Ministry for the Environment
Manatū Mō Te Taiao

New Zealand’s Greenhouse Gas Inventory 1990–2010



This **errata notice** is to inform users that a small error has been identified in the net removals data in the land use, land-use change and forestry (LULUCF) sector and net removals from land subject to all activities under Article 3.3 of the Kyoto Protocol as reported in New Zealand’s national greenhouse gas inventory 1990–2010.

This error was identified as part of regular internal auditing and quality assurance activities conducted throughout the year.

The significance of the error is that the net removals reported in the LULUCF sector of New Zealand’s national greenhouse gas inventory 1990–2010 are slightly higher (by 4 per cent) than should have been reported. Similarly, net removals from land subject to all activities under Article 3.3 of the Kyoto Protocol reported in New Zealand’s national greenhouse gas inventory 1990–2010 for the years 2008, 2009 and 2010 are also slightly higher (by 4 per cent) than should have been reported.

The net emissions and removals under Article 3.3 of the Kyoto Protocol for 2010 in the environmental snapshot *New Zealand Greenhouse Gas Inventory and Net Position Report 1990–2010* have been corrected where possible using the estimate from the 2012 Net Position Report. Please refer to Table 1 (page 8) in the environmental snapshot at www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2012-snapshot/index.html for the corrected figures.

New Zealand’s official submission to the UNFCCC has not been changed, and can be found at: www.unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/6598.php

Identifying and correcting errors and implementing improvements for the next annual submission are an integral part of the inventory process. The error will be addressed for the next inventory submission (April 2013).

For further details on the error and our response, please visit http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2012/index.html

New Zealand Government

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

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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 United Nations Framework Convention on Climate Change (Climate Change Convention) and the Kyoto Protocol.

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

This submission includes a complete time series of emissions and removals from 1990 through to 2010 (the current inventory year) and supplementary information required for the Kyoto Protocol. Consistent with the Climate Change Convention reporting guidelines, each inventory report is submitted 15 months after conclusion of the calendar year reported, allowing time for data to be collected and analysed.

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

ES.2 National trends

Total (gross) emissions

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

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

1990–2010

In 1990, New Zealand's total greenhouse gas emissions were 59,797.2 Gg carbon dioxide equivalent (CO_2-e). In 2010, total greenhouse gas emissions had increased by 11,860.0 Gg CO_2-e (19.8 per cent) to 71,657.2 Gg CO_2-e (figure ES 2.1.1). Between 1990 and 2010, the average annual growth in total emissions was 0.9 per cent per year.

The four emission sources that contributed the most to this increase in total emissions were road transport, dairy enteric fermentation,[2] agricultural soils, and public electricity and heat production.

2009–2010

Between 2009 and 2010, New Zealand's total greenhouse gas emissions slightly increased by 174 Gg CO_2-e (0.2 per cent). The size of the overall increase is small because, although emissions from the industrial processes and agriculture sectors rose, there was a decrease in emissions from the energy sector.

The decrease in energy emissions is primarily due to a decrease in emissions from electricity generation. The three main drivers that led to the decrease in emissions from electricity generation, despite a 3 per cent growth in electricity generated, were:

- an increase in the supply of geothermal generation
- a preference for gas over coal at New Zealand's largest electricity generation plant
- higher inflows into the hydro lakes.

The continued increase in emissions from the consumption in hydrofluorocarbons (HFCs) and an increase in steel and aluminium production were the main drivers in the rise of emissions from industrial processes. The consumption of HFCs has been increasing 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. The production of aluminium and steel decreased in 2009 due to falling international prices for the product in the wake of the economic downturn, while in 2010 these industries showed a recovery in production. In addition to market prices, aluminium production in 2009 was affected by a transformer failure at the smelter.

The continued increase in the national dairy cattle population coupled with a favourable milk price led to the increase in agricultural emissions. The dairy industry is the main user of nitrogen fertiliser in New Zealand, therefore, with a favourable milk price, there was an increase in the sale and use of nitrogen fertiliser in 2010.

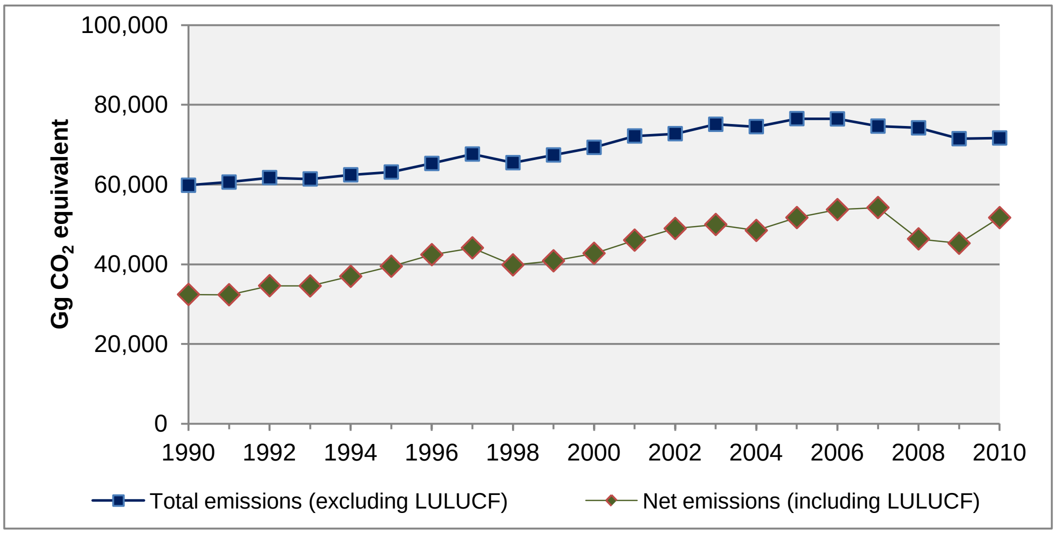
Net emissions – Climate Change Convention reporting

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

In 1990, New Zealand's net greenhouse gas emissions were 32,408.9 Gg CO_2-e. In 2010, net greenhouse gas emissions had increased by 19,267.8 Gg CO_2-e (59.5 per cent) to 51,676.7 Gg CO_2-e (figure ES 2.1.1).

[2] Methane emissions produced from ruminant livestock.

Figure ES 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2010



Accounting under the Kyoto Protocol

New Zealand's initial assigned amount under the Kyoto Protocol is recorded as 309,564,733 metric tonnes CO_2 equivalent (309,565 Gg CO_2-e). The initial assigned amount is five times the total 1990 emissions reported in the inventory submitted as part of *New Zealand's Initial Report under the Kyoto Protocol*.[3] The initial assigned amount does not change during the first commitment period (2008–2012) of the Kyoto Protocol. In contrast, the time series of emissions reported in each inventory submission are subject to continuous improvement. Consequently, the total emissions in 1990 as reported in this submission are 3.5 per cent lower than the 1990 level of 61,912.9 Gg CO_2-e, which was estimated in 2006 and used in the initial assigned amount calculation.

In 2010, net removals were 18,307.1 Gg CO_2-e from land subject to afforestation, reforestation and deforestation (see section ES.5 for further detail). The accounting quantity for 2010 was −18,462.5 Gg CO_2-e. This is different from net removals as debits resulting from harvesting of afforested and reforested land during the first commitment period are limited to the level of credits received for that land.

ES.3 Gas trends

The relative proportions of greenhouse gases emitted by New Zealand have changed since 1990. Whereas CH_4 and CO_2 contributed equally to New Zealand's total emissions in 1990, in 2010, CO_2 was the major greenhouse gas in New Zealand's emissions profile (table ES.3.1.1). This growth in emissions of CO_2 corresponds with growth in emissions from the energy sector.

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

Table ES 3.1.1 New Zealand's total (gross) emissions by gas in 1990 and 2010

Direct greenhouse gas emissions	Gg CO_2 equivalent 1990	2010	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
CO_2	25,014.1	33,199.2	+8,185.2	+32.7
CH_4	25,826.5	26,855.1	+1,028.7	+4.0
N_2O	8,311.6	10,454.7	+2,143.1	+25.8
HFCs	NO	1,087.2	+1,087.2	NA
PFCs	629.9	40.8	–589.1	–93.5
SF_6	15.2	20.2	+5.0	+32.6
Total	**59,797.2**	**71,657.2**	**+11,860.0**	**+19.8**

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

ES.4 Sector trends

Although the agriculture sector contributed the largest proportion of total emissions in 2010 (table ES.4.1.1 and figure ES.4.1.1), the proportion of emissions from the agriculture sector has generally been decreasing since 1990, while the proportion of emissions from the energy sector has been increasing (figure ES.4.1.2). For the first time in 2008, energy was the largest contributing sector to total emissions (agriculture had the greater proportion in 2009, 2010 and 2011). The energy sector has experienced the greatest increase over the period 1990–2010 (figure ES.4.1.3). Energy emissions have increased approximately two-and-a-half times as much as those from the agriculture sector. The energy sector has had the most influence on the trend in total emissions between 1990 and 2010 (figure ES.4.1.4). In 2010, the total effect of emission changes was also influenced by emission changes from the industrial processes and agriculture sectors.

Energy (chapter 3)

2010

The energy sector was the source of 31,107.8 Gg CO_2-e (43.4 per cent) of total emissions in 2010. The largest sources of emissions in the energy sector were road transport, contributing 12,514.1 Gg CO_2-e (40.2 per cent), and public electricity and heat production, contributing 5,374.9 Gg CO_2-e (17.0 per cent) to energy emissions.

1990–2010

In 2010, energy emissions had increased by 7,649.4 Gg CO_2-e (32.6 per cent) from the 1990 level of 23,458.4 Gg CO_2-e. This growth in emissions is primarily from road transport, which increased by 4,973.8 Gg CO_2-e (66.0 per cent), and electricity generation and heat production, which increased by 1,907.0 Gg CO_2-e (55.0 per cent).

2009–2010

Between 2009 and 2010, emissions from the energy sector decreased by 487.0 Gg CO_2-e (1.5 per cent). This decrease is primarily due to a decrease in emissions from public electricity and heat production. The three main drivers that led to the decrease in emissions from electricity generation, despite a 3 per cent growth in electricity generated, were:

- an increase in the supply of geothermal generation
- a preference for gas over coal at New Zealand's largest electricity generation plant
- higher inflows into the hydro lakes.

Industrial processes (chapter 4)

2010

The industrial processes sector contributed 4,778.1 Gg CO_2-e (6.7 per cent) of total emissions in 2010. The largest source of emissions was from iron and steel production, which contributed 1,646.9 Gg CO_2-e (34.5 per cent) to the industrial processes sector.

1990–2010

Emissions from the industrial processes sector increased 1,389.3 Gg CO_2-e (41.0 per cent) from the 1990 level of 3,388.8 Gg CO_2-e. This increase was mainly caused by growth in emissions from the consumption of HFCs. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol.

2009–2010

Between 2009 and 2010, emissions from the industrial processes sector increased by 427.7 Gg CO_2-e (9.8 per cent). The main emission sources that drove this increase were the consumption of HFCs and steel and aluminium production.

Solvent and other product use (chapter 5)

In 2010, the solvent and other product use sector was responsible for 31.0 Gg CO_2-e (0.04 per cent) of total emissions. The emission levels from the solvent and other products sector are negligible compared with other sectors.

Agriculture (chapter 6)

2010

The agriculture sector was the largest source of emissions in 2010, contributing 33,748.4 Gg CO_2-e (47.1 per cent) of total emissions. New Zealand has a unique emissions profile amongst developed countries. In most other developed countries, agricultural emissions are typically less than 10 per cent of total emissions.

The largest sources of emissions from the agriculture sector in 2010 were enteric fermentation from dairy cattle and sheep, and nitrous oxide emissions from agricultural soils.

1990–2010

In 2010, New Zealand's agricultural emissions increased by 2,893.2 Gg CO_2-e (9.4 per cent) from the 1990 level of 30,855.3 Gg CO_2-e. This increase is largely due to the increase in enteric fermentation emissions from dairy cattle and nitrous oxide emissions from agricultural soils.

2009–2010

Between 2009 and 2010, emissions from the agriculture sector increased 270.4 Gg CO_2-e (0.8 per cent). The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a favourable milk price there was an increase in both the dairy population and sale and use of nitrogen fertiliser in 2010.

There was also an increase in the sheep population; however, emissions from the increase in population were offset by a reduction in average sheep liveweight resulting in a small reduction in emissions from sheep.

LULUCF under the Climate Change Convention (chapter 7)

2010

In 2010, net removals from the LULUCF sector under the Climate Change Convention were 19,980.5 Gg CO_2-e. The highest contribution to removals in 2010 was from post-1989 forests, reported under land converted to forest land.

The largest source of emissions in LULUCF is from forest land remaining forest land. In 2010, net emissions for forest land remaining forest land contributed 6,450.7 Gg CO_2-e. This is largely due to the emissions from harvesting exceeding removals from growth of these forests during 2010.

1990–2010

Between 1990 and 2010, net removals from LULUCF decreased by 7,407.9 Gg CO_2-e (27.0 per cent) from the 1990 level of –27,388.3 Gg CO_2-e. This decrease in net removals is largely the result of increased harvesting and deforestation since 1990.

The fluctuations in net removals from LULUCF across the time series (figure ES 4.1.4) are influenced by harvesting and deforestation rates. Harvesting rates are driven by a number of factors particularly tree age and log prices. Deforestation rates are driven largely by the relative profitability of forestry compared with alternative land uses. The decrease in net removals between 2004 and 2007 was largely due to the increase in the planted forest deforestation that occurred leading up to 2008, before the introduction of the New Zealand Emissions Trading Scheme.[4] The high price of pastoral land between 2004 and 2008 also contributed to an increase in deforestation.

2009–2010

Between 2009 and 2010, net removals from LULUCF decreased by 6,253.6 Gg CO_2-e (23.8 per cent). This decrease in net removals is largely the result of an increase in harvesting of pre-1990 planted forest and increased new planting. New planting resulted in emissions due to a loss of biomass associated with the previous land use and a loss of soil carbon with the land-use change to forestry, outweighing removals by forest growth.

Waste (chapter 8)

The waste sector contributed 1,991.8 Gg CO_2-e (2.8 per cent) to total emissions in 2010. Emissions from the waste sector have decreased by 61.4 Gg CO_2-e (3.0 per cent) from the 1990 level of 2,053.2 Gg CO_2-e. This reduction occurred in the solid waste

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

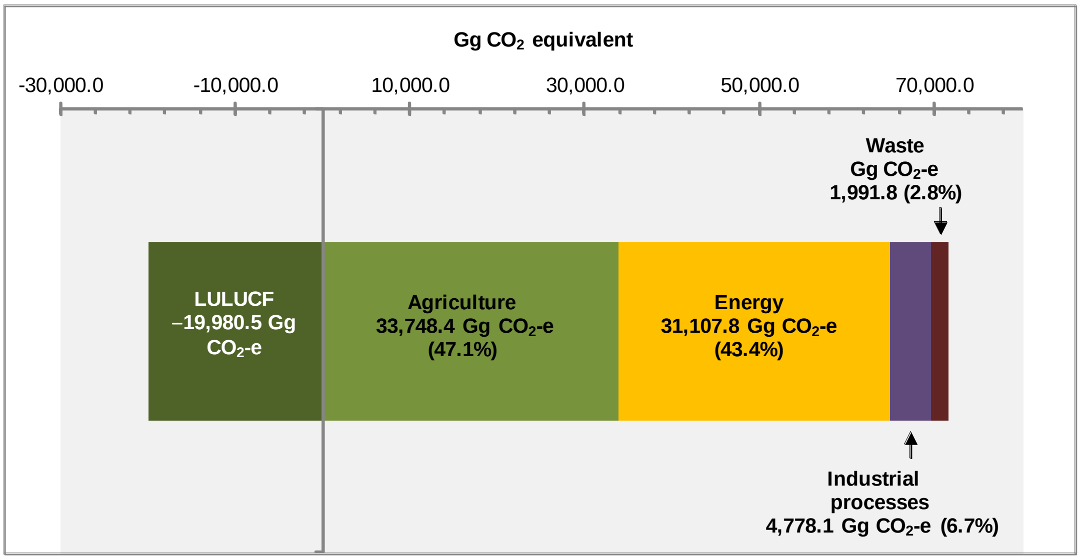
disposal on land category and is likely a result of initiatives to improve solid waste management practices.

Table ES 4.1.1 New Zealand's emissions by sector in 1990 and 2010

Sector	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2010	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
Energy	23,458.4	31,107.8	+7,649.4	+32.6
Industrial processes	3,388.8	4,778.1	+1,389.3	+41.0
Solvent and other product use	41.5	31.0	–10.5	–25.4
Agriculture	30,855.3	33,748.4	+2,893.2	+9.4
Waste	2,053.2	1,991.8	–61.4	–3.0
Total (excluding LULUCF)	**59,797.2**	**71,657.2**	**+11,860.0**	**+19.8**
LULUCF	–27,388.3	–19,980.5	+7,407.9	+27.0
Net Total (including LULUCF)	**32,408.9**	**51,676.7**	**+19,267.8**	**+59.5**

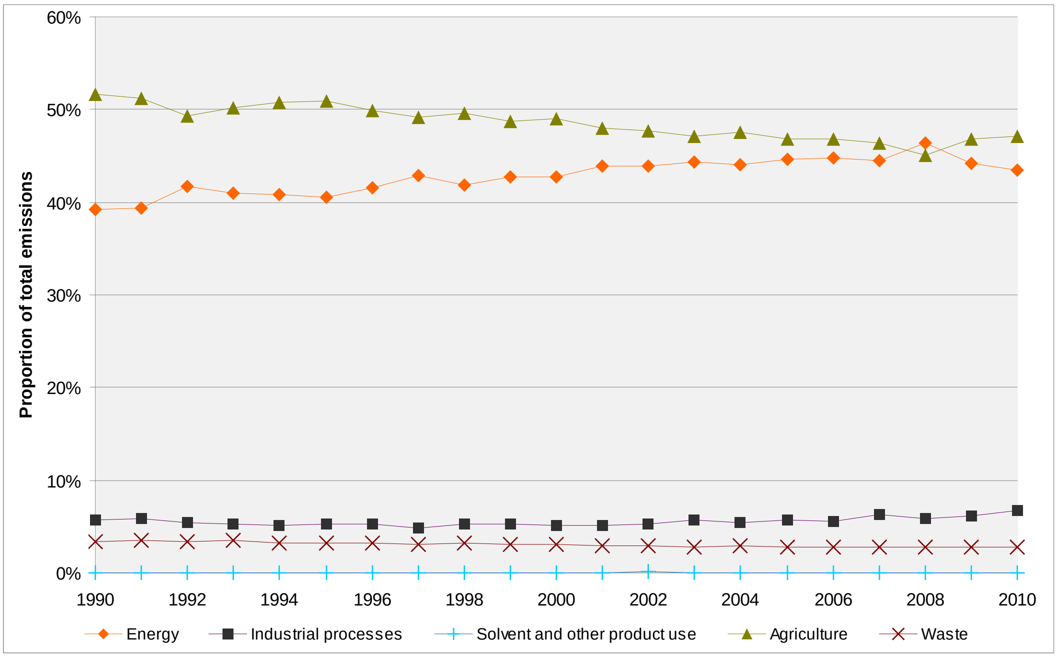
Note: Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 7). Columns may not total due to rounding.

Figure ES 4.1.1 New Zealand's emissions by sector in 2010



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

Figure ES 4.1.2 Proportion that sectors contributed to New Zealand's total emissions from 1990 to 2010



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

Figure ES 4.1.3 Change in New Zealand's emissions by sector in 1990 and 2010

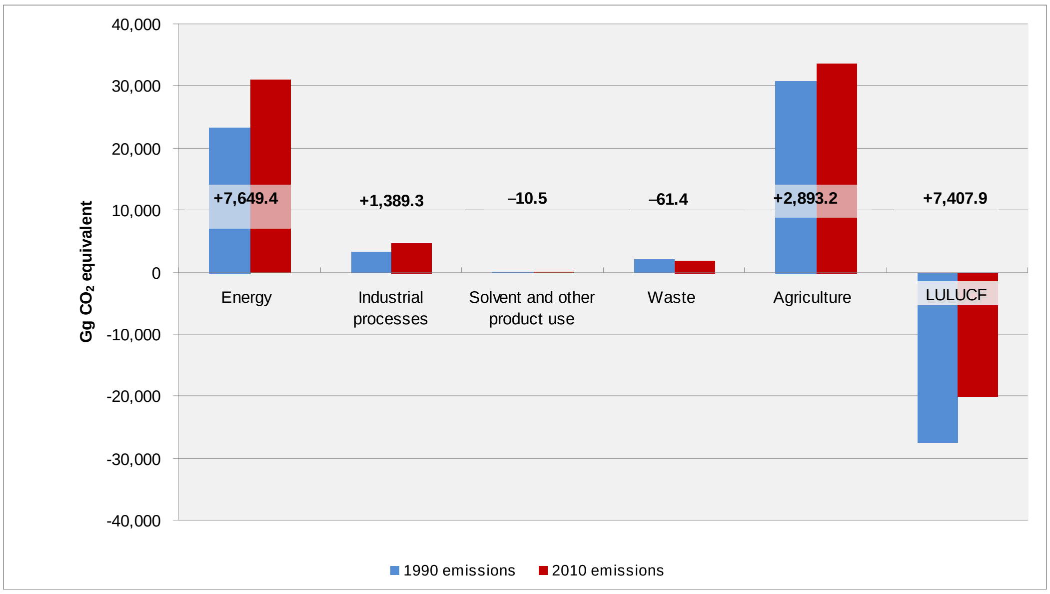
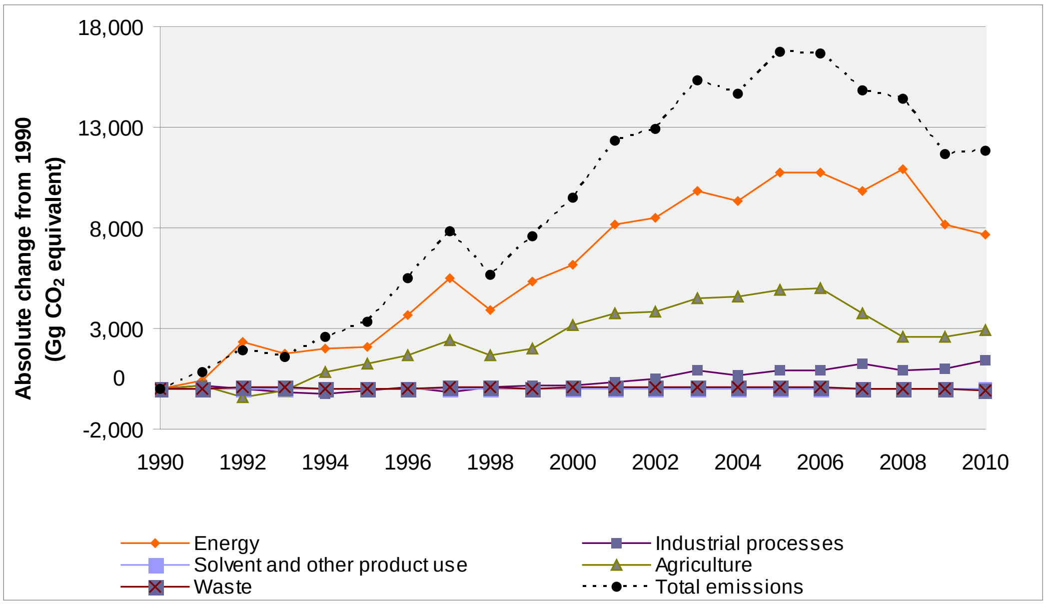


Figure ES 4.1.4 Absolute change from 1990 in New Zealand's total emissions by sector from 1990 to 2010



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

ES.5 Activities under Article 3.3 of the Kyoto Protocol

Estimates of removals and emissions under Article 3.3 of the Kyoto Protocol are included in the 2010 inventory (table ES 5.1.1).

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2010 was 593,821 hectares. The net area is the total area of post-1989 forest (611,149 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (17,327 hectares). Removals from this land in 2010 were 18,307.1 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2010 was 106,906 hectares. The area subject to deforestation in 2010 was 2,616 hectares. In 2010, deforestation emissions were 1,049.9 Gg CO_2-e, compared with 1,375.2 Gg CO_2-e in 2009 (a 23.6 per cent reduction). Deforestation emissions include non-carbon emissions and lagged CO_2 emissions that occurred in 2010 as a result of deforestation since 1990. Lagged emissions includes the liming of forest land converted to grassland and cropland, and the disturbance associated with forest land conversion to cropland.

Table ES 5.1.1 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, 2009 and 2010

Source	2008	2009	2010
Afforestation/reforestation			
Net cumulative area since 1990 (ha)	585,842	589,041	593,821
Area in calendar year (ha)	1,900	4,300	6,000
Removals in calendar year (Gg CO_2-e)	–19,132.6	–19,210.5	–19,357.0
Deforestation			
Cumulative area since 1990 (ha)	101,031	104,290	106,906
Area in calendar year (ha)	3,467	3,259	2,616
Emissions in calendar year (Gg CO_2-e)	1,573.3	1,375.2	1,049.9
Total area subject to afforestation, reforestation and deforestation since 1990 (ha)	686,873	693,331	700,727
Net removals (Gg CO_2-e)	–17,559.3	–17,835.3	–18,307.1

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

ES.6 Improvements introduced

The largest improvements in the accuracy of emissions and removals, made to *New Zealand's Greenhouse Gas Inventory* following the 2011 submission, were made in the LULUCF and agriculture sectors. Chapter 10 provides a summary of all recalculations made to the estimates. There was also a significant improvement made to deforestation estimates under Article 3.3 of the Kyoto Protocol.

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

LULUCF – Soils methodology (section 7.1.3)

This inventory has revised the approach for estimating emissions from mineral soils. In the previous inventory, a New Zealand-specific methodology was used that incorporated data on key factors that regulate mineral soil organic carbon stocks: land use, climate and soil class. For this inventory, an international default methodology is used. This change is because further development work to make the New Zealand-specific methodology acceptable to international reviewers is ongoing and was not ready in time to be used in this inventory. If these improvements are able to be made within the commitment period, we will return to using a New Zealand-specific methodology.

Deforestation area (sections 7.2.2 and 11.4)

The accuracy of the land-use change area has been improved in this submission. In the previous inventory, deforestation areas were mapped based on satellite imagery with a resolution of 22 metres. For this inventory, four areas, where most of the deforestation activity was detected in 2008 and 2009, were remapped using satellite imagery with

10-metre resolution. The improvement in mapping resolution affects only the estimates of deforestation in 2008 and 2009 and does not change emissions estimates for other years.

Liveweights for sheep and beef cattle (section 6.2.5)

This year, there have been a number of improvements to the Tier 2 model for estimating emissions from dairy and beef cattle and sheep. The improvements resulted in an increase in agricultural emissions across the time series, from an additional 890 Gg CO_2e in 2009 to an additional 800 Gg CO_2e in 1990. The most significant contributor to this recalculation was improving the estimate of the average liveweights of ewes and beef cows. The replacement rate[5] for beef cows was also improved. Consequently, New Zealand's agricultural emissions now more accurately reflect the actual liveweight of national breeding ewes and cows.

ES.7 National registry

In January 2008, New Zealand's national registry was issued with New Zealand's assigned amount of 309,564,733 metric tonnes of carbon dioxide equivalent (CO_2-e). At 31 December 2011, the registry held 306,248,485 assigned amount units. Of note during 2011, was that 3.9 million removal units were traded into New Zealand's national registry by a private entity. These removal units will not be part of the Crown account unless surrendered under the New Zealand Emissions Trading Scheme.

[5] The replacement rate is the number of beef cows estimated to be replaced each year by growing heifers.

Contents

Tables

Figures

General notes

Units

Standard metric prefixes used in this inventory are:

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

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

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

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

Gases

CO_2	carbon dioxide
CH_4	methane
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.[6]

The Climate Change Convention reporting requirements[7] stipulate that the 100-year global warming potentials contained in the IPCC Second Assessment Report are used in

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

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

national inventories.[8] 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,[9] indirect greenhouse gases that do not have global warming potentials are reported in the inventory but are not included in the inventory emissions total.

Common global warming potentials (100-year time period)

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

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

Conversion factors

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

Notation keys

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

NO Not occurring: when the activity or process does not occur in New Zealand.

NA Not applicable: when the activity occurs in New Zealand but the nature of the process does not result in emissions or removals.

NE Not estimated: where it is known that the activity occurs in New Zealand but there is no data or methodology available to derive an estimate of emissions. This can also apply to negligible emissions.

IE Included elsewhere: where emissions or removals are estimated but included elsewhere in the inventory. Table 9 of the common reporting format tables details the source category where these emissions or removals are reported.

C Confidential: where reporting of emissions or removals at a disaggregated level could lead to the disclosure of confidential information.

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

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

PART I: ANNUAL INVENTORY SUBMISSION

Chapter 1: Introduction

1.1 Background

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

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

1.1.1 The United Nations Framework Convention on Climate Change

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

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

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

All countries that ratify the Climate Change Convention (henceforth called 'Parties') are required to address climate change including monitoring trends in anthropogenic greenhouse gas emissions. The annual inventory of greenhouse gas emissions and removals fulfils this obligation. Parties are also obligated to protect and enhance carbon sinks and reservoirs, for example, forests, and implement measures that assist in national and/or regional climate change adaptation and mitigation. In addition, Parties listed in Annex II[10] to the Climate Change Convention commit to providing financial assistance to non-Annex I Parties (developing countries).

[10] 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[11] Parties that ratified the Climate Change Convention also agreed to non-binding targets, aiming to return greenhouse gas emissions to 1990 levels by the year 2000. Only a few Annex I Parties made appreciable progress towards achieving this aim. The international community recognised that the existing commitments in the Climate Change Convention were not enough to ensure greenhouse gas levels would be stabilised at a safe level. More urgent action was needed. In response, in 1995, Parties launched a new round of talks to provide stronger and more detailed commitments for Annex I Parties. After two-and-a-half years of negotiations, the Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997. New Zealand ratified the Kyoto Protocol on 19 December 2002. The Protocol came into force on 16 February 2005.

1.1.2 The Kyoto Protocol

The Kyoto Protocol shares and expands upon the Climate Change Convention's objective, principles and institutions. Only Parties to the Climate Change Convention that have also become Parties to the Protocol (by ratifying, accepting, approving or acceding to it) are bound by the Protocol's commitments. The objective of the Kyoto Protocol is to reduce the aggregate emissions of six greenhouse gases from Annex I Parties by at least 5 per cent below 1990 levels in the first commitment period (2008–2012). New Zealand's target is to return emissions to 1990 levels[12] on average over the commitment period or otherwise take responsibility for the excess.

A Party with a commitment under the Kyoto Protocol (as listed in Annex B of the Kyoto Protocol) must hold sufficient assigned amount units[13] to cover its total emissions during the first commitment period at the point that compliance is assessed after the end of the first commitment period. A Party's assigned amount comprises assigned amount units, removal units from land use, land-use change and forestry (LULUCF) activities under Article 3.3 or 3.4 activities of the Kyoto Protocol and any other units acquired under the flexibility mechanisms of the Kyoto Protocol. Flexibility mechanisms include the Clean Development Mechanism, Joint Implementation and the trading of assigned amount units between Annex I Parties. Further information on these mechanisms, review and compliance procedures can be obtained from the website of the Climate Change Convention (www.unfccc.int). The Kyoto Protocol compliance equation for the first commitment period is depicted in figure 1.1.1.

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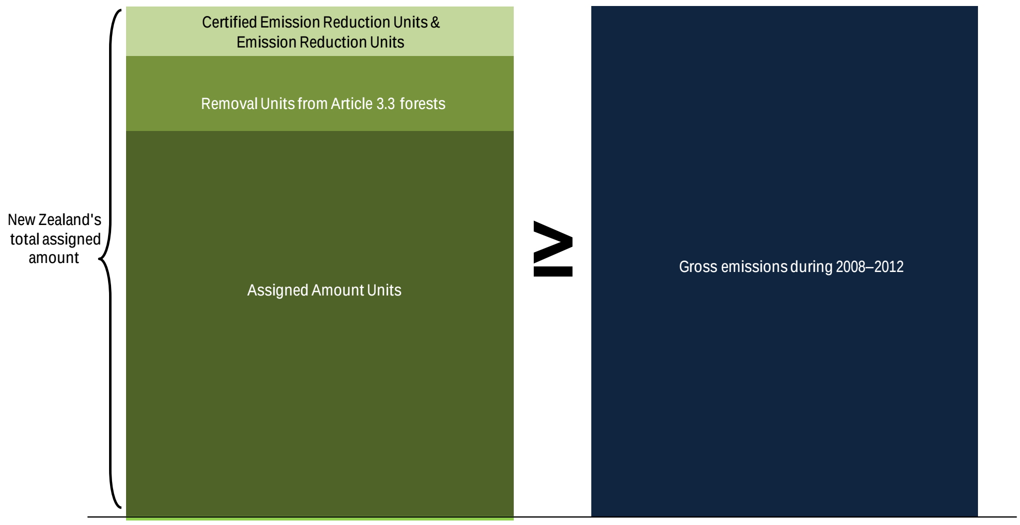
[11] Annex I to the Climate Change Convention lists the countries included in Annex II, as defined above, together with countries defined at the time as undergoing the process of transition to a market economy, commonly known as 'economies in transition'.

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

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

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



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

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

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

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

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

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

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

1.1.3 The inventory

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

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

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

1.1.4 Supplementary information required

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

The supplementary information required includes:

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

1.2 Institutional arrangements

1.2.1 Legal and procedural arrangements

The Climate Change Response Act 2002 (updated 5 December 2011) enables New Zealand to meet its international obligations under the Climate Change Convention and Kyoto Protocol. A Prime Ministerial directive for the administration of the Climate Change Response Act 2002 names the Ministry for the Environment as New Zealand's 'Inventory Agency'. Part 3, section 32 of the Climate Change Response Act 2002 specifies the following functions and requirements:

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

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

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

1.2.2 The national system

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

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

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

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

The Ministry of Agriculture and Forestry compiles emissions from the agriculture sector. Estimates are underpinned by the research and modelling undertaken at New Zealand's Crown research institutes and universities. The Ministry of Agriculture and Forestry provided data from the *National Exotic Forest Description* and from the New Zealand Emissions Trading Scheme (NZ ETS) on planting, harvesting and deforestation to the Ministry for the Environment's Land Use and Carbon Analysis System (LUCAS).

The Reporting Governance Group provides effective leadership over the reporting, modelling and projections of greenhouse gas emissions and removals. Membership includes representation from the Ministry for the Environment, Ministry of Agriculture and Forestry and the Ministry of Economic Development. The key roles and expectations of the Reporting Governance Group include:

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

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

The Climate Change Response Act 2002 (updated 5 December 2011) establishes the requirement for a registry and a registrar. The Environmental Protection Authority is designated as the agency responsible for the implementation and operation of New Zealand's national registry under the Kyoto Protocol, the New Zealand Emission

Unit Register. The registry is electronic and accessible via the internet (www.eur.govt.nz). Information on the annual holdings and transactions of transferred and acquired units under the Kyoto Protocol is provided in the standard electronic format tables accompanying this submission. Refer to chapter 12 for further information.

1.3 Inventory preparation processes

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

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

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

1.4 Methodologies and data sources used

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

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

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

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

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

Energy (chapter 3): Emissions from the energy sector are calculated using IPCC Tier 1 and 2 methods. Activity data is compiled from industry-supplied information by the Ministry of Economic Development. New Zealand-specific emission factors are used for all CO_2 emission calculations except for emissions from biogas, wood and wood waste. 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 most of the CO_2 emissions are supplied directly to the Ministry of Economic Development by industry sources. The remaining CO_2 estimates are either sourced from the New Zealand Emissions Unit Register or estimated by CRL Energy (2011). The IPCC Tier 2 approach is used and emission factors are New Zealand specific. Activity data for the non-CO_2 gases is collected via an industry survey. Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach, and SF_6 emissions from large users are estimated with the Tier 3a approach (IPCC, 2006a).

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

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

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

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

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

1.5 Key categories

1.5.1 Reporting under the Climate Change Convention

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

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

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

The key categories identified in the 2010 year are summarised in table 1.5.1. The major contributions to the level analysis including LULUCF (table 1.5.2(a)) were:

- CO_2 removals from conversion to forest land; a contribution of 26.9 per cent
- CH_4 emissions from dairy cattle enteric fermentation; a contribution of 8.8 per cent
- CH_4 emissions from sheep enteric fermentation; a contribution of 7.0 per cent
- CO_2 emissions from gasoline used in road transport; a contribution of 6.4 per cent.

The key categories that were identified as having the largest relative influence on the trend including LULUCF from 1990 to 2010, compared to the average change in net emissions from 1990 to 2010 (table 1.5.3(a)), were:

- CH_4 emissions from sheep enteric fermentation; contributed 22.0 per cent to the net emissions trend through a decrease
- CH_4 emissions from dairy cattle enteric fermentation; contributed 11.1 per cent to the net emissions trend through an increase
- CO_2 emissions from diesel oil road transportation; contributed 10.3 per cent to the net emissions trend through an increase

- CO_2 emissions from gaseous fuels used in the manufacture of solid fuels and other energy industries; contributed 5.5 per cent to the net emissions trend through a decrease.

Table 1.5.1 Summary of New Zealand's key categories for the 2010 level assessment and the trend assessment for 1990 to 2010 (including and excluding LULUCF activities)

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

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

Table 1.5.2 (a & b) 2010 level assessment for New Zealand's key category analysis including LULUCF (a) and excluding LULUCF (b)

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2010				
IPCC categories	**Gas**	**2010 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	29,992.1	26.9	26.9
Enteric fermentation – dairy cattle	CH_4	9,849.2	8.8	35.7
Enteric fermentation – sheep	CH_4	7,772.9	7.0	42.6
Transport – road transport – gasoline	CO_2	7,177.2	6.4	49.1
Forest land remaining forest land	CO_2	6,439.3	5.8	54.8
Agricultural soils – pasture, range and paddock	N_2O	5,649.6	5.1	59.9
Enteric fermentation – other	CH_4	5,518.5	4.9	64.8
Transport – road transport – diesel oil	CO_2	5,089.5	4.6	69.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	4,138.1	3.7	73.1
Agricultural soils – indirect emissions	N_2O	2,520.9	2.3	75.4
Grassland remaining grassland	CO_2	2,058.7	1.8	77.2
Manufacturing industries and construction – solid fuels	CO_2	1,925.0	1.7	78.9
Manufacturing industries and construction – gaseous fuels	CO_2	1,900.5	1.7	80.6
Agricultural soils – direct emissions	N_2O	1,734.7	1.6	82.2
Other sectors – liquid fuels	CO_2	1,726.4	1.5	83.7
Metal production – iron and steel production	CO_2	1,646.9	1.5	85.2
Solid waste disposal on land	CH_4	1,345.5	1.2	86.4
Energy industries – public electricity and heat production – solid fuels	CO_2	1,221.0	1.1	87.5
Manufacturing industries and construction – liquid fuels	CO_2	1,072.2	1.0	88.5
Conversion to grassland	CO_2	1,016.2	0.9	89.4
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,006.7	0.9	90.3
Transport – civil aviation – jet kerosene	CO_2	951.3	0.9	91.1
Energy industries – Petroleum refining – liquid fuels	CO_2	809.5	0.7	91.9
Fugitive emissions – flaring – combined	CO_2	803.1	0.7	92.6
Other sectors – gaseous fuels	CO_2	760.2	0.7	93.3
Manure management	CH_4	668.8	0.6	93.9
Fugitive emissions – geothermal	CO_2	642.2	0.6	94.4
Mineral products – cement production	CO_2	582.0	0.5	94.9
Metal production – aluminium production	CO_2	575.0	0.5	95.5

(b) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2010				
IPCC categories	**Gas**	**2010 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Enteric fermentation – dairy cattle	CH_4	9,849.2	13.7	13.7
Enteric fermentation – sheep	CH_4	7,772.9	10.8	24.6
Transport – road transport – gasoline	CO_2	7,177.2	10.0	34.6
Agricultural soils – pasture, range and paddock	N_2O	5,649.6	7.9	42.5
Enteric fermentation – other	CH_4	5,518.5	7.7	50.2
Transport – road transport – diesel oil	CO_2	5,089.5	7.1	57.3
Energy industries – public electricity and heat production – gaseous fuels	CO_2	4,138.1	5.8	63.1
Agricultural soils – indirect emissions	N_2O	2,520.9	3.5	66.6
Manufacturing industries and construction – solid fuels	CO_2	1,925.0	2.7	69.3
Manufacturing industries and construction – gaseous fuels	CO_2	1,900.5	2.7	71.9
Agricultural soils – direct emissions	N_2O	1,734.7	2.4	74.3
Other sectors – liquid fuels	CO_2	1,726.4	2.4	76.8
Metal production – iron and steel production	CO_2	1,646.9	2.3	79.1
Solid waste disposal on land	CH_4	1,345.5	1.9	80.9
Energy industries – public electricity and heat production – solid fuels	CO_2	1,221.0	1.7	82.6
Manufacturing industries and construction – liquid fuels	CO_2	1,072.2	1.5	84.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,006.7	1.4	85.5
Transport – civil aviation – jet kerosene	CO_2	951.3	1.3	86.9
Energy industries – Petroleum refining – liquid fuels	CO_2	809.5	1.1	88.0
Fugitive emissions – flaring – combined	CO_2	803.1	1.1	89.1
Other sectors – gaseous fuels	CO_2	760.2	1.1	90.2
Manure management	CH_4	668.8	0.9	91.1
Fugitive emissions – geothermal	CO_2	642.2	0.9	92.0
Mineral products – cement production	CO_2	582.0	0.8	92.8
Metal production – aluminium production	CO_2	575.0	0.8	93.6
Fugitive emissions – coal mining and handling	CH_4	552.2	0.8	94.4
Waste-water handling	CH_4	463.8	0.6	95.0

Table 1.5.3 1990–2010 trend assessment for New Zealand's key category analysis including LULUCF (a) and excluding LULUCF (b)

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

IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2010 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation – sheep	CH_4	11,822.6	7,772.9	0.050	22.0	22.0
Enteric fermentation – dairy cattle	CH_4	5,011.0	9,849.2	0.025	11.1	33.0
Transport – road transport – diesel oil	CO_2	1,417.3	5,089.5	0.024	10.3	43.3
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	393.9	0.013	5.5	48.8
Conversion to forest land	CO_2	22,556.5	29,992.1	0.012	5.2	54.0
Enteric fermentation – other	CH_4	5,588.2	5,518.5	0.011	4.6	58.7
Agricultural soils – direct emissions	N_2O	449.2	1,734.7	0.008	3.6	62.3
Agricultural soils – pasture, range and paddock	N_2O	5,385.5	5,649.6	0.008	3.4	65.8
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,006.7	0.007	3.1	68.9
Conversion to grassland	CO_2	109.3	1,016.2	0.006	2.7	71.6
Grassland remaining grassland	CO_2	1,009.0	2,058.7	0.006	2.5	74.1
Manufacturing industries and construction – solid fuels	CO_2	2,161.7	1,925.0	0.006	2.4	76.5
Metal production – aluminium production	PFCs	629.9	40.6	0.005	2.3	78.9
Forest land remaining forest land	CO_2	4,605.3	6,439.3	0.005	2.0	80.9
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	1,221.0	0.005	2.0	82.9
Solid waste disposal on land	CH_4	1,514.4	1,345.5	0.004	1.7	84.6
Fugitive emissions – flaring – combined	CO_2	228.9	803.1	0.004	1.6	86.2
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	4,138.1	0.003	1.2	87.4
Fugitive emissions – geothermal	CO_2	228.6	642.2	0.003	1.1	88.5
Other sectors – liquid fuels	CO_2	1,626.7	1,726.4	0.002	1.0	89.5
Other sectors – solid fuels	CO_2	511.8	349.3	0.002	0.9	90.4
Transport – road transport – liquefied petroleum gases	CO_2	237.8	71.6	0.002	0.7	91.1
Conversion to wetland	CO_2	165.7	0.0	0.001	0.6	91.8
Fugitive emissions – coal mining and handling	CH_4	274.5	552.2	0.001	0.6	92.4
Conversion to cropland	CO_2	213.7	71.9	0.001	0.6	93.0
Transport – road transport – gasoline	CO_2	5,570.7	7,177.2	0.001	0.6	93.6
Transport – road transport – gaseous fuels	CO_2	139.6	1.6	0.001	0.5	94.2
Fugitive emissions – natural gas	CH_4	438.1	379.3	0.001	0.5	94.7
Energy industries – Petroleum refining – liquid fuels	CO_2	773.9	809.5	0.001	0.5	95.2

(b) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)						
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**2010 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Enteric fermentation – sheep	CH_4	11,822.6	7,772.9	0.074	23.9	23.9
Enteric fermentation – dairy cattle	CH_4	5,011.0	9,849.2	0.045	14.4	38.3
Transport – road transport – diesel oil	CO_2	1,417.3	5,089.5	0.039	12.7	51.0
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	393.9	0.019	6.2	57.2
Agricultural soils – direct emissions	N_2O	449.2	1,734.7	0.014	4.5	61.7
Enteric fermentation – other	CH_4	5,588.2	5,518.5	0.014	4.4	66.1
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,006.7	0.012	3.8	69.9
Agricultural soils – pasture, range and paddock	N_2O	5,385.5	5,649.6	0.009	3.0	72.9
Metal production – aluminium production	PFCs	629.9	40.6	0.008	2.7	75.6
Manufactuing industries and construction – solid fuels	CO_2	2,161.7	1,925.0	0.008	2.5	78.1
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	1,221.0	0.008	2.5	80.5
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	4,138.1	0.007	2.1	82.6
Fugitive emissions – flaring – combined	CO_2	228.9	803.1	0.006	2.0	84.6
Transport – road transport – gasoline	CO_2	5,570.7	7,177.2	0.006	1.9	86.5
Solid waste disposal on land	CH_4	1,514.4	1,345.5	0.005	1.8	88.2
Fugitive emissions – geothermal	CO_2	228.6	642.2	0.004	1.4	89.6
Other sectors – solid fuels	CO_2	511.8	349.3	0.003	1.0	90.6
Fugitive emissions – coal mining and handling	CH_4	274.5	552.2	0.003	0.8	91.4
Other sectors – liquid fuels	CO_2	1,626.7	1,726.4	0.003	0.8	92.3
Transport – road transport – liquefied petroleum gases	CO_2	237.8	71.6	0.002	0.8	93.1
Transport – road transport – gaseous fuels	CO_2	139.6	1.6	0.002	0.6	93.7
Fugitive emissions – natural gas	CH_4	438.1	379.3	0.002	0.5	94.2
Other sectors – gaseous fuels	CO_2	520.7	760.2	0.002	0.5	94.8
Energy industries – Petroleum refining – liquid fuels	CO_2	773.9	809.5	0.001	0.4	95.2

1.5.2 LULUCF activities under the Kyoto Protocol

The LULUCF categories identified as key (level assessment) under the Climate Change Convention in the 2010 year that correspond to the key categories for Article 3.3 activities under the Kyoto Protocol are shown in table 1.5.4.

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

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

1.6 Quality assurance and quality control

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

1.6.1 Quality control

For this submission, the completion of the IPCC (2000) Tier 1, and in some sectors Tier 2, quality control check sheets for each sector was the responsibility of the leading agency. The national inventory complier was provided with common reporting format xml files for all sectors that passed all Tier 1 checks. The Tier 1 checks are based on the procedures suggested in the IPCC good practice guidance (IPCC, 2000). All key categories for the 2010 inventory year were checked.

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

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

1.6.2 Quality assurance

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

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

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

Prioritisation of improvements

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

Acceptance of improvements

The process of accepting any improvements into the inventory includes demonstrating that the improvement has been independently assessed. Resulting recalculations need to be approved by the national inventory compiler. In the agriculture sector, any improvements in method and/or parameters need the approval of the independent agricultural inventory advisory panel.

Independent assessment

Any change in a method or parameter needs to be reviewed by an independent expert. The change will only be included in the inventory if the expert concludes that the change is consistent with IPCC good practice.

Recalculation approval

All recalculations require the approval of the national inventory compiler. The recalculations need to be sufficiently explained in terms of improving one or more of the IPCC good practice principles. This is recorded on a form for documentation and archiving.

Independent agricultural inventory advisory panel

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

Expertise

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

New Zealand has developed a national inventory compiler manual that documents the tasks required for making an official submission starting from the submission of the previous year. The role of the agricultural and energy sector compilers is well documented within respective manuals. While not explicitly a manual, there is good documentation for compiling the waste sector and the development of a manual for compiling the LULUCF sector is under way. These manuals are designed to help lower the risk of losing compiling knowledge.

1.6.3 Verification activities

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

1.6.4 Treatment of confidentiality issues

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

1.6.5 Climate Change Convention annual inventory review

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

New Zealand has consistently met the reporting requirements under the Climate Change Convention and Kyoto Protocol. The submission of the inventory to the Climate Change Convention secretariat has consistently met the required deadline under decision 15/CMP.1. The 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, the first day of the first commitment period.

1.7 Inventory uncertainty

1.7.1 Reporting under the Climate Change Convention

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

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

In most instances, the uncertainty values are determined by analysis of emission factors or activity data using expert judgement from sectoral or industry experts, or by referring to uncertainty ranges provided in the IPCC guidelines. The uncertainty for CH_4 emissions from enteric fermentation was calculated by expressing the coefficient of variation according to the standard error of the methane yield. A Monte Carlo simulation has been used to determine uncertainty for N_2O from agricultural soils. For the 2010 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value.

Total emissions

Uncertainty in 2010

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) is ±12.0 per cent. The high uncertainty in a given year is dominated by emissions of N_2O from agricultural soils (section 6.5) and CH_4 from enteric fermentation (section 6.2). These categories comprised ±10.2 per cent and ±5.2 per cent respectively of New Zealand's total emissions uncertainty in 2010. The uncertainty in these categories reflects the inherent variability when estimating emissions from natural systems, for example, the uncertainty in cattle dry-matter intake and, hence, in estimates of CH_4 emissions per unit of dry-matter intake.

Uncertainty in the trend

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) in the trend from 1990 to 2010 is ±2.8 per cent. This is the same uncertainty as reported in the 2011 submission.

Net emissions

Uncertainty in 2010

The calculated uncertainty for New Zealand's inventory including emissions and removals from the LULUCF sector in 2010 is ±14.2 per cent. Removals of CO_2 from forest land were a major contribution to the uncertainty for 2010 at ±10.9 per cent of New Zealand's net emissions.

In this submission, the overall uncertainty when emissions and removals from the LULUCF sector are included for 2010 has increased 4.0 per cent since estimated for 2009 in the 2011 submission. This increase is mainly due to reverting back to a Tier 1 methodology for estimating emissions from mineral soils within the LULUCF sector (see section 7.1.5 for further detail).

Uncertainty in the trend

When emissions and removals from the LULUCF sector are included, the overall uncertainty in the trend from 1990 to 2010 is ±5.7 per cent. This is also an increase from the uncertainty estimates in the trend compared with the 2011 submission. This change is also mainly due to reverting back to a Tier 1 methodology for estimating emissions from mineral soils within the LULUCF sector (see section 7.1.5 for further detail).

1.7.2 LULUCF activities under the Kyoto Protocol

The combined uncertainty for emissions from afforestation and reforestation activities in 2010 was ±80.4 per cent. The combined uncertainty for deforestation in 2010 was ±156.3 per cent. Again, this change is mainly due to reverting back to a Tier 1 methodology for estimating emissions from mineral soils. Without the mineral soil component, uncertainty is much lower at ±13.4 per cent for afforestation and reforestation, and ±28.1 per cent for deforestation.

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 1990–2010 is complete. In accordance with good practice guidance (IPCC, 2000), New Zealand has focused its resources for inventory development in the key categories.

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

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

1.8.2 LULUCF activities under the Kyoto Protocol

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

1.9 National registry

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

At the beginning of the calendar year 2011, New Zealand's national registry held 307,259,426 AAUs, 20,328 emissions reduction units and 531,020 certified emission reduction units. There were no removal units held in the registry at the beginning of the 2011 calendar year (table 1 in table 12.2.2).

At the end of 2011, there were 306,248,485 AAUs, 530,346 emission reduction units, 2,935,654 certified emission reduction units and 3,900,000 removal units held in the New Zealand registry (table 4 in table 12.2.2). The removal units and majority of certified emission reduction units (approximately 2,800,000 units) were traded into New Zealand's national registry by private entities. These units will not be part of the Crown account unless surrendered under the NZ ETS.

New Zealand's national registry did not hold any temporary certified emission reduction units and long-term certified emissions reduction units during 2011 (table 4 in table 12.2.2).

1.10 New Zealand's Emissions Trading Scheme

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

1.10.1 The New Zealand Unit

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

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

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

Trading NZUs for international units

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

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

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

- an equivalent number of NZ AAUs are transferred from a New Zealand Initial Assigned Amount to the applicant
- those same NZ AAUs are transferred from the applicant's holding account to a holding account in an overseas national registry.

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

1.10.2 Verification

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

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

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

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

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

1.11 Improvements introduced

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

- activity data
- emission factors and/or other parameters
- methodology

- additional sources identified within the context of the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003)
- availability of activity data and emission factors for sources that were previously reported as NE (not estimated) because of insufficient data.

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

The largest improvements in the accuracy of the New Zealand greenhouse gas inventory since the 2011 submission, were made in the LULUCF and agriculture sectors. Chapter 10 provides a summary of all recalculations made to the estimates. There was also a significant improvement made to deforestation estimates under Article 3.3 of the Kyoto Protocol.

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

LULUCF – soils methodology (section 7.1.3)

New Zealand has revised the approach used for estimating emissions from mineral soils in this submission. A Tier 2 methodology was used in the previous submission, in which a linear statistical model estimated steady state organic carbon stocks for each land use, based on key factors that regulate mineral soil organic carbon stocks: land use, climate and soil class.

The 2010 review (UNFCCC, 2011) of New Zealand's 2008 submission commended New Zealand for estimating steady state organic soil carbon stocks by each land use. However, it was "unclear whether or not the [Tier 2] methodology can with any certainty detect significant changes in soil carbon stock changes for different land uses". "New Zealand [was] encouraged to include increased sampling in land-use classes (particularly other land, wetland, croplands and post-1989 forest), which are currently under represented in the national sample" to reduce uncertainty and enable detection of any statistically significant changes.

New Zealand has responded to the 2010 review report by shifting to a Tier 1 methodology to estimate steady state mineral soil organic carbon stocks for each land use in this submission. New Zealand intends to return to using a Tier 2 methodology once improvements are made to enable detection of any statistically significant changes between land uses. If these improvements are able to be made within the commitment period we will return to using a New Zealand-specific methodology.

Deforestation area (sections 7.2.2 and 11.4)

The accuracy of the 2008 and 2009 land-use change areas has been improved in this submission, particularly the area of deforestation. In the 2011 submission, deforestation areas were mapped based on satellite imagery with a resolution of 22 metres. For the 2012 submission, four areas where most of the deforestation activity was detected in 2008 and 2009 (identified in the previous year's deforestation mapping) were mapped using satellite imagery with 10-metre resolution. Based on this higher resolution imagery, new areas of forest destocking were identified (either harvesting or deforestation). These were assessed for land-use change using oblique aerial photography taken from a light aircraft. This resulted in an extra 3,609 hectares of deforestation being detected for 2008 and 2009 (an increase of 98.2 per cent). This increase includes areas where deforestation has been detected for the first time as well as confirming deforestation where previous assessments were unable to distinguish between harvesting and deforestation.

Liveweights for sheep and beef cattle (section 6.2.5)

This year, there have been a number of improvements to the Tier 2 model for estimating emissions from dairy and beef cattle and sheep. The improvements resulted in an increase in agriculture emissions across the time series from an additional 890 Gg CO_2-e in 2009 to an additional 800 Gg CO_2-e in 1990. The most significant contributor to this recalculation was improving the estimate of the average liveweights of ewes and beef cows. Muir and Thomson (2010) reviewed the estimates of liveweights for ewes and found that they were higher than previously estimated across the entire time series. The ewes that are slaughtered tend to be lighter on average. As carcass weight is used as a proxy for liveweight, the lighter carcass weight under-estimated liveweight. The dressing out percentage (the value used to convert carcass weight to liveweight) has now been adjusted so that estimated liveweights reflect the actual national ewe weight.

The replacement rate of beef cows was also reviewed by Muir and Thomson (2010). The replacement rate is the number of beef cows estimated to be replaced each year by growing heifers. This parameter is used to estimate the number of cows slaughtered that come from the beef herd and is used when estimating beef cow liveweight. It was reduced from 25 per cent of total beef cows to 17 per cent. This lowers the estimated number of beef cows slaughtered and this, along with a revised dressing out percentage, results in a higher average liveweight. Consequently, New Zealand's agricultural emissions now more accurately reflect the actual liveweight of national breeding ewes and cows.

Chapter 1: References

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Chapter 2: Trends in greenhouse gas emissions

2.1 Emission trends for aggregated greenhouse gas emissions

2.1.1 National trends

Total (gross) emissions

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

1990–2010

In 1990, New Zealand's total greenhouse gas emissions were 59,797.2 Gg carbon dioxide equivalent (CO_2-e). In 2010, total greenhouse gas emissions had increased by 11,860.0 Gg CO_2-e (19.8 per cent) to 71,657.2 Gg CO_2-e (figure 2.1.1). Between 1990 and 2010, the average annual growth in total emissions was 0.9 per cent per year.

The four emission sources that contributed the most to this increase in total emissions were road transport, dairy enteric fermentation,[14] agricultural soils, and public electricity and heat production.

2009–2010

Between 2009 and 2010, New Zealand's total greenhouse gas emissions increased by 174 Gg CO_2-e (0.2 per cent). The size of the overall increase is small because, although emissions from the industrial processes and agriculture sectors rose, there was a decrease in emissions from the energy sector.

The decrease in energy emissions is primarily due to a decrease in emissions from electricity generation. The three main drivers that led to the decrease in emissions from electricity generation, despite a 3 per cent growth in electricity generated, were:

- an increase in the supply of geothermal generation
- a preference for gas over coal at New Zealand's largest electricity generation plant
- higher inflows into the hydro lakes.

The continued increase in emissions from the consumption in hydrofluorocarbons (HFCs) and an increase in steel and aluminium production were the main drivers in the rise of emissions from industrial processes. The consumption of HFCs has been increasing since the mid-1990s when chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)

[14] Methane emissions produced from ruminant livestock.

began to be phased out under the Montreal Protocol. In New Zealand, the Ozone Layer Protection Act 1996 sets out a programme for phasing out the use of ozone-depleting substances by 2015. The production of aluminium and steel decreased in 2009 due to falling international prices for the product in the wake of the economic downturn, while in 2010 these industries showed a recovery in production. In addition to market prices, aluminium production in 2009 was affected by a transformer failure at the smelter.[15]

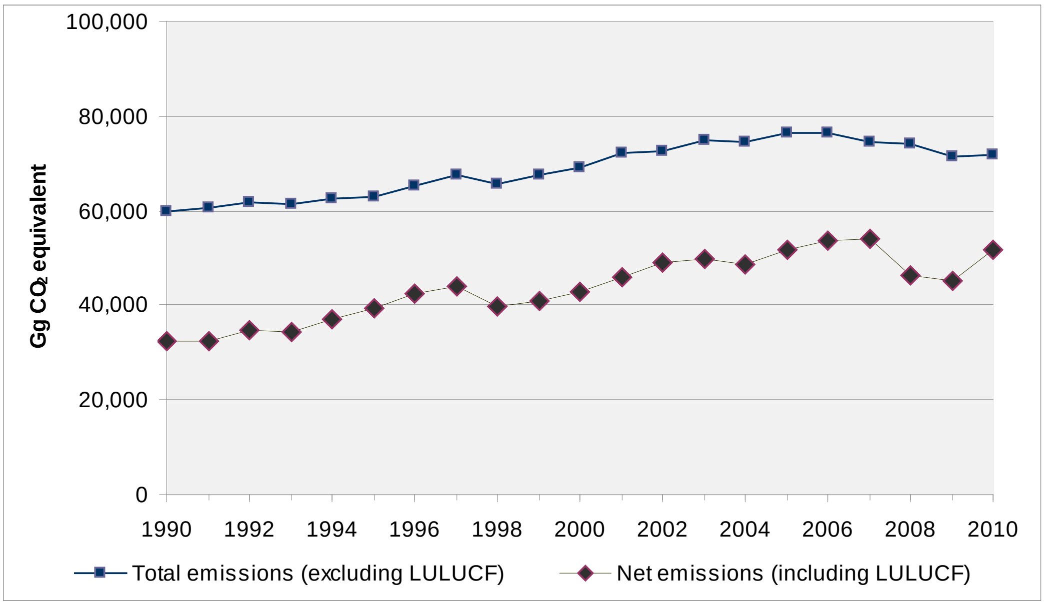
The continued increase in the national dairy cattle population, coupled with a favourable milk price, led to the increase in agricultural emissions. The dairy industry is the main user of nitrogen fertiliser in New Zealand, therefore, with a favourable milk price there was an increase in the sale and use of nitrogen fertiliser in 2010.

