_2 equal to 8 kg N_2O-N/kg N) for all years of the time series.

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 2008 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2008)

Year	N_2O emissions from agricultural soils (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	30.3	17.5	52.5
2002	37.3	21.6	64.9
2008	35.8	20.8	62.3

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 2008 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

Parameter	1990 Contribution to uncertainty (%)	2002 Contribution to uncertainty (%)
$EF_{3(PR\&P)}$	90.8	88.0
EF_4	2.9	3.3
Sheep N_{ex}	2.5	1.8
EF_5	2.2	2.8
Dairy N_{ex}	0.5	0.7
$Frac_{GASM}$	0.5	0.5
EF_1	0.3	2.4
Beef N_{ex}	0.2	0.3
$Frac_{LEACH}$	0.1	0.2

6.5.4 Source-specific QA/QC and verification

In 2008, 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 submission, the data for these categories underwent Tier 1 quality checks.

In 2008, the 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 2008. Data from the New Zealand Fertiliser Manufacturers' Research Association was year end May. The *Agricultural Production Survey* data for fertiliser use in New Zealand was within 26,000 tonnes (~10 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 fertiliser is provided from two large companies. Therefore this information will be more accurate than the survey as there is a multitude of differently named nitrogen fertilisers and the *Agricultural Production Survey* respondents often have problems filling in the fertiliser question in the questionnaire. Ten per cent variation in nitrogen fertiliser data between the New Zealand Fertiliser Manufacturers' Research Association and the *Agricultural Production Survey* is considered to be good.

Dicyandiamide data obtained from the *Agricultural Production Survey* was verified with data from the main supplier of DCD. This company has a 90 per cent share of the market. Values obtained from this company were approximately 87 per cent of the reported DCD usage data obtained from the *Agricultural Production Survey*, indicating the values were reasonably accurate.

Table 6.5.4 compares the New Zealand-specific values for EF_1 and $EF_{3PR\&P}$ with the 1996 IPCC default value and emission factors used by Australia and the United Kingdom. In both cases, 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). In Table A-1 (IPCC, 1996) it 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)
IPCC (2006b) developed temperate climate/Oceania default value	0.0125	0.02
Australian-specific IEF 2008 value	0.0125 (except animal production = 0.01)	0.004
United Kingdom-specific IEF 2008 value	0.0125	0.02
New Zealand-specific 2008 value	0.01	0.01

Note: IEF is implied emission factor.

Table 6.5.5 compares the New Zealand-specific values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$ with the 1996 IPCC default and fractions used by Australia and the United Kingdom. Details on these three fractions can be found in further detail in section 6.5.2. Although New Zealand has taken a country-specific value for $Frac_{GASF}$ of 0.1, it is the same as the IPCC default and that of Australia and the United Kingdom. This is because research showed that this 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 taken on board a lesser value of 0.1. The reduction is due to the different sources that make up this value. In New Zealand, 97 per cent of animal excreta is deposited onto pasture whereas the 1996 IPCC default value was calculated taking into account a much higher percentage of manure management and storage. This results in a much higher proportion of nitrogen being volatised and hence the higher $Frac_{GASM}$ default value.

New Zealand also has a much lower $Frac_{LEACH}$. Research showed that New Zealand applies a much lower rate of nitrogen fertiliser than what was assumed when developing the 1996 IPCC default value. When the OVERSEER® nutrient-budgeting model (Wheeler et al, 2003) took this lower rate into account, the rate of leaching was much lower than when compared with farms with a high nitrogen fertiliser rate than 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

Note: IEF is implied emission factor.

6.5.5 Source-specific recalculations

A country-specific value of 0.1 has been adopted for the emission factor $Frac_{GASM}$. As this differs from the 1996 IPCC default value of 0.2, recalculations have been carried out for all years from 1990. This resulted in a reduction of 685.3 Gg CO_2-e in 1990 and 737.2 Gg CO_2-e in 2007.

The $Frac_{GASF}$ value of 0.1 has been verified as appropriate to New Zealand conditions and has therefore been adopted as a country-specific emission factor. This value is no different to the 1996 IPCC default value, therefore it did not result in any recalculations.

Due to improvements in how dairy emissions are calculated (ie, using regional data rather than a national average) N_{ex} applied to soils have been recalculated for all years. Details of how activity data is sourced can be found in section 6.2.2. The impact of this change to the inventory is reported in chapter 10.

Estimates of emissions from alpacas have been incorporated into this submission and emissions have been recalculated back to 1990. See section 6.2 for further details. The impact of this change to the inventory is reported in chapter 10.

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2009), Meat and Wool statistics (2009), Livestock Improvement Corporation statistics (2009)).

Potatoes have been identified as an important crop in New Zealand (Thomas et al, 2008). Estimates have therefore been incorporated into this submission and emissions have been recalculated back to 1990. This resulted in an increase of 9.4 Gg CO_2-e in both 1990 and 2008.

An error in the calculation of crop residues has also been corrected. Prior to this submission, in the calculation for emissions from crop residue activity, data on maize was being adjusted for a proportion that was burnt. However, maize residue is not burnt in New Zealand and was therefore not included in the calculations of the agricultural burning of crop residue resulting in a small proportion of maize crop not being accounted for. This oversight has now been corrected.

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.

The calculation of DCD effectiveness is being improved. This is through the development of the programming for the Tier 2 model used to determine animal methane emissions and nitrogen excretion rates. Reductions in emissions factors due to DCD will be applied monthly and only during the respective months that it can be used. In this way it can be applied more precisely to the relevant animal populations during the year.

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 under way 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 to improve data obtained from the questionnaire and therefore improve the verification of fertiliser data from Fertiliser Manufacturers' Research Association.

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 2008, 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 2008, 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. 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.

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).

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

There was no source-specific quality assurance or quality control 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*. Assessment on this data will be carried out to determine if it represents an accurate area of tussock land burned, and the potential to include this data in future inventory submissions.

6.7 Field burning of agricultural residues (CRF 4F)

6.7.1 Description

Burning of agricultural residues produced 19.1 Gg CO_2-e in 2008. This was a decrease of 9.6 Gg CO_2-e (33.6 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 2008.

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). Burning of residues varies between years because of climatic conditions.

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.

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

There was no source-specific quality assurance or quality control for this category in 2008.

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 dropping since 1990. This fraction is also being looked into further 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[8]
United Kingdom-specific IEF 2008 value	0
New Zealand-specific 2008 value	0.3

Note: IEF is implied emission factor.

6.7.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2009)).

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 judgement 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.

8 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 2008, net removals by the land use, land-use change and forestry (LULUCF) sector were 26,176.8 Gg carbon dioxide equivalent (CO_2-e). This is made up of net removals of 26,219.1 Gg carbon dioxide and emissions of 38.2 CO_2-e of methane (CH_4), and 4.1 Gg CO_2-e of nitrous oxide (N_2O).

Net removals have decreased by 4,889.5 Gg CO_2-e (15.7 per cent) from the 1990 level of 31,066.3 Gg CO_2-e (Figure 7.1.1). This is largely due to the harvesting and replanting of plantation forests in the five years prior to 2008 as this lowered the average age and therefore the CO_2 absorption capacity of planted forests in 2008. The decrease is also due to direct emissions from deforestation. Figure 7.1.2 shows the changes in emissions and removals by land-use category from 1990 to 2008. The increase in emissions in the grassland land-use category is primarily the result of 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.

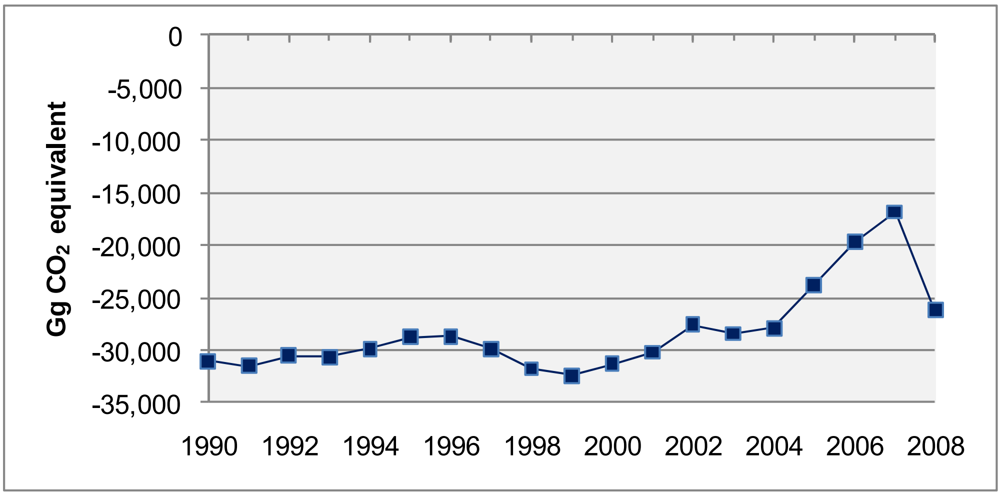
Carbon dioxide emissions and removals in the LULUCF sector are primarily controlled by the uptake from plant growth, emissions from harvesting production forests, deforestation and the decomposition of organic material. Nitrous oxide can be emitted from the ecosystem as a by-product of nitrification and de-nitrification, and the burning of organic matter. Other gases released during biomass burning include 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.

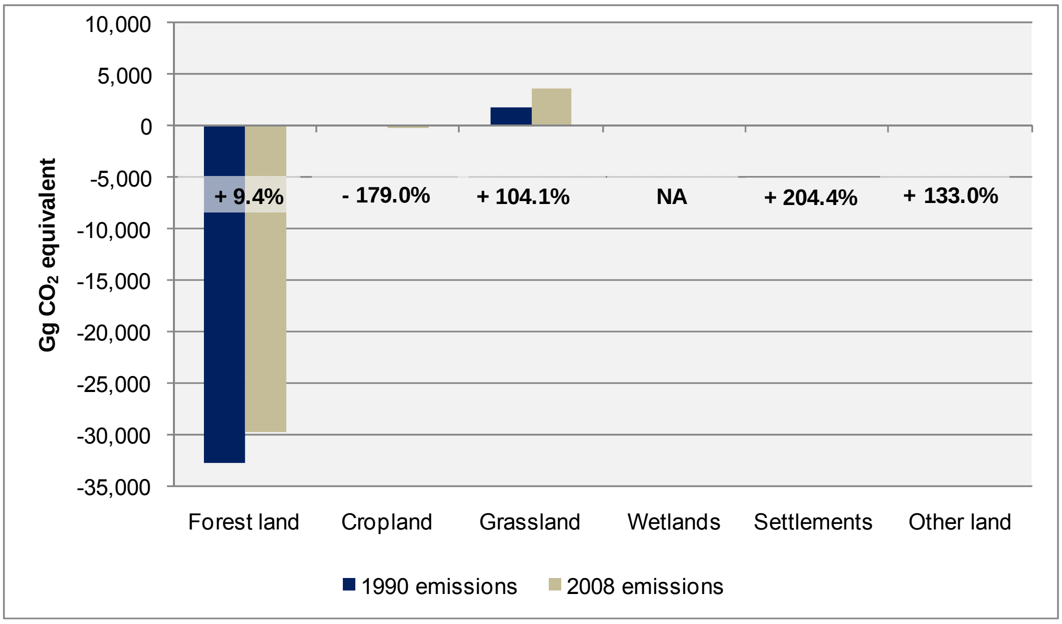
The land-use categories of forest land remaining forest land, conversion to forest land, grassland remaining grassland and conversion to grassland are key categories for New Zealand in 2008.

Figure 7.1.1 New Zealand's annual emissions and removals from the LULUCF sector from 1990 to 2008



Note: At this scale, emissions on cropland, wetland, settlements and other land are inseparable.

Figure 7.1.2 Change in New Zealand's emissions and removals from the LULUCF sector from 1990 to 2008



7.1.1 Land use in New Zealand

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 7.1.1.1). Nearly all lowland areas have been cleared of natural forest for agriculture, horticulture, plantation forestry and urban development.

Table 7.1.1.1 Land use in New Zealand in 2008

Land-use category	Subcategory	Net area in 2008 (ha)	Proportion of total area (%)
Forest land	Natural forest	8,118,004	30.2
	Pre-1990 planted forest	1,430,286	5.3
	Post-1989 forest	568,775	2.2
	Subtotal	*10,117,064*	37.7
Cropland	Annual	334,159	1.2
	Perennial	88,541	0.3
	Subtotal	*422,700*	*1.6*
Grassland	High producing	5,813,712	21.6
	Low producing	7,701,148	28.7
	With woody biomass	1,056,975	3.9
	Subtotal	*14,571,835*	*54.2*
Wetlands		644,135	2.4
Settlements		206,288	0.8
Other land		889,068	3.3
Total		**26,851,090**	**100.0**

Note: Areas as at 31 December 2008 and include deforestation of post-1989 forest since 1990.

Pasture establishment is thought to have slightly increased mineral soil carbon levels. However, losses of carbon due to erosion as a result of land-use change are also possible (Tate et al, 2003c). New Zealand soils are naturally acidic with low levels of nitrogen, phosphorus and sulphur. Consequently, soils used to grow crops and pasture need to be developed and maintained with nitrogen-fixing plants (such as clover), fertilisers and, often, lime to sustain high-yield plant growth.

New Zealand has a substantial estate of planted forests that are intensively managed for timber-supply purposes. In 2008, 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.

The description of the land-use subcategories mapped by New Zealand is provided in Table 7.1.2.6. The national threshold that New Zealand uses to define forest land for both Climate Change 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).

There continues to be considerable land-use change in New Zealand, and while the harvesting of natural forests has been restricted under the 1993 amendments to the Forests Act 1949 and the Forests (West Coast Accord) Act 2000, there are very few other regulations in place to influence other land-use change. Recently, the following regulations and government initiatives have been put in place to either encourage forest establishment or discourage deforestation:

- Climate Change Response Act 2002 (updated 8 December 2009)
- Permanent Forest Sink Initiative (Ministry of Agriculture and Forestry, 2008b)
- Afforestation Grant Scheme (Ministry of Agriculture and Forestry, 2009b).

7.1.2 Methodological issues for New Zealand

Recalculation of the 1990–2007 LULUCF inventory

For this submission, New Zealand has recalculated its emission and removal estimates for the LULUCF sector from 1990 to 2007 to incorporate improved New Zealand-specific methods and data. This follows the introduction in 2008 of a new data collection and modelling programme for the LULUCF sector, the Land Use and Carbon Analysis System (LUCAS) (see below and Annex A3.2 for further details).

With the change to using LUCAS information, there have been major recalculations to New Zealand's LULUCF emission and removal estimates. These have resulted in a decrease of 12,927.8 Gg CO_2-e in net emissions (an increase in removals) on the 1990 estimate, and an increase of 7,015.2 Gg CO_2-e in net emissions (a decrease in removals) on the 2007 estimate (see Table 7.1.2.1).

Table 7.1.2.1 Recalculations to New Zealand's total net removals

	Reported net removals		Change in estimate	
	2009 submission (Gg CO_2-e)	2010 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	–18,138.5	–31,066.3	–12,927.8	–71.3
2007	–23,836.0	–16,820.7	+7,015.3	+29.4

The LUCAS system has enabled New Zealand to make significant improvements to LULUCF estimates, including new mapping of land use and land-use change since 1990, and the use of improved New Zealand-specific methods, activity data and emission factors. This has improved the accuracy, completeness and transparency of the estimates.

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions and removals are the result of:

- new mapping of 1990 and 2007 land use and land-use change to improve the identification of 'land-use remaining' and 'land-use change' areas in the six land-use categories, and, in particular, of changes to and from forest land, resulting in the new mapping of 275.6 kilo hectares of previously unidentified forest land in 1990 (revising the total area of 1990 forest land from 9,368.9 kha to 9,644.6 kha in the current submission)
- changes in the land-use subcategories New Zealand is reporting on, to improve the alignment between New Zealand's forest land, grassland and wetlands categories, the IPCC land-use categories and the Kyoto Protocol forest definition. Previously, New Zealand had reported land-cover categories (Table 7.1.2.7)
- improved measurement of deforestation up to 1 January 2008 has been based on land-use change mapping rather than relying as previously on a range of information sources. Deforestation is also now reported on in the 'land converted to' category, whereas previously it had been included in the forest land remaining forest land subcategory
- methodological improvements to the calculation of emissions and removals by using the LUCAS 'calculation engine' to consistently estimate annual changes in carbon and non-carbon emissions, for the five carbon pools associated with annual land-use changes, using a master set of New Zealand-specific and IPCC default emission factors (see Tables 7.1.2.3, 7.1.2.4, 7.1.2.5 and 7.1.2.10)

- improvements to the accuracy of emission factors, in particular, the age-based carbon yield table for post-1989 forests and the national average carbon levels for natural forests
- the inclusion of soil carbon stock estimates using a Tier 2 method with New Zealand-specific georeferenced soil pedon data.

The impact of these recalculations on net CO_2-e removals in each land-use category is provided in Table 7.1.2.2. 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 2007, to enable a comparison of the two approaches.

Table 7.1.2.2 Recalculations to New Zealand's net emissions and removals for 1990 and 2007

Land-use category	Net emissions and removals (Gg CO_2-e)				Change in 1990 estimate (%)	Change in 2007 estimate (%)
	2009 submission: 1990 estimate	2010 submission: 1990 estimate	2009 submission: 2007 estimate	2010 submission: 2007 estimate		
Forest land	–18,649.2	–32,856.7	–24,527.9	–30,651.5	+76.2	+25.0
Cropland	–477.7	29.9	–510.3	17.5	–106.3	–103.4
Grassland	863.9	1,742.4	1,063.7	13,618.3	+101.7	+1180.3
Wetlands	0.7	0.0	0.7	4.2	–98.5	+482.7
Settlements	97.2	6.6	97.2	102.7	–93.2	+5.7
Other land	26.7	11.5	40.6	88.0	–56.8	+116.7
Total	**–18,138.5**	**–31,066.3**	**–23,836.0**	**–16,820.7**	**+71.3**	**–29.4**

Detailed information on the recalculations is provided below in the relevant source-specific recalculations sections, and in chapter 10.

Methodological approaches to calculating emissions and removals

New Zealand uses a combination of Tier 1 and Tier 2 methodologies for estimating and reporting emissions and removals for the LULUCF sector. The Tier 1 approach, based on a simple land-use change matrix, has been used to estimate carbon for the four biomass pools for all land-use categories except for natural forest, pre-1990 planted forest and post-1989 forests as these all 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, except for other land. The other land category uses a Tier 1 approach. Carbon in the organic soil component is not estimated independently from mineral soils, as this makes up just 0.9 per cent of New Zealand's total land area.

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 7.1.2.3 summarises the methods being used to estimate carbon by pool for each land use.

Table 7.1.2.3 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
	Kyoto Protocol reporting pool	**Above-ground biomass**	**Below-ground biomass**	**Dead wood**	**Litter**	**Soil organic matter**
Land-use category	Natural forest	Allometric equations	% of above-ground biomass	Allometric equations	Lab analysis	Soil carbon model
	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 model
	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 model
	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	IPCC Tier 1 default parameters	Not estimated	Not estimated	Not estimated	Soil carbon model
	Grassland (high and low producing)	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	Soil carbon model
	Grassland with woody biomass	Allometric equations	Per cent of above-ground biomass	Allometric equations	Allometric equations	
	Wetlands	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	Soil carbon model
	Settlements	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	Soil carbon model
	Other land	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	IPCC Tier 1 default parameters

Notes: AR = afforestation/reforestation, D = deforestation and NEFD = the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2009a). See the methodology sections on soils (section 7.1.2) and forests (section 7.2.2) for explanations of the soil carbon, C_Change and Forest Carbon Predictor models.

LUCAS Data Management System

New Zealand has established a data collection and modelling programme for the LULUCF sector called the Land Use and Carbon Analysis System (LUCAS) (see www.mfe.govt.nz/issues/climate/lucas/). This programme addresses the lack of information for some land-use categories, and 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, 2008); wall-to-wall land-use mapping for 1990 and 2008 using satellite and aircraft remotely sensed imagery; 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.

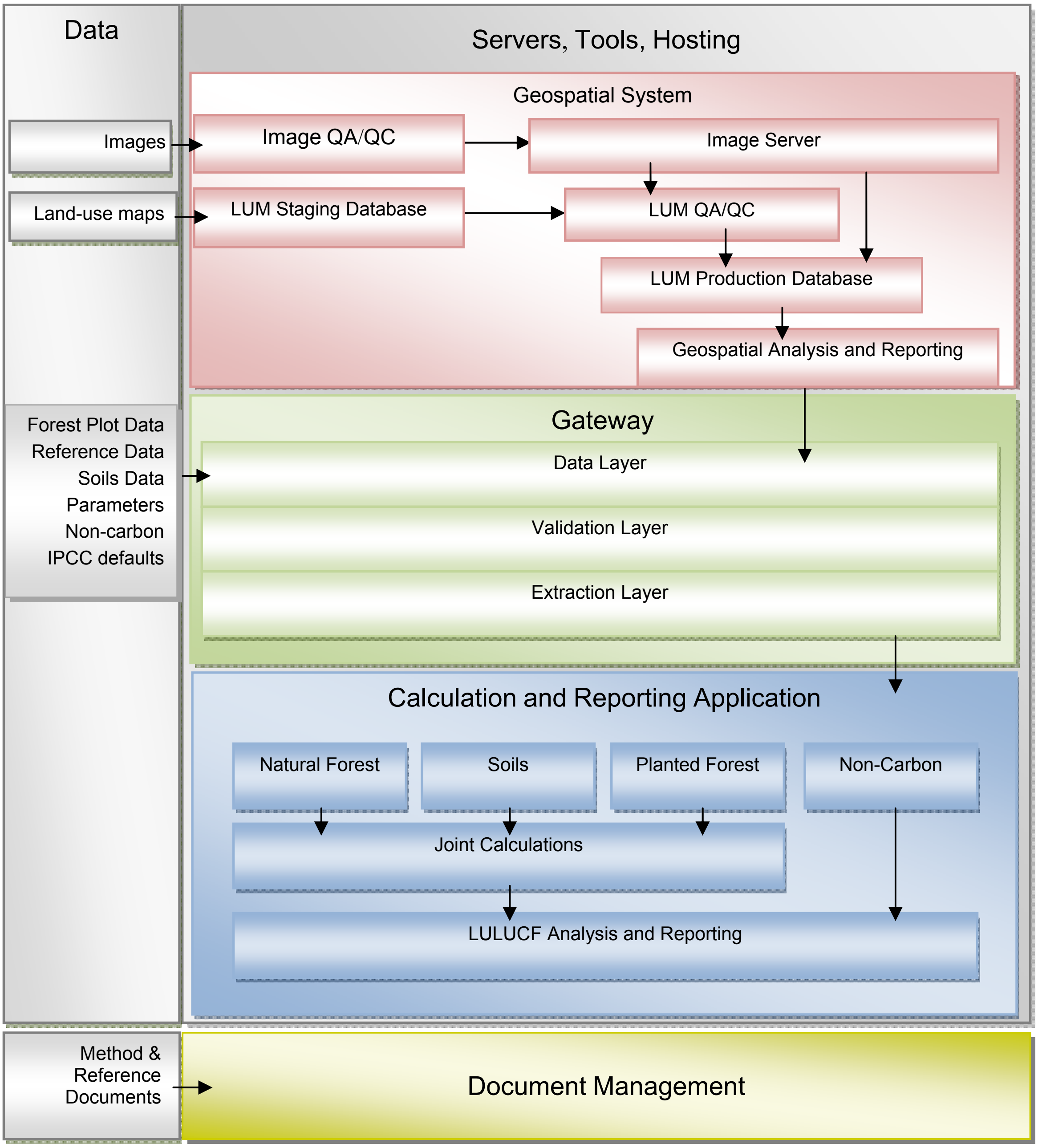
Details of the natural forest allometric equations, and the planted forest growth models and carbon allocation models, are provided in the forest land section (section 7.2). This section provides details about the database, including where the data is stored, the calculations performed, the soil carbon model, liming and biomass burning.

The LUCAS Data Management System stores, manages and retrieves data for international greenhouse gas reporting for the LULUCF sector. The system comprises three primary applications: the Geospatial System, the Gateway and the Calculation and Reporting Application (Figure 7.1.2.1). 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.

The LUCAS Data Management System:

- provides a transparent system for the storage and management of LULUCF activity data
- provides a transparent means for the versioning and validation of land-use data, plot measurements, reference data and emissions factors
- calculates carbon stocks, emissions and removals by land use and carbon pool for both Climate Change Convention and Kyoto Protocol reporting
- calculates biomass burning and liming emissions by land use based on spatial and emission factors stored in the Gateway
- produces the output required to populate the common reporting format tables for the LULUCF sector and reporting under Article 3.3 of the Kyoto Protocol.

Figure 7.1.2.1 New Zealand's LUCAS Data Management System



Note: LUM means land-use map, and joint calculations are described below.

'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 (CRA). For further details refer to Annex 3.2.

Calculation of national emission and removal estimates

To calculate emissions and removals for the New Zealand LULUCF sector, the following data are used:

- annual land use and land-use change area data
- biomass carbon stocks per hectare prior to land-use conversion, and annual growth in biomass carbon stocks per hectare following conversion (see Tables 7.1.2.4 and 7.1.2.5)

- 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:

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

The formula used to calculate emissions from soil changes is:

$$\frac{\textit{Soil carbon at steady state in the original land use} - \textit{Soil carbon at steady state in the converted to land use}}{\textit{20 years (transition period)}} \times \textit{Activity data (Area)}$$

For example, the annual change in carbon stock from the conversion of 100 hectares of low-producing grassland to perennial cropland would be calculated as follows:

Biomass change = (–3.05 x 100) + (2.25 x 100) = –80 t C
Soil change = (((117.66 – 114.91) / 20) x 100) = 13.75 t C

Total carbon change = –66.25 t C

Total emissions = (carbon stock change / 1000 x –1) x (44/12)
Total emissions = (–66.25 / 1000 x –1) x (44/12) = 0.2429 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.

Emission factors

The emission factors required to estimate carbon stock changes using the Tier 1 and Tier 2 equations are provided in Tables 7.1.2.4 and 7.1.2.5. These are split into biomass carbon stocks by land use prior to conversion and annual growth in stocks after land-use change. The values used for the previous submission are also provided for comparison, to illustrate the recalculations that have been made to the biomass emission factors used by New Zealand since the previous submission.

Table 7.1.2.4 New Zealand's biomass carbon stock emission factors in land use before conversion

Land-use category	Land-use subcategory	2009 submission emission factors (t C ha^{-1})	2010 submission emission factors (t C ha^{-1})	Carbon pools	Source/reference
Forest land	Natural forest	182	173	Live tree biomass only (2007) All biomass pools (2008)	Hall et al, 2001 (for the 2007 value) Beets et al, 2009 (for the 2008 value)
	Pre-1990 planted forest	222	Based on an age-based carbon yield table	All biomass pools	Wakelin, 2008
	Post-1989 forest	NE	Based on an age-based carbon yield table	All biomass pools	Kimberley et al, 2009
Cropland	Annual	0	5	Above- and below-ground biomass	Table 3.3.8, GPG-LULUCF IPCC, 2003
	Perennial	63	63	Above-ground biomass	Table 3.3.2, GPG-LULUCF IPCC, 2003
Grassland	High producing	1.35	6.75	Above-ground biomass (2007) Above- and below-ground biomass (2008)	Table 3.4.9, GPG-LULUCF, IPCC, 2003
	Low producing	0.8	3.05	Above-ground biomass (2007) Above- and below-ground biomass (2008)	Table 3.4.9, GPG-LULUCF, IPCC, 2003
	With woody biomass	29	29	All biomass pools	Wakelin, 2004
Wetlands		NE	NE	NA	Section 3.5.2.2 and Annex 3A, GPG-LULUCF, IPCC, 2003
Settlements		NE	NE	NA	Section 3.6.2, GPG-LULUCF, IPCC, 2003
Other land		NE	NE	NA	Section 3.7.2.1, GPG-LULUCF, IPCC, 2003

Notes: NE is not estimated and NA is not applicable. All biomass pools include above- and below-ground biomass, litter and dead organic matter pools. See below in section 7.1.2 and under *Methodological issues* in each category-specific section for further details.

Table 7.1.2.5 New Zealand's emission factors for annual growth in biomass for land converted to another use

Land-use category	Land-use subcategory	2009 submission emission factor (t C ha^{-1})	2010 submission emission factor (t C ha^{-1})	Years to reach steady state	Carbon pools	Source/ reference
Forest land	Natural forest	0.24	NA	NA	All biomass pools (2007)	Annex 3A, IPCC, 2003
	Pre-1990 planted forest	8.9	Based on age-based carbon yield table	28	Above-ground biomass (2007) All biomass pools (2008)	Annex 3A, IPCC, 2003
	Post-1989 forest	NE	Based on age-based carbon yield table	28	All biomass pools (2008)	Kimberley et al, 2009
Cropland	Annual	5	5	1	Above- and below-ground biomass	Table 3.3.8, IPCC, 2003
	Perennial	2.1	2.25	28	Above-ground biomass	Table 3.3.2, IPCC, 2003
Grassland	High producing	6.75	6.75	1	Above- and below-ground biomass	Table 3.4.9, IPCC, 2003
	Low producing	3.05	3.05	1	Above- and below-ground biomass	Table 3.4.9, IPCC, 2003
	With woody biomass	NE	1.04	28	All biomass pools	Wakelin, 2004
Wetlands		NE	NE	NA	NA	Assume steady state, IPCC, 2003
Settlements		NE	NE	NA	NA	Assume steady state, IPCC, 2003
Other land		NE	NE	NA	NA	Assume steady state, IPCC, 2003

Note: NE is not estimated and NA is not applicable See below in section 7.1.2 and under *Methodological issues* in each category-specific section for further details.

Representation of land areas

In this submission, the total land area of New Zealand used for all estimates of activity data is 26,851.1 kha. This value includes all significant New Zealand land masses, and comprises the North Island, South Island, Stewart Island, Great Barrier Island, Little Barrier Island and the Chatham Islands. All other small, outlying islands are excluded from the calculation of New Zealand's land-use areas as they are not subject to land-use change. The excluded area is 74,430 hectares, comprising less than 1 per cent of the total land area of New Zealand (66,637 hectares of which is accounted for by the Auckland Islands and Campbell Island).

New Zealand has used 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 2008 are based on wall-to-wall mapping of satellite and aircraft remotely sensed imagery taken in, or close to the start of, 1990 and 2008. Land-use changes during 2008 are then interpolated from other sources. This is described in further detail under the *Land-use change during 2008* section.

In this submission, the land-use subcategories mapped are different from those used in earlier submissions. The land-use subcategories used in this submission are defined in Table 7.1.2.6.

Table 7.1.2.6 New Zealand's definitions for land-use subcategories as mapped

Land-use subcategory	Definition
Natural forest	Areas that on 1 January 1990 were: • Tall forest on Department of Conservation land, including self-sown exotic trees. • Short forest or shrubland (with potential to reach ≥5 metres at maturity *in situ*) on Department of Conservation land. • Roads/tracks less than minimum width on Department of Conservation land, within the above two categories. • Tall non-planted forest (≥30 per cent cover) on other (non-Department of Conservation) land. • Broadleaved hardwood shrubland (eg, mahoe (*Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), manuka/kanuka (*Leptospermum scoparium*/*Kunzea ericoides*) shrubland or other woody shrubland (≥30 per cent cover, with potential to reach ≥5 metre at maturity *in situ*) on other (non-Department of Conservation) land under current land management.
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).* 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/skids 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 roads/tracks/skids 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 exotic species (eg, Perennial Ryegrass (*Lolium perenne* L). • Excludes linear shelterbelts that are larger than the minimum area/width criteria. (These are mapped separately as grassland – with woody biomass.)

Land-use subcategory	Definition
Grassland – low producing	• Low fertility grasses 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. • Excludes linear shelterbelts that are larger than the minimum area/width criteria. (These 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). • 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.
Wetland – open water	• Lakes and rivers.
Wetland – vegetated	• 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. • Any other remaining land.

The new 2008 land-use subcategories were chosen as they better conform to the dominant land-use types in New Zealand while still enabling reporting under the land-use categories specified in IPCC (2003). The alignment of these new land-use subcategories to those used in previous reports is shown in the Table 7.1.2.7 below.

Table 7.1.2.7 Change to land-use categories since the 2009 submission

Land-use categories in the 2009 submission	In this submission
Forest land	Forest land
Natural forest and (some) grassland – with woody biomass	Natural forest
Plantation crop and plantation understory	Pre-1990 planted forest
	Post-1989 forest
Cropland	Cropland
Cropland – annual	Cropland – annual
Cropland – perennial	Cropland – perennial
Grassland	Grassland
	Wetlands
Grassland – high producing	Grassland – high producing
Grassland – low producing and (some) grassland with woody biomass and (some) wetland – vegetated	Grassland – low producing
	Grassland – with woody biomass
Wetlands	Wetlands
Wetlands – managed	Wetlands – unmanaged ('vegetated' and 'open water')
Wetlands – unmanaged	
Settlements	Settlements
Other land	Other land

Note: Mapping between the subcategories used in the 2009 submission and in this submission is not 1:1 because some areas that were reported as separate subcategories in this submission were reported across more than one subcategory in the 2009 submission.

Wetlands have been split into 'wetland – open water' and 'wetland – vegetated' in the land-use mapping but they are reported on together in the common reporting format tables as 'wetlands'.

Further refinements are planned to improve these 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.

Land-use mapping

Land-use mapping – 1990

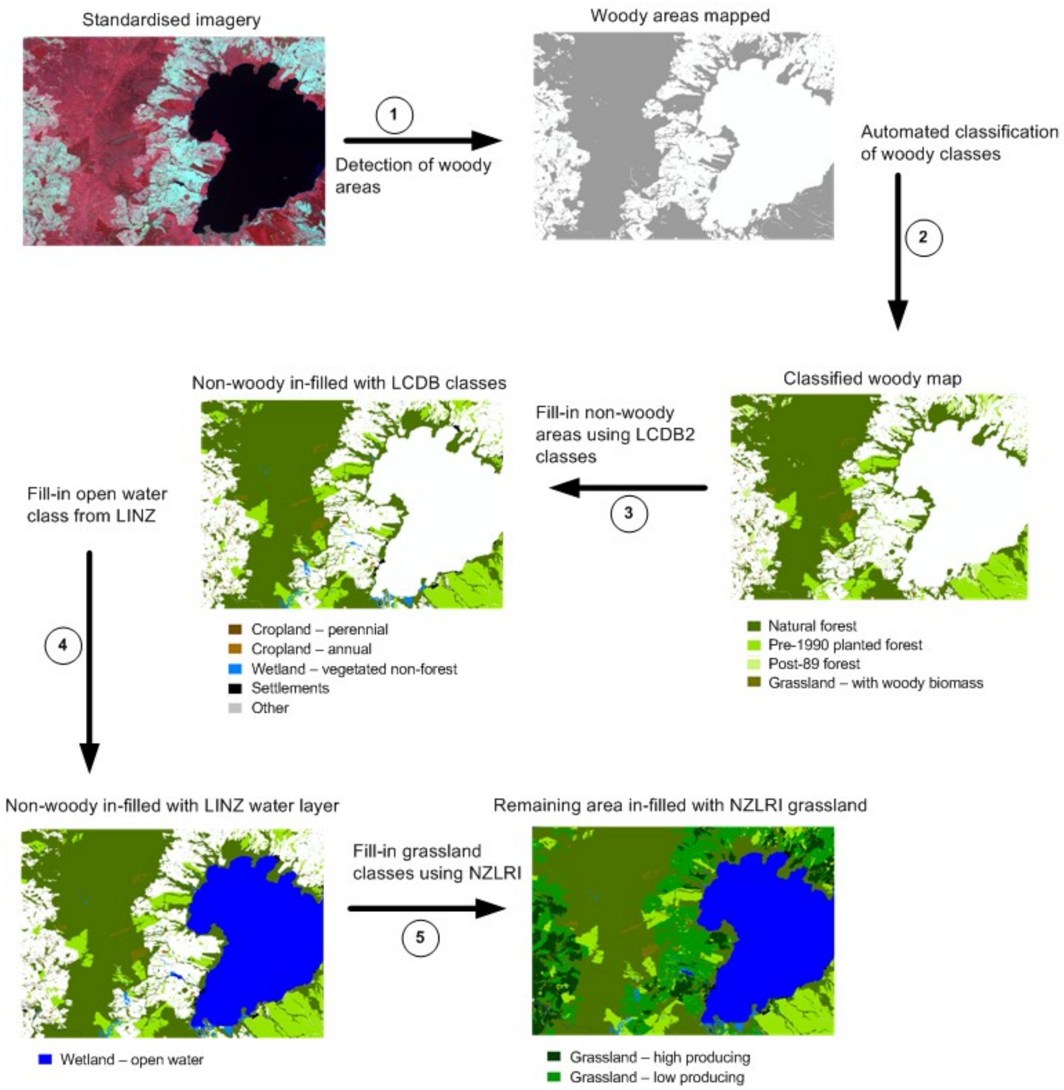
The 1990 land-use map is derived from 30 metre spatial resolution Landsat 4 and Landsat 5 satellite imagery taken in, or close to, 1990. The first of the images used were taken in November 1988 and the last in February 1993. In addition to orthorectification and atmospheric correction, the satellite 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 7.1.2.2 illustrates this mapping process.