Net emissions – Climate Change Convention reporting

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

In 1990, New Zealand's net greenhouse gas emissions were 32,408.9 Gg CO_2-e. In 2010, net greenhouse gas emissions had increased by 19,267.8 Gg CO_2-e (59.5 per cent) to 51,676.7 Gg CO_2-e (figure 2.1.1). The four categories that contributed the most to the increase in net emissions between 1990 and 2010 were forest land remaining forest land, road transport, dairy enteric fermentation and grassland remaining grassland categories.

Figure 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2010



Accounting under the Kyoto Protocol

New Zealand's initial assigned amount under the Kyoto Protocol is recorded as 309,564,733 metric tonnes CO_2 equivalent (309,565 Gg CO_2-e). The initial assigned amount is five times the total 1990 emissions reported in the inventory submitted as part of *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment,

[11] New Zealand has only one aluminium smelter.

2006). The initial assigned amount does not change during the first commitment period (2008–2012) of the Kyoto Protocol. In contrast, the time series of emissions reported in each inventory submission are subject to continuous improvement. Consequently, the total emissions in 1990 as reported in this submission are 3.5 per cent lower than the 1990 level of 61,912.9 Gg CO_2-e, which was estimated in 2006 and used in the initial assigned amount calculation.

In 2010, net removals were 18,307.1 Gg CO_2-e from land subject to afforestation, reforestation and deforestation (see section 2.5 for further detail). The accounting quantity for 2010 was−18,462.5 G g CO_2-e. This is different from net removals because debits resulting from harvesting of afforested and reforested land during the first commitment period are limited to the level of credits received for that land.

2.2 Emission trends by gas

Inventory reporting under the Climate Change Convention covers six direct greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and HFCs. Table 2.2.1 provides the change in each gas from 1990 to 2010. In 2010, CO_2 contributed the largest proportion of total emissions (figure 2.2.1), while in 1990, CO_2 and CH_4 contributed nearly equal proportions to total emissions (figure 2.2.2). The proportion of CH_4 has been decreasing over the time series while the proportion of CO_2 has been increasing. This trend reflects the increase in emissions from the energy sector (section 2.3) – nearly 90 per cent of New Zealand's CO_2 emissions come from the energy sector. Carbon dioxide was also the greenhouse gas that has had the strongest influence on the trend in total emissions between 1990 and 2010 (figures 2.2.3 and 2.2.4).

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

Carbon dioxide

2010

Carbon dioxide contributed the largest proportion of total emissions in 2010 at 33,199.2 Gg (46.3 per cent). The largest sources of total CO_2 emissions are from road transport and electricity and heat production. In 2010, road transport contributed 12,339.8 Gg (37.2 per cent) to total CO_2 emissions and public electricity and heat production contributed 5,360.4 Gg (16.1 per cent).

In 2010, net removals of CO_2 from the LULUCF sector (as reported under the Climate Change Convention) were 20,048.9 Gg. The forest land category is the biggest contributor to the sector, with net removals of 23,552.8 Gg CO_2 in 2010. Carbon dioxide removals from afforestation and reforestation activities (as accounted for under Article 3.3 of the Kyoto Protocol) were 19,362.1 Gg. The difference between the two estimates is largely due to the inclusion of pre-1990 forests within the LULUCF sector. While reporting under the Climate Change Convention includes pre-1990 forests, they are excluded from all but deforestation emissions under the Kyoto Protocol.

In 2010, CO_2 emissions from deforestation of all forests (2,616 hectares) contributed 1,049.9 Gg to net emissions. The deforestation was mainly for conversion into grassland, largely due to the relative profitability of pastoral farming, particularly dairy farming, compared with forestry.

1990–2010

Total CO_2 emissions have increased by 8,185.2 Gg (32.7 per cent) from the 1990 level of 25,014.1 Gg. The two largest sources of this growth were the increased emissions from road transport, and public electricity and heat production.

Between 1990 and 2010, net CO_2 removals from LULUCF have decreased by 7,407.9 Gg CO_2-e (27.1 per cent) from the 1990 level of –27,388.3 Gg CO_2-e. This decrease in net removals is largely the result of increased harvesting and deforestation since 1990.

2009–2010

Between 2009 and 2010, total CO_2 emissions decreased 393 Gg (1.2 per cent). This decrease is primarily due to a decrease in emissions from public electricity and heat production. The three main drivers that led to the decrease in emissions from electricity generation, despite a 3 per cent growth in electricity generated, were:

- an increase in the supply of geothermal generation
- a preference for gas over coal at New Zealand’s largest electricity generation plant
- higher inflows into the hydro lakes.

Between 2009 and 2010, net removals from LULUCF decreased by 6,253.6 Gg CO_2-e (23.8 per cent). This decrease in net removals is largely the result of an increase in harvesting of pre-1990 planted forest and increased new planting. New planting resulted in emissions due to a loss of biomass associated with the previous land use and loss of soil carbon with land-use change to forestry, outweighing removals by forest growth.

Between 2009 and 2010, CO_2 emissions from the deforestation of all forests decreased by 325.3 Gg (23.7 per cent) as there was less area deforested in 2010 than in 2009.

Methane

2010

Methane contributed 26,855.1 Gg CO_2-e (37.5 per cent) to total emissions in 2010. The principal source of CH_4 emissions is from enteric fermentation, particularly from the four major ruminant livestock populations of sheep, dairy cattle, non-dairy cattle and deer. In 2010, enteric fermentation CH_4 from all livestock contributed 23,140.7 Gg CO_2-e (86.2 per cent) to total CH_4 emissions.

1990–2010

In 2010, CH_4 emissions have increased by 1,028.7 Gg CO_2-e (4.0 per cent) from the 1990 level of 25,826.5 Gg CO_2-e. This is largely due to an increase in CH_4 emissions from enteric fermentation. While the decline in the population of sheep between 1990 and 2010 has led to a decrease in CH_4 of enteric fermentation from sheep by 4,049.7 Gg CO_2-e, the increase in the national dairy cattle herd over the same period has increased CH_4 from enteric fermentation from dairy cattle by 4,838.2 Gg CO_2-e.

2009–2010

Between 2009 and 2010, CH_4 emissions increased 33.0 Gg CO_2-e (0.1 per cent) primarily due to the increase in emissions from dairy cattle enteric fermentation.

Nitrous oxide

2010

Nitrous oxide contributed 10,454.7 Gg CO_2-e (14.6 per cent) to total emissions in 2010. The largest source of N_2O emissions is from agricultural soils. In 2010, the agricultural soils category contributed 9,905.2 Gg CO_2-e (94.7 per cent) to New Zealand's total N_2O emissions.

1990–2010

In 2010, N_2O emissions increased by 2,143.1 Gg CO_2-e (26.0 per cent) from the 1990 level of 8,311.6 Gg CO_2-e. The growth in N_2O is from the increase in emissions from the use of nitrogen fertilisers in the agriculture sector and from an increase in animal excreta. There has been an almost six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2010 time series, which has resulted in an increase of direct N_2O emissions from 259.8 Gg CO_2-e in 1990 to 1,459.9 Gg CO_2-e in 2010.

2009–2010

Between 2009 and 2010, emissions of nitrous oxide increased 322.1 Gg CO_2-e (3.2 per cent). This was largely due to an increase in the amount of nitrogen fertiliser applied to agricultural soils. The dairy industry is the main user of nitrogen fertiliser in New Zealand. The milk price was higher during 2010 compared with 2009 (Ministry of Agriculture and Forestry, 2011) and this increased the demand for nitrogen fertiliser in 2010.

Hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride

Hydrofluorocarbons, PFCs and SF_6 contributed the remaining 1,148.1 Gg CO_2-e (1.6 per cent) to total emissions in 2010.

In 1990, no HFCs were used in New Zealand and, therefore, no percentage is shown in table 2.2.1. In 2010, 1,087.2 Gg CO_2-e of HFC emissions occurred. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol.

Emissions of PFCs have decreased 589.1 Gg CO_2-e (94 per cent) from the 629.9 Gg CO_2-e in 1990, to 40.8 Gg CO_2-e in 2010. This decrease is the result of improvements in the aluminium smelting process.

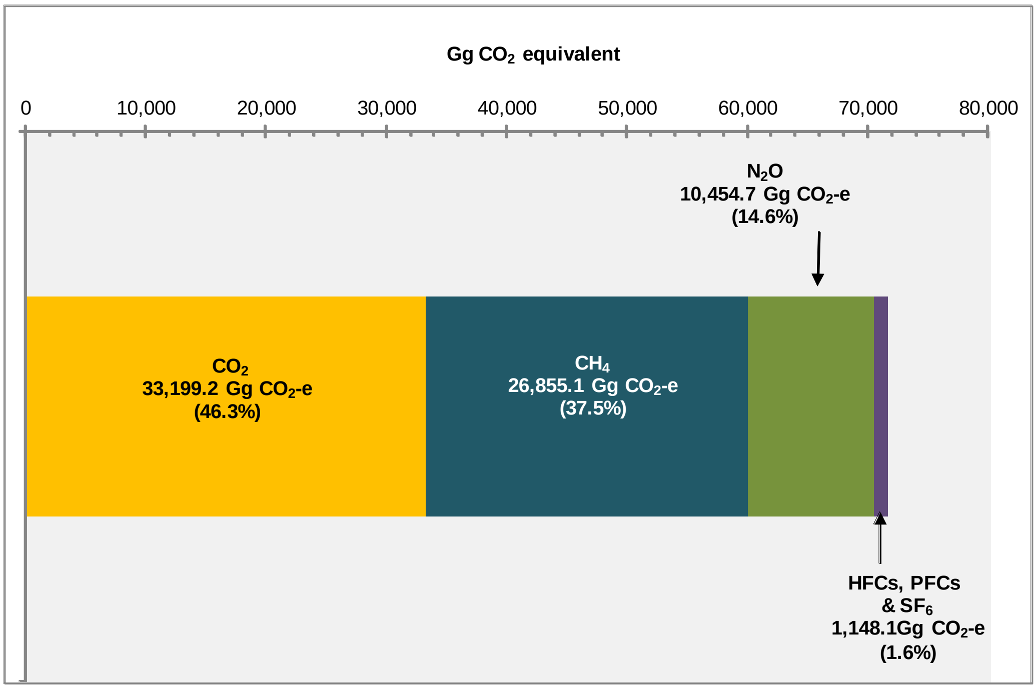
Emissions of SF_6 have increased 4.95 Gg CO_2-e (32.6 per cent) from the 1990 level of 15.2 Gg CO_2-e to the 2010 level of 20.2 Gg CO_2-e. This increase is largely due to the increase in use of electricity generators.

Table 2.2.1 New Zealand's total (gross) emissions by gas in 1990 and 2010

Direct greenhouse gas emissions	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2010	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
CO_2	25,014.1	33,199.2	+8,185.2	+32.7
CH_4	25,826.5	26,855.1	+1,028.7	+4.0
N_2O	8,311.6	10,454.7	+2,143.1	+25.8
HFCs	NO	1,087.2	+1,087.2	NA
PFCs	629.9	40.8	–589.1	–93.5
SF_6	15.2	20.2	+5.0	+32.6
Total	**59,797.2**	**71,657.2**	**+11,860.0**	**+19.8**

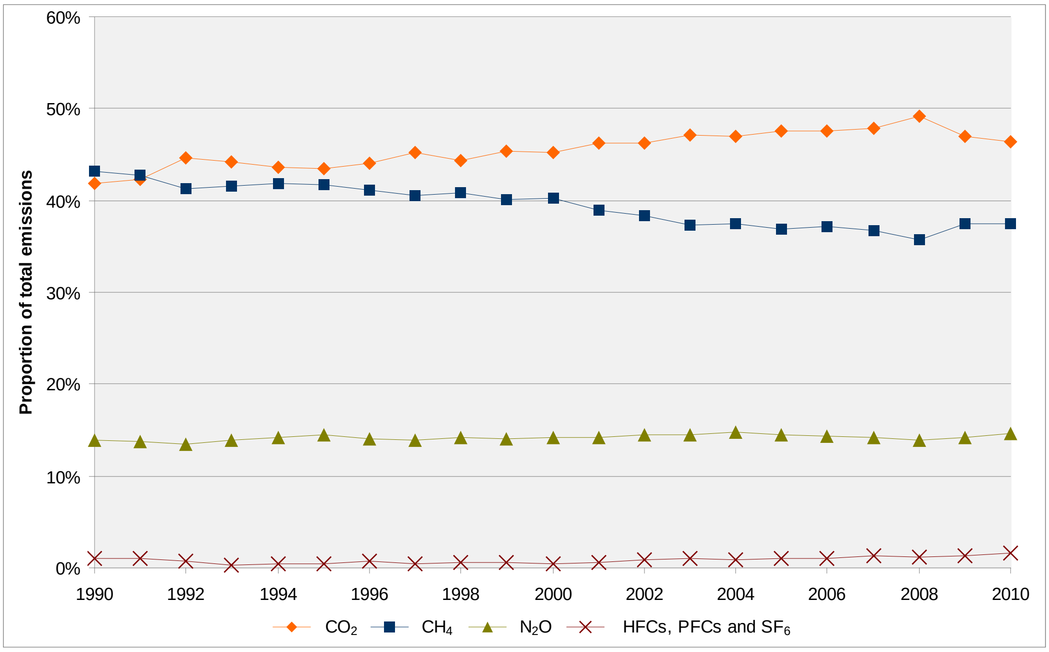
Note: Total emissions exclude net removals from the LULUCF sector. The per cent change for hydrofluorocarbons is not applicable (NA) as production of hydrofluorocarbons in 1990 was not occurring (NO). Columns may not total due to rounding.

Figure 2.2.1 New Zealand's total emissions by gas in 2010



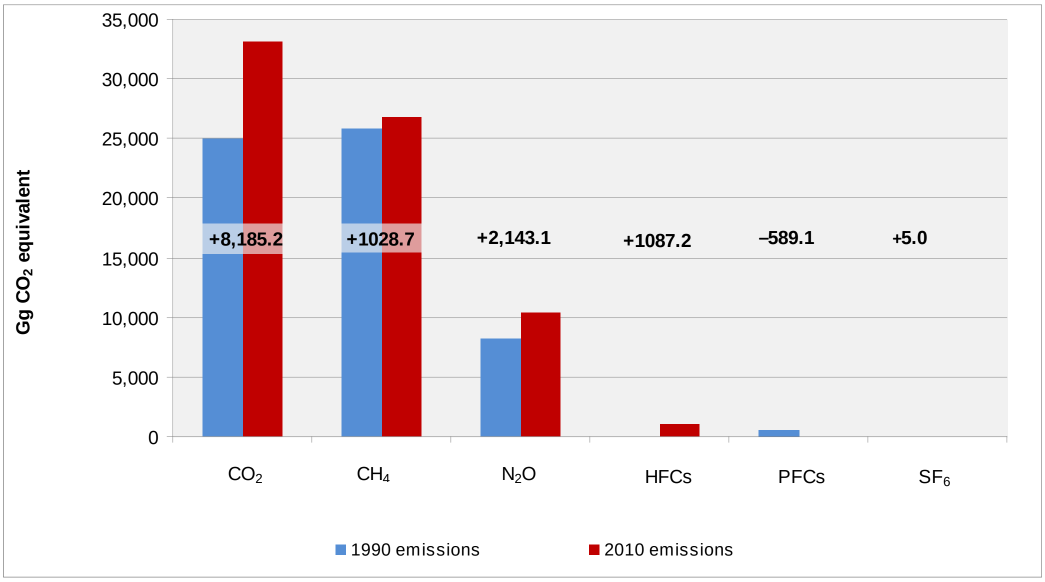
Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.2.2 Proportion that gases contributed to New Zealand's total emissions from 1990 to 2010



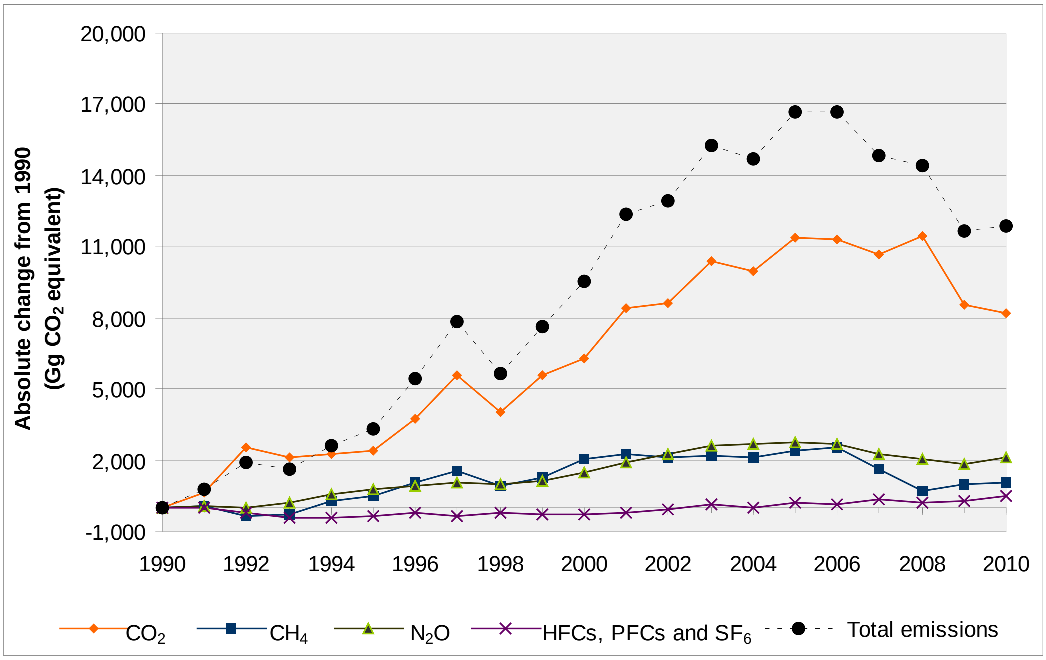
Note: Total emissions exclude net removals from the LULUCF sector.

Figure 2.2.3 Change in New Zealand's total emissions by gas in 1990 and 2010



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

Figure 2.2.4 Change from 1990 in New Zealand's total emissions by gas from 1990 to 2010



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

2.3 Emission trends by source

Inventory reporting under the Climate Change Convention covers six sectors: energy, industrial processes, solvent and other product use, agriculture, LULUCF and waste. Although the agriculture sector contributed the largest proportion of total emissions in 2010 (table 2.3.1 and figure 2.3.1), the proportion of emissions from the agriculture sector has generally been decreasing since 1990, while the proportion of emissions from the energy sector has been increasing (figure 2.3.2). For the first time, in 2008, energy was the largest contributing sector to total emissions, although agriculture had the greater proportion in 2009 and again in 2010. This trend reflects that the energy sector has experienced the greatest increase over the period 1990–2010 (figure 2.3.3). Energy emissions have increased approximately two-and-a-half times as much as those from the agriculture sector (in absolute terms). The energy sector has also been the sector that has had the most influence on the trend in total emissions between 1990 and 2010 (figure 2.3.4).

Energy (chapter 3)

2010

The energy sector was the source of 31,107.8 Gg CO_2-e (43.4 per cent) of total emissions in 2010. The largest sources of emissions in the energy sector were road transport, contributing 12,514.1 Gg CO_2-e (40.2 per cent), and public electricity and heat production contributing 5,374.9 Gg CO_2-e (17.3 per cent) to energy emissions.

1990–2010

In 2010, energy emissions had increased by 7,649.4 Gg CO_2-e (32.6 per cent) from the 1990 level of 23,458.4 Gg CO_2-e. This growth in emissions is primarily from road transport, which increased by 4,973.8 Gg CO_2-e (66.0 per cent), and electricity generation and heat production, which increased by 1,907.0 Gg CO_2-e (55.0 per cent).

2009–2010

Between 2009 and 2010, emissions from the energy sector decreased by 487.0 Gg CO_2-e (1.5 per cent). This decrease is primarily due to a decrease in emissions from public electricity and heat production. The three main drivers that led to the decrease in emissions from electricity generation, despite a 3 per cent growth in electricity generated, were:

- an increase in the supply of geothermal generation
- a preference for gas over coal at New Zealand's largest electricity generation plant
- higher inflows into the hydro lakes.

Industrial processes (chapter 4)

2010

The industrial processes sector contributed 4,778.1 Gg CO_2-e (6.7 per cent) of total emissions in 2010. The largest source of emissions was from iron and steel production, which contributed 1,646.9 Gg CO_2-e (34.5 per cent) to the industrial processes sector.

1990–2010

Emissions from the industrial processes sector increased 1,389.3 Gg CO_2-e (41.0 per cent) from the 1990 level of 3,388.8 Gg CO_2-e. This increase was mainly caused by growth in emissions from the consumption of HFCs. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons phased out under the Montreal Protocol.

2009–2010

Between 2009 and 2010, emissions from the industrial processes sector increased by 427.7 Gg CO_2-e (9.8 per cent). The main emission sources that drove this increase were the consumption of HFCs and steel and aluminium production.

Solvent and other product use (chapter 5)

In 2010, the solvent and other product use sector was responsible for 31.0 Gg CO_2-e (0.04 per cent) of total emissions. The emission levels from the solvent and other products sector are negligible compared with other sectors.

Agriculture (chapter 6)

2010

The agriculture sector was the largest source of emissions in 2010, contributing 33,748.4 Gg CO_2-e (47.1 per cent) of total emissions. New Zealand has a unique emissions profile amongst developed countries. In most other developed countries, agricultural emissions are typically less than 10 per cent of total emissions.

The largest sources of emissions from the agriculture sector in 2010 were enteric fermentation from dairy cattle and sheep, and nitrous oxide emissions from agricultural soils.

1990–2010

In 2010, New Zealand's agricultural emissions increased by 2,893.2 Gg CO_2-e (9.4 per cent) from the 1990 level of 30,855.3 Gg CO_2-e (figure 2.3.3). This increase is largely due to the increase in the enteric fermentation emissions from dairy cattle and nitrous oxide emissions from agriculture soils.

2009–2010

Between 2009 and 2010, emissions from the agriculture sector increased 270.4 Gg CO_2-e (0.8 per cent). The dairy industry is the main user of nitrogen fertiliser in New Zealand. With a favourable milk price, there was an increase in both dairy population and the sale and use of nitrogen fertiliser in 2010.

There was also an increase in the sheep population, however, emissions from the increase in population were offset by a reduction in average sheep liveweight resulting in a small reduction in emissions from sheep.

LULUCF (chapter 7)

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

2010

In 2010, net removals from the LULUCF sector under the Climate Change Convention were 19,980.5 Gg CO_2-e. The highest contribution to removals in 2010 was from post-1989 forests, reported under land converted to forest land.

The largest source of emissions in LULUCF is from forest land remaining forest land. In 2010, net emissions for forest land remaining forest land contributed 6,450.7 Gg CO_2-e. This is largely due to the emissions from harvesting exceeding removals from growth of these forests during 2010.

1990–2010

Between 1990 and 2010, net removals from LULUCF have decreased by 7,407.9 Gg CO_2-e (27.0 per cent) from the 1990 level of –27,388.3 Gg CO_2-e. This decrease in net removals is largely the result of increased harvesting and deforestation since 1990.

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

New Zealand Emissions Trading Scheme.[16] The high price of pastoral land between 2004 and 2008 also contributed to an increase in deforestation.

2009–2010

Between 2009 and 2010, net removals from LULUCF decreased by 6,253.6 Gg CO_2-e (23.8 per cent). This decrease in net removals is largely the result of an increase in harvesting of pre-1990 planted forest and increased new planting. New planting resulted in emissions due to a loss of biomass associated with the previous land use and a loss of soil carbon with the land-use change to forestry, outweighing removals by forest growth.

Waste (chapter 8)

The waste sector contributed 1,991.8 Gg CO_2-e (2.8 per cent) to total emissions in 2010. Emissions from the waste sector have decreased by 61.4 Gg CO_2-e (3.0 per cent) from the 1990 level of 2,053.2 Gg CO_2-e. This reduction occurred in the solid waste disposal on land category and is likely a result of initiatives to improve solid waste management practices.

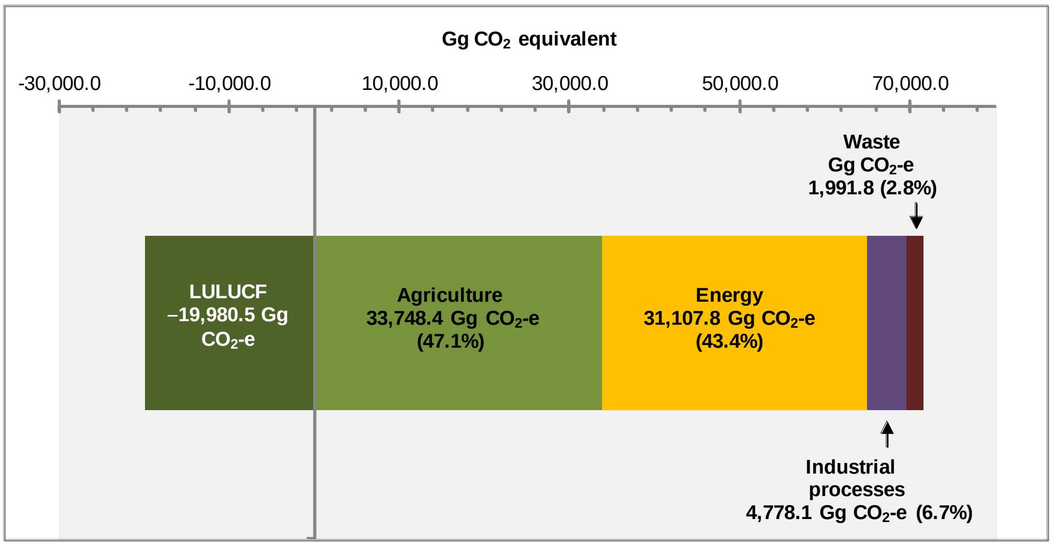
Table 2.3.1 New Zealand's emissions by sector in 1990 and 2010

Sector	Gg CO_2 equivalent 1990	Gg CO_2 equivalent 2010	Change from 1990 (Gg CO_2 equivalent)	Change from 1990 (%)
Energy	23,458.4	31,107.8	+7,649.4	+32.6
Industrial processes	3,388.8	4,778.1	+1,389.3	+41.0
Solvent and other product use	41.5	31.0	–10.5	–25.4
Agriculture	30,855.3	33,748.4	+2,893.2	+9.4
Waste	2,053.2	1,991.8	–61.4	–3.0
Total (excluding LULUCF)	**59,797.2**	**71,657.2**	**+11,860.0**	**+19.8**
LULUCF	–27,388.3	–19,980.5	+7,407.9	+27.0
Net Total (including LULUCF)	**32,408.9**	**51,676.7**	**+19,267.8**	**+59.5**

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

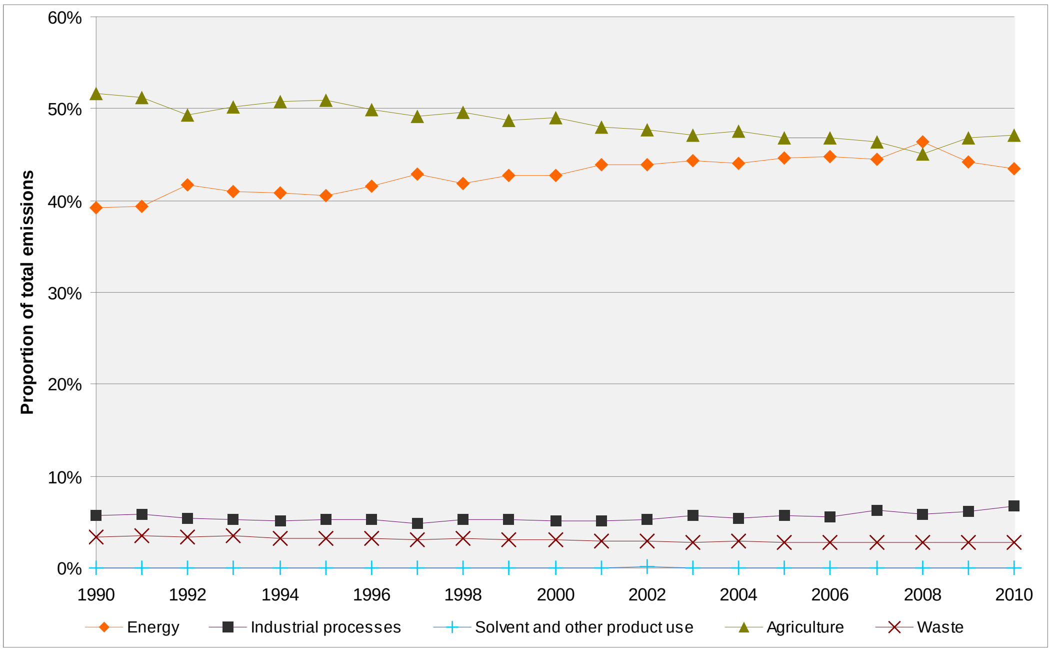
[16] The New Zealand Emissions Trading Scheme included the forestry sector as of 1 January 2008.

Figure 2.3.1 New Zealand's emissions by sector in 2010



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

Figure 2.3.2 Proportion that sectors contributed to New Zealand's total emissions from 1990 to 2010



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

Figure 2.3.3 Change in New Zealand's emissions by sector in 1990 and 2010

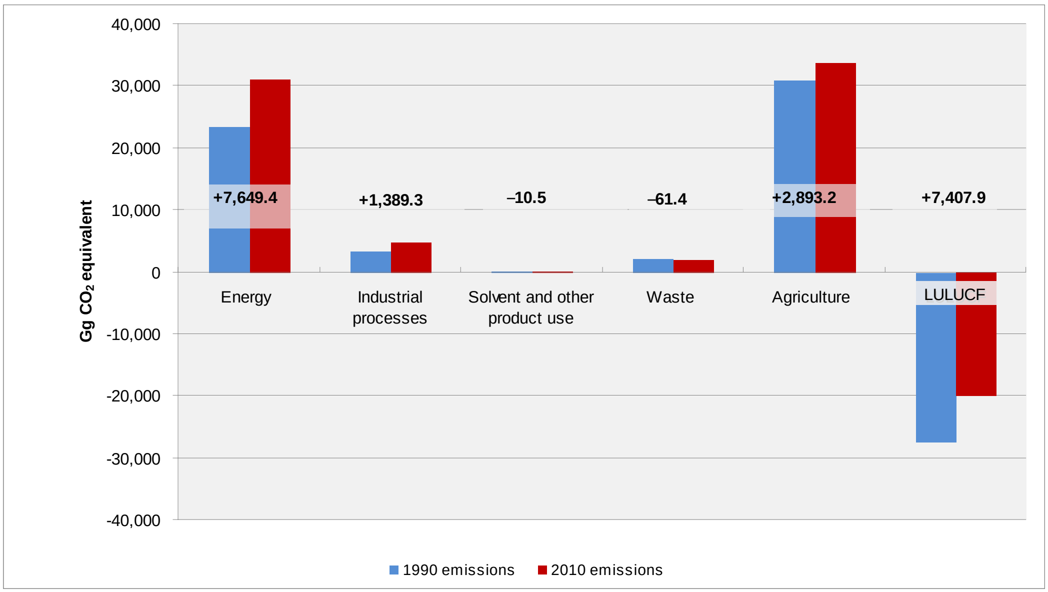
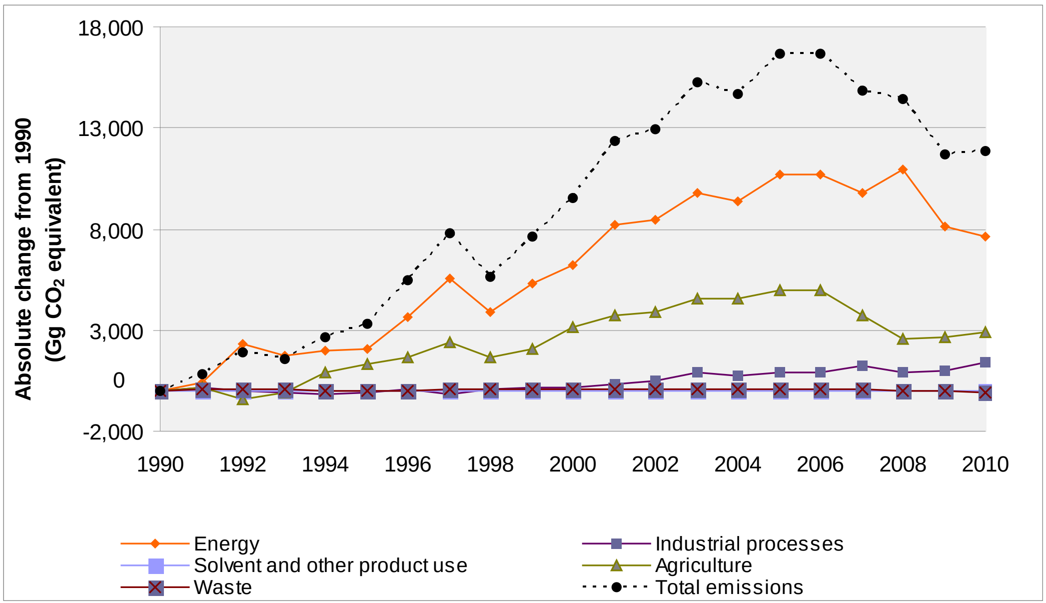
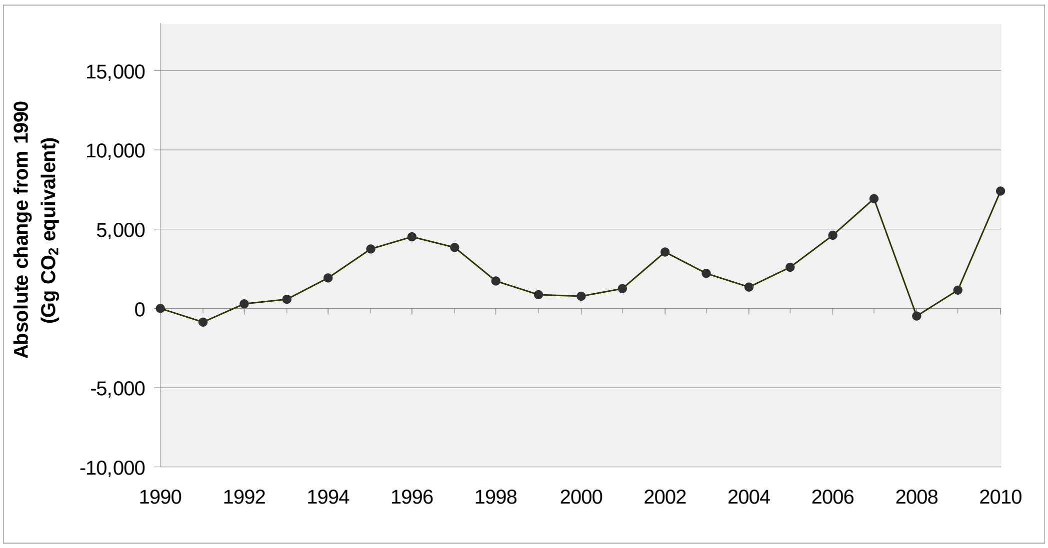


Figure 2.3.4 Absolute change from 1990 in New Zealand's total emissions by sector from 1990 to 2010



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

Figure 2.3.5 **Absolute change from 1990 in New Zealand's net removals from the LULUCF sector from 1990 to 2010 (UNFCCC reporting)**



2.4 Emission trends for indirect greenhouse gases

The indirect greenhouse gas emissions SO_2, CO, NO_x and NMVOCs are also reported in the inventory. Emissions of these gases in 1990 and 2010 are shown in table 2.4.1. Consistent with Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases are not included in New Zealand's greenhouse gas emissions total.

Table 2.4.1 New Zealand's emissions of indirect greenhouse gases in 1990 and 2010

Indirect gas	Gg of gas(es) 1990	Gg of gas(es) 2010	Change from 1990 (Gg)	Change from 1990 (%)
NO_x	100.4	148.3	+47.9	+47.8
CO	649.0	743.4	+94.4	+14.5
NMVOCs	136.6	175.8	+39.3	+28.8
SO_2	58.6	74.1	+15.5	+26.5
Total	**944.5**	**1,141.7**	**+197.14**	**+20.9**

Note: Columns may not total due to rounding.

Emissions of CO and NO_x are largely from the energy sector. The energy sector produced 88.0 per cent of total CO emissions in 2010. 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 (97.8 per cent), with the road transportation subcategory dominating. Other sources of NO_x emissions were from the manufacturing industries and construction category and the energy industries category.

The energy sector was also the largest producer of NMVOCs, producing 73.0 per cent of NMVOC emissions in 2010. Emissions from road transportation comprised 59.5 per cent of total NMVOC emissions. Other major sources of NMVOCs were in the solvent and other product use sector (20.1 per cent) and the industrial processes sector (6.9 per cent).

In 2010, emissions of SO_2 from the energy sector comprised 84.7 per cent of total SO_2 emissions. The energy industries category contributed 11.5 per cent, manufacturing industries and construction category 40.2 per cent and the transport category 15.1 per cent of total SO_2 emissions. The industrial processes sector contributed 15.3 per cent of total SO_2 emissions. Aluminium production accounted for 9.3 per cent of SO_2 emissions.

2.5 Article 3.3 activities under the Kyoto Protocol

In 2010, net removals from land subject to afforestation, reforestation and deforestation (Article 3.3 activities under the Kyoto Protocol) were 18,307.1 Gg CO_2-e (table 2.5.1). This estimate includes:

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

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

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

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2010 was 593,821 hectares. The net area is the total area of post-1989 forest (611,149 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (17,327 hectares). Removals from this land in 2010 were 18,307.1 Gg CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2010 was 106,906 hectares. The area subject to deforestation in 2010 was 2,616 hectares. In 2010, deforestation emissions were 1,049.9 Gg CO_2-e, compared with 1,375.2 Gg CO_2-e in 2009 (a 23.6 per cent reduction). Deforestation emissions include non-carbon emissions and lagged CO_2 emissions that occurred in 2010 as a result of deforestation since 1990. Lagged emissions include the liming of forest land converted to grassland and cropland, and the disturbance associated with forest land conversion to cropland.

Table 2.5.1 New Zealand's net emissions and removals from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2008, 2009 and 2010

Source	2008	2009	2010
Afforestation/reforestation			
Net cumulative area since 1990 (ha)	585,842	589,041	593,821
Area in calendar year (ha)	1,900	4,300	6,000
Removals in calendar year (Gg CO_2-e)	–19,132.6	–19,210.5	–19,357.0
Deforestation			
Cumulative area since 1990 (ha)	101,031	104,290	106,906
Area in calendar year (ha)	3,467	3,259	2,616
Emissions in calendar year (Gg CO_2-e)	1,573.3	1,375.2	1,049.9
Total area subject to afforestation, reforestation and deforestation since 1990 (ha)	686,873	693,331	700,727
Net removals (Gg CO_2-e)	–17,559.3	–17,835.3	–18,307.1

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

Chapter 2: References

Ministry of Agriculture and Forestry. 2011. *Situation and Outlook for New Zealand Agriculture and Forestry (SONZAF)*. Wellington: Ministry of Agriculture and Forestry.

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

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

Chapter 3: Energy

3.1 Sector overview

The energy sector produced 31,107.8 Gg carbon dioxide equivalent (CO_2-e) emissions in 2010, representing 43.4 per cent of New Zealand's total greenhouse gas emissions. Emissions from the energy sector were 32.6 per cent (7,694 Gg CO_2-e) above the 1990 level of 23,458.4 Gg CO_2-e (figure 3.1.1). The sources contributing most to this increase were emissions from the road transportation subcategory, an increase of 4,973.8 Gg CO_2-e (66.0 per cent), and the public electricity and heat production subcategory, an increase of 1,907.0 Gg CO_2-e (55.0 per cent). Emissions from the manufacture of solid fuels and the other energy industries subcategory have decreased by 1,317.9 Gg CO_2-e (76.7 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997.

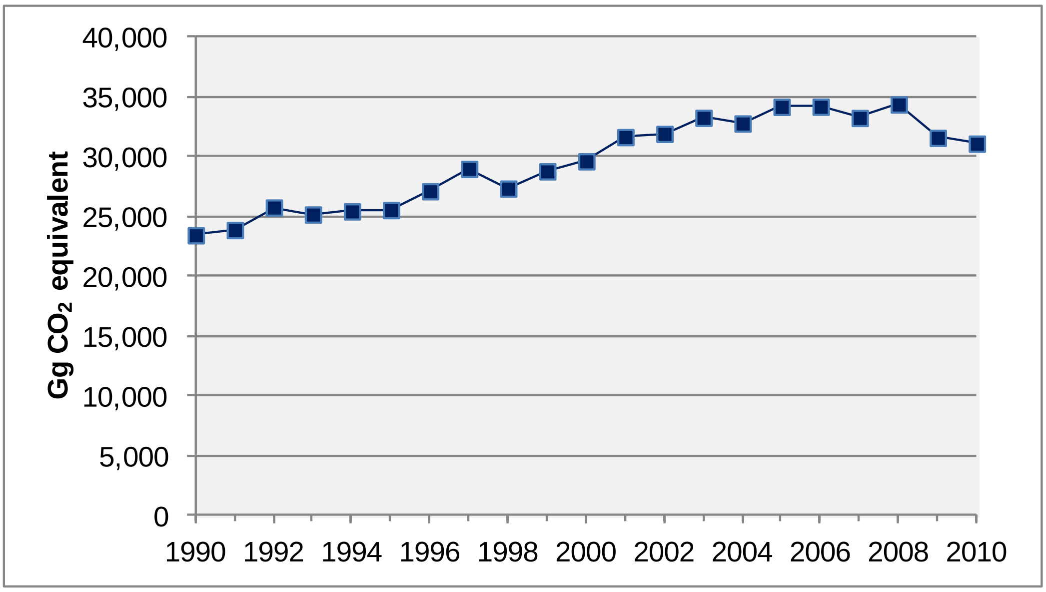
Changes in emissions between 2009 and 2010

Between 2009 and 2010, emissions from the energy sector decreased by 487.0 Gg CO_2-e (1.5 per cent). This is primarily due to a 879.4 Gg CO_2-e (14.1 per cent) decrease in emissions from public electricity and heat production. The three main drivers that led to the decrease in emissions from electricity generation, despite a 3 per cent growth in electricity generated, were:

- an increase in the supply of geothermal generation
- a preference for gas over coal at New Zealand's largest electricity generation plant
- higher inflows into the hydro lakes.

This increase in geothermal electricity generation was largely responsible for the 202.3 Gg CO_2-e increase (8.6 per cent) in fugitive emissions.

Figure 3.1.1 New Zealand's energy sector emissions from 1990–2010



Energy flows

This inventory submission includes energy flow diagrams (annex 2). These diagrams provide a snapshot of the flow of various fuels from the suppliers to the end users within New Zealand for the 2010 calendar year.

3.2 Background information

3.2.1 Comparison of sectoral approach with reference approach

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

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

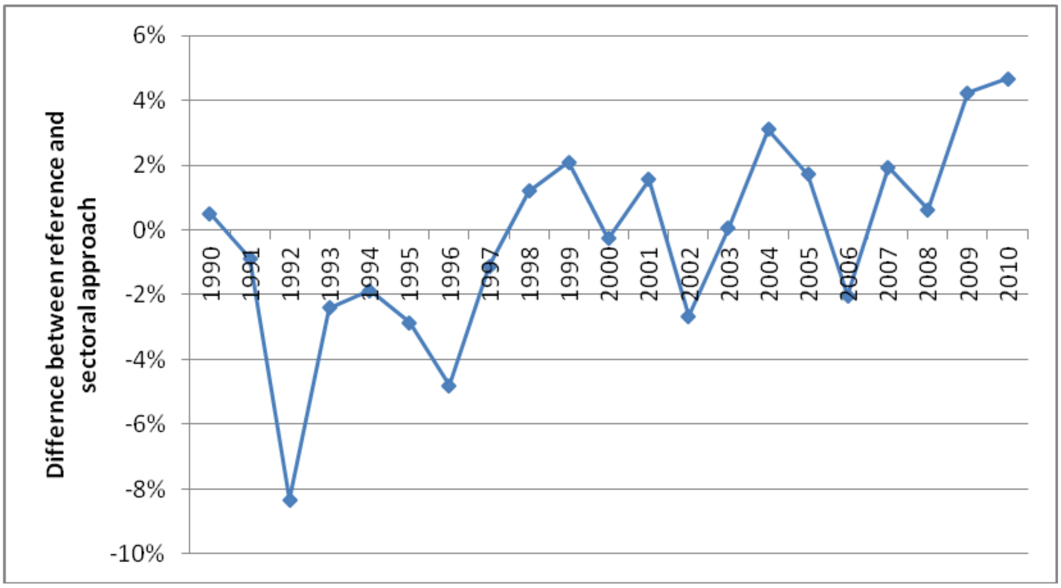
The majority of the carbon dioxide emission factors for the reference approach are New Zealand specific. Most emissions factors for liquid fuels are based on annual carbon content and the gross calorific value data provided by New Zealand's only oil refinery, the New Zealand Refining Company. Where this data is not available, an Intergovernmental Panel on Climate Change (IPCC) default is used. The natural gas emission factor is based on a production-derived, weighted average of emission factors from all gas production fields. The carbon dioxide emission factors for solid fuels are sourced from the *New Zealand Energy Information Handbook* (Baines, 1993).

The activity data for the reference approach is obtained from 'calculated' energy-use figures (see annex 2, section A2.4). These are derived as a residual figure from an energy balance equation comprising production, imports, exports, stock change and international transport on the supply side. From this value, energy use for transformation activities (such as the use of coal in steel production and natural gas in methanol production) is subtracted to get apparent consumption. The activity data used for the sectoral approach is referred to as 'observed' energy-use figures. These are based on surveys and questionnaires administered by the Ministry of Economic Development. 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, 2011).

Comparison of the two approaches for 2010 shows the sector total of carbon dioxide emissions is 4.7 per cent less than the reference total (figure 3.2.1). The fuel that showed the largest difference was gaseous fuels at 11.2 per cent, largely due to the inclusion of gas flared at off-shore platforms during oil and gas production in the reference approach. These emissions are considered fugitive in the sectoral approach so are not captured. If carbon dioxide emissions from flared gas were included in the sectoral approach for the purposes of this comparison, the difference would be reduced to 5.8 per cent. This is primarily due to the large statistical difference for gas in the national energy balances in 2010.

In some years, there are large differences between the reference and sectoral approaches, particularly from the mid-1990s to the year 2000. Much of this difference is due to the statistical differences found in the energy balance tables (Ministry of Economic Development, 2011) that are used as the basis for the reference and sectoral approach.

Figure 3.2.1 Differences between sectoral and reference approaches 1990–2010



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, 2011). 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.

3.2.3 Feedstock and non-energy use of fuels

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

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

- Part of the natural gas used in methanol and synthetic petrol production (although synthetic petrol production ceased in 1997) is stored in the product and therefore has no associated emissions. The rest of the natural gas used in methanol production results in emissions that are reported under the industrial processes sector while the rest of the natural gas used in synthetic petrol production results in emissions that are reported under the energy sector.

- Emissions from the use of natural gas used in urea production are reported under the industrial processes sector.
- Bitumen produced in New Zealand is not used as a fuel but rather used by the company Fulton Hogan in making roads (non-energy use). Bitumen therefore has no associated emissions.
- Coal used in steel production at New Zealand Steel is used as a reductant and therefore treated as an industrial process rather than an energy process. There are therefore no emissions from this coal in the energy sector instead it is dealt with under industrial processes.

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

There was no carbon dioxide capture from flue gases and subsequent carbon dioxide storage occurring in New Zealand between 1990 and 2010.

3.2.5 Country-specific issues

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

- Some of the coal production activity data in the reference approach is used in steel production. Carbon dioxide emissions from this coal have been accounted for under the industrial processes sector in the sectoral 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 sector activity data excludes energy sources containing carbon that is later stored in manufactured products, specifically methanol. Consequently, subsequent subtraction of emissions is not needed to account for this carbon sequestration.

3.2.6 Energy balance

The *New Zealand Energy Data File* (Ministry of Economic Development, 2011) 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: http://www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-data-file. Section A2.4 (annex 2) provides an overview of the 2010 energy supply and demand balance for New Zealand.

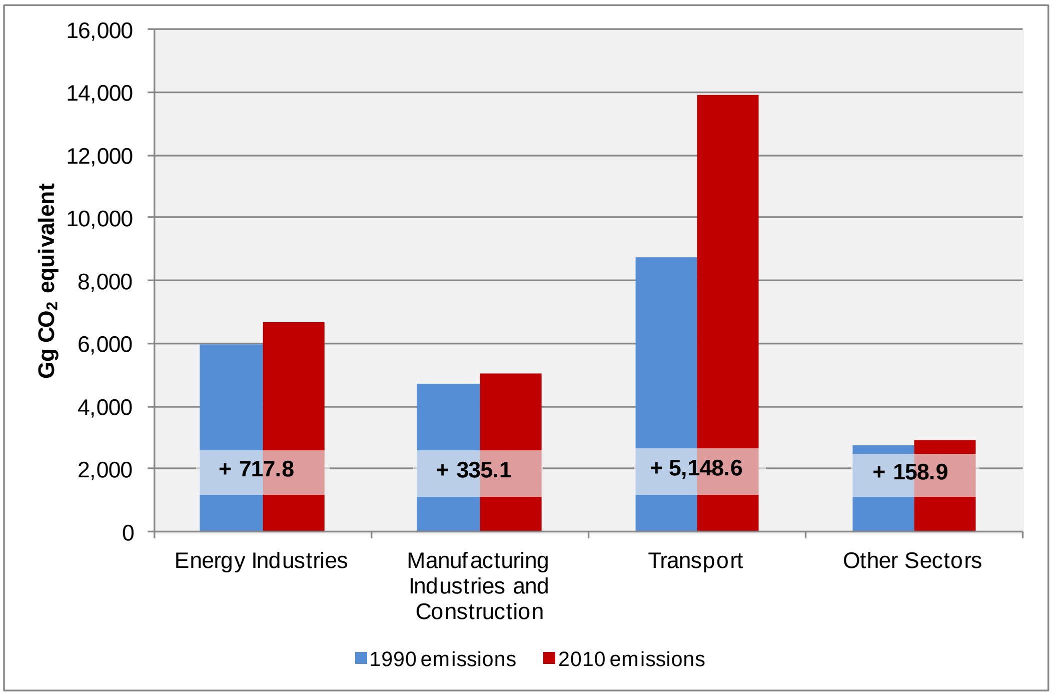
3.3 Fuel combustion (CRF 1A)

Description

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

Information about methodologies, emission factors, uncertainty, 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 1990–2010



Methodological issues

Energy emissions are compiled using the Ministry of Economic Development's energy statistics along with relevant New Zealand-specific emission factors. These greenhouse gas emissions are calculated by multiplying the emission factor of specific fuels by the relevant activity data using an IPCC 1996 Tier 2 method.

Activity data – Liquid fuels

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

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 thousand 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).

A Ministry of Economic Development-commissioned survey in 2008 (see http://www.med.govt.nz/sectors-industries/energy/energy-modelling/technical-papers/liquid-fuels-use-in-new-zealand) found that there are 19 independent fuel distribution companies operating in New Zealand that resell fuel bought wholesale from the oil companies. The study recommended starting an annual survey of the independent distributor companies' petrol and diesel deliveries to sectors. This data could then be used to correctly allocate sales of liquid fuels by small resellers to the appropriate sector.

The *Annual Liquid Fuel Survey* was started in 2009 (for the 2008 calendar year) and found that the 19 independent fuel distribution companies delivered 18 per cent of New Zealand's total diesel consumption, and 3 per cent of New Zealand's total petrol consumption. Using this data, each company's deliveries between 1990 and 2006 were estimated because no information was available for these years. The report *Delivering the Diesel – Liquid Fuel Deliveries in New Zealand 1990–2008* (see http://www.med.govt.nz/sectors-industries/energy/energy-modelling/technical-papers/delivering-the-diesel-liquid-fuel-deliveries-in-new-zealand-1990-2008) outlines in more detail the methodology employed to perform this calculation.

Activity data – Solid fuels

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

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

Activity data – Gaseous fuels

The Ministry of Economic Development receives activity data on gaseous fuels from a variety of sources. Individual gas field operators provide information on the amount of gas extracted, vented, flared and own use at each gas field. Information on processed gas, including the Kapuni gas field, and information on gas transmission and distribution throughout New Zealand is also provided. Large users of gas, including electricity generation companies, provide their activity data directly to the Ministry of Economic Development. Finally, the Ministry 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 based on the report *Heat Plant in New Zealand* (Bioenergy Association of New Zealand, 2008).

Liquid biofuel activity data is based on information collected under the Petroleum or Engine Fuel Monitoring Levy as reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2011).

Emission factors

New Zealand emission factors are based on gross calorific values. A list of emission factors for carbon dioxide, methane and nitrous oxide for all fuel types is listed in annex 2. Explanations of the characteristics of liquid, solid and gaseous fuels and biomass used in New Zealand are described under each of the fuel sections below. Where a New Zealand-specific value is not available, New Zealand uses either the IPCC value that best reflects New Zealand conditions or the mid-point value from the IPCC range. All emission factors from the IPCC (1996) are converted from net calorific value to gross calorific value.

Emission factors – Liquid fuels

The carbon dioxide emission factors for oil products are from the New Zealand Refining Company data, Baines (1993) and IPCC (1996) defaults. The liquid fuel emission factors are calculated on an annual basis. This inventory submission uses emission factors based on New Zealand Refining Company data fuel specifications such as on carbon content and calorific values. Annex 2 includes further information on liquid fuels emission factors, including a time series of gross calorific values.

Emission factors – Solid fuels

Emission factors for solid fuels are sourced from the *New Zealand Energy Information Handbook* (Baines, 1993). They are shown in table 3.3.1.

Table 3.3.1 Gross carbon dioxide emission factors for solid fuels

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

Emission factors – Gaseous fuels

The gaseous fuels emission factor is the calculated weighted average for all of the gas production fields. The emission factor takes into account gas compositional data from all gas fields. This method provides increased accuracy because the decline in production of both Maui and Kapuni gas fields has been replaced by other new gas fields (for example, Pohoukura) coming on stream. This emission factor fluctuates slightly from year to year, mainly due to the different gas fields that were producing gas in that year. New Zealand gas fields also seem to have higher carbon content than most international gas fields.

The Kapuni gas field has particularly high carbon dioxide content. Historically, this field has been valued by the petrochemicals industry as a feedstock. However, most of the gas from this field is now treated and the excess carbon dioxide removed at the Kapuni Gas Treatment Plant. Consequently, separate emission factors were used to calculate emissions from Kapuni treated and un-treated gas due to the difference in carbon content (refer to annex 2). The emissions from this removal of carbon dioxide are included under the manufacture of solid fuels and other energy industries category (section 3.3.2).

Emission factors – Biomass

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

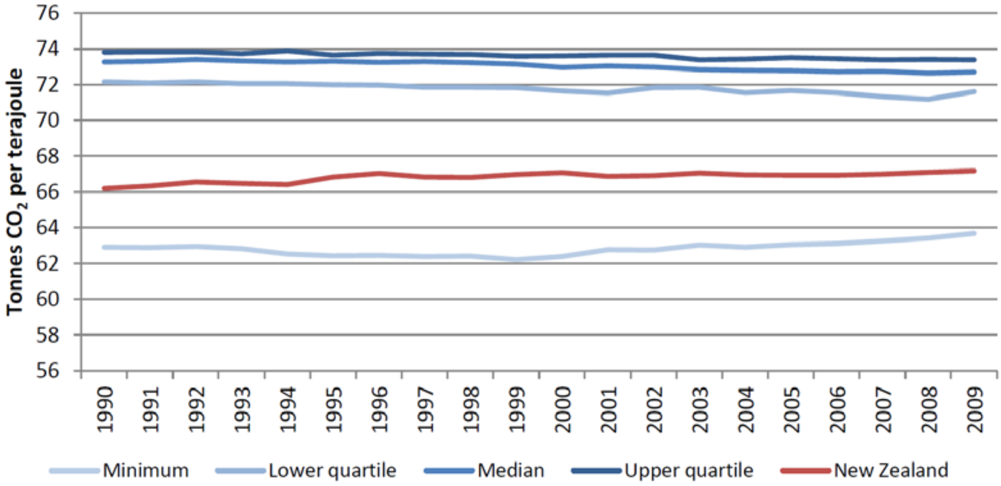
Sector-wide planned improvements

All source-specific planned improvements will be discussed in their corresponding sections. However, the Ministry of Economic Development will continue to examine the use of more specific solid fuel carbon dioxide emission factors. The introduction of the New Zealand Emissions Trading Scheme (NZ ETS) means more data and analysis around the carbon content of solid fuels should become available that may be able to be used in the 2013 inventory. Legal and confidentiality concerns have resulted in a delay in accessing this data for inventory purposes; however, these issues are expected to be resolved in time for the 2013 submission.

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

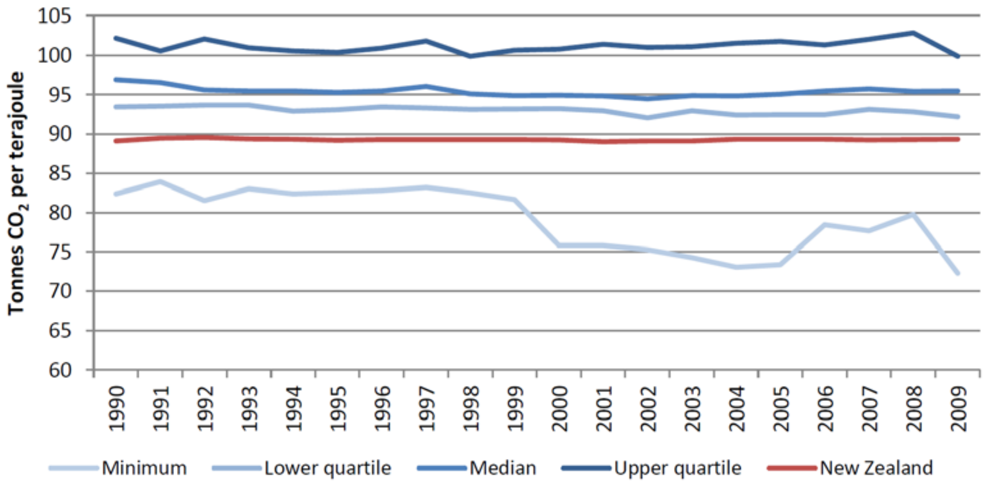
Implied carbon dioxide emission factors for combustion of liquid, solid and gaseous fuels from this inventory were compared with those in the IPCC database using the Locator Tool (version 3.4). The graphs below include the international median, minimum and first quartile along with New Zealand factors across the time series. For all fuels, New Zealand's implied emissions factors fall between the minimum and first quartile of international observations.

Figure 3.3.2 Carbon dioxide implied emission factor – Liquid fuel combustion (1990-2009)



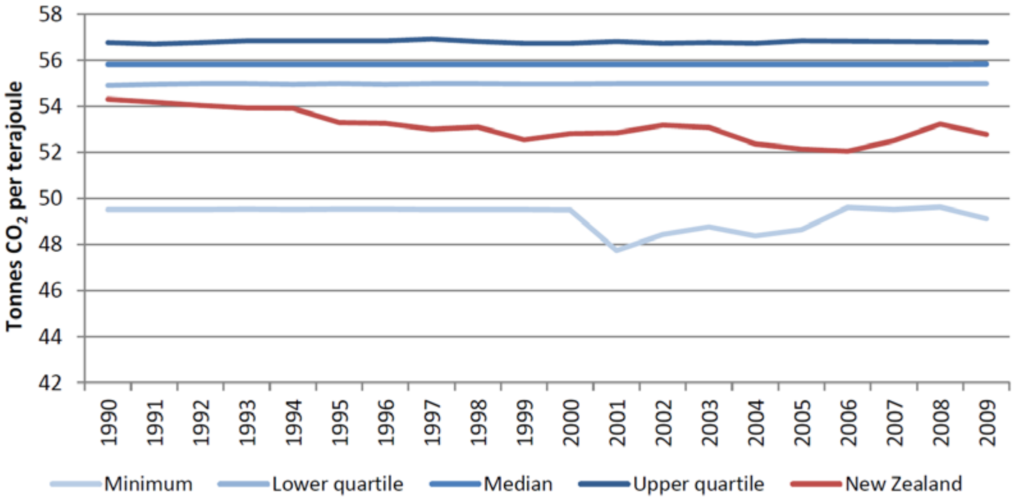
Note: 'Minimum', 'lower quartile', 'median' and 'upper quartile' refer to the set of international implied emission factors.

Figure 3.3.3 Carbon dioxide implied emission factor – Solid fuel combustion (1990-2009)



Note: 'Minimum', 'lower quartile', 'median' and 'upper quartile' refer to the set of international implied emission factors.

Figure 3.3.4 Carbon dioxide implied emission factor – Gaseous fuel combustion (1990-2009)



Note: 'Minimum', 'lower quartile', 'median' and 'upper quartile' refer to the set of international implied emission factors.

Uncertainties and time-series consistency

Uncertainty in greenhouse gas emissions from fuel combustion varies depending on the gas. The uncertainty of carbon dioxide emissions is relatively low, which is important because carbon dioxide emissions comprised 95.2 per cent of energy sector emissions in 2010. In comparison, emissions of the non-carbon dioxide gases are much less certain as emissions vary with combustion conditions. Uncertainties for carbon dioxide, methane and nitrous oxide activity data and emission factors are supplied in table 3.3.2. Many of the non-carbon dioxide emission factors used by New Zealand are the IPCC default values. More detailed information around uncertainties can be found in annex 2.

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

		Activity data uncertainty (%)	Emission factor uncertainty (%)
CO_2	Liquid Fuels	±0.17	±0.5
	Solid Fuels	±0.68	±3.5
	Gaseous Fuels	±9.24	±2.4
	Fugitive - Geothermal	±5.00	±5.0
	Fugitive - Venting/Flaring	±2.58	±2.4
	Fugitive - Oil Transport	±5.00	±50.0
	Fugitive - Transmission & Distribution	±2.58	±5.0
CH_4	Liquid Fuels	±0.17	±50.0
	Solid Fuels	±0.68	±50.0
	Gaseous Fuels	±9.24	±50.0
	Biomass	±5.00	±50.0
	Fugitive - Geothermal	±5.00	±5.0
	Fugitive - Venting/Flaring	±9.24	±50.0
	Fugitive - Coal Mining	±0.68	±50.0
	Fugitive - Transmission & Distribution	±9.24	±5.0
	Fugitive - Other Leakages	±5.00	±50.0
	Fugitive - Oil Transportation	±5.00	±50.0

		Activity data uncertainty (%)	Emission factor uncertainty (%)
N_2O	Liquid Fuels	±0.17	±50.0
	Solid Fuels	±0.68	±50.0
	Gaseous Fuels	±9.24	±50.0
	Biomass	±5.00	±50.0

3.3.1 Fuel combustion: Energy industries (CRF 1A1)

Description

This category comprises emissions from fossil fuels burnt in stationary combustion. It includes combustion for public electricity and heat production, petroleum refining and the manufacture of solid fuels and other energy industries. The latter subcategory includes estimates for natural gas in oil and gas extraction and from natural gas in synthetic petrol production. The excess carbon dioxide removed from Kapuni gas at the Kapuni Gas Treatment Plant has also been reported under the manufacture of solid fuels and other energy industries subcategory because of confidentiality concerns.

In 2010, emissions in the energy industries category totalled 6,679.6 Gg CO_2-e (21.5 per cent) of the energy sector. Emissions from energy industries have increased 717.8 Gg CO_2-e (12.0 per cent) since the 1990 level of 5,961.8 Gg CO_2-e. The public electricity and heat production subcategory accounted for 5,374.9 Gg CO_2-e (80.5 per cent) of the emissions from the energy industries category in 2010. This is an increase of 1,907.0 Gg CO_2-e (55.0 per cent) from the 1990 level of 3,467.9 Gg CO_2-e.

Between 2009 and 2010, there was a decrease of 879.4 Gg CO_2-e (14.1 per cent) in emissions from public electricity and heat production. The three main drivers that led to the decrease in emissions from electricity generation, despite a 3 per cent growth in electricity generated, were:

- an increase in the supply of geothermal generation
- a preference for gas over coal at New Zealand's largest electricity generation plant
- higher inflows into the hydro lakes.

Key categories identified in the 2010 level assessment from the energy industry category include CO_2 emissions from:

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

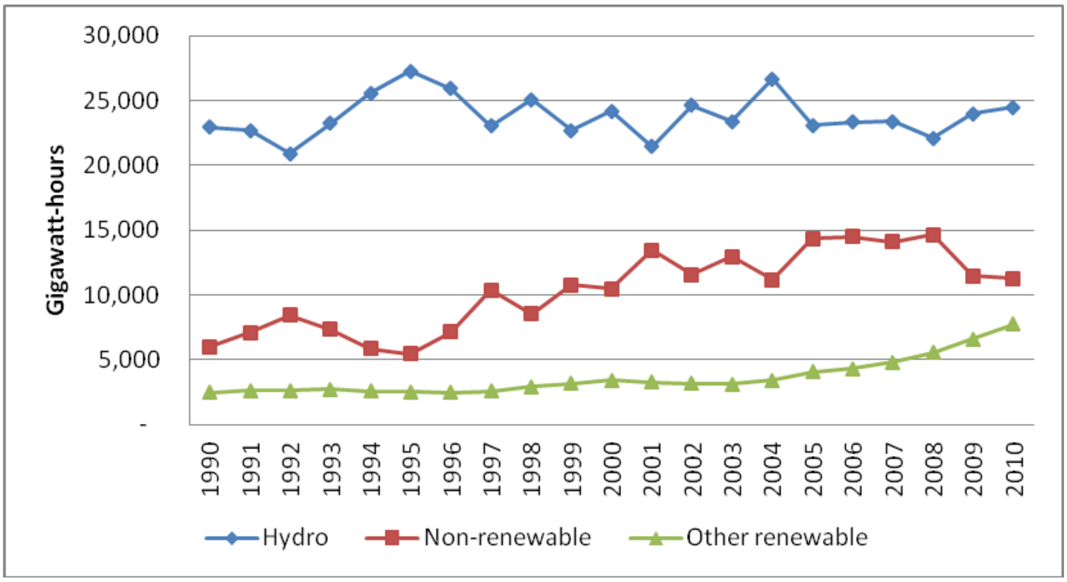
Key categories identified in the 2010 trend assessment from the energy industry category include CO_2 emissions from:

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

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2010 calendar year, hydro generation provided 56 per cent of New Zealand's electricity generation. A further 13 per cent came from geothermal, 4 per cent from wind and 1 per cent from biomass. The remaining 26 per cent was provided by fossil fuel thermal generation plants using oil, gas and coal (Ministry of Economic Development, 2011).

Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990 and 2010. These fluctuations can also be seen over the time series for New Zealand's total emissions. The fluctuations are influenced by the close inverse relationship between thermal and renewable generation (figure 3.3.5). 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 3.3.5 New Zealand's electricity generation by source from 1990–2010



Methodological issues

Public electricity and heat production

All thermal electricity generators provide figures for the amount of coal, gas and oil used for electricity generation to the Ministry of Economic Development.

Around 6 per cent of New Zealand's electricity is supplied by co-generation (also known as combined heat and power) (Ministry of Economic Development, 2011). Most of the major co-generation plants are attached to large industrial facilities that consume most of the electricity and heat generated.

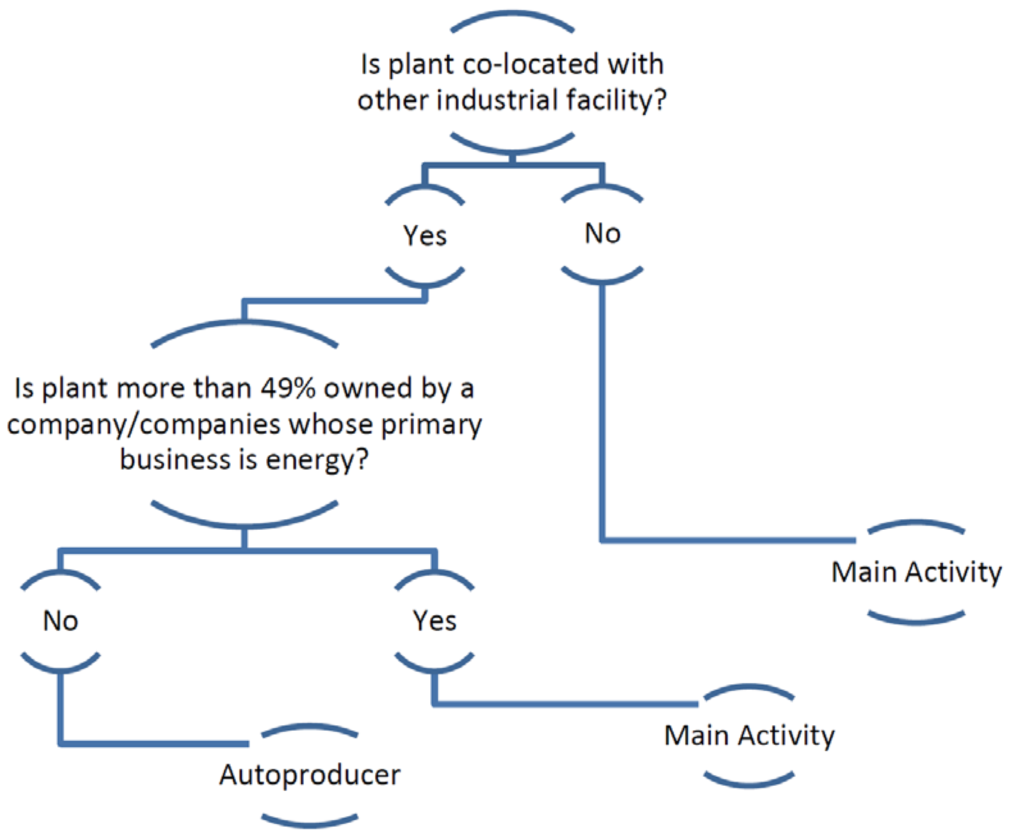
There are six co-generation plants that fit the IPCC (1996) definition of public electricity and heat production, which produce electricity as their primary purpose. The emissions from these plants are included under the public electricity and heat production subcategory, while emissions from other co-generation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

A Tier 1 method is used to calculate emissions for these co-generation plants. 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.

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

The Whareroa co-generation plant is a Fonterra/Todd Energy joint venture at a milk-processing facility. In past inventory submissions, gas combusted at Whareroa was captured in the manufacturing industries and construction sector as an auto-producer. In order to establish a consistent approach to on-site generation, the national electricity system developed a decision-tree to guide the allocation of associated fuel consumption (see figure 3.3.6).

Figure 3.3.6 Decision tree for on-site generation plant



Petroleum refining

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

In past inventories, emissions from the combustion of refinery gas were included in the gaseous fuels category in the sectoral approach. Refinery gas is obtained during the distillation of crude and production of oil products. As a result, emissions from its combustion are implicitly included under liquid fuels in the reference approach. In order to improve the validity of the reference approach as a quality check at a fuel level, these emissions are now allocated to liquid fuels in both approaches. This change has been applied across the time series.

Manufacture of solid fuels and other energy industries

Activity data for synthetic petrol production was provided by Methanex New Zealand while the plant was in operation (production of synthetic petrol ceased in 1997). A Tier 1 methodology was used to estimate emissions based on the annual weighted average gas emission factor.

Activity data and emission factors for the combustion of natural gas during oil and gas extraction are provided to the Ministry of Economic Development by each individual gas and/or oil field operator. In 2010, liquid fuels were combusted during oil and gas extraction. The activity data for this is provided by the individual gas and/or oil field operator while the IPCC default for crude oil combustion is used.

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Source-specific recalculations

Activity data for electricity generation from liquid fuels from 1990–1998 has been revised following a review of national energy data. Fuel consumption disagreed with the amount of electricity generated and known plant efficiencies. As the electricity data was considered more reliable than the fuel consumption data, new estimates were made, resulting in small recalculations.

Gaseous fuel activity data was revised following the discovery of a miscalculation in the reconciliation of monthly and annual data, resulting in small recalculation in several years from 1995–2009.

Gas combusted at the Whareroa co-generation facility is now included in the public electricity and heat production sector because it is considered a main activity producer.

Gas own use activity data has also been revised due to previous incorrect company level data.

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

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

Description

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

In 2010, emissions from the manufacturing industries and construction subcategory accounted for 5,031.1 Gg CO_2-e (16.2 per cent) emissions from the energy sector. Emissions were 335.1 Gg CO_2-e (7.1 per cent) above the 1990 level of 4,696.0 Gg CO_2-e. A decline in methanol production in 2003-2004 caused a significant reduction in emissions from this category. Methanol production is the largest source of emissions in the chemical subcategory.

Key categories identified in the 2010 level assessment from the manufacturing industries and construction category include CO_2 emissions from:

- gaseous fuels
- liquid fuels
- solid fuels.

Key categories identified in the 2010 trend assessment from the manufacturing industries and construction category include CO_2 emissions from:

- solid fuels.

Methodological issues

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

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

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

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

Energy balance tables used in the *New Zealand Energy Data File* (Ministry of Economic Development, 2011) split out industrial uses of energy using the Australia New Zealand Standard Industrial Classification (ANZSIC) 2006. This was possible because of the collection of more detailed information from the various surveys used to compile the energy balance tables since 2009.

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

Solid fuels

The 2010 *New Zealand Energy Data File* (Ministry of Economic Development, 2010) disaggregated the ‘industrial’ category for coal. This was the first time this category has been disaggregated and applied from 2009. These percentage splits were applied to activity data for the annual inventory submission across the whole time series (ie, back to 1990). Carbon dioxide, methane and nitrous oxide emissions have been split out using the same percentage splits. As more data becomes available, these splits will be reviewed and revised where necessary.

Table 3.3.3 Splits used for manufacturing industries and construction category – Solid fuels for 2010

Manufacturing industries and construction sub-category	Bituminous coal (%)	Sub-bituminous coal (%)	Lignite coal (%)
Iron and steel	NO	NO	NO
Non-ferrous metals	NO	0.06	NO
Chemicals	NO	NO	NO
Pulp, paper and print	NO	6.82	2.41
Food processing, beverages and tobacco	10.89	72.17	95.10
Mining and construction	0.21	1.15	0.45
Textiles	NO	1.10	NO
Non-metallic minerals	28.77	5.19	NO
Mechanical/electrical equipment	NO	0.12	NO
Other	60.13	13.38	2.04

Note: NO stands for not occurring.

Solid biomass

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

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

Manufacturing industries and construction sub-category	%
Iron and steel	NO
Non-ferrous metals	NO
Chemicals	NO
Pulp, paper and print	99.94
Food processing, beverages and tobacco	0.05
Mining and construction	NO
Textiles	NO
Non-metallic minerals	NO
Mechanical/electrical equipment	NO
Other	0.01

Note: NO stands for not occurring.

Liquid fuels (diesel and gasoline)

Following Expert Review Team recommendations, New Zealand began to disaggregate liquid fuel combustion in the manufacturing industries and construction category for the 2011 inventory. While data is not collected at this level of detail in energy surveys for liquid fuels, this inventory uses a method that takes sector-level reported consumption, along with Statistics New Zealand data around sub-sector fuel use and sub-sector gross domestic product (GDP), to develop activity data estimates across the time series.

Statistics New Zealand conducted a Manufacturing Energy Use Survey (Statistics New Zealand, 2010), which assessed energy consumption and end use across manufacturing industries for the 2009 calendar year.

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

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

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

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

Figure 3.3.7 Splits used for manufacturing industries and construction category – Gasoline (1990-2010)

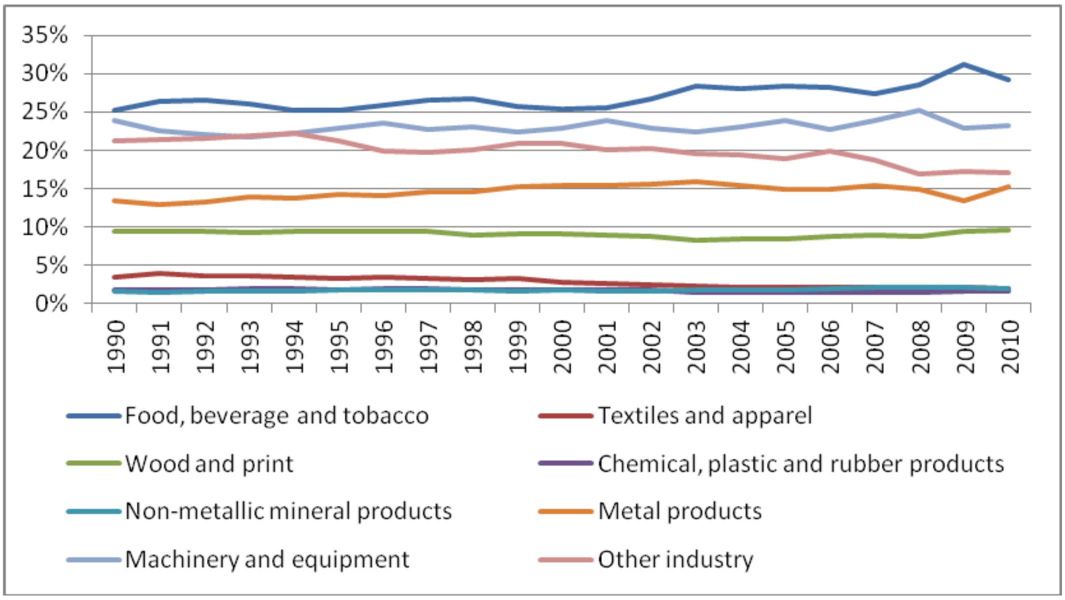
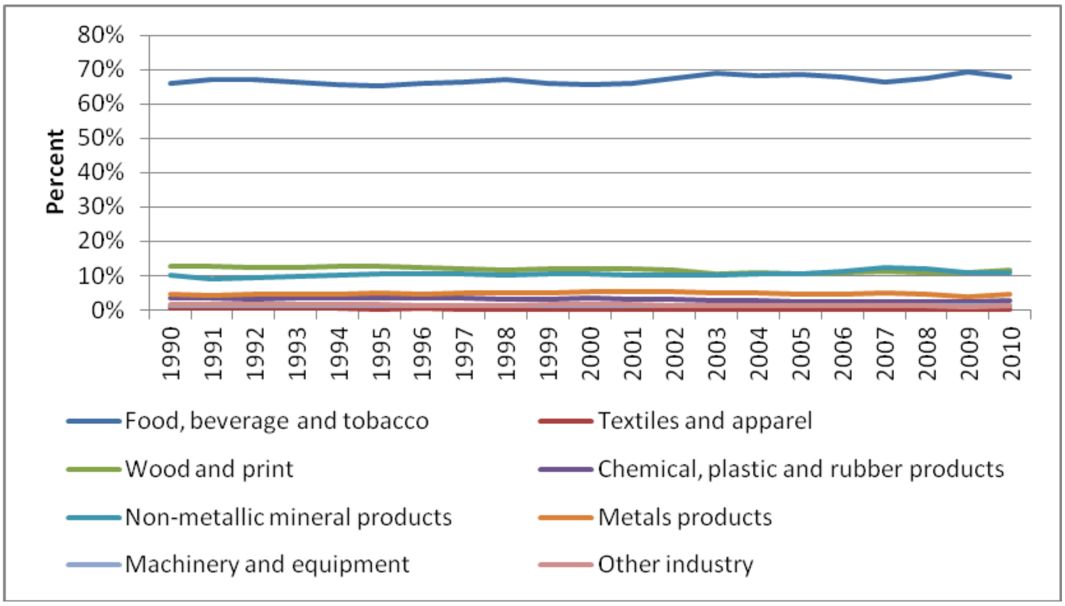


Figure 3.3.8 Splits used for manufacturing industries and construction category – Diesel (1990-2010)



Gaseous fuels

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

Method used in order of preference based on available data:

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

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

Chemicals

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

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

In addition, estimates for methanol production are also included in the chemicals subcategory because of confidentiality concerns. The activity data for methanol production is supplied directly by Methanex New Zealand. Until 2004, methanol was produced at two plants by Methanex New Zealand. In November 2004, production at the Motunui plant was halted and the plant re-opened in late 2008. Methanex New Zealand exports the majority of this methanol.

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

On-site electricity generation

As mentioned in the previous section, the co-generation plant at the Whareroa milk-processing plant was previously considered an auto-producer and therefore included in the manufacturing industries and construction sector. In order to establish a consistent approach to on-site electricity generation, the national electricity system now uses a decision tree to distinguish auto-producers from main activity producers.

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Source-specific recalculations

As mentioned under methodological issues, this inventory includes revised estimates of diesel and gasoline activity data in the disaggregated manufacturing industries and construction. This disaggregation was undertaken in order to reduce the large volumes of fuel allocated to 'other – not specified' in previous inventories.

There have been significant revisions to mining and construction across the time series due to new data from Statistics New Zealand, leading to new estimates of the volumes of fuel combusted in the mining sector allocated to 'primary industry' in historical surveys.

A review of national energy data in preparation for improvements in data systems revealed inconsistent sector reporting and missing data for gaseous fuel combustion. Activity data has been revised across the time series using consumer data followed by sales surveys and estimates based on sector energy intensity by GDP for known data points.

Gas combusted at the Whareroa co-generation facility is now included in the public electricity and heat production sector as it is considered a main activity producer.

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

Woody biomass combustion in the manufacturing industries and construction category was previously estimated using a model driven by the production of a number of different wood products. For this inventory, additional wood products were captured in the model, resulting in recalculations in activity data across the time series.

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

Source-specific planned improvements

The Ministry of Economic Development will continue to investigate disaggregation of other liquid fuels in this category and how this information is best displayed in future inventory submissions. Disaggregated data on fuel oil consumption, in particular, will be available in future energy end-use surveys.

On 1 July 2010, the stationary energy and industrial processes sector came into the NZ ETS. In March 2011, NZ ETS companies filed their returns stating the emissions they produced from 1 July to 31 December 2010. This will provide further information around quality assurance and quality checks performed by individual companies that can be used in future inventories. The Ministry of Economic Development will examine the best way this data and surrounding quality-assurance and quality-control practices may be incorporated into the national inventory.

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 2010, the transport category was responsible for 13,912.8 Gg CO_2-e (44.7 per cent) of emissions from the energy sector, or 19.4 per cent of total emissions. Emissions increased 5,148.6 Gg CO_2-e (58.7 per cent) from the 8,764.1 Gg CO_2-e emitted in 1990. The transport emissions profile in 2010 was dominated by emissions from the road transportation subcategory. In 2010, road transport accounted for 12,514.1 Gg CO_2-e (89.9 per cent) of total transport emissions. This was an increase of 4,973.8 Gg CO_2-e (66.0 per cent) from the 1990 level of 7,540.3 Gg CO_2-e.

Key categories identified in the 2010 level assessment from the transport category include CO_2 emissions from:

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

Key categories identified in the 2010 trend assessment from the transport category include CO_2 emissions from:

- road transport – gasoline
- road transport – diesel oil
- road transport – liquefied petroleum gases
- road transport – gaseous fuels.

Between 2009 and 2010, emissions from transport increased by 130.0 Gg CO_2-e (1.0 per cent).

Methodological issues

Activity data on the consumption of fuel by the transport sector was sourced from the *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Economic Development. Liquefied petroleum gas and compressed natural gas consumption figures are reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2011).

As mentioned in section 3.3, this inventory continues to use the results of the *Annual Liquid Fuel Survey* that began in 2009. The purpose of this survey is to capture the allocation of fuel resold by small independent resellers. In terms of energy sector emission estimates, emissions attributed to the transport category decreased by around 20 per cent, and emissions attributed to other categories, such as agriculture, forestry and fisheries, have increased significantly. For time-series consistency, these reallocations are also made from 1990–2008, prior to the collection of data on the resale of liquid fuel by small, independent distributors.

Road transportation

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

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

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

- vehicles manufactured (although New Zealand only manufactures a small number of buses and heavy trucks now) or imported for sale as new vehicles; and
- vehicles produced in Japan and then imported used into New Zealand.

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

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

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

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

Due to the presence of expensive catalysts, many used vehicles imported into New Zealand had their catalytic converters removed before sale. The Ministry of Transport undertook several testing studies to determine estimates of catalytic converter removal. Further information on these emission factors can be found in annex 2.

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

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

The Ministry of Economic Development and Ministry for the Environment met with the Australian inventory reporting team in July 2011 in order to conduct a review of proposed methodologies for calculating emissions of methane and nitrous oxide emissions associated with road transport. New Zealand's Tier 2 approach for road transport was presented, resulting in a recommendation from the Australian team that the new methodology be adopted for the 2012 submission and that New Zealand attempt to use the IPCC good practice guidance (IPCC, 2000) to choose an appropriate splicing method.

Figures 3.3.9 and 3.3.10 show a comparison of the previous method with the method used for this submission for gasoline.

Figure 3.3.9 Methane emissions from road transport from 2001 to 2010 - gasoline

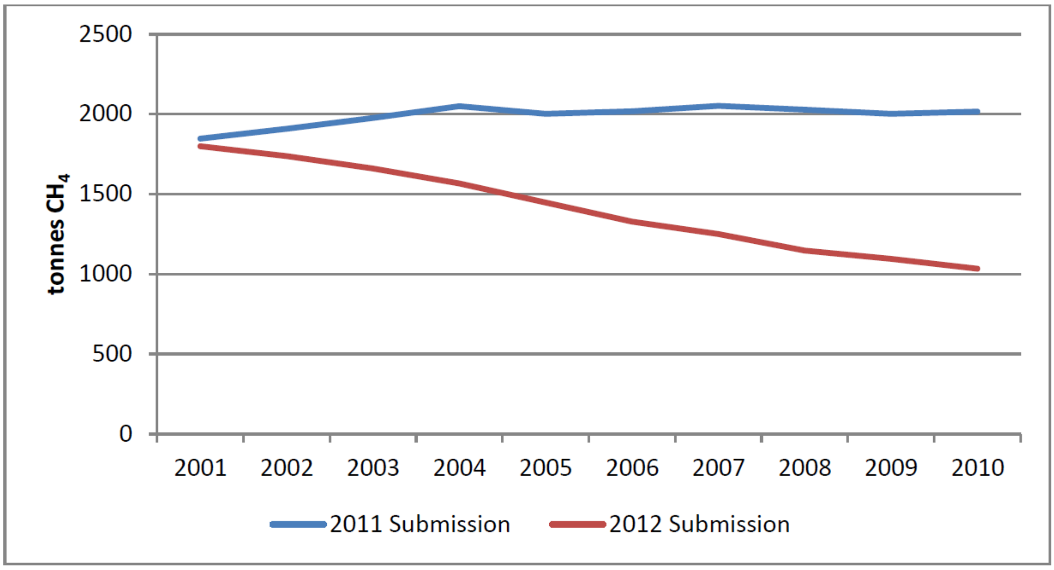
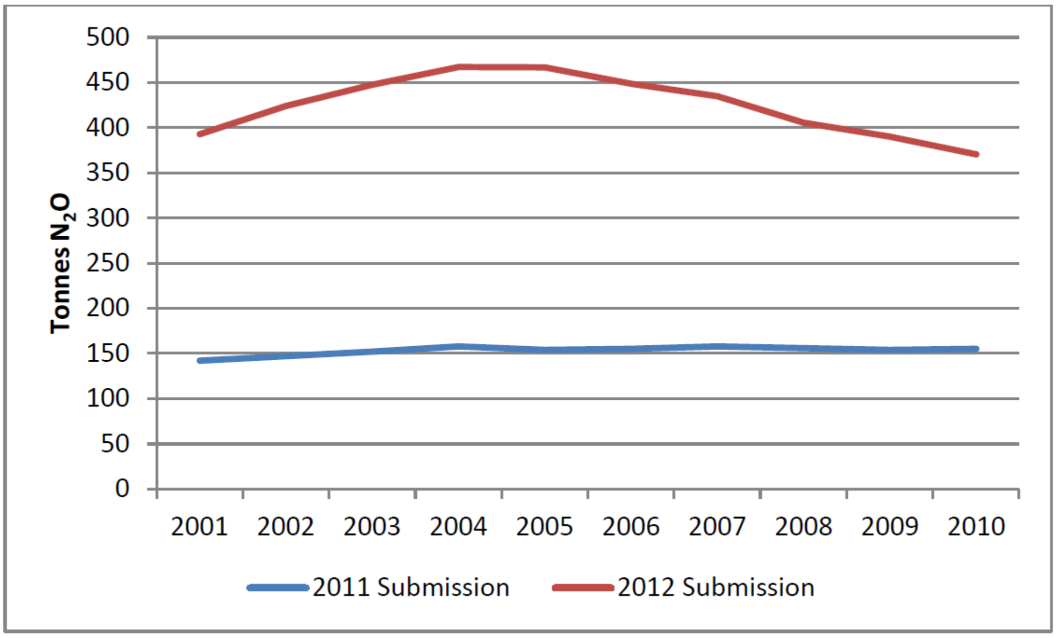


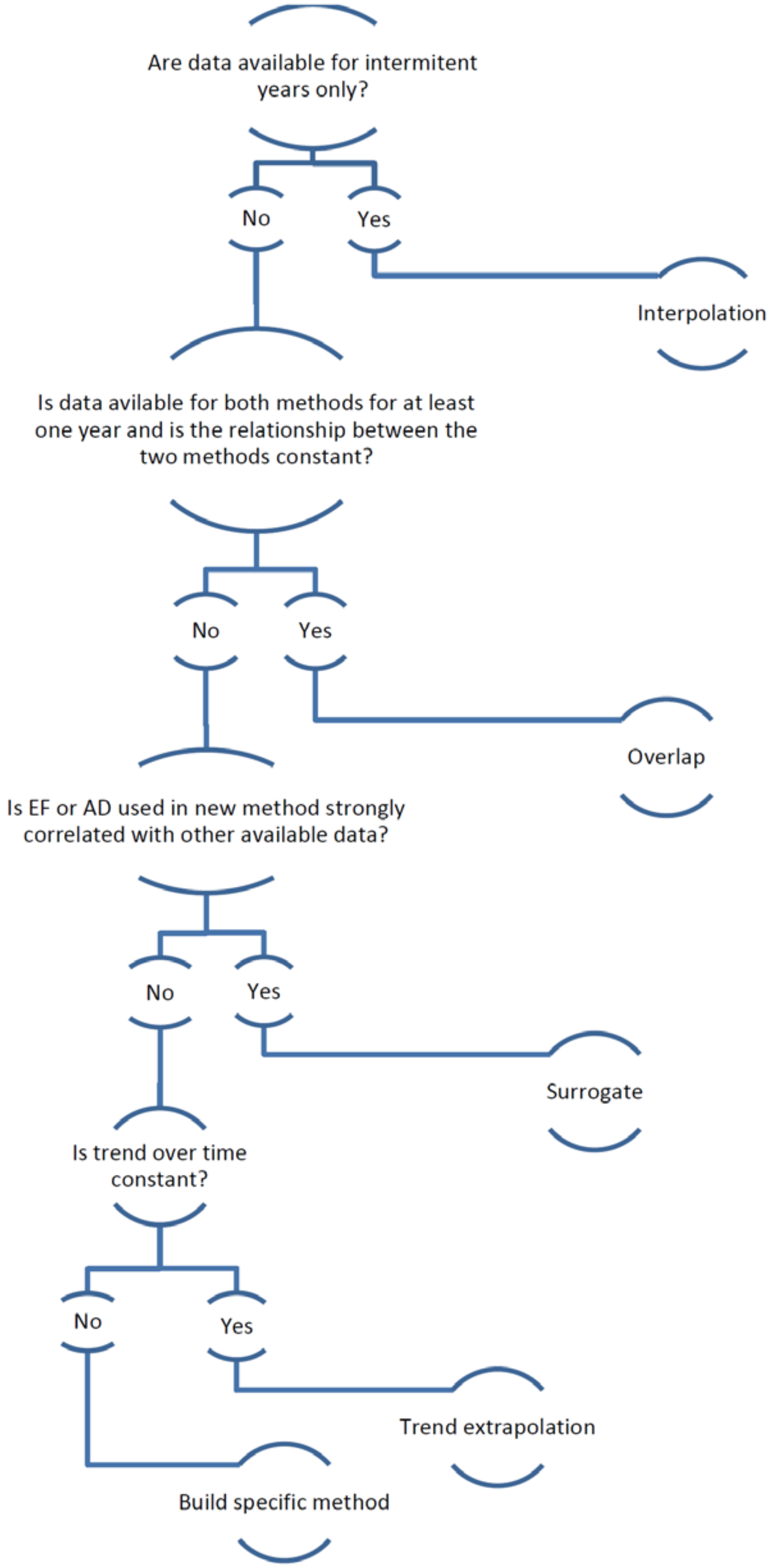
Figure 3.3.10 Nitrous oxide emissions from road transport from 2001 to 2010 – gasoline



Time-series consistency

From 1990 to 2000, insufficient data is available to use the Tier 2 methodology, therefore, some analysis of the relationship between the Tier 1 and Tier 2 methods was necessary to establish how best to splice them to achieve time-series consistency. Figure 3.3.11 was developed based upon IPCC good practice guidance in order to facilitate consistent decision making.

Figure 3.3.11 Splicing method decision tree for gasoline emissions



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

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

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

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

Where:

y_t is the recalculated emission estimate computed using the overlap method

x_t is the estimate developed using the previous method

y_i and x_i are the estimates prepared using the new and previously used methods during the period of overlap, as denoted by years m through n.

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

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

Where:

t is the year for which a new estimate is required

a is the slope of the line achieved by regressing Tier 2/Tier 1 for the overlap period

b is the intercept of the line achieved by regressing Tier 2/Tier 1 for the overlap period

x_t is the estimate for year *t* using the previous methodology.

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

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

A quality check was necessary to confirm that extrapolation of this trend over such a long period did not result in a New Zealand-implied emission factor diverging significantly from international observation. An international average implied emission factor was calculated using the IPCC database (2011). For the purposes of this calculation, all countries using default emission factors – including New Zealand – were removed from the calculation.

Figures 3.3.12 and 3.3.13 indicate that the implied emission factor resulting from the new methodology and splicing is consistent with those observed internationally across the time series. The agreement is poorer for nitrous oxide emissions due to the more complicated effect of changing technology and the lack of data at key stages in technology update.

A similar ‘hump’ as observed in the international figures likely occurred in New Zealand. The decline (2005–2010) is captured by the new methodology but the increase occurs before data is available. While it is probable that this increase began soon after 1996 when emissions controls become more common in the New Zealand fleet due to the removal of lead from all local gasoline, a conservative approach was chosen to reduce the risk of underestimating nitrous oxide emissions.

Figure 3.3.12 Nitrous oxide implied emission factors from 1990 to 2009 – gasoline road transport

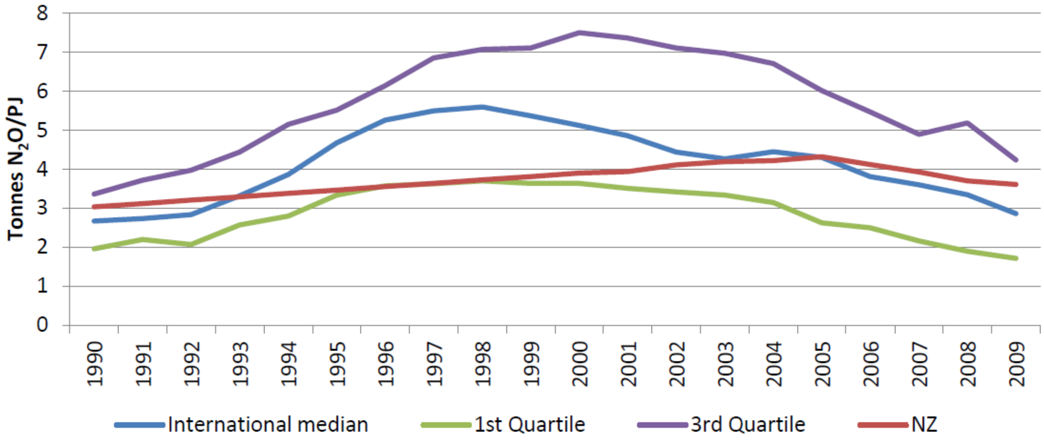
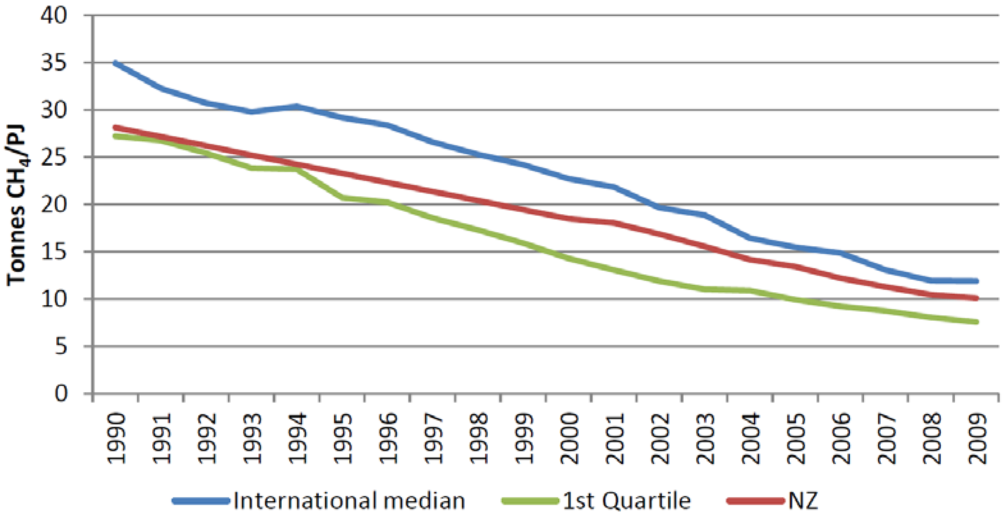


Figure 3.3.13 Methane implied emission factors from 1990 to 2009 – gasoline road transport



Dual-fuel vehicles

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

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

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

Blended biofuels

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

Overall effect of moving to Tier 2 methodology

The new methodology indicates that New Zealand was underestimating emissions of nitrous oxide and overestimating emissions of methane from 1990 to 2009. The combined result was an underestimation of CO_2-equivalent emissions from road transport for the period.

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

As more advanced emissions control technologies enter the fleet, the difference between nitrous oxide estimates from the Tier 2 methodology and Tier 1 methodology reduce while the differences between the methane emissions continue to increase. By 2010, the combined CO_2-equivalent emissions from nitrous oxide and methane in road transport is lower under the Tier 2 methodology than under the previous Tier 1 methodology, reflecting continued improvements in emission control technology entering the fleet.

Figure 3.3.14 Net change CO_2-e from methane and nitrous oxide from moving to Tier 2 methodology from 1990 to 2010

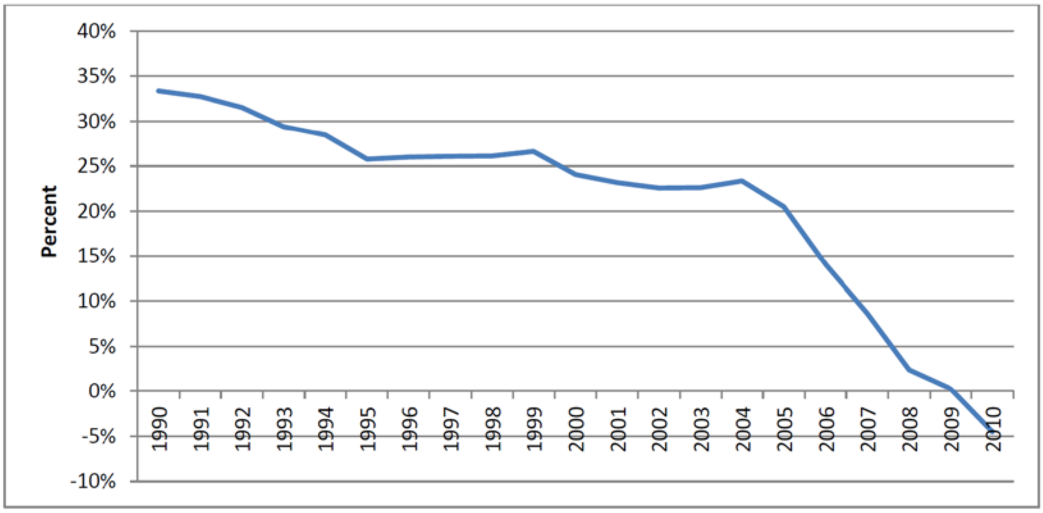
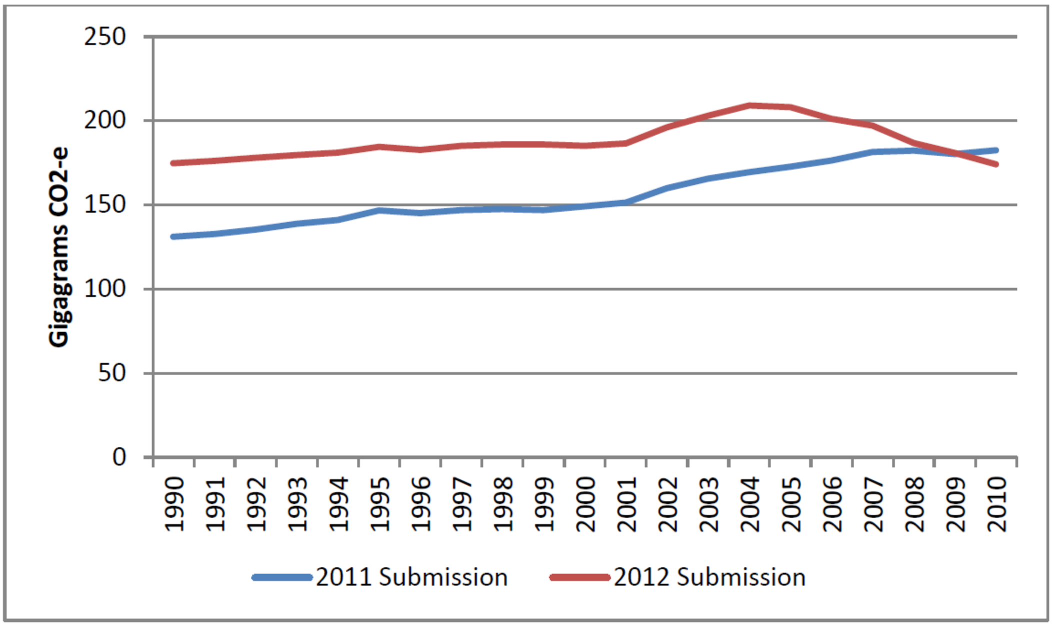


Figure 3.3.15 Total methane and nitrous oxide road transport emissions from 1990 to 2010



Railways

Emissions from the railways subcategory (including both liquid and solid fuels) were estimated using a Tier 1 approach (IPCC, 2000). New Zealand-specific emission factors were used to estimate carbon dioxide emissions and, because of insufficient data, the IPCC default emission factors were used to estimate methane and nitrous oxide emissions. The emission factors for carbon dioxide and non-carbon dioxide gases for the various fuel types used in the railway subcategory can be found in annex 2.

Navigation (domestic marine transport)

Emissions from the navigation subcategory in New Zealand were estimated using a Tier 1 approach (IPCC, 1996). Fuel oil activity data on fuel use by domestic transport is sourced from the quarterly *Delivery of Petroleum Fuels by Industry Survey* conducted by the

Ministry of Economic Development. Monthly oil statistics (MOS) provide monthly marine diesel supply figures that are added to automotive diesel consumption data provided by KiwiRail, operators of diesel ferries, to obtain total diesel consumption in the navigation sector. New Zealand-specific emission factors have been used to estimate carbon dioxide emissions and, because of insufficient data, the IPCC 1996 default emission factors have been used to estimate methane and nitrous oxide emissions.

Civil aviation

A Tier 1 approach (IPCC, 1996) that does not use landing and take-off cycles has been used to estimate emissions from the civil aviation subcategory. There is no gain in inventory quality by moving from a Tier 1 to a Tier 2 approach using landing and take-off cycles (IPCC, 2000).

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

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

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

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

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

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

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

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

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

Source-specific recalculations

As mentioned in the methodological issues section, New Zealand has moved to a IPCC Tier 2 (2000) methodology for estimating non-CO_2 emissions from road transport. This has resulted in recalculations across the time series in all fuels.

Small recalculations resulted from revisions to activity data provided by oil and gas companies.

Source-specific planned improvements

The Ministry of Economic Development will continue to consider how best to use data from the Ministry of Transport in estimating emissions from road transport. In particular, estimation of vehicle-kilometres-travelled by dual-fuel LPG vehicles will be addressed more completely in the 2013 national inventory report.

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 2010, fuel combustion of the other sectors category accounted for 2,918.7 Gg CO_2-e (9.4 per cent) of the emissions from the energy sector. This is an increase of 158.9 Gg CO_2-e (5.8 per cent) below the 1990 value of 2,759.9 Gg CO_2-e.

Emissions from the agriculture, forestry and fisheries subcategory were 1,452.3 Gg CO_2-e (49.8 per cent) of the other sectors category in 2010. This is an increase of 226.7 Gg CO_2-e (18.5 per cent) from the 1990 level of 1,225.6 Gg CO_2-e.

Emissions from the commercial and institutional subcategory were 896.8 Gg CO_2-e (30.7 per cent) of the other sectors category in 2010. This is a increase of 11.4 Gg CO_2-e (1.3 per cent) from the 1990 level of 885.4 Gg CO_2-e.

Emissions from the residential subcategory were 569.7 Gg CO_2-e (19.5 per cent) of the other sectors category in 2010. This is a decrease of 79.3 Gg CO_2-e (12.2 per cent) from the 1990 level of 648.9 Gg CO_2-e.

Key categories identified in the 2010 level assessment from the other sectors category include CO_2 emissions from:

- liquid fuels
- gaseous fuels.

Key categories identified in the 2010 trend assessment from the other sectors category include CO_2 emissions from:

- liquid fuels
- solid fuels.

Methodological issues

Liquid fuels

As mentioned in section 3.3, this inventory uses information from the *Annual Liquid Fuel Survey* from 2009. This data is used to correctly allocate liquid fuels resold by independent distributors that are included in the commercial sector in surveys completed by the major oil companies. In terms of energy sector emission estimates, emissions attributed to the transport category have decreased by around 20 per cent, and emissions attributed to other categories, such as the agriculture, forestry and fisheries subcategory have increased significantly. These changes have been applied to the entire time series, from 1990–2010.

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

Table 3.3.5 Split of ‘other primary industry’

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

Solid fuels

On-selling of coal reported as sold to the commercial sector was found in 2010. As a result, some activity previously reported in the commercial sector has been reallocated to the agriculture sector.

Gaseous fuels

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

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

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

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

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Source-specific recalculations

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

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

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

Source-specific planned improvements

There are no current planned improvements for this specific category.

3.4 Fugitive emissions from fuels (CRF 1B)

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

In 2010, fugitive emissions from fuels accounted for 2,565.6 Gg CO_2-e (8.2 per cent) of emissions from the energy sector. This is an increase of 1,289.0 Gg CO_2-e (101.0 per cent) from the 1990 level of 1,276.6 Gg CO_2-e.

Key categories identified in the 2010 level assessment from fugitive emissions include CO_2 emissions from:

- flaring combined
- geothermal electricity generation.

Key categories identified in the 2010 trend assessment from fugitive emissions include CO_2 emissions from:

- flaring combined
- geothermal electricity generation.

Key categories identified in the 2010 level assessment from fugitive emissions include CH_4 emissions from:

- coal mining and handling.

Key categories identified in the 2010 trend assessment from fugitive emissions include CH_4 emissions from:

- coal mining and handling
- natural gas.

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

Description

In 2010, fugitive emissions from the solid fuels subcategory produced 552.2 Gg CO_2-e (21.5 per cent) of emissions from the fugitive emissions category. This is an increase of 277.8 Gg CO_2-e (101.2 per cent) from the 274.5 Gg CO_2-e reported in 1990.

New Zealand's fugitive emissions from the solid fuels subcategory are a by-product of coal-mining operations. Methane is created during coal formation. The amount of methane released during coal mining is dependent on the coal grade and the depth of the coal seam. In 2010, 87 per cent of the methane from coal mining (including post-mining emissions) came from underground mining. This includes the emissions from post-underground mining activities such as coal processing, transportation and use. There is no known flaring of methane at coalmines, and methane captured for industrial use is negligible. In 2010, New Zealand coal production was 5.3 million tonnes, a 17 per cent increase from the 2009 production level of 4.6 million tonnes.

Methodological issues

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

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Source-specific recalculations

The split between underground and surface mining has been revised due to new data becoming available from mining companies.

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

Source-specific planned improvements

There are no current planned improvements for this specific category.

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

Description

In 2010, fugitive emissions from the oil and natural gas subcategory contributed 2,013.4 Gg CO_2-e (78.5 per cent) of emissions from the fugitive emissions category. This is an increase of 1,011.2 Gg CO_2-e (100.9 per cent) from 1,002.1 Gg CO_2-e in 1990.

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

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

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

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

The oil and natural gas subcategory also includes estimates for emissions from geothermal operations. While some of the energy from geothermal fields is transformed into electricity, emissions from geothermal electricity generation are reported in the fugitive emissions category because they are not the result of fuel combustion, unlike the emissions reported under the energy industries category. Geothermal sites, where there is no use of geothermal steam for energy production, have been excluded from the inventory. In 2010, emissions from geothermal operations were 757.4 Gg CO_2-e, an increase of 482.8 Gg CO_2-e (175.8 per cent) since the 1990 level of 274.6 Gg CO_2-e.

Between 2009 and 2010, emissions from geothermal have increased by 4.7 per cent.

Methodological issues

Venting and flaring from oil and gas production

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

Gas transmission and distribution

Carbon dioxide and methane emissions from gas leakage mainly occur from low-pressure distribution pipelines rather than from high-pressure transmission pipelines. In this inventory, submission emissions from transmission and distribution have been separated out.

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

Oil transport

Fugitive emissions from the oil transport subcategory are calculated using an IPCC Tier 1 approach (IPCC, 1996). The activity data is New Zealand's total production of crude oil reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2011). The carbon dioxide emission factor is the IPCC (2000) default for oil transport using tanker trucks and rail cars, while the methane emission factor is the mid-point of the IPCC (1996) default value range.

Oil refining and storage

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

Natural gas other leakage

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

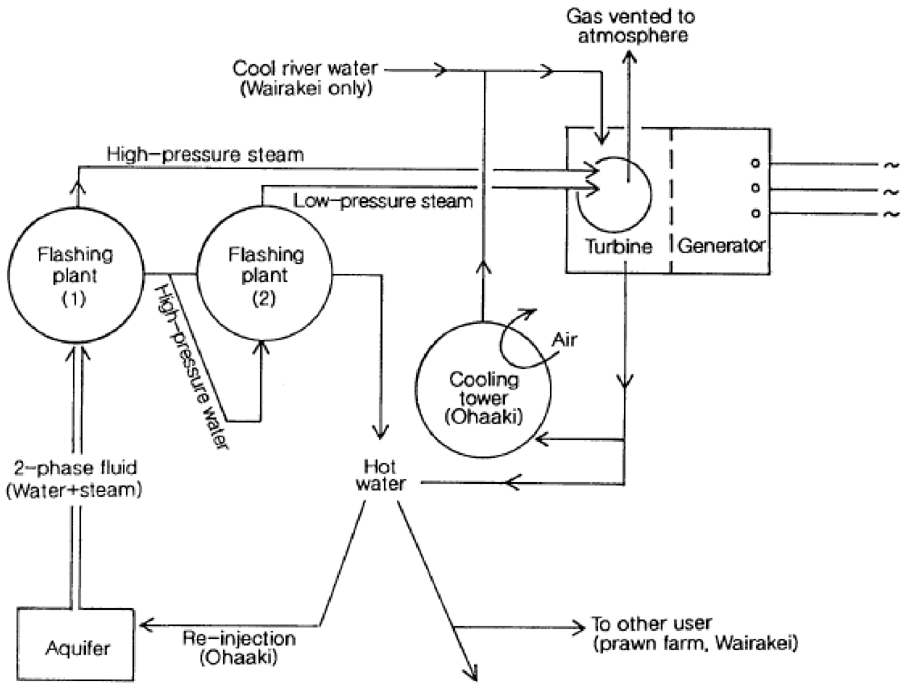
Activity data for leakages at industrial plants and power stations is taken from the total natural gas used for industrial and electricity generation use. The emission factor used is the mid-point of the 1996 IPCC default for 'leakage at industrial plants and power stations'.

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

Geothermal

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

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



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

Geothermal methodology for Company A

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

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

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

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

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

$$582.3 \frac{tonnes\ of\ steam}{hour} \ x \ \frac{0.612\ CO_2}{100} \ by\ weight\ of\ steam = 3.565 \frac{tonnes\ of\ CO_2}{hour} \ x 8760 \frac{hours}{year}$$

= 31,230 tonnes of carbon dioxide.

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

Geothermal methodology for Company B

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

Emissions from geothermal have increased greatly in recent years. These increases are driven by an increase in geothermal emissions related to electricity generation, particularly with the new 100 megawatt Kawerau geothermal plant coming online in late 2008.

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

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

- liquid fossil fuel
- coal
- natural gas – methane and nitrous oxide
- geothermal fluid
- used oil, waste oil, used tyres or waste.

The 2010 year was the first calendar year in which operators could apply for UEFs. The Ministry of Economic Development received five applications relating to the use of UEF of geothermal fluid for the 2010 calendar year. These five approved UEFs were then adopted by the greenhouse gas inventory after careful assessment of the materiality impact and time-series consistency. As 2010 was the introduction year, the Ministry of Economic Development made a judgement that the UEF would apply only for the 2010 inventory year and will reassess once more data is available in the near future.

Ozone precursors and sulphur dioxide from oil refining

New Zealand has only one oil refinery that has a hydrocracker rather than a catalytic cracker. There are, therefore, no emissions from fluid catalytic cracking but there are from sulphur recovery plants and storage and handling. All the emission factors used to calculate these emissions are IPCC default values.

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Source-specific recalculations

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

Source-specific planned improvements

There are no current planned improvements for this specific category.

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Chapter 4: Industrial processes

4.1 Sector overview

In 2010, New Zealand's industrial processes sector produced 4,778.1 Gg of carbon dioxide equivalent (CO_2-e), contributing 6.7 per cent of New Zealand's total greenhouse gas emissions. The largest source of industrial process emissions are from the metal production category (CO_2 and perfluorocarbons (PFCs)), contributing 47.4 per cent of sector emissions in 2010.

Emissions from industrial processes in 2010 had increased by 1,389.3 Gg CO_2-e (41.0 per cent) above the 1990 level of 3,388.8 Gg CO_2-e (figure 4.1.1). This increase has largely been driven by emissions from the consumption of halocarbons and sulphur hexafluoride (SF_6) category, with an increase in these emissions of 1,095.2 Gg CO_2-e (figure 4.1.2).

Figure 4.1.1 New Zealand's industrial processes sector emissions from 1990 to 2010

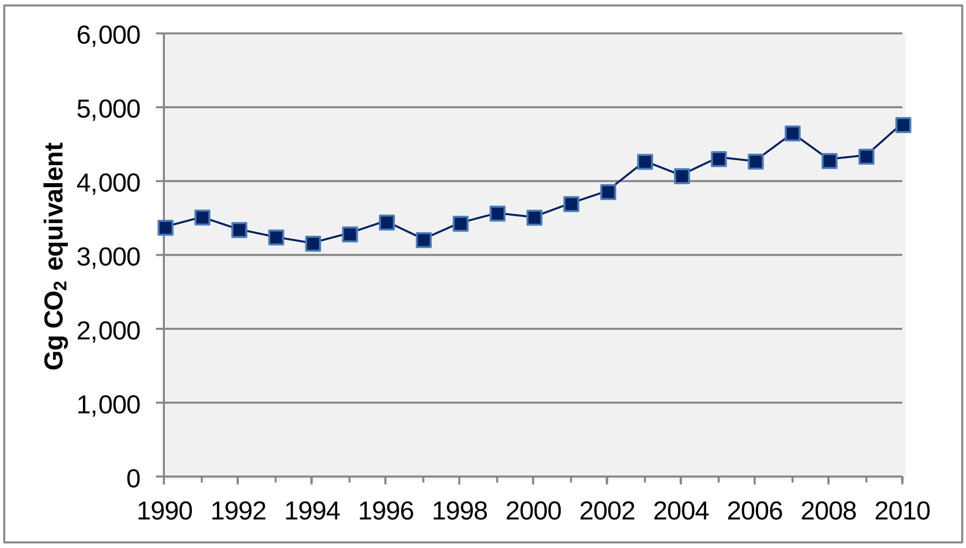
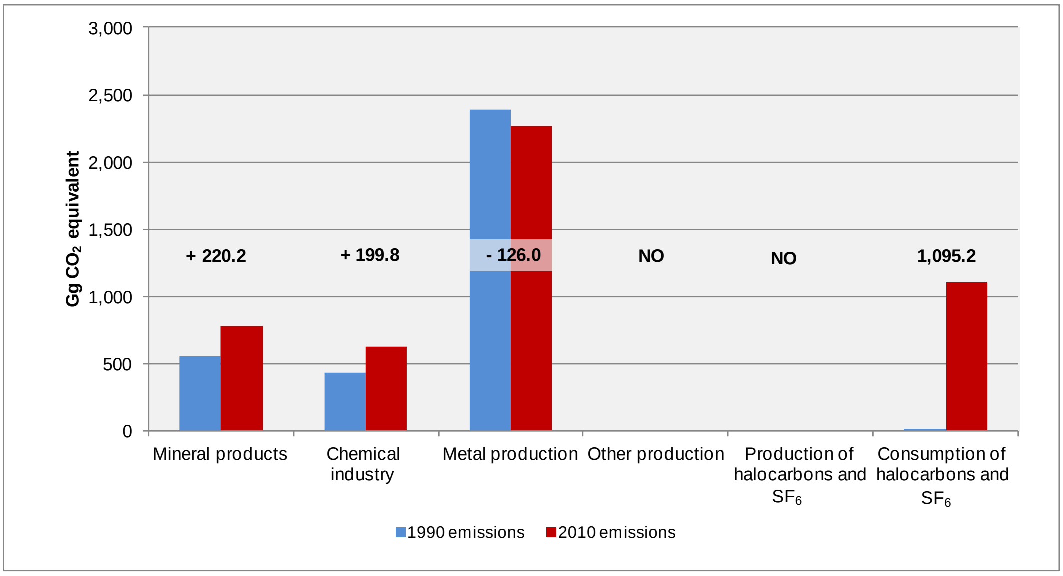


Figure 4.1.2 Change in New Zealand's industrial processes sector emissions from 1990 to 2010



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

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

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

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

Changes in emissions between 2009 and 2010

Between 2009 and 2010, emissions from the industrial processes sector increased by 427.7 Gg CO_2-e (9.8 per cent). The main emission sources that drove this increase were the consumption of hydrofluorocarbons (HFCs) and steel and aluminium production.

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.

Most of the activity data for the non-CO_2 gases is collated by an external consultant. Emissions of 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).

Between 1990 and 2010, the only known methane (CH_4) emissions from the industrial processes sector came from methanol production. For confidentiality reasons, CH_4 emissions from methanol production are reported under the energy sector (section 3.3.2).

4.1.2 Uncertainties

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

4.1.3 Verification

For this submission, the inventory agency verified CO_2 emissions reported in the 'mineral products' and 'iron and steel production' categories for the 2010 year with information provided by participants under the New Zealand Emissions Trading Scheme (NZ ETS). Results of the verification are discussed under the relevant sections below.

4.2 Mineral products (CRF 2A)

4.2.1 Description

In 2010, the mineral products category accounted for 778.0 Gg CO_2 (16.3 per cent) of total emissions from the industrial processes sector. Emissions in this category have increased by 220.2 Gg CO_2 (39.5 per cent) from the 1990 level of 557.8 Gg CO_2. There are no known emissions of CH_4 or nitrous oxide (N_2O) from the mineral products category. The emissions from the combustion of coal, used to provide heat for the calcination process, are reported in the energy sector.