Figure 7.1.2.2 New Zealand's land-use mapping process



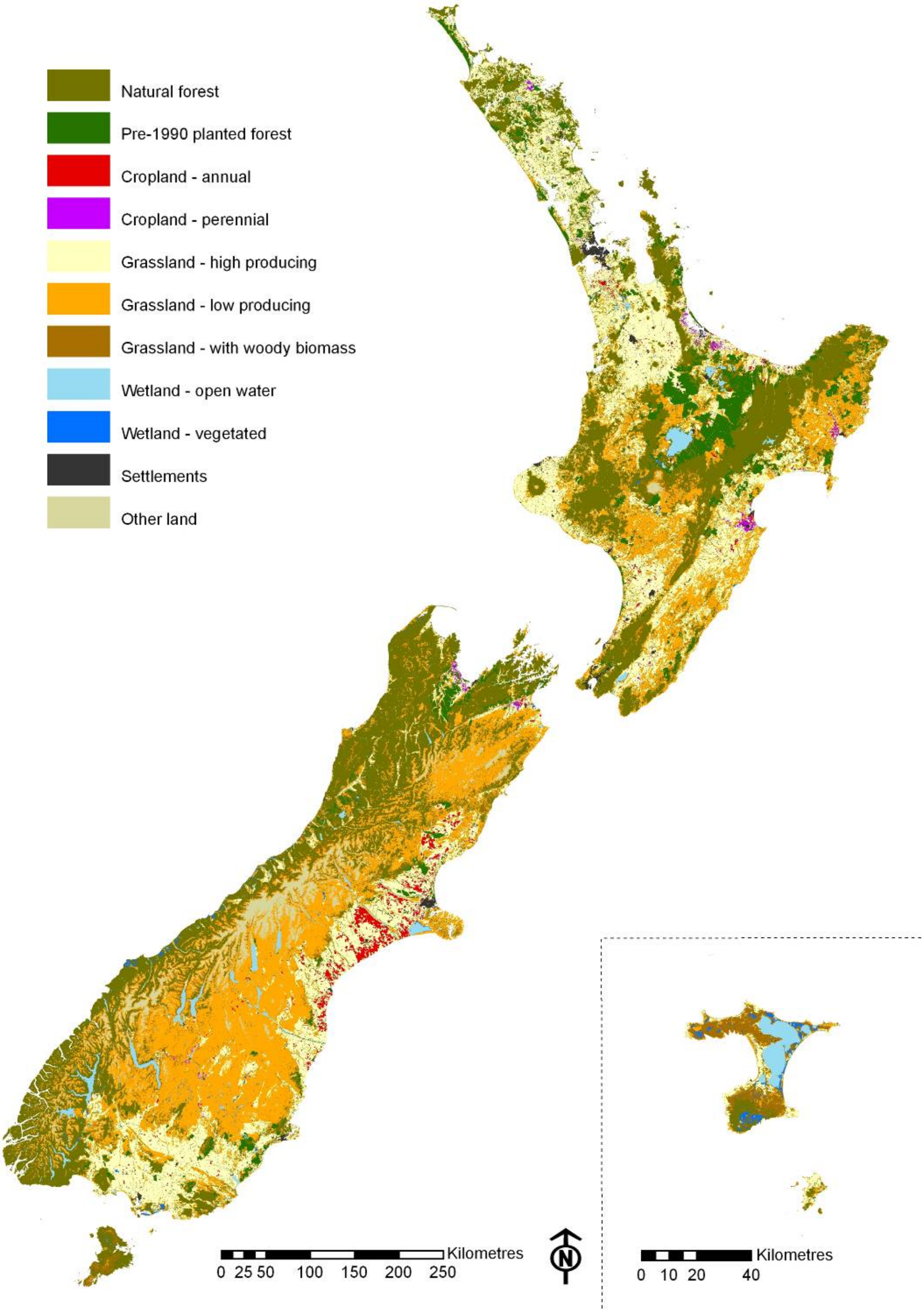
An interpretation guide for automated and visual interpretation was prepared and used to ensure a consistent basis for all mapping processes (Dougherty et al, 2009). Independent quality control was performed for all mapping. This involved an independent agency looking at randomly selected points across 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 percent of the time. This is described in more detail in GNS Science (2009).

Land-use mapping – 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. Further details are provided below under the *Mapping of deforestation and harvesting* section.

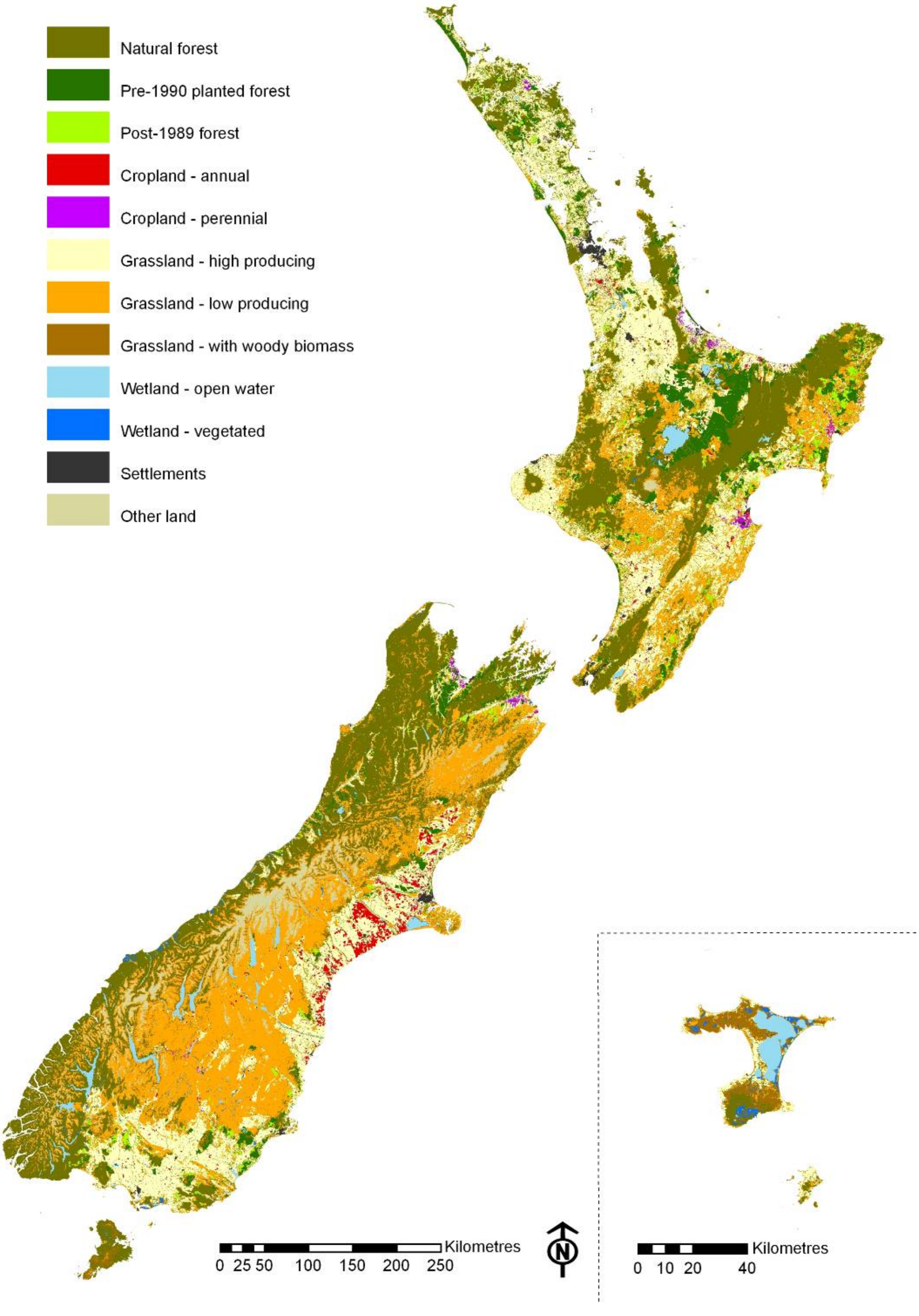
A list of the land-use categories and subcategories used to map land use and land-use change from 1990 to 2008 is provided in Table 7.1.2.6. Maps showing the land use in New Zealand as at 1 January 1990 and 1 January 2008 are shown in Figures 7.1.2.4 and 7.1.2.5.

Figure 7.1.2.3 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 7.1.2.4 Land-use map of New Zealand as at 1 January 2008

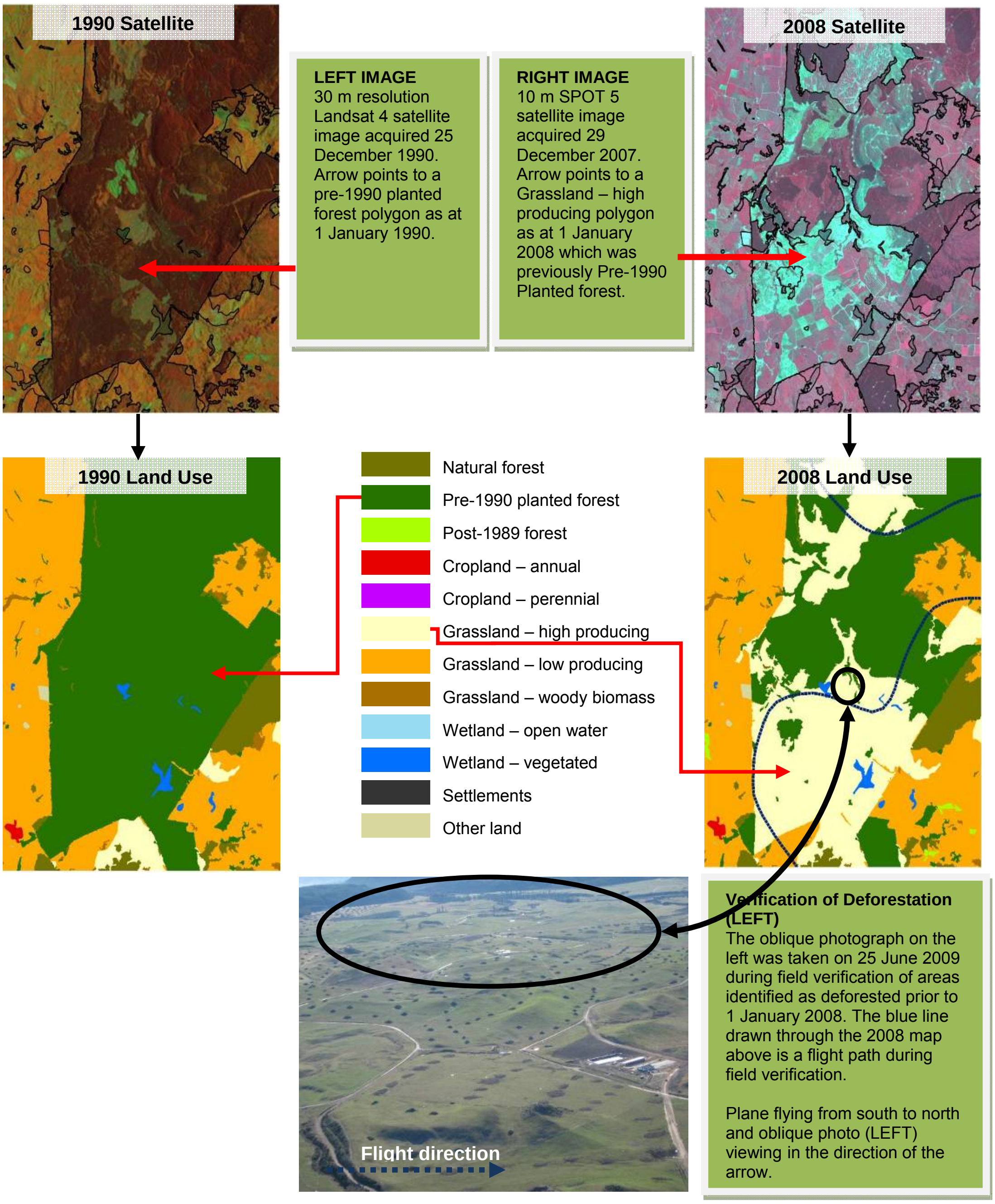


Note: The insert map is of the Chatham Islands, which lie approximately 660 km south-east of the Wairarapa coast, or 800 km due east of Banks Peninsula.

Mapping of deforestation and harvesting

New Zealand has used a combination of data sources to identify the location and timing of deforestation prior to 1 January 2008. Land-use data generated from classification of SPOT 5 satellite imagery acquired between November 2006 and April 2008 was used to identify the conversion of land from a forest land use to a non-forest land use. Evidential information to confirm land-use change was collected using higher-resolution aerial photography and field visits. This is illustrated in Figure 7.1.2.5.

Figure 7.1.2.5 New Zealand's identification of deforestation



To map deforestation and harvesting between 2008 and 2012, a similar approach will be used. Two years after harvesting has been mapped there will be an inspection of areas mapped as harvested, based on satellite imagery. The first exercise will be done using imagery acquired in December 2009 and January 2010. This exercise will identify harvesting and deforestation that will have occurred during 2008 and 2009.

Areas of possible deforestation will be confirmed using aerial photography, airborne scanning LiDAR and digital aerial photography. Supporting information from regional councils, Ministry of Agriculture and Forestry district offices and forestry consultants will also be searched to see if deforestation or restocking can be confirmed. This process is shown in Figure 11.2.2.1 in chapter 11.

Where areas of harvesting are unable to be confirmed as either restocked or deforestation, the proportion of potential deforestation in 2010 and 2011 will be estimated based on the harvesting and deforestation data collected for the years 2008 and 2009. These estimates will be validated in 2013 when wall-to-wall mapping of land use as at 31 December 2012 occurs.

For this submission, the estimate of the total area harvested each year between 1990 and 2007 is based on the area harvested as reported in the *National Exotic Forest Description*, a survey conducted by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2009a). Data for the year ending 31 December 2008 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 2002–2007 was used to estimate the area harvested in 2008 from the volume of roundwood produced. The harvesting values for 2008 will be updated in next year's submission when finalised data for 2008 becomes available.

The total area harvested was then split by forest type.

- *Natural forest:* In 2008, 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).
- *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.
- *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.

Land-use change

Land-use change during 2008

The 2008 land-use map shows land use and land-use change up to 1 January 2008. Land-use change occurring during 2008 was not mapped due to the expense of a national annual mapping programme. To fill this information gap for all land-use subcategories except pre-1990 planted forest and post-1989 forest, the average annual land-use change from 1990 to the end of 2007 was used to extrapolate an estimation of change in 2008. As there have been changes in the drivers for land-use changes for pre-1990 planted forest and post-1989 forest (including changes to legislation to discourage deforestation and initiatives to encourage afforestation), using the average annual change was not appropriate for these land-use subcategories, and so activity data was taken from other data sources.

The data sources used to estimate land-use change for pre-1990 planted forests and post-1989 forests (new planting, ie, afforestation and reforestation; and deforestation) are listed below.

- For pre-1990 planted forest and post-1989 forest deforestation: a combination of data from the 2008 Deforestation Survey (Manley, 2009) and unpublished work by Scion (NZ Forest Research Institute) was used. The work by Scion is referred to in Wakelin, 2008.
- For post-1989 afforestation/reforestation: data from the *National Exotic Forest Description* as at 1 April 2008 (Ministry of Agriculture and Forestry, 2009a) was used. The data for 2008 is still provisional and will be updated for the 2011 submission.

Land-use change from 1990 to 2008

Table 7.1.2.8 is a land-use change matrix for the years 1990 to 2008 using the 1990 and 2008 land-use maps, and activity data on land change during 2008 from the Ministry of Agriculture and Forestry.

Some prominent land-use changes between 1990 and 2008 include:

- forest establishment of 580,524 hectares (classified as post-1989 forest) that has mostly occurred on land that was previously grassland, primarily low-producing grassland. Approximately 11,500 hectares has subsequently been deforested.
- deforestation of 96,375 hectares. This has occurred mainly since 2004. Between 1990 and 2004 there was very little deforestation in New Zealand, due to market conditions.

Table 7.1.2.9 shows a similar land-use change matrix, for 2007 to 2008.

Table 7.1.2.8 New Zealand's land-use change matrix from 1990 to 2008 (1, 2, 3, 4, 5, 6)

2008 \ 1990		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2008 (kha)
		Natural	Pre-1990 Planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,118.0											8,118.0
	Pre-1990 planted		1,430.3										1,430.3
	Post-1989			NA	0.0	0.0	106.4	348.7	120.5	0.0	0.0	4.8	568.8
Cropland	Annual				334.0		0.1	0.0				0.0	334.2
	Perennial		0.2	0.0	5.2	78.6	4.2	0.2	0.1				88.5
Grassland	High producing	7.0	45.3	10.5			5,735.7	0.0	14.9	0.1		0.1	5,813.7
	Low producing	24.1	3.9	1.0			0.0	7,641.4	30.3	0.0		0.4	7,701.1
	With woody biomass	3.1	0.0	0.0			8.2	25.9	1,018.5		0.0	1.2	1,057.0
Wetlands	Wetlands		0.0	0.0						643.9	0.1	0.1	644.1
Settlements	Settlements	0.1	0.4	0.1		0.1	1.7	0.2	0.2	0.0	203.3		206.3
Other land	Other land	0.3	0.3	0.1			0.1	0.1	0.1			888.1	889.1
Area as at 1 Jan 1990 (kha)		8,152.6	1,480.3	0.0	339.2	78.7	5,856.5	8,016.9	1,184.7	644.1	203.4	894.8	26,851.1
Net change 1 Jan 1990–31 Dec 2008		–34.5	–50.1	568.8	–5.0	9.8	–42.8	–315.7	–127.7	0.1	2.8	–5.7	0.0
Net change 1990–2008 (%)		–0.4	–3.4	NA	–1.5	12.5	–0.7	–3.9	–10.8	0.0	1.4	–0.6	0.0

Table 7.1.2.9 New Zealand's land-use change matrix from 2007 to 2008 (1, 2, 3, 4, 5, 6)

2008 \ 2007		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2008 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,118.0											8,118.0
	Pre-1990 planted		1,430.3										1,430.3
	Post-1989			579.5	0.0	0.0	0.2	0.6	0.2	0.0	0.0	0.0	580.5
Cropland	Annual				334.2	0.0	0.0	0.0				0.0	334.2
	Perennial		0.0	0.0	0.3	88.0	0.2	0.0	0.0				88.5
Grassland	High producing	0.4	1.9	0.8			5,809.8	0.0	0.8	0.0		0.0	5,813.7
	Low producing	1.3	0.2	0.1			0.0	7,698.0	1.6	0.0		0.0	7,701.1
	With woody biomass	0.2	0.0	0.0			0.4	1.4	1,055.0		0.0	0.1	1,057.0
Wetlands	Wetlands		0.0	0.0						644.1	0.0	0.0	644.1
Settlements	Settlements	0.0	0.0	0.0		0.0	0.1	0.0	0.0	0.0	206.1		206.3
Other land	Other land	0.0	0.0	0.0			0.0	0.0	0.0			889.0	889.1
Net area as at 31 Dec 2007 (kha)		8,119.8	1,432.4	568.8	334.4	88.0	5,810.8	7,700.0	1,057.6	644.1	206.2	889.1	26,851.1
Net change 31 Dec 2007–31 Dec 2008		–1.8	–2.1	0.1	–0.3	0.5	2.9	1.1	–0.6	0.0	0.1	0.0	0.0
Net change 2007–2008 (%)		0.0	–0.1	–	–0.1	0.6	0.1	0.0	–0.1	0.0	0.1	0.0	0.0

Notes: (1) Units in 000's hectares. (2) The minimum area shown for land-use change is 100 ha, however, areas are mapped to 1 ha resolution. (3) Zeros are displayed where land-use changes are of less than 100 ha, blank cells indicate no land-use change during the period. (4) Land-use values since 1990 do not sum to total New Zealand area due to double-counting of 11,749 hectares of deforestation of post-1989 forest. Columns and rows may not total due to rounding. (5) Shaded cells indicate land remaining in each category. (6) Land-use change values refer to change over the course of the year. Land-use area values are as at point in time indicated (31 December for 2007 and 2008; 1 January for 1990).

Methodological change

The total land area of New Zealand used in this submission is 26,851.1 kha. This differs from the area used in the 2009 submission that reported 26,821.6 kha (a difference of 0.1 per cent). The difference arises from the use of alternative coastal boundaries. In the 2009 submission, the New Zealand boundaries were derived from the Land Cover Databases (LCDBs) that are based on satellite imagery. Where LCDB imagery stopped short of the coastline, the area between the LCDB edge and the coastline was ignored (not counted), creating a shortfall in the total area mapped. In this submission, we have been able to correct this as the imagery collected for LUCAS covers the total area of New Zealand (the edges of the imagery extend beyond the coastline). This means that the total area of New Zealand in this submission is the same as that derived from the official coastal boundary provided by Land Information New Zealand, the official government agency responsible for cadastral mapping in New Zealand (www.linz.govt.nz).

While New Zealand previously represented land areas using Approach 3, land areas were calculated using previously existing land cover databases – LCDB1 (c. 1996) and LCDB2 (c. 2001) (Thompson et al, 2004). The LCDBs were not specifically developed for use in Climate Change Convention reporting. The area of forest as at 1990 and 2008 presented in this submission is based on wall-to-wall mapping of satellite and aircraft remotely sensed imagery taken in, or close to, the start of 1990 and 2008. LCDB1 and 2 data, as well as information from the New Zealand Land Resource Inventory (Eyles, 1977) and hydrological data from Land Information New Zealand, have been used to map the non-forest categories. The approach used to map land use is described in Shepherd and Newsome (2009a, b).

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 2008 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.

The accuracy of mapping land-use changes between 1990 and 2008 has not been determined and will be included in the next submission.

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 2007 land-use mapping data have been independently 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.)

The approach used to implement quality-assurance processes is documented in the LUCAS Data Quality Framework (PricewaterhouseCoopers, 2008).

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 land-use mapping approach for both 1990 and 2008 mapping involved visual assessment and classification of all polygons greater than 5 hectares in woody classes. Polygons between 1 and 5 hectares, while classified, are likely to have a lower confidence limit and are tagged for further analysis during 2010. However, the area of New Zealand covered by polygons in the 1 to 5 hectare category only represents between 2–4 per cent of the area associated with the polygons larger than 5 hectares in size (Shepherd and Newsome, 2009a, b).
- The mapping of 1990 land use presented challenges, particularly in identifying newly established exotic forests using Landsat satellite imagery. Where trees are planted within 3 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 be updated and improved as more detailed land-use information becomes available from the New Zealand Emissions Trading Scheme. The Ministry of Agriculture and Forestry is administering the forestry component of the Emissions Trading Scheme and applicants to the scheme will be providing new land-management and land-use information as at 1990.
- Cropland areas were mapped using historical boundaries from LCDB2. It is expected that the mapping of this land-use category will be improved by either visually interpreting the satellite imagery at both 1990 and 2008, or by analysis of a New Zealand farm enterprise database (AgriBase) that has nationwide annual cropping spatial statistics from about 1999.

New Zealand will create a 2012 land-use map using high-resolution satellite data as the key source of information at the end of the first commitment period. 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.

Soils

In this submission, New Zealand uses a Tier 2 method to estimate soil carbon stock, with the use of New Zealand-specific land-use and soil pedon data (Scott et al, 2002). This is an improvement from the method used in the 2009 submission, as the previous method used a New Zealand-specific reference soil carbon stock value. This is explained further under *Methodological change* below.

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).

The Soil CMS does not estimate carbon stock or carbon changes for organic soils, as it calculates the total carbon from the carbon concentration of soil within a fixed depth, rather than the soil's total organic carbon mass (Tate et al, 2005). In order to accurately determine emissions from organic soils undergoing land-use change, changes in total organic carbon mass would need to be estimated, as any emissions would be caused by the loss of soil volume, rather than by changes to the soil's carbon concentration.

As a result of this constraint in the methodology, and as limited New Zealand data currently exists on the impact of land-use change on the total organic carbon mass of organic soils, New Zealand has estimated emissions from organic soils by aggregating the activity data for the two soil types together, and using the emission factors for mineral soils as the default emission factors for organic soils. New Zealand has accordingly recorded the notation key IE ('included elsewhere') for organic soils in the common reporting format tables.

While this methodology may slightly underestimate New Zealand's soil carbon emissions, it should be recognised that organic soils occupy a relatively small proportion of New Zealand's total land area (0.9 per cent) and that between January 1990 and January 2008, only 2,560 hectares of land with organic soils underwent land-use change, representing just 0.3 per cent of the total area of land-use change in New Zealand.

Model

Based on the well-established premise 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 describes 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) are 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 7.1.2.8)

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 recently 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). The current dataset consists of 1,235 records, distributed across land uses as shown in Figure 7.1.2.6 and Figure 7.1.2.7.

Figure 7.1.2.6 New Zealand soil plot distribution (plots used for 2009 model estimation of soil carbon stocks)

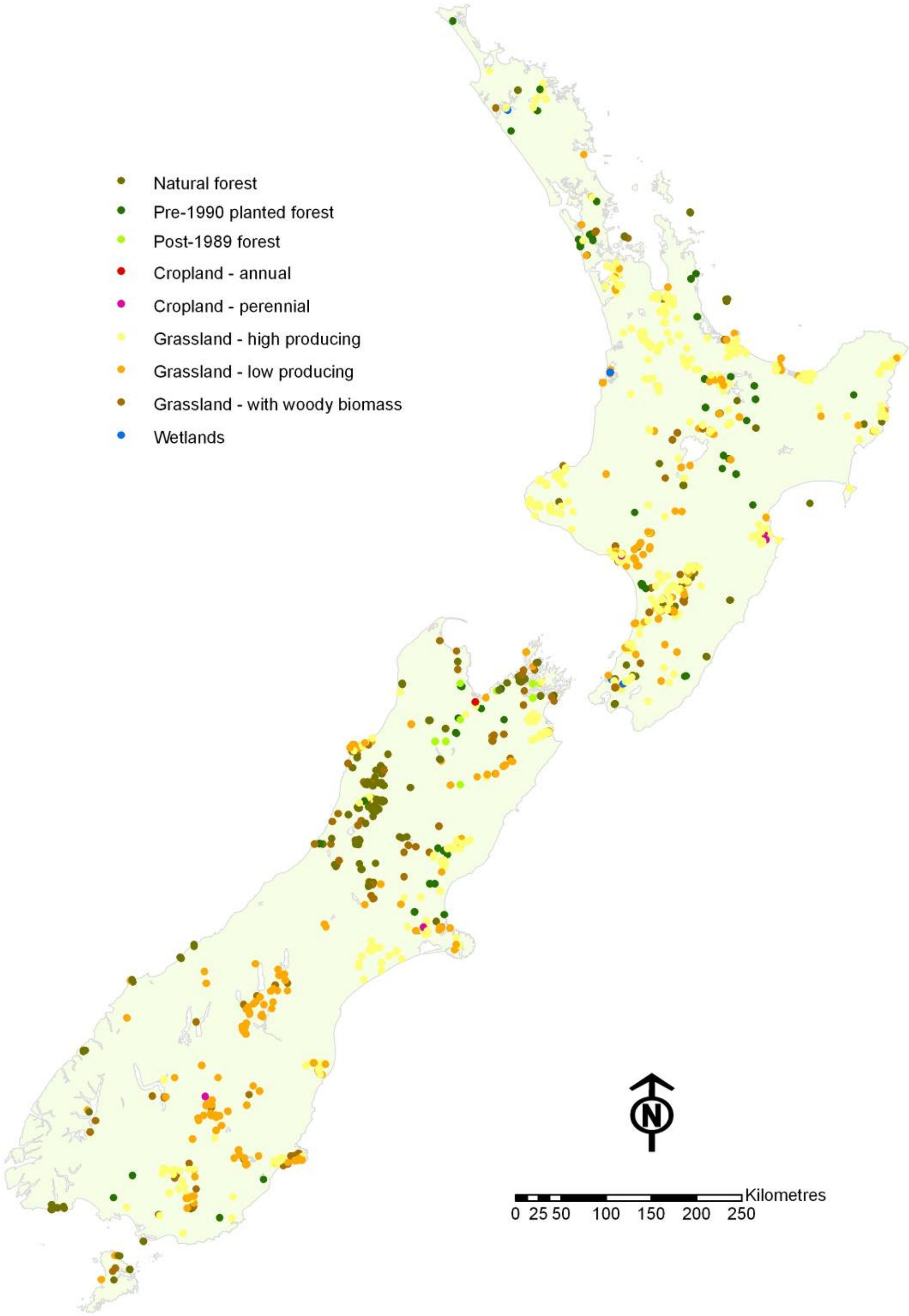
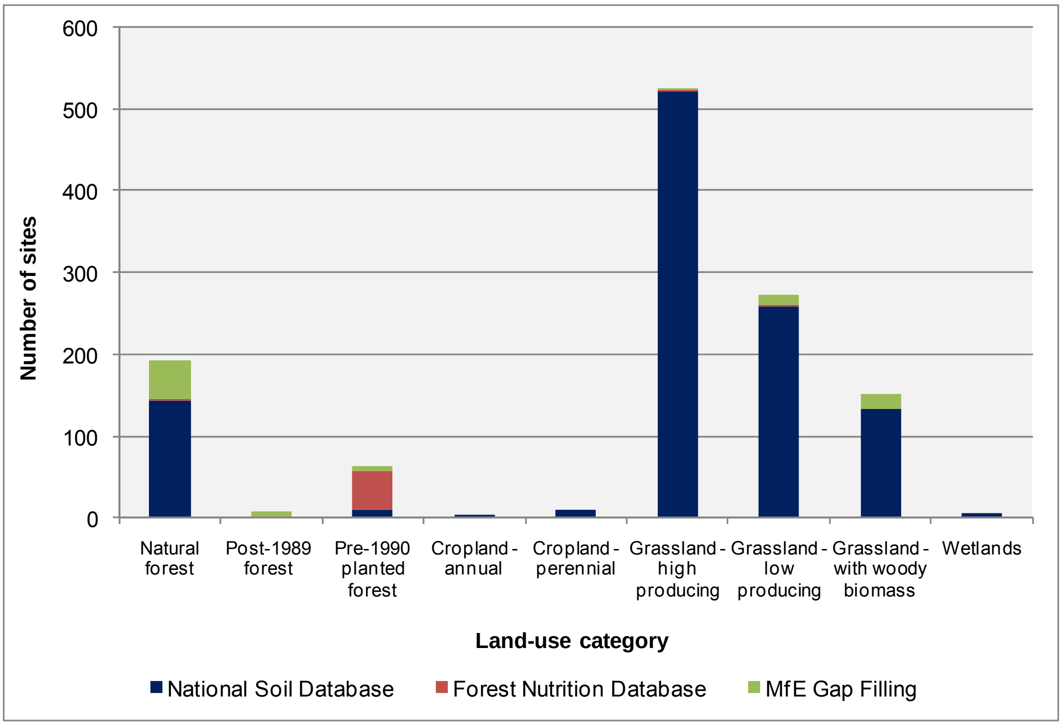


Figure 7.1.2.7 Number of New Zealand soil plot sites by land-use and dataset



Note: MfE is the 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 6,000 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 (2,000 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, tests have indicated that the Soil CMS estimates soil carbon stocks reasonably well at a range of scales (Tate et al, 2005).

The system has also been validated for its ability to predict soil carbon changes between land uses at steady state for New Zealand's main land-use change, grassland converted to planted forest. This was done by comparing the Soil CMS results with estimates based on 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 7.1.2.10 gives the national soil carbon stock estimates for all land-use categories and the associated standard errors. All estimates are produced by the Soil CMS, except for the other land estimate, as it is an IPCC default value.

Table 7.1.2.10 New Zealand's soil carbon stock (0–0.3 m) for land-use categories (after McNeill et al, 2009)

Land use	Soil carbon stock (t C ha^{-1})
Natural forest	111.85 ± 5.24
Planted forest (pre-1990, post-1989)	104.31 ± 6.44
Annual cropland	118.27 ± 22.47
Perennial cropland	114.91 ± 13.22
High-producing grassland	114.93 ± 3.56
Low-producing grassland	117.66 ± 12.56
Grassland with woody biomass	111.57 ± 4.29
Wetlands	104.62 ± 19.92
Settlements	117.66 ± 12.56
Other land	88

Methodological change

In previous submissions, New Zealand has used a country-specific reference soil carbon stock value, adjusted by IPCC land-use, management and input factor values (IPCC, 2003). However, land-use factors were double-counted in previous submissions for some land-use categories, and no land-use factors were available for key land-use categories (natural and planted forest). For this submission, New Zealand has used the Soil CMS. This represents a significant change in method from the previous submission.

The Soil CMS has been developed and refined over time to remove bias and increase accuracy. A recent refinement to the Soil CMS has been to remove the effect of bias from spatial clustering of soil samples. As the dataset used by the model consists primarily of historical data collected for specific purposes, it is not a random sample of 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 use of the Soil CMS model with the dataset was resulting in estimates in soil carbon stocks that were biased (McNeill et al, 2009). A correction factor for spatial correlation between data points was incorporated into the model in 2009 to address this issue. This resulted in a decrease in the difference in stock estimates between low producing grassland and post-1989 forest (the major land-use change) from –18.43 t C ha^{-1} (Baisden et al, 2006b) to –13.35 t C ha^{-1} (McNeill et al, 2009).

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 7.1.2.10. There is relatively little soil data for those land uses that comprise only minor land areas within New Zealand (croplands and wetlands), and the uncertainties associated with these estimates are correspondingly high. 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).
- 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), 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 model to better reflect the landform types where land-use change is occurring (eg, on eroding hill-country landscapes).
- 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.
- Further validation of the Soil CMS model by checking the results it gives against independent field soil/climate/land-use cell sampling and against targeted paired sites and time-series sampling to investigate soil carbon changes following specific land-use change.

Liming

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.

Information on agricultural lime (limestone) application is collected by the national statistics agency, Statistics New Zealand, as part of its annual *Agriculture Production Survey*. Previously, this survey has asked for the total weight (in tonnes) of lime applied but, for the first time in the 2008 survey, estimates of limestone use and dolomite use were reported separately. This showed that 1.2 per cent of total agricultural lime was dolomite. As this data is only available for one year and dolomite is such a small percentage of total lime use, lime is not separated from dolomite in this report or in the common reporting format tables.

The *Agriculture Production Survey* has gaps in the 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.

Biomass burning

Biomass burning is not a significant source of emissions for New Zealand due to the nature of New Zealand's climate and vegetation.

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 national data on the area burnt. Emissions from controlled burning in land converted to grassland are not reported in the inventory because of insufficient data on the area of land converted to grassland that is burnt. All emissions from the burning of crop stubble and controlled burning of savanna are reported in the agriculture sector (chapter 6).

Tier 2 methodologies are employed to estimate emissions from biomass burning in New Zealand. Country-specific biomass densities are applied (Wakelin et al, 2009) with IPCC defaults used for most emission factors (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 7.1.2 – 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 2008 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 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". In pre-1990 planted forest and post-1989 forest, the stock change calculations account for emissions from wildfire if the affected stand is harvested or the area is left to grow on at a reduced stocking. 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. Given the few incidences of wildfire in New Zealand's planted forest lands, these are not regarded as a significant source of error (Wakelin, 2008).

Controlled burning can be used to clear the slash residues (residual forest material) left behind after the forest land has been harvested, as part of site preparation for the next land use. In New Zealand, it is assumed that 25 per cent of grassland 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 land, because activity data is not available and the practice is not thought to be significant. 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 in the past four years; current research seeks to quantify emissions from this activity for 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 biomass densities and burning factors where insufficient data exists.

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 (biomass densities, 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).

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. Current research is seeking to quantify emissions from this activity for reporting in future submissions (Wakelin, 2008).

The LUCAS plot network is currently being analysed to develop a better estimate of biomass density for the grassland with woody biomass category.

7.2 Forest land (CRF 5A)

7.2.1 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 uses a minimum forest width of 30 metres from canopy-edge to canopy-edge. This removes linear shelterbelts from the forest land-use 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.

For inventory reporting three subcategories are used to cover all of New Zealand's forests: natural forest (predominantly native forest pre-dating 1990), pre-1990 planted forest and post-1989 forest.

Forest land is the most significant contributor to carbon stock changes in the LULUCF sector. Forests cover 37.7 per cent (around 10 million hectares) of New Zealand. In 2008, forest land contributed 29,757.9 Gg CO_2-e of net removals. This value includes removals from the growth of pre-1990 planted forests and post-1989 forests, emissions from the conversion of land to planted forest and emissions from harvesting and deforestation. Net removals from forest land have decreased by 3,098.9 Gg CO_2-e (9.4 per cent) over the 1990 level of 32,856.7 Gg CO_2-e. In 2008, forest land remaining forest land and conversion to forest land were key categories (trend and level assessment).

Table 7.2.1.1 New Zealand's land-use change within the forest land category in 1990 and 2008, and associated CO_2-e emissions

Forest land land-use category		Net area in 1990 (ha)	Net area in 2008 (ha)	Change from 1990 (%)	Net emissions/ removals (Gg CO_2-e) 1990	2008	Change from 1990 (%)
Forest land remaining forest land	Natural forest	8,150,732	8,118,004	–0.4	NE	NE	NA
	Pre-1990 planted forest	1,480,346	1,430,286	–3.4	–33,027.5	–12,430.5	–62.4
	Subtotal	*9,631,078*	*9,548,290*	*–0.9*	*–33,027.5*	*–12,430.5*	*–62.4*
Land converted to forest land	Post-1989 forest	13,473	568,775	+4,121.6	166.2	–17,327.7	–10,525.8
Total		**9,644,551**	**10,117,064**	**+4.9**	**–32,856.7**	**–29,757.9**	**–9.4**

Notes: 1990 and 2008 areas are as at 31 December. Net area values include deforestation of post-1989 forest since 1990. Net removals/emission estimates are for the whole year indicated. Natural forest remaining natural forest is assumed at the national level to be at steady state, with no emissions estimated (NE).

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 2008, 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.

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.

In 2008, the carbon stored in natural forest was 2,313,225.1 Gg C. Carbon stock has decreased by 9,843.9 Gg C (0.4 per cent) from the 1990 level of 2,323,069.0 Gg C. This is equivalent to emissions of 36,094.5 Gg CO_2-e from natural forest since 1990. This loss is due to natural forest land being converted to other land uses. Carbon stock change in natural forest remaining natural forest is not estimated, as the carbon stored in natural forests is assumed to be in steady state. 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.

Table 7.2.1.2 New Zealand's carbon stock change by carbon pool within the natural forest subcategory in 1990 and 2008

Carbon pool	Carbon stock in 1990 (Gg C)	Carbon stock in 2008 (Gg C)	Change since 1990 (%)
Living biomass	1,133,204.4	1,128,402.5	–0.4
Dead organic matter	278,001.9	276,823.9	–0.4
Soil	911,862.7	907,998.7	–0.4
Total	**2,323,069.0**	**2,313,225.1**	**–0.4**

Note: 1990 carbon stock values are as at 31 December 1989 and 2008 values are as at 31 December 2008.

Pre-1990 planted forest

New Zealand has a substantial estate of planted forests created specifically for timber supply purposes. In 2008, pre-1990 planted forests covered an estimated 1.43 million hectares of New Zealand (5.3 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.

In 2008, the carbon stored in pre-1990 planted forest was 383,841.9 Gg C. Carbon stock has increased by 104,896.7 Gg C (37.6 per cent) from the 1990 level of 278,945.1 Gg C. This is equivalent to removals of 384.6 Gg CO_2-e.