In New Zealand, the emissions from mineral products include emissions from the production of cement, lime and glass and from the use of soda ash and limestone. In 2010, cement production accounted for 582.0 Gg CO_2 (74.8 per cent) of emissions from the mineral products category. In the same year, lime production accounted for 131.1 Gg CO_2 (16.9 per cent), limestone use 59.6 Gg CO_2 (7.7 per cent) and soda ash use 5.2 Gg CO_2 (0.7 per cent).

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

Key categories identified in the 2010 level assessment from the minerals category include only CO_2 emissions from cement production. There were no sources identified in the 1990–2010 trend assessment as key categories from the minerals category.

4.2.2 Methodological issues

Cement production

In 2010, there were two cement production companies operating in New Zealand, Holcim New Zealand Ltd and Golden Bay Cement Ltd. Both companies produce general purpose and portland cement. Holcim New Zealand Ltd also produces general, blended cement. From 1995 to 1998 inclusive, another smaller cement company, Lee Cement Ltd, was also operating.

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

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

Methodology

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

The cement companies supply their emission data to the Ministry of Economic Development during an annual survey. The IPCC (2000) default cement-kiln dust correction factor, 1.02, is included in Holcim New Zealand Ltd's CO_2 emissions calculation. Cement-kiln dust is a mix of calcined and uncalcined raw materials and clinker. Golden Bay Cement Ltd has not included a correction factor as it operates a dry process with no cement-kiln dust lost to the system.

Trends

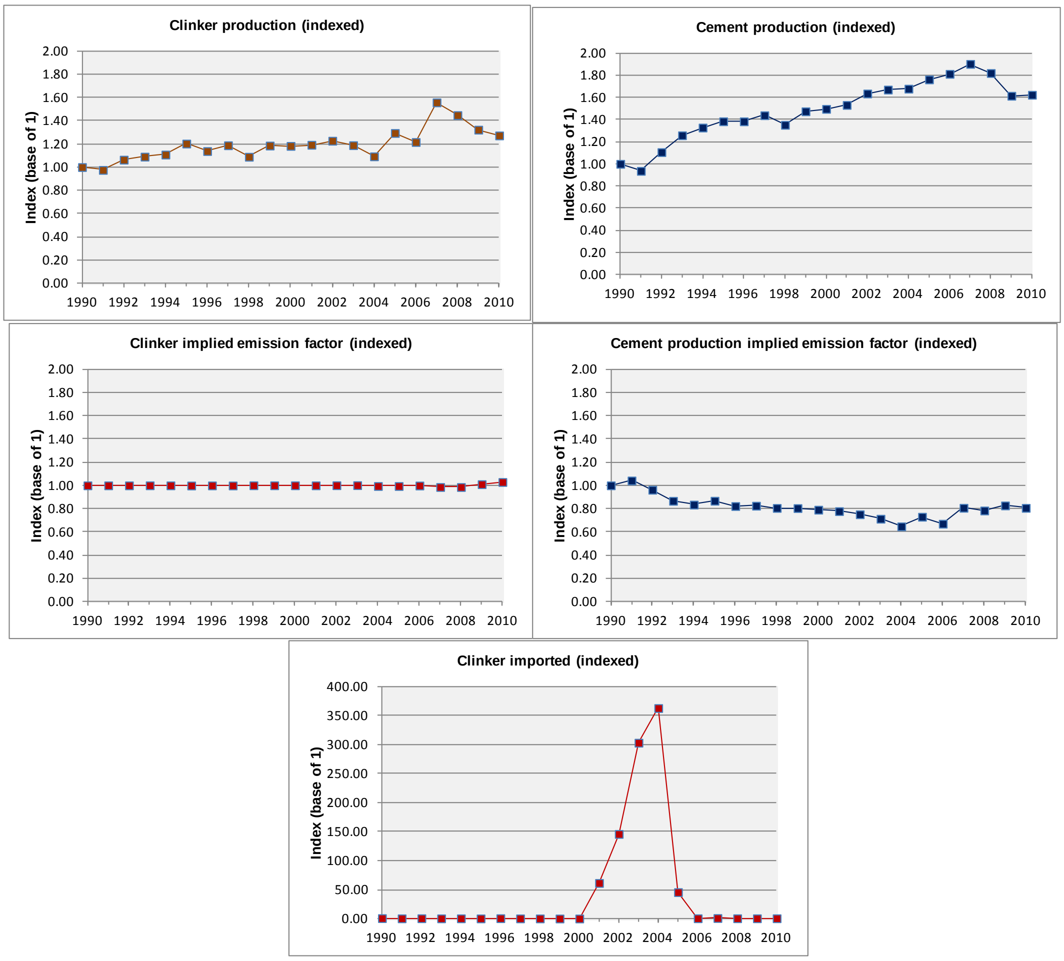
Figure 4.2.1 shows the trends in New Zealand clinker and cement production, imported clinker and the implied emission factor for clinker and cement for the 1990–2010 time series. In general, the figure shows clinker and cement production increasing over the time series 1990–2010. Relatively, over the same time series, cement production has increased more than clinker production. The cement-implied emission factor decreased between 2000 and 2004 with increasing amounts of imported clinker. Meanwhile, the implied emission factor for clinker remained relatively unchanged.

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

Sulphur dioxide

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

Figure 4.2.1 New Zealand's cement production data including clinker production, clinker imports, and cement and clinker-implied emission factors (indexed) from 1990–2010



Lime production

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

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

Methodology

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

Although there is no current verified country or plant-specific emission factors available for lime production, data from the NZ ETS may be able to be used for future inventory submissions.

Sulphur dioxide

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

Limestone and dolomite use

In New Zealand, small amounts of limestone are used in the production of iron and steel by New Zealand Steel Ltd and in the production of glass by O-I New Zealand and Tasman Insulation New Zealand Ltd. Activity data and emissions estimates from Tasman Insulation New Zealand Ltd have been included for the first time in this submission. See section 4.2.4 for further details.

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.

Iron and steel production

In the iron production process, New Zealand Steel Ltd blends the coal with limestone to achieve the required primary concentrate specifications. New Zealand has separated emissions arising from limestone, coke and electrodes used in the iron- and steel-making process from the remaining process CO_2 emissions, and reported these emissions under the limestone and dolomite use subcategory (2.A.3). This data provided by New Zealand Steel Ltd, could not be disaggregated any further (ie, reporting only limestone emissions from iron and steel production under 2.A.3). Emissions from limestone/coke/electrode use make up 1–2 per cent of total iron and steel process emissions.

Glass production

Emissions from limestone use in glass production are derived from multiplying the quantity of pure uncalcined limestone used by the company by the default emissions factor, 0.43970 tonnes of CO_2 per tonne of limestone. The quantity of pure uncalcined limestone used by each company was only available for the 2010 year through the NZ ETS. Consequently, the 2010 estimate has been held constant over the time series.

Soda ash production and use

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

Glass production – O-I New Zealand

A survey of the industrial processes sector estimated CO_2 emissions resulting from the use of imported soda ash in glass production in 2005 (CRL Energy, 2006). The glass manufacturer, O-I New Zealand, provided information on the amount of imported soda ash used in 2005. The manufacturer also provided approximate proportions of recycled glass 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 kilograms of CO_2 per tonne of soda ash was applied to the soda ash activity data to calculate the CO_2 emissions. For 2010, due to a lack of data availability, emissions have been held constant from 2009.

Glass production – Tasman Insulation New Zealand Ltd

Emissions from soda ash used in glass wool production by Tasman Insulation New Zealand Ltd are derived from multiplying the quantity of soda ash used by the company by the default emissions factor 0.415 tonnes of CO_2 per tonne of soda ash used and by the fraction 0.992 to account for the purity of the soda ash.

Aluminium production

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

Asphalt roofing

There is one company manufacturing asphalt roofing in New Zealand, Bitumen Supply Ltd. There are no known direct greenhouse gas emissions from asphalt roofing but there are indirect emissions. Default emission factors of 0.05 kilograms of non-methane volatile organic compound (NMVOC) per tonne of product and 0.0095 kilograms of 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 2006–2010.

Road paving with asphalt

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

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

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

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

For the 2004 inventory submission, the New Zealand Bitumen Contractors' Association provided a method for calculating total NMVOC emissions from the use of solvents in the roading industry (Box 4.1). The industrial processes survey for the 2005 calendar year (CRL Energy, 2006) showed that the fraction by weight of bitumen used to produce chip-seal has been changing as methods of laying bitumen have improved. From 1990 to 2001, the fraction by weight of bitumen used to produce chip-seal was 0.80. 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 2006–2010.

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 are two glass manufacturers in New Zealand, O-I New Zealand and Tasman Insulation New Zealand Ltd. All CO_2 emissions arising from glass production in New Zealand come from limestone and soda ash use. Emissions from the limestone used in the production of glass are reported under "Limestone and Dolomite Use" and emissions from soda ash use from glass production are reported under "Soda Ash Production and Use".

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

Non-methane volatile organic compounds may be emitted from the manufacture of glass and the IPCC (1996) suggest a default emissions factor of 4.5 kilograms of NMVOC per tonne 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.

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

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

4.2.3 Uncertainties and time-series consistency

The IPCC (2000) default uncertainties for CO_2 emission factors have been applied to cement and lime production (Table 4.2.1). The uncertainty for CO_2 from glass production has been assessed by CRL Energy (2011).

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

The uncertainty for lime production activity data is ±50 per cent. This takes into account the IPCC (2000) guidance that the uncertainty for activity data is likely to be much higher than for the emission factors because there is typically non-marketed lime that is not included in the estimates. The IPCC (2000) default of ±100 per cent for activity data uncertainty has been applied. The IPCC (2000) ±2 per cent uncertainty for the emission factor for lime has been applied.

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

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

Mineral product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Cement – CaO content of the clinker	±1	±1 (CO_2)
Cement – clinker kiln dust	±1	± 5(CO_2)
Cement	±1	±40 (SO_2)
Lime	±100	±2 (CO_2)
		±80 (SO_2)
Asphalt roofing	±30 (±50 for 1990–2000)	±40 (NMVOC and SO_2)
Road paving with asphalt	±10	±15 (chip-seal fraction and solvent emission fraction) to ±25 (solvent dilution)
Glass	±5	±7 (CO_2)
		±50 (NMVOC)
		±10 (SO_2)

4.2.4 Source-specific QA/QC and verification

In 2010, CO_2 emissions from cement production were a key category (2010 level assessment). In the preparation of this inventory, the data for these emissions underwent IPCC Tier 1 quality checks. The estimates for a non-key category, the soda use category, were also subject to IPCC Tier 1 quality checks. The outcome of these checks resulted in minor transcription corrections and improvements to the transparency of internal documentation for calculating soda use emissions.

Verification with the NZ ETS

A verification process was undertaken for data for the 2010 calendar year only. The emissions estimates in the inventory are based on the IPCC methodologies (IPCC, 1996; IPCC, 2000), and some industry methodologies. However, the methodologies in the NZ ETS are largely based on the input of raw materials and the stoichiometry of the final products. Therefore, this verification is mostly used for cross-checking purposes and whether the estimates from both sources are within our expectations. It is envisaged that this verification exercise will be performed annually by the government agencies involved with the annual greenhouse gas inventory submission and the NZ ETS.

Carbon dioxide emissions estimated for cement, limestone and glass production reported for the inventory were verified with data provided under the NZ ETS. The results of the verification for this inventory include the identification of a small producer of glass, Tasman Insulation New Zealand Ltd, which was previously unknown to the inventory agency. The information reported under the NZ ETS included emissions from soda ash and limestone use from both glass producers.

Additionally, it was not known to the inventory agency that O-I New Zealand used limestone in the production of glass. Due to this verification exercise, the completion of emissions from limestone use and soda ash use has improved for this inventory.

The results of the verification exercise also indicated the inventory could be slightly underestimating emissions from soda ash use from one of the glass producers. The NZ ETS and the inventory apply different methodologies for calculating emissions from soda ash use for glass production. The NZ ETS uses a Tier 3 method while the inventory uses a Tier 1 method (see section 4.2.2). While the methodology under the NZ ETS is considered more robust, there is only reported information available for the 2010 calendar year. One data point is insufficient to enable accurate and consistent back-casting to 1990. New Zealand plans to continue to monitor these apparent discrepancies until there are at least three data points available.

Further, the results of the verification exercise indicated the inventory could be slightly overestimating emissions for 2010 from one of the cement companies. The difference could be due to the way the cement kiln dust factor is incorporated into the inventory estimates. Further investigations will be made before the next inventory submission.

4.2.5 Source-specific recalculations

Limestone and dolomite use

The transparency and completion for reported emission estimates from limestone use has been improved. In the previous submission this subcategory included emissions from soda ash use to manage confidentiality concerns. These emissions have been reallocated to the ‘Soda ash production and use’ subcategory. This category now includes emissions from limestone use by O-I New Zealand and Tasman Insulation New Zealand in their production of glass. These sources of limestone were identified through verification with the NZ ETS. There have been no changes to the estimated emissions from limestone use by New Zealand Steel Ltd.

Soda ash production and use

The transparency and completion of reported emission estimates from soda ash use has been improved. Previously, to maintain the confidentiality, soda ash emissions from glass production were reported under the ‘Limestone and dolomite use’ subcategory and soda ash used by NZAS was reported under the ‘Aluminium production’ category. However through the verification with the NZ ETS data, a third user of soda ash was identified, Tasman Insulation New Zealand. Consequently, all three sources of soda ash use emission have been reported in the “Soda ash production and use” category.

4.2.6 Source-specific planned improvements

New Zealand plans to continue to verify mineral product data with information provided under the NZ ETS. The discrepancies in emission estimates for one of the glass producers will be monitored in particular. In addition, the potential overestimation of emissions from one of the cement companies for 2010 will be investigated.

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 2010, emissions from the chemical industry category comprised 630.0 Gg CO_2-e (13.2 per cent) of total emissions from the industrial processes sector. Emissions have increased by 199.8 Gg CO_2-e (46.4 per cent) from the 1990 level of 430.2 Gg CO_2-e. In 2010, CO_2 emissions from ammonia production accounted for 386.2 Gg CO_2-e (61.3 per cent) of emissions in the chemical industry category. Hydrogen production contributed the remaining 243.8 Gg CO_2-e (38.7 per cent) of emissions from the chemical industry in 2010.

A key category identified in the 2010 qualitative assessment from the chemical industry category was CO_2 emissions from ammonia production.

4.3.2 Methodological issues

Ammonia and urea

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

It is assumed that the carbon in urea is eventually released after it is applied to the land (IPCC, 1996). Emissions of CO_2 are calculated by multiplying the quantities of gas (from different gas fields) by their respective emission factors. The proportion of gas from each of these fields used in ammonia production changes on an annual basis. This explains the fluctuation in the CO_2 implied emission factor over the 1990–2010 time series.

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

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

Methanol

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

Hydrogen

Emissions of CO_2 from hydrogen production are supplied directly to 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 2010, the implied emission factor for the sum of both companies was 6.2 tonnes of CO_2 per tonne of hydrogen produced.

Formaldehyde

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

Fertiliser

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

Activity data supplied in 2005 has been used for 2006–2010. Plant-specific emission factors used in previous years were applied to the 2010 data. No reference is made to superphosphate production in the IPCC guidelines (IPCC, 1996). For sulphuric acid, the IPCC guidelines recommend a default emission factor of 17.5 kilograms of SO_2 (range of 1 to 25) per tonne of sulphuric acid. However, New Zealand industry experts have recommended that this is a factor of 2 to 10 times too high for the New Zealand industry. Consequently, emission estimates are based on emission factors supplied by industry. In 2010, the combined implied emission factor is 1.5 kilograms of SO_2 per tonne of sulphuric acid.

4.3.3 Uncertainties and time-series consistency

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

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

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

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

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

4.3.4 Source-specific QA/QC and verification

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

4.3.5 Source-specific recalculations

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

4.3.6 Source-specific planned improvements

There are no planned improvements for this source.

4.4 Metal production (CRF 2C)

4.4.1 Description

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

In 2010, emissions from the metal production category were 2,262.5 Gg CO_2-e, 47.4 per cent of emissions from the industrial processes sector. Emissions from this category decreased 126.0 Gg CO_2-e (5.3 per cent) from the 1990 level of 2,388.5 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 2010, the level of CO_2 emissions increased by 463.3 Gg CO_2 (26.3 per cent) above the 1990 level.

Perfluorocarbon emissions have decreased from the 629.9 Gg CO_2-e in 1990 to 40.6 Gg CO_2-e in 2010, a decrease of 589.3 Gg CO_2-e (93.6 per cent). This decrease is due to improvements made by the aluminium smelter. These improvements are discussed further in the following section.

In 2010, emissions from iron and steel contributed 1,646.9 Gg CO_2-e (72.8 per cent) and aluminium production contributed 615.6 Gg CO_2-e, 27.2 per cent to the metal production category.

Key categories identified in the 2010 level assessment from the metal production category include CO_2 emissions from:

- iron and steel production
- aluminium production.

Key categories identified in the 1990–2010 trend assessment from the metal production category include PFC emissions from aluminium.

4.4.2 Methodological issues

Iron and steel

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

The production data from the two steel producers is provided to the Ministry of Economic Development but is confidential and is reported as such in the common reporting format tables.

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

New Zealand Steel Ltd

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

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

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

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

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

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

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

Pacific Steel

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

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

The average carbon content of Pacific Steel finished product is 0.20 per cent.

Aluminium

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

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

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

Carbon dioxide

NZAS calculates the process CO_2 emissions using the International Aluminium Institute (2006) Tier 3 method (equations 1 to 3), which is the equivalent to the IPCC (2000) Tier 2 method. This method breaks the prebake anode process into three stages: baked anode consumption, pitch volatiles consumption and packing coke consumption.

NZAS adds soda ash to the reduction cells to maintain the electrolyte chemical composition. This results in CO_2 emissions as a by-product. These emissions are reported under the ‘soda production and use’ subcategory.

Perfluorocarbons

The PFC emissions from aluminium smelting are calculated using the IPCC/International Aluminium Institute (2006) Tier 2 methodology summarised below:

> Perfluorocarbon emissions (t CO_2-e) = hot metal production × 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 kilograms of CF_4 per tonne of aluminium and 0.04 kilograms of C_2F_6 per tonne of aluminium. The estimates for 1991 are based on the reduction cell operating conditions being similar to those in 1990.

To derive the value for 1992, the Tier 2 (International Aluminium Institute, 2006) method has been applied using the mid-point value for the extrapolated anode effect duration from the 1991 Tier 1 default PFC emission rate, and the 1993 anode effect duration. The reported estimate for 1992 is considered to better reflect PFC emissions than the IPCC default value.

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

Trends

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

Figure 4.4.1 New Zealand's implied emission factors for aluminium production from 1990 to 2010

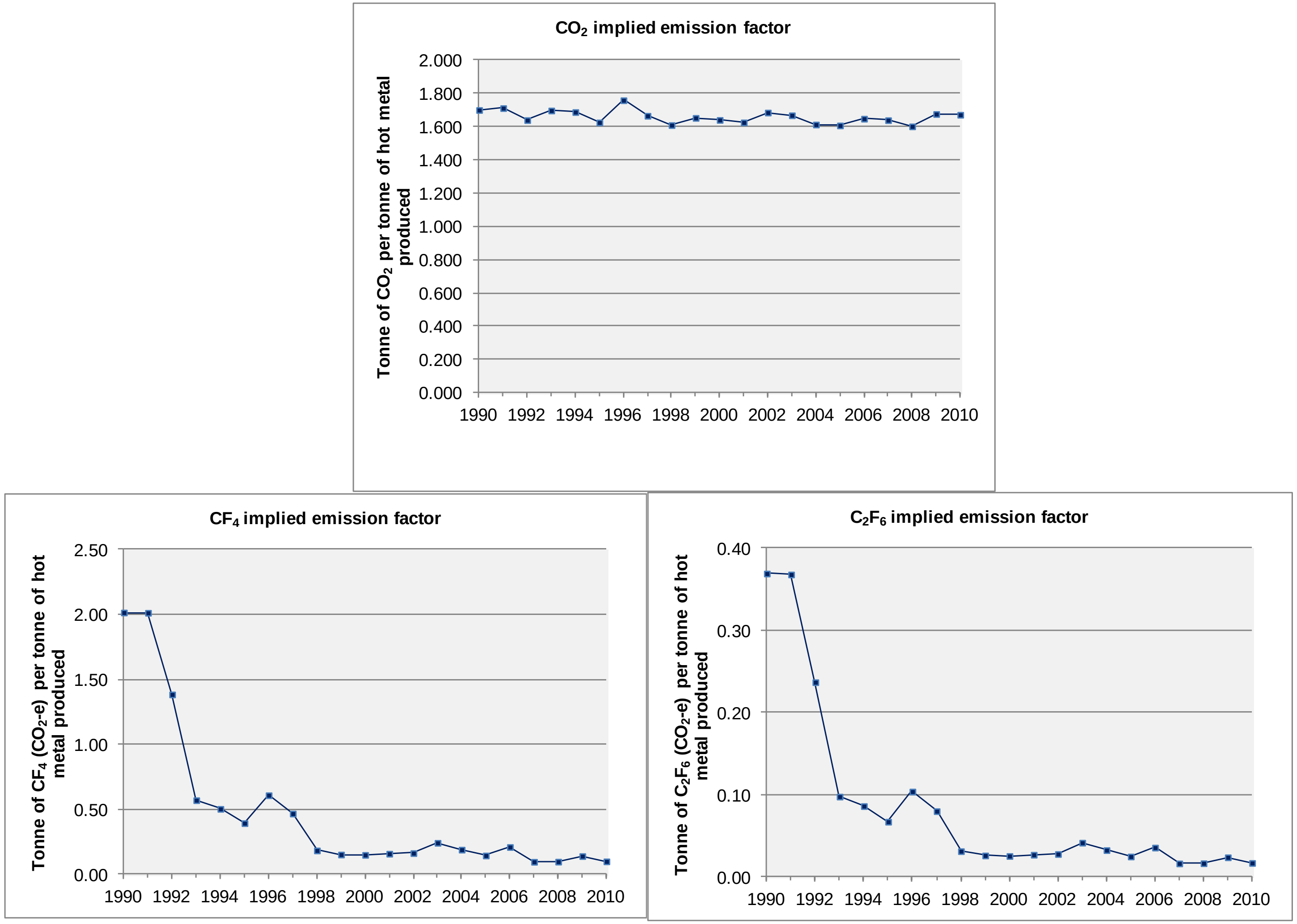


Table 4.4.2 Explanation of variations in New Zealand's aluminium emissions

Variation in emissions	Reason for variation
Increase in CO_2 and PFC emissions in 1996	Commissioning of the Line 4 cells
Decrease in CO_2 emissions in 1995	Good anode performance compared with 1994 and 1996
Decrease in CO_2 emissions in 1998	Good anode performance
Decrease in CO_2 emissions in 2001, 2003 and 2006	Fewer cells operating from reduced aluminium production due to reduced electricity supply
	Good anode performance contributed in 2001
Increase in CO_2 emissions in 1996	All cells operating, including introduction of additional cells
	Increasing aluminium production rate from the cells
Decrease in PFC emissions in 1995	Reduced anode frequencies
	The implementation of the change control strategy to all reduction cells
	Repairs made to cells exerting higher frequencies
PFC emissions remained high in 1997	Instability over the whole plant as the operating parameters were tuned for the material coming from the newly commissioned dry scrubbing equipment (removes the fluoride and particulate from the main stack discharge)
Decrease in PFC emissions in 1998	Cell operating parameter control from the introduction of modified software. This software has improved the detection of an anode effect onset and will initiate actions to prevent the anode effect from occurring
PFCs remain relatively static in 2001, 2003 and 2006	Increased emissions from restarting the cells

Indirect emissions

Aluminium production also produces indirect emissions. The most significant are CO emissions from the anode preparation. There is also a small amount of CO emitted during the electrolysis reaction in the cells. For estimates of indirect greenhouse gases, plant-specific emission factors were used for CO and SO_2. Sulphur dioxide emissions are calculated from the input sulphur levels and direct monitoring. An industry supplied value of 110 kilograms of CO per tonne of product was based on measurements and comparison with Australian CO emission factors. The IPCC default emission factor was used for NO_x emissions.

Other metal production

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

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

4.4.3 Uncertainties and time-series consistency

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

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

Table 4.4.3 Uncertainty in New Zealand's emissions from the metal production category

Metal product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Iron and steel	±5	±7 (CO_2)
		±20–30 (CO)
		±70 (NO_x)
Aluminium	±5	±2 (CO_2)
		±30 (PFCs)[1]
		±5 (SO_2)
		±40 (CO)
		±50 (NO_x)

[1] There is no independent means of assessing the calculations of PFC emissions from the smelter. Given the broad range of possible emission factors indicated in the IPCC (2000) table 3.10, and in the absence of measurement data and precision measures, the total uncertainty is assessed to be ±30 per cent (CRL Energy, 2006).

4.4.4 Source-specific QA/QC and verification

Carbon dioxide emissions from iron and steel production and aluminium production (2010 level assessment), and PFC emissions from aluminium production (trend assessment) underwent IPCC Tier 1 quality checks. There were no significant findings from these checks.

Verification with the NZ ETS

Reported estimates of CO_2 from the metal production category were verified with data provided under the NZ ETS for the 2010 calendar year. For example, the emission estimates from New Zealand Steel Ltd for the national inventory applies the mass-balance approach. In contrast, the method for calculating steel emissions under the NZ ETS uses the total amount of raw materials and the stoichiometry of each of the raw materials to calculate the final emissions. Once methodological differences were accounted for, there were no significant discrepancies between the datasets.

4.4.5 Source-specific recalculations

Aluminium production

To improve transparency of the ‘soda ash production and use’ subcategory, the emissions from the use of soda ash by NZAS were reallocated to the ‘soda ash production and use’ subcategory. In addition, there was a minor revision made to CO_2 emissions from anode consumption for 2009.

4.4.6 Source-specific planned improvements

There are no planned improvements for these subcategories.

4.5 Other production (CRF 2D)

4.5.1 Description

The other production category includes emissions from the production of pulp and paper, and food and drink. In 2010, emissions from this category totalled 7.7 Gg NMVOC. This was an increase of 1.8 Gg NMVOC from the 1990 level of 5.9 Gg NMVOC.

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

4.5.2 Methodological issues

All carbon dioxide emissions from this category are those from fuel combustion and, consequently, these are reported in the energy sector.

Pulp and paper

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

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

Pulp production in New Zealand is evenly split between mechanical pulp production and chemical production. Estimates of emissions from the chemical pulping process are calculated from production figures obtained from the Ministry 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 and are therefore reported within the energy sector.

Food and drink

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

4.5.3 Uncertainties and time-series consistency

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

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

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

4.5.4 Source-specific QA/QC and verification

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

4.5.5 Source-specific recalculations

There were no recalculations for this category.

4.5.6 Source-specific planned improvements

There are no planned improvements for this category.

4.6 Production of halocarbons and SF_6 (CRF 2E)

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

4.7 Consumption of halocarbons and SF_6 (CRF 2F)

4.7.1 Description

In 2010, emissions from the consumption of HFCs and PFCs totalled 1,087.4 Gg CO_2-e, 22.8 per cent of emissions from the industrial processes sector. There was no consumption of HFCs or PFCs in 1990. The first consumption of HFCs in New Zealand was reported in 1992 and the first consumption of PFCs in 1995.

Emissions from the consumption of HFCs and PFCs from refrigeration and air conditioning were identified as a key category in the 2010 level assessment and in the trend assessment.

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

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

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

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

In 2010, SF_6 emissions were 20.2 Gg CO_2-e. This is an increase of 7.8 Gg CO_2-e (63.4 per cent) from the 1990 level of 12.3 Gg CO_2-e. The majority of SF_6 emissions are from use in electrical equipment.

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

4.7.2 Methodological issues

Hydrofluorocarbons and perfluorocarbons

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

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

Potential emissions for HFCs and PFCs are included for completeness as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006). Potential emissions for HFCs and PFCs have been calculated using the IPCC 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, 2011).

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 (2006) equation 7.6	IPCC default factor of 50 per cent of the initial charge per year
Foam	IPCC (2006)	IPCC default factor of 10 per cent initial charge in first year and 4.5 per cent annual loss of initial charge over an assumed 20-year lifetime
Mobile air conditioning	IPCC (2000) equation 3.44	Top-down approach First fill: 0.5 per cent
Stationary refrigeration/ air conditioning	IPCC (2006) equation 7.9	Not applicable
Fire protection	IPCC (2006)	Top-down approach using an annual emission rate of 1.5 per cent
SF_6 source	**Calculation method**	**Emission factor**
Electrical equipment	IPCC (2000) equation 3.17	Tier 3 approach based on overall consumption and disposal. Company-specific emission factors measured annually and averaging 1 per cent for the main utility (representing 75 per cent of total holdings) and an equipment manufacturer This was supplemented by data from other utilities and users using the IPCC default emission factor of 2 per cent (Tier 2b approach)
Other applications	IPCC (2000) equation 3.22	No emission factor required as 100 per cent is emitted within two years

Aerosols and metered dose inhalers

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

Aerosols

Emissions from aerosols contributed 22.9 Gg CO_2-e in 2010, an increase from the 1996 level of 1.6 Gg CO_2-e. Aerosols were not widely used in New Zealand until 1994, and therefore emissions from aerosols are estimated from 1996. The initial charge is expected to be emitted within the first two years of sale.

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

Due to insufficient information at a sub-application level, a Tier 1a method (IPCC, 2006) is used to calculate HFC-134a emissions from aerosol use in New Zealand. This is a mass-balance approach, based on import and sales data. The approach accounts for the lag from time of sale to time of use.

Metered dose inhalers

In 2010, emissions from metered dose inhalers contributed 56.0 Gg CO_2-e, an increase from the 1995 level of 0.5 Gg CO_2-e. The consumption of HFCs in metered dose inhalers is not known to have occurred in New Zealand before 1995.

Data on the total number of doses contained in metered dose inhalers used from 1999 to 2010 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, 2011).

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

Solvents

A survey of distributors of solvent products and solvent recycling firms did not identify any use of HFCs or PFCs as solvents in New Zealand (CRL Energy, 2011).

Foam

In New Zealand, only emissions from closed-cell foam (hard foam) are known to have occurred between 2000 and 2010. In 2010, emissions from the use of HFC-134a in hard foam blowing were 0.3 Gg CO_2-e, an increase from the 2000 level of 0.1 Gg CO_2-e.

For 2010, use of the mixture HFC227ea/365mfc has been confirmed by one company.

The HFC-245fa/365mfc mixture is only known to have been used in New Zealand in foam blowing from 2004 to 2010. These emissions are estimated to have increased from 0.1 tonne in 2004 to 1.5 tonne in 2010. However, a global warming potential for this mixture has not been adopted by the Climate Change Convention for current reporting. This mixture is reported in the common reporting format tables 'information on additional greenhouse gases', as recommended by the in-country review team (UNFCCC, 2007).

For 2010, activity data was provided by the sole supplier of HFCs for foam blowing (CRL Energy, 2011). Fisher and Paykel provided information to estimate emissions from a minority of imported refrigeration equipment containing HFCs in its insulation foam. It is unlikely that any HFC is used for insulation foam in exported equipment. However, there is insufficient information to be certain of this.

The IPCC (2006) Tier 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 a 4.5 per cent annual loss of the initial charge over an assumed 20-year lifetime, is applied.

Stationary refrigeration and air conditioning

Emissions from the use of HFCs and PFCs in stationary refrigeration and air conditioning were 853.9 Gg CO_2-e in 2010. This is an increase from the 1992 level of 1.3 Gg CO_2-e. In 2010, stationary refrigeration and air conditioning made up 77.1 per cent of the emissions from the halocarbon and SF_6 consumption category. In 1992, only HFC-134a was used, while in 2010, HFCs -32, -23, -152a, -134a, -125, -143a and PFCs -218 (C_3F_8) and -116 (C_2F_6) were consumed. There was no use of HFCs and PFCs before 1992.

The increase in emissions from 1992 to 2010 is due to HFCs and PFCs used as replacement refrigerants for CFCs and HCFCs in refrigeration and air-conditioning equipment (section 4.7.1).

New Zealand uses the top-down IPCC (2006) Tier 2b approach (Box 4.2) and New Zealand-specific data to obtain actual emissions from stationary refrigeration and air conditioning. This approach is equivalent to the IPCC (2000) Tier 2 top-down approach. Table 4.7.2 provides a summary of results for the time series 1990–2010. Table 4.7.3 provides a breakdown of the annual sales of new refrigerant in New Zealand for 1990–2010. Table 4.7.4 provides a breakdown of the total charge of new equipment sold in New Zealand.

Box 4.2 Equation 7.9 (IPCC, 2006)

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

Table 4.7.2 HFC and PFC emissions from stationary refrigeration in New Zealand (CRL Energy, 2011)

Year	Annual sales of new refrigerant[1] (tonnes)	Total charge of new equipment sold in NZ (tonnes)	Emissions from retiring NZ equipment (tonnes)	Amount of intentional destruction (tonnes)	Emissions (tonnes)
1990	0.0	0.0	0.0	0	0.0
1991	0.0	0.0	0.0	0	0.0
1992	1.2	0.2	0.0	0	1.0
1993	2.9	0.9	0.0	0	2.0
1994	49.6	10.3	0.0	0	39.3
1995	110.4	23.9	0.0	0	86.5
1996	170.1	39.2	0.0	0	130.9
1997	81.7	41.2	0.0	0	40.4
1998	227.6	56.4	0.0	0	171.1
1999	208.5	67.3	0.0	0	141.2
2000	202.8	75.2	0.0	0	127.6
2001	209.5	76.0	0.0	0	133.5
2002	245.2	57.8	0.0	0	187.4

Year	Annual sales of new refrigerant[1] (tonnes)	Total charge of new equipment sold in NZ (tonnes)	Emissions from retiring NZ equipment (tonnes)	Amount of intentional destruction (tonnes)	Emissions (tonnes)
2003	304.1	65.2	0.1	0	239.0
2004	232.3	82.7	1.0	0	150.6
2005	345.6	127.8	2.8	0	220.5
2006	363.4	167.7	6.0	0	201.7
2007	480.4	205.6	9.8	0	284.5
2008	441.1	235.0	15.2	0	221.2
2009	441.5	218.2	21.4	0	244.7
2010	561.3	228.7	28.6	0	361.3

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

Table 4.7.3 Annual sales of new refrigerant in New Zealand (CRL Energy, 2011)

Year	Domestically manufactured chemical (tonnes)	Imported bulk chemical (tonnes)	Exported bulk chemical (tonnes)	Chemical in imported equipment (tonnes)	Chemical in exported equipment (tonnes)	Annual sales (tonnes)
1990	0	0.0	0	0.0	0.0	0.0
1991	0	0.0	0	0.0	0.0	0.0
1992	0	2.0	0	0.0	0.8	1.2
1993	0	6.0	0	0.1	3.2	2.9
1994	0	55.1	0	2.0	7.5	49.6
1995	0	123.1	0	5.9	18.5	110.4
1996	0	180.9	0	8.4	19.2	170.1
1997	0	90.6	0	8.8	17.7	81.7
1998	0	234.2	0	9.2	15.8	227.6
1999	0	211.9	0.1	13.4	16.7	208.5
2000	0	207.0	0.4	14.6	18.5	202.8
2001	0	216.5	0.8	14.6	20.8	209.5
2002	0	248.3	0.9	19.2	21.4	245.2
2003	0	305.9	2.4	25.7	25.1	304.1
2004	0	230.8	6.0	37.3	29.7	232.3
2005	0	302.9	6.5	76.3	27.0	345.6
2006	0	285.8	6.7	112.7	28.5	363.4
2007	0	377.1	12.1	157.2	41.8	480.4
2008	0	339.2	13.3	175.2	60.1	441.1
2009	0	355.6	16.6	161.8	59.2	441.5
2010	0	502.8	21.7	159.0	78.3	561.3

Table 4.7.4 Total charge of new equipment sold in New Zealand (CRL Energy, 2011)

Year	Chemical to charge domestically manufactured + imported equipment[1] (tonnes)	Chemical contained in factory-charged imported equipment (tonnes)	Total charge of new equipment sold in NZ (tonnes)
1990	0.0	0.0	0.0
1991	0.0	0.0	0.0
1992	0.2	0.0	0.2
1993	0.8	0.1	0.9
1994	8.4	2.0	10.3
1995	18.0	5.9	23.9
1996	30.8	8.4	39.2
1997	32.5	8.8	41.2
1998	47.2	9.2	56.4
1999	53.9	13.4	67.3
2000	60.6	14.6	75.2
2001	61.5	14.6	76.0
2002	38.6	19.2	57.8
2003	39.5	25.7	65.2
2004	45.4	37.3	82.7
2005	51.6	76.3	127.8
2006	55.0	112.7	167.7
2007	48.4	157.2	205.6
2008	59.8	175.2	235.0
2009	56.5	161.8	218.2
2010	69.6	159.0	228.7

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

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

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

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

It is estimated there are about 2.2 refrigerators and freezers per household in New Zealand. This calculation includes schools, factories, offices and hotels (Roke, pers. comm., Fisher and Paykel). Imported appliances account for around half of new sales each year, with the remainder manufactured locally. New Zealand also exports a significant number of factory-charged refrigerators and freezers.

Commercial refrigeration includes central rack systems used in supermarkets, self-contained refrigeration equipment, chillers used for commercial building air-conditioning and process-cooling applications, rooftop air conditioners, transport refrigeration systems and cool stores. In many instances, these types of systems are assembled and charged on site, although most imported units may already be pre-charged. Self-contained commercial equipment is pre-charged and includes some frozen food display cases, reach-in refrigerators and freezers, beverage merchandisers and vending machines.

The report on HFC and PFC emissions in New Zealand (CRL Energy, 2011) 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 2010, HFC-134a emissions from mobile air conditioning were 152.8 Gg CO_2-e, an increase over the 1994 level of 1.3 Gg CO_2-e. Emissions from mobile air conditioning made up 13.8 per cent of total emissions from the halocarbon and SF_6 consumption category in 2010. There was no use of HFCs as refrigerants for mobile air conditioning in New Zealand before 1994. The increase since 1994 can largely be attributed to pre-installed air-conditioning units in a large number of second-hand vehicles imported from Japan, as well as reflecting the global trend of increasing use of air conditioning in new vehicles.

The automotive industry has used HFC-134a as the refrigerant for mobile air conditioning in new vehicles since 1994. HFC-134a is imported into New Zealand for use in the mobile air-conditioning industry through bulk chemical importers/distributors and within the air-conditioning systems of imported vehicles. Industry sources report that air-conditioning systems were retrofitted (with ‘aftermarket’ units) to new trucks and buses and to second-hand cars. Refrigerated transport is included in the stationary refrigeration and air-conditioning subcategory.

New Zealand has used the IPCC (2000) Tier 2b method, mass-balance approach (Box 4.3). This approach does not require emission factors (except for the minor first-fill component) as it is based on chemical sales and not equipment leak rates. Table 4.7.5 provides a summary of results for the time series 1994–2010.

Box 4.3 Equation 3.44 (IPCC, 2000)

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

Table 4.7.5 HFC-134a emissions from mobile air conditioning in New Zealand (CRL Energy, 2011)

Year	Total virgin HFC in first-fill mobile air-conditioning systems (tonnes)	Emission factor	First-fill emissions (tonnes)
1994	0.1	0.005	0.000
1995	0.6	0.005	0.003
1996	3.2	0.005	0.016
1997	2.4	0.005	0.012
1998	1.5	0.005	0.008
1999	1.0	0.005	0.005
2000	1.1	0.005	0.005
2001	1.3	0.005	0.007
2002	2.0	0.005	0.010
2003	3.0	0.005	0.015
2004	0.6	0.005	0.003
2005	0.3	0.005	0.001
2006	0.3	0.005	0.001
2007	0.3	0.005	0.001
2008	0.4	0.005	0.002
2009	0.3	0.005	0.001
2010	0.2	0.005	0.001

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

Detailed information on the assumptions that have been used in the calculation of emissions from mobile air conditioning can be found in the report on HFC emissions in New Zealand (CRL Energy, 2011).

Fire protection

In 2010, HFC-227ea emissions from fire protection were 1.5 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, 2006) has been used to estimate emissions. A New Zealand-specific annual emission rate of 1.5 per cent has been applied to the total amount of HFC installed. This rate is based on industry experience. Due to limited data, it has been assumed that HFC from any retirements was totally recovered for use in other systems.

Electrical equipment

In 2010, SF_6 emissions from electrical equipment were 17.3 Gg CO_2-e, an increase from the 1990 level of 9.5 Gg CO_2-e.

The high dielectric strength of SF_6 makes it an effective insulant in electrical equipment. It is also very effective as an arc-extinguishing agent, preventing dangerous over-voltages once a current has been interrupted.

Actual emissions are calculated using the IPCC (2000) Tier 3a approach for the utility responsible for 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, 2011).

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, 2011).

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 2010 shows potential SF_6 emissions are again greater than actual emissions.

Other SF_6 applications

Emissions from other SF_6 applications in 1990 and 2010 were 2.9 Gg CO_2-e. In New Zealand, other applications include medical uses for eye surgery, tracer gas studies, magnesium casting, plumbing services, tyre manufacture and industrial machinery equipment. A Tier 2 method (IPCC, 2000) is applied and no emission factor is used as 100 per cent is assumed to be emitted over a short period of time.

Activity data for 2005 to 2010 was provided by one main supplier for eye surgery, scientific use, plumbing, tyre manufacture and industry. Scientific use was also discussed with the National Institute of Water and Atmospheric Research and GNS Science.

4.7.3 Uncertainties and time-series consistency

The uncertainty in estimates of actual emissions from the use of HFCs and PFCs varied with each application and is described in table 4.7.6. For most sources, a quantitative assessment is provided for activity data and other calculation components from expert opinion. These components are then combined for a statistical calculation of uncertainty.

Table 4.7.6 New Zealand's uncertainties in the consumption of halocarbons and SF_6 category (CRL Energy, 2011)

HFC source	Uncertainty estimates (%)
Aerosols	Combined uncertainty ±61
Metered dose inhalers	Combined uncertainty ±10
Solvents	Not occurring
Foam	Combined uncertainty ±51
Stationary refrigeration/air conditioning	Combined uncertainty ±22
Mobile air conditioning	Combined uncertainty ±35
Fire protection	Combined uncertainty ±32
SF_6 source	**Uncertainty estimates**
Electrical equipment	Combined uncertainty ±27
Other applications	±60

4.7.4 Source-specific QA/QC and verification

In the preparation of this inventory, the data for the consumption of halocarbons and SF_6 underwent Tier 1 quality checks. During data collection and calculation, activity data provided by industry was verified against national totals where possible and unreturned questionnaires and anomalous data were followed up and verified to ensure a complete and accurate record of activity data.

4.7.5 Source-specific recalculations

All categories

For this submission, CRL Energy conducted a stocktake on the appropriate use of notation keys. In the previous submission, the application of NA and NO was interpreted to be cross-gas specific, that is, NA could apply in early years where we know gases under the Montreal Protocol were being used. To improve transparency for the synthetic gases, NA and NO are now applied as gas specific. In general, there is insufficient evidence to estimate the first import year for minor refrigeration gases, so NA is applied from 1992 when the major ones were first imported. Whether and when each gas was used for manufacturing is now more certain and NO can be estimated more accurately.

For three sources, C3F8 from stationary refrigeration and air conditioning, HFC-227ea from fire extinguishers and SF_6 from electrical equipment, CRL Energy's stocktake resulted in a conclusion that there is insufficient evidence to justify applying the notation key NA and, consequently, there has been a change in notation key to NE.

Stationary refrigeration and mobile air conditioning

The largest improvement made to the 'stationary refrigeration and air conditioning' subcategory was in accuracy. The assumptions were improved for HFC-134a to account for a recent rise in R134A stocks. This resulted in the supermarket model for 2009 now including an additional 5 tonnes of R134A as well as the previously assumed 15 tonnes of R404A.

Recalculations were also due to an improvement in completion for mobile air conditioning. The period 1998–2009 now includes cars that have an engine size less than 1,000 cubic centimetres. The 1998 year is the first year for which records are available. The consequence of this improvement is that, for each small increase in HFC-134a for mobile air conditioning, there was an equivalent decrease for the stationary refrigeration air conditioning as the emissions are calculated by difference from the total emissions.

There was also an improvement in accuracy in the 'stationary refrigeration and air conditioning' subcategory for HFC-134a, HFC-32, HFC-125, HFC-143a. Assumptions were improved to reflect more accurate assumptions for equipment manufacturing, based on information provided by Temperzone, Fisher & Paykel and Skope. The information was provided by these manufacturers and applied from 1992 (the first year of manufacture with HFCs).

Stationary refrigeration, air conditioning and foam blowing

New information provided through the survey demonstrated that 2010 was the first year to import C_2F_6 for stationary refrigeration and air conditioning and HFC-227ea for hard foam.

Electrical equipment

There were two small improvements made to estimates for electrical equipment. New information on new and retired equipment has been now included for 2008 and 2009. In addition, an inconsistency has been corrected between the CRF input worksheet and the model.

4.7.6 Source-specific planned improvements

There are no planned improvements for this category.

4.8 Other (CRF 2G)

4.8.1 Description

Panel products

Particleboard and medium-density fibreboard activity data is obtained from the Ministry 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 2010 were 1.1 Gg. This is an increase over the 1990 level of 0.8 Gg.

The other production category was not identified as a key category in either the 2010 level assessment or the trend assessment.

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Chapter 5: Solvent and other product use

5.1 Sector overview

In 2010, New Zealand's solvent and other product use sector produced 31.0 Gg of carbon dioxide equivalent (CO_2-e), contributing 0.04 per cent of New Zealand's total greenhouse gas emissions.

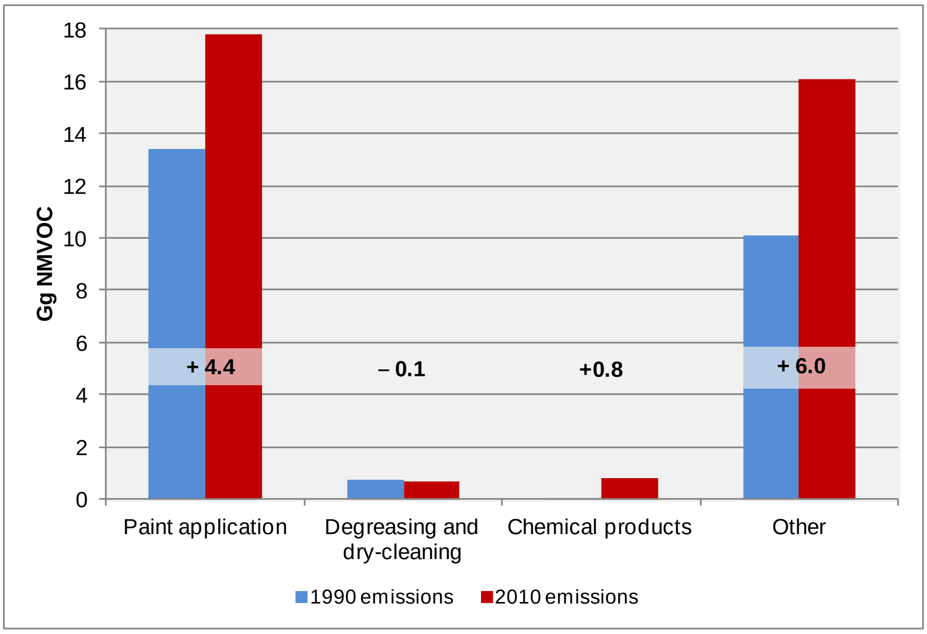
The only direct greenhouse gas reported in this category is nitrous oxide (N_2O) emissions from anaesthesia use. In 2010, N_2O emissions from anaesthesia use totalled 31.0 Gg CO_2-e. This was a decrease of 10.5 Gg CO_2-e (25.4 per cent) from the 1990 level of 41.5 Gg CO_2-e.

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

In 2010, non-methane volatile organic compound (NMVOC) emissions from the solvent and other product use sector were 35.4 Gg, or 20.1 per cent of total NMVOC emissions. This was an increase of 11.1 Gg (42.6 per cent) from the 1990 level of 24.3 Gg of NMVOCs. The categories dominating the sector are NMVOC emissions from paint application and other domestic and commercial-use subcategories (figure 5.1.1).

The solvent and other product use sector was not identified as a key category in either the 2010 level assessment or the trend assessment.

Figure 5.1.1 Change in New Zealand's emissions of NMVOC from the solvent and other product use sector from 1990 to 2010



Note: The percent change for chemical products is not applicable (NA) as there is no activity data available for 1990.

5.1.1 Description

Ethanol and methanol are the only solvents produced in New Zealand and the majority of both products are exported. All other solvents are imported, including some ethanol and methanol (for quality and price reasons).

5.1.2 Methodological issues

Detailed methodologies for emissions from the solvent and other product use sector are not provided in the revised 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1996). Two basic approaches for estimating emissions – consumption and production-based estimates – are documented. The IPCC guidelines note that, for many applications of solvents, the end uses are too small scale, diverse and dispersed to be tracked directly. Therefore, emission estimates are generally based on total consumption and an assumption that, once these products are sold to end users, they are applied and emissions are produced relatively rapidly. For most surface coating and general solvent use, this approach is recommended. The New Zealand inventory estimates solvent emissions with a consumption-based approach. Activity data is obtained by an industry survey (CRL Energy, 2006) and extrapolated for the 2006 to 2010 calendar years.

Emission factors are developed based on the likely final release of NMVOCs to the atmosphere per unit of product consumed. The emission factors are applied to sales data for the specific solvent or paint products. The subcategories of solvents and other products specified in the common reporting format are detailed below.

Nitrous oxide used for anaesthesia

The sole importer of bulk N_2O into New Zealand provided activity data for the 2010 calendar year (CRL Energy, 2011). As the importer supplies its competitor with its requirements, the emission estimate represents full coverage of N_2O use for in New Zealand. Most of the N_2O is used for anaesthesia and the production of Entonox (a half-and-half mixture of nitrous oxide and oxygen for pain relief). There is a very small amount used in motor sports and scientific analysis.

Paint application

Activity and emissions data for 2006 to 2010 were extrapolated from the 2005 survey data (CRL Energy, 2006). Consumption and emissions from paints and thinners were based on information from Nelson (1992) and the Auckland Regional Council (1997). Additional activity data for 1993 to 1996 was provided by the New Zealand Paint Manufacturers' Association.

Degreasing and dry-cleaning

Dry-cleaning activity and emission data were extrapolated from 2005 activity data (CRL Energy, 2006) for the 2006 to 2010 calendar years. Most dry-cleaners in New Zealand use perchloroethylene and a small number use white spirits. Trichloroethylene has never been used in dry-cleaning but it is used in degreasing, for example, in the leather manufacturing industry. In general, solvent losses from the dry-cleaning industry have reduced substantially as closed-circuit machines and refrigerated recovery units are increasingly used. Consumption of perchloroethylene and trichloroethylene are assumed to equal the volume of imports. Import data was supplied by Statistics New Zealand.

Chemical products (manufacturing and processing)

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

Losses of ethanol (and other minor components such as methanol, acetaldehyde and ethyl acetate) were monitored in the three ethanol plants in New Zealand. Using these values, an emission factor for NMVOCs of 6 grams per litre was calculated. Ethanol used for alcoholic beverage production has been reported under food and drink production in the industrial processes sector.

Due to data availability, data has remained unchanged since 2005.

Other – printing ink use

There is one major printing ink company in New Zealand with approximately 50 per cent of the solvent ink market share. The company provided a breakdown of the type of ink used. Approximately 50 per cent of inks used are oil inks (paste inks) containing high boiling temperature oils. These are evaporated off during heat setting, but the volatiles are generally treated in a solvent burner that minimises emissions. The remaining 50 per cent of inks are liquid, and 60 per cent of these are solvent inks (the remaining 40 per cent are water-based).

Due to data availability, data has remained unchanged since 2005.

Other – aerosols

Approximately 25 million aerosol units are sold in New Zealand each year. The average propellant charge is 84 grams and 95 per cent are hydrocarbon-based.

Other – domestic and commercial use

This category includes NMVOC emissions from domestic and commercial solvent use in the following areas: household products, toiletries, rubbing compounds, windshield washing fluids, adhesives, polishes and waxes, space deodorants, and laundry detergents and treatments. Emissions for this category are based on a per capita emission factor. The emission factor used is 2.54 kilograms NMVOC/capita/year (United States EPA, 1985). It is assumed that the emissions rate per capita derived by the United States Environmental Protection Agency is applicable to the average product use in New Zealand (CRL Energy, 2006). Population data is sourced from Statistics New Zealand.

5.1.3 Uncertainties and time-series consistency

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

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

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

5.1.4 Source-specific recalculations

There were no recalculations for this sector.

5.1.5 Source-specific planned improvements

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

Chapter 5: References

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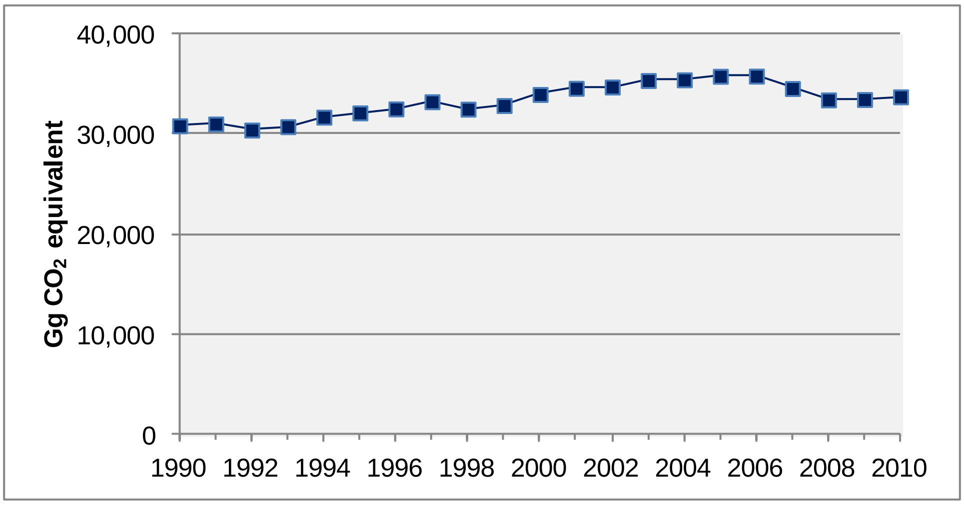
Chapter 6: Agriculture

6.1 Sector overview

In 2010, the agriculture sector contributed 33,748.4 Gg carbon dioxide equivalent (Gg CO_2-e) (47.1 per cent) to New Zealand's total greenhouse gas emissions. Emissions in this sector have increased by 2,893.2 Gg CO_2-e (9.4 per cent) from the 1990 level of 30,855.3 Gg CO_2-e (figure 6.1.1). The increase since 1990 is primarily due to a 718.9 Gg CO_2-e (3.2 per cent) increase in methane (CH_4) emissions from the enteric fermentation category and a 2,013.9 Gg CO_2-e (25.5 per cent) increase in nitrous oxide (N_2O) emissions from the agricultural soils category (figure 6.1.2).

Figure 6.1.1 New Zealand agriculture sector emissions from 1990 to 2010

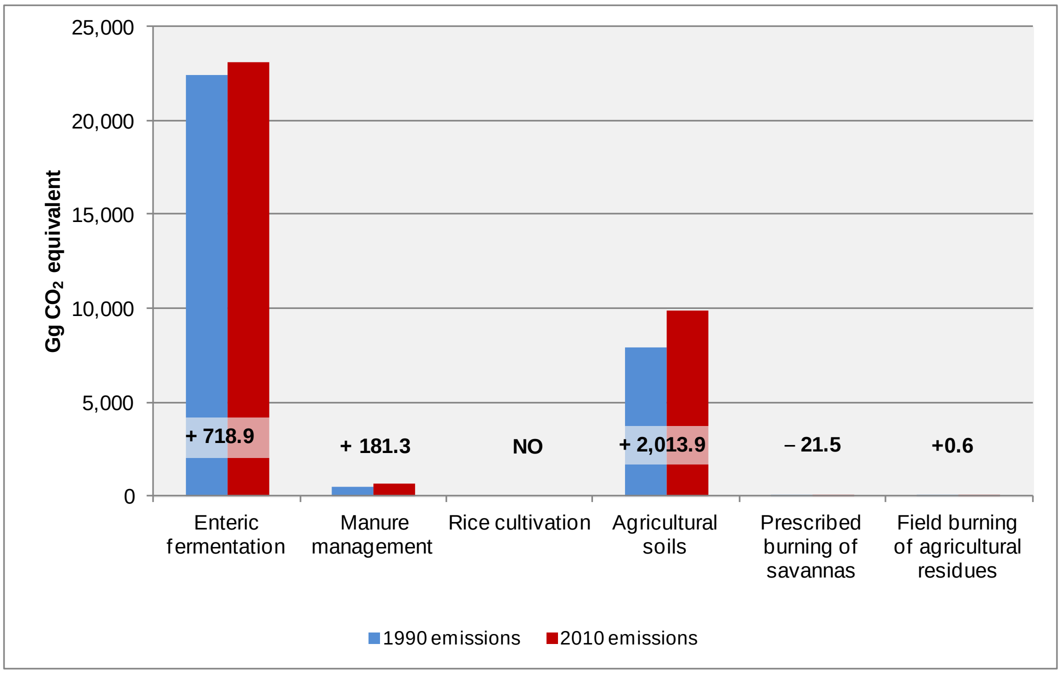


In 2010, CH_4 emissions from enteric fermentation were 68.6 per cent (23,140.7 Gg CO_2-e) of agricultural emissions and 32.3 per cent of New Zealand's total emissions. Nitrous oxide emissions from the agricultural soils category were 29.4 per cent (9,905.2 Gg CO_2-e) of agricultural emissions and 13.8 per cent of New Zealand's total emissions.

Agriculture is a major component of the New Zealand economy, and agricultural products comprise 58 per cent of total value of merchandise exports (Ministry of Agriculture and Forestry website: http://www.maf.govt.nz/agriculture/statistics-forecasting/international-trade). This is facilitated by the favourable temperate climate, the abundance of agricultural land and the unique farming practices used in New Zealand. These practices include the use of year-round extensive outdoor grazing systems and a reliance on nitrogen fixation by legumes rather than nitrogen fertiliser as the nitrogen source. For example, the majority (95 per cent) of dairy cattle and all (100 per cent) beef cattle, sheep and deer are grazed outside all year round. This means that New Zealand, like Australia, has a much lower proportion of agricultural emissions from manure management compared with other Annex 1 Parties, as intensive housing of major livestock is not practised in New Zealand. For further information of New Zealand's favourable agricultural growing conditions see chapters 1 and 2 (Executive summary and National Circumstances) of New Zealand's fifth national communication (http://www.mfe.govt.nz/publications/ climate/nz-fifth-national-communication/page3.html).

These chapters provide evidence of New Zealand's climate conditions, rainfall and temperature by region and season and, therefore, why there are no regions in New Zealand that need to house cattle, sheep and deer at any time of the year.