Table 7.2.1.3 New Zealand's carbon stock change by carbon pool within the pre-1990 planted forest subcategory in 1990 and 2008

Carbon pool	Carbon stock in 1990 (Gg C)	Carbon stock in 2008 (Gg C)	Change from 1990 (%)
Living biomass	106,996.4	195,603.4	+82.8
Dead organic matter	17,533.8	39,045.3	+122.7
Soil	154,414.9	149,193.1	–3.4
Total	**278,945.1**	**383,841.9**	**+37.6**

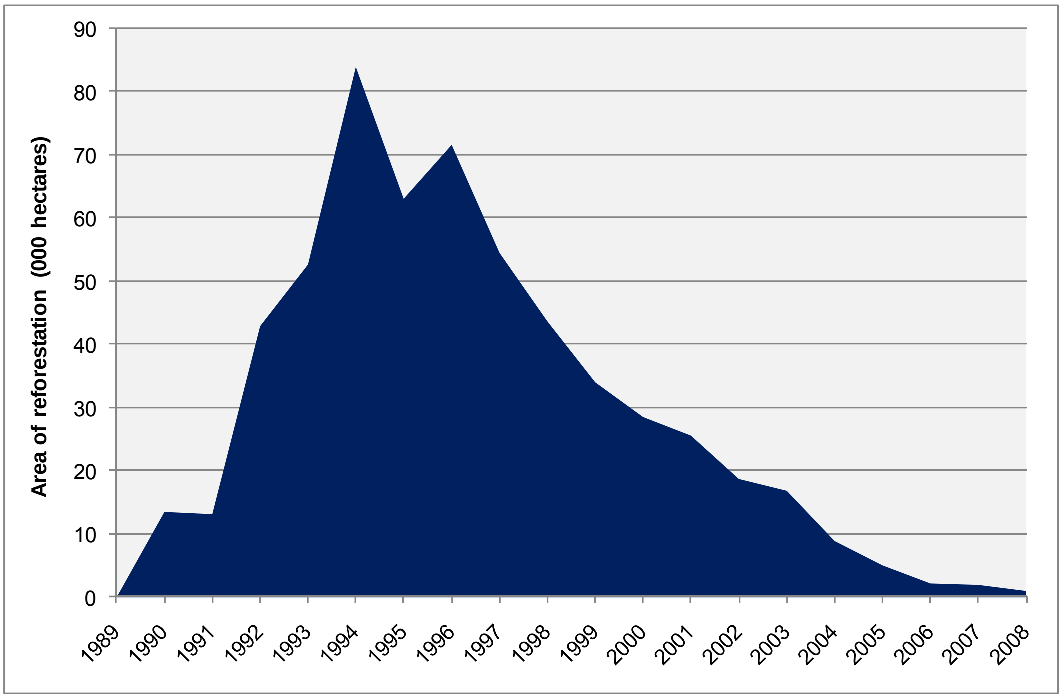
Note: 1990 carbon stock values are as at 31 December 1989 and 2008 values are as at 31 December 2008.

Post-1989 forest

Between the 1 January 1990 and 31 December 2008, the net area of forest established as a result of reforestation activities was 568,775 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* comprise 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 (Paul et al 2009).

The new forest planting rate (land reforested) between 1990 and 2008 was, on average, 31,000 hectares per year (Figure 7.2.1.1). New planting rates were high from 1992 to 1998 (averaging 59,000 hectares per year). Since 1998, the rate of new planting rapidly declined and is now at very low levels. In 2008, it was estimated that 1,000 hectares of new forest was established (Ministry of Agriculture and Forestry, 2009a).

Figure 7.2.1.1 Annual areas of reforestation in New Zealand from 1990 to 2008



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 expected to increase with the introduction of the Emissions Trading Scheme, 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).

In 2008, the carbon stored in post-1989 forest was 116,849.3 Gg C (see Table 7.2.1.4). Carbon stock as at the start of 1990 was nil by definition. The growth in carbon stock since 1990 is equivalent to removals of 428,447.4 Gg CO_2-e.

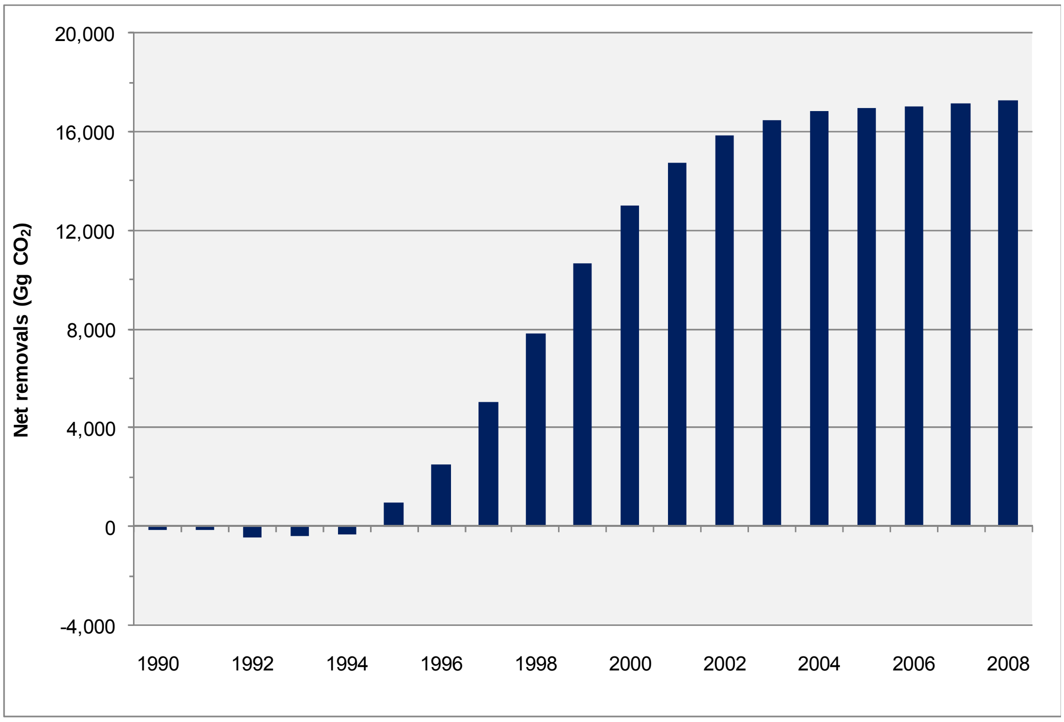
Table 7.2.1.4 New Zealand's carbon stock change by carbon pool within the post-1989 forest subcategory

Carbon pool	Carbon stock in 1990 (Gg C)	Carbon stock in 2008 (Gg C)	Change since 1990 (%)
Living biomass	0.0	40,947.8	NA
Dead organic matter	0.0	14,189.3	NA
Soil	0.0	61,712.2	NA
Total	**0.0**	**116,849.3**	**NA**

Note: 1990 carbon stock values are as at 31 December 1989 and 2008 values are as at 31 December 2008. Post-1989 forest is land that has been afforested or reforested since 31 December 1989, and hence had approximately nil carbon stock on 1 January 1990.

The trend in removals is shown in Figure 7.2.1.2. This graph shows that the post-1989 forests do not become a net sink until 1995. This is due to the emissions from loss of biomass carbon stocks associated with the previous land use and the change (loss) of soil carbon with a land-use change to forestry (see Table 7.1.2.10), outweighing removals by forest growth.

Figure 7.2.1.2 New Zealand's net removals by post-1989 forests from 1990 to 2008



Deforestation

In 2008, 4,818 hectares of forest land were converted to other land uses, primarily grassland. Table 7.2.1.5 below shows the areas of forest land subject to deforestation for conversion to other land uses in 2008, and since 1990.

Table 7.2.1.5 New Zealand's forest land subject to deforestation

Forest land subcategory	Area of forest in 1990 (hectares)	Deforestation since 1990 Area (hectares)	Deforestation since 1990 Proportion of 1990 area (%)	Deforestation in 2008 Area (hectares)	Deforestation in 2008 Proportion of 1990 area (%)
Natural forest	8,152,550	34,546	0.42	1,818	0.02
Pre-1990 planted forest	1,480,345	50,059	3.38	2,114	0.14
Post-1989 forest	0	11,749	NA	886	NA
Total	**9,632,895**	**96,355**	**1.00**	**4,818**	**0.05**

Notes: 2008 areas as at 31 December 2008, 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. Post-1989 forest comprises land that has been afforested or reforested since 31 December 1989, and hence its area was nil by definition on 1 January 1990.

The conversion of forest land to grassland was most likely due to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry. Figures 11.1.2 and 11.1.3 in chapter 11 show the area and net emissions respectively associated with deforestation between 1990 and 2008. These show the significant increase in deforestation of planted forests since 2003, with a significant decrease in 2008.

During the period 2008–2012, it is expected that the level of planted forest deforestation will be less than previous years (Manley, 2009). This is because policy measures are expected to be a disincentive to deforest.

The estimate of natural forest deforestation in 2008, which is based on previous trends, is also likely to be an overestimate. This is because land-use change during the 2008 calendar year was estimated by linear interpolation from the average land-use change mapped between 1 January 1990 and 1 January 2008. As there was no quantitative information on the annual rate of natural forest deforestation between 1990 and 2007, the same annual rate of change was assumed for the entire period (1,818 hectares per year), and extrapolated out to the end of 2008.

However, a number of factors suggest that the rate of natural forest deforestation is unlikely to have been constant over the 19-year period, 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 extrapolated estimate of natural forest deforestation will be updated in future submissions as new information becomes available, and will be replaced with an actual, mapped value in the 2013 submission at the latest, following production of the 2012 land-use map.

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 on soils). This approach is adopted because:

- the majority of deforestation is 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 7.1.2.5)
- 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.

7.2.2 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 transfers to the 'land remaining' category after having been in that land use for 28 years. New Zealand has chosen 28 years as the time period taken for land to reach a state of equilibrium (or maturity), as this is the average age that planted forests are harvested (Ministry of Agriculture and Forestry, 2008a). Lands categorised as post-1989 forest were 18 years old (at a maximum) in 2008.

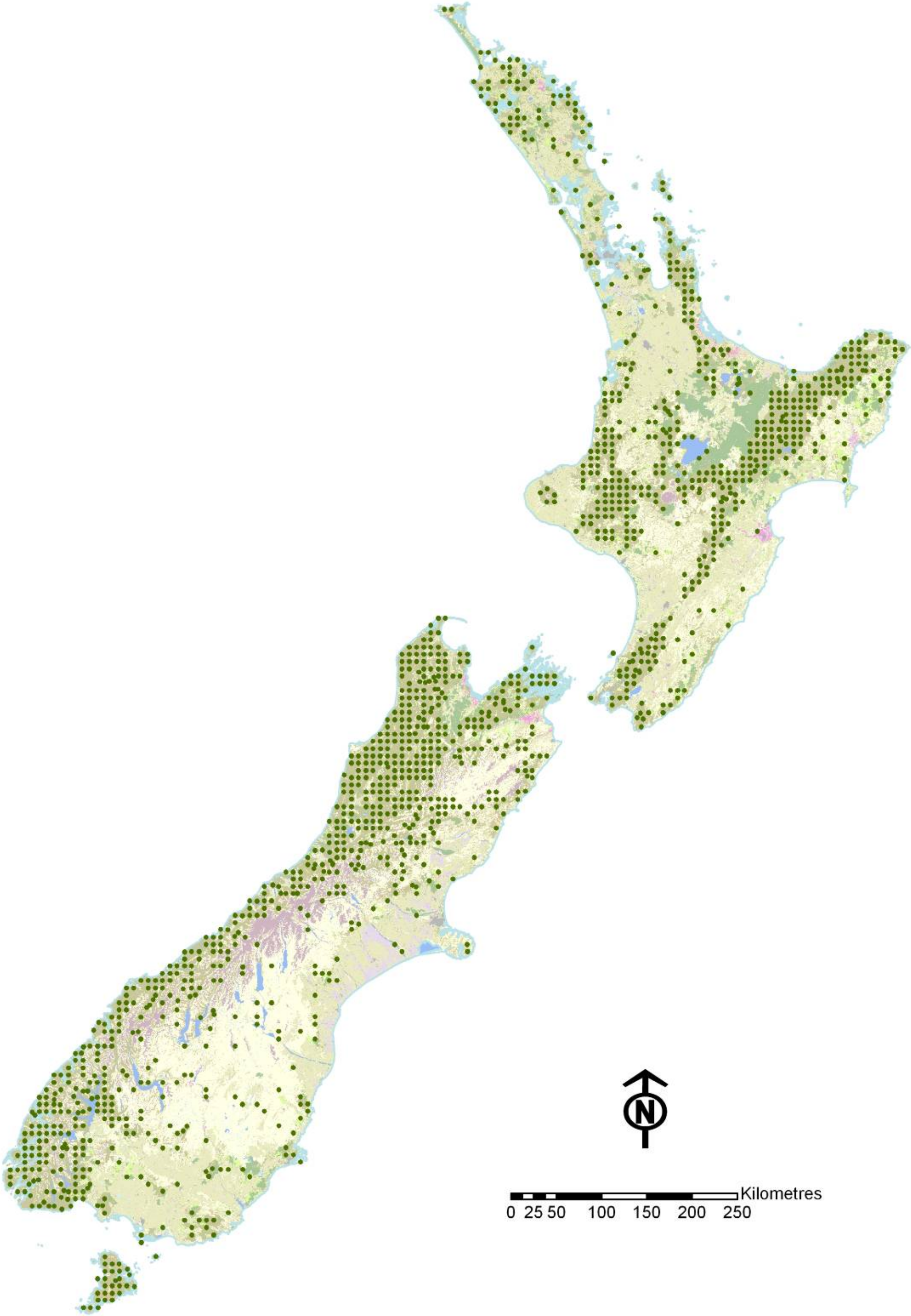
New Zealand has established a sampling framework for forest inventory purposes based on a grid system established across the country. The grid has a randomly selected origin and provides an unbiased framework for establishing plots for field and/or LiDAR measurements. The grid is an 8 kilometre grid with divisions on a 4 kilometre grid being used for measurement of post-1989 forest areas.

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 1,256 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 remeasured, the data collected will be suitable for determining if New Zealand's natural forests are carbon neutral, or whether they are a source or a sink of carbon. Where possible, the network incorporated plots that had been established previously and remeasured during the establishment phase of the national network to enable an initial assessment to be made of forest changes over time. Figure 7.2.2.1 shows the distribution of the carbon monitoring plots throughout New Zealand.

Figure 7.2.2.1 Location of New Zealand's natural forest carbon monitoring plots



Remeasurement of the national plot network has begun. The remeasurement programme will run from 2009–2013. Once field work has been completed and the data has been quality assured and analysed, national carbon estimates will be updated in time for the 2012 submission (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 7.2.2.1 summarises the method used to calculate the carbon stock in each biomass pool from the information collected at each plot.

Table 7.2.2.1 Summary of methods used to calculate New Zealand's 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 pools.

- Above-ground biomass. The carbon content of individual trees and shrubs are 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. Below-ground biomass is derived from above-ground biomass and is assumed to be 25 per cent of above-ground biomass (or 20 per cent of total biomass). This value is based on a few 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, species, if able to be identified, and what stage of decay it is at. Dead wood comprises woody debris with a 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.

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 carbon sink between 1990 and 2004 (Beets et al, 2009). Until the entire plot network has been remeasured, 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 carbon

Soil 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, as described in section 7.1.2. The soil carbon stock at equilibrium state is estimated to be 111.85 t C ha^{-1} with a standard error of 5.24 (Table 7.1.2.10).

Natural forest carbon

Total carbon stocks in natural forest are determined by combining the biomass and soil carbon pools (of 173 and 111.85 respectively) to give a mean of 284.85 t C ha^{-1} (±6.0 per cent). 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 forests

Living biomass and dead organic matter

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 (Beets et al, 1999), which is used to derive forest biomass and carbon by pool from stem volume yield tables.

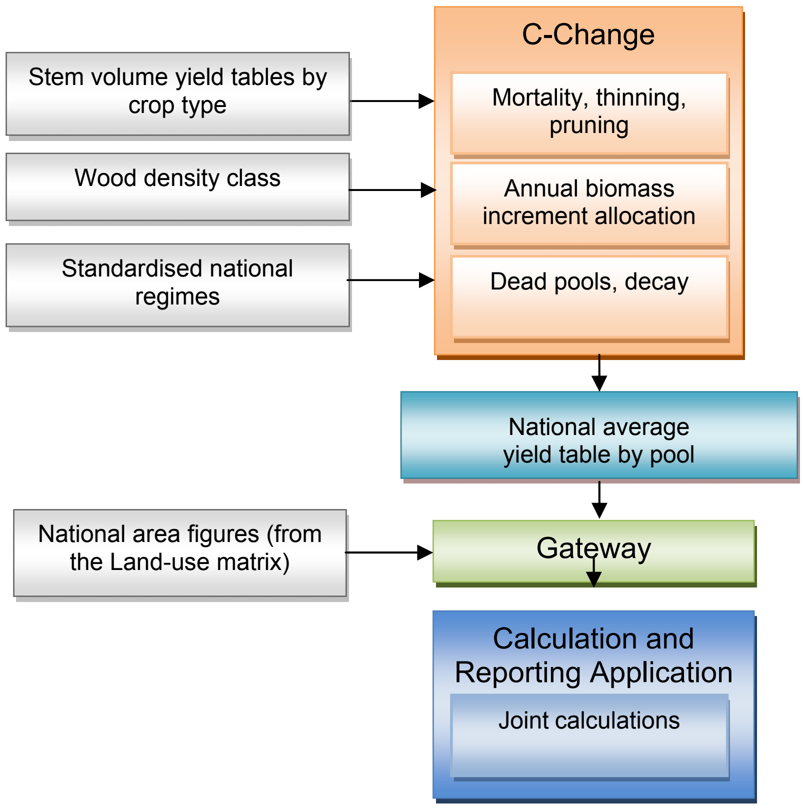
This method is essentially the same as used in the 2009 submission. The process is illustrated in Figure 7.2.2.2. The differences between the method used in the 2009 submission and this submission are as follows.

- The age-based carbon yield table (derived from the *National Exotic Forest Description* and attributed to biomass pool using C_Change) is used in the LUCAS Calculation and Reporting Application, and not within the FOLPI modelling system (a forest estate modelling package for forest management planning).
- In the 2009 submission, harvesting emissions were estimated as 85 per cent of the stem biomass, compared with 70 per cent of live biomass in this submission (the results of this change are minor). Future research is planned to verify this estimate.
- In the 2009 submission, first and second rotation forests were treated separately but reported together. In this submission, all pre-1990 planted forests are treated the same (regardless of rotation number) but post-1989 forests are separated.

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.

Figure 7.2.2.2 New Zealand's pre-1990 planted forest inventory modelling process



Wood density is an important variable in the estimation of carbon levels. It is related to the individual effects of temperature, stand age, nitrogen fertility and management factors (Beets et al, 2007a). 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 7.2.2.2. 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}.

Table 7.2.2.2 Influence of individual site and management factors on predicted wood density for New Zealand

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 output from C_Change is a dry-matter yield table with estimates of dry matter per hectare by age class for each component. These are aggregated into the biomass carbon pools and converted to carbon using a carbon fraction of 0.5 (default value given in GPG-LULUCF, IPCC, 2003). These are then combined with the activity data (area of forest by age class) to estimate carbon stock by pool.

There are losses in this category of forest land remaining forest land associated with forest harvesting. The proportion of total stem volume removed at harvest varies, but is generally around 85 per cent and is equivalent to about 70 per cent of above-ground live biomass at typical rotation ages (Wakelin, 2008). This is treated as an instantaneous carbon loss. These losses are estimated as 70 per cent of above-ground live biomass, with the remaining 30 per cent of above-ground biomass being transferred to the dead organic matter pool and decayed in a linear manner over 20 years; however, work is currently under way to confirm these estimates.

Soil carbon

Soil carbon stock in pre-1990 planted forest land remaining pre-1990 planted forest land is estimated using a Tier 2 method as described in section 7.1.2 – Soils. The soil carbon stock in pre-1990 planted forests at equilibrium state is estimated to be 104.31 t C ha^{-1}, with a standard error of ±6.44 (Table 7.1.2.10). 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 – Forest land remaining forest land

Non-CO_2 emissions from drainage of soils and wetlands

New Zealand has not prepared estimates for this category as allowed for in the IPCC good practice guidance for LULUCF chapter 1.7.

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 no activity data on this (Wakelin et al, 2009). 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 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 2009. 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

All land converted to forest land 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) since 1990 is included in the subcategory post-1989 forests.

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 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 of post-1989 forests and to determine the average level of carbon per hectare for the PSPs are briefly described and are shown in Figure 7.2.2.3. 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 7.2.2.4).
- 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.
- Making and storing tree, dead wood, litter and soil fertility measurements on plots. Soil fertility measurements are made to assist in predicting 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 3 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 7.2.2.3 New Zealand's approach used to inventory post-1989 forests and estimate the average carbon stock per pool for the plots within the forest

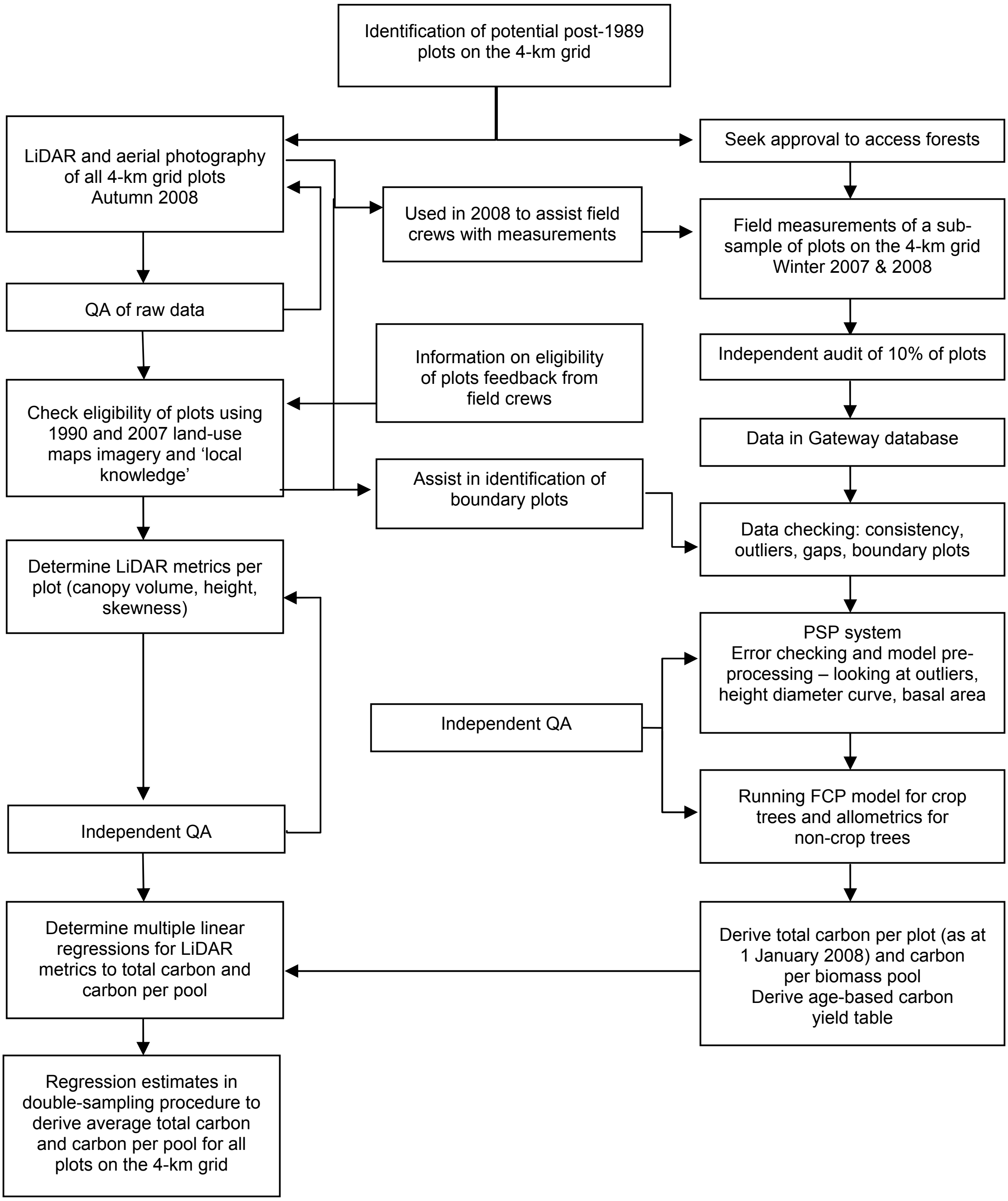
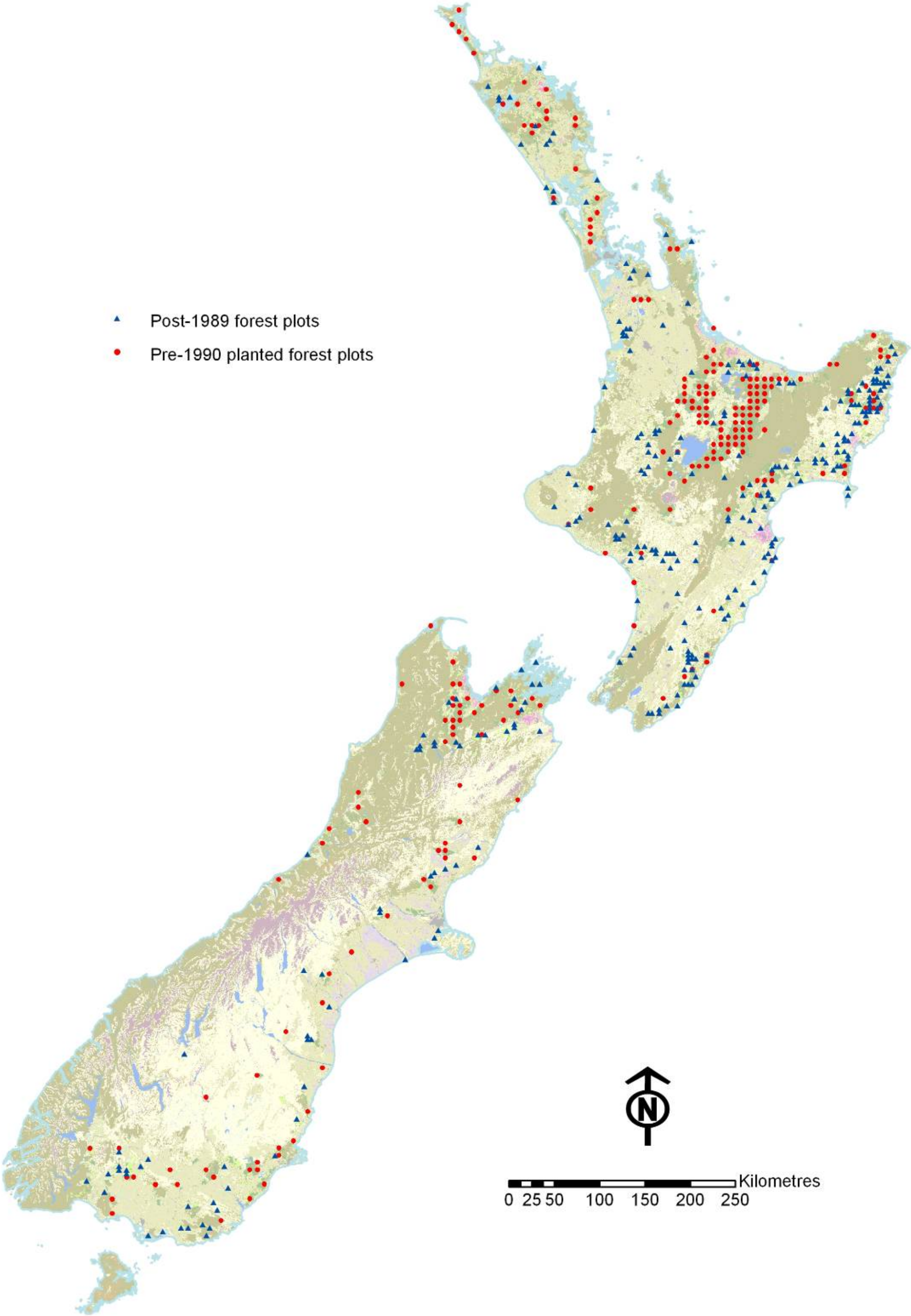


Figure 7.2.2.4 Location of New Zealand's pre-1990 planted forest and post-1989 forest plots



Quality assurance and quality control

Quality-assurance and quality-control activities were conducted throughout the post-1989 forest data capture and processing steps. These quality-assurance and quality-control activities are indicated in Figure 7.2.2.3, 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). These activities are described more fully in section 7.2.4.

Modelling and LiDAR double sampling

The plot data collected was modelled using a forest carbon modelling system called '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 300 Index Growth model for radiata pine (*Pinus radiata*) generates a productivity index for a plot from the stand age, mean top height, basal area, stocking, and stand silvicultural history that it uses to predict gross and net stem volume under bark over a full rotation. The stem volume increment predictions are combined with estimates of the density of stem wood annual growth sheaths, which C_Change uses to estimate carbon stocks in four pools: above-ground biomass, below-ground biomass, dead wood and litter, taking into account natural and management-induced mortality and decay rates.

The use of the forest carbon modelling system enabled the production of plot-based estimates of carbon per plot at a specific date, and an area-weighted and age-based carbon yield table. Paul and Kimberley (2009) have 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 that 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.

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 differing in mean height and basal area. In this study, involving 36 plots independent of either 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 of 95 per cent actively managed production forestry. The average age of post-1989 forest trees as at 1 January 2008 is 12 years. This submission's yield table has been compared with the yield table used in the last submission (see section 7.2.5 for further details).

Living biomass

The living biomass pool is separated into two pools.

1. Above-ground biomass. The carbon content of plantation crop trees and shrubs under crop trees is estimated using the FCPv2.2 model. For the other shrubs and non-crop tree species, the carbon content is estimated using species-specific allometric equations that enable carbon to be determined from diameter, height, wood density (for trees) and canopy cover measures (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.
2. 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.

1. Dead wood. The carbon content of the dead wood pool is estimated using the FCPv2.2 model. 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.
2. Litter. The carbon content of the litter pool in post-1989 forests is estimated using the FCPv2.2 model.

Soil carbon

Soil carbon stocks in land converted to post-1989 forest are estimated using a Tier 2 method as described in section 7.1.2. 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 18 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 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 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 117.66 t C ha^{-1}) to planted forest (soil carbon stock 104.31 t C ha^{-1}), would be a loss of 13.35 t C ha^{-1} over the 20-year period.

Non-carbon dioxide 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 unburned 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. 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).

7.2.3 Uncertainties and time-series consistency

Removals from forest land are 3.0 per cent of New Zealand's total emissions and removals uncertainty in 2008 (Annex 7). Forest land introduces 2.6 per cent uncertainty into the trend in the national total from 1990 to 2008. This is the second largest impact on the trend following CO_2 emissions from the energy sector.

Natural Forest

The uncertainty in mapping natural forest is ±4 per cent.

The natural forest plot network provides carbon stock estimates that are within 95 percent confidence intervals of 3.67 percent of the mean (±8.0 t/ha) in forests and 15.0 per cent of the mean (±8.6 t/ha) in shrublands (Beets et al, 2009).

No uncertainty estimates are currently available for emissions from harvesting of natural forests.

Table 7.2.3.1 Uncertainty in New Zealand's 2008 estimates from natural forest

Variable	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	
Uncertainty in land area	±5.7
Emission factor uncertainty	
Uncertainty in biomass carbon stocks	±3.7
Uncertainty in soil carbon stocks	±4.7
Uncertainty in liming emissions	NO
Combined emission factor uncertainty	±3.7
Implied uncertainty in N_2O emissions	±6.0
Combined uncertainty	**±6.8**

Notes: Lime application to natural forest does not occur (NO) in New Zealand. Nitrous oxide emissions are calculated as a proportion of carbon stock changes with the same uncertainty as for CO_2, and therefore do not add to the combined uncertainty value. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

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. For example, the wood density and yield table information as outlined in section 7.2.2.

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 error 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 at least ±16.0 per cent. The total national planted area from the *National Exotic Forest Description* is considered to be accurate to within ±5.0 per cent (Ministry of Agriculture and Forestry, 2009a) and the *National Exotic Forest Description* yield tables are assumed to be accurate to within ±5.0 per cent.

A sensitivity analysis was conducted using the above accuracy ranges for total planted area and commercial yield, and a proportional uncertainty error of ±16.0 per cent. The C_Change model runs indicate that the precision of the carbon stock estimates could be of the order of ±25.0 per cent.

Table 7.2.3.2 Uncertainty in New Zealand's 2008 estimates from pre-1990 planted forest

Variable	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	
Uncertainty in land area	**±9.9**
Emission factor uncertainty	
Uncertainty in biomass accumulation rates	±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	±6.2
Uncertainty in liming emissions	NO
Combined emission factor uncertainty	**±16.9**
Implied uncertainty in N_2O emissions	±17.9
Total combined uncertainty	**±19.5**

Notes: 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. Nitrous oxide emissions are calculated as a proportion of carbon stock changes with the same uncertainty as for CO_2, and therefore do not add to the combined uncertainty value. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

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 (r^2=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 (In press (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 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 7.2.3.3 Uncertainty in New Zealand's 2008 estimates from post-1989 forest

Variable	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	
Uncertainty in land area	**±6.5**
Emission factor uncertainty	
Uncertainty in biomass accumulation rates	±11.9 based on:
Modelling	*±10.3*
Sampling	*±5.9*
Forecasting	*±1.0*
Uncertainty in soil carbon stocks	±6.2
Uncertainty in liming emissions	NO
Combined emission factor uncertainty	**±10.1**
Implied uncertainty in N_2O emissions	±13.4
Total combined uncertainty	**±12.0**

Notes: Lime application to post-1990 forest does not occur (NO) in New Zealand. Nitrous oxide emissions from lime application on deforested land is 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).

7.2.4 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 checks.

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 7.2.2.3). The field measurements of the permanent sample plots were formally audited through the remeasurement 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 reflown. 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 were 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.

7.2.5 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 7.2.5.1. 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 7.2.5.1 Recalculations on New Zealand's estimates for the forest land category in 1990 and 2007

	Net removals and areas		Change from the 2009 submission	
	2009 submission	2010 submission		(%)
1990 net removals	–18,649.2 Gg CO_2-e	–32,856.7 Gg CO_2-e	–14,207.5 Gg CO_2-e	+76.2
2007 net removals	–24,527.9 Gg CO_2-e	–30,651.5 Gg CO_2-e	–6,123.6 Gg CO_2-e	+25.0
1990 land areas	9,368,950 ha	9,644,551 ha	+275,601 ha	+2.9
2007 land areas	9,993,180 ha	10,131,746 ha	+138,566 ha	+1.4

For forest land, the reasons for the recalculation differences are explained below.

Land area

The estimate of land area in each of the forest land subcategories was updated as a result of the land-use mapping programme. A comparison of the estimates used in this submission compared with the previous submission is given in Table 7.2.5.1. There have been changes in all three forest subcategories because the definitions of the classes have changed since the previous submission (see Table 7.1.2.7). The key points to note are as follows.

- Previous estimates of total planted forest land were derived from the Ministry of Agriculture and Forestry's *National Exotic Forest Description*. This data is compiled from a voluntary postal survey of commercial forest owners. *National Exotic Forest Description* data is reported primarily as net stocking while the area of natural forest (gross area not net area) was derived for the LCDB created from the classification of satellite imagery.
- The LUCAS mapping now estimates the total area of forest land to be 3 per cent higher than previously reported. This difference can be attributed to the difference between data sources for planted forest. The LUCAS mapping area estimates of planted forest represent gross areas (using the Kyoto Protocol forest definition) while the *National Exotic Forest Description* estimates represent net stocked area. In New Zealand, the difference between net and gross area is generally between 10 and 15 per cent. Additionally, the new estimate for planted forest land area also covers all planted forest areas, including riparian and erosion-control plantings that meet the Kyoto Protocol forest definition, not just areas of plantation crop as in the previous submission.

Age-based and area-adjusted carbon yield tables

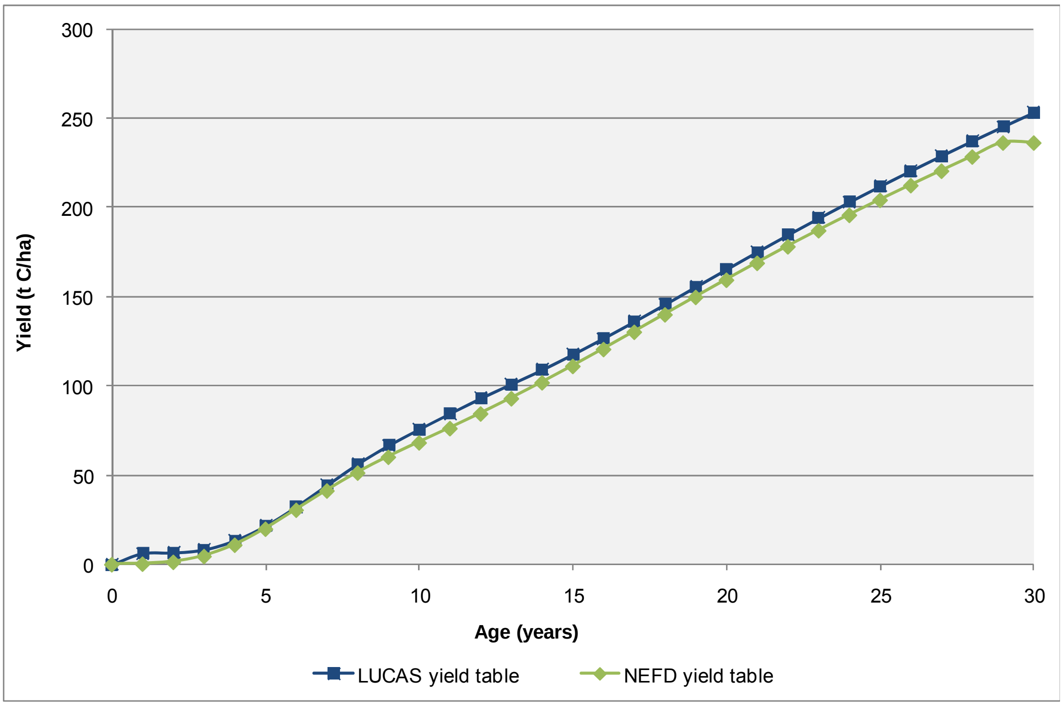
The LUCAS programme has introduced a new approach to estimate carbon stock change in post-1989 forests, as described in section 7.2.3. This approach is based on a forest inventory of permanent sample plots to establish the carbon stock as at 1 January 2008, and a national area-weighted and age-based carbon yield table for this forest subcategory. This new approach has only been implemented for the post-1989 forests, but will be implemented for the pre-1990 planted forests during 2010, and the results will be in the 2012 submission.

From 2010, New Zealand will estimate carbon in the two subcategories of planted forests (pre-1990 and post-1989) in the same manner. A comparison between the two national carbon yield tables, namely, the previous *National Exotic Forest Description*-based table as used for the 2009 submission and the current LUCAS double-sampling, inventory-based table used for this submission, has been undertaken. This comparison was completed by Scion, an independent research provider (Steve Wakelin, Scion, pers comm). The result of this comparison is provided in Figure 7.2.5.1. The approach to develop the two yield tables was as follows.

1. The *National Exotic Forest Description* carbon yield table was established from regional volume tables based on data voluntarily supplied by large forest owners. Each table was converted to a carbon yield table using the C_Change model (also part of FCPv2.2), and subsequently weighted by area to create a national average carbon yield table. This is used for pre-1990 planted forests.
2. The LUCAS carbon yield table was established by using the forest carbon modelling system, FCPv2.2 (explained above) to estimate biomass carbon (t C ha⁻1) for each of the inventory plots from planting to maturity. This was updated to provide an area-weighted table by LiDAR regression estimators using double-sampling procedures described in section 7.2 (Kimberley et al, 2009).

Figure 7.2.5.1 shows the differences between the current and previous yield tables. The *National Exotic Forest Description* yield table does not reflect the specific characteristics of the post-1989 forests that have been planted into ex-grassland, especially those with relatively high soil fertility. The LUCAS yield table has been constructed using national data collected specifically for carbon reporting.

Figure 7.2.5.1 New Zealand's previous and current post-1989 forest age-based and area-weighted forest carbon yield tables



Calculation method

Both the previous and current approaches use an age-class distribution for planted forests. The previous approach used three age-class distributions: first rotation planted forests; second rotation planted forests; and first rotation post-1989 planted forests. These were modelled separately but reported with pre-1990 planted forest under plantation (crop).

The current approach uses two age-class distributions, one for the pre-1990 planted forests and one for the post-1989 forests. The previous approach used the latest *National Exotic Forest Description* statistics as at 1 April 2007 (Ministry of Agriculture and Forestry, 2008a) to establish the age-class distributions and back-cast these to 1990. For pre-1990 planted forests, the current approach used the 1991 *National Exotic Forest Description* statistics to establish the 1990 age-class distribution. For the post-1989 forests, the age data from the national plot network was used to establish the age-class distribution as at 1 January 2008. The data was then used with *National Exotic Forest Description* annual new planting information to establish the 1990–2008 planting profile for these recently established forests (see Figure 7.2.1.1).

The previous *National Exotic Forest Description*-based approach for post-1989 forests estimates more carbon stock over the period 1994 to 2002 when compared with the current LUCAS approach. However, the current LUCAS approach estimates more carbon stock over the period 2002 to 2013.

Soil carbon stock factors

These factors have been improved (see section 7.1 – Soils). The previous reference soil carbon stock value was 83 t C ha^{-1}. This previous reference value had been calculated incorrectly, where the effect of management on soil carbon was applied twice. The Soil CMS stock value includes the effect of management. The current reference value is 117.66 ± 12.56 t C ha^{-1} (Table 7.1.2.10), and the stock values for natural forest and planted forest are 111.85 ± 5.24 t C ha^{-1} and 104.31 ± 6.44 t C ha^{-1} respectively. The previous approach used the reference soil carbon stock for both natural and planted forests.

Natural forest carbon stock estimates

Previous estimates of national carbon stock values for natural forest that were used to populate previous submissions were derived from historic data. These data were not collected specifically for the purpose of estimating carbon stocks at a national scale. Essential data had not necessarily been collected, and important vegetation types and some regions with substantial forest cover were significantly under-represented. The establishment and first measurement of the national grid-based network of permanent plots has provided an unbiased estimate of carbon stored in the natural forests. The estimate used in this report is based on data collected from a complete set of plots, includes the full set of data required for carbon calculations and the result is more accurate with reduced uncertainty. The methods used are fully documented, repeatable and will be comparable once the full network of plots has been remeasured.

Deforestation area

The area estimates of deforestation have 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 new LUCAS land-use mapping, whilst deforestation of post-1989 forest has been estimated from a variety 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 within 2008 of pre-1990 and post-1989 planted forest is sourced from the Deforestation Intentions Survey (Manley, 2009) and unpublished work by Scion (New Zealand Forest Research Institute).

The estimate of natural forest deforestation in 2008 was 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, and extrapolated out to the end of 2008. The extrapolated estimate of natural forest deforestation will be updated in future submissions as new information becomes available, and will be replaced with an actual, mapped value in the 2013 submission at the latest, following production of the 2012 land-use map. For more detail on natural forest deforestation, see section 7.2.1.

Mapping methods and data sources are described in further detail in section 7.1.2.

7.2.6 Category-specific planned improvements

A natural forest remeasurement is under way. After this remeasurement is complete, New Zealand will be able to better illustrate whether its natural forests are a source, sink or carbon neutral.

The inventory of the pre-1990 planted forests is still in the planning stage but is scheduled for 2010. Given the experience of the carbon inventory of post-1989 forests (see Land converted to forest land – section 7.2.2), a similar double-sampling approach will be employed using LiDAR in combination with ground-based permanent sample plots. The pre-1990 approach will be consistent with the inventory approach used for post-1989 forests. It is likely that at least 200 ground sites (see Figure 7.2.2.4) will be 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 will be sufficient to estimate the stock of carbon to a PLE[9] 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 field measurements for the pre-1990 planted forests, the methods to estimate carbon of the two subcategories (pre-1990 planted and post-1989 forests) will likely be standardised.

To ensure that all of the 4-kilometre grid intersections located within mapped post-1989 forest are sampled, the mapping of these forests will be iteratively improved to ensure that carbon estimates are unbiased. Sampling at the grid intersections would be by LiDAR only, or with both LiDAR and field measurements. The post-1989 forests will be remeasured at the end of the commitment period (2012), allowing carbon stock changes over the commitment period to be measured.

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 well LiDAR data is co-located with field measurements, and the effect of mislocation on the carbon regression between LiDAR plots
- improved knowledge of decay rates associated with forest harvesting residues
- improvement of the Douglas fir biomass database and the ability to model growth and carbon allocation using the Forest Carbon Predictor modelling system

9 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 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.

Planned future improvements also include further soil data collection for land under planted forest, and further measurement of paired sites for validation.

7.3 Cropland (CRF 5B)

7.3.1 Description

Cropland in New Zealand is separated into two subcategories: annual and perennial. In 2008, there were 334,159 hectares of annual cropland in New Zealand (1.2 per cent of total land area) and 88,541 hectares of perennial cropland (0.3 per cent of total land area). Annual crops include cereals, grains, oil seeds, vegetables, root crops and forages. Perennial crops include orchards, vineyards and shelterbelts except where these shelterbelts meet the criteria for forest land. A summary of land-use change within the cropland category is provided in Table 7.3.1.1.

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 2008, the net removals by cropland were 23.7 Gg CO_2-e. Net removals from cropland have increased 53.6 Gg CO_2-e (179.0 per cent) from the 1990 level when net emissions were 29.9 Gg CO_2-e (see Table 7.3.1.1).

Table 7.3.1.1 New Zealand's land-use change within the cropland category in 1990 and 2008

Cropland land-use category	Net area in 1990 (ha)	Net area in 2008 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2-e)		Change from 1990 (%)
				1990	2008	
Cropland remaining cropland	417,913	417,825	–0.02	25.9	3.1	–88.0
Land converted to cropland	246	4,875	+1,881.7	4.0	–26.7	–767.5
Total	**418,159**	**422,700**	**+1.1**	**29.9**	**–23.7**	**–179.3**

Notes: 1990 and 2008 areas are as at 31 December. Net emission/removal values are for the whole year indicated.

The change within the cropland category from being a small source of emissions in 1990, to a small CO_2 sink in 2008, reflects the net increase in the area of land converted to perennial cropland from other land-use subcategories with lower carbon emission factors, including 5,179 hectares from annual cropland and 4,249 hectares from high-producing grassland.

The carbon stored in cropland in 2008 was 116,849.3 Gg C. The growth in carbon stock since 1990 is 728.5 Gg C, equivalent to removals of 2,671.0 CO_2-e. A summary of the carbon stock change by carbon pool within the cropland category is shown in Table 7.3.1.2.

Table 7.3.1.2 New Zealand's carbon stock change by carbon pool within the cropland category in 1990 and 2008

Carbon pool	Carbon stock in 1990 (Gg C)	Carbon stock in 2008 (Gg C)	Change from 1990 (%)
Living biomass	6,655.7	6,844.9	+2.8
Dead organic matter	NE	NE	NA
Soil	49,162.6	49,701.9	+1.1
Total	**55,818.3**	**56,546.8**	**+1.3**

Notes: 1990 carbon stock values are as at 31 December 1989, and 2008 values are as at 31 December 2008. Dead organic matter 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).

Cropland remaining cropland

In New Zealand, there were 417,825 hectares of cropland remaining cropland in 2008. This is made up of 334,007 hectares of annual cropland remaining annual cropland, 78,639 hectares of perennial cropland remaining perennial cropland and 5,179 hectares of annual cropland converted to perennial cropland between 1990 and 2008.

The only emissions for cropland remaining cropland are a result of the land-use change from annual cropland to perennial cropland. This land-use change resulted in net removals of 34.5 Gg CO_2-e in 2008. Over the period 1990 to 2008, removals totalled 300.4 Gg CO_2-e.

These removals are mostly because the carbon accumulation in living biomass in perennial cropland is higher than for annual cropland (63 t C ha^{-1} versus 5 t C ha^{-1}). Net change in living biomass between 1990 and 2008 for annual cropland converted to perennial cropland was 90.6 Gg C (332.3 Gg CO_2-e of net removals); net change in soils over the same period was –8.7 Gg C (31.9 Gg CO_2-e of net emissions). Net change in dead organic matter is not estimated as no Tier 1 defaults are available for estimating carbon stocks or change in this pool (IPCC, 2003).

In 2008, emissions from liming of cropland remaining cropland accounted for 37.6 Gg CO_2-e of net emissions. Net emissions from cropland liming have increased 14.6 Gg CO_2-e (63.2 per cent) from the 1990 level of 23.0 Gg CO_2-e.

Land converted to cropland

Between 1990 and 2008, the net area of land converted to cropland was 4,875 hectares. Most of this (4,249 hectares) was high-producing grassland converted to perennial cropland. The net carbon change associated with land-use change to cropland was 32.1 Gg C (net removals of 117.8 Gg CO_2-e).

The net change in carbon stocks for the 152 hectares of land converted to annual cropland between 1990 and 2008 was a gain of 0.478 Gg C (net removals of 1.8 Gg CO_2-e). This is made up of a loss of 0.057 Gg C from living biomass (emissions of 0.2 Gg CO_2-e) and a gain of 0.535 Gg C from soil organic matter (removals of 2.0 Gg CO_2-e).

The net change in carbon stocks for the 4,723 hectares of land converted to perennial cropland between 1990 and 2008 was 31.6 Gg C (net removals of 116.0 Gg CO_2-e). This is made up of a gain of 35.2 Gg C from living biomass (removals of 129.1 Gg CO_2-e), a gain of 0.117 Gg C from soil organic matter (removals of 0.4 Gg CO_2-e) and a loss of 3.7 Gg C from dead organic matter (emissions of 13.6 Gg CO_2-e).

Between 1990 and 2008, emissions of nitrous oxide resulting from cultivation of land converted to cropland were 0.001 Gg N_2O (0.2 Gg CO_2-e).

7.3.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using IPCC Tier 1 emission and removal factors, and activity data as described in section 7.1.2 – Representation of land areas. Emissions and removals by the soil pool are estimated using a Tier 2 method. This is described in section 7.1.2 – Soils.

Cropland remaining cropland

As well as annual cropland remaining annual cropland, and perennial cropland remaining perennial cropland, the estimates for cropland remaining cropland include area and carbon stock changes for annual cropland converted to perennial cropland.

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 2.25 t C ha^{-1} yr^{-1}. This value is based on 63 t C ha^{-1}, the default value for perennial cropland in a temperate climate (all moisture regimes) from GPG-LULUCF, Table 3.3.2 (IPCC, 2003), spread over (or divided by) 28 years, which is the maturity period New Zealand has chosen 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 carbon

Soil carbon stocks in cropland remaining cropland are estimated using a Tier 2 method as described in section 7.1.2 – Soils.

The Tier 2 value for soil carbon in annual cropland at steady state is estimated to be 118.27 t C ha^{-1}, with a standard error of 22.47 (Table 7.1.2.10). While the estimate appears high, New Zealand soils generally do contain higher soil carbon levels than similar soils in other countries (Tate et al, 1997) and than default IPCC values (Scott et al, 2002).

The Tier 2 value for soil carbon in perennial cropland at steady state is estimated to be 114.91 t C ha^{-1}, with a standard error of 13.22 (Table 7.1.2.10).

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 steady state value for annual cropland (118.27 t C ha^{-1}) to the steady state perennial cropland value (114.91 t C ha^{-1}).

There are large standard errors associated with the soil carbon stock values due to the small size of the datasets. There are two reasons for the small datasets; historically, little focus has been placed on collecting soil data under this land use as it represents only 1.6 per cent of New Zealand's total land area (1.2 per cent being annual cropland and 0.3 per cent being perennial cropland). In addition, recent improvements to the dataset to remove potential bias from the emphasis of historical soil survey on undisturbed pedons resulted in the invalidation of the majority of cropland records as they could not be definitely identified as being within the cultivated area (Fraser et al, 2009). Planned future improvements in the soils area include soil data collection for identified gaps.

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 7.1.2 – 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 2007 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 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 7.1.2.4 and 7.1.2.5.

The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place, as outlined in equation 3.3.8 of GPG-LULUCF (IPCC, 2003).

To estimate growth after conversion to annual cropland, New Zealand uses the IPCC default biomass accumulation rate of 5 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 2.25 t C ha^{-1} yr^{-1}. This value is based on the 63 t C ha^{-1}, the default value for perennial cropland in a temperate climate (all moisture regimes) from GPG-LULUCF, Table 3.3.2 (IPCC, 2003), being gained over 28 years, which is the maturity period New Zealand has chosen 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 carbon

Soil carbon stocks in land converted to annual and perennial cropland are estimated using a Tier 2 method as described in section 7.1.2 – Soils. 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.

Non-CO_2 emissions

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland

Nitrous oxide emissions result from the mineralisation of soil organic matter with conversion 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 in land converted to cropland: this value is calculated from the land converted to cropland soil carbon calculations
- EF_1: 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).

Nitrous oxide emissions from disturbance associated with land-use conversion to croplands are minor in New Zealand (0.1 tonnes in 2008, and 0.7 tonnes N_2O in total since 1990). As New Zealand is only reporting emissions to the nearest tonne and the N_2O emissions for 2008 are less than 1 tonne in 2008, the notation key NE ('not estimated') is used in the common reporting format tables.

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 NO ('not occurring') is used in the common reporting format tables.

7.3.3 Uncertainties and time-series consistency

Uncertainties are analysed as uncertainty in activity data and uncertainty in emission factors. The combined effect of uncertainty is estimated at ±96.1 per cent in annual cropland and ±94.9 per cent in perennial cropland (95 per cent confidence interval).

As shown in Table 7.3.3.1, 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. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone as error is introduced from extrapolation of land-use change out to the end of 2008. Extrapolation of land-use change rates is needed as mapping is not repeated annually (only two data points (1 January 1990 and 1 January 2008) of mapped activity data are used).

Table 7.3.3.1 Uncertainty in New Zealand's 2008 cropland estimates

Variable	**Uncertainty at a 95% confidence interval (%)**	
Land-use subcategory	Annual cropland	Perennial cropland
Activity data uncertainty		
Uncertainty in land area	±9.9	±8.8
Emission factor uncertainty		
Uncertainty in biomass accumulation rates	±75.0 (IPCC, 2003, Table 3.3.2)	±75.0 (IPCC, 2003, Table 3.3.2)
Uncertainty in soil carbon stocks	±19.0	±11.5
Uncertainty in liming emissions	±40.0	±40.0
Combined emission factor uncertainty	**±40.3**	**±84.1**
Implied uncertainty in N_2O emissions	**NA**	**NA**
Total combined uncertainty	**±41.5**	**±84.6**

Notes: Not applicable (NA) is shown for the uncertainty in N_2O emissions, which are minor for this land-use category and reported as not estimated (NE) in the common reporting format tables. See section 7.3.2 for details. 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

In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.3.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the cropland category is shown in Table 7.3.5.1. Recalculations were carried out for this category as a result of new activity data from a modified mapping process as described in section 7.1.2 – Representation of land areas.

The annual growth in biomass for land converted to perennial cropland has been increased (from 2.1 to 2.25 t C ha^{-1} – see Table 7.1.2.5) and the use of this factor has been improved. Previously, 'land converted' was only in this state for one year. The current method has 'land in a conversion' state for 28 years, before it moves to the 'land remaining land' category.

Further, the soil carbon stock factors have been improved (see section 7.1.2 – Soils). The previous reference soil carbon stock value was 83 t C ha^{-1}. The current value is 117.66

± 12.56 t C ha^{-1} (Table 7.1.2.10), and the stock values for annual and perennial cropland are 118.27 ± 22.47 t C ha^{-1}and 114.91 ± 13.22 t C ha^{-1} respectively. The previous approach used the reference soil carbon stock for both annual and perennial cropland.

The amount of agricultural lime (limestone) applied was also updated following the final results from the 2007 Agricultural Census being released.

Table 7.3.5.1 Recalculations for New Zealand's net emissions and removals from the cropland category in 1990 and 2007

	Net emissions and removals		Change from the 2009 submission	
	2009 submission (Gg CO_2-e)	2010 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	–477.7	29.9	+507.6	+106.3
2007	–510.3	17.5	+527.8	+103.4

7.3.6 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 7.1.2 – Soils.

The use of historic activity data for cropland is to be investigated. This would allow for improved estimates of the area in the land converted to cropland and cropland remaining cropland categories. As there is no one dataset on land use prior to 1990, the initial work will focus on what datasets are available for all land uses before 1990 and how these datasets might be combined.

The biomass value used for perennial cropland is also under review. Indications are that the IPCC default value of 63 t C ha^{-1} is too high for New Zealand's perennial cropland that is dominated by grape and kiwifruit vines.

7.4 Grassland (CRF 5C)

7.4.1 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, a new land-use subcategory in 2008, consists of grassland areas where the cover of woody species is less than 30 per cent and 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 7.4.1.1.

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 time frame (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 modifies land management that encourages sustained growth of woody vegetation, such as removing stock, then these areas will be mapped as forest. A description of the land-management approaches that result in sustained growth of woody vegetation is contained in the mapping interpretation guide (Dougherty et al, 2009).

In 2008, there were 5,813,712 hectares of high-producing grassland (21.6 per cent of total land area) 7,701,148 hectares of low-producing grassland (28.7 per cent of total land area) and 1,056,975 hectares of grassland with woody biomass (3.9 per cent of total land area).

In 2008, the net emissions from grassland were 3,557.0 Gg CO_2-e. Net emissions from grassland have increased by 1,814.6 Gg CO_2-e (104.1 per cent) from the 1990 level of 1,742.4 Gg CO_2-e.

Land converted to grassland was identified as a key category (level and trend) for 2008.

Table 7.4.1.1 New Zealand's land-use change within the grassland category in 1990 and 2008

Grassland land-use category	Area in 1990 (ha)	Area in 2008 (ha)	Change from 1990 (%)	Net emissions/removals ($Gg\ CO_2$-e) 1990	2008	Change from 1990 (%)
Grassland remaining grassland	15,044,271	14,475,052	–3.8	627.6	707.4	+12.7
Land converted to grassland	1,899	96,783	4,996.5	1,114.8	2,849.6	+155.6
Total	**15,046,170**	**14,571,835**	**–3.2**	**1,742.4**	**3,557.0**	**+104.1**

Notes: 1990 and 2008 areas are as at 31 December. Net emission/removal estimates are for the whole year indicated.

The carbon stored in grassland in 2008 was 1,784,245.8 Gg C. The change in carbon stock since 1990 is a loss of 62,615.8 Gg C, equivalent to emissions of 229,591.3 Gg CO_2-e. A summary of the carbon stock change by carbon pool within the cropland category is shown in Table 7.4.1.2.

Table 7.4.1.2 New Zealand's carbon stock change by carbon pool within the grassland category in 1990 and 2008

Carbon pool	Carbon stock in 1990 (Gg C)	Carbon stock in 2008 (Gg C)	Change from 1990
Living biomass	87,676.2	83,375.7	–4.9
Dead organic matter	10,662.1	9,290.1	–12.9
Soil	1,748,523.3	1,691,580.1	–3.3
Total	**1,846,861.7**	**1,784,245.8**	**–3.4**

Note: 1990 carbon stock values are as at 31 December 1989, 2008 values are as at 31 December 2008.

Grassland remaining grassland

In New Zealand, there were 14,475,052 hectares of grassland remaining grassland in 2008. This is split into the three subcategories and changes between subcategories, as shown in Table 7.4.1.3.

Table 7.4.1.3 New Zealand's land-use change between grassland subcategories from 1990 to 2008

Grassland land-use change category	Net area in 2008 (ha)
High producing remaining high producing	5,735,734
High producing to low producing	18
High producing to with woody biomass	8,190
Low producing remaining low producing	7,641,422
Low producing to high producing	1
Low producing to with woody biomass	25,912
With woody biomass remaining with woody biomass	1,018,495
With woody biomass to high producing	14,933
With woody biomass to low producing	30,347

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 2008.

The emissions and removals associated with land-use change to and from grassland with woody biomass dominate as the area of change is large and there are significant levels of carbon in the living biomass and dead organic matter components of grassland with woody biomass (29 t C ha^{-1}).

In 2008, emissions from burning of grassland remaining grassland were estimated as 1.345 Gg of CH_4 (28.2 Gg CO_2-e) and 0.010 Gg of N_2O (3.1 Gg CO_2-e). This is a decrease in CH_4 emissions of 25.5 per cent from the 1990 level of 1.8 Gg CH_4 (37.8 Gg CO_2-e), and a decrease of 23.1 per cent in N_2O emissions from the 1990 level of 0.013 Gg N_2O (4.0 Gg CO_2-e).

In 2008, emissions from liming of grassland remaining grassland accounted for 572.6 Gg O_2-e of net emissions. Net liming emissions from cropland have increased 221.8 Gg CO_2-e (63.2 per cent) from the 1990 level of 350.8 Gg CO_2-e.

Land converted to grassland

Between 1990 and 2008, 96,783 hectares of land was converted to grassland. The total net carbon change associated with land converted to grassland was 17,013 Gg C (equating to net emissions of 62,381 Gg CO_2-e).

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 percent) of land converted to grassland was land previously in forestry. The 94,906 hectares of forest land converted to grassland since 1990 comprises an estimated 34,170 hectares of natural forest deforestation, 49,188 hectares of pre-1990 planted forest deforestation and 11,548 hectares of post-1989 forest deforestation. (For more information on deforestation, see sections 7.1.1 and 7.2.1.) The net effect of this land-use change between 1990 and 2008 was 17,051 Gg C, equating to net emissions of 62,521.8 Gg CO_2-e.

7.4.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using a mix of IPCC Tier 1 emission and removal factors and country-specific factors. Emissions and removals by the soil pool are estimated using a Tier 2 method as described in section 7.1.2 – Soils, and the activity data used is described in section 7.1.2 – Representation of land areas.

Grassland remaining grassland

For grassland remaining grassland, the Tier 1 assumption is that 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 NE ('not estimated') in the common reporting format tables where there is no land-use change at the subdivision level because no estimate of removals or emissions is able to be calculated. However, there is a significant amount of 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 where there is a change in the subdivision level (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 7.1.2.5 – Annual growth in biomass for land converted to another land use. The values given in Table 7.1.2.4 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 change in 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 as described in section 7.1.2 – Soils.

The soil carbon values for the three grassland subdivisions at steady state are given in Table 7.4.2.1.

Table 7.4.2.1 New Zealand's soil carbon stock values for the grassland subcategories

Land-use	Soil carbon stock (t C ha^{-1})
High-producing grassland	114.93 ± 3.56
Low-producing grassland	117.66 ± 12.56
Grassland with woody biomass	111.57 ± 4.29

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 7.1.2 – 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 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 savanna 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 IE ('included elsewhere') 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 (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 Tables 7.1.2.4 and 7.1.2.5. The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place as outlined in equation 3.3.8 of GPG-LULUCF (IPCC, 2003).

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 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, as described in section 7.1.2. 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.

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.

7.4.3 Uncertainties and time-series consistency

Uncertainties can be analysed as uncertainty in activity data and uncertainty in variables such as emission factors, growth rates and the effect of land-management factors. The combined effect of uncertainty in each of the grassland subcategories is estimated to be approximately ±94 per cent (95 per cent confidence interval). As shown in Table 7.3.3.1, while uncertainty in 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 provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the land-use maps alone. Error is introduced from extrapolation, as mapping is not repeated annually. Only two data points (1 January 1990 and 1 January 2008) of mapped activity data are used.

Uncertainties in liming are estimated as ±40.0 per cent based on sampling and survey respondent error. Uncertainties in N_2O are also estimated as ±40.0 per cent.

Table 7.4.3.1 Uncertainty in New Zealand's 2008 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	±7.0	±6.0	±9.5
Emission factor uncertainty			
Uncertainty in biomass accumulation rates	±75.0 (IPCC, 2003, Table 3.3.2)	±75.0 (IPCC, 2003, Table 3.3.2)	±75.0 (IPCC, 2003, Table 3.3.2)
Uncertainty in soil carbon stocks	±3.1	±10.7	±3.9
Uncertainty in liming emissions	±40.0	±40.0	±40.0
Combined emission factor uncertainty	**±47.1**	**±60.5**	**±834.2**
Implied uncertainty in N_2O emissions	±**94.0**	±**94.5**	±**94.0**
Total combined uncertainty	**±47.6**	**±60.8**	**±834.3**

Notes: Nitrous oxide emissions are calculated as a proportion of carbon stock changes with the same uncertainty as for CO_2, and therefore do not add to the combined uncertainty value. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC (2003).

7.4.4 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 quality checks.

7.4.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the grassland category is shown in Table 7.4.5.1 below. The largest net emission/removal recalculation change for this category is the result of reporting the impacts of deforestation in the 'land converted to grassland' subcategory. In the previous submission, deforestation emissions were not explicitly separated from harvesting emissions, and were reported in either land remaining forest land or grassland converted to forest land categories.

Some differences between the previous and current submissions have resulted from new activity data from the improved mapping process as described in section 7.1.2 – Representation of land areas.

The annual growth in biomass for grassland now includes above- and below-ground biomass for the three grassland subcategories. Previously, only above-ground biomass carbon stock changes were estimated.

Grassland with woody biomass has been added as a new grassland subcategory and therefore grassland categories better reflect land types/uses within New Zealand.

The soil carbon stock factors have been improved (see section 7.1.2 – Soils). The previous reference soil carbon stock value was 83 t C ha^{-1}. The current value is 117.66 ± 12.56 (Table 7.1.2.10), and the stock values for the three grassland subcategories are 114.93 ± 3.56, 117.66 ± 12.56 and 111.57 ± 4.29 t C ha^{-1} for high-producing, low-producing and woody biomass grasslands respectively. The previous approach used the reference soil carbon stock for the first two grasslands subcategories.

Table 7.4.5.1 Recalculations for New Zealand's net emissions from the grassland category in 1990 and 2007

	Net emissions		Change from the 2009 submission	
	2009 submission ($Gg\ CO_2$-e)	2010 submission ($Gg\ CO_2$-e)	($Gg\ CO_2$-e)	(%)
1990	863.9	1,742.4	+878.5	+101.7
2007	1,063.7	13,618.3	+12,554.6	+1,180.3

7.4.6 Category-specific planned improvements

The use of historic activity data for grassland is to be investigated. This would allow for improved estimates of the area in the land converted to grassland and grassland remaining grassland categories. As there is no one dataset on land use prior to 1990, the initial work will focus on what datasets are available for all land uses before 1990 and how these datasets might be combined.

The carbon stock for the grassland with woody biomass land-use subcategory will be improved once a sampling framework has been established and plot measurements made. Additional work to improve the mapping of this land-use class will also be carried out.

7.5 Wetlands (CRF 5D)

7.5.1 Description

New Zealand has 425,000 kilometres of rivers and streams, and almost 4,000 lakes that are larger than 1 hectare. Damming, diverting and extracting water for power generation, irrigation and human consumption has modified the nature of these waterways and can deplete flows and reduce groundwater levels. Demand for accessible land has also led to the modification of a large proportion of New Zealand's vegetated wetland areas in order to provide pastoral land cover. Just over 10 per cent of wetlands present prior to European settlement remain across New Zealand (McGlone, 2009).

Section 3.5 of GPG-LULUCF defines wetlands as "land that is covered or saturated by water for all or part of the year (eg, peat land) and that does not fall into the forest land, cropland, grassland or settlements categories". This category can be further subdivided into managed and unmanaged wetlands according to national definitions. The definition includes reservoirs and flooded land as managed subdivisions, and natural rivers and lakes as unmanaged subdivisions. Flooded lands are defined in GPG-LULUCF as "water bodies regulated by human activities for energy production, irrigation, navigation, recreation, etc, and where substantial changes in water area due to water regulation occur. Regulated lakes and rivers, where the main pre-flooded ecosystem was a natural lake or river, are not considered as flooded lands". As the majority of New Zealand's hydroelectric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river, they are not defined as flooded lands.[10] 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

10 For example, the Clyde Dam was created from the damming of the Clutha River in the South Island, creating Lake Dunstan.

‘unmanaged’, even though, more broadly, it can be said that all land in New Zealand is under some form of management and management plan (see section 11.4.1).

New Zealand’s wetlands are mapped into two subcategories: ‘wetland – open water’, which includes lakes and rivers, and ‘wetland – vegetated’, which includes herbaceous vegetation that is periodically flooded, and estuarine and tidal areas. New Zealand has mapped its vegetated wetlands using existing LCDB data. Areas of open water have been mapped using hydrological boundaries defined by Land Information New Zealand (LINZ).

There were 644,135 hectares of wetlands in 2008 in New Zealand, an increase of 70 hectares since 1990. This category is 2.4 per cent of the total New Zealand land area.

In 2008, the net emissions from wetlands were 0.8 Gg CO_2-e. Net emissions from wetlands have increased 0.8 Gg CO_2-e from the 1990 level, when net emissions were 0.01 Gg CO_2-e. These emissions are the result of marginal land conversions to wetlands, mainly from the subcategory forest land converted to wetlands, as carbon stored in forest land is lost instantly on land conversion, and there is no Tier 1 method for estimating carbon gain in biomass for wetlands.

Wetlands were not a key category in 2008.

Table 7.5.1.1 New Zealand’s land-use change for the wetlands category in 1990 and 2008, and associated CO_2-equivalent emissions

Wetlands land-use category	Net area in 1990 (ha)	Net area in 2008 (ha)	Change from 1990 (%)	Net emissions/ removals (Gg CO_2-e) 1990	2008	Change from 1990 (%)
Wetlands remaining wetlands	644,054	643,920	–0.02	NE	NE	NA
Land converted to wetlands	11	215	+1,854.6	0.011	0.829	–7,433.3
Total	**644,065**	**644,135**	**+0.01**	**0.011**	**0.829**	**–7,433.3**

Notes: 1990 and 2008 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 7.5.2 for details.

7.5.2 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 as described in section 7.1.2 – Soils.

The soil carbon stock at equilibrium state is estimated to be 104.62 t C ha^{-1}, with a standard error of 19.92 (Table 7.1.2.10).

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 2.4 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 further uncertainty associated with the estimate for wetlands because organic soils are often associated with vegetated non-forest wetlands, and organic soils are currently excluded from the Soil Carbon Monitoring System calculations. However, the effect of this on emissions from soil carbon is probably negligible as organic soils cover approximately 0.9 per cent of New Zealand's total land area (Tate et al, 2005), and there is very little conversion to and from wetlands (only 70 hectares of change between 1990 and 2008).

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 7.1.2 – Soils. 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.

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.

7.5.3 Uncertainties and time-series consistency

Uncertainties are analysed as uncertainty in activity data and uncertainty in emission factors. The uncertainties for wetlands are estimated as ±77.7 per cent based on the uncertainty in mapping and in carbon stocks lost during conversion to wetlands (GPG-

LULUCF, section 3.5.2.1.1.4, Table 3.5.2). While uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two data points (1 January 1990 and 1 January 2008) of mapped activity data are used.

Table 7.5.3.1 Uncertainty in New Zealand's 2008 estimates for the wetlands category

Variable	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	
Uncertainty in land area	±9.9
Emission factor uncertainty	
Uncertainty in biomass accumulation rates	±75.0
Uncertainty in soil carbon stocks	±19.0
Combined emission factor uncertainty	±97.2
Total combined uncertainty	**±97.7**

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).

7.5.4 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.

7.5.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the wetlands land-use category is shown in Table 7.5.5.1. Recalculations were carried out for this category as a result of new activity data from the improved mapping process as described in section 7.1.2 – Representation of land areas.

The carbon stock in soils at steady state has also been recalculated since the last submission. Details of this process are described in section 7.1.2 – Soils.

Table 7.5.5.1 Recalculations for New Zealand's net emissions from the wetlands category in 1990 and 2007

	Net emissions		Change from the 2009 submission	
	2009 submission (Gg CO_2-e)	2010 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	0.7	0.0	–0.7	–98.5
2007	0.7	4.2	+3.5	+482.7

7.6 Settlements (CRF 5E)

7.6.1 Description

This 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 206,288 hectares of settlements in 2008 in New Zealand, an increase of 2,747 hectares since 1990. This category was 0.8 per cent of New Zealand's total land area in 2008. The largest area of change to settlements between 1990 and 2008 was from high-producing grassland, with 1,675 hectares of high-producing grassland converted to settlement between 1990 and 2008.

In 2008, the net emissions from settlements were 20.0 Gg CO_2-e. These emissions are from the subcategory land converted to settlements.

Settlements were not a key category in 2008.

Settlements remaining settlements

In 2008, there were 203,272 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.

Land converted to settlements

There were 3,016 hectares of land converted to settlements between 1990 and 2008. The change in carbon stocks for this land-use change between 1990 and 2008 was estimated to be a loss of 125.0 Gg C (emissions of 458.2 Gg CO_2-e).

Table 7.6.1.1 New Zealand's land-use change within the settlements category in 1990 and 2008, and associated CO_2-equivalent emissions

Settlements land-use category	Net area as at 1990 (ha)	Net area as at 2008 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2-e) 1990	2008	Change from 1990 (%)
Settlements remaining settlements	203,408	203,272	–0.1	NE	NE	NA
Land converted to settlements	133	3,016	+2,167.7	6.585	20.046	+204.4
Total	**203,541**	**206,288**	**+1.3**	**6.585**	**20.046**	**+204.4**

Notes: 1990 and 2008 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.

7.6.2 Methodological issues

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 as described in section 7.1.2 – Soils, 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 intercept value (117.66 tonnes C ha^{-1}) was used as the default.

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.

Soil carbon

Soil carbon stocks in land converted to settlements are estimated using a Tier 2 method as described in section 7.1.2 – Soils. 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 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.

7.6.3 Uncertainties and time-series consistency

Uncertainties are analysed as uncertainty in activity data and uncertainty in emission factors. The uncertainties for settlements are estimated as ±75.3 per cent based on the uncertainty for Tier 1 grassland carbon stocks (GPG-LULUCF, Table 3.4.2, IPCC, 2003). While uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two data points (1 January 1990 and 1 January 2008) of mapped activity data are used. In addition, mapping is not specific to IPCC categories.

Table 7.6.3.1 Uncertainty in New Zealand’s 2008 estimates for the settlements category

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	±9.8
Emission factor uncertainty	±56.3
Total combined uncertainty	**±57.2**

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 settlements land-use category is shown in Table 7.6.5.1. Recalculations were carried out for this category as a result of new activity data from the improved mapping process as described in section 7.1.2 – Representation of land areas.

The carbon stock in soils at steady state has also been recalculated since the last submission. Details of this process are described in section 7.1.2 – Soils.

Table 7.6.5.1 Recalculations for New Zealand's net emissions from the settlements category in 1990 and 2007

National Inventory Report	Net emissions (Gg CO_2-e) 2009 submission	Net emissions (Gg CO_2-e) 2010 submission	Change from the 2009 submission (Gg CO_2-e)	Change from the 2009 submission (%)
1990 estimate	97.2	6.6	–90.6	–93.2
2007 estimate	97.2	102.7	+5.6	+5.7

7.7 Other land (CRF 5F)

7.7.1 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 2008, the net emissions from other land were 26.9 Gg CO_2-e. Net emissions from other land are 15.4 Gg CO_2-e (133.0 per cent) higher than the 1990 level of 11.5 Gg CO_2-e. These emissions are from the land converted to other land category. Other land was not a key category in 2008.

The LCDB analysis shows that most of the land converted to other land between 1990 and 2008 was from the forest land category (Table 7.1.2.8). Between 1990 and 2008, 314 hectares of natural forest, 292 hectares of pre-1990 planted forest and 68 hectares of post-1989 forest were converted to other land. This is likely to be from erosion of forested land. The net effect of this land-use change was a loss of 138.0 Gg C, equivalent to emissions of 506.0 Gg CO_2-e.

Table 7.7.1.1 New Zealand's land-use change within the other land category in 1990 and 2008

Other land land-use category	Net area as at 1990 (ha)	Net area as at 2008 (ha)	Change from 1990 (%)	Net emissions/removals (Gg CO_2-e) 1990	Net emissions/removals (Gg CO_2-e) 2008	Change from 1990 (%)
Other land remaining other land	894,577	888,112	–0.7	NA	NA	NA
Land converted to other land	32	956	+2,887.5	11.5	26.9	+133.0
Other land	894,609	889,068	–0.6	11.5	26.9	+133.0

Notes: 1990 and 2008 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 7.2.2 for details.

7.7.2 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 7.1.2 – Representation of land area.

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 unable to be estimated using the Tier 2 method described in section 7.1.2 – Soils, as there is no soil data for this land use. Soil data has not been collected for 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. To estimate soil carbon in other land, the IPCC Tier 1 default of 88 t C ha^{-1} is used. This is the default for Moist Temperate High Activity Clay (HAC) and is the value that relates to the largest soil–climate category for New Zealand (Scott et al, 2002). It provides a balance between the knowledge that New Zealand soils generally do contain higher soil carbon levels than similar soils in other countries (Tate et al, 1997) and the recognition that carbon levels in bare soils are likely to be less than in soils under other land uses.

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 7.1.2 – Soils. 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.

7.7.3 Uncertainties and time-series consistency

Uncertainties are analysed as uncertainty in activity data and uncertainty in emission factors. The uncertainties for other land are estimated as ±75.3 per cent based on the uncertainty in carbon stocks lost during the conversion to other land, for example, GPG-LULUCF Table 3.4.2. While uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two data points (1 January 1990 and 1 January 2008) of mapped activity data are used. In addition, mapping is not specific to IPCC categories.

Table 7.7.3.1 Uncertainty in New Zealand's 2008 estimates for the other land category

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	±9.9
Emission factor uncertainty	±40.7
Total combined uncertainty	**±41.9**

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 activity data and emissions factor for soil carbon change underwent Tier 1 quality checks.

7.7.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the other land category is shown in Table 7.7.5.1. Recalculations were carried out for this category as a result of new activity data from the improved mapping process as described in section 7.1.2 – Representation of land areas.