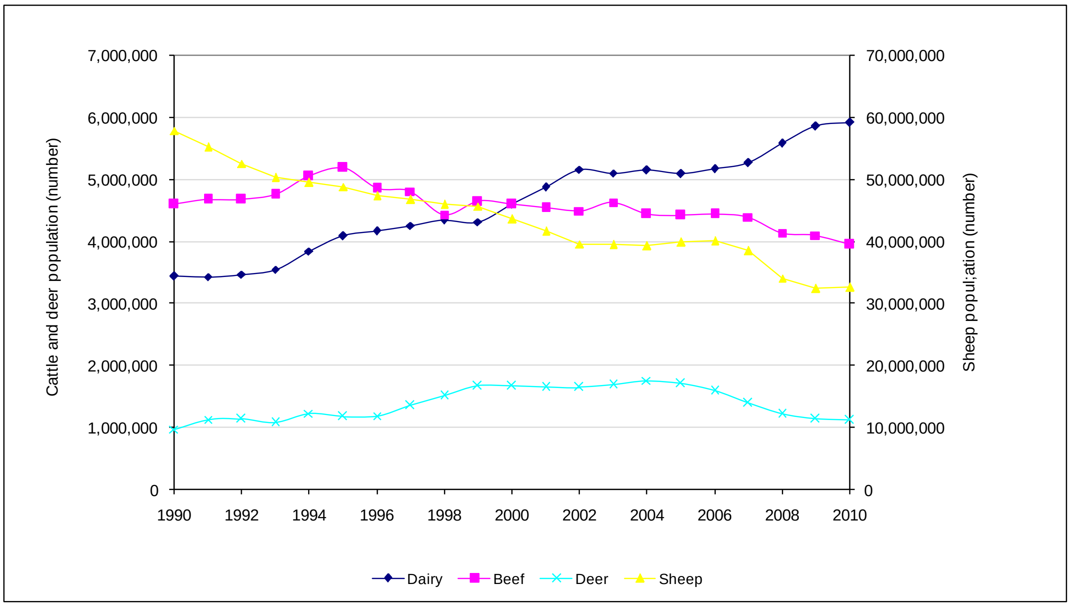
Figure 6.1.2 Change in New Zealand's emissions from the agriculture sector from 1990 to 2010



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

Since 1990, there have been changes in the proportions of the main livestock species farmed in New Zealand. Since 1990, the profitability of dairy products has become relatively higher while the profitability of sheep products has reduced. Therefore, there has been an increase in dairy production with the extra land required to accommodate the extra dairy production mainly coming out of sheep farming. Since 1990, there has also been more forestry on areas that were previously sheep pasture. Over the period since 1990, beef numbers have remained relatively static (figure 6.1.3).

Figure 6.1.3 Population of New Zealand's major ruminant livestock from 1990 to 2010 – as at 30 June



There was a gradual increase in the implied emission factors for dairy cattle and beef cattle that reflects the increased levels of productivity achieved by New Zealand farmers between 1990 and 2010. Increases in animal liveweight and performance (milk yield and liveweight gain per animal) require increased feed intake by the animal to meet higher energy demands. Increased feed intake results in increased CH_4 emissions per animal. In 2008, there was a nationwide drought that affected livestock numbers and productivity, resulting in lower livestock emissions. The implied emission factors have started to increase again now the drought is over.

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

Changes in emissions between 2009 and 2010

Total agricultural emissions in 2010 were 270.4 Gg CO_2-e (0.8 per cent) higher than the 2009 level. This was largely due to an increase in the population of dairy cattle (54,676 or 1 per cent) and volume of nitrogen fertiliser (53,229 tonnes or 19.0 per cent) although there was a decrease in the population of deer (23,163 or 2 per cent) and non-dairy cattle (152,198 or 3.7 per cent). There was an increase in the sheep population (179,023 or 0.6 per cent), however, this was offset by a reduction in average sheep liveweight resulting in a small reduction in emissions from sheep (245.5 Gg CO_2-e or 2.3 per cent). The increase in these livestock numbers is primarily due to the recovery from the drought that affected nearly all of New Zealand throughout 2008 (Ministry of Agriculture and Forestry, 2010). The dairy industry is the main user of nitrogen fertiliser in New Zealand. The milk price was higher during 2010 compared with 2009 (Ministry of Agriculture and Forestry, 2011) and this increased the sale and use of nitrogen fertiliser in 2010.

6.1.1 Methodological issues for the agriculture sector

Agricultural Inventory Advisory Panel

New Zealand has formed an independent Agricultural Inventory Advisory Panel. This panel is made up of representatives from the Ministry of Agriculture and Forestry, the Ministry for the Environment, and science representatives from the Royal Society of New Zealand, New Zealand Methanet and New Zealand NzOnet expert advisory groups. New Zealand Methanet and NzOnet are two groups of New Zealand experts in the areas of agricultural inventory methane and inventory nitrous oxide emissions respectively. The panel is independent of policy and industry influences, and has been formed to give advice on whether changes to New Zealand's agricultural section of the national inventory are scientifically justified. Reports and papers on proposed changes must be peer reviewed before they are presented to the panel. The panel assesses if the proposed changes have been appropriately researched using recognised scientific principals and if there is sufficient scientific evidence to support the change. The panel advises the Ministry of Agriculture and Forestry of its recommendations. The 2011 meeting of the panel was held on 15 November 2011 where several changes were recommended for inclusion into the agricultural greenhouse gas inventory. The changes are detailed in the relevant sections of this report.

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

Methane from enteric fermentation and manure management, and nitrous oxide from nitrogen excretion from the four largest categories in the New Zealand ruminant population (dairy cattle, beef cattle, sheep and deer), are calculated using New Zealand's Tier 2 method (Clark et al, 2003). This method uses a detailed livestock population characterisation and livestock productivity data to calculate energy requirements and feed intake. From the calculated feed intake, annual calculations of enteric methane and nitrous oxide emissions are derived.

New Zealand uses a different characterisation for dairy and beef cattle compared with that recommended in the Revised 1996 IPCC Guidelines, the IPCC good practice guidelines and the 2006 IPCC good practice guidance. In the New Zealand inventory, dairy cattle encompasses all cattle that are required to support the milking dairy herd. This includes calves, young growing non-lactating heifers, dry cows and bulls. All other cattle in New Zealand tend to be used for the breeding of animals that are slaughtered for meat consumption. These animals are characterised as beef animals. These include breeding lactating cows used for breeding slaughter animals from calves, dry cows, bulls and all slaughter classes. The full characterisation list for both of these animal populations can be found in the inventory methodology document on the Ministry of Agriculture and Forestry website: (http://www.maf.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx).

Activity data

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

Major species

Livestock population data

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

Dairy livestock numbers are calculated on a regional basis and, therefore, regional dairy population numbers are used to take into account regional differences in production (Clark, 2008a).

Statistics New Zealand collects population data on a territorial authority basis. Territorial authorities are the lowest local political division in New Zealand. Territorial authorities are then aggregated up to regional council boundaries by Statistics New Zealand. In 1993, the regional council boundaries changed. Therefore, dairy population data for 1990–1993 was collected from Statistics New Zealand at a territorial authority level and then aggregated up to the regional council boundaries currently used. From 1993, Statistics New Zealand supplied livestock population data at the required regional council aggregation and, therefore, no manipulation of data was required.

Livestock productivity data

Productivity data comes from New Zealand Dairy Statistics, Beef and Lamb New Zealand and slaughter statistics collected by the Ministry of Agriculture and Forestry. To ensure consistency, the same data sources are used each year.

Data on the productivity of ruminant livestock in New Zealand, and how it has changed over time, has several limitations. 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 the liveweight of dairy cattle and breeding bulls, is collected at irregular intervals from small survey populations, or is not available. Where limitations occur, expert opinion and extrapolation from existing data are used.

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

The inventory model was developed to conform to the Revised 1996 IPCC Guidelines and the IPCC good practice guidance and is constantly under improvement. To ensure consistency, a single livestock population characterisation and feed-intake estimate is used to estimate CH_4 emissions for the enteric fermentation category, CH_4 and N_2O emissions for the manure management category and N_2O emissions for the pasture, range and paddock manure subcategory.

Dairy cattle: Data on milk production is provided by the Livestock Improvement Corporation, a dairy-farmer-owned company providing services to the dairy, beef and deer industries (2011). This data includes the amount of milk processed through New Zealand dairy factories largely for export and milk for the domestic market.

Productivity data (milk yield and composition) is collected by the Livestock Improvement Corporation at the same territorial authority level as the population data is collected by Statistics New Zealand. Ministry of Agriculture and Forestry officials then aggregate this data up into the regional council boundaries used for the population data. Before 2004, not all productivity data required could be collected from the Livestock Improvement Corporation at a territorial authority level. Therefore, some extrapolation of data was required to obtain the required values. For example, from 1993–2003 milk per cow was determined by the following equation:

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

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

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

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

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

Beef cattle: The principal source of information for estimating productivity for beef cattle is livestock slaughter statistics provided by the Ministry of Agriculture and Forestry. All growing beef animals are assumed to be slaughtered at two years of age and the average weight at slaughter for the three subcategories (heifers, steers and bulls) is estimated from the carcass weight at slaughter. Liveweights at birth are assumed to be 9 per cent of an adult cow weight for heifers and 10 per cent of an adult cow weight for steers and bulls. As with dairy cattle, growth rates of all growing animals are divided into two periods: birth to weaning and weaning to slaughter. Higher growth rates are applied before weaning when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

The carcass weights obtained from the Ministry of Agriculture and Forestry slaughter statistics do not separate carcass weights of adult dairy cows and adult beef cows. Therefore, a number of assumptions[17] are made to estimate the liveweights of beef breeding cows. A total milk yield of 800 litres per breeding beef cow is assumed.

Sheep: Livestock slaughter statistics from the Ministry of Agriculture and Forestry are used to estimate the liveweights of adult sheep and lambs, assuming killing-out[18] percentages of 40 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 kilograms per annum in mature sheep (ewes, rams and wethers) and 2.5 kilograms per annum in growing sheep and lambs. Beef and Lamb New Zealand, the industry body representing the beef cattle and sheep industry, provides estimates of the total wool production from 1990 to 2010 from which the individual fleece weight is estimated.

17 The number of beef breeding cows was assumed to be 17 per cent of the total beef breeding cow herd and other adult cows slaughtered were assumed to be dairy cows. The carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing-out percentage of 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 42.6 per cent (Thomson et al, 2010).

18 Percentage of carcass weight in relation to liveweight.

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

Dry-matter intake calculation

Dry-matter intake (DMI) for the major livestock classes (dairy cattle, beef cattle, sheep and deer) and sub-classes of animals (breeding and growing) is estimated by calculating the energy required to meet the levels of animal performance (metabolisable energy (ME)) and dividing this by the energy concentration of the diet consumed. For dairy cattle, beef cattle and sheep, energy requirements are calculated using algorithms developed in Australia (CSIRO, 2007). These algorithms are chosen because they specifically include methods to estimate the energy requirements of grazing animals, the feeding method used in New Zealand. This method estimates a maintenance requirement (a function of liveweight, the amount of energy expended on the grazing process) and production energy requirement needed for a given level of productivity (eg, milk yield and liveweight gain), physiological state (eg, pregnant or lactating) and the stage of maturity of the animal. All calculations are performed on a monthly basis. The equation below is the general equation from the Australian feeding standards. This has been adjusted to suit New Zealand conditions and the term ECOLD (additional energy expenditure in cold stress by animals in below lower critical temperature) has been removed as it was found not to apply to New Zealand conditions.

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

Where:

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

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

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

Monthly diet energy concentrations

A single data set of monthly energy concentrations of the diets consumed by beef cattle, dairy cattle, sheep and deer is used for all years in the time series. This is because there is no comprehensive published data available that allows the estimation of a time series dating back to 1990. The data used is derived from research trial data and publications, and supplemented with actual data from farm surveys on commercial cattle and sheep farms.

Other minor livestock categories

For goats, horses, swine, poultry and alpaca, the Revised 1996 IPCC Guidelines Tier 1 methodology is used with a combination of default and country-specific emission factors. The country-specific emission factors are detailed in the relevant sections.

The populations of goats, horses and swine are reported using the animal census (or survey) data from Statistics New Zealand. The population of alpacas is provided by the Alpaca Association New Zealand (AANZ), where available, and supplemented by adjusted data from Statistics New Zealand (Henderson and Cameron, 2010).

Statistics New Zealand provides estimates of average annual broiler flock sizes using industry data on the numbers of broilers processed every year since 1990, mortality rates and days alive. The methodology accounts for the downtime common in New Zealand broiler sheds between production rounds to minimise disease outbreaks. This methodology also accounts for productivity in broiler production through the average number of days to the same slaughter weight and mortality rates. Statistics New Zealand also obtains estimates of the number of layers and other poultry (eg, ducks, turkeys and breeder) from the animal census (or survey).

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

Average annual flock size = (days alive)/365 × Annual numbers of bird processed/(1- rate of mortality).

6.2 Enteric fermentation (CRF 4A)

6.2.1 Description

Methane (CH_4) 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, the energy expenditure of the animal and the amount of feed consumed.

Methane emissions from the dairy cattle and sheep enteric fermentation category were identified as the largest key categories for New Zealand in the 2010 level assessment. Methane emissions from sheep enteric fermentation and dairy cattle enteric fermentation were also assessed as key categories for trend assessment. In accordance with IPCC good practice guidance (IPCC, 2000), the methodology for estimating CH_4 emissions from enteric fermentation in domestic livestock is a Tier 2 modelling approach.

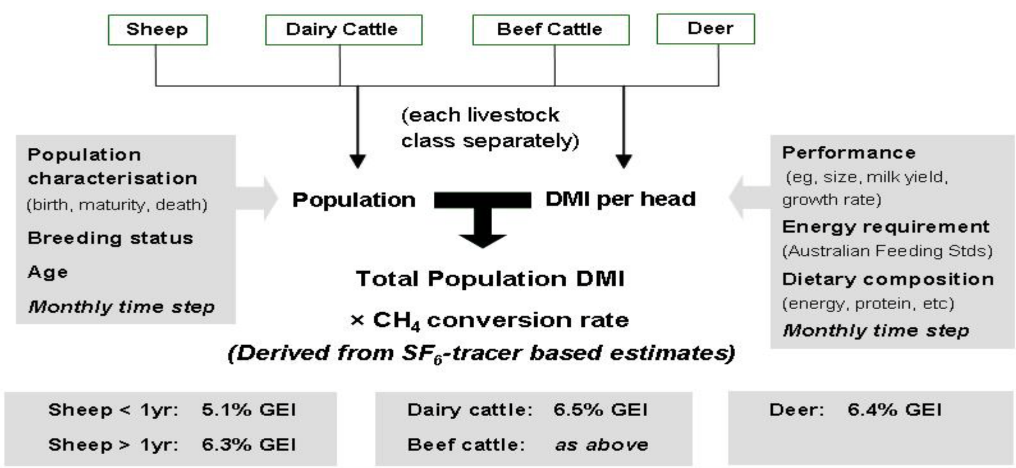
In 2010, enteric fermentation contributed 23,140.7 Gg CO_2-e. This represented 32.3 per cent of New Zealand's total CO_2-e emissions and 68.6 per cent of agricultural emissions. Cattle contributed 14,816.8 Gg CO_2-e (64.0 per cent) of emissions from the enteric fermentation category, and sheep contributed 7,772.9 Gg CO_2-e (33.6 per cent) of emissions from this category. Emissions from the enteric fermentation category in 2010 were 718.9 Gg CO_2-e (3.2 per cent) above the 1990 level of 22,421.8 Gg CO_2-e. Since 1990, there have been changes in the source of emissions within the enteric fermentation category. The largest increase came from emissions from dairy cattle. In 2010, dairy cattle were responsible for 9,849.2 Gg CO_2-e, an increase of 4,838.2 Gg CO_2-e (96.6 per cent) from the 1990 level of 5,011.0 Gg CO_2-e. Meanwhile, there have been decreases in emissions from sheep and minor livestock populations, such as goats, horses and swine. In 2010, emissions from sheep were 7,772.9 Gg CO_2-e, a decrease of 4,049.7 Gg CO_2-e (34.3 per cent) from the 1990 level of 11,822.6 Gg CO_2-e.

6.2.2 Methodological issues

Emissions from cattle, sheep and deer

Using the DMI and population data calculated by New Zealand's Tier 2 inventory model (section 6.1.1), the amount of CH_4 emitted per animal is calculated using CH_4 emissions per unit of feed intake (figure 6.2.1).

Figure 6.2.1 Schematic diagram of how New Zealand's emissions from enteric fermentation are calculated



Note: GEI is the gross energy intake and DMI is the dry-matter intake.

The equation for the total production of methane (kilogram CH_4 per head per month) is:

$$M = (DMI \times CH_4 \text{ conversion rate}/1{,}000).$$

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

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

There are a number of published algorithms and models[19] of ruminant digestion for estimating CH_4 emissions per unit of feed intake. The data requirements of the digestion models make them difficult to use in generalised national inventories and none of the methods have high predictive power when compared against empirical experimental data. Additionally, the relationships in the models have been derived from animals fed indoors on diets unlike those consumed by New Zealand's grazing ruminants.

Since 1996, New Zealand scientists have been measuring CH_4 emissions from grazing cattle and sheep using the SF_6 tracer technique (Lassey et al, 1997; Ulyatt et al, 1999). New Zealand now has one of the largest data-sets in the world of CH_4 emissions determined using the SF_6 technique on grazing ruminants. To obtain New Zealand-specific values, published and unpublished data on CH_4 emissions from New Zealand were collated and average values for CH_4 emissions from different categories of livestock were obtained. Sufficient data was available to obtain values for adult dairy cattle, sheep more than one year of age and growing sheep (less than one year of age). This data is presented in table 6.2.1 together with the IPCC default values for per cent gross energy (GE) used to produce CH_4 (IPCC, 2000). The New Zealand values fall within the IPCC range and are applied in this submission. Table 6.2.2 shows a time series of CH_4 implied emission factors for dairy cattle, beef cattle, sheep and deer. Measurements using open-circuit respiration chamber techniques that provided complete gas balances were conducted to further confirm the SF_6 tracer technique.

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

	Adult dairy cattle	Adult sheep	Adult sheep < 1 year
New Zealand data (g CH_4/kg DMI)	21.6	20.9	16.8
New Zealand data (%GE)	6.5	6.3	5.1
IPCC (2000) default values (%GE)	6 ±0.5	6 ±0.5	5 ±0.5

The adult dairy cattle value is assumed to apply to all dairy and beef cattle, irrespective of age, and the adult ewe value is applied to all sheep more than one year of age. An average of the adult cow and adult ewe value (21.25 grams CH_4/kg DMI) is assumed to apply to all deer. 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.

[19] For example, Blaxter and Clapperton (1965); Moe and Tyrrel (1975); Baldwin et al (1988); Djikstra et al (1992) and Benchaar et al (2001) – all cited in Clark et al (2003).

Table 6.2.2 New Zealand's implied emission factors for enteric fermentation from 1990 to 2010

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	69.3	51.8	9.4	18.7
1995	72.7	55.0	9.6	20.6
2000	76.8	58.5	10.8	21.7
2005	79.1	61.1	11.2	22.1
2006	78.8	62.3	11.1	22.2
2007	77.5	60.4	10.9	22.2
2008	77.0	59.1	11.2	22.4
2009	77.2	59.9	11.3	22.3
2010	79.3	59.9	11.1	21.2

Emissions from other minor livestock categories

A Tier 1 approach is adopted for the minor livestock categories of goats, horses, swine and alpaca using either IPCC default emission factors (horses and alpaca) or New Zealand country-specific emission factors (goats and swine). These minor species comprised 0.2 per cent of total enteric CH_4 emissions in 2010.

Livestock population data

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

Livestock emissions data

Goats: New Zealand uses a country-specific emission factor for enteric fermentation of 7.4 kilograms CH_4/head for 1990 and 8.5 kilograms CH_4/head for 2009 based on the differing population characteristics for those two years (Lassey, 2011). From 1990 to 2009, the population declined from 1,062,900 goats to 82,229 goats. Most of the decline in the herd was in the non-milking goat population. Therefore, for the intermediate years between 1990 and 2009 and for 2010, the emission factor was interpolated based on the assumption that the dairy goat population has remained in a near constant state over time, while the rest of the goat population has declined.

Horses: In the absence of data to develop New Zealand emissions' factors, the IPCC 1996 default value (18 kilograms CH_4/head/year) was used to determine emissions from enteric fermentation from horses.

Swine: New Zealand uses a country-specific emission factor of 1.08 Kg CH_4/head/year (Hill, 2012). This is based on the lower GE value of feed fed to swine in New Zealand.

Poultry: New Zealand does not estimate emissions from enteric fermentation of poultry because there is no IPCC 1996 methodology to estimate emissions from this category.

Alpacas*:* The IPCC default value from the 2006 IPCC Guidelines based on a study carried out in New Zealand. In the absence of further work carried out on alpacas in New Zealand, this value (8 kilograms CH_4/head/year) has been used but is yet to be approved 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 was subjected to Monte Carlo analysis using the software package @RISK to determine the uncertainty of the annual estimate (Clark et al, 2003). In subsequent submissions, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value.

In 2009, the Ministry of Agriculture and Forestry commissioned a report that recalculated 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 New Zealand on measuring enteric methane emissions from sheep and cattle. The initial analysis expressed the coefficient of variation (CV) according to the standard deviation of the methane yield. The report (Kelliher et al, 2009) investigated calculating the uncertainty by expressing the CV according to the standard error of the methane yield. As further research has been conducted since 2003, the number of studies this uncertainty analysis is based on is now a larger sample. The current analysis was restricted to one diet, grass, the predominant diet of sheep and cattle in New Zealand. The new overall uncertainty of the enteric methane emissions inventory, expressed as a 95 per cent confidence interval, is ±16 per cent (Kelliher et al, 2009).

Table 6.2.3 New Zealand's uncertainty in the annual estimate of enteric fermentation emissions for 1990 and 2010, estimated using the 95 per cent confidence interval of mean ±16 per cent

Year	Enteric CH_4 emissions (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	1,067.7	896.9	1,238.5
2010	1,101.9	925.6	1,278.2

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

Uncertainty in the annual estimate is dominated by variance in the measurements of the 'CH_4 per unit of intake' factor. For the measurements used to determine this factor, the CV (standard error as a percentage of the mean; the standard error was the standard deviation divided by the number of records raised to a power of 0.5) 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 quality assurance/quality control (QA/QC) and verification

In 2010, CH_4 from enteric fermentation was identified as a key category (level and trend assessment). In the preparation for this inventory, the data for this category underwent Tier 1 and Tier 2 quality checks.

Methane emission rates measured for 20 dairy cows and scaled up to a herd have been corroborated using micrometeorological techniques. Laubach and Kelliher (2004) used the integrated horizontal flux technique and the flux gradient technique to measure CH_4 flux above a dairy herd. Both techniques are comparable, within estimated errors, to scaled-up animal emissions. The emissions from the cows measured by integrated horizontal flux and averaged over three campaigns are 329 (±153) grams CH_4/day/cow compared with 365 (±61) grams CH_4/day/cow for the scaled-up measurements reported by Waghorn et al (2002; 2003). 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 grams CH_4/day, when measured using calorimeter chambers or the SF_6 tracer technique respectively.

Table 6.2.4 shows a comparison of the New Zealand-specific 2010 implied emission factor for enteric fermentation with the IPCC Oceania default and the Australian and United Kingdom implied emission factors for dairy, beef cattle and sheep (IPCC 1996; IPCC 2000; UNFCCC 2011a; UNFCCC2011b). All calculations in this model are based on the Revised 1996 IPCC Guidelines, and the IPCC good practice guidance and IPCC good practice guidance for LULUCF and the 2006 IPCC Guidelines.

New Zealand has a slightly higher implied emission factor for dairy than the IPCC Oceania default due to the higher productivity of the livestock compared with the Oceania average. The converse is true when comparing the implied emission factor with Australia and the United Kingdom. New Zealand livestock have a predominant diet of pasture with a higher digestibility than the value reported in table A-1 of the revised 1996 IPCC guidelines (IPCC, 1996), which would result in a lower implied emission factor compared with Australia and the United Kingdom. Also, in New Zealand’s Tier 2 inventory model, dairy cattle encompasses all cattle that are required to support the milking dairy herd. This includes calves, young growing non-lactating heifers, dry cows and bulls. By taking the emissions from these animals into account, the implied emission factor will be lower than if only mature milking cows had been taken into account.

New Zealand’s emission factor for sheep is higher than the IPCC default, and higher than Australia’s and the United Kingdom. New Zealand takes into account lambs when determining actual methane emissions but not when estimating the implied emission factor. Therefore, a higher implied emission factor is determined than when the lamb population is taken into account. Other countries report an implied emission factor including lambs.

Table 6.2.4 Comparison of IPCC default emission factors and country-specific implied emission factors for 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[20] (kg CH_4/head/year)
IPCC (2006) Oceania default value	68	53	8
Australian-specific IEF 2009 value	115	72	7
United Kingdom-specific IEF 2009 value	109	43	5
New Zealand-specific 2009 value	77	56	11

Note: IEF – implied emission factor.

For beef cattle, the implied emission factor is similar to the other values that it is compared against. Differences such as feed type and quality, which animals are characterised as non-dairy, breed and so on will, however, influence the implied emission factor.

Overall, IPCC default values and values from some countries for methane emissions from cattle are also determined from relationships based on analyses of the higher-quality feeds typically found in the United States of America's temperate agricultural system (IPCC, 1996). New Zealand methane emissions from cattle have been based on algorithms related to a pasture diet and will therefore produce different values for emissions.

6.2.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2011), Livestock Improvement Corporation statistics (2011)).

This year, there have been a number of improvements to the Tier 2 inventory model. The dressing out percentages used to convert carcass weights from slaughter data into liveweights have been reviewed for beef cattle and sheep. For ewes, the dressing out percentage has changed from 43 per cent to 40 per cent. The dressing out percentage for dairy cows has been reduced from 44 per cent to 42 per cent, and for beef cattle the dressing out percentage has been reduced from 45 per cent to 42.6 per cent. Reducing the dressing out percentage will increase the liveweight estimates of these livestock. These revisions are based on work by Muir and Thomson (2010). The estimated liveweights for sheep and beef cattle now more accurately reflect the actual liveweight of national breeding ewes and cows. Other enhancements to New Zealand's Tier 2 inventory model have resulted in recalculations of dairy, non-dairy, sheep and deer, including some recoding of the Tier 2 model into Visual Basic. The recoding is improving the usability of the model as well as increasing its transparency and accuracy.

As detailed in 6.2.2, New Zealand has developed a country-specific emission factor for enteric fermentation from goats based on the differing population characteristics over the time series. This new emission factor changes slightly each year because it is based on the different proportions of dairy and other goats in the herd since 1990. Updated country-specific emission factors have been applied to every year since 1990 and, therefore, recalculations have been carried out on the entire time series.

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

A country-specific value for enteric fermentation has been determined for swine. This value has been applied to all years back to 1990 and, therefore, recalculations have been carried out for all years in the time series.

Data for poultry has been disaggregated into broilers (meat chickens), layers and all other poultry (ducks, turkeys, breeders, geese and so on), with country-specific emission factors being used for broilers and layers. Estimation and modelling of official broiler population numbers for the entire time series has been improved with better information on broiler production. See section 6.1.1 for further details. Updated activity data and changes to the methodology have been applied to the entire time series and, therefore, recalculations have been carried out for all years from 1990.

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. These improvements cover such variables as dressing out percentage, birth dates, death dates and rates, and will be incorporated in future submissions.

Also, further work into improving the values of the metabolisable energy concentration, digestibility and nitrogen content used in the Tier 2 inventory model is being investigated.

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 for ruminants but also on improving on-farm inventories. The consortium is funded from both public and private sector sources.

New Zealand has also set up the New Zealand Agricultural Greenhouse Gas Research Centre, comprising eight of New Zealand’s research providers including the Pastoral Greenhouse Gas Research Consortium. The aim of the Centre is to contribute to the agricultural greenhouse gas mitigation strategy through research programmes and international collaboration. Funding is made available through the Primary Growth Partnership funded by the New Zealand Government. The results of research by the Centre will also feed into improving the national inventory.

6.3 Manure management (CRF 4B)

6.3.1 Description

In 2010, emissions from the manure management category comprised 668.8 Gg CO_2-e (2.0 per cent) of emissions from the agriculture sector. Emissions from manure management had increased by 181.3 Gg CO_2-e (37.2 per cent) from the 1990 level of 487.5 Gg CO_2-e.

Livestock manure is composed principally of organic material. When the manure decomposes in the absence of oxygen, methanogenic bacteria produce CH_4. The amount of CH_4 emissions is related to the amount of manure produced and the amount that decomposes anaerobically. Methane from manure management was identified as a key category for New Zealand in the 2010 level assessment (excluding land use, land-use change and forestry (LULUCF)).

The manure management category also includes N_2O emissions related to manure handling before the manure is added to the soil. The amount of N_2O emissions depends on the system of waste management and the duration of storage. With New Zealand's extensive use of all-year-round grazing systems, this category contributed a relatively small amount of N_2O (44.6 Gg CO_2-e) in 2010. In comparison, N_2O emissions from the agricultural soils category totalled 9,905.2 Gg CO_2-e in 2010.

In New Zealand, dairy cows have only a fraction (5 per cent) of their excreta stored in anaerobic lagoon waste systems (Ledgard and Brier, 2004). The remaining 95 per cent of excreta from dairy cattle is deposited directly onto pasture. These fractions relate to the proportion of time dairy cattle spend on pasture compared with the time they spend in the milking shed. Other livestock species (sheep, beef cattle, goats, deer, alpaca and horses) graze outdoors all year and deposit all of their faecal material (dung and urine) directly onto pastures. This distribution is consistent with the revised 1996 IPCC guidelines (IPCC, 1996) for the Oceania region. New Zealand scientists and Ministry of Agriculture and Forestry officials consider the default distributions are applicable to New Zealand farming practices for the ruminant animals listed. Estimates of the proportions of different waste management systems for swine and poultry broilers in the manure management systems have been provided by Hill (2012) and Fick et al (2011) respectively. Table 6.3.1 shows the current distribution of livestock in animal waste management systems in New Zealand. Further work is anticipated to confirm the proportions of different waste management systems for other poultry in the manure management system. Emissions from the pasture range and paddock, and daily spread animal management systems are reported under the agricultural soils category.

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

Livestock	Anaerobic lagoon	Daily spread[21]	Pasture, range and paddock[22]	Solid storage and dry-lot	Other
Non-dairy cattle	–		100	–	–
Dairy cattle	5		95	–	–
Sheep	–		100	–	–
Deer	–		100	–	–
Goats	–		100	–	–
Horses	–		100	–	–
Swine[23]	21	26	9	42	2
Poultry – Broilers[24]	0		4.9	0	95.1
Poultry – Layers[24]	-		5.8		94.2
Poultry – Other[25]	–		3	–	97
Alpaca	–		100	–	–

21 Reported under 'agricultural soils' under direct soil emissions from agricultural fields.

22 Reported under 'agricultural soils' under direct soil emissions from animal production.

23 Hill (2011).

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

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

6.3.2 Methodological issues

Methane from cattle, sheep and deer

A Tier 2 approach, which is consistent with the Revised 1996 IPCC Guidelines and the IPCC good practice guidance, is used to calculate CH_4 emissions from ruminant animal wastes from cattle, sheep and deer in New Zealand. The Tier 2 approach is based on the methods recommended by Saggar et al (2003) in a review commissioned by the Ministry of Agriculture and Forestry.

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

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

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

Where:

FDM = faecal dry-matter output

DMI = dry-matter intake

DMD = dry-matter digestibility.

These feed intake and dry-matter digestibility estimates are the same as are used in the enteric CH_4 and N_2O Tier 2 model calculations and are based on animal performance (section 6.1.1). Table 6.3.2 summarises the key New Zealand-specific variables in the calculation of CH_4 from manure management, including the proportion of this faecal matter deposited on pasture and anaerobic lagoons and the country-specific methane yields determined from each.

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

Animal species	Proportion of faecal material deposited on pasture (%)	CH_4 from animal waste on pastures (g CH_4/kg faecal dry-matter)	Proportion of faecal material stored in anaerobic lagoons (%)	Water dilution rate (litres water/kg faecal dry matter)	Average depth of a lagoon (metres)	CH4 from anaerobic lagoon (g CH_4/m^2/ year)
Dairy cattle	0.95	0.98[26]	0.05	90[27]	4.6[28]	3.27[29]
Beef cattle	1.0	0.98[30]	0.0	–	–	–
Sheep	1.0	0.69[31]	0.0	–	–	–
Deer	1.0	0.92[32]	0.0	–	–	–

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

27 Heatly (2001).

28 McGrath and Mason (2002).

29 McGrath and Mason (2002).

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

31 Carran et al (2003).

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

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

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

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

And for anaerobic lagoons the following equation is used:

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

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

Dairy cattle

Faecal material deposited directly onto pastures: Consistent with the N_2O inventory, 95 per cent of faecal material arising from dairy cows is assumed to be deposited directly onto pastures (Ledgard and Brier, 2004). The quantity of CH_4 produced per unit of faecal dry matter is 0.98 grams CH_4/kg. This value is obtained from New Zealand studies on dairy cows and ranged from approximately 0.92 to 1.04 grams CH_4/kg (Saggar et al, 2003; Sherlock et al, 2003).

Faecal material stored in anaerobic lagoons: Five per cent of faecal material arising from dairy cows is assumed to be stored in anaerobic lagoons. The current method assumes that all faeces deposited in lagoons are diluted with 90 litres of water per kilogram of dung dry matter (Heatley, 2001). This gives the total volume of effluent stored. Annual CH_4 emissions are estimated using the data of McGrath and Mason (2004). McGrath and Mason (2004) calculated specific emissions values of 0.33–6.21 kilograms CH_4/m^2/year from anaerobic lagoons in New Zealand. The mean value of 3.27 CH_4/m^2/year of this range is assumed in the New Zealand Tier 2 calculations.

Beef cattle, sheep and deer

Beef cattle, sheep and deer are not housed in New Zealand, and all faecal material is deposited directly onto pastures.

No specific studies have been conducted in New Zealand on CH_4 emissions from beef cattle faeces, and values obtained from dairy cattle studies (0.98 grams CH_4/kg) are used (Saggar et al, 2003; Sherlock et al, 2003).

The quantity of CH_4 produced per unit of sheep faecal dry matter is 0.69 grams CH_4/kg. This value is obtained from a New Zealand study on sheep and ranged from 0.340 to 1.288 over six sample periods (Carran et al, 2003).

There are no New Zealand studies on CH_4 emissions from deer manure, and values obtained from sheep and cattle are used. The quantity of CH_4 produced per unit of faecal dry matter is assumed to be 0.92 grams CH_4/kg. This value is the average value obtained from all New Zealand studies on sheep (Carran et al, 2003) and dairy cattle (Saggar et al, 2003; Sherlock et al, 2003).

Methane from other minor livestock categories

Goats and horses: New Zealand-specific emission factors are not available for CH_4 emissions from manure management for goats and horses. These are minor livestock categories in New Zealand, and IPCC 1996 default emission factors (goats 0.18 kilograms CH_4/head/year and horses 2.1 kilograms CH_4/head/year) are used to calculate emissions. All faecal material from goats and horses is deposited directly onto pastures.

Swine: New Zealand uses a country-specific emission factor of 5.94 Kg CH_4/head/ year (Hill, 2012) for estimating emissions from swine manure management. This is based on New Zealand-specific proportions of swine faeces in manure management systems.

Poultry: Methane emissions from poultry manure management use New Zealand-specific emission factor values. These are based on New Zealand-specific volatile solids and proportions of poultry faeces in each manure management system for each production category. The poultry population has been disaggregated into three different categories and the values for each are: broiler birds – 0.022 kilograms CH_4/head/year; layer hens – 0.016 Kg CH_4/head/year; and other – 0.117 kilograms CH_4/head/year. The value for other (turkeys, ducks and so on) is the IPCC default as further work is being carried out on this category. Until country-specific information is available for these categories the IPCC default value will continue to be used.

Alpaca: There is no IPCC default value available for CH_4 emissions from manure management for alpacas. Therefore, this was calculated by assuming a default CH_4 emission from manure management value for alpacas for all years that is equal to the per head value of the average sheep in 1990 (ie, total sheep emissions per total sheep population). The alpaca emission factor is not indexed to sheep over time because there is no data to support the kind of productivity increases that have been seen in sheep.

Nitrous oxide from cattle, sheep and deer

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

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

The N_{ex} values are calculated from the nitrogen intake less the nitrogen retained in animal products. Nitrogen intake is determined from feed intake and the nitrogen content of the feed. Feed intake and animal productivity values are the same as used in the Tier 2 model for determining DMI (Clark et al, 2003; section 6.1.1). The nitrogen content of feed is estimated from a review of over 6,000 pasture samples of dairy and sheep and beef systems (Ledgard et al, 2003).

The nitrogen content of product is derived from industry data. For lactating cattle, the nitrogen content of milk is derived from the protein content of milk (nitrogen

= protein/6.25) published annually by the Livestock Improvement Corporation. The nitrogen content of sheep meat and wool and beef, and the nitrogen retained in deer velvet, are taken from New Zealand-based research.

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

Table 6.3.3 N_{ex} values for New Zealand's main livestock classes from 1990 to 2010

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	13.2	66.9	104.1	24.9
1995	13.4	71.3	108.1	27.4
2000	15.3	75.9	113.0	28.8
2005	16.8	79.2	116.5	29.4
2006	15.8	80.8	115.7	29.5
2007	15.5	78.2	114.0	29.6
2008	15.9	79.3	113.1	29.7
2009	16.1	77.5	113.5	29.6
2010	15.7	77.1	116.5	28.2

Nitrous oxide from other minor livestock categories

Goats: New Zealand uses country-specific N_{ex} values rates for goats to estimate nitrous oxide emissions of 10.6 kilograms N/head/year for 1990 and 12.1 kilograms N/head/year for 2009 based on the differing population characteristics for those two years (Lassey, 2011). As explained in section 6.2.2, for enteric fermentation, for the intermediate years between 1990 and 2009 and for 2010, the excretion rate was interpolated based on assumptions that the dairy goat population has remained in a near constant state over time, while the rest of the goat population has declined.

Horses: New Zealand-specific N_{ex} values are not available for horses. Horses are in the minor livestock category in New Zealand, and the 1996 IPCC default emission factor (25.0 kilograms N/head/year) is used to calculate emissions (IPCC, 1996).

Swine: Nitrous oxide from manure management of swine is estimated using a New Zealand-specific N_{ex} value of 10.8 kilograms N/head/year (Hill, 2012) in 2010. This is based on the weighted average of the animal distribution of animal weights by swine subcategory. Estimates of N_{ex} for all other years are indexed to changes in average pig kill weights for each year.

Poultry: New Zealand-specific and IPCC default N_{ex} values are used for poultry (Fick et al, 2011). These are the country-specific values of 0.39 kilograms N/head/year for broiler birds and 0.42 kilograms N/head/year for layer hens. The default value of 0.60 kilograms N/head/year for ducks and turkeys is retained.

Alpaca: There is no IPCC default value available for N_{ex} for alpacas. Therefore, this was calculated by assuming a default N_{ex} value for alpacas for all years that is equal to the per-head value of the average sheep in 1990 (ie, total sheep emissions per total sheep population). The alpaca emission factor is not indexed to sheep over time because there is no data to support the kind of productivity increases that have been seen in sheep. Sheep were used rather than the IPCC default value for 'other animals' as the literature indicates that alpacas have a nitrogen intake close to that of sheep and no significant difference in the partitioning of nitrogen (Pinares-Patino et al, 2003). Therefore, using the much higher default value for 'other animals' would be overestimating the true N_{ex} value for alpacas.

6.3.3 Uncertainties and time-series consistency

Methane emissions

The major sources of uncertainty in CH_4 emissions from manure management are the accuracy of emission factors and manure management system distribution, and activity data that includes the livestock population (IPCC, 2000).

New Zealand does not currently have country-specific uncertainty values for methane from manure management. Also, the IPCC good practice guidelines do not list default uncertainty values for methane from manure management. Therefore, the IPCC 2006 guidelines default values have been used. The IPCC 2006 guidelines state that: "The uncertainty range for the default factors is estimated to be ± 30%. Improvements achieved by tier 2 methodologies are estimated to reduce uncertainty ranges in the emission factors to ± 20%".

Nitrous oxide emissions

The main factors causing uncertainty in N_2O emissions from manure management are the emission factors from manure and manure management systems, the livestock population, nitrogen excretion rates, and the use of the various manure management systems (IPCC, 2000).

New Zealand uses the IPCC default values for EF_3 (direct emissions from waste) for all animal waste systems except for $EF_{3(PR\&P)}$ (manure deposited on pasture, range and paddock). The current New Zealand-specific emission factor for $EF_{3(PR\&P)}$ is 0.01 kilograms N_2O-N/kg. Recent research has shown that the dung of cattle, sheep and deer produce much smaller amounts of nitrous oxide than urine. Therefore, a country-specific emission factor to be applied to the nitrogen contained in the dung from cattle, sheep and deer has been developed ($EF_{3(PR\&P\ DUNG)}$). For further details, see section 6.5.2. The IPCC default values have uncertainties of –50 per cent to +100 per cent (IPCC, 2000).

6.3.4 Source-specific QA/QC and verification

Methane from manure management was identified as a key category (level assessment) in 2010. In the preparation for this inventory submission, the data for this category underwent Tier 1 and Tier 2 quality checks.

Table 6.3.4 shows a comparison of the New Zealand-specific 2009 implied emission factor for CH_4 from manure management with the 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 1996 IPCC Oceania default and the United Kingdom. This is due to the much higher proportion of animals in New Zealand that are grazed on pastures and not housed, resulting in less manure being stored in a management system. This is also reflected in the Australian implied emission factor (table 6.3.4) as Australia also has a significant number of pasture-grazed livestock.

Differences between the implied emission factors and the IPCC default factors are also due to the reasons outlined in the enteric fermentation section, that is, productivity of the animals and the use of different algorithms to determine energy intake as well as values used for nitrogen content of feed and digestibility.

Table 6.3.4 Comparison of IPCC default emission factors and country-specific implied emission factors for 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 2009 value	8.87	0.04	0.00
United Kingdom-specific IEF 2009 value	26.88	4.15	0.11
New Zealand-specific 2009 value[33]	3.29	0.69	0.11

6.3.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2011), Livestock Improvement Corporation statistics (2011)).

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

As detailed in section 6.3.2, New Zealand has developed a country-specific value for N_{ex} from goats based on the differing population characteristics over the time series. This new emission factor changes slightly each year as it is based on the different proportions of dairy and other goats in the herd since 1990. Updated country-specific emission factors have been applied to every year since 1990 and, therefore, recalculations have been carried out on the entire time series.

Typical animal mass for swine, used in the estimation of N_{ex} values, was collected from New Zealand Pork. Country-specific values for methane production from manure management and N_{ex} have been determined for swine. These values have been applied to all years back to 1990 and, therefore, recalculations have been carried out for all years in the time series. The country-specific proportion for swine management systems has also been determined, affecting the proportion of swine faeces in each animal waste management system.

Data for poultry has been disaggregated into broilers (meat chickens), layers and all other poultry (ducks, turkeys, breeders, geese and so on) with country-specific emission factors being used for broilers and layers. Estimation and modelling of official bird population numbers for the entire time series has been improved, with better information on bird rotation in the production of broiler birds being incorporated. Updated activity data

33 As reported in New Zealand's Greenhouse Gas Inventory 1990–2009 (Ministry for the Environment, 2011).

and changes to the methodology have been applied to the entire time series and, therefore, recalculations have been carried out for all years from 1990. See section 6.1.1. for further details. The country-specific proportion for poultry management systems has also been determined, affecting the proportion of poultry manure in each animal waste management system.

6.3.6 Source-specific planned improvements

New Zealand scientists are investigating improvements to the population models and live animal weights used in the Tier 2 method. These improvements cover such variables as birth dates, death dates and rates, and will be incorporated in future submissions and may influence the amount of faeces produced by cattle, sheep and deer.

An improvement to the disaggregation of dairy effluent into manure management systems is being investigated by New Zealand scientists. Findings will be incorporated in future submissions.

While country-specific values have been determined for poultry broilers and layers, the current default values apply to all other poultry (turkeys, ducks and so on). Work is under way to obtain data to disaggregate poultry species further and to improve the representation of waste systems used in the poultry industry.

6.4 Rice cultivation (CRF 4C)

6.4.1 Description

Although it is possible to grow rice in New Zealand, it is uneconomical to do so. At present, no rice cultivation is being carried out in New Zealand. This has been confirmed with experts from Plant and Food Research, Lincoln, New Zealand. The 'NO' notation is reported in the common reporting format tables.

6.5 Agricultural soils (CRF 4D)

6.5.1 Description

In 2010, the agricultural soils category contributed 9,905.2 Gg CO_2-e (13.9 per cent) to New Zealand's total emissions and 94.7 per cent to total N_2O emissions. Emissions were 2,013.9 Gg CO_2-e (25.5 per cent) above the 1990 level of 7,891.3 Gg CO_2-e. The subcategories are:

- Direct N_2O emissions from agricultural soils as a result of adding nitrogen in the form of synthetic fertilisers, animal waste, biological fixation in crops, inputs from crop residues and cultivation of organic soils. Direct N_2O soil emissions contributed 1,734.7 Gg CO_2-e (17.5 per cent) to emissions from the agricultural soils category in 2010. This was an increase of 1,285.5 Gg CO_2-e (286.2 per cent) from the 1990 level of 449.2 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 nitrate (NO_3), ammonia (NH_3) or nitrogen oxides (NO_x) through volitastation and leaching. In 2010, indirect N_2O emissions from nitrogen used in agriculture contributed 2,520.9 Gg CO_2-e (25.5 per cent) to emissions from the agricultural soils category. This was an increase of 464.4 Gg CO_2-e (22.6 per cent) from the 1990 level of 2,056.6 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). In 2010, N_2O emissions from animal production contributed 5,649.6 Gg CO_2-e (57.0 per cent) to emissions from the agricultural soils category. This is an increase of 264.1 Gg CO_2-e (4.9 per cent) from the 1990 level of 5,385.5 Gg CO_2-e. Direct N_2O emissions from animal production were identified as a key category (trend and level assessment).

Key categories identified in the 2010 level assessment from the agricultural soils category include N_2O emissions from:

- pasture range and paddock
- indirect emissions
- direct emissions.

Key categories identified in the 2010 trend assessment from the agricultural soils category include N_2O emissions from:

- pasture, range and paddock
- direct emissions.

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

6.5.2 Methodological issues

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

Six New Zealand-specific emission factors and parameters are used in the inventory: EF_1, $EF_{3(PR\&P\ DUNG)}$, $EF_{3(PR\&P)}$, $Frac_{LEACH}$, $Frac_{GASM}$ and $Frac_{GASF}$. The use of a country-specific emission factor for EF_1 (direct emissions from nitrogen input to soil) of 1 per cent is based on work by Kelliher and de Klein (2006). The country-specific $EF_{3(PR\&P)}$ emission factor of 1 per cent and $Frac_{LEACH}$ of 0.07 are based on extensively reviewed literature and field studies (Carran et al, 1995; de Klein et al, 2003; Muller et al, 1995; Thomas et al, 2005). Recently, extensive research has shown that nitrous oxide emissions from dung are substantially lower than nitrous oxide emissions from urine. Therefore, separate emission factors are now allocated to dung and urine for cattle, sheep and deer; $EF_{3(PR\&P)}$ (0.01) for urine from cattle, sheep and deer and manure for all other species and $EF_{3(PR\&P\ DUNG)}$ (0.0025) for dung from cattle, sheep and deer. Further details of this split can be found under the animal production section. A value of 0.1 has been adopted for the emission factor $Frac_{GASM}$ after an extensive review of scientific literature (Sherlock et al, 2009). The 1996 IPCC default value of 0.1 for $Frac_{GASF}$ has been verified as appropriate to New Zealand after an extensive review of the scientific literature (Sherlock et al, 2009) and has therefore been adopted as a country-specific emission factor. Details of recalculations can be found in section 6.5.5 and chapter 10.

The emission factors and other parameters used in this category are documented in annex 3.1. The calculations are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate).

Direct N_2O emissions from agricultural soils

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

Where N_{ex} values and allocation to animal waste management systems are used, these are the same as are discussed in section 6.3. The N_{ex} values have been calculated based on the same animal intake and animal productivity values used for calculating CH_4 emissions for the different animal classes and species in the Tier 2 model (section 6.1.1). This ensures the same base DMI values are used for both the CH_4 and N_2O emission calculations. Further details can be found in the inventory methodology document on the Ministry of Agriculture and Forestry website (www.maf.govt.nz).

Synthetic nitrogen fertiliser

Anthropogenic N_2O emissions from nitrogen containing fertiliser are a relatively small proportion of total N_2O emissions, although still significant. The majority of synthetic nitrogen fertiliser used in New Zealand is urea applied to dairy pasture land to boost pasture growth during autumn and spring months.

Data on nitrogen fertiliser use is provided by the New Zealand Fertiliser Manufacturers' Research Association from sales records for 1990 to 2010. There has been an almost six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2010 time series, from 59,265 tonnes in 1990 to 332,981 tonnes in 2010, which has resulted in an increase of direct N_2O emissions from 259.8 Gg CO_2-e in 1990 (0.8 per cent of agricultural emissions) to 1,459.9 Gg CO_2-e (4.3 per cent of agricultural emissions) in 2010.

In accordance with IPCC good practice guidance (IPCC, 2000), the following equations are used to determine direct N_2O emissions from the application of nitrogen fertiliser.

$$F_{SN} = N_{fert} \times (1\text{-}Frac_{gasf})$$

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

Where:

F_{SN} = annual amount of synthetic fertiliser nitrogen applied to soils after adjusting for the amount that volatilises

N_{fert} = amount of nitrogen fertiliser applied to soils

$Frac_{gasf}$ = fraction of total synthetic fertiliser emitted as NO_x or NH_3

EF_1 = proportion of direct emissions from nitrogen input to the soil.

Animal waste

The majority of animal waste in New Zealand is excreted directly onto pasture, 95 per cent of dairy and 100 per cent of sheep, beef and deer. However, some manure is kept in waste systems and is then applied to soils at a later date as an organic fertiliser. Some manure is also collected but not stored, rather it is spread onto pasture daily (eg, swine). The calculation for animal waste includes all manure that is spread on agricultural soils, irrespective of the animal waste management system it was initially stored in. This includes all agricultural waste in New Zealand except for emissions from the pasture, range and paddock animal waste management system. Because the majority of animal manure is excreted directly onto pasture, the animal waste subcategory is relatively small. However, it has almost doubled since 1990 due to the increase in the dairy population numbers. In 1990, animal waste levels were 108.9 Gg CO_2-e (0.4 per cent of agricultural emissions) and, in 2010, this had increased to 190.3 Gg CO_2-e (0.6 per cent of agricultural emissions).

In accordance with IPCC good practice guidance (IPCC, 2000), the following equations are used to determine direct N_2O emissions from the application of animal waste to soil.

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

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

Where:

F_{AW} = the total amount of animal manure nitrogen applied to soils from waste management systems (other than pasture range and paddock) after adjusting for the amount which volatilises during storage

N_{AW} = the amount of animal manure nitrogen in each waste management system, other than pasture range and paddock, for all species

= $N_{ex} \times MS$

Where: N_{ex} = nitrogen excreted for each species

MS = fraction of N in each management system except pasture range and paddock for each species

$Frac_{GASM}$ = fraction of total animal manure emitted as NO_x or NH_3

EF_1 = proportion of direct emissions from N input to soil.

Nitrogen fixing crops

The tonnage of nitrogen fixing crops grown in New Zealand is supplied by Statistics New Zealand from its Agricultural Production Survey. It is made up of peas grown for both processing and seed markets as well as lentil production and legume seeds grown for pasture production. Emissions from this subcategory make up a very small amount of New Zealand's agricultural emission and, in 2010, N_2O emission from this subcategory totalled 5.3 Gg CO_2-e (0.02 per cent of agricultural emissions), which is a decrease from the 1990 value of 7.2 Gg CO_2-e (0.02 per cent of agricultural emissions). This is mainly due to a decrease in pea and lentil production in New Zealand. A country-specific methodology is used to calculate emissions from this section as detailed below. This new approach uses harvest index values, root to shoot ratios and nitrogen contents of above- and below-ground residues compiled and used in the OVERSEER® nutrient budget model for New Zealand (Wheeler et al, 2003). The OVERSEER® model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems. OVERSEER® is a source of scientific consensus where nutrient factors are estimated, reviewed and generally agreed among New Zealand experts.

$TRG_N = AG_N + BG_N$

$AG_N = dmf \times (CropT/HI - CropT) \times (1 - Frac_{BURN} - Frac_R) \times N_{AG}$

$BG_N = dmf \times (CropT/HI) \times N_{BG} \times RatioBG$

$N_2O_{direct\ N\ fix}\text{-}N = TRG_N \times EF_1$

Where:

TRG_N = Total Ground Nitrogen (above and below ground residue)

AG_N = amount of above-ground nitrogen returned to soils annually through incorporation of crop residues

BG_N = amount of below-ground nitrogen returned to soils annually through incorporation of crop residues

dmf = dry-matter factor

CropT = annual crop production of crops

HI = Harvest Index

$Frac_{BURN}$ = fraction of above-ground biomass that is burned

$Frac_R$ = fraction of above-ground biomass that is removed from the field as product

N_{AG} = above ground N fraction

N_{BG} = below ground N fraction

RatioBG = Root Shoot Ratio

EF_1 = proportion of direct emissions from N input to soil.

Crop-specific factors are provided in annex 3.1.

Nitrous oxide from crop residue returned to soil

Crop residues are made up from both nitrogen-fixing and non-nitrogen-fixing crops. The non-nitrogen-fixing crops in New Zealand include crops such as barley, wheat, maize, oats, onions, squash, potato and some seed crops. The tonnage of these crops is supplied by Statistics New Zealand from its Agricultural Production Survey. Additional information on seed crops is provided by AsureQuality which certifies seeds in New Zealand. Although there has been a decline in oat crops in New Zealand since 1990, there has been an increase in maize and wheat, resulting in an overall slight increase in emissions from crop residue since 1990. However, the contribution of crop residues to the overall agricultural emissions is very small, with 41.9 Gg CO_2-e (0.1 per cent of agricultural emissions) in 1990 and, in 2010, 48.0 Gg CO_2-e (0.1 per cent of agricultural emissions).

For the 2012 submission, New Zealand has introduced emissions from additional cropping activity not previously estimated (such as onions, squash and sweet corn) and has implemented a country-specific approach to calculate N_2O emissions from crop residue. This methodology is the same as that detailed above under nitrogen-fixing crops. However, nitrous oxide nitrogen from crop residue is determined rather than nitrous oxide nitrogen from nitrogen-fixing crops.

$N_2O_{direct\ crop\ residue}\text{-}N = TRG_N \times EF_1$

Cultivation of histols

Direct N_2O emissions from organic soils are calculated by multiplying the area of cultivated organic soils by an emission factor (EF_2). The area of 'organic agricultural soils' cultivated in New Zealand is 160,385 hectares (Dresser et al, 2011). This area includes the proportion of organic agricultural soil as reported within the LULUCF sector that has been cultivated (135,718 hectares) and the area of mineral agricultural soils with a peaty layer that are cultivated (24,667 hectares).

Mineral soils with a peaty layer are included in the definition of organic soils under the agriculture section as it was determined that these soils will have similar emissions behaviour to that of organic soils. Therefore, for the agriculture sector, mineral soils with a peaty layer should be included with organic soils when estimating nitrous oxide emission from cultivation of organic soils (Dresser et al, 2011).

The full definition used in the agriculture section for organic soils (plus mineral soils with a peaty layer) is:

- 17 per cent organic matter content (includes slightly peaty, peaty and peat soils of 17–30 per cent, 30–50 per cent and greater than 50 per cent organic matter content)
- 0.1 metres of this depth occurring within 0.3 metres of the surface.

Dresser et al (2011) determined that the current assumption that 5 per cent of organic soils (plus mineral soils with a peaty layer) under agricultural pasture is cultivated on an annual bases (Kelliher et al, 2002) should be retained until further information has been gathered. This results in 8,019 hectares of 'organic agricultural soils' being cultivated annually.

New Zealand uses the IPCC default emission factor (EF_2 equal to 8 kilograms N_2O-N/kg N) and Tier 1 methodology for all years of the time series. The contribution of organic soils (plus mineral soils with a peaty layer) to the overall agricultural emissions is relatively small, with 31.3 Gg CO_2-e (0.1 per cent of agricultural emissions) in 1990 and, in 2010, 31.3 Gg CO_2-e (0.1 per cent of agricultural emissions).

Animal production (N_2O)

Direct soil emissions from animal production refers to the N_2O produced from the pasture, range and paddock animal waste management system. This system is the predominant regime for animal waste in New Zealand as 95 per cent of dairy cattle excreta and 100 per cent of sheep, deer and non-dairy cattle excreta are allocated to it (table 6.3.1).

The emissions calculation is based on the livestock population multiplied by nitrogen excretion (N_{ex}) values and the percentage of the population on the pasture, range and paddock animal waste management system. The N_{ex} values and allocation to animal waste management systems are discussed in section 6.3. The N_{ex} values have been calculated based on the same animal intake and animal productivity values used for calculating CH_4 emissions for the different animal classes and species in the Tier 2 model. This ensures the same base values are used for both the CH_4 and N_2O emission calculations. Further details can be found in the inventory methodology document (http://www.maf.govt.nz/agriculture/statistics-forecasting/greenhouse-gas.aspx). In accordance with IPCC good practice guidance (IPCC, 2000), the following equation are used to determine direct N_2O emissions from animal production.

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

Where: N = population

N_{ex} = nitrogen excreted by each species (these values are the same as used in section 6.3)

MS = proportion of manure excreted directly onto pasture (table 6.3.2)

$EF_{3(PR\&P)}$ = emission factor for direct emissions from waste in the pasture range and paddock animal waste management system (ie, manure deposited directly onto pasture during grazing).

New Zealand uses a country-specific emission factor for $EF_{3(PR\&P)}$ of 0.01 (Carran et al, 1995; Muller et al, 1995; de Klein et al, 2003; Kelliher et al, 2003) for the urine of cattle, sheep and deer and the manure from all other livestock classes. For the dung of cattle, sheep and deer, a new country-specific emission factor for $EF_{3(PR\&P\ DUNG)}$ of 0.0025 has been implemented.

Considerable research effort has gone into establishing a New Zealand-specific emission factor for $EF_{3(PR\&P)}$. Field studies have been performed as part of a collaborative research effort called NzOnet. The $EF_{3(PR\&P)}$ parameter has been measured by NzOnet researchers in the Waikato (Hamilton), Manawatu (Palmerston North), Canterbury (Lincoln) and Otago (Invermay) regions for pastoral soils of different drainage classes (de Klein et al, 2003). This regional data is comparable because the same measurement methods were used at the four locations. The percentage of applied nitrogen emitted as N_2O, and relevant environmental variables, were measured in four separate trials in autumn 2000, summer 2002, spring 2002 and winter 2003. Measurements were carried out for up to 250 days at each trial site or until urine-treated pasture measurements dropped back to background emission levels.

Kelliher et al (2003, 2005), assessed all available $EF_{3(PR\&P)}$ data and its distribution to pastoral soil drainage class, to determine an appropriate national annual mean value. The complete $EF_{3(PR\&P)}$ data set of NzOnet was synthesised using the national assessment of three pastoral soil drainage classes. These studies recognise that:

- environmental (climate) data is not used to estimate N_2O emissions using the methodology in the revised 1996 IPCC guidelines (IPCC, 1996)
- the N_2O emission rate can be strongly governed by soil water content
- soil water content depends on drainage that can moderate the effects of rainfall and drought
- drainage classes of pastoral soils, as a surrogate for soil water content, can be assessed nationally using a geographic information system.

An earlier analysis in New Zealand showed that the distribution of drainage classes for pasture land is highly skewed, with 74 per cent well drained, 17 per cent imperfectly drained and 9 per cent poorly drained (Sherlock et al, 2001).

As with the $EF_{3(PR\&P)}$ parameter, considerable research effort has gone into establishing a New Zealand-specific value for dung. This included field studies ranging over eight years being performed in Waikato, Southern Hawke's Bay, Manawatu, Canterbury and Otago regions on free and poorly drained soils in the spring, summer, autumn and winter. These field studies used methodologies developed during the research into the original New Zealand-specific parameter for $EF_{3(PR\&P)}$.

Luo et al (2009) assessed all available $EF_{3(PR\&P\ DUNG)}$ data and its distribution to the pastoral soil drainage class, and carried out a further trial to confirm data during the spring, to determine an appropriate national annual mean value. This review found that:

- results confirm a disaggregation of $EF_{3(PR\&P)}$ between dung and urine is warranted
- EF_3 decreases as follows: cow urine > cow or cattle dung > sheep dung
- however, when seasonal data was pooled, there was no significant difference between cattle and sheep dung.

It was recommended that the N_2O emission factor for urine remain at the country-specific value of 1 per cent and the N_2O emission factor for cattle and sheep dung be reduced to one quarter of a per cent.

Incorporation of the mitigation technology DCD into the agricultural inventory

A methodology to incorporate an N_2O mitigation technology, the nitrification inhibitor dicyandiamide (DCD), into the agricultural sector of the inventory has been developed. A detailed description of the methodology can be found in Clough et al (2008). The N_2O emissions reported in the agricultural soils category for 2010 take into account the use of nitrification inhibitors on dairy farms using the methodology described in Clough et al (2008). For the 2010 calendar year, DCD mitigated 16.3 Gg CO_2-e, a 0.05 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 grazed pastures.