Table 7.7.5.1 Recalculations for New Zealand's net emissions from the other land category in 1990 and 2007

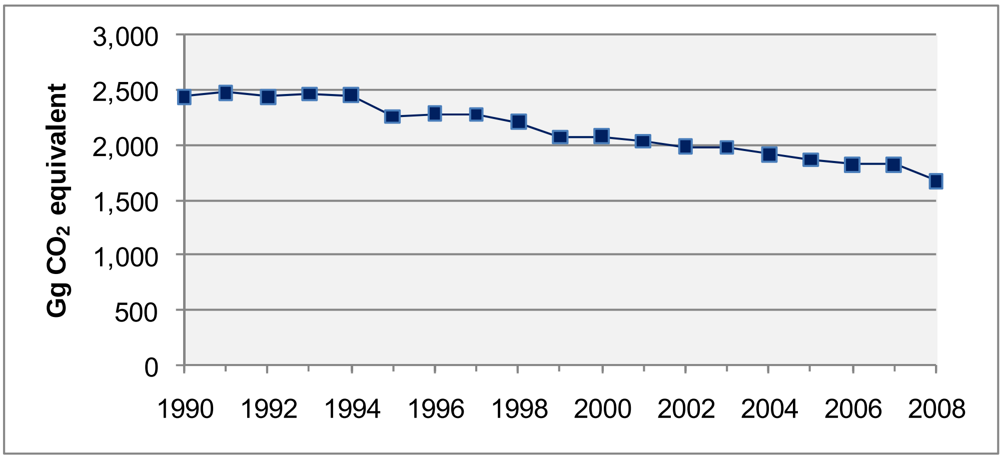
	Net emissions		Change from the 2009 submission	
	2009 submission (Gg CO_2-e)	2010 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990	26.7	11.5	–15.2	–56.8
2007	40.6	88.0	+47.4	+116.7

Chapter 8: Waste

8.1 Sector overview

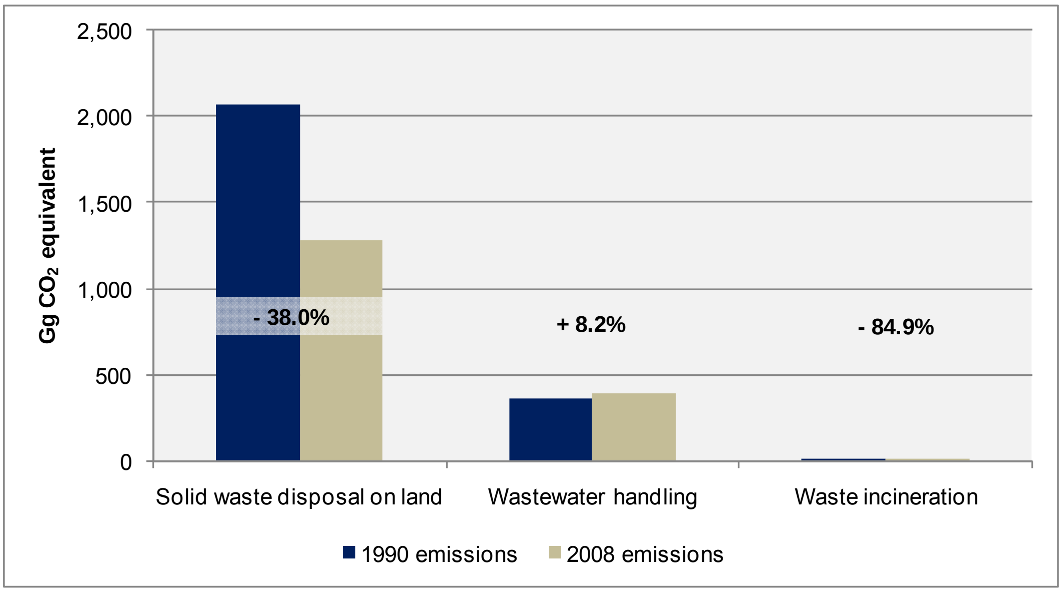
In 2008, the waste sector accounted for 1,670.7 Gg carbon dioxide equivalent (CO_2-e) (2.2 per cent) of total emissions. Emissions from the waste sector were 767.5 Gg CO_2-e (31.5 per cent) below the 1990 baseline value of 2,438.2 Gg CO_2-e (Figure 8.1.1). This reduction occurred in the solid waste disposal on land subcategory as a result of initiatives to improve solid waste management practices.

Figure 8.1.1 New Zealand's waste sector emissions from 1990 to 2008



Emissions from the waste sector are calculated from solid waste disposal on land, wastewater handling and waste incineration (Figure 8.1.2). Methane (CH_4) from solid waste disposal was a key category (level and trend assessment) in 2008.

Figure 8.1.2 Change in New Zealand's emissions from the waste sector from 1990 to 2008



Disposal and treatment of industrial and municipal waste can produce emissions of CO_2 and CH_4. The CO_2 is produced from the aerobic decomposition of organic material. These emissions are not included as a net emission because the CO_2 is considered to be reabsorbed in the following year. The CH_4 is produced as a by-product of anaerobic decomposition.

8.2 Solid waste disposal on land (CRF 6A)

8.2.1 Description

Solid waste disposal on land contributed 1,278.4 Gg CO_2-e (76.5 per cent) of emissions from the waste sector in 2008. This was a decrease of 784.8 Gg CO_2-e (38.0 per cent) from the 1990 level of 2,063.2 Gg CO_2-e. Methane emissions from solid waste were identified as a key category (level and trend) for 2008.

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 and is assumed to be reabsorbed in the following year. The amount of CH_4 generated depends on a number of factors including the waste disposal practices (managed versus unmanaged landfills), the composition of the waste, and physical factors such as the moisture content and temperature of the solid waste disposal sites. The CH_4 produced can go directly into the atmosphere via venting or leakage, or it may be flared off and converted to CO_2.

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 3,180,000 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 have included preparing guidelines for the development and operation of landfills, closure and management of landfill sites, and consent conditions for landfills 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 rely increasingly on modern regional disposal facilities for disposal of their solid waste. The *2006 Landfill Census* reported 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 3,156,000 tonnes of solid waste were deposited in 2006.

New Zealand's focus regarding waste is towards waste minimisation and resource recovery. In March 2002, the Government announced the *New Zealand Waste Strategy* (Ministry for the Environment, 2002a). The strategy sets targets for a range of waste streams as well as for improving landfill practices by the year 2010. As part of the implementation and monitoring of the strategy, the Government developed the *Solid Waste Analysis Protocol* (Ministry for the Environment, 2002b) that provided a classification system, sampling regimes and survey procedures to measure the composition of solid waste streams. In 2008, the Government passed the Waste Minimisation Act that 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 under this Act will significantly improve New Zealand's knowledge of solid waste volumes and composition.

8.2.2 Methodological issues

New Zealand has used a first order decay approach with the model contained in the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines to report emissions from solid waste in the inventory. New Zealand uses default values for the starting year, delay time, degradable organic carbon content of specific waste streams, and the default 'wet temperate' values for methane generation rate constants (k) for each compositional type.

New Zealand-specific activity data on current and historic waste disposal and waste composition is used. An oxidation correction factor of 0.1 is used as landfills in New Zealand are capped and are categorised as well managed (IPCC, 2006c).

Some modifications were made to the IPCC (2006c) workbook tables. These include the addition of an assumptions worksheet that documents the sources of data and judgements made for the method. A worksheet was added to enable direct input into the common reporting format software. Another additional worksheet provides an estimate of emissions using the IPCC (1996) Tier 1 calculations. These estimates were used for a quality-control check as described in section 8.2.4.

New Zealand does not have sufficient data to be able to categorise solid waste as either municipal solid waste or industrial waste, as many municipal landfills accept industrial waste. All national data is therefore reported in the municipal solid waste class.

Activity data on solid waste composition was documented for 1995 and 2004 (Ministry for the Environment, 1997; Waste Not Consulting, 2006). Linear extrapolations and interpolations were used where no new data was available. The estimate of degradable organic carbon in 1995 (and 1990) was 0.15 Gg C/Gg waste, and increased over time to 0.17 Gg C/Gg waste in 2004 (and 2007) mainly through increases in the proportion of wood waste going to landfills.

Calculation of the CH_4 generation potential is based on the same data contained in Ministry for the Environment (1997) and Waste Not Consulting (2006) reports, and adjusted for changes in the management of landfilled waste through the CH_4 correction factor. In 1990, 1995 and 2007, the CH_4 generation potential was 0.05 Gg CH_4/Gg waste.

There is no New Zealand-specific composition data on the specific half-lives of solid waste. Consequently, New Zealand uses the IPCC (2006c) default CH_4 generation rate for a wet temperate climate. This climate type is considered the best fit for New Zealand's complex climate systems and geography.[11]

There has been no new data on solid waste composition since 2004. Consequently, the value for degradable organic content per Gg of waste has remained constant since 2004. However, the CH_4 correction factor has been increasing due to the closure of unmanaged landfills and increasing volumes being disposed to larger, modern landfills. It is estimated that, in 1995, 90 per cent of New Zealand's waste was disposed to managed solid waste disposal sites and 10 per cent to uncategorised sites (Ministry for the Environment,

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[11] Mean average temperatures vary from 10 degrees Celsius in the south to 16 degrees in the north National Institute of Water and Atmospheric Research (NIWA). Mean annual precipitation ranges from 600 to 1,600 mm (NIWA). Mean annual potential evapo-transpiration ranges from 200 mm to 1,100 mm.

1997).[12] The IPCC (2006c) default values are used for the carbon content of the various components of the solid waste stream.

Total waste to landfill has been estimated for the years 1995, 1998, 2002, 2003, 2004 and 2006. Based on the 2006/07 National Landfill Census, the 2002 Landfill Review and Audit, and the 2006 report *Waste Composition and Construction Waste Data*, it is estimated that 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 reduction of 12.6 per cent in waste generation from 858.0 kg per person per year in 1995. The 2006 data on kilograms of solid waste per person per day was extrapolated for 2008 using estimated national population data. 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.

New Zealand uses the IPCC (2006c) default value for the fraction of degradable organic carbon that actually degrades (0.5).

The rate of recovered CH_4 per year is estimated based on information from a 2005 survey of solid waste disposal sites that serve populations of over 20,000 in New Zealand (Waste Management New Zealand, 2005). There was no landfill gas collected in 1990 and 1991, with the first flaring system installed in 1992. The consultants surveyed 18 landfills known to have installed, or that were planning to install, landfill gas systems. The method involved initial modelling of the major landfills that had good operational data, to establish benchmarks for the CH_4 generation potential (Lo), the CH_4 generation rate constant (k) and system recovery efficiency. This information was then used as a starting point for preparing estimates for other sites, with adjustments made based on knowledge of site conditions, system design and assessed operating performance. The landfill CH_4 recovery data was then compiled for all of the sites. The consultants used the IPCC (1996) first order decay model. The quality-assurance and quality-control worksheet was used to check the data.

The benchmarks for the CH_4 generation potential (Lo) and the CH_4 generation rate constant (k) for landfills with gas recovery systems developed by Waste Management New Zealand are not the same as the values used to estimate New Zealand's gross CH_4 emissions in the IPCC (2006c) worksheets. Waste Management New Zealand assumed higher Lo and k values because it argued waste would be managed to biodegrade and emit CH_4 faster at landfills with gas recovery systems. This methodological inconsistency probably results in an underestimation of gross and net national CH_4 emissions from solid waste disposal. During 2009, new estimates for landfill gas recovery were calculated and the results show landfill gas recovery is being overestimated. Once these estimates are peer reviewed, they will be included in the inventory. It is anticipated this will be in the 2011 inventory submission.

8.2.3 Uncertainties and time-series consistency

The overall estimated level of uncertainty is estimated at ±20 per cent. This level of uncertainty is the same as the 2008 inventory submission, but an improvement on prior submissions. The improvement was due to the utilisation of the IPCC (2006c) spreadsheet model, the 2002 Landfill Audit and Review, and an assessment of comparability between data sources as performed in Waste Not Consulting (2006). Due to the unknown level of

[12] The 10 per cent of solid waste not disposed to 'managed' solid waste disposal sites went to sites that fell outside the definition of 'managed', yet insufficient information is held about the sites to classify them as deep or shallow, unmanaged solid waste disposal sites, hence the 'unclassified' status. This submission assumed that, by 2010, all solid waste would be disposed to 'managed' solid waste disposal sites. This has led to a linearly increasing CH_4 correction factor.

uncertainty associated with the accuracy of some of the input data, it has not been possible to perform a statistical analysis to precisely determine uncertainty levels. The incomplete dataset makes statistical analysis impractical. Uncertainty in the data is primarily from uncertainty in changes to solid waste composition since 1990 and actual recovered CH_4, based on the 1997 *National Waste Data Report* (Ministry for the Environment, 1997), the *Waste Composition and Construction Waste Data* (Waste Not Consulting, 2006) and the *Landfill Methane Recovery Estimate* report (Waste Management New Zealand, 2005).

The New Zealand waste composition categories from the Waste Not Consulting (2006) report do not exactly match the categories required for the IPCC degradable organic carbon calculation. The major difference is that, in New Zealand's degradable organic carbon calculation, the putrescibles category includes food waste as well as garden waste. A separation into the IPCC categories was not feasible given the available data in the report by Waste Not Consulting (2006). The effect of this difference is zero, as the IPCC (2006c) default carbon contents are identical for non-food (15 per cent carbon content) and food categories (15 per cent carbon content).

8.2.4 Source-specific QA/QC and verification

Methane from solid waste disposal was identified as a key category (level and trend assessment) in 2008. In preparation for this inventory submission, the data for this category underwent Tier 1 quality checks.

Gross CH_4 estimates from solid waste emissions calculated using both the IPCC Tier 1 and Tier 2 approaches were compared. For the 2008 year, the IPCC (2006c) Tier 2 value of gross annual CH_4 generation was 131.9 Gg CH_4 and the IPCC (1996) Tier 1 value was 179.3 Gg CH_4. The assumptions used to calculate net CH_4 emissions from available activity data were the same for both Tier approaches.

8.2.5 Source-specific recalculations

The 2007 value for CH_4 from solid waste has been recalculated due to an updated population estimate from Statistics New Zealand.

8.2.6 Source-specific planned improvements

In 2009, the Ministry for the Environment obtained new estimates for landfill gas recovery. These estimates are currently going through the external peer review process as required by New Zealand's national system before acceptance into the inventory.

8.3 Wastewater handling (CRF 6B)

8.3.1 Description

In 2008, wastewater handling produced 390.0 Gg CO_2-e (23.3 per cent) of emissions from the waste sector. This was an increase of 29.6 Gg CO_2-e (8.2 per cent) from the 1990 level of 360.4 Gg CO_2-e.

Wastewater from almost every town in New Zealand with a population over 1,000 is collected and treated in community wastewater treatment plants. There are approximately 317 municipal wastewater treatment plants in New Zealand and approximately 50 government or privately owned treatment plants serving more than 100 people.

Although most of the treatment processes are aerobic, and therefore produce no CH_4, there are a significant number of plants that use partially anaerobic processes such as oxidation ponds or septic tanks. Small communities and individual rural dwellings are generally served by simple septic tanks followed by ground soakage trenches.

Large quantities of industrial wastewater are produced by New Zealand's primary industries. Most of the treatment is aerobic and any CH_4 from anaerobic treatment is flared. There are a number of anaerobic ponds that do not have CH_4 collection, particularly serving the meat-processing industry. These are the major sources of industrial wastewater CH_4 in New Zealand.

8.3.2 Methodological issues

Methane emissions from domestic wastewater treatment

Methane emissions from domestic wastewater handling have been calculated using a refinement of the IPCC method (IPCC, 2006c). The population using each municipal treatment plant in New Zealand has been determined (SCS Wetherill Environmental, 2002; Beca, 2007). Where industrial wastewater flows to a municipal wastewater treatment plant, an equivalent population for that industry has been calculated based on a biological oxygen demand (BOD) loading of 70 g per person per day.

Populations not served by municipal wastewater treatment plants have been estimated and their type of wastewater treatment assessed (SCS Wetherill Environmental, 2002; Beca, 2007). The plants have been assigned to one of nine typical treatment processes. A characteristic emissions factor for each treatment is calculated from the proportion of biological oxygen demand to the plant that is anaerobically degraded, multiplied by the CH_4 conversion factor (SCS Wetherill Environmental, 2002; Beca, 2007).

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 (IPCC, 1996) recommend using B_o of 0.25 CH_4/kg COD (chemical oxygen demand) or 0.6 kg CH_4/kg BOD. The IPCC biological oxygen demand value is based on a 2.5 scaling factor of chemical oxygen demand (IPCC, 2000). New Zealand has used these IPCC default factors in this inventory submission.

New Zealand uses a value of 0.026 kg BOD/1000 person/year, as it is equivalent to the IPCC high-range default value for the Oceania region of 70 g/person/day.

Methane removal via flaring or energy use is known to occur at eight plants in New Zealand. They all use anaerobic digesters as a component of the treatment. However, because these plants are categorised as "centralised aerobic treatment plant, well managed" according to the IPCC (2006c), the CH_4 emission factor is zero. The CH_4 generated in those plants is an abnormality by that classification, as all the CH_4 generated is flared or used for energy production. The net result is no CH_4 emissions and no CH_4 flared volumes are included in the equation.

Methane emissions from industrial wastewater treatment

The IPCC (2006c) default method is also used to calculate emissions from industrial wastewater treatment. Three industries were identified as having organic-rich wastewaters that are treated anaerobically. These are (in order of significance): meat processing, pulp and paper, and dairy processing. The meat industry is divided into kills and rendering, because the 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. The dairy industry predominantly uses aerobic treatment. There is only one remaining factory that uses anaerobic treatment. The wastewater is covered and the majority of the captured biogas (55 per cent CH_4) is used to operate the boilers. The remainder is flared.

For each industry, an estimate is made of the total industrial output in tonnes per year. The IPCC (2006c) default values for wastewater generated and chemical oxygen demand are used. The exception is for the pulp and paper industry where the chemical oxygen demand (COD)/t product is determined from industry figures of 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. For dairy processing, the IPCC (2006c) default method is followed.

Earlier submissions included estimates of CH_4 and N_2O from the wool scouring and beverage industries. There is no anaerobic treatment of wastewater from these industries now (Beca, 2007).

Methane emissions from sludge

The organic solids produced from wastewater treatment are known as sludge. In New Zealand, the sludge from wastewater treatment plants is typically sent to landfills.

In large treatment plants in New Zealand, sludge is handled anaerobically and the CH_4 is almost always flared or used.[13] 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, 2007).

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.

Nitrous oxide emissions from domestic wastewater treatment

New Zealand's calculation uses the IPCC (2006c) method. The IPCC method calculates nitrogen production based on the average per capita protein intake. A value of 36.135 kg N/person/year is assumed for 1990 to 2008. 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 2008. Default IPCC (2006c) values are used for the fraction of nitrogen in protein, fraction of non-consumption protein, fraction of industrial and commercial co-discharged protein, and nitrogen removed with sludge. The IPCC (2006c) default emission factor of 0.005 kg N_2O-N/kg N is used.

[13] An exception is the Christchurch sewage treatment plant that uses anaerobic lagoons for sludge treatment. Based on volatile solids reduction measurements in the lagoons, the plant estimates CH_4 production of 0.46 Gg/year plus an additional 0.16 Gg/year from unburned CH_4 from the digester-gas fuelled engines.

Nitrous oxide emissions from industrial wastewater treatment

The IPCC (2006c) state that, compared with domestic wastewater, the N_2O emissions from industrial wastewater are insignificant and can therefore be ignored. However, this statement 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.

The IPCC (2006c) do not have a method for calculating N_2O emissions from industrial wastewater. Emissions are calculated using an emissions 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. 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.

8.3.3 Uncertainties and time-series consistency

Methane 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 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 –25 per cent to +40 per cent (SCS Wetherill Environmental, 2002; Beca, 2007).

Methane from industrial wastewater

Total CH_4 production from industrial wastewater has an estimated accuracy of ±40 per cent based on assessed levels of uncertainty in the input data (SCS Wetherill Environmental, 2002, Beca 2007).

Nitrous oxide from 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) meaning that the estimates have only order of magnitude accuracy.

8.3.4 Source-specific QA/QC and verification

No specific quality checks were carried out for this category.

8.3.5 Source-specific recalculations

The 2007 value for CH_4 from domestic wastewater handling has been recalculated due to an updated population estimate from Statistics New Zealand.

8.3.6 Source-specific planned improvements

No improvements are planned for this category.

8.4 Waste incineration (CRF 6C)

8.4.1 Description

In 2008, 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.

There is no incineration of municipal waste in New Zealand. The only incineration is for small specific waste streams, including medical, quarantine and hazardous wastes. The practice of incinerating these waste streams has declined since the early 1990s due to environmental regulations and alternative technologies, primarily improved sterilisation techniques. Consents under New Zealand's Resource Management Act 1991 control non-greenhouse gas emissions from these incinerators.

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 Methodology

The 2006 IPCC guidelines (IPCC, 2006c) are used to calculate emissions from the incineration of waste as the revised 1996 IPCC guidelines (IPCC, 1996) do not contain methods for estimating emissions from waste incineration. New Zealand considers the 2006 IPCC guidelines (IPCC, 2006) contain the most appropriate and current methodologies for estimating emissions from waste incineration.

Incineration devices that do not control combustion air to maintain adequate temperature, and do not provide sufficient residence time for complete combustion, are considered as open burning systems (IPCC, 2006c). This excluded many small facilities that may have burned plastics and other mixed waste, such as at schools.

Only CO_2 resulting from burning of carbon in waste that is fossil in origin is included under the IPCC methodology, such as in plastics, synthetic textiles, rubber, liquid, solvents and waste oil. Biogenic CO_2, such as that from paper, cardboard and food, is excluded in accordance with the 2006 IPCC guidelines (IPCC, 2006c). Also excluded are emissions from waste to energy incineration facilities, as they are reported within the energy sector of the inventory.

Default compositional values from the IPCC 2006 guidelines are used to estimate the fossil fuel-derived carbon. These values are 27.5 per cent for hazardous waste (being the mean of the recommended range) and 25 per cent for clinical waste.

Many incinerators are quarantine waste incinerators. The 2006 IPCC guidelines (IPCC, 2006c) do not have a default category for quarantine incinerators. Only three default classifications are available: clinical waste, hazardous waste, or sewage sludge. None of these categories appropriately represent New Zealand quarantine waste that 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, 2007).

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.

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 the energy handbook, so this value was used, although it is noted this is inconsistent with the IPCC approach that uses net values.

The Japanese emission factor is used for sewage sludge. The IPCC 2006 guidelines note that the most detailed observations of CH_4 emissions from waste incineration have been made in Japan (Volume 5, section 5.4.2).

8.4.3 Uncertainties and time-series consistency

The measurement of uncertainty in the data collected from each individual site was difficult to quantify. For most sites, tonnes per year of waste incinerated was obtained from file information or this was calculated from a mass burn rate (kg per hour) and assumed operating hours on an annual basis. Estimates based on consented limits are likely to be overestimates of the actual waste burnt.

The annual rates were projected for the corresponding number of years of operation. This provided an estimated total amount of wet waste incinerated from 1990 to 2008.

As per the recommendation for uncertainties relating to activity data (IPCC, 2006, Volume 5, section 5.7.2), the conservative estimated uncertainty for the amount of wet waste incinerated is ±10 per cent. The estimated value in the 2006 IPCC guidelines is ±5 per cent. This uncertainty has increased to ±10 per cent due to the lack of detailed data. 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, 2007).

The data collected for the composition of waste is not detailed. Therefore, as per the recommendation for uncertainties relating to emission factors (IPCC, 2006 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, 2006 Volume 5, section 5.7.1); hence, the default estimated uncertainty for default CH_4 and N_2O factors is ±100 per cent (SKM, 2007).

8.4.4 Source-specific QA/QC and verification

All data collected was from reliable sources and all default emission factors for emissions calculations were extracted from the 2006 IPCC guidelines. All calculations were externally and internally reviewed. Hand calculations were used to check calculations. Limited information was provided by some individual sites. This meant activity data had to be interpolated and extrapolated from the available data. This could have led to inaccuracies in the quantification of the total waste incinerated annually. There is generally no detailed information about the actual composition of the waste incinerated, only the consented types of waste allowed.

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 2009 submission. Further detail on the recalculations is provided in chapters 3 to 8.

Each year the inventory is updated (existing activity data and/or emissions' factors may be improved) and extended (each inventory submission includes a new inventory year). The inventory may also be expanded to include emissions from additional sources if a new source has been identified within the context of the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003). Recalculations may also occur if activity data and emission factors have become available for sources that were previously reported as NE ('not estimated') because of insufficient data.

The use of improved methodologies and activity data in any sector will result in recalculation of the whole time series from 1990 to the current inventory. This means estimates of emissions in a given year may differ from emissions reported in the previous inventory submission. There may be exemptions to recalculating the entire time series and, where this has occurred, explanations are provided.

There are no recalculations included for Article 3.3 under the Kyoto Protocol as this is the first submission that includes the tables.

10.1 Explanations and justifications for recalculations

10.1.1 Energy

In this submission, the improvements made to the energy sector are summarised below.

All fuel combustion categories

- Revisions in liquid, solid and gaseous fuels data sources have led to small activity data revisions (sections 3.3.1, 3.3.2, 3.3.3 and 3.3.4).
- Emission factors for liquid fuels and gaseous fuels have been improved (sections 3.3.1, 3.3.2 and 3.3.3).

Fuel combustion: energy industries

- Activity data for gaseous fuels reported for the public electricity and heat production subcategory is now annual data rather than quarterly data (section 3.3.1).
- Activity data for biomass fuels reported for the public electricity and heat production subcategory is now reported back to 1990 (section 3.3.1).
- Activity data for gaseous fuels reported for the manufacture of solid fuels and other energy industries subcategory now includes data direct from the gas fields (section 3.3.1).

Fuel combustion: manufacture of solid fuels and other energy industries

- The manufacturing industries and construction category has been further disaggregated from 2000 onwards (section 3.3.2).
- Activity data for gaseous fuels used in co-generation is now reported back to 1990 (section 3.3.2).
- Electricity and co-generation biomass data is now based on quarterly data from companies involved with combusting wood residues to provide process heat in the wood processing industry (ie, kiln drying) (section 3.3.2).

Fuel combustion: other sectors

- Improved commercial biomass data is now available from the Cogeneration Association of New Zealand. Residential biomass data is now based on New Zealand census results and wood consumption from a household energy end-use project (BRANZ, 2002) (section 3.3.4).
- Activity data for liquid fuels in the other sectors category has been further disaggregated. Different emission factors applied to each type of liquid fuel have also been used (section 3.3.4).
- Stationary and mobile splits for the agriculture subcategory have been improved by using the Statistics New Zealand's *Energy Use Survey: Primary industries 2008* (section 3.3.4).

Fugitive emissions from fuels: oil and natural gas

- Venting, flaring and own-use activity data from gas/oil field operators has been revised due to the correction of manual entry errors in the data set (section 3.4.2).
- Geothermal activity data has been revised due to the removal of the geothermal field 'Tarawera' (section 3.4.2).
- Activity data of crude oil production in New Zealand (provided by the New Zealand Refining Company) has been revised (section 3.4.2).
- Transmission and distribution data has been disaggregated. Activity data has also been revised as, previously, the total amount of gas entering the pipelines was reported where now the actual amount lost in terajoules is instead reported (section 3.4.2).

10.1.2 Industrial processes

In this submission, the improvements made to the industrial processes sector are summarised below.

Mineral products (section 4.2.5)

- The IPCC (2000) default factor for cement-kiln dust correction factor has been applied to the whole time series for one cement company.
- A data correction was made by one lime company for the 2007 calendar year.
- Emissions from soda ash use are now included in this subcategory because of confidentiality concerns.

Chemical industry (section 4.3.5)

- Daily emissions factor data for the three main gas fields in New Zealand is now used to derive a weighted average emission factor to estimate ammonia emissions for the whole time series.
- Corrections were made to the hydrogen dataset by the Ministry of Economic Developing during the improvements made to their database during 2009.
- All methanol emission estimates are now reported in the energy sector because of confidentiality concerns.

Metal production (section 4.4.5)

- The accuracy, completeness and consistency of the emission estimates for steel production for Pacific Steel have improved for 2000–2007 due to a revision of assumptions for the scope and boundary of the emission source.
- The accuracy, completeness and consistency of the entire time series for carbon dioxide emission from aluminium production have been largely improved due to revised input data.
- The accuracy and consistency of the entire time series for perfluorocarbons from aluminium production have largely improved due to revised methodologies to earlier years, improved input data and corrections made to database errors at the aluminium plant.

Consumption of halocarbons and SF_6 (section 4.7.5)

- The accuracy of emission estimates from halocarbon consumption has improved largely due to revised supply assumptions for the stationary refrigeration and air conditioning and mobile air conditioning categories.
- The accuracy of the entire time series of SF_6 emission estimates has largely improved due to revised assumptions due to new information.
- There has been a review of the notation keys for consumption of halocarbons and sulphur hexafluoride.

10.1.3 Solvent and other product use

There have been no recalculations made to this sector.

10.1.4 Agriculture

In this submission, the improvements made to the agriculture sector are summarised below.

- Emissions from dairy cattle are now calculated using regional data rather than national averages.
- Alpacas have a small population in New Zealand but are increasing in number and are therefore now included.
- Although cropping makes up a very small part of New Zealand's emissions from agriculture, potatoes are an important crop and therefore have been included in this submission.
- New Zealand has adopted a country-specific $Frac_{GASM}$ value of 0.1.

All activity data reported in the agriculture sector has been updated with the latest available data (Statistics New Zealand table builder and Infoshare database, 2008).

10.1.5 Land use, land-use change and forestry (LULUCF)

With the introduction of the Land Use and Carbon Analysis System (LUCAS) in 2008, New Zealand has recalculated the LULUCF emission estimates for the entire time series.

The main reasons for the recalculation has been the improved mapping of land use and land-use change since 1990 and the inclusion of emissions resulting from land-use change from forest land to grassland. Improved New Zealand-specific methods, activity data and emission factors have also improved the accuracy, completeness and transparency of the estimates. The recalculations are summarised below.

- Improved activity data as a result of new mapping of land use at 1990 and 2008 (section 7.1.2).
- Changes in the land-use subcategories to improve the alignment between New Zealand's forest land, grassland and wetlands categories, the IPCC land-use categories and the Kyoto Protocol forest definition. Previously, New Zealand had reported land-cover categories (section 7.1.2, Table 7.1.2.6).
- Improved measurement of deforestation up until 1 January 2008 based on land-use change mapping rather than relying as previously on a range of information sources.
- Land-use changes are now being reported in the 'land converted to' category where a land-use change has occurred since 1990. Previously, some land-use changes were being reported in land remaining land categories.
- Improved modelling of soil carbon stock based on a country-specific model and data (section 7.1.2).
- Updated liming data for 2007. In the previous submission, this data was still provisional and was based on a three-year average (section 7.1.2).
- The use of conversion-specific biomass densities for biomass burning (section 7.1.2).
- Improved accuracy of biomass carbon stocks in land use before conversion and annual growth in biomass for land converted to another land use (section 7.1.2, Tables 7.1.2.3 and 7.1.2.4).
- An updated natural forest emission factor based on an analysis of the plot network established as part of LUCAS between 2002 and 2007 (section 7.2.1).
- The use of an age-based and area-adjusted carbon yield table for the post-1989 forest category (section 7.2.5).
- Recalculated figures for cropland and grassland to include both above- and below-ground biomass where IPCC defaults exist (section 7.1.2).
- A modified age-class distribution used for pre-1990 planted forest and post-1989 forest (section 7.2.5).
- Improved calculation of emissions resulting from changes between land-use subcategories, and from multiple land-use changes between 1990 and 2008. The new LUCAS Data Management System means that New Zealand can now consistently estimate annual changes in carbon and non-carbon emissions associated with annual land-use changes for the five carbon pools and using a master set of New Zealand-specific and IPCC default emission factors (section 7.1.2).

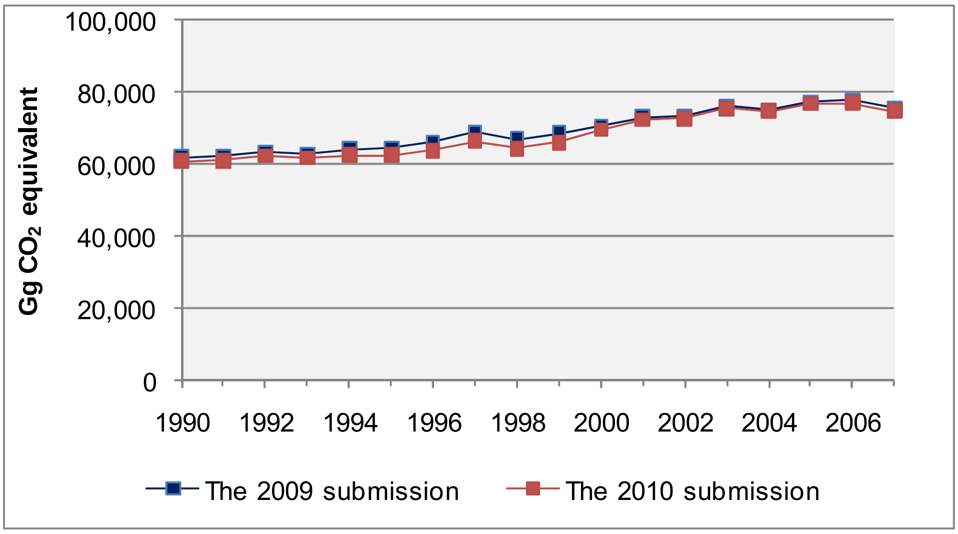
10.1.6 Waste

The only recalculation made to the waste sector was the 2007 value for methane from solid waste and domestic wastewater handling due to an updated population estimate from Statistics New Zealand.

10.2 Implications for emission levels

The overall effect of all recalculations in the 2010 inventory submission is shown in Figure 10.3.2. There was a 1.7 per cent (1,079.2 Gg CO_2-e) decrease in total emissions for the base year, 1990, and a 1.1 cent (831.4 Gg CO_2-e) decrease in total emissions for the 2007 year.

Figure 10.2.1 Effect of recalculations on New Zealand's total greenhouse gas emissions from 1990 to 2007



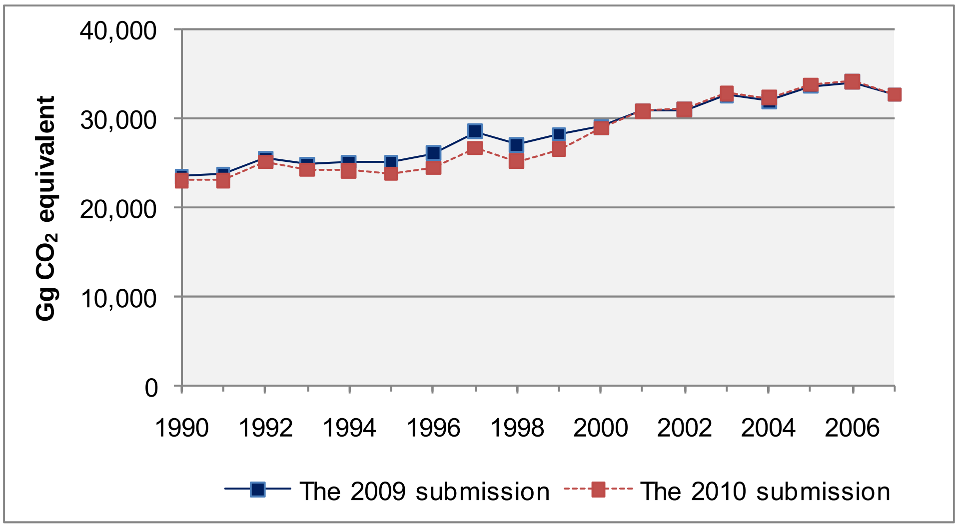
10.3 Implications for emission trends

In New Zealand's 2009 inventory submission (1990–2007), emissions were 22.1 per cent above the level reported in 1990. As a result of the recalculations in the 2010 inventory submission, total emissions for 2007 were 22.9 per cent above 1990. Changes in trends for individual sectors (excluding the solvent other product use sector) are discussed in the following sections. The solvent and other product use sector is not included because emissions are negligible throughout the time series.

Energy sector

The recalculations made within the energy sector (Figure 10.3.2) are summarised in section 10.1.1. The recalculations have resulted in a 410.1 Gg CO_2-e decrease in energy emissions for 1990 and a 0.5 Gg CO_2-e increase in energy emissions in 2007 (Figure 10.3.1). These recalculations were responsible for a 0.7 per cent decrease of the 1990 recalculation in total emissions and a 0.001 per cent increase of the recalculation for the 2007 year.

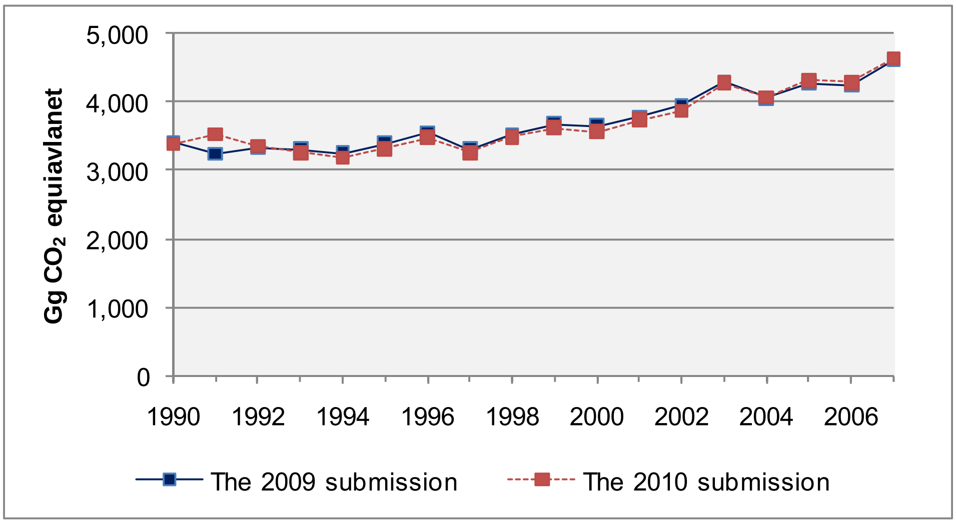
Figure 10.3.1 Effect of recalculations on New Zealand's energy sector from 1990 to 2007



Industrial processes

The recalculations made within the industrial processes sector (Figure 10.3.2) are summarised in section 10.1.2. The recalculations have resulted in a 23.4 Gg CO_2-e decrease in industrial processes emissions for 1990 and a 34.7 Gg CO_2-e increase in industrial processes emissions in 2007. These recalculations were responsible for a 0.01 per cent decrease of the 1990 recalculation in total emissions and a 0.1 per cent increase of the recalculation for the 2007 year.