The DCD product is applied to pastures based on research that has identified good management practice to maximise N_2O emission reductions. This is at a rate of 10 kilograms per hectare of DCD, applied twice per year in autumn and early spring within seven days of the application of excreta or fertiliser nitrogen. 'Good practice' application methods of DCD can be by slurry or granule.

Changes to the emission factors $EF_{3PR\&P}$, EF_1 and parameter $Frac_{LEACH}$ were established for use with DCD application. These emission factors and parameters were modified based on comprehensive field-based research that showed significant reductions in direct and indirect N_2O emissions and nitrate leaching where DCD was applied.

The peer-reviewed literature on DCD use in grazed pasture systems was 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. There has been some research into the effect of DCD on $EF_{3(PR\&P\ DUNG)}$, however, this data is limited and further work needs to be assessed before incorporating this research into the New Zealand inventory.

The reductions in the emission factors and parameters are used along with the fraction of dairy land treated with DCD to calculate DCD weighting factors.

$$DCD\ weighting\ factor = (1 - \frac{\%\ reduction\ in\ EF_x}{100} \times \frac{DCD\ treated\ area}{Effective\ dairy\ area})$$

The appropriate weighting factor is then used as an additional multiplier in the current methodology for calculating indirect and direct emissions of N_2O from grazed pastures. The calculations use a modified $EF_{3(PR\&P)}$ of 0.0099 and $Frac_{LEACH}$ of 0.0697 for dairy grazing area in the months that DCD is applied (May to September). The modified emission factors are based on information from the Agricultural Production Survey that 2.2 per cent of the effective dairying area in New Zealand received DCD in 2010.

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	2.2	0.0099
$Frac_{LEACH}$	0.07	53	2.2	0.0697

All other emission factors and parameters relating to animal excreta and fertiliser use ($Frac_{GASM}$, $Frac_{GASF}$, EF_4 and EF_5) remain unchanged when DCD is used as an N_2O mitigation technology. DCD was found to have no effect on ammonia volatilisation during May to September when DCD is applied. This is supported by the results of field studies (Clough et al, 2008; Sherlock et al, 2009).

The derivations of the modified emission factors and the resulting calculations are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate).

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

Indirect N_2O from nitrogen used in agriculture

Nitrous oxide is emitted indirectly from nitrogen lost from agricultural soils through leaching and run-off. This nitrogen enters water systems and eventually reaches the sea, with N_2O being emitted along the way. The amount of nitrogen that leaches is a fraction ($Frac_{LEACH}$) of that deposited or spread on land.

Research studies and a literature review in New Zealand have shown lower rates of nitrogen leaching than are suggested in the revised 1996 IPCC guidelines (IPCC, 1996). A New Zealand parameter for $Frac_{LEACH}$ of 0.15 was used in inventories submitted before 2003. However, using a $Frac_{LEACH}$ of 0.15, IPCC-based estimates for different farm systems were found on average to be 50 per cent higher than those estimated using the OVERSEER® nutrient-budgeting model (Wheeler et al, 2003). The OVERSEER® model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems. In pastoral systems, nitrogen leaching is determined by the amount of nitrogen applied in fertiliser, in dairy farm effluent and that excreted in urine and dung by grazing animals. The latter is calculated from the difference between nitrogen intake by grazing animals and nitrogen output in animal products, based on user inputs of stocking rate or production and an internal database with information on the nitrogen content of pasture and animal products and calibrated against field measurements.

The IPCC estimates were closer for farms using high rates of nitrogen fertiliser, indicating that the IPCC-based estimates for nitrogen leaching associated with animal excreta were too high for New Zealand. When the IPCC method was applied to field sites where nitrogen leaching was measured (four large scale, multi-year animal grazing trials), it resulted in values that were double the measured values. This indicated that a value of 0.07 for $Frac_{LEACH}$ more closely followed actual field leaching in New Zealand (Thomas et al, 2005). The 0.07 value has been adopted and is used for all years as it best reflects New Zealand's national circumstances. In 2010, nitrous oxide emissions from leaching made up 4.8 per cent (1,603.3 Gg CO_2-e) of agricultural emissions, an increase of 22.5 per cent from the 1990 value of 1,308.7 Gg CO_2-e.

Some of the nitrogen contained in animal excreta and fertiliser deposited or spread on land is emitted into the atmosphere as NH_3 and NO_x through volatilisation. A fraction of this returns to the ground during rainfall and is then re-emitted as N_2O. This is calculated as an indirect emission of N_2O. The fraction of nitrogen that is deposited or spread on land that then indirectly becomes 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 their reported $Frac_{GASM}$ inventory values, whereas in New Zealand, 97 per cent of all livestock urine and dung is deposited directly on soils during grazing. Excluding studies on nitrification inhibitors, eight international papers covering 45 individual measurements and nine New Zealand papers covering 19 individual measurements were reported on. The authors recommended a value of 0.1 for $Frac_{GASM}$ was more appropriate for New Zealand conditions (Sherlock et al, 2009). The 0.1 value has been adopted and is used for all years as it best reflects New Zealand's national circumstances.

Seventeen peer reviewed papers covering 79 individual measurements have also been reviewed for $Frac_{GASF}$. Taking into account that approximately 80 per cent of nitrogen fertiliser used in New Zealand is urea with the remaining being diammonium phosphate (DAP), a value of 0.096 for $Frac_{GASF}$ was determined (Sherlock et al, 2009). As this is almost identical to the IPCC default value of 0.1 currently used, 0.1 has been adopted as a country-specific value for $Frac_{GASF}$.

New Zealand uses the IPCC default EF_4 emission factor for indirect emissions from volatilisation of nitrogen in the form of NH_3 and oxides of NO_x. In 2010, nitrous oxide emissions from volatilisation made up 2.7 per cent (917.6 Gg CO_2-e) of agricultural emissions, an increase of 22.7 per cent from the 1990 value of 747.8 Gg CO_2-e.

6.5.3 Uncertainties and time-series consistency

Uncertainties in N_2O emissions from agricultural soils were assessed for the 1990 and 2002 inventory using a Monte Carlo simulation of 5,000 scenarios with the @RISK software (Kelliher et al, 2003) (table 6.5.2). The emissions' distributions are strongly skewed, reflecting pastoral soil drainage whereby 74 per cent of soils are classified as well drained and 9 per cent are classified as poorly drained. For the 2010 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 2010 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2010)

Year	N_2O emissions from agricultural soils (Gg/annum)	95% confidence interval minimum (Gg/annum)	95% confidence interval maximum (Gg/annum)
1990	25.5	14.8	44.3
2002	32.2	18.7	56.1
2010	32.0	18.5	55.6

The overall inventory uncertainty analysis shown in annex 7 demonstrates that the uncertainty in annual emissions from agricultural soils is a major contributor to uncertainty in the total estimate and to the uncertainty in the trend from 1990. The uncertainty between years was assumed to be correlated. Therefore, the uncertainty is mostly in the emission factors and the uncertainty in the trend is much lower than the uncertainty for an annual estimate.

The Monte Carlo numerical assessment is also used to determine the effects of variability in the nine most influential parameters on uncertainty of the calculated N_2O emissions in 1990 and 2002. These parameters are shown in table 6.5.3, together with their percentage contributions to the uncertainty. There was no recalculation of the influence of parameters for the 2010 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 preparation for the 2012 inventory submission, the data for the direct soil, pasture range and paddock manure, and indirect emissions categories underwent Tier 1 and Tier 2 quality checks.

In 2008 and 2011, the Ministry of Agriculture and Forestry commissioned a report investigating nitrous oxide emission factors and activity data for crops (Thomas et al, 2008; Curtin et al, 2011). Statistics New Zealand's Agricultural Production Survey activity data for wheat and maize was verified with the Foundation for Arable Research production database between 1995 and 2007. Data for wheat and maize between the two data sources was very similar.

Fertiliser sales data received from the New Zealand Fertiliser Manufacturers' Research Association was verified with data collected from the Agricultural Production Survey from Statistics New Zealand for year end June 2009. Data from the New Zealand Fertiliser Manufacturers' Research Association was year end May. The Agricultural Production Survey data for fertiliser use in New Zealand was 95,000 tonnes lower (approximately 29 per cent) compared with the fertiliser sales value supplied by the New Zealand Fertiliser Manufacturers' Research Association. The New Zealand Fertiliser Manufacturers' Research Association data is used rather than the Agricultural Production Survey data as 95 per cent of New Zealand nitrogen fertiliser is provided by two large companies. Therefore, this information will be more accurate than the errors associated with a survey of some 35,000 farmers. There are a large number of differently named nitrogen fertilisers, and the Agricultural Production Survey respondents often have difficulty filling in the fertiliser question in the annual questionnaire.

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

Table 6.5.4 compares the New Zealand-specific values for EF_1, $EF_{3PR\&P}$ and $EF_{3(PR\&P\ DUNG)}$ with the 1996 IPCC default value and emission factors used by Australia and the United Kingdom, where available. For EF_1 and $EF_{3PR\&P}$ the New Zealand value is lower than the IPCC default value. This is due to the large proportion of well-drained soils within New Zealand as well as the type of soils as indicated in table A-1 of the revised 1996 IPCC guidelines (IPCC, 1996). Although there is no IPCC default value or United Kingdom value for $EF_{3(PR\&P\ DUNG)}$, Australia applies a country-specific value. Although slightly higher than the New Zealand value it is of similar magnitude. Table A-1 (IPCC, 1996) demonstrates that New Zealand silt loams have significantly less nitrous oxide emissions from dung and urine deposits than other countries and soil types.

Table 6.5.4 Comparison of IPCC default emission factors and country-specific implied emission factors for EF_1 and $EF_{3PR\&P}$

	EF_1 (kg N_2O-N/kg N)	$EF_{3PR\&P}$ (kg N_2O-N/kg N excreted)	$EF_{3(PR\&P\ DUNG)}$ (kg N_2O-N/kg N excreted)
IPCC (2006) developed temperate climate/Oceania default value	0.0125	0.02	NA
Australian-specific IEF 2009 value	0.0125 (except animal manure and fertiliser = 0.006)	0.004	NA
United Kingdom-specific IEF 2009 value	0.0125	0.02	NA
New Zealand-specific 2009 value	0.01	0.01	0.0025

Note: IEF = implied emission factor

Table 6.5.5 compares the New Zealand-specific values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$ with the 1996 IPCC default and fractions used by Australia and the United Kingdom. Details on these three fractions can be found in more detail in section 6.5.2. Although

New Zealand has taken a country-specific value for $Frac_{GASF}$ of 0.1, it is the same as the IPCC default and that of Australia and the United Kingdom. Research showed that the 0.1 value was appropriate to New Zealand conditions.

However, research showed that the default value of 0.2 for $Frac_{GASM}$ was too high and therefore New Zealand has adopted a lesser value of 0.1. The reduction is due to the proportion of the different sources that make up this value. In New Zealand, 97 per cent of animal excreta is deposited onto pasture and only 3 per cent is managed. Whereas the 1996 IPCC default value was calculated taking into account a much higher percentage of manure management and storage. Manure management and storage results in a much higher proportion of nitrogen being volatised and hence the higher $Frac_{GASM}$ for the default value compared with the country-specific New Zealand value (Sherlock et al, 2009).

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

Table 6.5.5 Comparison of IPCC default emission factors and country-specific implied emission factors for $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$

	$Frac_{GASF}$ (kg NH_3-N and NO_x-N/kg of N input)	$Frac_{GASM}$ (kg NH_3-N and NO_x-N/kg of N excreted)	$Frac_{LEACH}$ (kg N/kg fertiliser or manure N)
IPCC (1996) developed temperate climate/Oceania default value	0.1	0.2	0.3
Australian-specific IEF 2009 value	0.1	0.0	0.3
United Kingdom-specific IEF 2009 value	0.1	0.20	0.3
New Zealand-specific 2009 value	0.1	0.1	0.07

6.5.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database (2011) and Livestock Improvement Corporation statistics (2011)).

Country-specific values for N_{ex} have been determined for goats, swine and poultry. Country-specific proportions of animal waste from swine and goats have also been determined. Further details can be found in section 6.3.2. Both of these changes affect the amount of nitrogen in each animal waste management system and, therefore, affect the estimated emissions from the animal waste section. Country-specific values have been applied to all years back to 1990 and, therefore, recalculations have been carried out for all years in the time series.

A country-specific methodology has been implemented for the estimation of nitrous oxide emissions from nitrogen-fixing crops. The new methodology uses country-specific emissions factors for nitrogen and carbon content of crop biomass and is elaborated in section 6.5.2. This methodology has been applied to the entire time series and, therefore, recalculations of emissions from nitrogen-fixing crops have been carried out for all years from 1990 to 2009.

New crops have been included in the New Zealand inventory for 1990 to 2010. These, along with the incorporation of a country-specific methodology to calculate nitrogen inputs to agricultural soils from crop residues, have been incorporated into the entire time series. The new methodology uses country-specific emissions factors for nitrogen and carbon content of crop biomass and is elaborated in section 6.5.2.

The methodology used to estimate the area of organic soils under agriculture that is cultivated has been improved. The revised methodology and subsequent area has been applied to all years in the time series and, therefore, recalculations have been carried out for all years from 1990 to 2009. Further details on the revised area are elaborated on in section 6.5.2.

Enhancements, described in 6.2.5 to New Zealand's Tier 2 inventory model have resulted in recalculations of nitrogen inputs from dairy cattle, non-dairy cattle, sheep and deer.

As detailed in 6.3.2, New Zealand has developed country-specific values for N_{ex} for goats, swine and poultry. Country-specific proportions of animal waste from swine and goats have also been determined. Further details can be found in section 6.3.2. Estimation and modelling of official bird population numbers for the entire time series have also been improved, with better information on bird rotation in the production of broiler birds being incorporated. See section 6.1.1. All of these changes affect the amount of nitrogen in each animal waste management system and, therefore, affect the estimated emissions from the animal production section. Country-specific values have been applied to all years back to 1990 and, therefore, recalculations have been carried out for all years in the time series.

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 DCD nitrification inhibitors.

Enhancements to the New Zealand Tier 2 inventory model that will improve usability are currently in progress. These enhancements will also permit the use of regional DCD data as activity data allow, as well as the use of regional emission factors as they are developed. The use of regional activity data and emission factors will improve the accuracy of emissions estimations.

Forage brassicas have been identified as an important crop in New Zealand but activity data is currently inadequate to be able to carry out emission calculations. 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 nitrogen fertiliser data from the Fertiliser Manufacturers' Research Association.

Further Monte Carlo simulations on the uncertainties in N_2O emissions from agricultural soils are planned for future submissions.

Research into another emissions mitigation technology, Urease inhibitors, and the influence it has on ammonia emissions, is currently being carried out. Results will be incorporated in future submissions.

6.6 Prescribed burning of savanna (CRF 4E)

6.6.1 Description

In 2010, 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 2010, prescribed burning emissions accounted for 8.8 Gg CO_2-e, a 21.5 Gg CO_2-e (71.0 per cent) reduction in emissions from the 30.3 Gg CO_2-e reported in 1990.

The revised 1996 IPCC guidelines (IPCC, 1996) state that, in agricultural burning, the CO_2 released is not considered to be a net emission as the biomass burned is generally replaced by regrowth over the subsequent year. Therefore, the long-term net emissions of CO_2 are considered to be zero. However, the by-products of incomplete combustion (CH_4, CO, N_2O and NO_x) are net transfers from the biosphere to the atmosphere.

6.6.2 Methodological issues

New Zealand has adopted a modified version of the IPCC methodology (IPCC, 1996). The same equations are used to calculate emissions as detailed in the revised 1996 IPCC guidelines.

However, instead of using total grassland and a fraction burnt, New Zealand uses statistics of the total area of tussock grassland that has been burnt. Expert opinion concludes that, from 1990 to 2004, information on land that has been granted consent (a legal right) for burning, under New Zealand's Resource Management Act 1991, provides the best option for estimating tussock burning (Curtin et al, 2011). However, from 2003, this data has become less reliable as burning has become permitted in some regions. Since 2005, however, Statistics New Zealand has started to collect data on tussock grassland burning, and it is therefore recommended that this data be used from 2005 (Curtin et al, 2011).

Curtin et al (2011) reviewed the methodology and activity data to estimate emissions from tussock burning in New Zealand and recommended changes to the emission factors and the activity data. Analysis of the data showed that the original assumption that only 20 per cent of consented area is burned is likely to be underestimating actual burning. The consents last for five years. Therefore, the burning may not actually occur in the year of the burn, and the consenting data does not include illegal burns and accidents. Comparing data from Statistics New Zealand on tussock burning with data on all land consented for burning indicates that the total area consented provides a more accurate estimate and improves the consistency of activity data over the time series.

Current practice in New Zealand is to burn in damp spring conditions, reducing the amount of biomass consumed in the fire. Most of the composition and burning ratios used in calculations are from New Zealand-specific research and have been updated (Payton and Pearce, 2009). Curtin et al (2011) also recommended small modifications to the methodology incorporating new variables from this updated research. The variables carbon content of live biomass and carbon content of dead biomass have been replaced by one variable – Ratio of carbon loss to above-ground biomass loss. The fractions of live and dead material have been combined into one value and only one equation is now required to determine the carbon released from live and dead biomass. One value for the fraction of live and dead material oxidised is now only required.

The following equations are used to estimate the total amount of carbon released during the burning of tussock land in New Zealand. Table 6.6.1 details the emission factors used.

Biomass burned (Gg dam) = area of tussock burned annually × above-ground biomass density (t dm/ha) × fraction actually burned/1000

C released biomass (Gg C) = biomass burned (t dm) × Ratio of C loss to above-ground biomass × fraction that is live and dead biomass × fraction oxidised

Total carbon released is then used to estimate CH_4, CO, N_2O and NO_x emissions.

N_2O emissions (Gg N_2O) = C released biomass (Gg C) × Ratio of N:C loss × N_2O emissions factor × 44/28

NO_x emissions = total C released × C released biomass (Gg C) × Ratio of N:C loss × NO_x emission factor × 46/14

CH_4 emissions = total C released × CH_4 emission factor × 16/12

CO emissions = total C released × CO emission factor × 28/12

Table 6.6.1 Emission factors used to estimate emissions from tussock burning in New Zealand

Description	Factor	Source
Tussock above-ground biomass density	28	Payton and Pearce, 2001
Biomass fraction burned (fraction actually burned)	0.356	Payton and Pearce, 2009
Ratio of C loss to above-ground biomass	0.45	Payton and Pearce, 2009
Fraction that is live and dead biomass	1	Curtin et al, 2011
Fraction oxidised	1	Curtin et al, 2011
Ratio of N:C loss	0.45	Payton and Pearce, 2009
CH_4 emission factor	0.005	Revised IPCC 1996 guidelines
CO emission factor	0.06	Revised IPCC 1996 guidelines
N_2O emission factor	0.07	Revised IPCC 1996 guidelines
NO_x emission factor	0.121	Revised IPCC 1996 guidelines

Source: Payton and Pearce, 2009; Payton and Pearce, 2001; and IPCC, 1996 – all cited in Curtin et al. 2011.

6.6.3 Uncertainties and time-series consistency

The same emission factors were used for the whole time series. However, the source of the area of tussock land burned changes in 2005. Analysis between the two sources does, however, indicate that they are comparable around the time of the change over. The major sources of uncertainty are the extrapolation of biomass data from two study sites for all areas of tussock and the change in activity data sources. Uncertainty in the New Zealand biomass data has been quantified at ±6 per cent (Payton and Pearce, 2001). However, many IPCC parameters vary by ±50 per cent and some parameters do not have uncertainty estimates.

6.6.4 Source-specific QA/QC and verification

Data on consented area of tussock burning has been compared against data from Statistics New Zealand for tussock burning area in the years where both data sources are available.

6.6.5 Source-specific recalculations

Improvements to the source of activity data, methodology and the emission factors used have been incorporated. Activity data for area of tussock burning now is obtained from the total area of consented land for burning for 1990 to 2004, and Statistics New Zealand for 2005 to 2010 and updated country-specific emissions factors are used. See section 6.6.2. for further details.

6.6.6 Source-specific planned improvements

No improvements are currently planned for this emissions source category.

6.7 Field burning of agricultural residues (CRF 4F)

6.7.1 Description

Burning of agricultural residues produced 24.9 Gg CO_2-e in 2010. This was an increase of 0.6 Gg CO_2-e (2.5 per cent) above the level of 24.3 Gg CO_2-e in 1990. Burning of agricultural residues was not identified as a key category in 2010.

New Zealand reports emissions from burning barley, wheat and oats residue in this category. Maize and other crop residues are not burnt in New Zealand.

Burning of crop residues is not considered to be a net source of CO_2, as the CO_2 released into the atmosphere is reabsorbed during the next growing season. However, the burning is a source of emissions of CH_4, CO, N_2O and NO_x (IPCC, 1996). The area of burning of residues varies between years due to climatic conditions and the value of the burnt straw.

6.7.2 Methodological issues

The emissions from burning agricultural residues are estimated using country-specific methodology and emission factors (Curtin et al, 2011). The methodology is aligned with the 1996 IPCC methodology but utilises country-specific parameters. This calculation uses crop production and burning statistics, along with country-specific parameters for the proportion of residue actually burnt, harvests indices, dry-matter fractions, fraction oxidised and the carbon and nitrogen fractions of the residue. The country-specific values for these parameters are those from the OVERSEER® nutrient budget model for New Zealand (Wheeler et al, 2003) and are the same as those used for estimates of emission from crop residues. This provides consistency between the two emissions estimates for crop residue and crop burning. See section 6.5.2 for further details on these values.

These parameters were multiplied to calculate the carbon and nitrogen released based on estimates of carbon and nitrogen fractions in different crop biomass. The emissions of CH_4, CO, N_2O and NO_x were calculated using the carbon and nitrogen released and an emissions ratio.

IPCC good practice guidance suggests that an estimate of 10 per cent of residue burned may be appropriate for developed countries but also notes that the IPCC default values: "are very speculative and should be used with caution. The actual percentage burned varies substantially by country and crop type. This is an area where locally developed, country-specific data is highly desirable" (IPCC, 2000).

For the years 1990 to 2004, the following equations are used for each individual crop, implementing annual crop production values for wheat, barley and oats from Statistics New Zealand. The methodology, parameters and data sources for 2005 onwards are discussed later in this section. Neither legume nor maize crops are burnt in New Zealand but, rather, crop residue is incorporated back into the soil or harvested for supplementary feed for livestock.

Annual dry matter production (t dm) = Total crop production (t) × dry matter fraction

Above-ground dry-matter residue (t dm) = (Annual dry-matter production (t dm) / crop-specific Harvest Index) – dry-matter production (t dm)

Biomass burned (Gg) = Above-ground dry-matter residue (t dm) × Area burned as a proportion of total production area × Proportion of residue remaining after any removal × Proportion of remaining residue actually burned/1000

Total biomass burned is then used to estimate N_2O, NO_x, CH_4, and CO.

N_2O = Biomass burned (Gg) × Fraction oxidised × Fraction of N in biomass × N_2O emission factor × 44/28

NO_x = Biomass burned (Gg) × Fraction oxidised × Fraction of N in biomass × NO_x emission factor × 44/28

CH_4 = Biomass burned (Gg) × Fraction oxidised × Fraction of C in biomass × CH_4 emission factor × 16/12

CO = Biomass burned (Gg) × Fraction oxidised × Fraction of C in biomass × CO emission factor × 16/12

Statistics New Zealand did not collect statistics on crop residue burning prior to 2005. Therefore, there was no annual data series for crop residue previously and other methods for obtaining this data were determined.

The recommended proportion of crop area burned for 1990 to 2004 was determined by a farmer survey and is 70 per cent of wheat, 50 per cent of barley and 50 per cent of oat crops (Curtin et al, 2011). These values are in alignment with Statistics New Zealand data for 2005–2007 (2005 being the first year Statistics New Zealand gathered this data) and, therefore, are applied to the years 1990–2004. Values for 2005 onwards are discussed later in this section.

Expert opinion suggests that if crop residue is to be burned, there is generally no prior removal for feed and bedding. Therefore, 100 per cent of residue is left for burning after the harvested proportion has been removed (Curtin et al, 2011).

The proportion of residue actually burned has been estimated as 70 per cent for the years 1990–2004 as this takes into account required fire break areas and differences in the methods used. It is also assumed that farmers will generally be aiming to have as close to complete combustion as possible.

Table 6.7.1 Values used to calculate New Zealand emissions from burning of agricultural residues

	Barley	Wheat	Oats
Fraction of residue actually burnt	0.7	0.7	0.7
Fraction oxidised	0.9	0.9	0.9
Fraction of nitrogen in biomass	0.005	0.005	0.005
Fraction of carbon in biomass	0.4567	0.4853	0.4567
Dry-matter fraction	0.86	0.86	0.86
Harvest index	0.46	0.46	0.30
Wheat residue remaining in field	1	1	1

Source: Curtin et al, 2011.

Table 6.7.2 Emission ratios for agricultural residue burning

Compound	Emission ratio (Revised IPCC 1996 guidelines)
CH_4	0.005
CO	0.06
N_2O	0.007
NO_x	0.121

A slightly different methodology is used for estimating emissions from agricultural residue burning from 2005 to account for, and take advantage of, extra data available from this year onwards.

From 2005, data on the total area of crop residues burned in New Zealand is collected. Estimates of the proportion of this total area of wheat, barley and oats is then made using the same proportion for wheat as used for the 1990–2004 calculations (70 per cent). The remaining residue burning area is then allocated to barley and oats using the same proportion as the area of each of these crops grown in relation to the total area of barley and oats grown.

The following are the equations used for estimating emissions from agricultural residue burning from 2005 onwards.

> Production dry-matter area burned (t dm) = Estimated area burned (ha) × Average crop yield (t/ha) × dry-matter fraction
>
> Above ground dry-matter residue (t dm) = (Production dry- matter area burned (t dm)/ crop-specific Harvest Index) – Area of crop burned (t dm)
>
> Biomass burned (Gg) = Above-ground dry-matter residue (t dm) × Proportion of residue remaining after any removal × Proportion of remaining residue actually burned/1000

Total biomass burned is then used to estimate N_2O, NO_x, CH_4, and CO using the same equations as for 1990–2004.

All parameters used in the calculation of emissions from agricultural residue burning for all years are detailed in table 6.7.1 and emission ratios in table 6.7.2.

6.7.3 Uncertainties and time-series consistency

The fraction of agricultural residue burned in the field was considered to make the largest contribution to uncertainty in the estimated emissions. Expert opinion for the fraction of crops burnt in fields between 1990 and 2004 is 70 per cent of wheat, 50 per cent of barley and 50 per cent of oat crops. These values are taken from farmer surveys in the Canterbury area, where 80 per cent of cereal production occurs and between 2005 and 2009 an average of 86 per cent of residue burning occurs. Estimates of crop burning for 2010 are 49 per cent and have ranged from a high in 2006 of 61 per cent to a low in 2009 of 40 per cent reflecting variations in annual weather patterns.

6.7.4 Source-specific QA/QC and verification

Table 6.7.3 compares the New Zealand-specific values $Frac_{BURN}$ with the Revised 1996 IPCC Guidelines default value and fractions used by Australia and the United Kingdom. New Zealand's value is higher than that of the Revised 1996 IPCC Guidelines default value, Australian and the United Kingdom values. This is because the IPCC default value was based on the assumption that little field residue burning was carried out in developed countries. This appears to be the case for both Australia and the United Kingdom. However, in some regions of New Zealand, burning of barley and wheat is still carried out, although this has been declining since 1990.

Table 6.7.3 Comparison of IPCC default emission factors and country-specific implied emission factors for $Frac_{BURN}$

	$Frac_{BURN}$ (kg N/kg crop-N)
IPCC developed temperate climate/Oceania default value	0.1
Australian-specific IEF 2009 value	NA[34]
United Kingdom-specific IEF 2009 value	0
New Zealand-specific 2010 value	0.49

Note: IEF = implied emission factor

6.7.5 Source-specific recalculations

A country-specific methodology is now used for estimating emissions from agricultural residue burning using updated parameters and country-specific emissions factors as detailed in section 6.7.2. Changes apply to the entire time series so recalculations have been carried out for all years from 1990 to 2009.

6.7.6 Source-specific planned improvements

No improvements are currently planned.

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

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Chapter 7: Land use, land-use change and forestry

7.1 Sector overview

In 2010, net emissions by the land use, land-use change and forestry (LULUCF) sector were –19,980.5 Gg carbon dioxide equivalents (CO_2-e). This comprises net removals of 20,048.9 Gg carbon dioxide, emissions of 53.8 Gg CO_2-e of methane (CH_4) and 14.6 Gg CO_2-e of nitrous oxide (N_2O).

Net emissions in 2010 have increased by 7,407.9 Gg CO_2-e (27.0 per cent) from the 1990 level of –27,388.3 Gg CO_2-e (table 7.1.1). This is largely the result of increased harvesting of plantation forests as a larger proportion of the estate reaches harvest age. Figure 7.1.1 shows the changes in emissions by land-use category from 1990 to 2010. The increase in emissions in the grassland land-use category is primarily due to the increased deforestation and conversion to grassland of plantation forests that occurred in the five years prior to 2008, as emissions from land-use change are reported in the 'land converted to' category.

Table 7.1.1 New Zealand's greenhouse gas emissions for the LULUCF sector by land-use category in 1990 and 2010 as well as their share and trend

Land-use category	1990 Emissions (Gg CO_2-e)	2010 Emissions (Gg CO_2-e)	Difference 1990–2010	% Change 1990–2010	1990 Share (%)	2010 Share (%)
Forest land	–27,149.9	–23,539.1	3,610.8	13.3	99.1	117.8
Cropland	567.1	392.1	–175.0	–30.9	2.1	2.0
Grassland	–1,075.4	3,120.8	4,196.2	390.2	3.9	15.6
Wetlands	165.7	NO/NE	–165.7	–100.0	0.6	NO/NE
Settlements	97.7	34.9	–62.8	–64.3	0.4	0.2
Other land	6.5	10.8	4.4	67.3	0.0	0.1
Total LULUCF	**–27,388.3**	**–19,980.5**	**7,407.9**	**27.0**	**100.0**	**100.0**

Note: Net removals are expressed as a negative value in the table to assist the reader in clarifying that the value is a removal and not an emission. NO = not occurring; NE = not estimated.

Reported emissions in the LULUCF sector are primarily caused by harvesting production forests, deforestation and the decomposition of organic material whereas removals are primarily because of the uptake of carbon dioxide from plant growth. Nitrous oxide can be emitted from the ecosystem as a by-product of nitrification and de-nitrification, and the burning of organic matter. Other gases released during biomass burning include CH_4, carbon monoxide (CO), other oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs).

New Zealand has adopted the six broad categories of land use as described in *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003), hereafter referred to as GPG-LULUCF.

The land-use categories forest land remaining forest land, conversion to forest land, conversion to cropland, grassland remaining grassland, conversion to grassland and conversion to wetland are key categories for New Zealand in 2010.

Figure 7.1.1 New Zealand's annual emissions from the LULUCF sector from 1990 to 2010

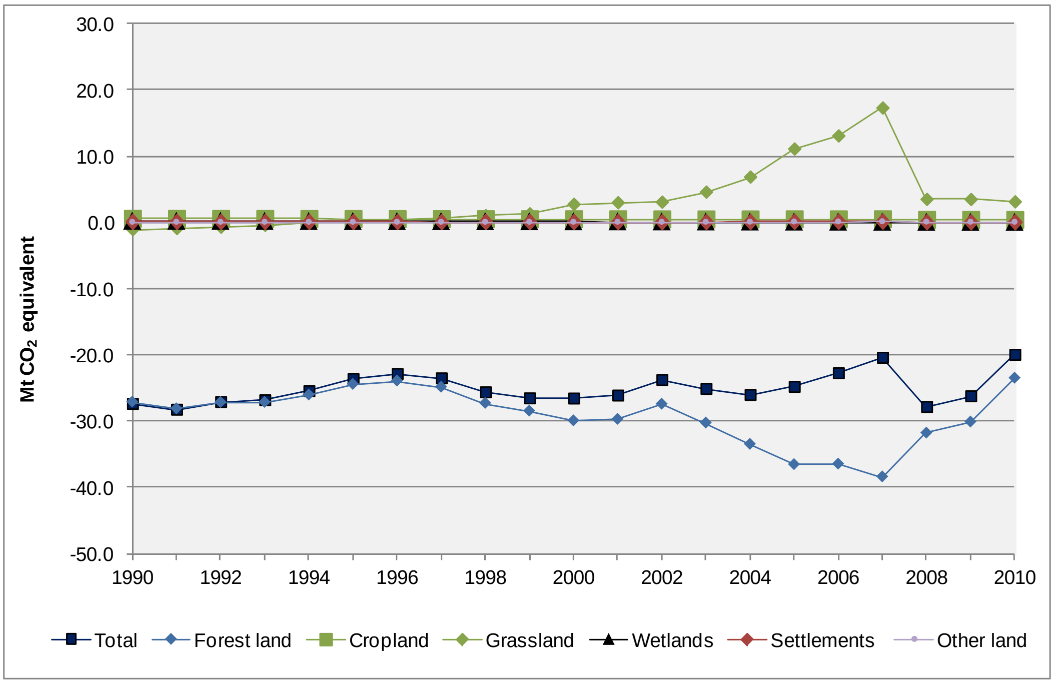
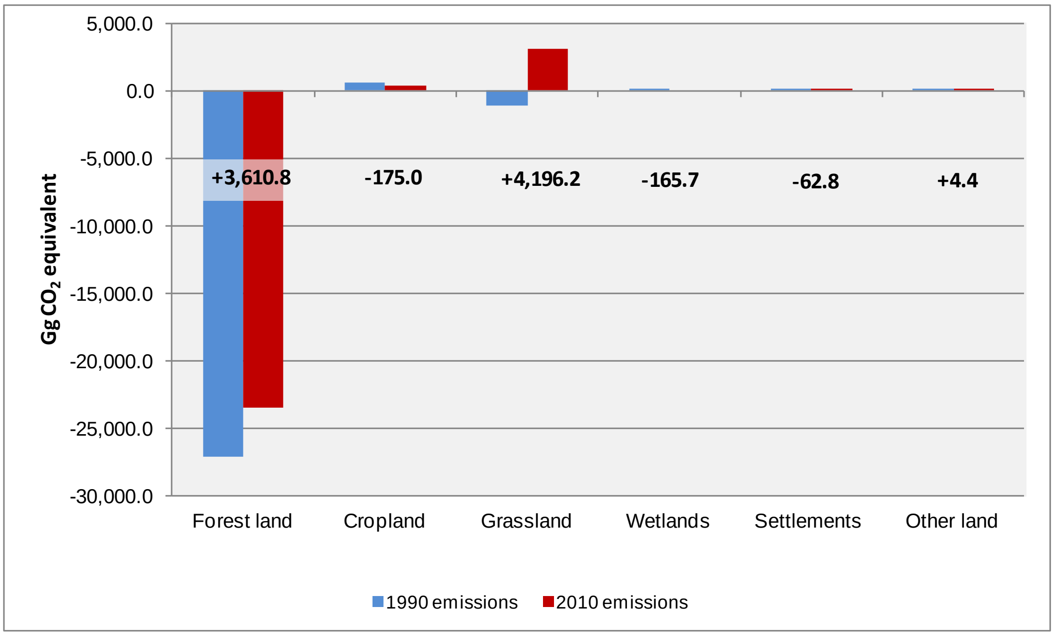


Figure 7.1.2 Change in New Zealand's emissions from the LULUCF sector from 1990 to 2010



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

New Zealand has a land area of approximately 270,000 km^2 with extensive coastlines (11,500 kilometres). Its climate is temperate and highly influenced by the surrounding ocean, with 60 per cent of the land hilly or mountainous with many lakes and fast-flowing rivers and streams.

Before human settlement, natural forests were New Zealand's predominant land cover, estimated at 75 per cent of total land area. Today, natural forest covers around 30 per cent of the total land area of New Zealand (see table 7.1.2). Nearly all lowland areas have been cleared of natural forest for agriculture, horticulture, plantation forestry and urban development. Much of the remaining natural vegetation, however, is now legally protected, with 31 per cent of the total country (8.4 million hectares) within the conservation estate.

Forestry and agriculture are core to the New Zealand economy and the main determinants of its LULUCF emissions profile. Intensive forest management plus a temperate climate, fertile soils and high rainfall mean New Zealand has amongst the highest CO_2 removals under Article 3.3 of Kyoto Protocol and the highest rates of Kyoto forest growth among Annex 1 countries.

New Zealand's exotic forest plantation estate is intensively managed for production forestry, with rapid growing genotypes selected and enhanced for optimum growth. In 2010, plantation forests covered approximately 2 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.

Table 7.1.2 Land use in New Zealand in 2010

Land-use category	Subcategory	Net area in 2010 (ha)	Proportion of total area (%)
Forest land	Natural forest	8,084,403	30.0
	Pre-1990 planted forest	1,441,894	5.4
	Post-1989 forest	593,821	2.2
	Subtotal	*10,120,118*	*37.6*
Cropland	Annual	334,865	1.2
	Perennial	102,901	0.4
	Subtotal	*437,765*	*1.6*
Grassland	High producing	5,795,395	21.5
	Low producing	7,674,138	28.5
	With woody biomass	1,134,031	4.2
	Subtotal	*14,603,564*	*54.2*
Wetlands		663,552	2.5
Settlements		207,169	0.8
Other land		893,199	3.3
Total		**26,925,367**	**100.0**

Note: Areas as at 31 December 2010 and includes deforestation of post-1989 forest since 1990. Totals may not add due to rounding.

Since 1990, New Zealand has undergone land-use change on approximately 4.5 per cent of the total land area.

7.1.2 Methodological issues for the LULUCF sector

New Zealand uses a combination of Tier 1 and Tier 2 methodologies for estimating and reporting emissions for the LULUCF sector. A Tier 1 approach, based on a land-use change matrix, has been used to estimate carbon change in the four biomass pools for all land-use categories except for forest land, perennial cropland and grassland with woody biomass, which use a Tier 2 approach.

A Tier 1 modelling approach has been used to estimate carbon in the mineral soil component of the soil organic matter pool and for organic soils for all land-use categories.

Emission factors

The emission factors required to estimate carbon stock changes using the Tier 1 and Tier 2 equations are provided in tables 7.1.3 and 7.1.4. Table 7.1.3 contains biomass carbon stocks in each land prior to conversion and table 7.1.4 contains the annual growth in carbon stocks after land-use change.

Table 7.1.3 New Zealand's biomass carbon stock emission factors in land use before conversion

Land-use category	Land-use subcategory	2011 submission emission factors (t C ha^{-1})	Carbon pools	Reference
Forest land	Natural forest national average	173.0[(1)]	All biomass pools	Beets et al, 2009
	Natural forest: shrub	57.1[(2)]	All biomass pools	Beets et al, 2009
	Natural forest: tall forest	217.9[(2)]	All biomass pools	Beets et al, 2009
	Pre-1990 planted forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot based estimate
	Post-1989 forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot based estimate
Cropland	Annual	5	Above- and below-ground biomass	Table 3.3.8 (IPCC, 2003)
	Perennial	18.76	Above-ground biomass	Davis & Wakelin, 2010
Grassland	High producing	6.75	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	Low producing	3.05	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	With woody biomass	29	All biomass pools	Wakelin, 2004
Wetlands		NE	NA	Section 3.5.2.2 and annex 3A (IPCC, 2003)
Settlements		NE	NA	Section 3.6.2 (IPCC, 2003)
Other land		NE	NA	Section 3.7.2.1 (IPCC, 2003)

Note: NE = not estimated; NA = not applicable. (1) The indicated amount is emitted instantaneously for conversions from natural forest prior to 2008. (2) For conversions from natural forest since 1 January 2008, the indicated stock is emitted instantaneously depending on the vegetation type present (tall forest or shrub) immediately before conversion. Biomass pools include above- and below-ground biomass, litter and dead organic matter. See below in section 7.1.3 and under Methodological issues in each category-specific section for further details.

Table 7.1.4 New Zealand's emission factors for annual growth in biomass for land converted to another use

Land-use category	Land-use subcategory	2011 submission emission factor (t C ha^{-1})	Years to reach steady state	Carbon pools	Reference
Forest land	Natural forest	NO(1)	NA	NA	NA
	Pre-1990 planted forest	Based on age-based carbon yield table	28	All biomass pools	Wakelin, 2008
	Post-1989 forest	Based on age-based carbon yield table	28	All biomass pools	Kimberley et al, 2009
Cropland	Annual	5	1	Above- and below-ground biomass	Table 3.3.8 (IPCC, 2003)
	Perennial	0.67	28	Above-ground biomass	Davis & Wakelin, 2010
Grassland	High producing	6.75	1	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	Low producing	3.05	1	Above- and below-ground biomass	Table 3.4.9 (IPCC, 2003)
	With woody biomass	1.04	28	All biomass pools	Wakelin, 2004
Wetlands		NE	NA	NA	Assume steady state (IPCC, 2003)
Settlements		NE	NA	NA	Assume steady state (IPCC, 2003)
Other land		NE	NA	NA	Assume steady state (IPCC, 2003)

Note: NO = not occurring; NE = not estimated; NA = not applicable. (1) No conversions to natural forest have occurred since 1962.. See section 7.3 for further details.

In order to meet reporting requirements under the Kyoto Protocol, New Zealand is estimating carbon stock change for each of the five Kyoto Protocol carbon pools and aggregating the results to the three Climate Change Convention reporting pools. Table 7.1.5 summarises the methods being used to estimate carbon by pool for each land use.

Table 7.1.5 Relationships between carbon pool, land-use category, LULUCF activity and model calculations used by New Zealand

Climate Change Convention reporting pool		Living biomass		Dead organic matter		Soils	
						Soil organic matter	
Kyoto Protocol reporting pool		Above-ground biomass	Below-ground biomass	Dead wood	Litter	Mineral soils	Organic soils
Land-use category	Natural forest	Allometric equations	Per cent of above-ground biomass	Allometric equations	Lab analysis	IPCC Tier 1 default parameters	Not applicable
	Natural forest [D]	Look-up table based on natural forest national average for deforestation occurring before 1 January 2008 or the vegetation type present (tall forest or shrub) immediately before deforestation occurring since 1 January 2008					
	Pre-1990 planted forest	Age-based carbon yield table by pool derived from the Land Use and Carbon Analysis System (LUCAS) plot network and the Forest Carbon Predictor model				IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Pre-1990 planted forest [D]	Age-based carbon yield table by pool derived from the LUCAS plot network and the Forest Carbon Predictor model					
	Post-1989 forest [AR]	Age-based carbon yield table by pool derived from the LUCAS plot network and the Forest Carbon Predictor model				IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Post-1989 forest [D]	Age-based carbon yield table by pool derived from the LUCAS plot network and the Forest Carbon Predictor model					
	Cropland – annual	IPCC Tier 1 default parameters	Not estimated	Not estimated	Not estimated	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Cropland – perennial	Country-specific emission factor	Not estimated	Not estimated	Not estimated	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Grassland (high and low producing)	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters	Not estimated	Not estimated	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Grassland with woody biomass	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	Country-specific emission factor	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters
	Wetlands	IPCC Tier 1 default parameters (NE)	IPCC Tier 1 default parameter (NE)	Not estimated	Not estimated	IPCC Tier 1 default parameters	Not estimated
	Settlements	IPCC Tier 1 default parameter (NE)	IPCC Tier 1 default parameter (NE)	Not estimated	Not estimated	IPCC Tier 1 default parameters	Not estimated
	Other land	IPCC Tier 1 default parameter (NE)	IPCC Tier 1 default parameter (NE)	Not estimated	Not estimated	IPCC Tier 1 default parameters	Not estimated

Note: AR = afforestation/reforestation, D = deforestation and NEFD = the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2010). See the methodology sections on soils (section 7.1.3) and forests (section 7.3.2) for explanations of the soil carbon, C_Change and Forest Carbon Predictor models.

Calculation of national emission estimates

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

- land use and land-use change areas from 1962 to 1989, which provides land in a transition state as at 1990 for each land-use subcategory
- annual land use and land-use change area data from 1990 to 2010 (see section 7.2)
- biomass carbon stocks per hectare prior to land-use conversion, and annual growth in biomass carbon stocks per hectare following conversion (see tables 7.1.3 and 7.1.4)
- age-based carbon yield tables for pre-1990 planted forests and post-1989 forests
- emission factors and country-level activity data on biomass burning and liming
- IPCC default conversion factors.

The formula used to calculate emissions from biomass changes is:

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

The formula used to calculate emissions from soil changes is:

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

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

Biomass change = (–3.05 x 100) + (0.67 x 100) = –238 t C
Soil change = (((97.76 – 105.55) / 20) x 100) = –39 t C
Total carbon stock change = –277 t C

Total emissions = (carbon stock change / 1000 x –1) x (44/12)
Total emissions = 1.015 Gg CO_2-e

These calculations are performed to produce estimates of annual carbon stock and carbon stock changes since 1990 to inform the Climate Change Convention and Kyoto Protocol Article 3.3 reporting.

New Zealand land use and carbon analysis system

New Zealand's LULUCF estimates are calculated using a data collection and modelling programme called the Land Use and Carbon Analysis System (LUCAS) (see www.mfe.govt.nz/issues/climate/lucas). The LUCAS Data Management System stores, manages and retrieves data for international greenhouse gas reporting for the LULUCF sector. The system comprises the Geospatial System, a data warehousing 'Gateway' and the Calculation and Reporting Application. These systems are used for managing the land-use spatial databases and the plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting. Details on these databases and applications are provided in annex 3.2.

7.1.3 Soils

In this submission, New Zealand uses a Tier 1 method to estimate soil carbon emissions for mineral and organic soils.

Mineral soils

New Zealand uses a Tier 1 method to estimate soil carbon stock and stock change for mineral soils. The method estimates a steady state carbon stock for each land use in New Zealand, and calculates changes in soil carbon stocks associated with land-use change.

Data

New Zealand-specific climate and soil data are used in estimating the areas of each soil type found in each climate zone. Climate data is based on two underlying data layers of the Land Environments of New Zealand classification (Leathwick et al, 2002). These layers provide data about the temperature and moisture conditions necessary to characterise climate zones described in figure 3.1.3 of GPG-LULUCF. Soil-type data are based on the Fundamental Soils Layer associated with the New Zealand Land Resources Inventory (Newsome et al, 2000), with soil types converted to IPCC classifications (Daly & Wilde, 1997).

These data layers have been analysed in a GIS system to determine the areas in table 7.1.6. Some area around the margins of mainland New Zealand and offshore islands do not have underlying soil or climate data. Values have been assigned to areas around the margins of New Zealand using the attributes of neighbouring polygons. The climate and soil types of islands not touching mainland New Zealand remain unknown, meaning they are not included in New Zealand's estimation of emissions from mineral soils. Areas with no data represent around 109,000 hectares, which is 0.0004 per cent of New Zealand's land area. About 300 hectares of this land underwent land-use change. The exclusion of these areas has a negligible impact on the reported emissions from mineral soil.

Table 7.1.6 Areas of mineral soil types in climate zones, hectares

Climate zone	HAC soil	LAC soil	Sandy soil	Spodic soil	Volcanic soil	Aquic soil	Estuarine soil
Boreal	696		4,620				
Cold dry	84,609		97			4,330	
Cold wet	8,533,706		497,171	2,400,409	652,178	120,596	833
Warm dry	19,652		1,402			621	
Warm wet	8,261,744	128,553	372,214	940,441	2,927,123	628,378	9,364

Note: The total area of table 7.1.6 does not equal the total area of New Zealand. Areas with no data, or with soil type mapped as organic, icefield, riverbed, lakebed or settlement are excluded from the analysis. Organic soils are reported separately, and the other soil types have no default emission factors.

Calculations

The general approach of the Tier 1 method follows the equation (IPCC, 2003):

$$\Delta C = [SOC_0 - SOC_{(0\text{-}T)} * A]/T$$
$$SOC = SOC_{REF} * F_{LU} * F_{MG} * F_I$$

Where:

ΔC = annual change in carbon stocks, tonnes C yr^{-1}
SOC_0 = organic carbon stock in the inventory year, tonnes C yr^{-1}
$SOC_{(0-T)}$ = organic carbon stock T years prior to the inventory year, tonnes C yr^{-1}
A = land area of parcels with these SOC terms, ha
T = inventory time period, yr (New Zealand uses the 20-year default)
SOC_{REF} = the reference carbon stock, tonnes C ha^{-1}
F_{LU} = stock change factor for land use or land-use change type, dimensionless
F_{MG} = stock change factor for management regime, dimensionless
F_I = stock change factor for input of organic matter, dimensionless

New Zealand has estimated a national value of SOC_{REF} based on the areas of each soil type found in each climate zone (table 7.1.6), and the default reference soil organic carbon stock under native vegetation for each climate/soil combination given in table 3.3.3 of IPCC, 2003. SOC_{REF} has been calculated as 92.59 tonnes C ha^{-1}.

Stock change factors have been determined for each of the LULUCF land-use classes used in New Zealand using guidance provided in GPG-LULUCF. These factors have been applied to the national SOC_{REF} to determine a steady state organic carbon stock (SOC) for each land use (table 7.1.7) to use in calculating annual changes in carbon stocks.

Table 7.1.7 Stock change factors and steady state soil organic carbon stocks for land-use classes

Land-use class	Land-use factor (FLU)	Management regime factor (FMG)	Input factor (FI)	SOC
Natural forest	1.0	1.0	1.0	92.59
Pre-90 planted forest	1.0	1.0	1.0	92.59
Post-89 planted forest	1.0	1.0	1.0	92.59
Grassland with woody biomass	1.0	1.0	1.0	92.59
High-producing grassland	1.0	1.14	1.11	117.16
Low-producing grassland	1.0	1.14	1.0	105.55
Perennial cropland	0.82	1.16	1.11	97.76
Annual cropland	0.71	1.0	0.91	59.82
Open water	0	0	0	0
Vegetated wetland	1.0	1.0	1.0	92.59
Settlements*	1.0	0.70	1.0	64.81
Other land	1.0	1.0	1.0	92.59

Note: * The stock change factors for unimproved grassland with severe degradation were used in the absence of IPCC default stock change factors for settlements for this land use.

Organic soils

New Zealand uses a Tier 1 method to estimate soil carbon stock change in organic soils.

New Zealand-specific climate and soil data are used in estimating the areas of organic soil found in each climate zone. Climate data is based on an underlying data layer of the Land Environments of New Zealand classification (Leathwick et al, 2002). The layer provides data about the temperature conditions necessary to characterise the climate zones described in GPG-LULUCF.

Soil-type data is based on the Fundamental Soils Layer associated with the New Zealand Land Resources Inventory (Newsome et al, 2000), with soil types converted to IPCC classifications (Daly & Wilde, 1997). The definition of organic soils is from the New Zealand Soil Classification (Hewitt, 1998) and is broadly summarised as having at least 18 per cent organic carbon in 30 centimetre or more thick horizons within 60 centimetres of the soil surface.

These data layers have been analysed in a GIS system to determine the areas of organic soils in warm and cold climate zones. This is intersected with the land-use mapping layer to determine area data for organic soils by IPCC land use.

New Zealand has used IPCC default emission factors for organic soils under forest, grassland and cropland to estimate organic soil emissions, as shown in table 7.1.8 (IPCC, 2003: sections 3.2.1.3, 3.3.1.2 and 3.4.1.2). IPCC guidance for organic soils under forest is limited to estimates associated with the drainage of organic soils in managed forests. It is assumed that all planted forests on organic soils in New Zealand are drained prior to forest establishment. In New Zealand, natural forests are not drained and therefore the default emission factor is not applicable. The warm temperate and cold temperate defaults for grassland and cropland are applied in proportion to the area of land in New Zealand where the mean annual temperature is above or below 10°C respectively. There are no default emission factors for organic soils under settlements, wetlands and other land, and therefore emissions from organic soils under these land uses are not estimated. It is not known whether the use of IPCC defaults for organic soils results in either an overestimate or an underestimate of New Zealand's soil carbon emissions. However, organic soils occupy a relatively small proportion of New Zealand's total land area (0.9 per cent) and the area of organic soils subject to land-use change is even smaller (approximately 0.5 per cent of total land area).

Table 7.1.8 New Zealand emission factors for organic soils

Land use	Climatic temperature regime	IPCC Tier 1 default emission factor applied & ranges (t C ha^{-1} yr^{-1})	Reference
Natural forest	Temperate	NA	IPCC guidance applies only to drained forest organic soils, which do not occur in natural forests in New Zealand. IPCC (2003), section 3.2.1.3.
Pre-1990 planted forest Post-1989 forest	Temperate	0.68 (range 0.41–1.91)	IPCC (2003), section 3.2.1.3, table 3.2.3.
Cropland	Cold temperate Warm temperate	1.0 ± 90 % 10.0 ± 90 %	IPCC (2003), section 3.3.1.2, table 3.3.5.
Grassland	Cold temperate Warm temperate	0.25 ± 90 % 2.5 ± 90 %	IPCC (2003), section 3.4.1.2, table 3.4.6.
Wetlands	NA	NE	IPCC guidance applies only to peat extraction, which is not a significant activity in New Zealand. IPCC (2003), section 3.5.2.1.
Settlements Other land	NA	NE	No IPCC guidance is available. IPCC (2003), chapters 3.6, 3.7.

Note: NA = not applicable; NE = not estimated.

Methodological change

New Zealand has revised the approach to estimating emissions from mineral soils in this submission.

A Tier 2 methodology was used in the previous submission, in which a linear statistical model estimated steady state organic carbon stocks for each land use, based on key factors that regulate soil organic carbon stocks, land use, climate and soil class.

The 2010 review (UNFCCC, 2011) of New Zealand's 2008 submission commended New Zealand for estimating steady state organic soil carbon stocks by each land use. However, it was "unclear whether or not the [Tier 2] methodology can with any certainty detect significant changes in soil carbon stock changes for different land uses". "New Zealand [was] encouraged to include increased sampling in land-use classes (particularly other land, wetland, croplands and post-1989 forest), which are currently under represented in the national sample" to reduce uncertainty and enable detection of any statistically significant changes.

New Zealand has responded to the 2010 review report by shifting to a Tier 1 methodology to estimate steady state organic carbon stocks for each land use in this submission. New Zealand intends to return to using a Tier 2 methodology once improvements are made to enable detection of any statistically significant changes between land uses.

The calculations to determine annual changes in carbon stocks due to land-use change have not changed between submissions. These are calculated as the differences in steady state soil carbon values between the initial and final land use and the area undergoing that land-use change, with 20 years to move from one steady state to the other.

The change to Tier 1 emission factors has resulted in a decrease in the difference in stock estimates for mineral soils between low-producing grassland and post-1989 forest (the major land-use change) from –16.85 t C ha^{-1} to –12.96 t C ha^{-1}.

New Zealand has applied Tier 1 default emission factors for organic soils, which is the same method used in the previous submission.

Uncertainties and time-series consistency

- The mean annual temperature and water balance ratio data layers that determine the climate zones are described in the Land Environments of New Zealand, Leathwick et al, 2002.
- Mean annual temperature: standard errors of temperature estimates are mostly less than 0.35°C, though this generally increases (up to 0.5°C) with increasing elevation, reflecting the paucity of records from montane environments (Leathwick et al, 2002).
- Water balance ratio: no estimates of error have been made because of conceptual difficulties in combining the errors of the contributing surfaces (Leathwick et al, 2002).
- Uncertainties associated with the default soil organic carbon contents in each soil climate zone are given in table 3.3.3 of GPG-LULUCF.
- Uncertainties associated with the default stock change factors are given in tables 3.3.4 and 3.4.5 of GPG-LULUCF. The uncertainties in soil carbon stock are high at between 107 per cent and 95 per cent.

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

Quality-control and quality-assurance procedures have been adopted for all data analyses, to be consistent with GPG-LULUCF and New Zealand's inventory quality-control and quality-assurance plan. The data layers used in the analyses have also undergone independent quality assurance before publication.

Source-specific planned improvements

Recent reviews of the Soil Carbon Monitoring System (Soil CMS) identify a range of potential areas for improvement of the system (Baisden et al, 2006; Kirschbaum et al, 2009; UNFCCC, 2011). These aim to improve estimates of soil organic carbon from the Soil CMS model so that New Zealand can use a Tier 2 methodology for future inventory submissions. Specific improvements that have been prioritised for the next year include:

- additional data for the perennial cropland land use
- recalibration and uncertainty analysis of the Soil CMS with reclassified climate data
- investigation of the impact of using Tier 1 methodology for poorly sampled non-key land-use classes and excluding these from the Soil CMS estimates.

7.1.4 Uncertainties in LULUCF

Table 7.1.9 shows the six land-use transitions within the LULUCF sector with the greatest contribution to uncertainty in the net carbon emissions for the LULUCF sector. These are given in descending order.

Table 7.1.9 Land-use transitions with the greatest contribution to uncertainty in the LULUCF sector

Land-use transitions	Per cent error attributed to activity data (area)	Per cent error attributed to emission factors	Total per cent error by land-use transition
Low-producing grassland converted to post-1989 forest	4.5	43.2	43.4
Pre-1990 planted forest remaining pre-1990 planted forest	11.0	22.2	24.8
High-producing grassland converted to post-1989 forest	1.2	12.6	12.7
Pre-1990 planted forest converted to high-producing grassland	0.06	5.5	5.5
High-producing grassland remaining high-producing grassland	0.3	4.9	4.9
Grassland with woody biomass converted to pre-1990 planted forest	1.8	4.5	4.8

The land-use subcategory that introduces the greatest uncertainty (when expressed as a proportion of total net LULUCF carbon emissions) is low-producing grassland converted to post-1989 forest. The error attributed to the emission factor for the post-1989 forest is high at 43.2 per cent. The error in the biomass component of the post-1989 forest emission factor is 10.2 per cent, but the error in the soils component is high at 95 per cent as this is an IPCC default. This is also the land-use transition with the largest area of change, with 365,190 hectares of change between 1990 and 2010.

The second greatest contributor is pre-1990 planted forest remaining pre-1990 planted forest. This category was the largest contributor in the 2011 submission but the incorporation of a new yield table for pre-1990 planted forest has reduced the uncertainty factor for biomass emissions from 16.9 per cent to 14.1 per cent.

More details on the emission factor and activity data uncertainties for specific land uses and non-carbon emissions are given within the relevant sections of this chapter.

7.1.5 Recalculations in LULUCF

For the 2012 submission, New Zealand has recalculated its emission estimates for the LULUCF sector from 1990 to 2010 to incorporate new activity data, New Zealand-specific emission factors and improved methodology.

The recalculations have resulted in improvements to the accuracy and completeness of the LULUCF estimates. Their impact on total net LULUCF emissions in 1990 and 2009, based on a comparison of the current and previous submissions, is summarised in table 7.1.10. The overall effect of the recalculations has been to decrease emissions in 1990 by 16.8 per cent, and decrease emissions in 2009 by 1.7 per cent.

Table 7.1.10 Recalculations to New Zealand's total net LULUCF emissions

	Reported net emissions		Change in estimate	
	2011 submission ($Gg\ CO_2$-e)	2012 submission ($Gg\ CO_2$-e)	($Gg\ CO_2$-e)	(%)
1990	–23,451.1	–27,388.3	–3,937.2	–16.8
2009	–26,682.7	–26,234.1	+448.6	1.7

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions reported in the 2011 submission are the result of (in decreasing order of magnitude):

- moving to Tier 1 methodology for estimating carbon change associated with land-use change for mineral soils
- the inclusion of temperature dependent deadwood and litter decay functions into the Calculation and Reporting Application for the decay of harvest residues in pre-1990 and post-1989 planted forest (Garrett et al, 2010). Previously, the 20-year linear IPCC default was used for harvest residue decay. As the level of harvesting varies from year to year, this changes the profile of emissions from the deadwood and litter pools
- improved estimation of deforestation through polygon-specific mapping (IPCC Approach 2) of deforestation from high-resolution (SPOT) satellite imagery in priority areas and uncertainty analysis to provide a more accurate estimate of total annual deforestation occurring since the start of the first commitment period (1 January 2008)
- the use of a permanent sample plot network-based yield table for the estimation of carbon stock and stock change in pre-1990 planted forests. Previously, a yield table based on the *National Exotic Forest Description*, a survey conducted by the Ministry of Agriculture and Forestry, was used (Ministry of Agriculture and Forestry, 2010)
- the use of the Forest Carbon Predictor, version 3, in the development of the pre-1990 and post-1989 planted forest yield tables. Version 3 of the Forest Carbon Predictor

contains new temperature-dependent decay functions and species-specific growth trajectory and biomass adjustments (Beets & Kimberley, 2011). New breast height pith-to-bark density functions and a stand-management module for improved estimation of past and future silvicultural events when stand records are incomplete, are also included since the previous submission (Beets & Kimberley, 2011)

- improvements have been made to the 1990 and 2008 land-use maps. There was a correction of just over 10,000 hectares of wetlands that was previously mapped as natural forest. Also, mapping data provided from the New Zealand Emissions Trading Scheme (NZ ETS) was integrated into the 1990 and 2008 maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest.
- a new emission factor for wildfire in forest land remaining forest land based on New Zealand's national permanent sample plot network
- updated activity data for biomass burning
- the inclusion of new, disaggregated activity data on dolomite and liming emissions, sourced from Statistics New Zealand.

The impact of these recalculations on net CO_2-e emissions in each land-use category is provided in table 7.1.11. The differences shown are a result of recalculations for all carbon pools used for Climate Change Convention and Kyoto Protocol reporting for the whole time series for the LULUCF sector. This table includes only recalculations from 1990 to 2009, to enable a comparison of the two approaches.

In this submission, New Zealand has reported only land-use change within the estimated mapping margin of error. Therefore, land-use changes of less than 100 hectares in total for 1990 to 2010 are not reported, given the lack of confidence that the minor areas estimated represent real change.

Table 7.1.11 Recalculations to New Zealand's net emissions for 1990 and 2009

	Net emissions (Gg CO_2-e)					
Land-use category	**2011 submission: 1990 estimate**	**2012 submission: 1990 estimate**	**2011 submission: 2009 estimate**	**2012 submission: 2009 estimate**	**Change in 1990 estimate (%)**	**Change in 2009 estimate (%)**
Forest land	–25,344.9	–27,149.9	–29,559.4	–30,157.5	–7.1	–2.0
Cropland	395.3	567.1	337.5	396.3	43.4	17.4
Grassland	1,309.1	–1,075.4	2,529.4	3,474.5	–182.1	37.4
Wetlands	164.7	165.7	0.0	0.0	0.6	0.0
Settlements	–7.2	97.7	2.5	34.9	1,458.8	1,301.9
Other land	31.9	6.5	7.2	17.7	–79.7	143.9
Total	**–23,451.1**	**–27,388.3**	**–26,682.7**	**–26,234.1**	**–16.8**	**1.7**

Note: Net removals are expressed as a negative value to assist the reader in clarifying that the value is a removal and not an emission. Columns may not add due to rounding.

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

7.1.6 LULUCF planned improvements

Category-specific planned improvements are reported separately under each of the relevant sections of this chapter. The major themes are:

- continuation of data collection programmes
- ground and aerial-based forest stock inventories
- improvements to carbon assessment of planted forests and associated emissions relating to forest management practices
- improvements to land-use mapping
- improvements to soil carbon assessment.

7.2 Representation of land areas

7.2.1 Land-use category definitions

The New Zealand land-use categories and subcategories are shown in table 7.2.1. The land-use subcategories are consistent with those used for the 2011 submission.

Table 7.2.1 New Zealand's land-use categories and subcategories

IPCC land-use category	New Zealand land-use subcategory
Forest land	Natural forest Pre-1990 planted forest Post-1989 forest
Cropland	Cropland – annual Cropland – perennial
Grassland	Grassland – high producing Grassland – low producing Grassland – with woody biomass
Wetlands	Wetlands[1]
Settlements	Settlements
Other land	Other land

Note: (1) Mapped as 'wetlands – open water' and 'wetlands – vegetated non-forest'.

The land-use subcategories were chosen for their conformation with the dominant land-use types in New Zealand, while still enabling reporting under the land-use categories specified in the IPCC good practice guidance (2003).

The national thresholds used by New Zealand to define forest land for both Convention and Kyoto Protocol reporting are:

- a minimum area of 1 hectare
- a crown cover of 30 per cent
- a minimum height of 5 metres at maturity *in situ* (Ministry for the Environment, 2006).

Wetlands have been mapped separately as 'open water' and 'vegetated non-forest'. These subcategories are then aggregated for reporting in the common reporting format (CRF) tables. See section 7.6 for details.

The definitions of New Zealand's land-use subcategories, as they have been mapped, are provided in table 7.2.2.

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

Land-use subcategory	Definition
Natural forest	Areas that on 1 January 1990 were: • tall indigenous forest • self-sown exotic trees, such as wilding pines and grey willows, established before 1 January 1990 • broadleaved hardwood shrubland, manuka/kanuka shrubland and other woody shrubland (≥ 30 per cent cover, with potential to reach ≥ 5 metres at maturity *in situ* under current land management within 30–40 years) • areas of bare ground of any size that were previously forested but, due to natural disturbances (eg, erosion, storms, fire) have lost vegetation cover • includes roads/tracks/skid sites and other temporarily unstocked areas associated with a forest land-use
Pre-1990 planted forest	• radiata pine (*Pinus radiata*), Douglas-fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.) or other planted species (with potential to reach ≥ 5 metre height at maturity *in situ)* established before 1 January 1990, or replanted on land that was forest land as at 31 December 1989 • exotic forest species that were planted after 31 December 1989 into land that was natural forest • riparian or erosion control plantings that meet the forest definition and that were planted before 1 January 1990 • harvested areas within pre-1990 planted forest (assumes these will be replanted, unless deforestation is later detected) • includes roads/tracks/skid sites and other temporarily unstocked areas associated with a forest land-use • areas of bare ground of any size that were previously forested at 31 December 1989 but, due to natural disturbances (eg, erosion, storms, fire) have lost vegetation cover
Post-1989 forest	• exotic forest (with the potential to reach ≥ 5 metre height at maturity *in situ*) planted or established on land that was non-forest land as at 31 December 1989 (eg, radiata pine, Douglas-fir, eucalypts or other planted species) • harvested areas within post-1989 forest land (assumes these will be replanted, unless deforestation is later detected) • forests arising from natural regeneration of indigenous tree species as a result of management change after 31 December 1989 • self-sown exotic trees, such as wilding conifers or grey willows, established after 31 December 1989 • riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989 • includes roads/tracks/skid sites and other temporarily unstocked areas associated with a forest land-use • areas of bare ground of any size that were previously forested (established after 31 December 1989) but, due to natural disturbances (eg, erosion, storms, fire) have lost vegetation cover
Cropland – annual	• all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland
Cropland – perennial	• all orchards and vineyards • linear shelterbelts associated with perennial cropland

Land-use subcategory	Definition
Grassland – high producing	• grassland with high-quality pasture species • includes linear shelterbelts that are < 1 hectare in area or 30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • areas of bare ground of any size that were previously grassland but, due to natural disturbances (eg, erosion) have lost vegetation cover
Grassland – low producing	• low fertility grassland and tussock grasslands (eg, *Chionochloa* and *Festuca* spp.) • mostly on hill country • montane herbfields at either an altitude higher than above-timberline vegetation, or where the herbfields are not mixed up with woody vegetation • includes linear shelterbelts that are < 1 hectare in area or < 30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • other areas of limited vegetation cover and significant bare soil, including erosion
Grassland – with woody biomass	• grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (eg, mahoe (*Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), manuka/kanuka (*Leptospermum scoparium*/*Kunzea ericoides*) shrubland and other woody shrubland (< 5 metres tall 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 intermixed with montane herbfields (does not have the potential to reach > 5 metres in height *in situ*) • grassland with tall tree species (< 30 per cent cover), such as golf courses in rural areas (except where the Land Cover Database (LCDB) has classified these as settlements) • grassland with riparian or erosion control plantings (< 30 per cent cover) • linear shelterbelts that are > 1 hectare in area and < 30 metres in mean width • areas of bare ground of any size that previously contained grassland with woody biomass but, due to natural disturbances (eg, erosion, fire) have lost vegetation cover
Wetlands	• classified and mapped separately as 'wetlands – open water' and 'wetlands – vegetated non-forest' • open water comprises lakes and rivers • vegetated non-forest wetlands comprise herbaceous and/or non-forest woody vegetation that may be periodically flooded. Includes scattered patches of tall tree-like vegetation in the wetland environment where cover reaches < 30 per cent • estuarine/tidal areas including mangroves
Settlements	• built-up areas and impervious surfaces • grassland within 'settlements' including recreational areas, urban parklands and open spaces that do not meet the forest definition • major roading infrastructure • airports and runways • dam infrastructure • urban subdivisions under construction
Other land	• montane rock/scree • river gravels, rocky outcrops, sand dunes and beaches, coastal cliffs, mines (including spoil), quarries • permanent ice/snow and glaciers • any other remaining land that does not fall into any of the other land-use categories

Further refinements are planned to improve New Zealand's estimates of land-use change, as stated at the end of this section under planned improvements. Land areas reported as ‘converted’ and ‘remaining’ within each land-use category are the best current estimates and will be improved should additional activity data become available.

7.2.2 Land-use mapping

Land-use area

In this submission, the total land area of New Zealand used for all estimates of activity data is 26,925.4 kilohectares. This value includes all significant New Zealand land masses, the two main islands, the North Island and South Island, as well as Stewart Island, Great Barrier Island, Little Barrier Island, the Chatham Islands, the sub-Antarctic islands and other, small outlying islands.

New Zealand has used Method 1 and a mix of Approaches 2 and 3 to map land-use changes between 1 January 1990 and 31 December 2007 (IPCC, 2003, chapter 2.3.2.3). The areas of forest as at 1 January 1990 and 1 January 2008 are based on wall-to-wall mapping of satellite and aircraft remotely sensed imagery taken in, or close to the start of, 1990 and 2008. The area includes improvements made up to August 2011 using additional satellite imagery, aerial photography and data from NZ ETS. Land-use changes during 2008, 2009 and 2010 are then interpolated from other sources. This is described in further detail in section 7.2.3.

Land-use mapping – 1 January 1990

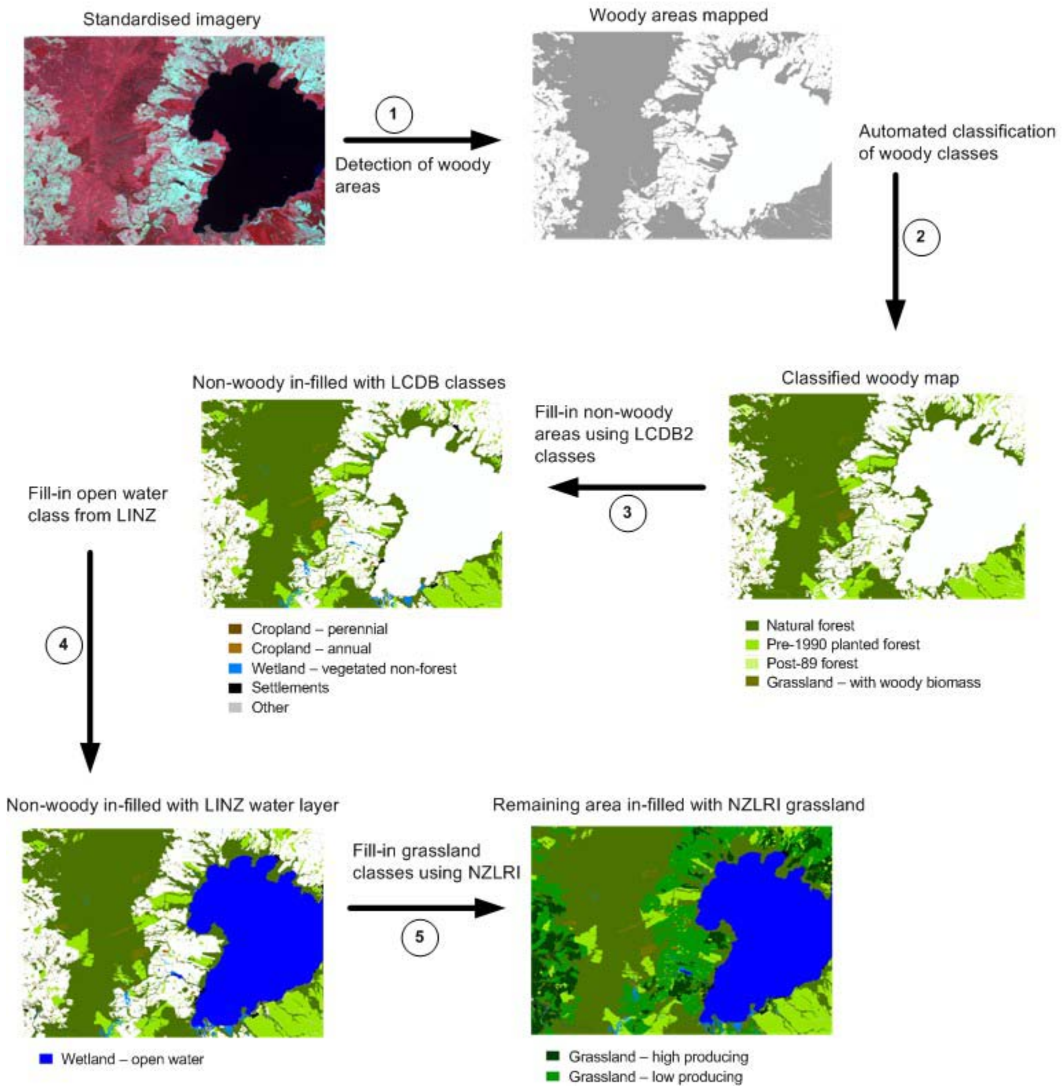
The 1990 land-use map is derived from 30-metre spatial resolution Landsat 4 and Landsat 5 satellite imagery taken in, or close to, 1990. The first of the images used were taken in November 1988 and the last in February 1993. In addition to orthorectification and atmospheric correction, the satellite images were standardised for spectral reflectance using the Ecosat algorithms documented in Dymond et al (2001), Shepherd and Dymond (2003), as well as Dymond and Shepherd (2004). These standardised images were used for the automated mapping of woody biomass and then 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 & Newsome, 2009a; 2009b).

The NZLRI database was used to better define the area of high- and low-producing grassland. Areas tagged as ‘improved pasture’ in the NZLRI vegetation records were classified as grassland – high producing in the land-use maps. All other areas were classified as grassland – low producing. Figure 7.2.1 illustrates this mapping process.

Figure 7.2.1 New Zealand's land-use mapping process

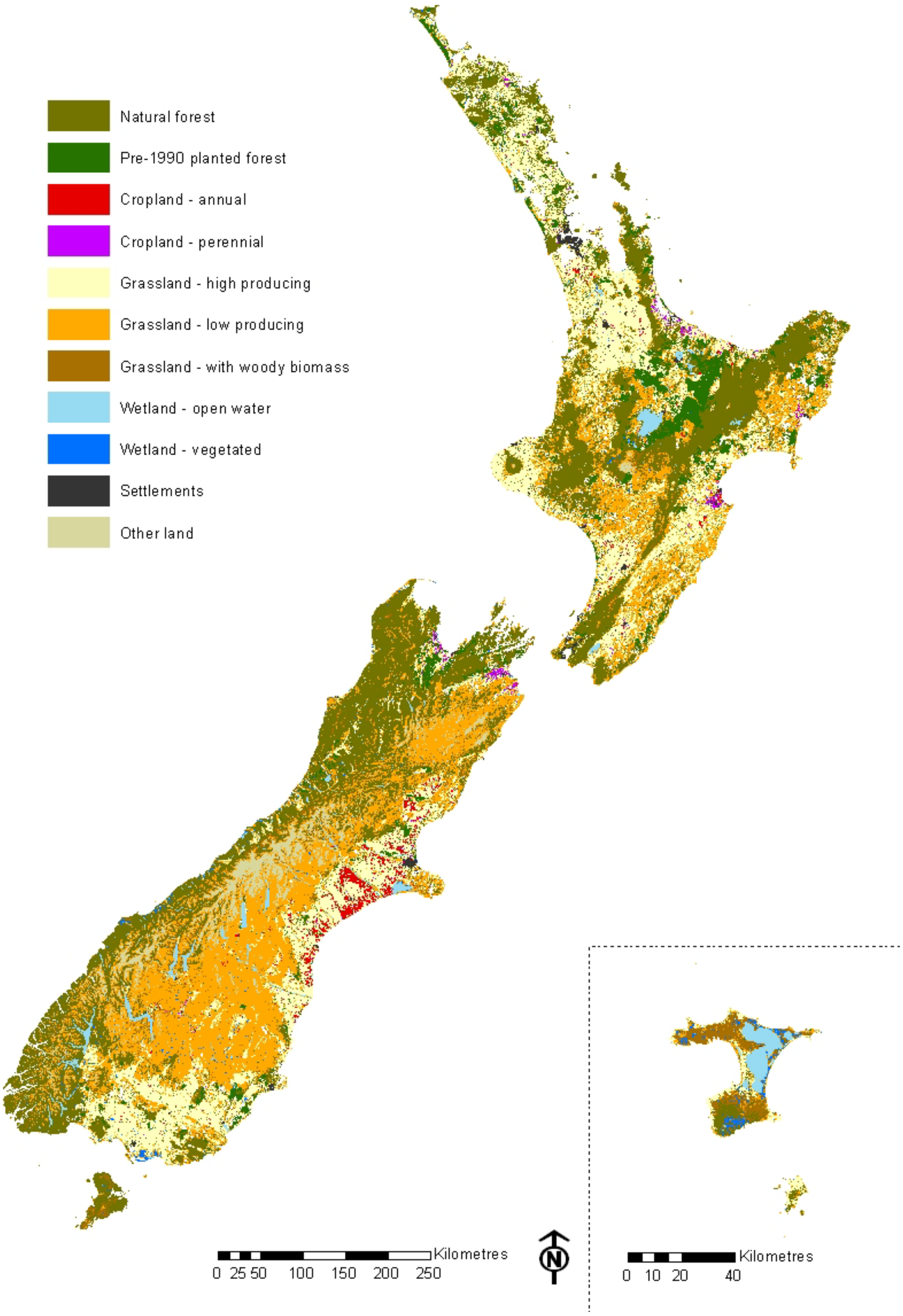


Note: LINZ = Land Information New Zealand.

An interpretation guide for automated and visual interpretation was prepared and used to ensure a consistent basis for all mapping processes (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 within what land-use category the point fell. The two operators were in agreement at least 95 per cent of the time. This is described in more detail in GNS Science (2009).

Figure 7.2.2 shows the land-use map of New Zealand as at 1 January 1990.

Figure 7.2.2 Land-use map of New Zealand as at 1 January 1990

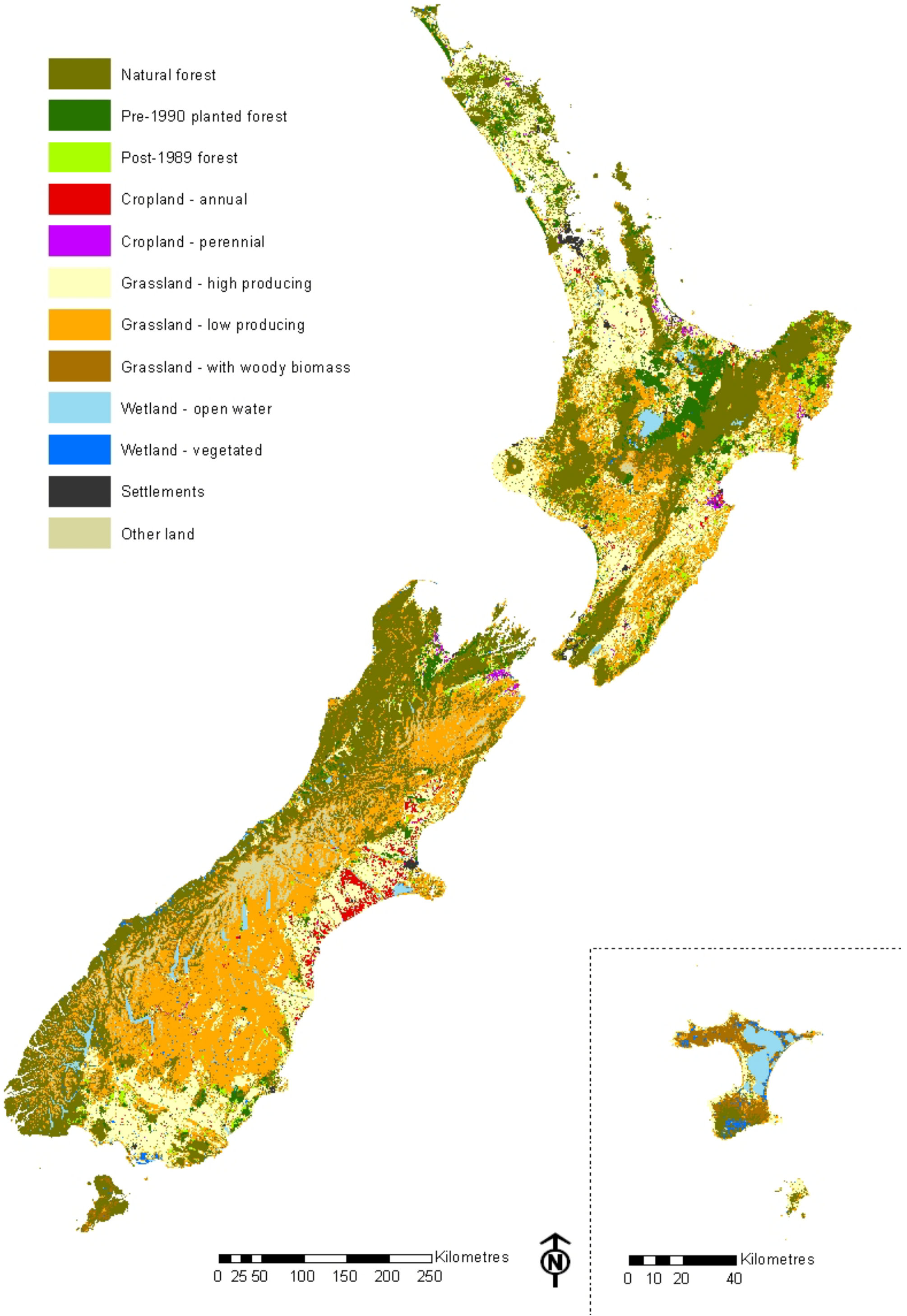


Note: The insert map is of the Chatham Islands, which lie approximately 660 kilometres south-east of the Wairarapa coast, or 800 kilometres due east of Banks Peninsula.

Land-use mapping – 1 January 2008

The 2008 land-use map (land use as at 1 January 2008) is derived from 10-metre spatial resolution SPOT 5 satellite imagery and was processed into standardised reflectance images, using the same approach as for the 1990 imagery. The SPOT 5 imagery was taken over the summers of 2006–2007 and 2007–2008 (November to April), to establish a national set of cloud-free imagery. Where the SPOT 5 imagery pre-dates 1 January 2008, a combination of aerial photography, Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery and field verification has been used to identify where deforestation has occurred to ensure that the 2008 land-use map is as accurate as possible. Figure 7.2.3 shows the land-use map of New Zealand as at 1 January 2008.

Figure 7.2.3 Land-use map of New Zealand as at 1 January 2008



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

Decision process for mapping post-1989 forests

The use of remote sensing has some limitations, in particular, the ability to map young planted forest of less than three years of age. Where trees are planted within three years of the image acquisition date they (and their surrounding vegetation) are unlikely to show a distinguishable spectral signature in satellite imagery. This occurs particularly with coarse resolution (30 metres) 1990 Landsat imagery. This situation is compounded by the lack of ancillary data to support land-use classification decisions.

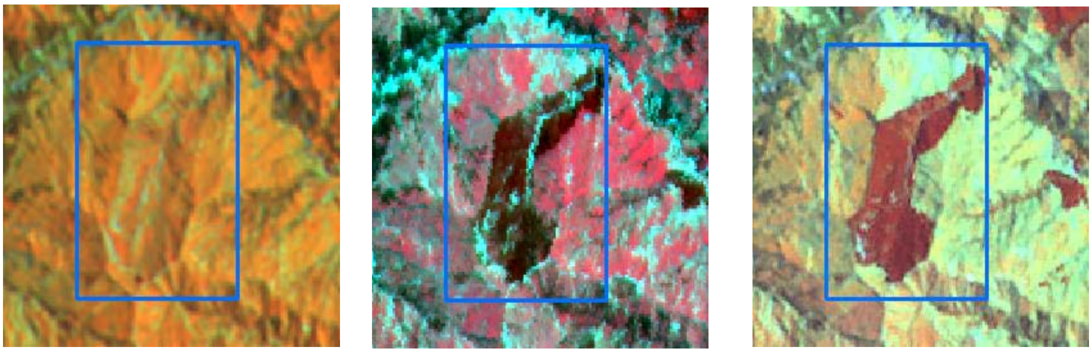
To aid the decision-making process, the LUCAS mapping also used nationwide and cloud-free 1996 SPOT and 2001 Landsat 7 satellite imagery to determine the age of forest that might have been planted between 1990 and 1993. This process is designed to reduce errors of omission and ensures all forests are mapped. Figure 7.2.4 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 2000 satellite imagery. The 1990 image shows no obvious spectral signature of any forest vegetation within the blue box. However, the 1996 and 2000 images show strong forestry spectral signatures. If the 1990 imagery had shown some spectral signature that corresponded to the forest boundary in 1996, the mapping operators would have classified the area as pre-1990 planted forest. By applying this method, the later date imagery is used to confirm subtle variations in spectral signature in the 1990 imagery that correspond with young planted forest.

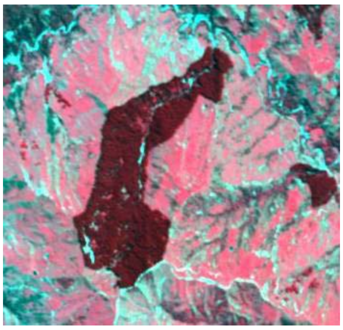
Where possible, information obtained directly from forest owners and the national planted forest plot network is also used to improve the accuracy of the pre-1990/post-1989 forest classification.

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

Mapping from the NZ ETS has also provided a significant source of planting date information to help with the determination of the correct classification of planted forest. The Forestry Allocation Plan, which forms part of the NZ ETS, compensates pre-1990 planted forest owners partially for the loss in land value arising from the introduction of penalties for deforesting pre-1990 forest land. Forest owners must apply for this compensation, providing detailed mapping and evidence of their forest planting date. Approximately 90 per cent of New Zealand’s pre-1990 forest area has been lodged in this scheme to date. This mapping data is regularly used to improve the classification accuracy of the LUCAS land-use maps.

Figure 7.2.4 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.

Mapping of deforestation 2008–2009

New Zealand has used a combination of data sources to identify the location and timing of deforestation after 1 January 2008. Land-use data generated from classification of SPOT 5 satellite imagery acquired between November 2006 and April 2008 was compared with DMC (Disaster Monitoring Constellation) satellite imagery acquired over the summer of 2009–2010 in conjunction with some field verification. From this, temporarily destocked land and land converted from a forest land use to a non-forest land use was identified. Evidential information to confirm land-use change was collected using higher-resolution aerial photography and field visits. This is illustrated in figure 7.2.6.

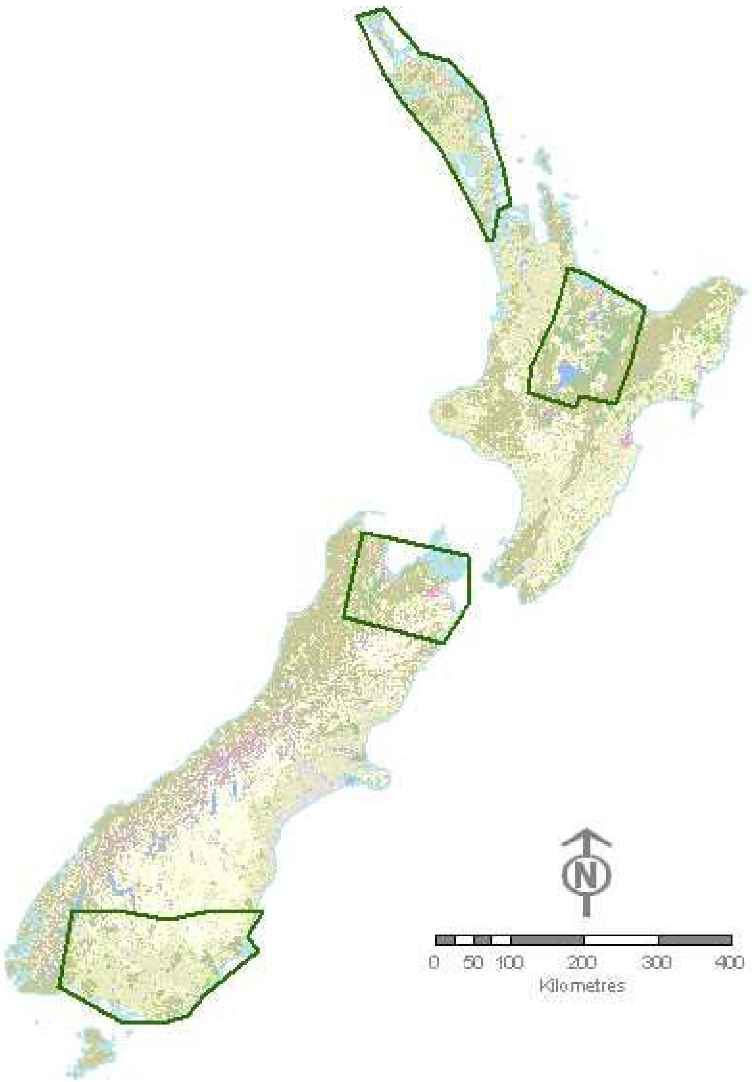
Areas of possible deforestation were confirmed using oblique aerial photography. Supporting information from regional councils, Ministry of Agriculture and Forestry district offices and forestry consultants was also consulted to see if deforestation or restocking could be confirmed.

Areas of forest destocking that were unable to be confirmed as either harvesting or deforestation, were flagged for tracking. Those areas that are not replanted within four years will be deemed to be deforested at the clearing date.

Mapping of deforestation 2010

Deforestation mapping for 2010 was carried out over four priority areas where the largest extent of deforestation was anticipated based on the 2008 and 2009 deforestation mapping. Figure 7.2.5 shows the four priority areas. High resolution (10 metre) SPOT satellite imagery was acquired over these priority areas in Northland, Waikato, Marlborough and Southland. The area mapped represents approximately one quarter of the total land area of New Zealand. For areas not mapped in 2010, deforestation area has been estimated. These areas will be mapped and, in the course of the next two years and 2010 deforestation events, identified.

Figure 7.2.5 Four priority areas where deforestation mapping was carried out in 2010



Estimation of harvesting 2008–2010

The estimate of the total area of planted forest harvested each year between 1990 and 2010 is based on the harvested area reported in the *National Exotic Forest Description*, a survey conducted by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2010). Data for the year ending 31 December 2010 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 2004–2009 was used to estimate the area harvested in 2010 from the volume of roundwood produced. The harvesting values for 2010 will be updated in next year's submission when finalised planted forest data for 2010 becomes available.

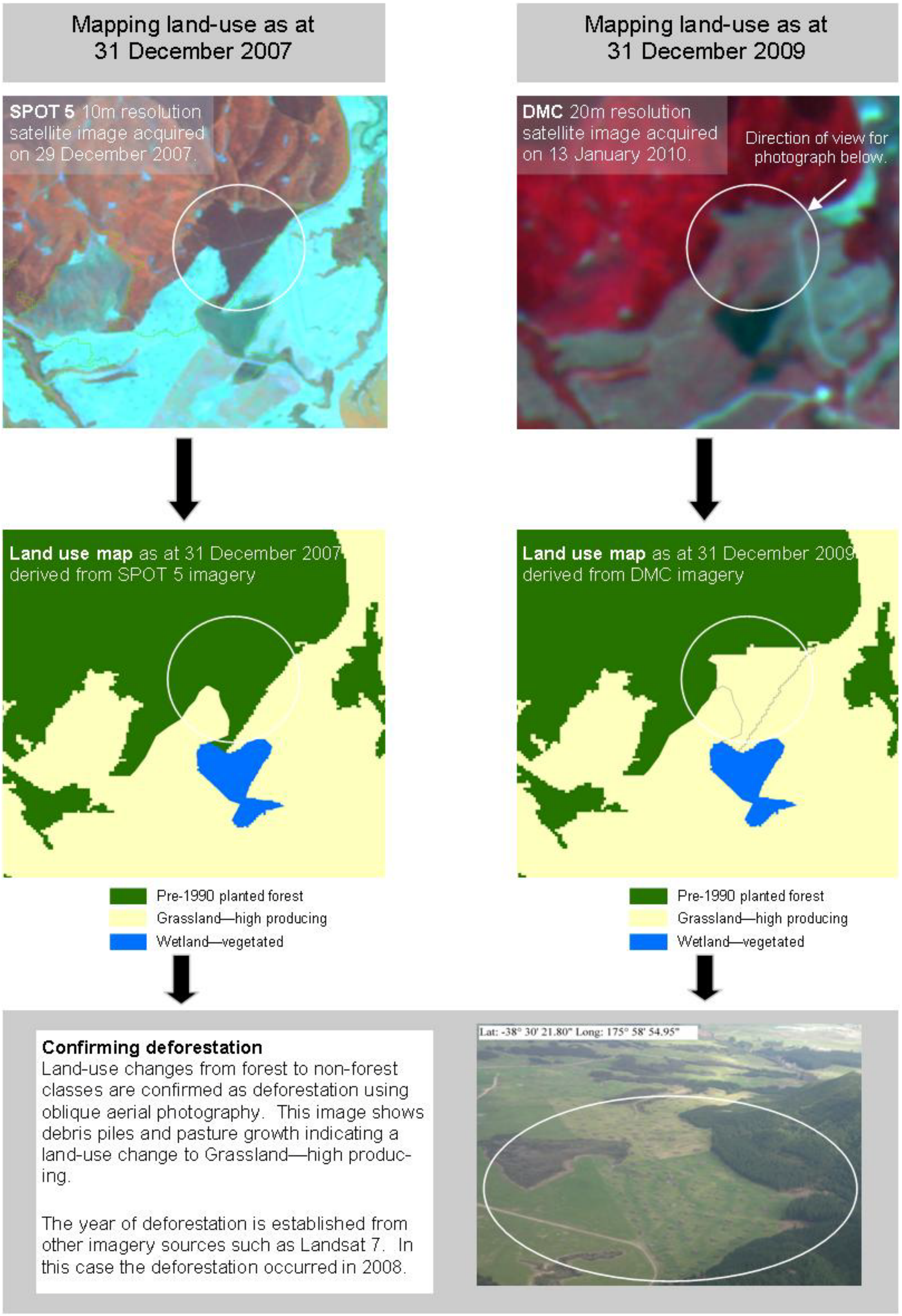
At present, there are differences in the definition of forest used for reporting of pre-1990 planted forest for the Convention on Climate Changereporting and the area included in the *National Exotic Forest Description* from which the harvesting statistics are sourced. The activity data required to estimate harvesting emissions in pre-1990 planted forests will need to take account of these differences. Future improvements are planned to better align these sources for activity data.

The total area harvested was then split by forest type.

- *Pre-1990 planted forest harvesting:* This was estimated as the difference between total harvesting (based on statistics from the Ministry of Agriculture and Forestry, as outlined above) and the amount of post-1989 forest harvesting estimated.
- *Post-1989 forest:* There is no published information available for the area of post-1989 forest harvesting in New Zealand, but, because of the young age of this resource, 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.

In 2010, it is estimated that 0.07 per cent of New Zealand's total forest timber production was from the harvesting of natural forests. The harvesting that occurs in natural forests is carried out under sustainable practices and the activity is captured within the natural forest stock estimates.

Figure 7.2.6 New Zealand's identification of deforestation



7.2.3 Land-use change

Land-use change during the period 2008 to 2010

With the exceptions of deforestation and post-1989 afforestation, land-use change between 2008 and 2010 has been extrapolated based on the change that occurred during the period 1990–2008. Deforestation for 2008 to 2010 has been mapped, and post-1989 afforestation has been based on data from the *National Exotic Forest Description* as at 1 April 2010 (Ministry of Agriculture and Forestry, 2011b). The data for 2010 is still provisional and will be updated for the 2013 submission.

Land-use change from 1990 to 2010

Land-use change from 1990 to 2010 is based on:

- mapped land-use change from 1 January 1990 to 1 January 2008
- mapped deforestation occurring in 2008 and 2009
- partially mapped and partially estimated deforestation occurring in 2010
- afforestation in 2008, 2009 and 2010, estimated from the *National Exotic Forest Description* as at 1 April 2010 (Ministry of Agriculture and Forestry, 2011b)
- estimates of deforestation area from the 2008 Deforestation Survey (Manley, 2009) and unpublished work by Scion (the New Zealand Forest Research Institute). The work by Scion is referred to in Wakelin (2008)
- all other 2008 to 2010 land-use change is extrapolated from pre-2008 trends.

Table 7.2.3 shows a land-use change matrix for the years 1990 to 2010 based on these inputs.

Prominent land-use changes between 1990 and 2010 include:

- forest establishment of 611,149 hectares (classified as post-1989 forest) that has occurred mostly on land that was previously grassland, primarily low-producing grassland. Approximately 17,327 hectares of this post-1989 forest has subsequently been deforested.
- deforestation of 106,906 hectares. This includes the 17,327 hectares of post-1989 forest mentioned above. This deforestation has occurred mainly in planted forests since 2004. Between 1990 and 2004, there was very little deforestation of planted forests in New Zealand due to market conditions.

Table 7.2.4 shows a land-use change matrix for the period 31 December 2009 to 31 December 2010.

Land-use change prior to 1990

Estimating of land-use change prior to 1990 was introduced in the 2011 submission and more details on the methodology used are available in that document. In the 2010 submission, New Zealand assumed that all land was in a steady state at 1990. A consequence of this was land-use change that occurred prior to 1990 was ignored and the associated carbon changes were not accurately reflected. As this assumption was not consistent with international IPCC good practice guidance, which requires identification of land in a conversion state as at 1990 (IPCC, 2003, Vol 4, chapter 3, page 9), New Zealand developed and applied a procedure for estimating land use and land-use change back to 1962 (28 years prior to 1990, equivalent to one rotation of a *Pinus radiata* exotic plantation forest).

A variety of data sources were used to determine land areas prior to 1990. Data sources suitable for determining land use at a national level typically comprise either maps or scaled images depicting land use or proxies for land use (eg, a ‘map of forest areas’), or tabulated land-use area data collected for an administrative area (eg, county, district or region) or production sector (eg, the area of orchard crops).

The same land-use data and methodology used to determine land use prior to 1990 in the 2011 submission has been used for the 2012 submission. This methodology was peer-reviewed by Landcare Research Ltd (Hunter & McNeill, 2010), which provided independent subject-matter expertise. The land-use change matrix from 1962 to 1990 is presented in table 7.2.5.

Table 7.2.3 New Zealand's land-use change matrix from 1990 to 2010

2010 \ 1990		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2010 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,084.4											8,084.4
	Pre-1990 planted	21.2	1,420.7										1,441.9
	Post-1989						97.5	365.2	126.2			4.9	593.8
Cropland	Annual				331.3		2.5	1.1					334.9
	Perennial		0.3		4.6	76.9	18.9	2.2	0.1				102.9
Grassland	High producing	9.2	43.8			0.3	5,724.2	0.1	17.5	0.2			5,795.4
	Low producing	21.4	10.3					7,608.8	33.2			0.4	7,674.1
	With woody biomass	3.2	0.3			0.4	9.2	28.9	1,090.6			1.4	1,134.0
Wetlands	Wetlands									663.6			663.6
Settlements	Settlements	0.2	0.4			0.2	2.3	0.7	0.2		203.3		207.2
Other land	Other land	0.2	0.3				0.2		0.1			892.4	893.2
Area as at 1 Jan 1990 (kha)		8,139.8	1,476.1	–	335.8	77.7	5,854.9	8,007.1	1,267.9	663.7	203.3	899.1	26,925.4
Net change 1 Jan 1990–31 Dec 2010		–55.4	–34.2	593.8	–1.0	25.2	–59.5	–333.0	–133.8	–0.2	3.9	–5.9	–
Net change 1990–2010 (%)		–0.01	–0.02	N/A	–0.003	0.3	–0.01	–0.04	–0.1	–0.0003	0.02	–0.01	NA

Note: Units in 000's hectares. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 hectares, however, areas are mapped to 1 hectare resolution. Blank cells indicate no land-use change during the period greater than 100 hectares. Land-use change areas do not include deforestation of post-1989 forest since 1990 (15,503 hectares), as this land became forest after 1990. Land-use change values refer to change over the course of the period. Land-use area values are as at point in time indicated (31 December for 2010, 1 January for 1990.) Columns and rows may not total due to rounding.

Table 7.2.4 New Zealand's land-use change matrix from 2009 to 2010

2010 \ 2009		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 31 Dec 2010 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,084.4											8,084.4
	Pre-1990 planted		1,441.9										1,441.9
	Post-1989			587.8			1.0	3.5	1.4			0.1	593.8
Cropland	Annual				334.7		0.1	0.1					334.9
	Perennial				0.2	101.7	0.9	0.1	0.01				102.9
Grassland	High producing	0.02	0.1	0.1		0.01	5,794.4	0.01	0.8	0.01			5,795.4
	Low producing	0.2	1.1	1.2				7,670.1	1.6			0.02	7,674.1
	With woody biomass					0.02	0.4	1.4	1,132.1			0.1	1,134.0
Wetlands	Wetlands									663.6			663.6
Settlements	Settlements					0.01	0.1	0.03	0.01		207.0		207.2
Other land	Other land	0.02					0.01		0.01			893.2	893.2
Net area as at 31 Dec 2009 (kha)		8,084.6	1,443.1	589.0	334.9	101.7	5,797.0	7,675.1	1,136.0	663.6	207.0	893.3	26,925.4
Net change 31 Dec 2009–31 Dec 2010		–0.2	–1.2	4.8	–0.05	1.2	–1.6	–1.0	–1.9	0.0	0.2	–0.1	NA
Net change 2009–2010 (%)		0.00	–0.08	0.81	–0.01	1.17	–0.03	–0.01	–0.17	0.00	0.08	–0.01	NA

Note: Units in 000's hectares. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 hectares, however, areas are mapped to 1 hectare resolution. Blank cells indicate no land-use change during the period greater than 100 hectares. Land-use change areas do not include deforestation of post-1989 forest since 1990 (15,503 ha), as this land became forest after 1990. Land-use change values refer to change over the course of the period. Land-use area values are as at point in time indicated (31 December for 2009 and 2010, 1 January for 1990.) Columns and rows may not total due to rounding.

Table 7.2.5 New Zealand's land-use change matrix from 1962 to 1989

1989 \ 1962		Forest land			Cropland		Grassland			Wetlands	Settlements	Other land	Net area 1 Jan 1989 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Wetlands	Settlements	Other land	
Forest land	Natural	8,089.8							50.0				8,139.8
	Pre-1990 planted	230.4	429.6					335.2	481.0				1,476.1
	Post-1989												–
Cropland	Annual				305.8	1.7	21.0	7.2					335.8
	Perennial				1.3	67.8	5.0	3.6					77.7
Grassland	High producing	51.5			82.0	21.2	4,820.3	421.3	411.6	47.1			5,854.9
	Low producing	292.5						7,674.8	39.8				8,007.1
	With woody biomass	25.4						284.8	957.6				1,267.9
Wetlands	Wetlands	14.4								649.4			663.7
Settlements	Settlements	5.2			3.8		6.6	3.7	3.9		180.0		203.3
Other land	Other land											899.1	899.1
Net area as at 31 Dec 1962 (kha)		8,709.3	429.6	–	392.8	90.7	4,853.0	8,730.6	1,943.8	696.4	180.0	899.1	26,925.4
Net change 1962–1989		–569.5	1,046.5	0.0	–57.0	–13.0	1,001.9	–723.5	–676.0	–32.7	23.3	0.0	0.0
Net change 1962–1989 (%)		–6.5	243.6	NA	–14.5	–14.3	20.6	–8.3	–34.8	–4.7	12.9	0.0	NA

Note: Units in 000's hectares.

7.2.4 Methodological change

For 2008 and 2009 deforestation reporting, wall-to-wall mapping was completed using DMC 22 metre resolution satellite imagery. For 2010, only a partial mapping of deforestation across New Zealand was completed using 10 metre resolution SPOT satellite imagery. During the course of this mapping over four priority areas, extra areas of 2008 and 2009 deforestation were identified from the higher resolution imagery.

In order to obtain an estimate of the total deforestation occurring in 2008, 2009 and 2010, it was necessary to estimate the deforestation activity occurring outside the priority mapped areas. In the case of 2008 and 2009, this required an estimation of the extra deforestation area that would be identified were higher resolution imagery available compared with the 22 metre resolution DMC imagery used to originally map it. In the case of 2010, this required an estimation of all the deforestation occurring outside the priority mapped areas. A scaling approach was used to estimate the extra areas of deforestation based on the proportion of deforestation that had been previously mapped inside and outside the priority areas. This approach was based on the assumption that deforestation activity was spatially consistent for the years 2008 to 2010.

7.2.5 Uncertainties and time-series consistency

Due to constraints in time and resources, New Zealand has not completed a full accuracy assessment to determine uncertainty in the mapping data. However, the approach to mapping land-use change between 1990 and 2010 is based on a peer-reviewed and published work by Dymond et al, 2008. With this approach, it was estimated that an accuracy of within ±7.0 per cent of actual afforestation can be achieved in mapping change in planted forests in New Zealand. One of the planned improvements for the activity data is to perform an accuracy assessment and determine the uncertainty for the woody biomass categories mapped under LUCAS. The levels of uncertainty for non-woody classes (±6.0 per cent) and for natural forest (±4.0 per cent) are similar to what was reported in previous submissions because the same data sources have been used.

7.2.6 Source-specific QA/QC and verification

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, consistent with GPG-LULUCF and New Zealand's inventory quality-control and quality-assurance plan. Data quality and data assurance plans are established for each type of data used to determine carbon stock and stock changes, as well as for the mapping of the areal extent and spatial location of land-use changes.

The 1990 and 2008 land-use mapping data has been checked to determine the level of consistency in satellite image classification to the requirements set out in the *Guide to Mapping Woody Land-use Classes Using Satellite Imagery* (Dougherty et al, 2009). Through this process, approximately 28,000 randomly selected points in the 1990 and 2008 woody classes were evaluated by independent assessors. From this exercise, 91 per cent of the time, independent assessors agreed with the original classification. Where there was disagreement, the points were recorded in a register and this has been used as the basis for preparing the improvement plan described in this report. The process does not determine errors of omission and/or commission that would provide an accuracy assessment and definitive level of uncertainty. (An error of commission is where a particular class has been mapped incorrectly, for example, as a result of similarities in spectral signatures; an error of omission error is where mapping has failed to detect a particular land use, for example, a planted forest block visible in imagery.)

Each mapping improvement activity carried out on the 1990 and 2008 maps has been subjected to quality-assurance checks to ensure accuracy and consistency. Quality-assurance strategies have been tailored to each improvement activity, usually including a combination of random sampling of updated areas and analysis of the changes in land-use areas.

During 2011, data from the NZ ETS was reconciled with the 1 January 2008 land-use map. The NZ ETS data contains pre-1990 and post-1989 forest boundaries as submitted by forest owners and verified by the Ministry of Agriculture and Forestry. The NZ ETS forest areas were checked against the 2008 land-use map. Where mapping differences were identified, these areas were assessed against satellite imagery and the LUCAS forest land-use definitions to determine whether the 2008 land-use map should be changed. After integration, quality-assurance checks were performed to ensure that updates to the 2008 land-use map were accurate and complete.

Quality assurance of the 2008–2009 and 2010 deforestation mapping activities was a multi-stage process. The contractor undertook initial quality assurance by cross-checking operator interpretation of harvesting and/or deforestation events in satellite imagery. For the 2008–2009 deforestation mapping, key areas of deforestation identified in satellite imagery were then field checked using oblique aerial photography acquired from light aircraft. For the 2010 deforestation mapping activity, all areas of deforestation and a stratified sample of areas mapped as either harvested or awaiting[35] were field checked using oblique aerial photography. This allowed an uncertainty analysis to be completed on the 2010 deforestation mapping.

Finally, all areas of mapped deforestation were visually checked by LUCAS analysts to verify both the deforestation decision and the original mapped land use.

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

7.2.7 Source-specific planned improvements

The quality-control and quality-assurance process followed during mapping exposed a number of limitations in the mapping method. Future improvements to both the 1990 and 2008 maps will focus on these areas:

- the mapping of 1990 land use presented challenges, particularly in identifying newly established exotic forests using Landsat satellite imagery. Where trees are planted within three years of the image acquisition date, they (and their surrounding vegetation) are unlikely to show a distinguishable spectral signature on 30-metre resolution imagery. For LUCAS mapping, this situation is compounded by the lack of ancillary data to support land-use classification decisions at 1990. Land-use mapping will continually be updated and improved with information from the NZ ETS. The Ministry of Agriculture and Forestry is administering the forestry component of the NZ ETS, and applicants to the scheme are providing new land-management and land-use information as at 1990.

[35] For further information on the ‘awaiting’ category, introduced for 2010 deforestation mapping, see section 11.4.3.

- the Ministry of Agriculture and Forestry administers a number of other funds to encourage forest planting and preservation. Spatial data from the Afforestation Grants Scheme, the Permanent Forest Sink Initiative and the East Coast Forestry Project will also be used to improve the accuracy of forest mapping in the 1990 and 2008 land-use maps.

At the end of the first commitment period, New Zealand will create a 2012 land-use map using high-resolution satellite data as the key source of information. This mapping will be used to make comparisons with the 2008 land-use map (prepared using similar high-resolution imagery) to improve the spatial determination of harvesting, deforestation and land-use changes between 1 January 2008 and 31 December 2012.

7.3 Forest land (CRF 5A)

7.3.1 Description

In New Zealand's *Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006), national forest definition parameters were specified as required by UNFCCC Decision 16/CMP.1. The New Zealand parameters are a minimum area of 1 hectare, a height of 5 metres and a minimum crown cover of 30 per cent. Where the height and canopy cover parameters are not met at the time of mapping, the land has been classified as forest land if the land-management practice(s) and local site conditions (including climate) are such that the forest parameters will be met over a 30 to 40 year timeframe.

New Zealand also uses a minimum forest width of 30 metres from canopy-edge to canopy-edge. This removes linear shelterbelts from the forest land category. The width and height of linear shelterbelts can vary as they are trimmed and topped from time to time. Further, they form part of non-forest land uses, namely cropland and grassland (as shelter to crops and/or animals).

New Zealand has adopted the definition of managed forest land as provided in GPG-LULUCF: "Forest management is the process of planning and implementing practices for stewardship and use of the forest aimed at fulfilling relevant ecological, economic and social functions of the forest". Accordingly, all of New Zealand's forests, both those planted for timber production and natural forests managed for conservation values, are considered managed forests.

Forest land is the most significant contributor to carbon stock changes in the LULUCF sector. Forests cover 37.6 per cent (around 10 million hectares) of New Zealand. In 2010, forest land contributed –23,539.1 Gg CO_2-e of net emissions. This value includes removals from the growth of pre-1990 planted forests and post-1989 forests, but not from natural forests, which are assumed to be in steady state, and emissions from the conversion of land to planted forest, harvesting, deforestation and fire. Net emissions from forest land have increased by 3,610.9 Gg CO_2-e (15.3 per cent) on the 1990 level of 27,149.9 Gg CO_2-e (table 7.3.1).

In 2010, forest land remaining forest land and conversion to forest land were key categories (trend and level assessment).

Table 7.3.1 New Zealand's land-use change within the forest land category in 1990 and 2010, and associated CO_2-e emissions

Forest land land-use category	Net area in 1990 (ha)	Net area in 2010 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$-e) 1990	2010	Change from 1990 (%)
Forest land remaining forest land	8,751,293	9,199,725	+5.1	–4,598.0	6,450.7	+240.3
Land converted to forest land	876,699	920,394	+5.0	–22,551.9	–29,989.9	–33.0
Total	**9,627,992**	**10,120,118**	**+5.1**	**–27,149.9**	**–23,539.1**	**+13.3**

Note: 1990 and 2010 areas are as at 31 December. Net area values include land in a state of conversion (due to land-use change prior to 1990) and afforestation and deforestation since 1990. Net emission estimates are for the whole year indicated. Columns may not add due to rounding.

For Climate Change Convention and Kyoto Protocol reporting, New Zealand has subdivided its forest land into three forest land subcategories: natural forest (predominantly native forest pre-dating 1990), pre-1990 planted forest and post-1989 forest (all forest established after 31 December 1989). The definitions used for mapping these land-use subcategories are given in table 7.2.2.

Table 7.3.2 shows land-use change by forest subcategory since 1990, and the associated CO_2 emissions from carbon stock change alone.

Table 7.3.2 New Zealand's land-use change within forest land subcategories in 1990 to 2010, and associated CO_2 emissions from carbon stock change

Forest land land-use category	Net area in 1990 (ha)	Net area in 2010 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$ only) 1990	2010	Change from 1990 (%)
Natural forest[1]	8,136,779	8,084,403	–0.6	NA	NA	NA
Pre-1990 planted forest	1,477,288	1,441,894	–2.4	–27,355.3	–4,190.8	84.7
Post-1989 forest	13,925	593,821	+4,164.5	193.5	–19,362.1	–10,106.3
Total	**9,627,992**	**10,120,118**	**+5.1**	**–27,161.8**	**–23,552.8**	**13.3**

Note: 1990 and 2010 areas are as at 31 December. Net area values include land in a state of conversion (due to land-use change prior to 1990) and afforestation and deforestation since 1990. Net emission estimates are for the whole year indicated. NA = not applicable. Columns may not add due to rounding.
(1) At the national scale, natural forest carbon stocks are assumed to be at steady state. Emissions associated with the conversion of natural forest are reported in the land-use category the land is converted to.

Table 7.3.3 shows New Zealand's carbon stock change by carbon pool within the forest land category from 1990 to 2010. From 1990 to 2010, the total carbon stock stored in forest land had increased by 167,292.8 Gg C, equivalent to emissions of –613,406.8 Gg CO_2 by forest land since 1990.

Table 7.3.3 New Zealand's net carbon stock change by carbon pool within the forest land category from 1990 to 2010

Forest land subcategory	Net carbon stock change 1990–2010 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2010 (Gg CO_2)
Natural forest[(1)]	NA	NA	NA	NA	NA
Pre-1990 planted forest	98,062.8	12,726.8	–2,439.4	108,350.2	–397,284.0
Post-1989 forest	49,778.6	14,531.5	–5,367.5	58,942.6	–216,122.8
Total	**147,841.4**	**27,258.3**	**–7,807.0**	**167,292.8**	**–613,406.8**

Note: NA = not applicable. (1) At the national scale, natural forest is assumed to be at steady state. Emissions associated with the conversion of natural forest are reported in the land-use category the land is converted to. Columns may not add due to rounding.

Natural forest

Natural forest is the term used to distinguish New Zealand's native and unplanted (self-sown or naturally regenerated) forests that existed prior to 1990 from pre-1990 planted and post-1989 forests. The category includes both mature forest and areas of regenerating vegetation that have the potential to return to forest under the management regime that existed in 1990. Natural forest ecosystems comprise a range of indigenous and some naturalised exotic species. In New Zealand, two principal types of natural forest exist: beech forests (mainly *Nothofagus* species) and podocarp/broadleaf forests. In addition, a wide range of seral plant communities fit into the natural forest category where they have the potential to succeed to forest *in situ*. At present, New Zealand has just under an estimated 8.1 million hectares of natural forest (including these successional communities).

In 2010, it was estimated that 0.07 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, 2011a). No timber is legally harvested from New Zealand's publicly owned natural forests (an area approximately 5.5 million hectares in size). Most other harvesting of natural forests is required by law to be undertaken on a sustainable basis. The only natural forest harvesting that is not required by law to be on a sustainable basis is the harvesting of forests on land returned to Māori under the South Island Landless Natives Act 1906. These forests are currently exempt from provisions that apply to all other privately owned natural forests that require a sustainable forest management plan or permit before any harvesting. Approximately 57,500 hectares are covered by the Act. A survey of this land was completed in 1999; this indicated that 17,300 hectares of this land was natural forest available for harvest (Ministry of Agriculture and Forestry, 2011c).The New Zealand Government provides assistance to the South Island Landless Natives Act 1906 forest owners who wish to develop sustainable forestry practices, and, because timber that is harvested without a sustainable forest management plan or permit cannot be exported, the unsustainable harvesting of natural forest has virtually ceased.

Harvesting under the sustainable forest plans and permits is restricted to the removal of growth and sometimes takes place on a selective logging basis. This means the area from where trees are extracted still meets the forest definition chosen by New Zealand. Therefore, over the long term, the carbon stored in these forests is in steady state.

Carbon stock change in natural forest remaining natural forest is not estimated, because, while we now have evidence that natural forests are not in steady state (preliminary analysis suggests they are a slight carbon sink (Beets et al, 2009)),we require the full set of plot re-measurement data to quantify carbon stock changes. The emissions associated with the conversion of natural forest to other land uses are reported in the land-use category the land was converted to.

Pre-1990 planted forest

New Zealand has a substantial estate of planted forests created specifically for timber supply purposes. In 2010, pre-1990 planted forests covered an estimated 1.45 million hectares of New Zealand (5.4 per cent of the total land area). New Zealand's planted forests are intensively managed and there is well-established data on the estate's extent and characteristics. Having a renewable timber resource has allowed New Zealand to protect and sustainably manage its natural forests. *Pinus radiata* is the dominant species, making up about 90 per cent of the planted forest area. These forests are usually composed of stands of trees of a single age class and all forests are subject to relatively standard silvicultural management regimes.

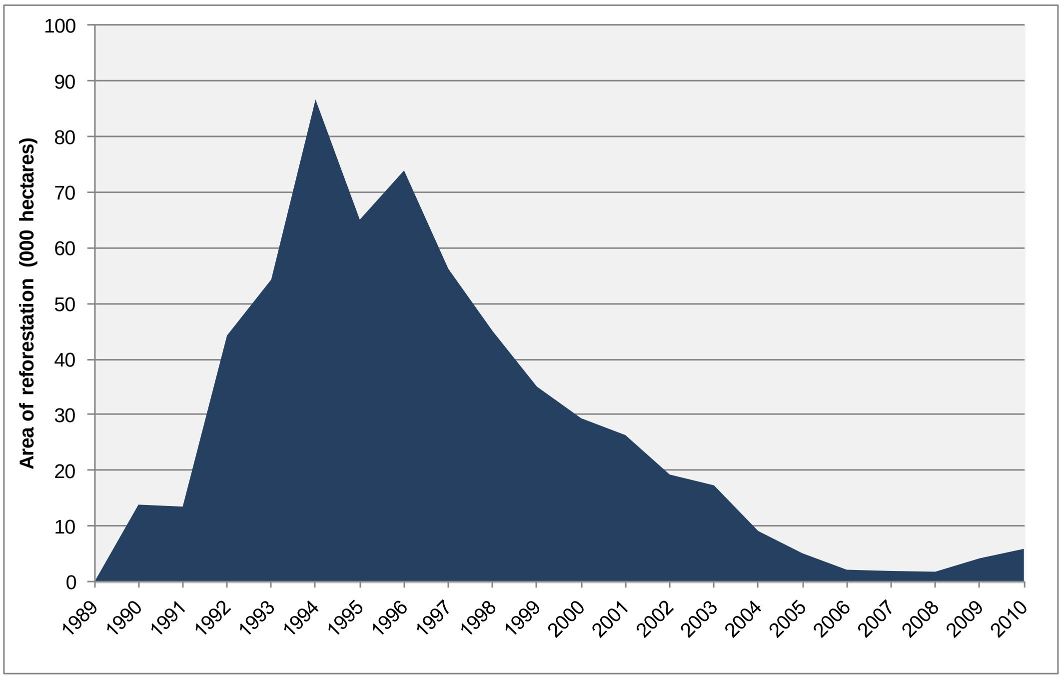
Post-1989 forest

Between 1 January 1990 and 31 December 2010, the net area of forest established as a result of reforestation activities was 593,821 hectares (taking into account deforestation of post-1989 forests). Based on the plots measured, 95 per cent of this forest subcategory comprises planted tree species (Paul et al, 2009), with the remaining area comprising regenerating native tree species. *Pinus radiata* comprises 89 per cent of the planted tree species in this forest subcategory, with Douglas-fir (*Pseudotsuga menziesii*) and *Eucalyptus* species being the two species making up most of the remainder (Ministry of Agriculture and Forestry, 2010).