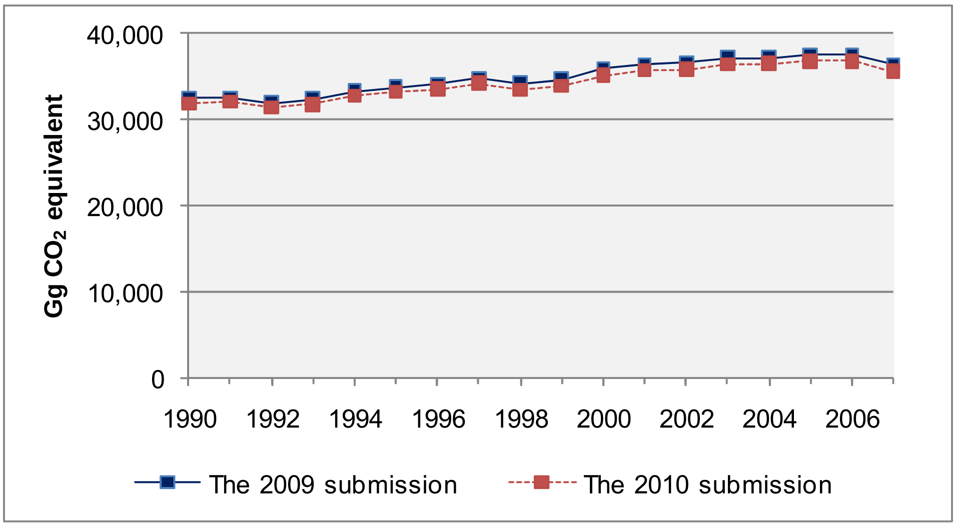
Figure 10.3.2 Effect of recalculations on New Zealand's industrial processes sector from 1990 to 2007



Agriculture

The recalculations made within the agriculture sector (Figure 10.3.3) are summarised in section 10.1.2. There was a 645.7 Gg CO_2-e decrease in agriculture emissions in 1990 and an 866.6 Gg CO_2-e decrease in agriculture emissions in 2007. These changes were responsible for a 1.0 per cent decrease of the 1990 recalculation in total emissions and a 1.1 per cent decrease of the recalculation for the 2007 year.

Figure 10.3.3 Effect of recalculations on New Zealand's agriculture sector from 1990 to 2007



LULUCF

The recalculations made within the LULUCF sector (Figure 10.3.4) are explained in section 10.1.5. The recalculations have resulted in a 12,927.8 Gg CO_2-e decrease in net LULUCF emissions in 1990 and a 7,015.3 Gg CO_2-e increase to net LULUCF emissions in 2007.

The recalculations made to net removals from the LULUCF sector are largely a result of changes to the assumptions used to estimate emissions and removals from the forest land and grassland categories. The effect of recalculations to the forest land and grassland categories is shown in Figures 10.3.5 and 10.3.6.

Figure 10.3.4 Effect of recalculations on net removals from New Zealand's LULUCF sector from 1990 to 2007

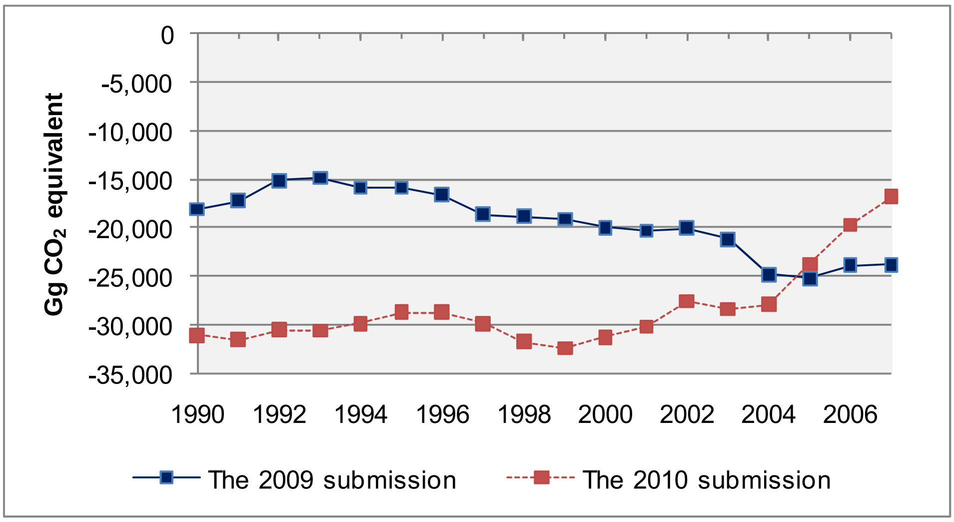


Figure 10.3.5 Effect of recalculations on net removals from New Zealand's forest land category from 1990 to 2007

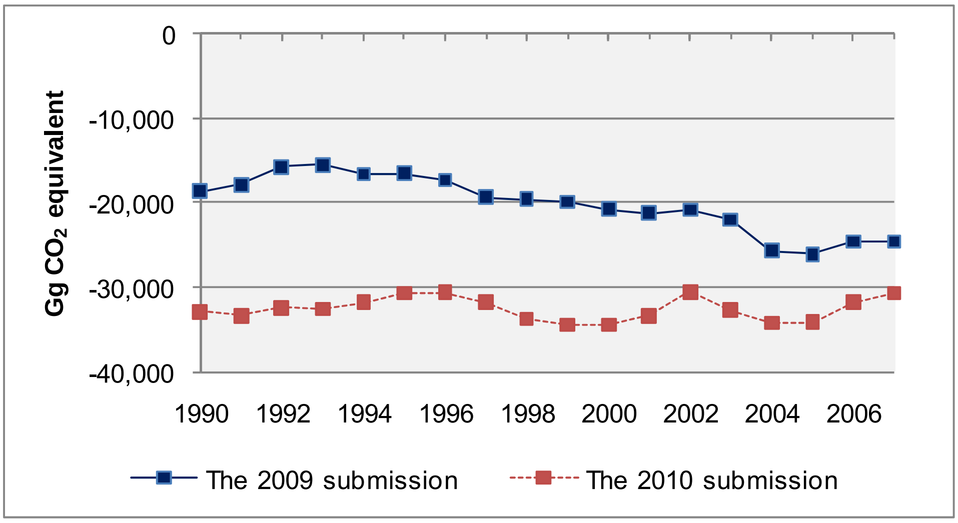
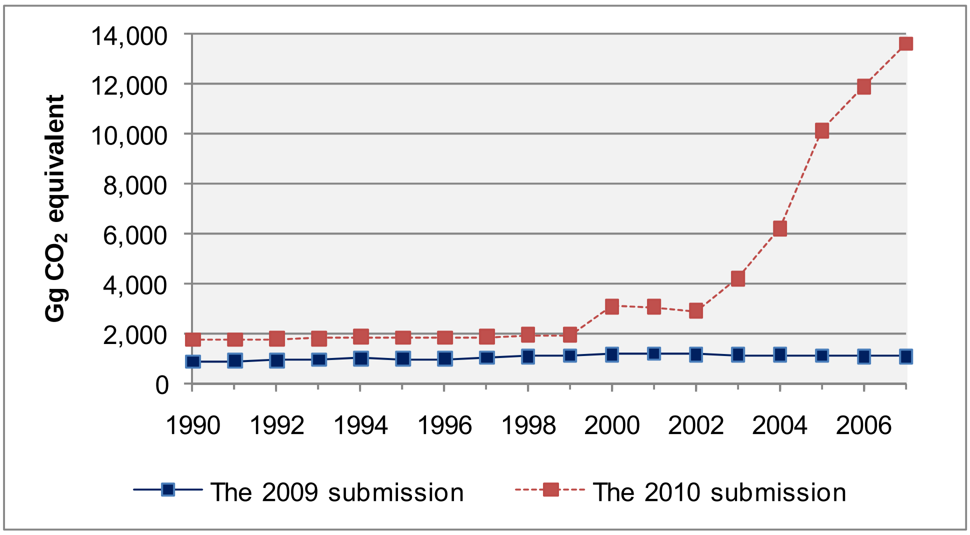


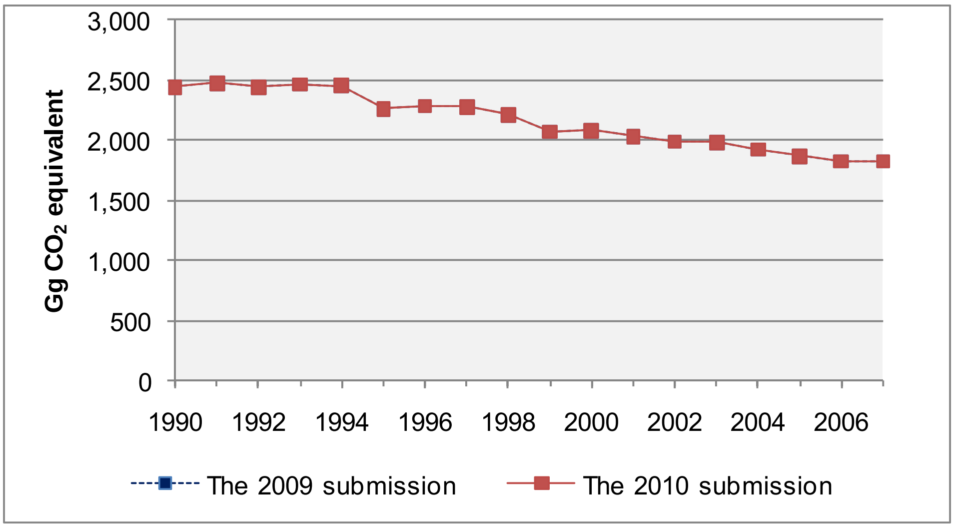
Figure 10.3.6 Effect of recalculations on net removals from New Zealand's grassland category from 1990 to 2007



Waste

The recalculations made within the waste sector (Figure 10.3.7) are explained in section 10.1.6. There were no recalculations made to the waste sector for the base year and for 2007.

Figure 10.3.7 Effect of recalculations on New Zealand's waste sector from 1990 to 2007



10.4 Recalculations in response to the review process and planned improvements

10.4.1 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. The recommendations made in UNFCCC (2009) and New Zealand's response are included below in Table 10.4.1. There were no recommendations made for the agriculture sector.

Table 10.4.1 New Zealand's response to expert review team recommendations from the individual review of the greenhouse gas inventories of New Zealand submitted 2007 and 2008

Year of review	Sector	Expert review team recommendation	New Zealand response
2008	General	Provide more information in the national inventory report on how recalculations affect the time series for categories and a justification of how recalculations have improved the accuracy of emission estimates, time-series consistency and completeness of the inventory.	Implemented. Further information has been included in the uncertainties, time-series consistency and category-specific recalculations sections of the report.
2008	Energy: sector-wide	Data produced externally should be subject to procedures, including quality-assurance and quality-control procedures, in accordance with the IPCC (2000).	Partially implemented. Further documentation and explanatory background material has been included in this inventory submission, in particular, fugitive emissions from oil and gas. New Zealand will continue to work on this.

Year of review	Sector	Expert review team recommendation	New Zealand response
2008	Energy: sector-wide	Consult with Statistics New Zealand in order to ensure the proper aggregation of detailed data from the statistical office into the subcategories required in the common reporting format tables.	Implemented. This inventory submission includes disaggregated data under the manufacturing industries and construction category post-2000. Some of the notation keys in the common reporting format tables have also been updated where relevant.
2008	Energy: comparison of the reference approach with the sectoral approach and international statistics	Update the references for gaseous fuels and provide an appropriate explanation for the NZEIH abbreviation used in the national inventory report.	Implemented. These references have now been updated and explained.
2008	Energy: comparison of the reference approach with the sectoral approach and international statistics	Provide a general explanation of the differences for solid, liquid and gaseous fuels and, in particular, address the issue of negative differences in future submissions. Reconcile the methods used in estimating activity data.	Ongoing. New Zealand is investigating why large differences occur between the reference and sectoral approaches for some years. This mainly involves investigating historical data and statistical differences in the supply and demand tables.
2008	Energy: feedstocks and non-energy use of fuels	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 in order to avoid double counting or the possible underestimation of emissions from fuel combustion.	Implemented. This inventory submission includes energy flow diagrams for liquid fuels, solid fuels and natural gas.
2008	Energy: country-specific issues	Improve transparency by providing a description of the geothermal emission estimation methodology in the national inventory report.	Ongoing. New Zealand has started investigating the discrepancies between activity data, CO_2 and CH_4 emissions for some years, particularly the late 1990s.
2008	Energy: stationary combustion liquid fuels – CO_2	Review the allocation, reallocate the data into appropriate mobile combustion categories, if necessary, and perform the corresponding recalculations.	Implemented. Using the Statistics New Zealand's *Energy Use Survey: Primary industries 2008*, New Zealand was able to calculate more accurate and detailed mobile/stationary splits. These splits have now been implemented into the system along with documentation of how these splits were arrived at.
2008	Energy: stationary combustion solid fuels – CO_2	Address the discrepancy between the emission estimates and the methods described in the national inventory report and, in order to improve transparency, provide appropriate background information on carbon content of coal used in different sectors.	Implemented. Carbon dioxide emission factors for coal-use are now consistently applied.

Year of review	Sector	Expert review team recommendation	New Zealand response
2008	Energy: stationary combustion gaseous fuels – CO_2	Provide full carbon flow from Maui and Kapuni gas fields through mixing stations and crude methanol production to treated natural gas available to the end consumers and carbon stored as feedstock in future national inventory report, along with the appropriate corresponding activity data.	Implemented. Section 3.3.1 now states that the CO_2 that is released is included in the manufacturing of solid fuels and other energy industries subcategory. An energy flow diagram for natural gas is also included in this inventory submission.
2008	Energy: stationary combustion gaseous fuels – CO_2	Improve transparency of emission estimates and address this issue in future submissions by providing a carbon flow of natural gas produced, stored as feedstock and used for combustion.	Implemented. This inventory submission includes an energy flow diagram for liquid fuels, solid fuels and natural gas. An updated balance table is also provided in this inventory submission, which includes an updated non-energy use category.
2008	Industrial processes: sector-wide	Implement source-specific quality-assurance and quality-control activities for the largest key categories.	Implemented. Six of New Zealand's industrial process companies were visited by members of the national inventory team to assess the quality-assurance and control procedures employed by the companies.
2007 and 2008	Industrial processes: sector-wide	Provide more information on how recalculations affect the time series of categories and a justification of how they improve the accuracy of the emissions, time-series consistency or completeness.	Implemented. New Zealand provided more information for recalculation explanations in the 2009 submission. The development of recalculation forms has further enabled the transparency for this submission.
2008	Industrial processes: sector-wide	Provide consistent supplementary information on the corresponding sectoral part of the national inventory report in the common reporting format feedstock Table 1A(d) and its documentation box.	Implemented for the 2009 submission.
2008	Industrial processes: sector-wide	Reassess the uncertainty estimates for the activity data and provide a more detailed and comprehensive description of the uncertainty estimates used for each category.	Ongoing.
2008	Industrial processes: cement production	Improve transparency by including in the national inventory report the tier of the method used to calculate emissions for each year, information on the selected cement-kiln dust correction factor values and its trends, a description of the quality control performed by the plants/inventory agency on reported data as well as the conclusion of the quality-control procedure performed during the Party's review of the emission factor.	Partially implemented. New Zealand has provided information on the tier used and the selected cement-kiln dust correction factor. As the cement-kiln dust correction factor is the IPCC (2000) default, New Zealand has not provided information on its trend. New Zealand will work with the cement companies to include text describing their quality-control procedures for future inventory submissions.

Year of review	Sector	Expert review team recommendation	New Zealand response
2008	Industrial processes: ammonia production	Improve, in particular, the section in the national inventory report on emissions and storage of the feedstocks and other non-energy use of fuels as discussed in the energy sector of this report and explain or resolve the apparent discrepancies observed during the review.	Implemented.
2008	Industrial processes: iron and steel production CO_2	Improve the description of the category in the national inventory report, including the rationale for the selection of the emission factors and carbon contents, and provide information on which flux elements are included in the mass balance calculation, and where and how the resulting emissions are reported in the common reporting format tables.	Partially implemented. In this submission, New Zealand has recalculated emissions from 2000 onwards for Pacific Steel and has included a description explaining the method used. New Zealand will continue to work with the steel companies to provide text regarding the rationale for the parameters.
2008	Industrial processes: aluminium production CO_2	Improve transparency by providing in the national inventory report a more detailed description of methods, including the formulas used to calculate the emissions, and the rationale for the selection of the emission factors and carbon contents.	Partially implemented. In this submission, New Zealand has provided more information on the method used to calculate carbon dioxide emissions. New Zealand will continue working with NZAS to further improve transparency in future submissions.
2008	Industrial processes: aluminium production PFCs	Provide information on inter-annual variations and how emission factors for the early 1990s were determined and what tiers were used for what years, in future submissions. Further check that calculations were performed correctly.	Implemented. New Zealand tabled explanations for inter-annual variations in the 2009 submission. In this submission, New Zealand has recalculated the time series and has provided information on how estimates were derived. The ratio of the PFCs is now consistent with the improved estimates.
2008	Industrial processes: consumption of halocarbons and SF_6 and HFCs	Provide more information in the national inventory report on the emission factors and leakage rates used, particularly for the largest sources (eg, commercial refrigeration and mobile air conditioning) in future submissions.	Ongoing.
2008	Solvent and other product use: sector-wide	Change the notation keys for CO_2 to not estimated and review the notation keys for N_2O from solvent and other product use.	Implemented. New Zealand changed the notation keys for CO_2, SO_2, CO and NO_X to NE (not estimated) in the 2009 submission.
2008	LULUCF: sector-wide	Prepare and implement quality-assurance and quality-control procedures for all reported land-use categories in future submissions.	Implemented. Quality-assurance and quality-control plans have been developed for all areas of data collection. IPCC (2000) Tier 1 checks have been carried out on all default factors used for calculating biomass carbon stocks in land-use categories before conversion, and annual growth in biomass for land converted to another land use.

Year of review	Sector	Expert review team recommendation	New Zealand response
2008	LULUCF: sector-wide	Use a minimum of 20 years as the conversion period in order to distinguish the subcategories in LUCAS.	Partially implemented. New Zealand is using a conversion period of 28 years where the data is available. Otherwise, New Zealand has assumed that land use was constant at 1990 where data on land use prior to 1990 is unavailable. Twenty-eight years is the maturity period New Zealand has chosen for its lands to reach a steady state of equilibrium, and is the average age that planted forests are harvested (Ministry of Agriculture and Forestry, 2008a).
2008	LULUCF: sector-wide	Review land-area and emission estimates, particularly for forest conversion, as emissions may be being underestimated.	Implemented. For natural and pre-1990 planted forest categories, the area of deforestation between 1990 and 2007 has been provided by new land-use mapping. Information on deforestation in 2008 and on the deforestation of post-1989 forests between 1990 and 2007 is from the *Deforestation Intentions Survey* commissioned by the Ministry of Agriculture and Forestry. The data has been compared with other publically available information on deforestation (from companies' annual reports) and is comparable.
2008	LULUCF: sector-wide	Review the method for estimating carbon stock changes in soils in future submissions as changes in mineral soils from land conversion post-1990 are lagged but those from pre-1990 are not.	Not implemented. The lack of data on land-use change prior to 1990 has restricted New Zealand's ability to progress this issue. Additional work to look at what data on land-use change prior to 1990 is available is under way to help New Zealand fulfil this reporting requirement. A commitment has been made to go back 28 years prior to 1990 and establish land-use change from 31 December 1961. This will be implemented in time for the 2011 national inventory report.
2008	LULUCF: forest land remaining forest land CO_2	Collect data for, and estimate the changes in, carbon stock in the mineral soils of plantations, and reconsider the parameter for dead organic matter in future submissions, in particular, in the New Zealand LUCAS.	Implemented. In this submission, the carbon stock change in mineral soils has been estimated, and the estimate of dead organic matter has been recalculated. Data collection on the amount of dead organic matter in forest land continues.
2008	LULUCF: land converted to forest land CO_2	With the exception of low-producing grassland converted to forest land, carbon stock changes for land converted to forest are inputted as included elsewhere in the common reporting format Table 5.A. The changes were incorrectly reported in forest land remaining forest land.	Partially implemented. As a result of having additional data on land use as at the commencement of 1990, in this submission all land-use changes as at the start of 2008 are being reported in 'land converted to' categories for a minimum of 18 years (1990–2008). Additional

Year of review	Sector	Expert review team recommendation	New Zealand response
			information about land use prior to 1990 is available and has been incorporated where it is available, eg, for pre-1990 planted forest. Additional work to investigate what data on land-use change prior to 1990 is available is under way to help New Zealand fulfil this reporting requirement.
2008	LULUCF: cropland remaining cropland CO_2	The expert review team recommends that New Zealand use country-specific parameters, include carbon loss from perennial crops, and estimate carbon stock changes in soils, particularly in cultivated organic soils, in future submissions.	Partially implemented. In this submission, New Zealand is accounting for both carbon loss and gain in land converted to and from perennial cropland. Tier 1 defaults are used for these estimates where a default is available. Where no Tier 1 factor is available, for example, for dead organic matter (GPG-LULUCF, section 3.3.1.1.1, IPCC, 2003), changes in this pool are reported as not estimated. Carbon stock changes in soils are estimated in this submission using the Soils Carbon Monitoring System.
2008	LULUCF: N_2O emissions associated with land-use conversion to cropland N_2O (non-key category)	That the Party use the same country-specific emission factor for N_2O as used in the agriculture sector for estimating N_2O emissions associated with land-use conversion to cropland.	Implemented. This has been done for this submission.
2008	Waste: solid waste disposal on land CH_4	Either revise the methods used to estimate the net emissions of methane, or provide more detailed justification for the current method and the reported volume of recovered methane demonstrating that it is not overestimated.	In 2009, New Zealand obtained new estimates for landfill gas recovery. These estimates are currently going through the external peer-review process as required by New Zealand's national system before acceptance into the inventory.
2008	Waste: industrial wastewater CH_4 and N_2O	Estimate and report emissions from wine industry (CH_4 and N_2O) and wool scouring (N_2O), or provide sufficient information to indicate that the emissions from these sources have become negligible by 2006.	There is no anaerobic treatment of wastewater from these industries now (Beca, 2007).

10.4.2 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

For 2008, net removals from land subject to afforestation, reforestation and deforestation were –14,416.8 Gg CO_2-e (Table 11.1.1). This value includes removals from the growth of post-1989 forest, and emissions from the conversion of land to post-1989 forest, harvesting of forests planted on non-forest land after 31 December 1989, deforestation of all forest, and from disturbance associated with land-use conversion to cropland, liming and biomass burning. These net emissions and removals are reported by the North and South Islands for the five carbon pools (Figure 11.1.1). Afforestation, reforestation and deforestation are key categories (Table 1.5.4).

For reporting under Article 3.3 of the Kyoto Protocol, New Zealand has chosen to categorise its forests into three subcategories: natural forest; pre-1990 planted forest and post-1989 forest. These three subcategories are also used for reporting on the land use, land-use change and forestry (LULUCF) sector under the Climate Change Convention (chapter 7). All forest land that existed at 31 December 1989 is 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 year of the commitment period.

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 2008

Source	Gross area (ha) 1990–2008	Net area (ha) 2008	Emissions in 2008 (Gg CO_2-e)
Afforestation/reforestation	580,524	568,775	–17,327.4
Forest land not harvested since the beginning of the commitment period	–	568,274	–17,395.1
Forest land harvested since the beginning of the commitment period	–	500	67.8
Deforestation	96,355	4,818	2,910.6
Total	–	–	**–14,416.8**

Notes: Afforestation/reforestation refers to new forest established since 1 January 1990. The gross afforestation/reforestation area includes 11,749 hectares of land in transition to post-1989 forest that has subsequently been deforested. The net afforestation/reforestation area includes 1,000 hectares of new forest plantings in 2008. The 2008 areas are as at 31 December 2008. Columns may not total due to rounding.

Between 1990 and 2008, 580,524 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities – an average of 31,000 hectares per year (refer to Figure 7.2.1.1). Deforestation in 2008 of all subcategories of forest land (post-1989, pre-1990 planted and natural forest) is estimated at 4,818 hectares (equivalent to emissions of 2,910.6 Gg CO_2-e).

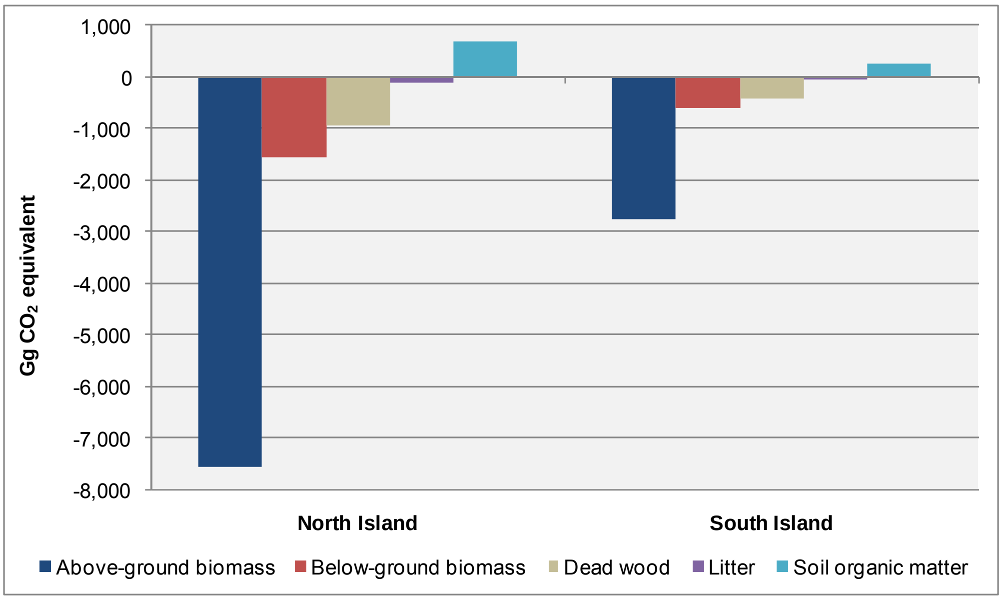
A detailed analysis of 2008 emissions and removals shows:

- the total net CO_2 removals based on carbon stock change were –14,417.3 Gg CO_2
- nitrous oxide emissions from disturbance associated with land-use conversion to cropland were 0.001 Gg N_2O (0.3 Gg CO_2-e)

- carbon dioxide emissions from lime application of deforested land are estimated at 0.7 Gg CO_2
- emissions from the burning of biomass on afforestation/reforestation land were 0.016 Gg CH_4 (0.3 Gg CO_2-e) and 0.001 Gg N_2O (0.02 Gg CO_2-e).

There is no reduction in the carbon stock made for 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.

Figure 11.1.1 New Zealand's net CO_2 emissions and removals associated with afforestation, reforestation and deforestation activities in 2008



Note: Emissions and removals shown are the result of changes in carbon stock only and do not include non-CO_2 emissions.

New Zealand is not reporting on:

- liming of afforested and reforested land as this activity does not occur
- non-carbon dioxide emissions from controlled burning on deforested land as 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 fertiliser use on deforested land, as these are reported in the agriculture sector.

Afforestation and reforestation

Between 1990 and 2008, it is estimated that 580,524 hectares of new forest (post-1989 forest) was established as a result of afforestation and reforestation activities. The net area of post-1989 forest as at 31 December 2008 was 568,775 hectares. The net area is the total area of new forest minus deforestation since 1 January 1990.

Deforestation of all forest types in 2008 is estimated at 4,818 hectares (equivalent to emissions of 2,909.8 Gg CO_2 from carbon stock change). This is a decrease from the 18,151 hectares (13,115.6 Gg CO_2) of deforestation in 2007. New Zealand's post-1989 forests are described in further detail in section 7.2.2.

The new planting rate (land reforested or afforested) between 1990 and 2008 was, on average, 31,000 hectares per year (refer to Figure 7.2.1.1). While new planting rates were high from 1992 to 1998 (averaging 59,000 hectares per year), the rate of new planting has declined rapidly since 1998 and is now at very low levels. In the 2008 calendar year, it was estimated that only 1,000 hectares of new forest was established. The annual area of new planting is expected to increase with the implementation of the New Zealand Emissions Trading Scheme, Permanent Forest Sinks Initiative and Afforestation Grant Scheme, that have both been introduced by the New Zealand Government to encourage new planting (Ministry of Agriculture and Forestry, 2009b).

Deforestation

In 2008, 4,818 hectares of forest land are estimated to have been deforested, which is equivalent to emissions of 2,909.8 Gg CO_2 from the estimated change in carbon stock. Table 11.1.2 shows the areas of forest land subject to deforestation in 2008, and Figure 11.1.2 shows the net emissions associated with this deforestation.

Table 11.1.2 New Zealand's forest land subject to deforestation in 2008

Forest land subcategory	Area of deforestation in 2008 (ha)	Emissions in 2008 from resulting carbon stock change (Gg CO_2)
Natural forest	1,818	1,090.8
Pre-1990 planted forest	2,114	1,552.6
Post-1989 forest	886	266.4
Total	**4,818**	**2,909.8**

Note: 2008 areas as at 31 December 2008.

The New Zealand Government has recently introduced legislation and government initiatives to either encourage forest establishment or discourage the deforestation of planted forests. These include:

- Climate Change Response Act 2002 (updated 8 December 2009)
- Permanent Forest Sink Initiative (Ministry of Agriculture and Forestry, 2008b)
- Afforestation Grant Scheme (Ministry of Agriculture and Forestry, 2009b).

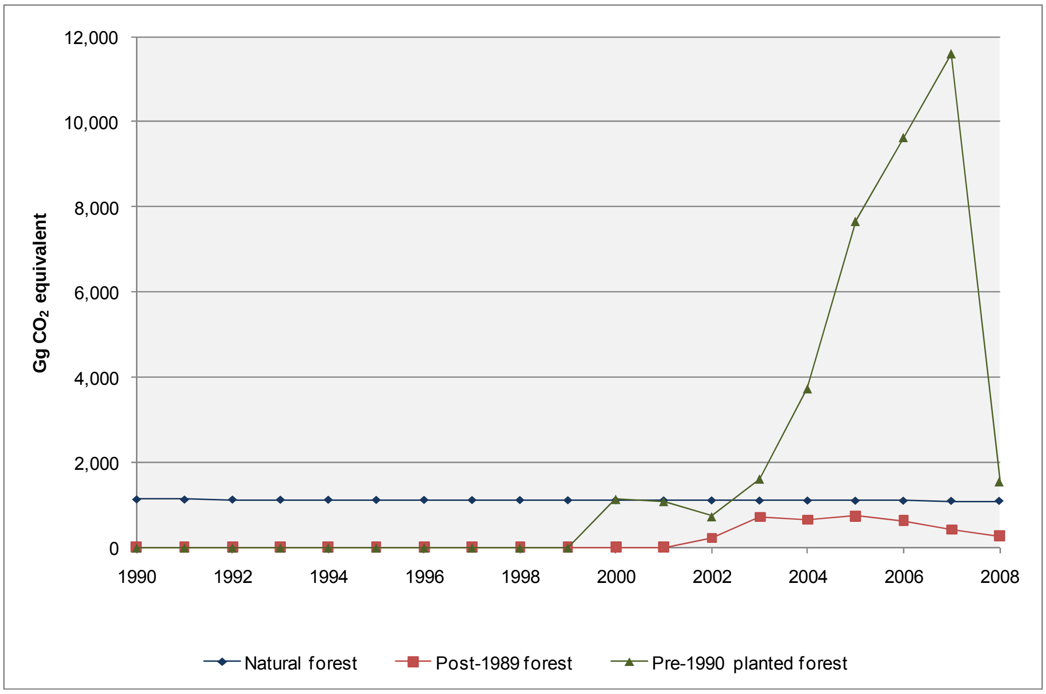
The New Zealand Emissions Trading Scheme means that owners of pre-1990 planted forest are only able to deforest 2 hectares in any five-year period starting from 1 January 2008 without having to surrender emissions units (Ministry of Agriculture and Forestry, 2009b). Above this level of deforestation they have to surrender units equal to reported emissions, with some exemptions for smaller forest owners.

The area of deforestation of natural forests estimated for 2008 is based on previous trends and is likely to be an overestimate. This is because land-use change during the 2008 calendar year was estimated by linear interpolation from the average land-use change mapped between 1 January 1990 and 1 January 2008. As there was no quantitative information on the annual rate of natural forest deforestation between 1990 and 2007, the same annual rate of change was assumed for the entire period (1,818 hectares per year), and extrapolated out to the end of 2008.

However, a number of factors suggest that the rate of natural forest deforestation is unlikely to have been constant over the 19-year period, and instead mostly occurred prior to 2002. The area available for harvesting (and potentially deforestation) was higher before amendments were made in 1993 to the Forests Act 1949. There have also been government controls on deforestation of natural forests since the 1970s, with only a small proportion of privately owned natural forest exempt from these controls (0.7 per cent of the total area of natural forest is exempt). Further restrictions to the logging of natural forests were introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand in 2002. These developments are all likely to have reduced natural forest deforestation since their introduction.

The extrapolated estimate of natural forest deforestation will be updated in future submissions as new information becomes available, and will be replaced with an actual, mapped value in the 2013 submission at the latest, following production of the 2012 land-use map.

Figure 11.1.2 New Zealand's net emissions from deforestation from 1990 to 2008



While conversion of land from one land use to another is not uncommon in New Zealand, deforestation on the scale seen since 2004 is a new phenomenon. Most of the area of planted forest deforested from the mid-2000s has been converted to grassland. This conversion is most likely primarily due to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry.

Deforestation in New Zealand is more fully described in sections 7.2.1 and 11.4.2.

11.1.1 Definitions of forest and any other criteria

New Zealand has used the same forest land definition as used 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 11.1.1.1 provides the defining parameters for forest land.

Table 11.1.1.1 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.

The minimum width of 30 metres 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 forests. There is an overlap where post-1989 forest has been established with native species or is the result of revegetation.

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.

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 2008, 580,524 hectares were reforested and 1,000 hectares of this occurred in 2008. Of the total area reforested between 1990 and 2008, an estimated 11,749 hectares were deforested between 1990 and 2008. 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 1990 and 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.

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 7.1.2 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 have been used (Shepherd and Newsome, 2009a, b).

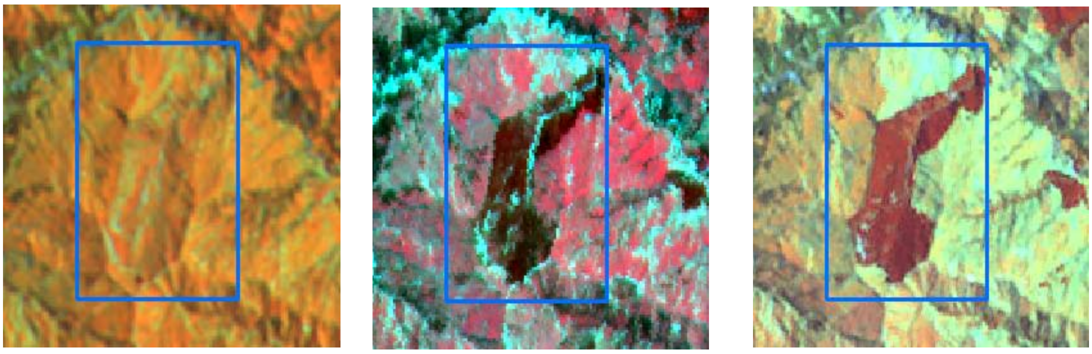
Decision process for mapping post-1989 forests

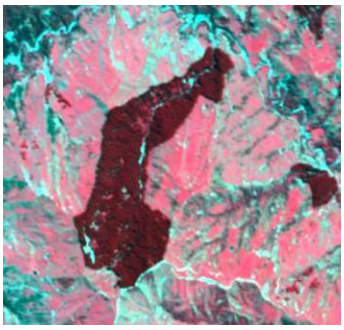
The use of remote sensing has some limitations, in particular, the ability to map young planted forest of less than three years of age. Where trees are planted within three years of the image acquisition date they (and their surrounding vegetation) are unlikely to show a distinguishable spectral signature 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 11.2.2.1 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 corresponds 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 to 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 11.2.2.1 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, 2009a). This process is described in section 7.1.2.

To estimate land-use change in 2008, data from the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2008) and the *2008 Deforestation Intentions Survey* (Manley, 2009) and unpublished work by Scion (referenced in Wakelin, 2008) were used for the forest land uses. For the non-forest land uses, change during 2008 was estimated based on the average annual change between 1 January 1990 and 1 January 2008. This is further explained in section 7.1.2.

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 is using Reporting Method 1 for afforestation, reforestation and deforestation.

The geographic units New Zealand has chosen to report by are the North Island, including Great Barrier and Little Barrier Islands, and the South Island, including Stewart Island and the Chatham Islands.

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 the Climate Change Convention reporting and are described more fully in chapter 7.

Emissions and removals from afforestation and reforestation are determined at the national scale. Carbon analyses based on a plot network is performed to estimate the average amount of carbon per hectare per pool.

Currently, emissions from deforestation are estimated based on average carbon yield tables for each subcategory of forest (natural forest, pre-1990 planted forest and post-1989 forest). A future improvement planned 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 for the new land use then accumulates at rates as given in Table 7.1.2.4.

Justification when omitting any carbon pool or GHG emissions/ removals from activities under Activity 3.3 and elected activities under Article 3.4

New Zealand has accounted for all carbon pools. The carbon in organic soils, however, has been calculated as for mineral soils.

New Zealand uses a Tier 2 method to estimate soil carbon stock, with the use of New Zealand-specific land-use and soil pedon data (Scott et al, 2002). The peer-reviewed Soil Carbon Monitoring System (Soil CMS) does not estimate carbon stock or carbon changes for organic soils, as it calculates concentration within a fixed depth rather than total organic carbon mass (Tate et al, 2005).

Approximately 0.9 per cent of New Zealand's land area has organic soils, and between 1 January 1990 and 1 January 2008, 2,560 hectares of land with organic soils underwent land-use change. This represents 0.3 per cent of the total area of land-use change. New Zealand has reported organic soils as mineral soils in the reporting of soil carbon, and has used the notation key IE ('included elsewhere') for organic soils in the common reporting format tables. See section 7.1.2 for further detail.

Factoring out information

Indirect and natural greenhouse gas emissions and removals have not been factored out, and are therefore included in New Zealand's emission and removals estimates.

Recalculations

This is New Zealand's first inventory report to be submitted within the first commitment period of the Kyoto Protocol, and consequently there are no recalculations to afforestation, reforestation and deforestation estimates. However, estimates reported for the LULUCF sector under the Climate Change Convention have been recalculated since the previous submission to incorporate improved New Zealand-specific methods, activity data and emission factors, as detailed under section 7.1.2.

Uncertainty

The uncertainty in emissions and removals from afforestation and reforestation units are 15.1 per cent, based on the uncertainty in emissions and removals from post-1989 forest (refer to section 7.2.3 and Table 7.2.3.1 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 11.3.1.1). Further detail on the uncertainty in emissions and removals for natural forest and pre-1990 forest is provided in chapter 7, section 7.2.

Table 11.3.1.1 Uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2008

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
Activity data uncertainty	±6.5	±5.7	±9.9	±6.5
Emission factor uncertainty	±10.1	±3.7	±16.9	±10.1
Combined uncertainty	**±12.0**	**±6.8**	**±19.5**	**±12.0**

Note: All land that has been afforested/reforested since 1 January 2008 is, by definition, 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 are 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 have also undergone quality assurance as described in section 7.2.4.

Year of the onset of an activity

For the purpose of accounting as required in paragraph 18 of the annex to CMP.1 (land use, land-use change and forestry) attached to decision 11/CP.7, an indication of the year of the onset of an activity is required for activities starting after the beginning of the first commitment period. During 2008, 1,000 hectares of post-1989 forest were established and 4,818 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

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), 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.

New Zealand has used satellite imagery collected around 1990 and 2008 to detect changes in land use between these two periods. To estimate land-use change in 2008, ancillary data has been used.

Data from the Ministry of Agriculture and Forestry's new planting survey (the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2009a)) was used to estimate afforestation and reforestation during 2008. To estimate deforestation during 2008, data from forest owners and from the 2008 Deforestation Intentions Survey has been used (Manley, 2009).

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

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).

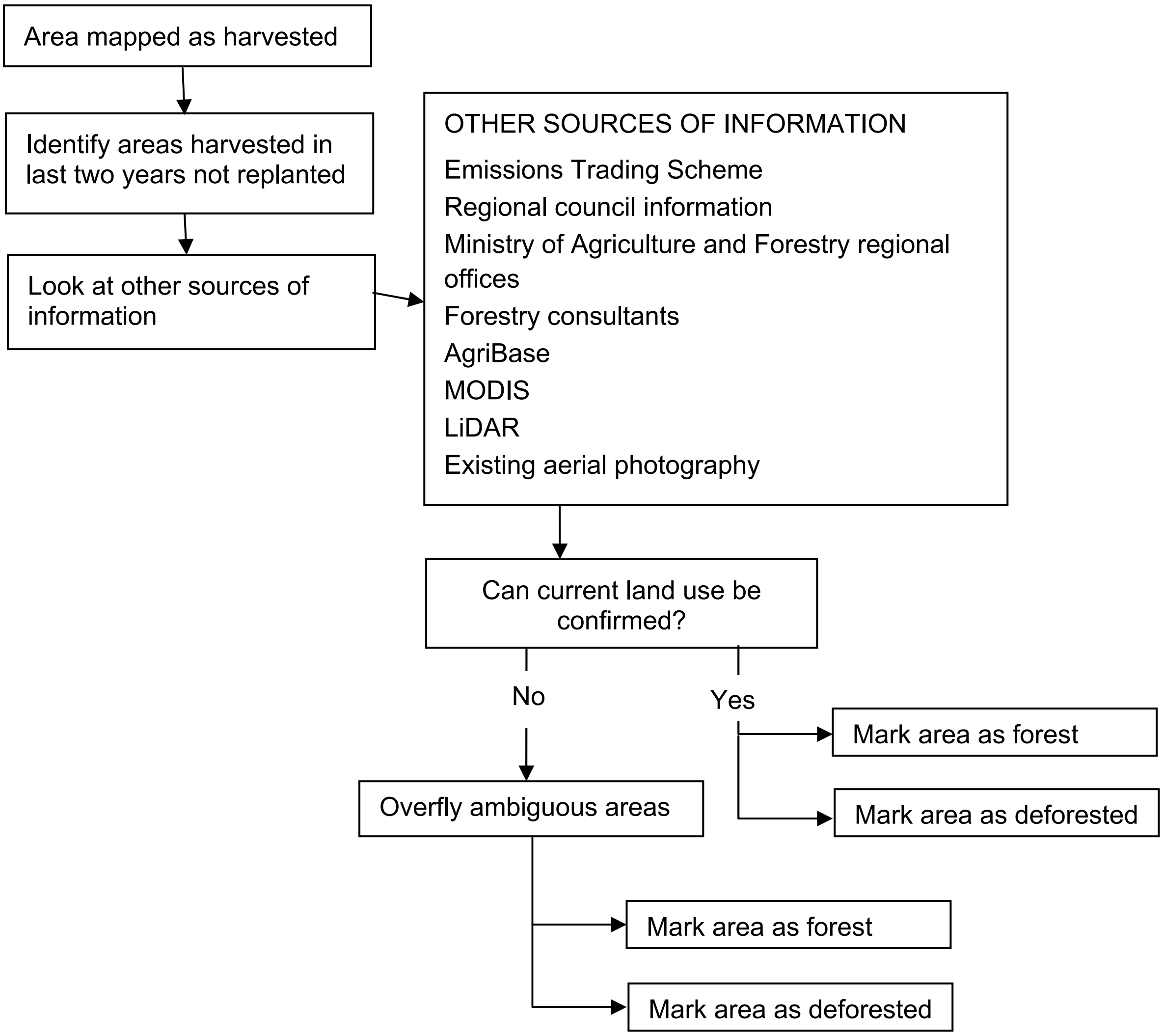
In New Zealand, temporarily unstocked areas (eg, harvested areas and areas subject to disturbances) remain as forest land unless there is a confirmed change in land use or after four years no reforestation (replanting or revegetation) has occurred. The four-year time period was selected because, in New Zealand, the tree grower and land owner are often different people. Forest land can be temporarily unstocked for a number of years while land owners 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 7.1.2. – Mapping of deforestation and harvesting.

Under New Zealand's Emissions Trading Scheme, 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, 2009). There is a data sharing agreement that the Ministry of Agriculture and Forestry, the agency that administers the forestry aspects of New Zealand's Emissions Trading Scheme, 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 11.4.2.1.

Figure 11.4.2.1 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 associated emissions occurred in that year.

11.4.3 Unclassified deforestation

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

Afforestation and reforestation, and deforestation of pre-1990 forests are key categories for 2008 (level and trend analysis).

11.7 Information relating to Article 6

New Zealand is not involved in any activities under Article 6 of the Kyoto Protocol.

Chapter 12: Information on accounting Kyoto Protocol units

12.1 Background information

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 2009, New Zealand's national registry held 308,435,921 units equivalent to metric tonnes of CO_2-e.

The commitment period reserve of 278,608,260 metric tonnes of CO_2-e is 90 per cent of the assigned amount, fixed in 2007 after the review of *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006).

Holdings and transactions of Kyoto Protocol units

Please refer to the standard reporting format tables below (Table 12.2.2). These tables are also provided in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/ publications/climate).

General note

Abbreviations used in this chapter include:

AAUs	Assigned Amount units
ERUs	Emission Reduction units
RMUs	Removal units
CERs	Certified Emission Reduction units
tCERs	Temporary Certified Emission Reduction units
lCERs	Long-term Certified Emission Reduction units
NZEUR	New Zealand Emission Unit Register
CDM	Clean Development Mechanism
AT	Austria
CH	Switzerland
FR	France
GB	United Kingdom of Great Britain and Northern Ireland
JP	Japan
NL	Netherlands
NO	Norway (only for *Table 2b Annual external transactions* in Table 12.2.2 in the column 'Transfers and acquisitions').

12.2 Summary of the standard electronic format tables for reporting Kyoto Protocol units

At the beginning of the calendar year 2009, New Zealand's national registry held 309,444,733 assigned amount units, 120,000 emissions reduction units and 10,108 certified emission reduction units (Table 1 in Table 12.2.2). At the end of 2009, there were 308,377,715 assigned amount units, 48,098 emission reduction units and 10,108 certified emission reduction units.

New Zealand's national registry did not hold any temporary certified emission reduction units and long-term certified emissions reduction units during 2009 (Table 4 in Table 12.2.2).

The transactions made to New Zealand's national registry during 2009 (Tables 2 (a), (b), (c) in Table 12.2.2) are summarised below:

- 1,000 assigned amount units were added to New Zealand's national registry and 1,068,018 were subtracted. The only addition was acquired from the United Kingdom of Great Britain and Northern Ireland and the greatest subtraction was 540,281 units to Norway
- 496,567 emission reduction units were added to New Zealand's national registry and 568,469 were subtracted. The only addition was a New Zealand-verified project under Article 6 of the Kyoto Protocol. There were no external additions. The greatest subtraction was 240,000 emission reduction units to the Netherlands. There were 5,000 emission reduction units transferred internally within New Zealand's national registry
- 401,000 certified emission reduction units were added to New Zealand's national registry and 401,000 were subtracted. The greatest addition was 400,500 certified emission reduction units from Switzerland. The only subtraction was made to United Kingdom of Great Britain and Northern Ireland. There were no internal transactions
- there were no transactions of removal units, temporary certified emission reduction units and long-term certified emissions reduction units.

During 2009, no Kyoto Protocol units were expired, replaced or cancelled.

Table 12.2.1 New Zealand's submission of the standard electronic format

Annual submission item	New Zealand's national registry response
15/CMP.1 annex I.E paragraph 11: Standard electronic format	The standard electronic format report for 2009 has been submitted to the Climate Change Convention 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	2010
Reported year	2009
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	309420003	NO	NO	NO	NO	NO
Entity holding accounts	24730	120000	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	309444733	120000	NO	10108	NO	NO

Party	New Zealand
Submission year	2010
Reported year	2009
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		496567					496567		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							NO	NO	NO	NO	NO	NO
Sub-total		496567	NO				496567	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	2010
Reported year	2009
Commitment period	1

Add registry | Delete registry | No external transactions

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	29641	NO	NO	NO	NO
CH	NO	NO	NO	400500	NO	NO	30170	94579	NO	NO	NO	NO
FR	NO	NO	NO	NO	NO	NO	NO	45911	NO	NO	NO	NO
GB	1000	NO	NO	500	NO	NO	1000	98338	NO	401000	NO	NO
JP	NO	NO	NO	NO	NO	NO	NO	60000	NO	NO	NO	NO
NL	NO	NO	NO	NO	NO	NO	NO	240000	NO	NO	NO	NO
NO	NO	NO	NO	NO	NO	NO	540281	NO	NO	NO	NO	NO
Sub-total	1000	NO	NO	401000	NO	NO	571451	568469	NO	401000	NO	NO

Additional information

Independently verified ERUs								NO				

Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	1000	496567	NO	401000	NO	NO	1068018	568469	NO	401000	NO	NO

Party	New Zealand
Submission year	2010
Reported year	2009
Commitment period	1

Table 3. Expiry, cancellation and replacement

Transaction or event type	Expiry, cancellation and requirement to replace – Unit type: tCERs	Expiry, cancellation and requirement to replace – Unit type: lCERs	Replacement – Unit type: 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	2010
Reported year	2009
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	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	2010
Reported year	2009
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)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	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	1000	616567	NO	426108	NO	NO	1188018	568469	NO	416800	NO	NO
Total	309565733	616567	NO	426108	NO	NO	1188018	568469	NO	416800	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

Table 5 (c). Summary information on retirement

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

Party New Zealand
Submission year 2010
Reported year 2009
Commitment period 1

Add transaction | Delete transaction | No corrective transaction

Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions

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

Add transaction | Delete transaction | No corrective transaction

Table 6 (b). Memo item: Corrective transactions relating to replacement

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

Add transaction | Delete transaction | No corrective transaction

Table 6 (c). Memo item: Corrective transactions relating to retirement

	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

12.3 Discrepancies and notifications

New Zealand has not received any notification of discrepancies, failures or invalid units as shown in Table 12.3.1.

Table 12.3.1 Discrepancies and notifications from New Zealand's national registry

Annual submission item	New Zealand's national registry response
15/CMP.1 Annex I.E, paragraph 12: List of discrepant transactions	No discrepant transactions occurred in 2009. 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 2009. 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 2009. 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 2009. 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 Publically 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 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 44–48
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.			

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 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 44–48
45. The information referred to in paragraph 44 above shall include up-to-date information for each account number in that registry on the following:			
(a) Account name: the holder of the account.	Yes (refer Search the Register: Accounts).	Up to date (real-time)	n/a
(b) Account type: the type of account (holding, cancellation or retirement).	Yes (refer Search the Register: Accounts).	Up to date (real-time)	n/a
(c) Commitment period: the commitment period with which a 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 (refer Search the Register: Accounts: Click on Account Number hyperlink to access Account Information Report: Representative Details).	Up to date (real-time)	n/a
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: 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: Projects).	Up to date (real-time)	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be 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 44–48
(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 through the Ministers' Directions menu item. This lists directions relating to the transfer of emission reduction units to individual Joint Implementation Projects. The NZEUR Unit Holding and Transaction Summary Report shows in aggregate the total ERUs converted from AAUs by year)	Up to date (real-time)	n/a
(d) Reports: downloadable electronic versions of all publicly available documentation relating to the project, including proposals, monitoring, verification and issuance of ERUs, where relevant, subject to the confidentiality provisions in decision 9/CMP.1.	Partial – this information is published on the Ministry for the Environment's website for Joint Implementation Projects at www.mfe.govt.nz/issues/climate/policies-initiatives/joint-implementation/notice.html and is not replicated on the New Zealand's national registry website (www.eur.govt.nz) The following information for each JI project is published on the Ministry for the Environment website: • project description • non-host party project approval • annual reports • verification reports. Project proposals are not included as they contain 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):			

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 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 44–48
(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 1st 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. (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 1 January of each year.	n/a
(d) The total quantity of ERUs, CERs, AAUs and RMUs acquired from other registries and the identity of the transferring accounts and registries.	Partial – the total quantity of ERUs, CERs, AAUs and RMUs acquired from other registries, and the identity of the registries is publicly available by 31 January for the previous calendar year (refer Search the Register: NZEUR Incoming Transactions for the Year).	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		Section 27(j) of the Climate Change Response Act 2002 requires that only the

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 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 44–48
	individual transferring accounts is not available as it is considered to be confidential information.		following be made publicly available: • total quantity of units transferred; and • total quantity and type of unit transferred; and • the identity of the transferring overseas registries including the total quantity of units transferred from each overseas registry and each type of unit transferred from each overseas registry.
(e) The total quantity of RMUs issued on the basis of each activity under 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. The identity of the individual acquiring accounts is not available as it is considered to be confidential information.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year	n/a Section 27(k) of the Climate Change Response Act 2002 requires that only the following be publicly available: • total quantity of units transferred; and • total quantity and type of unit transferred; and • the identity of the acquiring overseas registries including the total quantity of units transferred to each overseas registry and each type of unit transferred to each overseas registry.

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 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 44–48
(g) The total quantity of ERUs, CERs, AAUs and RMUs cancelled on the basis of activities under Article 3, paragraphs 3 and 4.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	n/a
(h) The total quantity of ERUs, CERs, AAUs and RMUs cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	n/a
(i) The total quantity of other ERUs, CERs, AAUs and RMUs cancelled.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). 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, lCERs, 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 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 44–48
	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.
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 2009 is:

Commitment period reserve limit:	278,608,260
Units held:	308,435,121
Commitment period reserve level:	308,435,121
Commitment period reserve level (% of assigned amount)	99.64

Commitment period reserve level comprises of the following units:

AAUs	308,377,715
ERUs (converted from AAUs)	48,098
CERs	9,308
Total units	308,435,121

New Zealand's commitment period reserve level is also available at: www.eur,govt.nz, and is updated on a daily basis.

Chapter 13: Information on changes to the national system

There have been two major improvements to New Zealand's national system since the 2009 inventory submission.

The first improvement has been the establishment of a cross-government reporting governance group to provide effective leadership over reporting and projections of greenhouse gas emissions and removals. The reporting governance group will enhance consistency, coordination, timeliness and risk management of reporting information and processes. The scope of the group includes New Zealand's national greenhouse gas inventory, projections reporting for the Kyoto Protocol and beyond, New Zealand's national system for reporting under the Kyoto Protocol, and quantitative analysis of emissions and removals supporting policy formation. Meetings are held monthly.

The key roles and expectations of the reporting governance group are:

i. **guide, confer and agree** on inventory and projections improvements and assumptions, planning and priorities, key messages, management of stakeholders and risks

ii. **focus on delivery of** reporting commitments to meet national and international requirements

iii. **provide reporting leadership and guidance** to analysts, modellers and technical specialists

iv. **share** information, provide feedback and resolve any differences between departments that impact on the delivery of the work programme

v. **monitor and report** to the Strategic Advisory Group on the 'big picture' of the reporting work programme, direction, progress in delivery and capability to deliver.

New Zealand has also established an independent agricultural inventory advisory panel to assess whether proposed changes to New Zealand's agricultural section of the national inventory are scientifically robust to be accepted 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 their recommendations for changes. Refer to section 6.1.1 for further details.

Other improvements include the following.

- Four government officials have passed their expert review exams under the Climate Change Convention for the energy, agriculture, waste and land use, land-use change and forestry sectors. Three other government officials, already expert reviewers under the Climate Change Convention, passed their mandatory Kyoto Protocol exams.
- All estimate recalculations now require a recalculation form to be filled out and, if approved, signed by the national inventory compiler for documentation.
- The sector leads are now responsible for the completion of the Tier 1 quality-control checks (IPCC, 2000) for their sector.

- The energy and agriculture sector contributions to the national inventory report, common reporting format exports and Tier 1 quality-control checks are now required to be signed off by the Ministry of Economic Development and the Ministry of Agriculture.

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 2009 submission are included in Table 14.1.

Contact information for New Zealand's national registry administrator is provided in Table 14.2.

New Zealand's response to the most recent recommendation made by the expert review team is included in Table 14.3.

A list of reference documents included in the submitted zip file 'Recertification' is provided in Table 14.4.

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	Changes made to Main Contact, Alternative Contact and Release Manager. The National Focal Point advised the ITL administrator of these changes as recorded in the table below.
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 2009, New Zealand performed an important release which introduced its domestic unit, the New Zealand Unit, under the New Zealand Emissions Trading Scheme. This release required the recertification of New Zealand's national registry with the data exchange standards. This meant that, after consultation with the UN ITL, PQA on behalf of the New Zealand national registry performed the Annex H Part 4 tests. These tests were performed between 26 April and 9 May 2009 and the test results were submitted to ITL Service desk, together with the SOAP/XML files and the back up of the database at the conclusion of the tests on 9 May 2009 (refer to the ITL Service Desk call number OSD000002930293). Upon passing Annex H Part 4 tests, the New Zealand national registry released the changes to the production and DR environments. 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 back-up procedures, no changes to the back-up retention periods, no changes to the frequency of the database back ups), 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.

Section subheading	New Zealand's response
15/CMP.1 Annex II.E, paragraph 32.(f): Change in security	No change of security measures occurred during the reporting period.
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.
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 2009, the New Zealand national registry introduced its domestic unit, the New Zealand unit. This was achieved by a release of system code. For this change, the New Zealand national registry updated the business acceptance test plan, the test scripts (by creating additional tests for the new domestic unit) 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 14.4). The vendor also performed their testing (test documentation attached) (items 5 to 11 in Table 14.4). As part of the test process, before release to production, the New Zealand national registry, together with the vendor, performed the developer tests required under Annex H part 4 during the developer test cycle. These have been documented (including the summary of the developer testing) and are attached. The test results were submitted to ITL Service desk in form of SOAP/XML files and a back up of the database at the conclusion of the tests (item 12 in Table 14.4 below).

Table 14.2 Information for the administrator of New Zealand's national registry

Organisation designated as the administrator of New Zealand's national registry	Name: Ministry of Economic Development Postal address: PO Box 1473, 33 Bowen Street, Wellington 6011, New Zealand Phone number: +64 4 474 2843 Fax number: +64 4 978 3661 Web site address: www.med.govt.nz
Contact person	Name: Anita Dahya Position: Acting Manager, New Zealand Emission Unit Register, Ministry of Economic Development Postal address: PO Box 1473, 33 Bowen Street, Wellington 6011, New Zealand Phone number: +64 4 474 2843 Fax number: +64 4 978 3661 Email address: anita.dahya@med.govt.nz
Alternative contact person	Name: Anca Slusanschi Position: Project Manager, Emissions Trading Scheme, Ministry of Economic Development Postal address: PO Box 1473, 33 Bowen Street, Wellington 6011, New Zealand Phone number: +64 4 474 2665 Fax number: +64 4 978 3661 Email address: anca.slusanschi@med.govt.nz

Release manager	Name: Anca Slusanschi Position: Project Manager, Emissions Trading Scheme, Ministry of Economic Development Postal address: PO Box 1473, 33 Bowen Street, Wellington 6011, New Zealand Phone number: +64 4 474 2665 Fax number: +64 4 978 3661 Email address: anca.slusanschi@med.govt.nz

Table 14.3 Previous recommendations for New Zealand from the expert review team (UNFCCC, in preparation 2010)

Previous annual review recommendations	New Zealand addressed the recommendation as follows
The expert review team recommended that New Zealand should improve its reporting on changes made to the test procedures or test results, in accordance with paragraph 32(j) of the annex to decision 15/CMP.1, and report on those changes in its next annual submission.	For the 2008 reporting year, there were no changes made to the test procedures or test results as there were no system changes during the reporting period. For the 2009 calendar year, there were changes made to the test procedures and the test results due to the introduction of New Zealand's domestic unit of trade as mentioned in the table above 15/CMP.1 Annex II.E, paragraph 32.(j): Change of the test results and as covered in the attached documentation forwarded with this report.

Table 14.4 Reference documents list – all zipped under 'Recertification.zip'

ID	Document name	Document description
1	NZEUR Business Acceptance Test Plan - SOW2 Phase 2.doc	NZEUR test plan for testing the new domestic unit NZU functionality.
2	NZEUR Business Acceptance Test Completion Report - SOW2 Phase 2.doc	NZEUR Business Acceptance test report at the end of testing the new domestic unit NZU functionality.
3	NZEUR General Information.doc	NZEUR testing general guidance.
4	TS-00210.doc	NZEUR test script sample.
5	SOW2 MED 6 May.xls	NZEUR test results log.
6	Developer Testing Cycle.doc	PQA Developer testing cycle documentation.
7	Developer Testing Cycle with Modifications and Test Results.doc	PQA developer testing cycle documentation which captures the test cycle modification and results.
8	Developer Testing Summary.xls	PQA developer testing summary sheet/log.
9	UN - re-certification email - no formal notice.txt	UN recertification email.
10	Re-certification.htm	UN recertification email.
11	Re OSD000002930293 FW Re certification of NZEUR.htm	UN recertification email
12	PQA Recertification which contains: • AnnexHGovtAccountsNZ.csv • EATS_NZ PostRecertification.zip • NZ Recertification - SoapMessageStore.zip	Files submitted to UN during the recertification process – developer results of testing Annex H Part 4.

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 New Zealand's International Aid and Development Programme (www.nzaid.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.

New Zealand's International Aid and Development 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 and 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**.**

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.

New Zealand, through the Ministry of Economic Development, has worked with the Tuvalu Electricity Corporation to help provide higher quality electricity services at the lowest costs to consumers. This project has included a review and identification of demand-side management and renewable energy opportunities, developing methods for the Tuvalu Electricity Corporation to evaluate solar photovoltaic options, feasibility studies on the use of copra oil and wind for electricity generation and identification of opportunities for increased energy efficiency.

The training/capacity building component of the project means that the Tuvalu Electricity Corporation can improve its service itself and be less dependent on external consultants. As well as identifying key renewable energy options for Tuvalu, the project developed methods through which the Tuvalu Electricity Corporation could evaluate renewable energy options itself. By considering the overall design of the electricity system, and making recommendations on corporate management, the project may also help to ensure the continued economic viability of Tuvalu’s electricity company.

The project recommended a number of ways that Tuvalu can reduce its reliance on diesel generation through increased use of wind, copra oil, biogas and energy-efficiency technologies.

Depending on the outcome of the project, increased use of renewable energy and energy-efficiency measures will reduce Tuvalu’s use of diesel for electricity generation and reduce greenhouse gas emissions.

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.

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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) = 1,000 tonnes = 1 kilotonne (kt)

1 megatonne (Mt) = 1,000,000 tonnes = 1,000 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 = 2,800
N_2O = 310	HFC-134a = 1,300
CF_4 = 6,500	HFC-143a = 3,800
C_2F_6 = 9,200	HFC-227ea = 2,900
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.

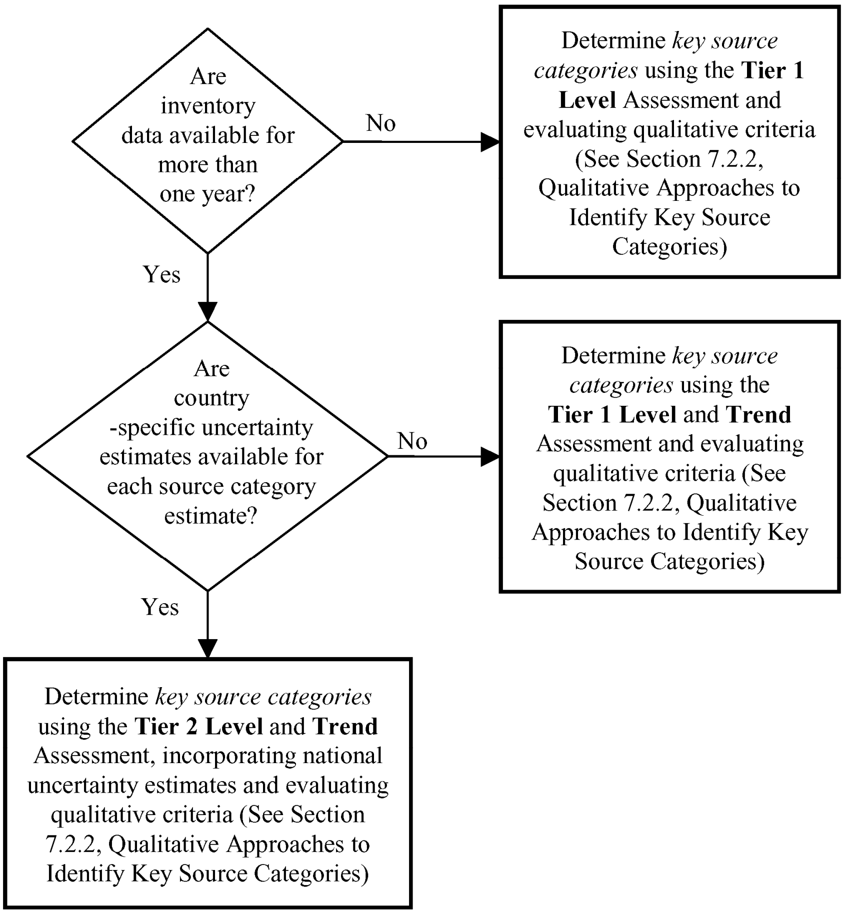
Annexes to New Zealand's National Inventory Report for 2008

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.

Figure A1.1 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 A1.1 Results of the key category level analysis for 99 per cent of the total emissions and removals for New Zealand in 2008. Key categories are those that comprise 95 per cent of the total.

(a) IPCC Tier 1 category level assessment - including LULUCF (net emissions)				
IPCC categories	Gas	2008 estimate ($Gg\ CO_2$-e)	Level assessment (%)	Cumulative total (%)
Enteric fermentation	CH_4	22,657.5	21.0	21.0
Conversion to forest land	CO_2	17,327.7	16.1	37.1
Transport – road transportation	CO_2	12,670.2	11.8	48.8
Forest land remaining forest land	CO_2	12,441.1	11.5	60.4
Stationary combustion – gas	CO_2	8,033.0	7.5	67.8
Agricultural soils – pasture, range and paddock	N_2O	7,125.9	6.6	74.5
Stationary combustion – solid	CO_2	6,148.4	5.7	80.2
Stationary combustion – liquid	CO_2	3,144.1	2.9	83.1
Conversion to grassland	CO_2	2,849.6	2.6	85.7
Agricultural soils – indirect emissions	N_2O	2,468.8	2.3	88.0
Agricultural soils - direct emissions	N_2O	1,777.7	1.6	89.7
Metal production - iron and steel production	CO_2	1,539.2	1.4	91.1
Solid waste disposal on land	CH_4	1,278.4	1.2	92.3
Transport – civil aviation	CO_2	942.9	0.9	93.1
Fugitive emissions from oil and gas operations	CO_2	796.4	0.7	93.9
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	727.7	0.7	94.6
Manure management	CH_4	719.5	0.7	95.2
Grassland remaining grassland	CO_2	676.1	0.6	95.9
Mineral products - cement production	CO_2	634.2	0.6	96.4
Metal production - aluminium production	CO_2	506.0	0.5	96.9
Fugitive emissions from geothermal operations	CO_2	445.4	0.4	97.3
Fugitive emissions from oil and gas operations	CH_4	404.8	0.4	97.7
Fugitive emissions from coal mining and handling	CH_4	342.6	0.3	98.0
Chemical industry - ammonia production	CO_2	331.6	0.3	98.3
Transport – navigation (domestic shipping)	CO_2	295.5	0.3	98.6
Chemical industry - hydrogen production	CO_2	246.7	0.2	98.8
Wastewater handling	CH_4	206.3	0.2	99.0

Table A1.2 Results of the key category level analysis for 99 per cent of the total 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)

IPCC categories	Gas	Base year estimate (Gg CO_2-e)	Level assessment (%)	Cumulative total (%)
Forest land remaining forest land	CO_2	33,034.1	34.5	34.5
Enteric fermentation	CH_4	21,837.2	22.8	57.3
Transport – road transportation	CO_2	7,500.2	7.8	65.1
Stationary combustion – gas	CO_2	7,306.8	7.6	72.8
Agricultural soils – pasture, range and paddock	N_2O	6,858.7	7.2	79.9
Stationary combustion – solid	CO_2	3,139.7	3.3	83.2
Stationary combustion – liquid	CO_2	2,501.6	2.6	85.8
Solid waste disposal on land	CH_4	2,063.2	2.2	88.0
Agricultural soils – indirect emissions	N_2O	2,005.1	2.1	90.1
Metal production - iron and steel production	CO_2	1,310.9	1.4	91.4
Conversion to grassland	CO_2	1,114.8	1.2	92.6
Transport – civil aviation	CO_2	771.4	0.8	93.4
Metal production - aluminium production	PFCs	629.9	0.7	94.0
Grassland remaining grassland	CO_2	585.5	0.6	94.7
Manure management	CH_4	579.1	0.6	95.3
Agricultural soils - direct emissions	N_2O	515.2	0.5	95.8
Metal production - aluminium production	CO_2	449.0	0.5	96.3
Mineral products - cement production	CO_2	444.7	0.5	96.7
Fugitive emissions from geothermal operations	CO_2	357.3	0.4	97.1
Chemical industry - ammonia production	CO_2	278.0	0.3	97.4
Fugitive emissions from coal mining and handling	CH_4	272.1	0.3	97.7
Fugitive emissions from oil and gas operations	CH_4	262.5	0.3	98.0
Transport – navigation (domestic shipping)	CO_2	247.7	0.3	98.2
Fugitive emissions from oil and gas operations	CO_2	230.1	0.2	98.5
Waste-water handling	CH_4	207.0	0.2	98.7
Conversion to forest land	CO_2	166.2	0.2	98.8
Wastewater handling	N_2O	153.5	0.2	99.0

Table A1.3 Results of the key category trend analysis for 99 per cent of the total emissions and removals for New Zealand in 2008. 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	Base year estimate (Gg CO_2-e)	2008 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Forest land remaining forest land	CO_2	33034.12	12441.13	0.204	42.2	42.2
Conversion to forest land	CO_2	166.24	17327.74	0.141	29.2	71.4
Transport – road transportation	CO_2	7500.22	12670.17	0.035	7.2	78.6
Stationary combustion – solid	CO_2	3139.65	6148.38	0.022	4.5	83.0
Enteric fermentation	CH_4	21837.22	22657.49	0.016	3.3	86.3
Conversion to grassland	CO_2	1114.80	2849.61	0.013	2.7	89.0
Solid waste disposal on land	CH_4	2063.21	1278.45	0.009	1.8	90.8
Agricultural soils - direct emissions	N_2O	515.17	1777.67	0.010	2.0	92.9
Consumption of halocarbons and SF_6 - refrigeration and air conditioning	HFCs & PFCs	0.00	727.74	0.006	1.2	94.1
Metal production - aluminium production	PFCs	629.87	36.47	0.006	1.1	95.2
Agricultural soils – pasture, range and paddock	N_2O	6858.75	7125.90	0.005	1.0	96.3
Fugitive emissions from oil and gas operations	CO_2	230.14	796.37	0.004	0.9	97.2
Stationary combustion – liquid	CO_2	2501.64	3144.10	0.003	0.6	97.7
Stationary combustion – gas	CO_2	7306.82	8033.04	0.002	0.3	98.1
Agricultural soils – indirect emissions	N_2O	2005.11	2468.78	0.002	0.4	98.4
Mineral products - cement production	CO_2	444.72	634.24	0.001	0.2	98.6
Fugitive emissions from oil and gas operations	CH_4	262.46	404.76	0.001	0.2	98.8
Consumption of halocarbons and SF_6 - foam blowing	HFCs & PFCs	0.00	83.25	0.001	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 CO_2 emission factors used for New Zealand's energy sector in 2008 (before oxidation)

	Emission factor ($t\ CO_2/TJ$)	Emission factor (t C/TJ)	Source
Gas			
Maui	52.37	14.28	1
Kapuni Treated	53.02	14.46	1
Kapuni low temperature separator	84.10	22.94	1
Weighted average for distributed gas	53.59	14.61	
Methanol – mixed feed (1990–1994)	62.44	17.00	3
Methanol – low temperature separator (1990–1994)	83.97	22.94	3
Kaimiro	55.09	15.02	2
Ngatoro	53.07	14.47	3
Rimu/Kauri	51.85	14.14	3
Waihapa/Ngaere + Tariki/Ahuroa	54.85	14.96	3
McKee	54.30	14.81	3
Mangahewa	57.40	15.65	3
Turangi	54.67	14.91	3
Pohokura	54.23	14.79	1
Liquid fuels			
Regular petrol	66.48	18.13	4
Petrol – premium	66.91	18.25	4
Diesel (50 ppm)	69.53	18.96	4
Jet Kerosene	68.53	18.69	4
Av gas	65.89	17.97	4
Fugitive – flared	65.10	17.75	4
Liquefied petroleum gas	60.43	16.48	2
Heavy fuel oil	73.90	20.16	4
Light fuel oil	72.86	19.87	4
Bitumen (asphalt)	72.40	19.75	4
Biomass			
Biogas	100.98	27.54	5
Wood (industrial)	104.15	28.41	5
Wood (residential)	104.15	28.41	5
Coal			
All sectors (sub-bituminous)	91.20	24.87	2
All sectors (bituminous)	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* (Eng et al, 2008)
3. Specific gas field operator
4. New Zealand Refinery Company
5. IPCC guidelines (1996)

Table A2.2 IPCC (1996) CH_4 emission factors used for New Zealand's energy sector for 1990 to 2008

	Emission factor t CH_4/PJ	Source
Natural gas		
Electricity – boilers	0.09	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 (compressed natural gas)	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 – liquid petroleum gas	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 – liquid petroleum gas	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 – liquid petroleum gas	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		
Liquid petroleum gas	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
Biogas	1.08	IPCC Tier 2 (Table 1–19) gas boilers

Table A2.3 IPCC (1996) N_2O emission factors used for New Zealand's energy sector for 1990 to 2008

	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 (compressed natural gas)	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
Liquid petroleum gas (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		
Liquid petroleum gas	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 has a ±5 per cent uncertainty associated with the sectoral energy allocation. However, certainty is likely to be greater for the annual totals (Ministry of Economic Development, 2006).

As the survey is run as a census there is no sampling error. The two main sources of non-sample error are the respondent and the processing error explained below.

- Respondent error: The Ministry of Economic Development makes every effort to confirm values supplied by respondents, and given assurances of accuracy. Statistics New Zealand is bound to accept them. If a discrepancy is discovered at a later date, revised values are supplied at the earliest possible opportunity.
- Processing error: The Ministry of Economic Development has thorough checking procedures to ensure that the risk of processing errors is minimised.

A2.1.2 Emission factors and uncertainties

Carbon dioxide emission factors are described in Table A2.1. The CO_2 emission factors for oil products are from the New Zealand Refining Company, import data from industry and from Eng et al (2008). The New Zealand Refining Company estimates a ±5 per cent uncertainty in emission factors (Ministry of Economic Development, 2006).

A2.2 Emissions from solid fuels

A2.2.1 Activity data and uncertainties

The *Quarterly Statistical Return of Coal Production and Sales* conducted by the Ministry of Economic Development on behalf of Statistics New Zealand is an ongoing quarterly survey. The survey began in 1981. The survey is a full coverage of the sector and, therefore, has no sampling errors. Non-sampling errors in the survey data may result from errors in the sample frame (eg, units with the incorrect Australian New Zealand Standard Industrial Classification), respondent error (eg, incorrect values supplied) and errors made during processing survey results or non-response imputation. The Ministry of Economic Development adopts procedures to detect and minimise these potential errors.

The process of dividing coal use between different sectors will introduce greater uncertainty than the uncertainty in total coal sales. Uncertainty is also introduced from the assumption that coal used by sector is an average of the different ranks. These assumptions are thought to introduce an uncertainty of ±5 per cent (Ministry of Economic Development, 2006).

The sectoral partitioning used for coal was examined in 2003 by the Ministry for the Environment. There was concern in extrapolating sectoral allocations from 1995 to 2002 given some probable changes in sectoral coal usage. However, New Zealand coal industry experts did not consider a survey could be justified because of the difficulty and expense in collating and verifying data from a number of sectors. In addition, the major categories of coal exports, coal used by the residential sector and coal used for steel production and electricity generation are all known accurately and are not affected by the sectoral partitioning. In 2009, the Ministry of Economic Development took over the *New Zealand Coal Sales and Production Quarterly Survey*. Prior to 2009, when Statistics

New Zealand ran the survey, seven sectors were used. The survey now splits coal sold into over 20 sectors using the Australian and New Zealand Standard Industry Classification 2006 classification (Australian Bureau of Statistics and Statistics New Zealand, 2006).

A2.2.2 Emission factors and uncertainties

The CO_2 emission factors for coal are shown in Table A2.1. The non-CO_2 emission factors are shown in Tables A2.2 and A2.3. The estimated uncertainty in coal emission factors is ±3 per cent (Ministry of Economic Development, 2006). An uncertainty of ±2 per cent is used for the sub-bituminous coal used in public electricity generation. All New Zealand emissions' factors are ±2 per cent of the IPCC (1996) default values.

A2.3 Emissions from gaseous fuels

A2.3.1 Activity data

Vector Limited, a gas transmission and distribution company, has contracts with large gas users that allow metering errors of ±2 per cent. Whenever the error between the meter reading and actual gas supplied exceeds 2 per cent, adjustments are made to the reported quantities of gas supplied. Consequently, uncertainty is assumed to have an upper limit of ±2 per cent (Ministry of Economic Development, 2006).

A2.3.2 Emission factors

As discussed in section 3.3, New Zealand now uses the gas production of all fields to support the calculation of a weighted average annual CO_2 emission factor for natural gas. This average emission factor is applied to a number of categories in the energy sector, such as the manufacturing industries and construction category.

The emission factors for each gas stream are shown in Table A2.1. The CO_2 emission factors for distributed gas are shown in Table A2.4.

This is calculated based on all the gas production fields (Ministry of Economic Development, 2009b).

Table A2.4 Variation in New Zealand's CO_2 emission factors for distributed natural gas (before oxidation)

Year	National average (kt CO_2/PJ)
1990	52.96
1991	52.98
1992	52.93
1993	52.69
1994	52.52
1995	52.34
1996	52.49
1997	52.50
1998	52.46
1999	52.10
2000	52.28
2001	52.50
2002	52.66
2003	52.61
2004	52.72
2005	52.71
2006	52.76
2007	53.49
2008	53.59

A2.4 Energy balance for year ended December 2008

Table A2.5 New Zealand energy balance for year ended December 2008 (Ministry of Economic Development, 2009b)

Energy Supply and Demand Balance December Year 2008

Converted into Petajolues using Gross Calorific Values	COAL					OIL								GAS	RENEWABLES							ELEC-TRICITY	WASTE HEAT	TOTAL
	Bitum.	Sub-bitum.	Bituminous & Sub-bitum.	Lignite	Total	Crudes/ Feedstocks	LPG/ NGL	Petrol	Diesel	Fuel Oil	Av. Fuel/ Kero	Others	Total	Natural Gas	Hydro	Geo-thermal	Solar	Wind	Biogas	Wood	Total			
Indigenous Production	75.78	47.89	123.67	3.80	127.47	127.62	4.24						131.85	159.93	80.32	113.21	0.32	3.81	2.87	40.42	240.95		1.21	661.41
+ Imports	2.86	11.19	14.06	0.00	14.06	223.72	5.00	40.21	38.00	1.75	11.78	7.28	327.74											341.80
- Exports	78.51		78.51	0.00	78.51	119.83	0.00	1.31	0.01	7.78	0.00	0.00	128.94											207.45
- Stock Change			-17.38		-17.38	-2.41	0.04	-0.23	-1.39	3.16	1.72	-0.37	0.52	-0.01										-16.87
- International Transport								0.00	1.47	13.46	37.33	0.01	52.27											52.27
TOTAL PRIMARY ENERGY	0.13	59.08	76.60	3.80	80.40	233.92	9.19	39.12	37.91	-22.65	-27.27	7.64	277.86	159.94	80.32	113.21	0.32	3.81	2.87	40.42	240.95		1.21	760.36
ENERGY TRANSFORMATION			-59.07		-59.07	-234.13	-0.55	69.64	75.54	29.66	41.00	5.17	-13.67	-89.76	-80.32	-103.45		-3.81	-2.59	-4.42	-194.59	137.29	-1.21	-220.99
Electricity Generation			-43.09		-43.09									-60.76	-80.32	-96.20		-3.81	-1.83		-182.16	146.08		-139.94
Cogeneration			-9.29		-9.29									-23.12		-1.25			-0.76	-4.42	-6.43	11.51	-1.21	-28.54
Oil Production						-234.13		70.62	74.31	29.65	41.40	13.22	-4.93											-4.93
Other Transformation			-6.66		-6.66																	0.00		-6.66
Losses and Own Use			-0.03		-0.03		-0.55	-0.98	1.23	0.01	-0.39	-8.05	-8.74	-5.87		-6.00					-6.00	-20.30		-40.93
Non-energy Use												-12.81	-12.81	-17.98										-30.79
CONSUMER ENERGY (calculated)			17.53	3.80	21.33		8.64	108.77	113.45	7.01	13.73	0.00	251.38	52.20		9.76	0.32	0.00	0.28	36.00	46.36	137.29	0.00	508.57
Agriculture			1.73	0.01	1.74			0.81	7.60	1.85	0.15		10.41	1.62								6.78		20.54
Agriculture and Hunting			1.73	0.01	1.74			0.80	5.68	0.00	0.15		6.63	1.62								6.31		16.30
Fishing								0.01	1.92	1.85	0.00		3.78									0.46		4.25
Industrial			14.67	4.08	18.75		2.61	3.55	14.97	2.05	0.11		23.28	37.06		5.81				28.25	34.06	53.31		166.46
Other Primary Industry								0.01	3.44	0.31	0.00		3.76	0.11								1.39		5.26
Food Processing								0.00	0.06	0.10	0.00		0.16	9.76								7.84		17.77
Textiles														0.63								0.55		1.18
Wood, Pulp, Paper and Printing														5.40								12.38		17.78
Chemicals														13.44								2.81		16.26
Non-metallic Minerals														1.56								0.94		2.50
Basic Metals									0.00					3.11								22.96		26.07
Mechanical/Electrical Equipment														0.54								0.90		1.44
Building and Construction								0.01	2.06	0.01	0.05		2.13	0.11								0.78		3.02
Unallocated			14.67	4.08	18.75		2.61	3.54	9.41	1.62	0.06		17.23	2.40		5.81				28.25	34.06	2.75		75.19
Commercial			4.06	0.55	4.61		3.46	1.15	29.42	4.34	14.46		52.84	4.40		3.86			0.28	0.00	4.14	33.35		99.34
Transport Industry			0.08		0.08		1.70	0.68	25.27	4.07	13.86		45.58	0.15								1.92		47.73
Other Commercial			3.98	0.55	4.53		1.76	0.47	4.15	0.27	0.60		7.26	4.25		3.86			0.28		4.14	31.43		51.61
Residential			0.15	0.22	0.36		2.56	0.00	0.01	0.00	0.00		2.57	5.38		0.10	0.32			7.75	8.17	44.76		61.24
Unallocated								105.44	57.83	0.00	0.06		163.34											163.34
CONSUMER ENERGY (observed)			20.62	4.85	25.46	0.00	8.64	110.96	109.82	8.25	14.78	0.00	252.44	48.46	0.00	9.76	0.32	0.00	0.28	36.00	46.36	138.20	0.00	510.93
Statistical Differences			-3.08	-1.04	-4.13		0.00	-2.19	3.63	-1.24	-1.05	0.00	-1.06	3.74		0.00	0.00		0.00	0.00	0.00	-0.91	0.00	-2.36

A2.5 Fuel Flow Diagrams for year ended December 2008

Figure A2.1 New Zealand coal energy flow summary for 2008

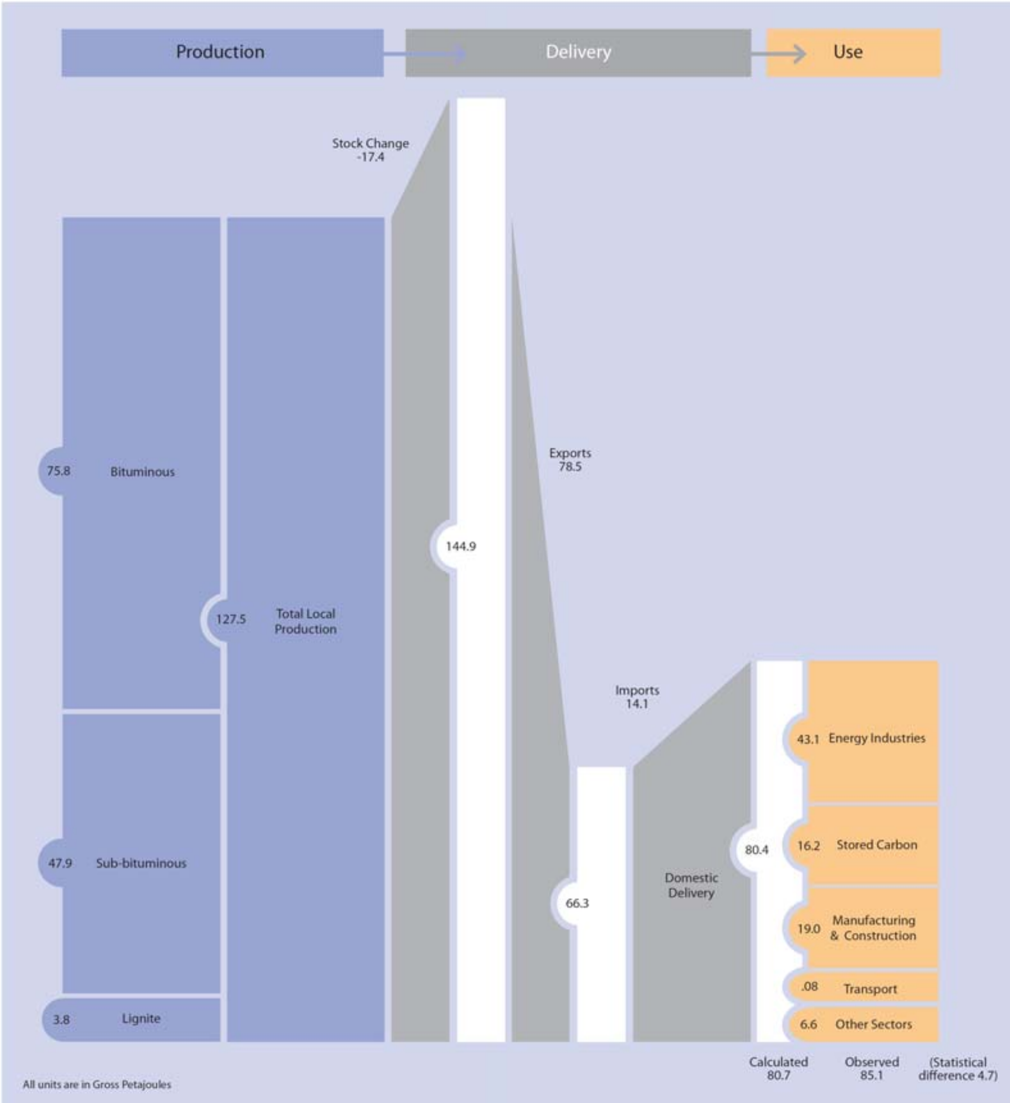
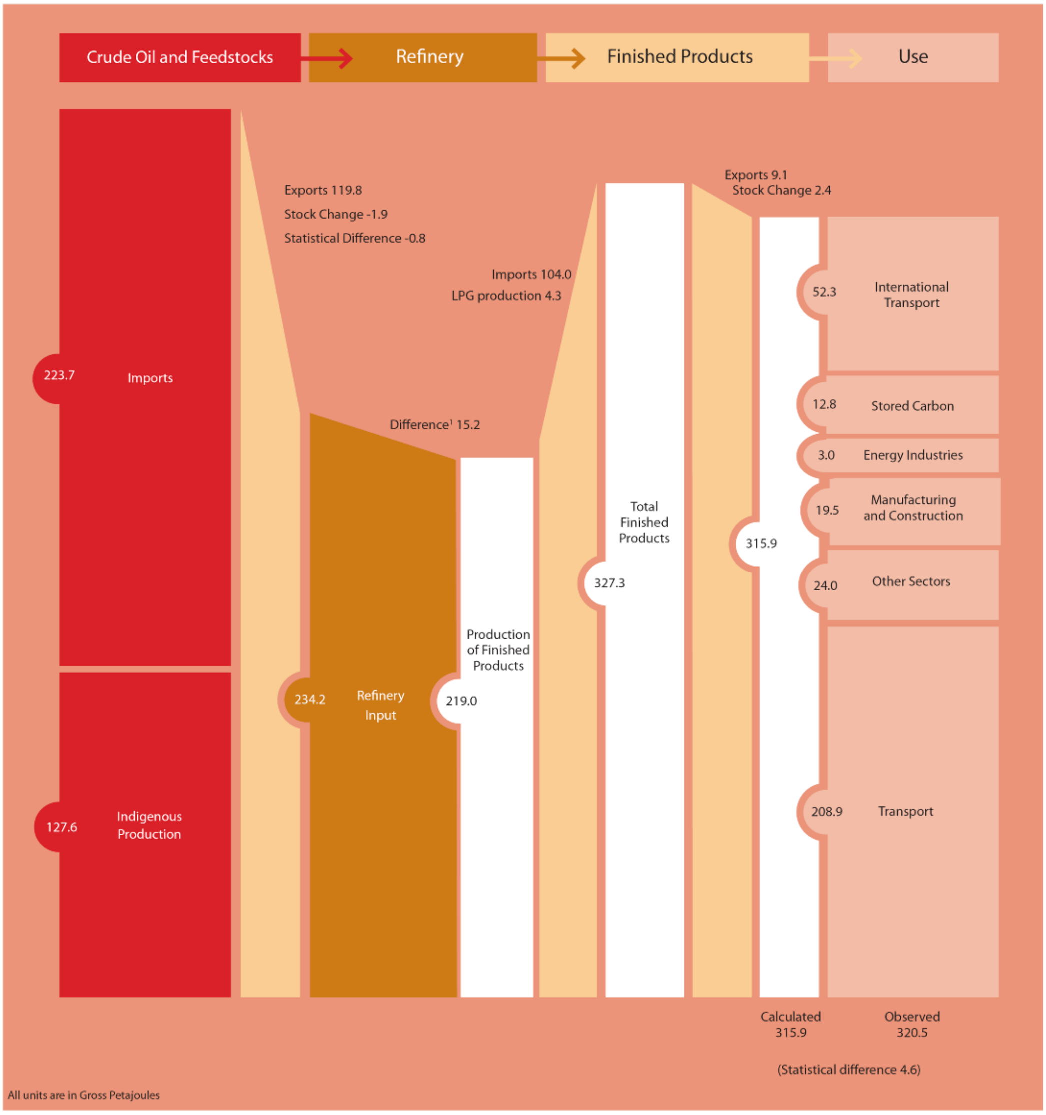
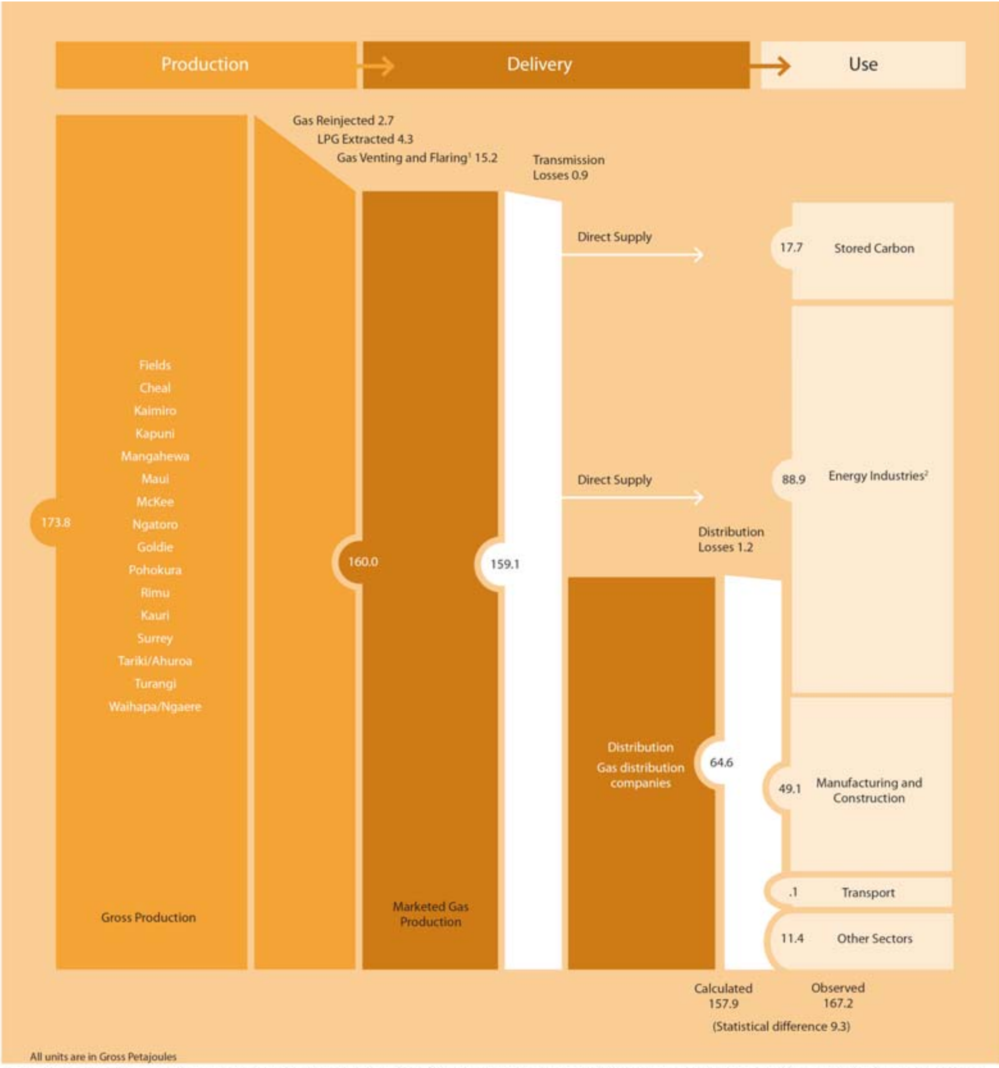


Figure A2.2 New Zealand oil energy flow summary for 2008



1 This 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 A2.3 New Zealand gas energy flow summary for 2008



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 *2008 Agricultural Production Survey* were all units that were engaged in agricultural production activity (including livestock, cropping, horticulture and forestry) or that owned land that was intended for agricultural activity during the year ended 30 June 2008. The response rate was 84 per cent. These businesses represent 85 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 *2008 Agricultural Production Survey* are provided in Table A3.1.1.

The *2008 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 *2008 Agricultural Production Survey*

Statistic	Proportion of total estimate imputed (%)	Sample error (%)
Ewe hoggets put to ram	24	7
Breeding ewes, 2 tooth and over	18	2
Total number of sheep	19	2
Lamb born to ewe hoggets	18	6
Lambs born to ewes	18	2
Beef cows and heifers (in calf) 2 years and over	18	3
Beef cows and heifers (in calf) 1–2 years	20	5
Total number of beef cattle	19	2
Calves born alive to beef heifers/cows	18	2
Dairy cows and heifers, in milk or calf	23	3
Total number of dairy cattle	23	2
Calves born alive to dairy heifers/cows	24	3
Female deer mated	15	5
Total number of deer	16	4
Fawns born on farm and alive at 4 months	16	4
Area of wheat harvested	25	11
Area of barley harvested	21	8

A3.1.2 Key parameters and emission factors used in the agricultural sector

Table A3.1.2.1 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

Parameter (fraction)	Fraction of the parameter	Source	Parameter value
$Frac_{NCR0}$ (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 A3.1.2.2 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 AWMS	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 AWMS	IPCC (2000) Table 4.12	0.02
EF_{3PRP} (kg N_2O-N/kg N excreted)	Direct emissions from waste in the pasture range and paddock AWMS	Carran et al (1995); Muller et al (1995); de Klein et al (2003)	0.01
EF_{3OTHER} (kg N_2O-N/kg N excreted)	Direct emissions from waste in other AWMSs	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 A3.1.2.3 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)

Systems

The data collected as part of LUCAS is stored and manipulated within three systems: the Geospatial System, the Gateway and the Calculation and Reporting Application (CRA).

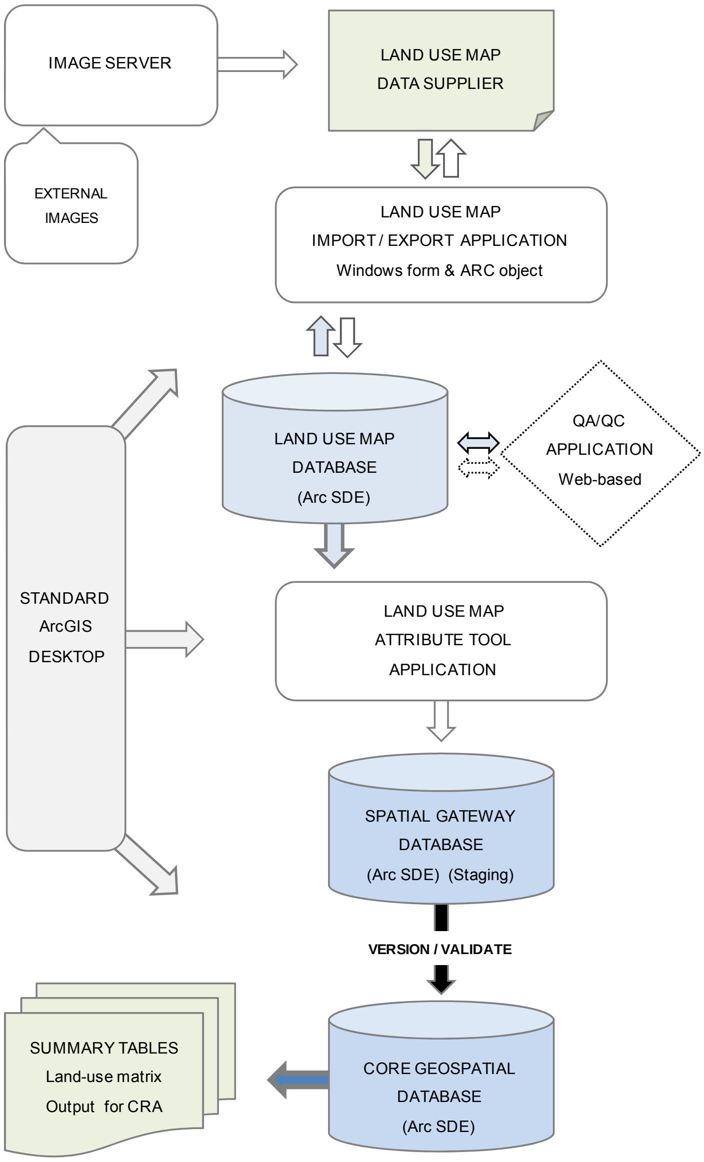
The key objectives of these systems are to:

- 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.

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 A3.2.2.1 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 three 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.

The Gateway

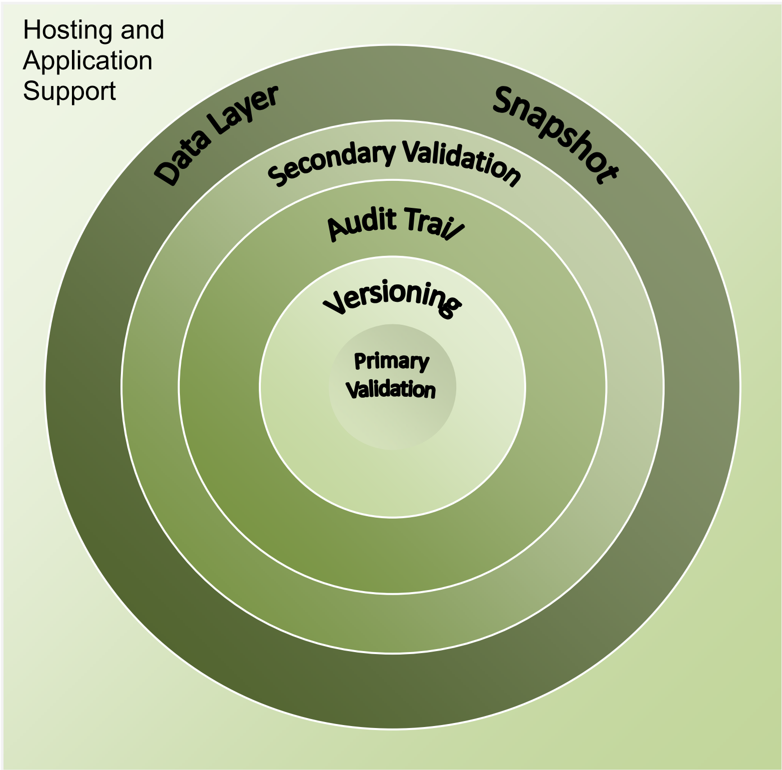
A key component of the LUCAS programme is the Gateway database. The Gateway enables the storage of field collected, land-use area, biomass burning, liming and other data, such as IPCC defaults, needed by the CRA.

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 CRA.

All survey data is stored within the Gateway database and is broken down into layers (Figure A3.2.2.2).

- A data layer contains all survey 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 CRA to select from a range of data snapshots and also ensures that past results can be replicated over time.
- A secondary validation layer allows users to judge the suitability of data for use in the CRA 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 CRA 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 that only data that has passed acceptability criteria are available for a publishable CRA run.
- Hosting and application support provides hosting services, system security, backup and restore, daily maintenance and monitoring for the Gateway and CRA.

Figure A3.2.2.2 The layers of New Zealand's LUCAS Gateway database

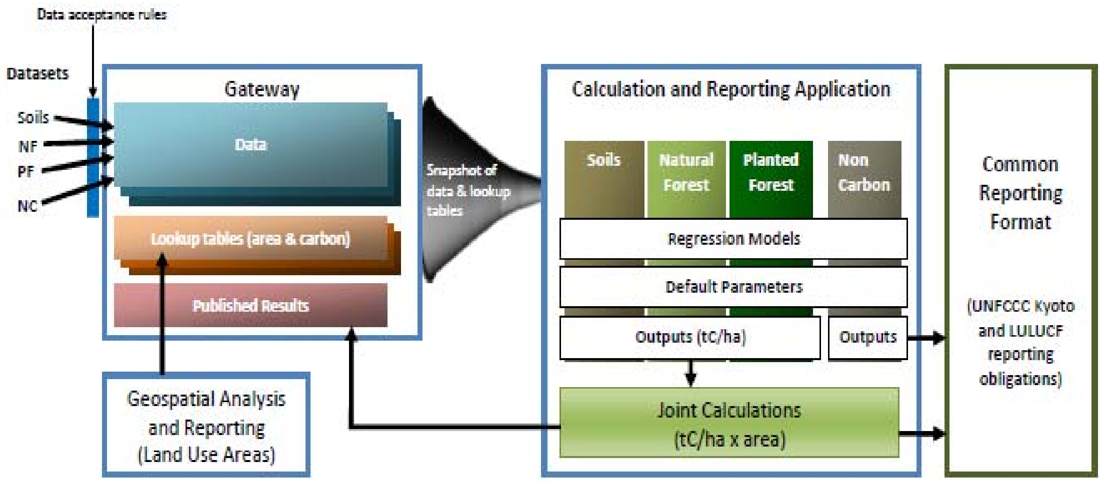


Calculation and Reporting Application

The Calculation and Reporting Application (CRA) enables users to import carbon and non-carbon data from the Gateway and, by running the various modules, determines 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 CRA is built to have enough flexibility to allow 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 CRA 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 CRA application is deployed as a client-based application that sources the required data from the Gateway.

Figure A3.2.2.3 Interaction between New Zealand's Gateway and CRA



Note: Soils, NF, PF and NC refer to the soils, natural forest, planted forest (pre-1990 planted and post-1989) and non-carbon datasets. The IPCC default emission factors are also an input.

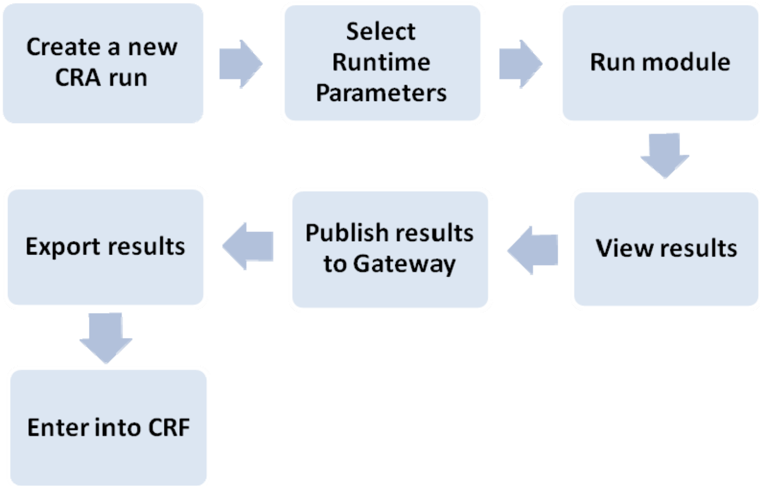
There are five modules that comprise the CRA: natural forest, planted forest, soils, non-carbon and joint calculations. Any of these modules can be run independently or as a group. The results are provided as 'views' to the user at the completion of the run.

To activate the module, the user selects the module to run within the CRA, 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 A3.2.2.4 How New Zealand used the CRA for entry into the common reporting format database



The CRA application is maintained and supported by Interpine Forestry Limited, a New Zealand-based company that specialises in forestry inventories and related IT development. Interpine is contracted to provide hosting of the Gateway and CRA application in a secure environment. Interpine also provides general support services such as back ups and system security (firewalls and virus control), day-to-day issue resolution and enhancement projects to the Gateway or the CRA as required.

Any changes to the data or table structure within the Gateway, or to people accessing the Gateway or CRA, 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.

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 and A7.2, 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, that is, “since 1990, gross emissions have gone up by 23 per cent ±5.5 per cent”. 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 The uncertainty calculation (including LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2008* (IPCC Tier 1)

IPCC source category	Gas	Base year emissions or absolute value of removals	Year t 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 year t	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 sector	CO_2	22,139.7	32,636.2	5	0	5.0	1.5	0.0786	0.3429	0.0000	2.4243	2.4	M	R	2.2798353	5.87740983
Industrial processes sector	CO_2	2,740.7	3,426.0	5	0	5.0	0.2	0.0033	0.0360	0.0000	0.2545	0.3	M	R	0.02512416	0.06477003
LULUCF sector - forest land	CO_2	33,200.4	29,768.9	6	9	10.8	3.0	-0.0830	0.3127	-0.7608	2.4988	2.6	M	R	8.80281466	6.8229487
LULUCF sector other land use categories	CO_2	1,162.9	3,603.2	5	38	37.8	1.3	0.0240	0.0379	0.8997	0.2507	0.9	M	R	1.58911279	0.87230322
CRF6C - w aste incineration	CO_2	12.9	0.9	10	40	41.2	0.0	-0.0001	0.0000	-0.0058	0.0001	0.0	D	D	1.2319E-07	3.336E-05
Energy sector	CH_4	745.8	939.4	5	50	50.2	0.4	0.0010	0.0099	0.0487	0.0698	0.1	D	R	0.1907687	0.00723769
CRF2A - mineral products	CH_4	0.0	0.0	0	0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0			0	0
CRF2B - chemical industry	CH_4	0.0	0.0	0	0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	R	0	0
CRF4A - enteric fermentation	CH_4	21,837.2	22,657.5	0	16	16.0	3.4	-0.0224	0.2380	-0.3581	0.0000	0.4	M	M	11.2519568	0.1282172
CRF4B - manure management	CH_4	579.1	719.5	5	100	100.1	0.7	0.0007	0.0076	0.0651	0.0534	0.1	M	M	0.44427395	0.00709224
CRF4E- prescribed burning	CH_4	2.7	0.9	20	60	63.2	0.0	0.0000	0.0000	-0.0014	0.0003	0.0	D	R	2.623E-07	2.0426E-06
CRF4F - burning of residues	CH_4	21.4	14.3	0	40	40.0	0.0	-0.0001	0.0002	-0.0042	0.0000	0.0	D	R	2.8208E-05	1.7387E-05
LULUCF sector	CH_4	48.0	38.2	8	56	56.1	0.0	-0.0002	0.0004	-0.0095	0.0044	0.0	R	R	0.00039398	0.00010945
CRF 6A - solid w aste disposal	CH_4	2,063.2	1,278.4	0	40	40.0	0.5	-0.0112	0.0134	-0.4470	0.0000	0.4	M	R	0.22389763	0.19981505
CRF 6B - w astew ater handling	CH_4	207.0	206.3	0	20	20.0	0.0	-0.0003	0.0022	-0.0060	0.0000	0.0	D	R	0.00145686	3.6392E-05
CRF6C - w aste incineration	CH_4	0.0	0.0	10	100	100.5	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D	1.12E-12	9.0471E-11
Energy sector	N_2O	157.3	263.2	5	50	50.2	0.1	0.0009	0.0028	0.0445	0.0196	0.0	D	R	0.01497783	0.00235965
Solvents - N_2O use	N_2O	41.5	31.0	10	0	10.0	0.0	-0.0002	0.0003	0.0000	0.0046	0.0	R		8.2279E-06	2.1211E-05
CRF4D - agricultural soils	N_2O	9,379.0	11,372.3	0	74	74.0	7.8	0.0076	0.1195	0.5622	0.0000	0.6	M	M	60.6356373	0.31611102
CRF4B - manure management	N_2O	38.1	56.9	5	100	100.1	0.1	0.0001	0.0006	0.0143	0.0042	0.0	R	R	0.0027773	0.00022376
CRF4E - prescribed burning	N_2O	0.5	0.2	20	60	63.2	0.0	0.0000	0.0000	-0.0003	0.0000	0.0	D	R	8.7532E-09	6.8163E-08
CRF4F - burning of residues	N_2O	7.4	4.7	0	40	40.0	0.0	0.0000	0.0000	-0.0015	0.0000	0.0	D	R	3.0858E-06	2.298E-06
LULUCF sector	N_2O	5.1	4.1	8	57	57.9	0.0	0.0000	0.0000	-0.0011	0.0005	0.0	R	R	4.7567E-06	1.3626E-06
CRF6B - w astew ater handling	N_2O	153.5	183.8	0	1200	1200.0	2.0	0.0001	0.0019	0.1205	0.0000	0.1	D	R	4.16472939	0.0145172
CRF6C - w aste incineration	N_2O	1.6	1.3	10	100	100.5	0.0	0.0000	0.0000	-0.0006	0.0002	0.0	D	D	1.406E-06	4.0142E-07
CRF2F	HFCs	0.0	812.5	0	26	25.9	0.2	0.0085	0.0085	0.2213	0.0000	0.2		R	0.03798484	0.04896241
CRF2C	PFCs	629.9	38.8	0	30	30.0	0.0	-0.0071	0.0004	-0.2131	0.0000	0.2	M	M	0.00011627	0.04541992
CRF2F	SF_6	15.2	14.5	0	24	24.0	0.0	0.0000	0.0002	-0.0007	0.0000	0.0	R	R	1.0427E-05	4.6896E-07
Total emissions/removals		**95,190.0**	**108,073.1**		**Uncertainty in the year**		**9.5%**		**Uncertainty in the trend**			**3.8%**			**89.665914**	**14.407612**

Table A7.2 The uncertainty calculation (excluding LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2008* (IPCC Tier 1)

IPCC source category	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as a % of the total emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in the trend in national totals introduced by emission factor uncertainty	Uncertainty in trend in national total introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions	Emission /removal factor quality indicator	Activity data quality indicator	column H^2 (Year t)	column M^2 (Trend)
Energy sector	CO_2	22,139.7	32,636.2	5	0	5	2.2	0.0892	0.5370	0.0000	3.7973	3.8	M	R	4.77724439	14.4191128
Industrial processes sector	CO_2	2,740.7	3,426.0	5	0	5	0.2	0.0010	0.0564	0.0000	0.3986	0.4	M	R	0.05264603	0.15890102
CRF6C - waste incineration	CO_2	12.9	0.9	10	40	41	0.0	-0.0002	0.0000	-0.0098	0.0002	0.0	D	D	2.5814E-07	9.6787E-05
Energy sector	CH_4	745.8	939.4	5	50	50	0.6	0.0004	0.0155	0.0191	0.1093	0.1	D	R	0.39974321	0.01231022
CRF2A - mineral products	CH_4	0.0	0.0	0	0	0	0.0	0.0000	0.0000	0.0000	0.0000	0.0			0	0
CRF2B - chemical industry	CH_4	0.0	0.0	0	0	0	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	R	0	0
CRF4A - enteric fermentation	CH_4	21,837.2	22,657.5	0	16	16	4.9	-0.0684	0.3728	-1.0936	0.0000	1.1	M	M	23.5777328	1.19604509
CRF4B - manure management	CH_4	579.1	719.5	5	100	100	1.0	0.0001	0.0118	0.0132	0.0837	0.1	M	M	0.93094674	0.00718144
CRF4E - prescribed burning	CH_4	2.7	0.9	20	60	63	0.0	0.0000	0.0000	-0.0025	0.0004	0.0	D	R	5.4963E-07	6.1812E-06
CRF4F - burning of residues	CH_4	21.4	14.3	0	40	40	0.0	-0.0002	0.0002	-0.0078	0.0000	0.0	D	R	5.9107E-05	6.1492E-05
CRF 6A - solid waste disposal	CH_4	2,063.2	1,278.4	0	40	40	0.7	-0.0207	0.0210	-0.8265	0.0000	0.8	M	R	0.4691627	0.68308507
CRF 6B - wastewater handling	CH_4	207.0	206.3	0	20	20	0.1	-0.0008	0.0034	-0.0158	0.0000	0.0	D	R	0.00305275	0.00024937
CRF6C - waste incineration	CH_4	0.0	0.0	10	100	100	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D	2.3469E-12	2.6482E-10
Energy sector	N_2O	157.3	263.2	5	50	50	0.2	0.0012	0.0043	0.0576	0.0306	0.1	D	R	0.03138505	0.0042555
Solvents - N_2O use	N_2O	41.5	31.0	10	0	10	0.0	-0.0003	0.0005	0.0000	0.0072	0.0			1.7241E-05	5.2038E-05
CRF4D - agricultural soils	N_2O	9,379.0	11,372.3	0	74	74	11.3	-0.0025	0.1871	-0.1818	0.0000	0.2	M	M	127.057976	0.03305271
CRF4B - manure management	N_2O	38.1	56.9	5	100	100	0.1	0.0002	0.0009	0.0166	0.0066	0.0	R	R	0.00581965	0.00032073
CRF4E- prescribed burning	N_2O	0.5	0.2	20	60	63	0.0	0.0000	0.0000	-0.0004	0.0001	0.0	D	R	1.8342E-08	2.0627E-07
CRF4F - burning of residues	N_2O	7.4	4.7	0	40	40	0.0	-0.0001	0.0001	-0.0028	0.0000	0.0	D	R	6.4661E-06	7.9827E-06
CRF6B - wastewater handling	N_2O	153.5	183.8	0	1200	1200	3.0	-0.0001	0.0030	-0.0935	0.0000	0.1	D	R	8.72691555	0.00873976
CRF6C - waste incineration	N_2O	1.6	1.3	10	100	100	0.0	0.0000	0.0000	-0.0012	0.0003	0.0	D	D	2.9461E-06	1.5203E-06
CRF2F	HFCs	0.0	812.5	0	26	26	0.3	0.0134	0.0134	0.3466	0.0000	0.3		R	0.07959472	0.12012001
CRF2C	PFCs	629.9	38.8	0	30	30	0.0	-0.0121	0.0006	-0.3628	0.0000	0.4	M	M	0.00024363	0.13158884
CRF2F	SF_6	15.2	14.5	0	24	24	0.0	-0.0001	0.0002	-0.0016	0.0000	0.0	R	R	2.1849E-05	2.6622E-06
Total emissions/removals		**60,773.6**	**74,658.7**		**Uncertainty in the year**		**12.9%**		**Uncertainty in the trend**			**4.1%**			**166.11257**	**16.775191**