The new forest planting rate (land reforested) between 1990 and 2010 was, on average, 29,000 hectares per year (figure 7.3.1). New planting rates were high from 1992 to 1998 (averaging 61,000 hectares per year). This followed a change in the taxation regime, an unprecedented price spike for forest products with subsequent favourable publicity, a government focus on forestry as an instrument for regional development and the conclusion of the state forest assets sale (Rhodes & Novis, 2002). The removal of agricultural subsidies and generally poor performance of the New Zealand and international share markets also encouraged investors to seek alternatives (Rhodes & Novis, 2002).

Since 1998, the rate of new planting declined rapidly, reaching a low of 1,900 hectares in 2008. In 2010, it was estimated that 6,000 hectares of new plantation forest were established (Ministry of Agriculture and Forestry, 2011b). This compares with 4,000 hectares of new planting in 2009 (Ministry of Agriculture and Forestry, 2010). The increase in planting between 2008 and 2010 is largely attributable to the NZ ETS, Afforestation Grants Scheme and Permanent Forest Sink Initiative that have been introduced by the New Zealand Government to encourage new planting and regeneration of natural species (Ministry of Agriculture and Forestry, 2009).

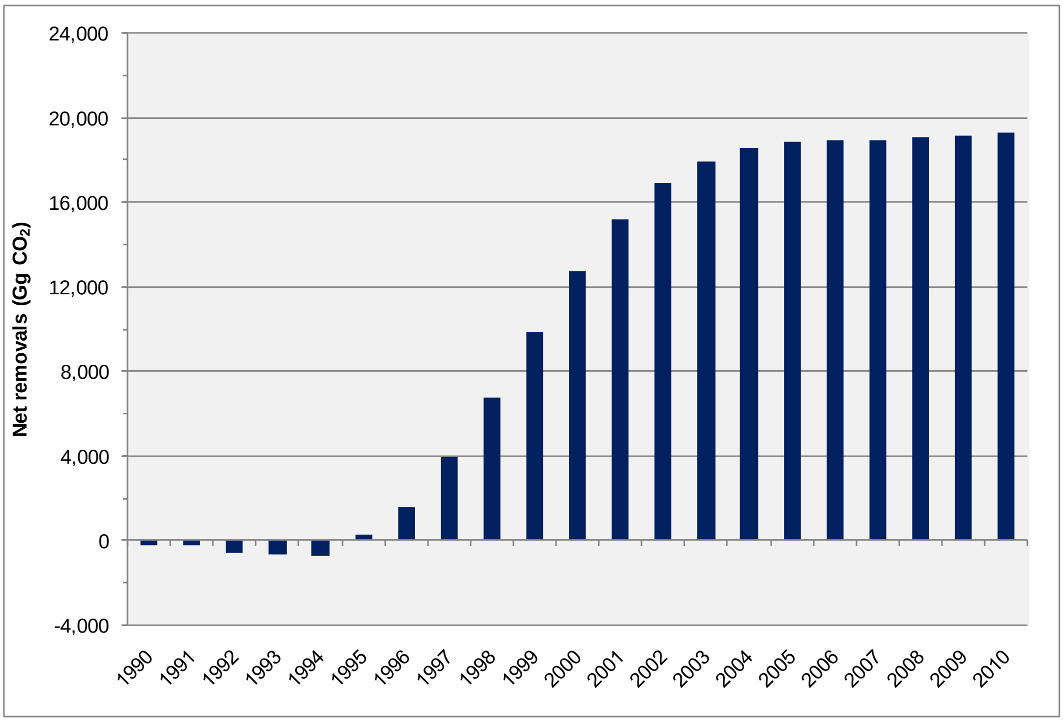
Figure 7.3.1 Annual areas of afforestation/reforestation in New Zealand from 1990 to 2010



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, 2011b) and have been scaled downwards using a ratio derived from the LUCAS mapping of post-1989 forest area.

The trend in removals is shown in figure 7.3.2. This graph shows that the post-1989 forests did not become a net sink until 1995. This was due to the emissions from loss of biomass carbon stocks associated with the previous land use and the change (loss) of soil carbon with a land-use change to forestry, outweighing removals by forest growth.

Figure 7.3.2 New Zealand's net CO_2 removals by post-1989 forests from 1990 to 2010



Deforestation

In 2010, 2,616 hectares of forest land were converted to other land uses, primarily grassland. Table 7.3.4 shows the areas of forest land subject to deforestation in 2010, and since 1990. The land uses that forest land has been converted to following deforestation are shown in tables 7.2.3 and 7.2.4 in section 7.2 – representation of land areas.

Table 7.3.4 New Zealand's forest land subject to deforestation

Forest land subcategory	Area of forest in 1990 (hectares)	Deforestation since 1990		Deforestation in 2010	
		Area (hectares)	Proportion of 1990 area (%)	Area (hectares)	Proportion of 1990 area (%)
Natural forest	8,139,762	37,424	0.46	240	0.00
Pre-1990 planted forest	1,476,113	55,369	3.75	1,157	0.08
Post-1989 forest	0	17,327	NA	1,220	NA
Total	**9,615,875**	**110,121**	**1.15**	**2,616**	**0.03**

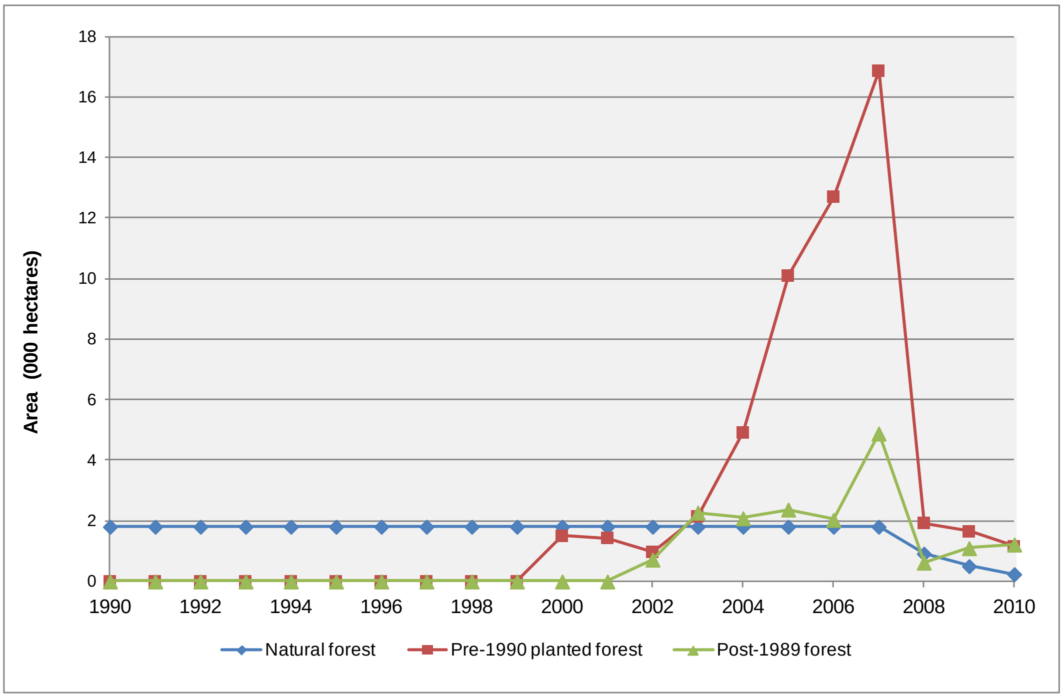
Note: 2010 areas are as at 31 December 2010, 1990 areas are as at 1 January 1990 and, therefore, differ from 1990 area values in the common reporting format tables, which are as at 31 December 1990. NA = not applicable. Columns may not add due to rounding.

The conversion of forest land to grassland is due in part to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry.

Figure 7.3.3 illustrates the increase in the planted forest deforestation that occurred leading up to 2008 and the decrease after the introduction of the NZ ETS in 2008.

During the remainder of the first Kyoto Protocol commitment period (2008–2012), it is expected that the level of planted forest deforestation will continue to be less than seen prior to the introduction of the NZ ETS in 2008 (Manley, 2009).

Figure 7.3.3 New Zealand's area of deforestation since 1990, by forest subcategory



The rate of natural forest deforestation has also decreased since 2007. A number of factors suggest that the rate of natural forest deforestation is unlikely to have been constant over the 18-year period between 1990 and 2007, but, instead, occurred mostly prior to 2002. As there is no information on what the deforestation profile for natural forests might have been between 1990 and 2007, the total area of deforestation detected over this period is allocated evenly across the years. The area available for harvesting (and potentially deforestation) was higher before 1993 when the Forests Act 1949 was amended to bring an end to unsustainable harvesting and deforestation of natural forest. Further restrictions to the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand in 2002. Both of these developments are likely to have reduced natural forest deforestation since 2002. The reduced rate of natural forest deforestation has been confirmed from 2008 to 2010 through satellite image mapping of deforestation (see figure 7.2.6 in section 7.2 – representation of land areas).

New Zealand assumes instant emissions of all biomass carbon at the time of deforestation, and soil carbon changes are modelled over a 20-year time period (refer to the section 7.1.3 – soils). The basis for this assumption is:

- the majority of deforestation since 2000 has resulted from land converted to high-producing grassland, resulting in the rapid removal of all biomass as the land is prepared for intensive dairy farming (see figure 7.2.4)
- it is not practical to estimate the volume of residues left on site after the deforestation activity, given the rapid conversion from one land use to another. Further estimating any residue biomass carbon pools and decay rates is difficult and costly
- there is insufficient data prior to 2008 to estimate deforestation biomass residue coming into the first commitment period. If a different approach was adopted for deforestation before and after 2008, this would raise issues around consistency and might not meet GPG-LULUCF.

These deforestation emissions are reported in the relevant ‘land converted to’ category, as are all emissions from land-use change. See section 11.1 of chapter 11 for further information on deforestation.

7.3.2 Methodological issues

Forest land remaining forest land

Only natural forest and pre-1990 planted forest are described in this section because land in the post-1989 forest subcategory is included in the ‘land converted to forest land’ category. Land areas converted to post-1989 forest had been in that land use for a maximum of 20 years in 2010 so are still within the land converted to forest land subcategory, given New Zealand has chosen 28 years as the time it takes for land to reach a state of equilibrium. Where there has been land-use change between natural forest and pre-1990 forest, the associated carbon changes are reported under forest land remaining forest land.

Land is transferred to the ‘land remaining’ category after a conversion period of 28 years. New Zealand has chosen 28 years as the time taken for land to reach a state of equilibrium (or maturity) under its new land use, as this is the average age at which the majority of planted forests are harvested (Ministry of Agriculture and Forestry, 2008).

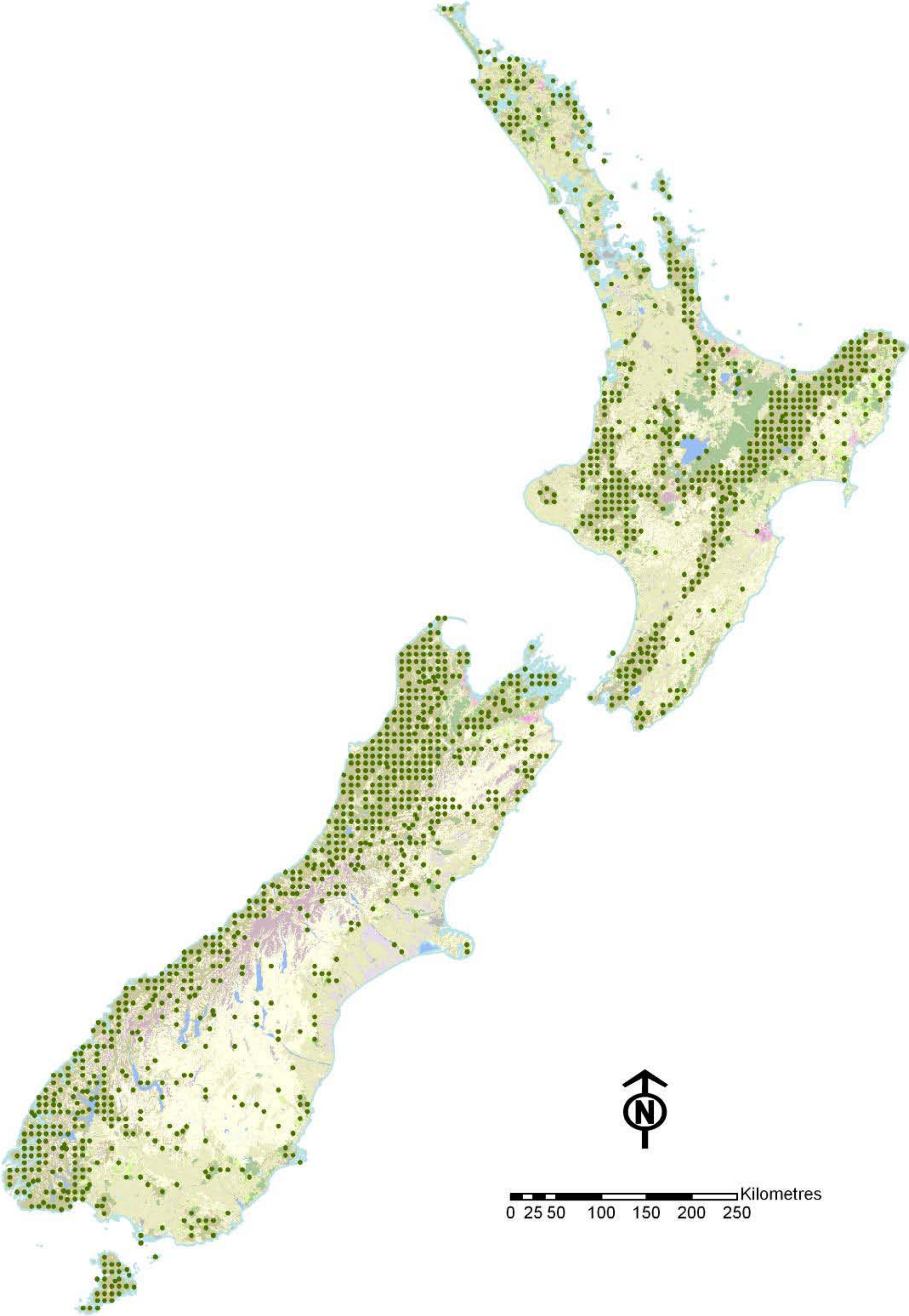
New Zealand has established a sampling framework for forest inventory purposes based on a grid system established across the country. The grid has a randomly selected origin and provides an unbiased framework for establishing plots for field and/or Light Detection and Ranging (LiDAR) measurements. The grid is an 8-kilometre grid, with divisions on a 4-kilometre grid being used for measurement of post-1989 forest areas. Pre-1990 planted forests were sampled in 2010, and the results from the analysis of the data collected have provided, for the first time, a plot-based estimate of carbon stock and mean carbon density within this forest subcategory.

Natural forest

A national monitoring programme to enable unbiased estimates of carbon stock and change for New Zealand's natural forests was developed between 1998 and 2001 (Goulding et al, 2001). There were 1,255 permanent sample plots installed systematically on the 8-kilometre grid across New Zealand's natural forests and these were first measured between 2002 and 2007.

The plots were sampled using a method designed specifically for the purpose of calculating carbon stocks (Payton & Moss, 2001; Payton et al, 2004b). As the plot network is re-measured, the data collected will be suitable for determining if New Zealand's natural forests are carbon neutral (as assumed in this submission), or whether they are a net source of emissions or a sink for carbon. Where possible, the network incorporated plots that had been previously established and re-measured them during the establishment phase of the national network to enable an initial assessment of forest changes over time. Figure 7.3.4 shows the distribution of the carbon monitoring plots throughout New Zealand.

Figure 7.3.4 Location of New Zealand's natural forest carbon monitoring plots



Re-measurement of the national plot network has begun. The re-measurement programme will run from 2009–2014 following methodology revised for this purpose (Payton & Brandon, 2010). Once field work has been completed and the data has been quality-assured and analysed, national carbon estimates will be updated for the 2012 inventory (to be submitted in 2014).

At each plot, data is collected to calculate the volumes of trees, shrubs and dead organic matter present. These measurements are then used to estimate the carbon stocks for the following biomass pools:

- living biomass (comprising above-ground biomass and below-ground biomass)
- dead organic matter (comprising dead wood and litter).

Table 7.3.5 summarises the method used to calculate the carbon stock in each biomass pool from the information collected at each plot.

Table 7.3.5 Summary of methods used to calculate New Zealand's natural forest biomass carbon stock from plot data

Pool		Method	Source
Living biomass	Above-ground biomass	Plot measurements; Allometric equations	Beets et al, 2009
	Below-ground biomass	Assumed to be 20 per cent of total biomass	Coomes et al, 2002
Dead organic matter	Dead wood	Plot measurements; Allometric equations	Beets et al, 2009
	Litter	Plot samples; Laboratory analysis of samples collected at plots (Garrett et al, 2009)	Beets et al, 2009

Living biomass

Living biomass is separated into two carbon pools:

- above-ground biomass: the carbon content of individual trees and shrubs is calculated using species-specific allometric relationships between diameter, height and wood density (for trees), a non-specific conversion factor with diameter and height (for tree ferns), or volume and biomass (for shrubs) (Beets et al, 2009). Shrub volumes are converted to carbon stocks using species and/or site-specific conversion factors, determined from the destructive harvesting of reference samples
- below-ground biomass is derived from above-ground biomass and is assumed to be 25 per cent of above-ground biomass (or 20 per cent of total biomass). This value is based on studies that report root to total biomass ratios of 9 to 33 per cent (Coomes et al, 2002). Coomes et al (2002) acknowledge more work is needed but use the average of the cited studies to justify allocating 20 per cent of total biomass to below-ground biomass.

Dead organic matter

Dead organic matter is separated into two pools.

- dead wood: the carbon content of dead standing trees is determined in the same way as live trees but excludes branch and foliage biomass calculations. The carbon content of the fallen wood and stumps is derived from the volume of the piece of wood, its species (if able to be identified) and what stage of decay it is at. Dead wood comprises woody debris with a diameter greater than 10 centimetres

- litter: the carbon content of the fine debris is calculated by laboratory analysis of sampled material. Litter comprises fine woody debris (dead wood from 2.5 to 10 centimetres in diameter), the litter (all material less than 2.5 centimetres in diameter) and the fermented humic horizons. Samples were taken at approximately one-third of the natural forest plots.

Biomass carbon stocks in New Zealand's natural forests (excluding the soils pool) of 173 (±6) t C ha^{-1} were estimated from the first full round of measurements (Beets et al, 2009) and this data is used for this report. The subset of plots for historic data that exist were separately analysed to estimate the change. Thirteen per cent of the natural forest LUCAS plots were used in the analysis, which found that natural forests in New Zealand were a net carbon sink between 1990 and 2004 (Beets et al, 2009). Until the entire plot network has been re-measured, New Zealand will continue to report natural forests remaining natural forests as carbon neutral and, therefore, no removals or emissions are estimated in this submission.

Soil organic carbon

Mineral soil organic carbon stocks in natural forest land remaining natural forest land are estimated using a Tier 1 method that draws on IPCC default values. The steady state mineral soil carbon stock in natural forest is estimated to be 92.59 t C ha^{-1}.

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with the drainage of organic soils in managed forests (IPCC, 2003, section 3.2.1.3). In New Zealand, natural forests are not drained, and therefore oxidation processes associated with drainage are not occurring. It is therefore assumed that there are no carbon emissions from organic soils in natural forest remaining natural forest.

Natural forest carbon

Total carbon stocks in natural forest are determined by multiplying the area of natural forest land remaining natural forest land by the emission factors for each pool to give a national total.

Non-CO_2 emissions for natural forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use, and therefore all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the category 'direct soils emissions'.

Biomass burning

No emissions are reported for controlled burning in forest land remaining forest land in New Zealand. This practice is not common and there has been no data available on this activity (Wakelin et al, 2009). New Zealand currently reports the notation key NE (not estimated) for controlled burning emissions in the common reporting format tables. Investigations are under way to identify and source, if available, controlled burning data in forest land remaining forest land.

For wildfire in the natural forest subcategory, activity data is sourced from the National Rural Fire Authority (NRFA) database, which has data from 1992 onwards. The average area burnt between 1992 and 2009 from this database is used as the estimate of area burnt for 1990 to 1991 as the estimates for this period are inaccurate because of incomplete coverage in data collection. The April year data is then converted to calendar years for use in the inventory (Wakelin et al, 2009).

The inventory reports only non-CO_2 emissions resulting from wildfire for this subcategory. Carbon dioxide emissions from wildfire in natural forest are not reported because the subsequent regrowth is not captured in the inventory (GPG-LULUCF, section 3.2.1.4.2, IPCC, 2003). In these cases, the notation key IE (included elsewhere) is used. See section 7.9.5 for further details on biomass burning.

Pre-1990 planted forest

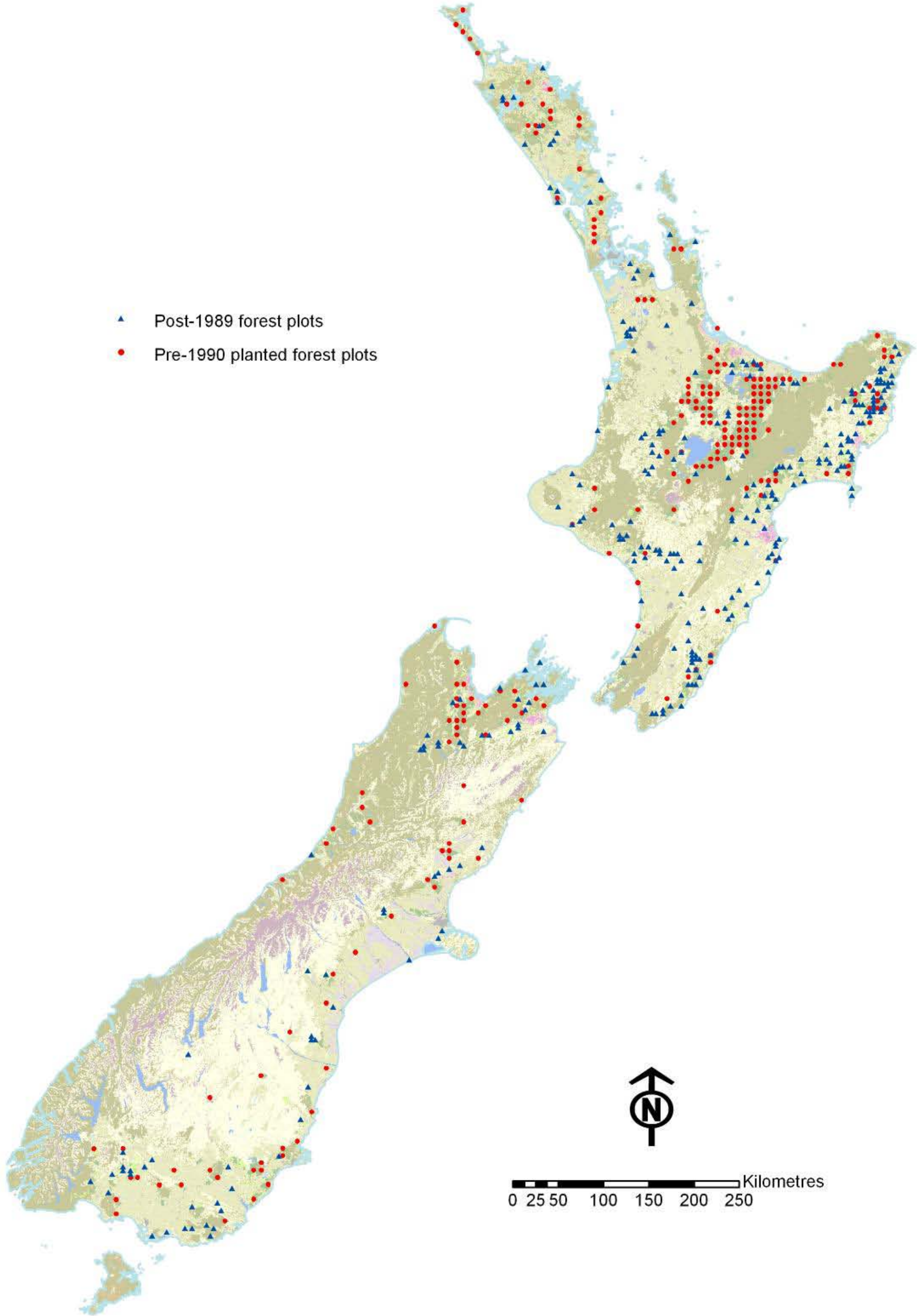
All planted forest land established prior to 1990 whether established for wood production or soil control purposes is included in the pre-1990 planted forests subcategory. This subcategory also includes areas that were natural forest in 1990 but have since been planted with exotic planted forest. The emissions associated with this area are calculated as the removal of biomass associated with natural forest and the subsequent growth of pre-1990 planted forest. The pre-1990 planted forest yield table is thought to best represent the forest growth on ex-natural forest land because it remains in the forest land category, as opposed to the post-1989 forest yield table, which represents new forest growth mostly on land that originates from the grassland category (see table 7.2.3).

Pre-1990 planted forest inventory

New Zealand's pre-1990 planted forests were sampled in 2010, and the analysis of the data collected has provided, for the first time, a plot-based estimate of carbon stock and mean carbon density within this forest subcategory. The pre-1990 inventory is closely linked, in terms of design and methodology, with the post-1989 forest inventory described later. A double sampling or two-phase sampling approach (described later, see LiDAR double sampling) is employed in the pre-1990 planted forest inventory to improve the precision of the carbon stock and carbon density estimates and reduce the overall cost of the inventory.

For the pre-1990 planted forest inventory, 192 circular 0.06 hectare plots (see figure 7.3.5) were established on a systematic 8-kilometre grid consistent with that used for all forest subcategories. These plots were ground measured using procedures as described in Payton et al, 2008. Stand records and ground measurements were recorded between June and September 2010 at each plot. Measurements included: tree age; stocking (stems per hectare); stem diameters of live and dead trees at breast height; a sample of tree total heights for each tree species; pruned heights; and the timing of pruning and thinning activities. Ground plot centres were located using a 12-channel differential GPS for accurate LiDAR co-location and relocation for future measurements.

Figure 7.3.5 Location of New Zealand's pre-1990 planted forest and post-1989 forest plots



Airborne scanning LiDAR data was collected from 893 plots, including those that were ground measured. The LiDAR only plots are located on a 1 kilometre (north-south) by 8 kilometre (east-west) grid within the mapped area of pre-1990 planted forest.

Living biomass and dead organic matter

The crop tree plot data collected from the planted forest inventories was modelled using a forest carbon modelling system called the 'Forest Carbon Predictor', version 3 (FCPv3) (Beets & Kimberley, 2011), developed for *Pinus radiata*, the most common plantation tree species in New Zealand. This integrates the 300 Index Growth Model (Kimberley et al., 2005), a wood density model (Beets et al, 2007a), a stand tending model (Beets & Kimberley, 2011) and the C_Change carbon allocation model (Beets et al, 1999), to enable predictions of carbon stocks and changes in New Zealand's planted forests.

The improvements over the previous version of the Forest Carbon Predictor (FCPv2.2) include; temperature-dependent decay functions; species-specific growth trajectory and biomass adjustments; new breast height pith-to-bark density functions; and a stand tending module (Beets & Kimberley, 2011).

The individual components of the Forest Carbon Predictor are explained below.

The 300 Index Growth Model produces a productivity index for forest plots derived from stand parameters. Stand parameters gathered from the national planted forest plot network are inputted into the 300 Index Growth Model. These inputs include: stand age, mean top height, basal area, stocking and stand silvicultural history. Plot latitude and altitude are also required to run the model. The 300 Index Growth Model uses these parameters to predict stem volume under bark over a full rotation (planting to harvest). A specific productivity index (or 300 Index) is produced for each plot, which is used to estimate the total live and dead stem volume by annual increment. The 300 Index Growth Model accounts for past and future silviculture treatments using plot data, information on past silvicultural treatments and assumptions of future management events based on plot observations and standard regimes. As Douglas-fir is the second most common plantation species in New Zealand a specific Douglas-fir module has been incorporated into the 300 Index Growth Model for the 2012 submission. This includes a specific growth trajectory for plots containing that species (Beets & Kimberley, 2011).

The wood density model within the Forest Carbon Predictor uses site mean annual temperature, soil nitrogen fertility, ring age and stocking to determine the mean density of stem wood growth sheaths produced annually in *Pinus radiata*. Wood density is an important variable in the estimation of carbon. Of the parameters inputted into the wood density model, temperature and stand age have the greatest influence on wood density, followed by site fertility and stocking. The influence of the individual effects on wood density is provided in table 7.3.6. The combined result of these individual effects can be large. For example, the 15-year growth sheath of a stand of standard genetics *Pinus radiata* at a low stocking (200 stems ha^{-1}) on a fertile (C/N=12), cool (8°C) site has a predicted wood density of 339 kg m^{-3}, while a stand of the same age and genetics at a high stocking (500 stems ha^{-1}) on a moderately fertile (C/N=25), warm (16°C) site has a predicted wood density of 467 kg m^{-3} (Beets et al, 2007a).

Table 7.3.6 Influence of individual site and management factors on predicted wood density for New Zealand planted forest

Factor affecting wood density	Range in predicted density (kg m^{-3})	Range in predicted density (% difference)
Temperature: 8°C versus 16°C	359–439	22
Age: 10-year old versus 30-year old	380–446	17
C/N ratio: 12 versus 25	384–418	9
Stocking: 200 versus 500 stems ha^{-1}	395–411	4

New Zealand's plantation forests are intensively managed and therefore pruning and thinning provides the majority of the inputs to the deadwood and litter pools. The Forest Carbon Predictor requires silvicultural history inputs in order to predict changes between biomass pools over time. The information required includes initial stocking, the timing of management events, stocking following each thinning operation, and the pruned height and number of stems pruned for each pruning lift. Information on silvicultural events prior to the plot measurement date is normally gathered from forest owners but sometimes this data is incomplete. A history module has been incorporated into the FCPv3 that makes use of existing data to identify potential gaps in the stand history. Within the history module, assumptions are made to complete the stand history based on field observations, standard management regimes and known silviculture to date (Beets & Kimberley, 2011). The history module enables reasonable estimates of stand history and, therefore, biomass transfers between pools resulting from past silvicultural events.

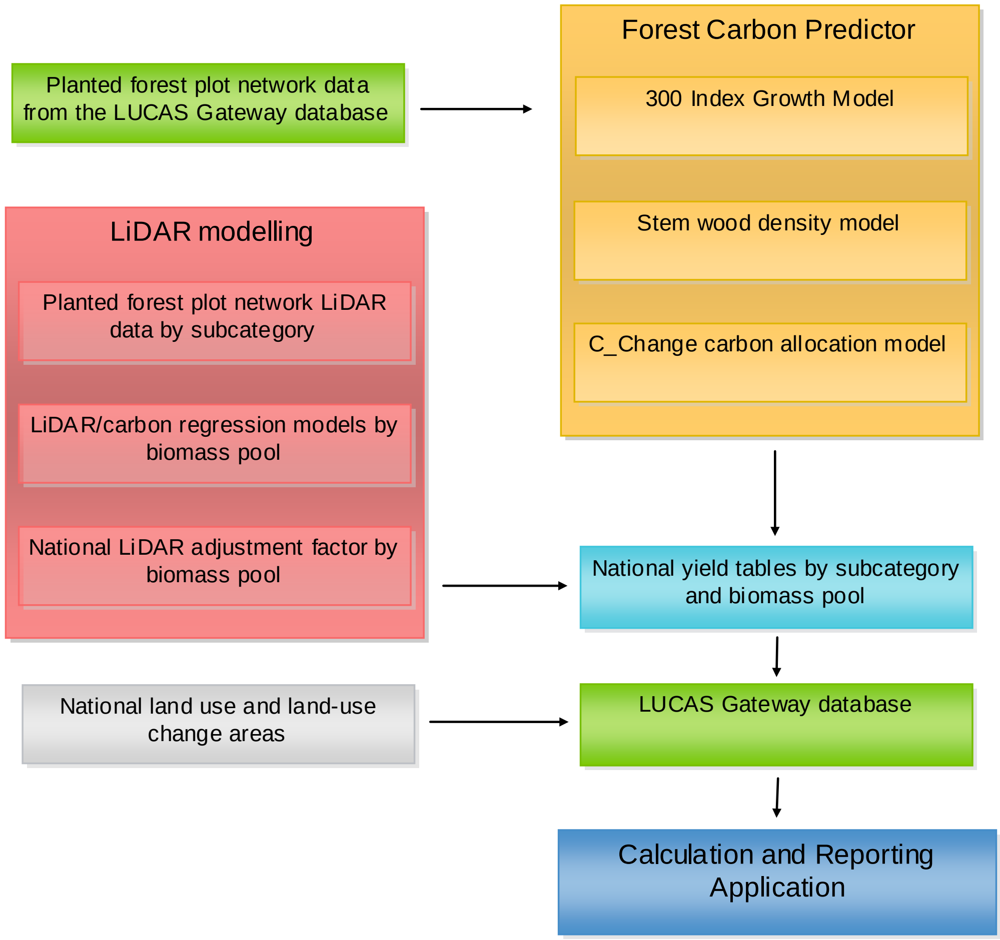
The C_Change carbon allocation model is integrated into the Forest Carbon Predictor and is designed to apportion carbon to needles, branches, stems, roots and reproductive parts via growth partitioning functions. Dead wood and litter pools are estimated by accounting for losses to the live pools from natural mortality, disease effects on needle retention, branch and crown mortality and silvicultural management activities, for example, pruning and thinning. Component-specific and temperature-dependent decay functions are used to estimate losses of carbon to the atmosphere (Beets et al, 1999). The Forest Carbon Predictor also takes into account biomass removals during production thinning. For the 2012 submission, Douglas-fir adjustment factors have been added to C_Change to more accurately estimate live and dead biomass in plots that contain this species. These include adjustment factors for stem wood plus bark, crown needles, live and dead branches and root:shoot ratio (Beets & Kimberley, 2011).

The individual plot yield curves generated by the Forest Carbon Predictor are combined into estimates of above-ground live biomass, below-ground live biomass, deadwood and litter in an area-weighted and age-based carbon yield table for each planted forest subcategory. Estimates from plots in unstocked areas within the mapped forest boundary are included in the summarised yield table (T Paul, New Zealand Forest Research Institute, pers. comm., 12 January 2012).

Below-ground biomass is derived from the above-ground biomass estimates. For plantation crop trees, the above- to below-ground biomass ratio is 5:1 (Beets et al, 2007b). The ratio for non-crop trees and shrubs is 4:1 (Coomes et al, 2002).

The carbon content of the dead wood pool within rotation is estimated using the FCPv3 model as described above. Immediately following harvesting, 30 per cent of the above-ground biomass pool is transferred to the dead wood pool; with the other 70 per cent being instantaneously emitted (Wakelin & Garrett, 2010). All material in the deadwood and litter pools is decayed using an empirically derived, temperature-dependent decay profile as described in Garrett et al, 2010.

Figure 7.3.6 New Zealand's planted forest inventory modelling process



Analysis by Paul & Kimberley, 2009, has demonstrated that using the Forest Carbon Predictor for all planted forest tree species produces an average t C ha^{-1} value similar to the values produced using more specific carbon models and/or allometric equations for non-radiata species (mainly Douglas-fir (*Pseudotsuga menziesii*) and eucalypts (*Eucalyptus* spp.)). The authors established there was a marginal decrease (0.77 t C ha^{-1}) in the average amount of carbon removals per plot using the one model for all planted forest species. Since this analysis, a correction factor for the growth trajectory and biomass of Douglas-fir in the 300 Index has been implemented. New Zealand is currently investigating the reporting of the post-1989 forest and pre-1990 planted forest subcategories by species.

For shrubs and non-crop tree species measured within the planted forest plot network, the carbon content is estimated using species-specific allometric equations. These equations estimate carbon content from diameter and height measurements, and wood density by species (Beets et al, 2008).

When non-forest land is converted to forest land, all living biomass that was present at the time of forest establishment is assumed to be instantly emitted as a result of forest land preparation. Between 1990 and 2010, approximately 30 per cent of the non-forest land converted to post-1989 forest has been from grassland with woody biomass, and this land-use subcategory provides the largest source of emissions associated with land-use change to forestry.

LiDAR double sampling

The outputs of the FCPv3 and LiDAR metrics are used to develop subcategory-specific regression models that are used in a double-sampling framework to improve the precision of carbon stock and stock change estimates in pre-1990 planted forests.

The analysis of the pre-1990 planted forest ground and LiDAR data closely followed that of the post-1989 analysis, where regression models were developed for total carbon and each of the four biomass pools. Good relationships were found between carbon stocks estimated using ground-based measurements and LiDAR metrics in pre-1990 planted forests. The LiDAR metric found to most accurately predict total carbon was a height metric. Additional variation was also explained by a canopy cover metric. With these metrics combined a regression model was developed to explain 81 per cent of the variation in total carbon.

Regression models applied to the above- and below-ground biomass pools provided good correlations with R^2 values around 80 per cent. The model was less successful predicting deadwood and litter, with R^2 values of 18 and 48 per cent respectively. This was also the case in the post-1989 inventory. The regression models employed in this analysis used the same model form for both forest types with carbon in the four biomass pools summed to total carbon. In the pre-1990 planted forest inventory, the LiDAR metric, 95th height percentile, had a very high correlation with ground measured mean top height with an R^2 of 96 per cent (Kimberley, 2011).

The double-sampling approach used to sample pre-1990 forests utilised nearly four times as many LiDAR plots as ground plots and, therefore, produced carbon estimates with improved precision when compared with an analysis based on the ground plots alone. The confidence interval for the estimate reduced from 14.1 per cent to 11.1 per cent with the addition of LiDAR (Kimberley, 2011).

The double-sampling approach improves the precision of the national plot-based yield table by applying an adjustment factor derived from the LiDAR regression models. The yield table was adjusted to include the additional information obtained from the LiDAR only plots by using a multiplier based on the ratio of the LiDAR regression estimate to the ground-based estimate (0.9984). The end result is a LiDAR-adjusted national yield table for pre-1990 planted forest (Kimberley, 2011).

The carbon stock in pre-1990 planted forest as at 1 January 2008, estimated from the national plot network, is 123.97 ± 9.93 t C ha^{-1} (at the 95 per cent confidence interval). The average age of pre-1990 planted forest is 15.2 years as at 1 January 2008 (Paul et al, 2011).

Soil organic carbon

Soil carbon stocks in pre-1990 planted forest land remaining pre-1990 planted forest land are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3 – soils. The steady state mineral soil carbon stock in pre-1990 planted forest is estimated to be 92.59 t C ha^{-1} (table 7.1.7).

The IPCC default emission factor for organic soils under planted forest is 0.68 t C ha^{-1} per annum. Soil carbon change with harvesting is not explicitly estimated, as the long-term soil carbon stock for this land use includes any emissions associated with harvesting.

Non-CO_2 emissions for pre-1990 planted forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use, and therefore all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the category 'direct soils emissions'.

Biomass burning

No emissions are reported for controlled burning in forest land remaining forest land in New Zealand. This practice is not common and there has been no data available on this activity (Wakelin et al, 2009). New Zealand currently reports the notation key NE (not estimated) for controlled burning emissions in the common reporting format tables. Investigations are under way to identify and source, if available, controlled burning data in forest land remaining forest land.

The inventory reports emissions resulting from wildfire for this category. New Zealand estimates non-CO_2 emissions from wildfire using:

- the IPCC default temperate forest fuel consumption rate of 45 per cent of total biomass (IPCC, 2003, table 3A.1.12)
- wildfire activity data for May 1991 to April 2011. 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. in Wakelin et al, 2009).

Carbon dioxide emissions from wildfire in planted forest are captured by the stock change calculation at the time of clear-fell, as there is no reduction in carbon stock for areas burnt prior to harvesting or deforestation. The total area of wildfires in planted forest is small and this is not regarded as a significant source of error in carbon dioxide emissions. See section 7.9.5 for further details on biomass burning.

Land converted to forest land

Post-1989 forests

All land converted to forest land since 1 January 1990, either by planting or as a result of human-induced changes in land-management practice (eg, removing grazing stock and allowing revegetation of tree species), is included in the post-1989 forest subcategory.

Living biomass and dead organic matter

The majority of post-1989 forests in New Zealand are privately owned and ground access cannot be guaranteed. A double-sampling approach involving LiDAR and ground-based measurements has been employed to reduce the possibility of sampling bias arising from unmeasured plots. This approach enables data to be gathered from sample points when ground access is restricted while simultaneously improving the precision of the carbon stock estimates (Stephens et al, 2012).

The double-sampling approach used in the post-1989 forest inventory is described in detail in Stephens et al, 2012. The approach follows that described in Parker and Evans, 2004, and Corona and Fattorini, 2008. Double sampling combines ground-based plot measurements with auxiliary data (LiDAR) obtained from a larger sample of the population. The auxiliary data is used to improve the precision of the forest carbon estimates when compared with those based on ground measurements alone. Regression or ratio estimators, based on ground-measured variables and LiDAR parameters, are utilised to improve the precision of the carbon stock estimates. The approach relies on good relationships between LiDAR parameters and ground-measured variables (Stephens et al, 2012). These relationships were verified during pilot studies carried out in two geographically separate study areas independent of the post-1989 and pre-1990 planted forest plot networks during 2006 and 2007 (Stephens et al, 2007). The pilot studies were also used to develop the plot design and the measurement methodology used in both the post-1989 and pre-1990 planted forest inventories.

A plot-based forest inventory system has been developed for carbon estimation in New Zealand's post-1989 forest and is described in detail in Beets et al, 2011a. In the inventory circular, 0.06 hectares of permanent sample plots have been established within post-1989 forests on a systematic 4-kilometre square grid coincident with that used for the natural forest and pre-1990 planted forest inventories (Moore & Goulding, 2005). Permanent sample plots were selected over temporary sample plots because historical trend data are more easily analysed for change in plots with multiple measurements (Beets et al, 2011a).

The initial post-1989 forest inventory was carried out during the winters of 2007 and 2008. There were 246 plots ground sampled using methodology as described in Payton et al, 2008. The ground measurements included: stem diameters of live and dead trees at breast height; a sample of tree total heights for each tree species; pruned heights, measurement of deadwood and soil fertility samples for predicting wood density (Beets et al, 2007a). Silvicultural information including tree age, stocking (stems per hectare) and timing of pruning and thinning activities were gathered from the individual forest owners. Ground plot centres were located using a 12-channel differential GPS for sub-meter LiDAR co-location and for relocation in future inventories.

LiDAR data was captured from 292 plots (see figure 7.3.5), including those that were ground sampled (Beets et al, 2011a). LiDAR data was acquired at a minimum of three points (or returns) per square metre. Aerial photography, at 200 millimetre resolution, was captured at the same time to aid in data analysis and for plot centre location during ground sampling.

At the time of the initial post-1989 forest inventory, the mapped area of the post-1989 forest had not been defined. Subsequent remapping of post-1989 forest has resulted in 140 additional plots that will be established during the post-1989 forest plot re-measurement during the winters of 2011 and 2012. Re-measurement will provide a plot-based estimate of carbon stock change for the 2013 and 2014 submissions. Stock change in post-1989 forests is currently estimated using a subcategory-specific national yield table approach similar to that described in *Living biomass and dead organic matter* in the pre-1990 planted forest section above.

LiDAR double sampling

The outputs of the FCPv3 and LiDAR metrics are used to develop subcategory-specific regression models to improve the precision of carbon stock and stock change estimates in post-1989 planted forests.

Good relationships were found between carbon stocks from ground-based tree measurements and LiDAR metrics for post-1989 forests. The best fitting LiDAR metric for predicting total carbon was a height metric (the 30th height percentile), but significant variation was also explained by a canopy cover metric (percent cover). A regression model explaining 74 per cent of the variation in total carbon was developed using these two LiDAR metrics (Stephens et al, 2012).

Regression models using the same model form were fitted for each of the four biomass pools, providing good predictions for above-ground biomass carbon (R^2=81 per cent and below-ground biomass carbon (R^2=80 per cent), but less successful predictions for litter carbon (R^2=38 per cent) and dead wood carbon (R^2=21 per cent). The R^2 for the regression between the LiDAR metric, 95th height percentile, and mean top height calculated from ground measurements was 96 per cent, with a root mean square error of 1.09 metres (Stephens et al, 2012).

These regression models were used to obtain estimates, as at 1 January 2008, of the national level of carbon stock in the post-1989 forests using double-sampling procedures, and to develop a national age-based and area-weighted carbon yield table for the subcategory. Carbon estimates from 246 ground plots were supplemented with LiDAR data from 46 additional plots. The regression estimators (using the LiDAR data) improved precision by 6 per cent compared with the ground-based estimates alone. The carbon stock estimate derived from LiDAR 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 ground-measured plot data is 88.46 ± 2.94 t C ha^{-1} (Beets et al, 2011a). This carbon stock estimate, while high, is consistent with the international comparisons provided in table 3A.1.4 (IPCC, 2003) and reflects the composition of the forest subcategory made up of 95 per cent actively managed production forestry. The average age of post-1989 forest trees as at 1 January 2008 is 12 years (Paul et al, 2009).

Quality assurance and quality control

Quality-assurance and quality-control activities were conducted throughout the post-1989 forest data capture and processing steps. These activities were associated with the following: inventory design (Moore & Goulding, 2005, Brack, 2009); acquisition of raw LiDAR data and LiDAR processing; checking eligibility of plots; independent audits of field plot measurements; data processing and modelling; and regression analysis and double-sampling procedures (Woollens, 2009); and investigating LiDAR and ground plot co-location (Brack & Broadley, 2010). These activities are described more fully in section 7.3.4.

Soil organic carbon

Soil carbon stocks in land converted to post-1989 forest are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3 – soils. The steady state mineral soil carbon stock in post-1989 forest is estimated to be 92.59 t C ha^{-1} (table 7.1.7).

In the absence of country- and land-use specific data on the time rate of change, the IPCC default method of a linear change over a 20-year period is used to estimate the change in soil organic carbon stocks between the original land use and planted forest land for any given period. For example, the soil carbon change associated with a land-use change from low-producing grassland (soil carbon stock 105.55 t C ha^{-1}) to planted forest (soil carbon stock 92.59 t C ha^{-1}), would be a loss of 12.97 t C ha^{-1} over the 20-year period.

The IPCC default emission factor for organic soils under planted forest is 0.68 t C ha^{-1} per annum. This is also applied to organic soils on land converted to post-1989 forest.

Non-CO_2 emissions for post-1989 forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use, and, therefore, all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the category ‘direct soils emissions’.

Biomass burning

In New Zealand, it is assumed that 25 per cent of grassland with woody biomass converted to forest land is cleared using controlled burning (Wakelin, 2006). New Zealand is currently investigating a data source to refine the assumption for this activity. A country-specific fuel consumption rate of 70 per cent of above-ground biomass is used to estimate emissions from controlled burning. The remainder (30 per cent of above-ground biomass) and all biomass on un-burned sites is instantly emitted at conversion (IPCC Tier 1 default, section 3.6.2, IPCC, 2003).

Non-CO_2 emissions from wildfires in land converted to forest land are reported under the post-1989 forest subcategory for the first time in the 2012 submission. The activity data does not distinguish between forest land subcategories. Therefore, non-CO_2 emissions resulting from wildfire are attributed to the post-1989 forest subcategory by the proportion of area of post-1989 forest in relation to the total forest area. An age-based carbon-yield table is then used to estimate non-CO_2 emissions in post-1989 forest. This approach assumes that the carbon stock affected by wildfire is equivalent to the carbon stock at the average stand age each year throughout the time series.

Carbon dioxide emissions resulting from wildfire events are not reported, as the methods applied do not capture subsequent regrowth (IPCC, 2003, GPG-LULUCF, section 3.2.1.4.2). See section 7.9.5 for further details on biomass burning.

7.3.3 Uncertainties and time-series consistency

Emissions from forest land are 10.9 per cent of New Zealand’s net emissions uncertainty in 2010 (annex 7). Forest land introduces 5.2 per cent uncertainty into the trend in the national total from 1990 to 2010. This is the largest impact on the trend and second largest impact on the 2010 net emissions following agricultural soils.

Natural forest

The uncertainty in mapping natural forest is ± 4 per cent. More details on this are given in section 7.2.5.

The natural forest plot network provides biomass carbon stock estimates that are within 95 per cent confidence intervals of 3.63 per cent of the mean (173 ± 6.27 t C ha^{-1}) in natural forests (Beets et al, 2009). Natural forests are assumed to be in steady state, therefore, no emissions are reported from this forest type and no uncertainty is introduced into net emissions from this land-use subcategory.

The uncertainty in soil carbon stocks for natural forests is ± 95.0 per cent. This is the IPCC default uncertainty.

Table 7.3.7 Uncertainty in New Zealand's 2010 estimates from natural forest

Variable	Value	Uncertainty at a 95% confidence interval
Activity data		
Uncertainty in land area	8,084,403 ha	4.0%
Uncertainty introduced into net LULUCF emissions	–19,980.5 Gg CO_2-e	0.0%
Emission factors		
Uncertainty in biomass carbon stocks	173 t C ha^{-1}	3.6%
Uncertainty in soil carbon stocks	92.6 t C ha^{-1}	95.0%
Uncertainty in liming emissions	NO	
Uncertainty introduced into net LULUCF emissions	–19,980.5 Gg CO_2-e	0.0%

Note: NO = not occurring.

Pre-1990 planted forest

A national plot-based inventory system in conjunction with a suite of models is being used to estimate carbon stock and change within New Zealand's planted forest. These models are collectively called the Forest Carbon Predictor version 3 (Beets & Kimberley, 2011) and are described in more detail in *Living biomass and dead organic matter* in the pre-1990 planted forest section above. Extensive work has been carried out to reduce the uncertainty in the estimates including the use of a specifically designed plot network and research-based improvements to the models.

New Zealand's pre-1990 planted forests were sampled in 2010 and the analysis of the data collected has provided, for the first time, a plot-based estimate of carbon stock within this forest subcategory. This has reduced the uncertainty of the biomass estimates and growth from the previous estimate based on the National Exotic Forest Description (Ministry of Agriculture and Forestry, 2010). Double sampling using airborne scanning LiDAR is employed in the pre-1990 planted forest inventory to further improve the precision of the carbon stock estimates over that obtained using ground measurements alone. The confidence interval for the estimate reduced from 14.1 per cent to 11.1 per cent with the addition of LiDAR (Kimberley, 2011).

Recently, a Forest Carbon Predictor validation paper was accepted for publication (Beets et al, 2011b) that describes the recent improvements to the models and the associated improvement in precision. This study found that estimates of total carbon stock per plot were predicted with an accuracy of approximately 5 per cent using the Forest Carbon Predictor. The Forest Carbon Predictor provides estimates of above-ground biomass per plot with an accuracy of approximately 1 per cent. Carbon stock change was estimated within 5 per cent accuracy when linked with plot data at the start and end of each five-year period, linking closely with the scheduled duration between the national plot-based inventories (Moore & Goulding, 2005).

The accuracy associated with the Forest Carbon Predictor and the pre-1990 planted forest inventory data for the 2012 submission are provided in table 7.3.8.

Table 7.3.8 Uncertainty in New Zealand's 2010 estimates from pre-1990 planted forest

Variable	Value	Uncertainty at a 95% confidence interval
Activity data uncertainty		
Uncertainty in land area	1,441,894 ha	7.0%
Uncertainty introduced into net LULUCF emissions	–19,980.5 Gg CO_2-e	11.3%
Emission factor uncertainty		
Uncertainty in biomass accumulation rates	Varies by age	14.1% based on:
Modelling		5.0%
Sampling		11.1%
Forecasting		5.0%
National statistics		5.0%
Uncertainty in soil carbon stocks	92.6 t C ha^{-1}	95.0%
Uncertainty in liming emissions		NO
Uncertainty introduced into net LULUCF emissions	–19,980.5 Gg CO_2-e	22.9%

Note: Land area includes land in transition in 2010. Lime application to pre-1990 planted forest does not occur (NO) in New Zealand. The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equations 5.2.1 and 5.2.2 from GPG-LULUCF, IPCC (2003). National statistics is a new source of uncertainty that previously wasn't included in the calculation of total uncertainty.

Post-1989 forest

Biomass

A national plot-based inventory system, in conjunction with a suite of models, is being used to estimate carbon stock and change within New Zealand's planted forest. The modelling process for post-1989 forest is identical to pre-1990 planted forest and the uncertainty in the modelling process is outlined above. Additionally, the Forest Carbon Predictor validation is described in Beets et al, 2011b and New Zealand's inventory approach is described in Beets et al, 2011a.

New Zealand's post-1989 forests were first sampled during the winters of 2007 and 2008. The inventory provides a plot-based estimate of carbon stock within this forest subcategory. A double-sampling approach involving LiDAR and ground-based measurements has been employed to reduce the possibility of sampling bias arising from unmeasured plots due to access restrictions. Double sampling also increases the precision of the carbon stock estimates over that obtained using ground measurements alone. Double sampling in the post-1989 forest inventory resulted in a 6 per cent improvement in precision. The confidence interval for the estimate reduced from 5.7 per cent to 5.4 per cent with the addition of LiDAR (Beets et al, 2011a).

Re-measurement of the post-1989 forest plot network is currently under way and will be completed by October 2012. Re-measurement of the plot network will provide a plot-based estimate of carbon stock change, reduce assumptions on future silviculture events and further validate the Forest Carbon Predictor model.

When post-1989 forests were initially inventoried in 2007 and 2008, the mapping of the forest extent had yet to be completed. Consequently, the initial post-1989 forest sample was incomplete. The national forest map has been now completed, and 140 additional plots have been identified. The inclusion of these plots in the re-measurement will provide an unbiased and representative sample of post-1989 forests. The re-measurement data, including the additional plots, will be introduced from the 2013 submission.

Table 7.3.9 Uncertainty in New Zealand's 2010 estimates from post-1989 forest

Variable	Value	Uncertainty at a 95% confidence interval
Activity data uncertainty		
Uncertainty in net land area	593,821 ha	7.0%
Uncertainty introduced into net LULUCF emissions	–19,980.5 Gg CO_2-e	4.8%
Emission factor uncertainty		
Uncertainty in biomass accumulation rates	Varies by age	10.2% based on:
Modelling		5.0%
Sampling		5.4%
Forecasting		5.0%
National statistics		5.0%
Uncertainty in soil carbon stocks	92.59 t C ha^{-1}	95.0%
Uncertainty in liming emissions		NO
Uncertainty introduced into net LULUCF emissions	–19,980.5 Gg CO_2-e	40.0%

Note: Land area includes land in transition in 2010. Lime application to post-1989 forest does not occur (NO) in New Zealand. Nitrous oxide emissions are calculated as a proportion of carbon stock change, with the same uncertainty as for CO_2 and, therefore, 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). National statistics is a new source of uncertainty that previously wasn't included in the calculation of total uncertainty.

7.3.4 Category-specific QA/QC and verification

Carbon dioxide emissions from both 'forest land remaining forest land' and 'land converted to forest land' are key categories (for both level and trend assessments). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality-assurance and quality-control checks as well as Tier 2, category-specific quality-assurance and quality-control checks. Details of these checks are provided below.

Natural forest

During the initial measurement of the natural forest plot network, 5 per cent of plots measured in the first field season were subject to audit (Beets & Payton, 2003). In all field seasons, data collection followed quality-assurance and quality-control processes as described in Payton et al, 2004a and Payton et al, 2004b. This included on-site quality-control checks of field data and review by senior ecologists. Data was collected in the field by hand on field sheets. The electronic data entry of all data has been subject to ongoing quality assurance and quality control, including line-by-line checking of the transcription of all data used in carbon calculations.

As the natural forest plot network is re-measured, 10 per cent of plots measured are subject to independent audit. This involves a partial re-measure of the plot and the assessment of measurements against data quality standards as described in Payton & Brandon, 2010. Data entry of all data is subject to quality assurance by the Ministry for the Environment for 10 per cent of plots.

Pre-1990 planted forest and post-1989 forest

During the ground-measurement season, 10 per cent of plots were randomly audited without the prior knowledge of the inventory teams. Plots were fully re-measured with feedback supplied no later than one month after measurement to ensure prompt identification of data collection errors and procedural issues. Differences between the inventory and audit measurements were objectively and quantitatively scored. Measurements that exceeded predefined tolerances incurred incremental demerit points. Demerit severity depended on the size of error and the type of measurement. Special attention was given to the most influential measurements, for example, tree diameter, tree height and the number of trees in a plot. Plots that failed the quality control had to be re-measured (Beets et al, 2011a). Following each inventory season, the data collection manual (Herries et al, 2011) is revised to clarify procedures and highlight potential sources of error.

The inventory data was pre-processed using the New Zealand Forest Research Institute's Permanent Sample Plot (PSP) system. The PSP system has been programmed to check for erroneous values over a wide range of attributes. The system automatically identifies fields that do meet predetermined validation rules so these can be repaired manually before plot data is modelled by the Forest Carbon Predictor. The PSP data validation system and the Forest Carbon Predictor model were independently reviewed by Woollens, 2009. The Forest Carbon Predictor has been recently validated in Beets et al, 2011b.

Quality-assurance and quality-control procedures for LiDAR collected during the planted forest inventories involved the checking of data as it was acquired following the methodology outlined in Stephens et al, 2008. To ensure that the data was supplied within the predetermined specifications, the following activities were carried out: LiDAR sensor calibration and bore-sight alignment, checking of LiDAR point positional accuracy and point densities, correct point cloud classification and accuracy of digital terrain mapping. For example, the post-1989 forest inventory LiDAR acquisition included four individual sensor calibrations; six LiDAR point positional accuracy tests and a summary of returns describing LiDAR specifications were provided for all data deliveries. Sites that failed to meet the required specifications were re-flown. These analyses were carried out using the LiDAR analysis software FUSION (McGaughey et al, 2004; McGaughey, 2010) and the Esri Arc Map GIS application. LiDAR metrics or parameters describing the forest from the canopy to the ground were extracted using FUSION. The process of extracting LiDAR metrics and the extracted metrics were audited by an organisation independent of the data capture and analysis (Stephens et al, 2008).

7.3.5 Category-specific recalculations

In this submission, New Zealand has recalculated its emissions estimates for the whole LULUCF sector from 1990, including the forest land category. These recalculations have involved improved country-specific methods, activity data and emission factors. The impact of the recalculations on net CO_2-e emissions estimates for the forest land category is provided in table 7.3.10. The differences shown are a result of recalculations for all carbon pools used in Climate Change Convention and Kyoto Protocol reporting for the whole time series for the LULUCF sector.

Table 7.3.10 Recalculations of New Zealand's estimates for the forest land category in 1990 and 2009

Forest land recalculations		Net emissions and areas 2011 submission	2012 submission	Change from the 2011 submission	(%)
Net emissions	1990	–25,344.9 Gg CO_2-e	–27,149.9 Gg CO_2-e	–1,805.0 Gg CO_2-e	–7.1
	2009	–29,559.4 Gg CO_2-e	–30,157.5 Gg CO_2-e	–598.0 Gg CO_2-e	–2.0
Land areas	1990	9,636,822 ha	9,627,992 ha	–8,830 ha	–0.1
	2009	10,132,722 ha	10,116,734 ha	–15,987 ha	–0.2

Note: Areas are as at the end of the year indicated.

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

Activity data

Deforestation

The area estimates of deforestation have also been updated from the previous submission. These areas and the associated emissions are reported in the 'land converted to' category.

For 2008 and 2009 deforestation reporting, wall-to-wall mapping was initially completed using DMC 22 metre resolution satellite imagery. Results of this mapping were reported in the 2011 submission. For the 2012 submission, a partial mapping of 2010 deforestation was completed using 10 metre resolution SPOT satellite imagery. During the course of this mapping, over four priority areas, extra areas of 2008 and 2009 deforestation were identified from the higher resolution imagery. These areas, together with mapping uncertainty estimates, were added to the total deforestation reported for 2008 and 2009 in the 2012 submission (see section 7.2.2).

Emission factors

Planted forest carbon stock change

New Zealand has revised the reporting of emissions in pre-1990 planted forests with the use of a permanent sample-plot network-based yield table. Previously, a yield table based on the *National Exotic Forest Description*, a survey conducted by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2010) was used.

In the 2012 submission, New Zealand has utilised an updated version of the Forest Carbon Predictor (FCPv3) in the development of the pre-1990 and post-1989 planted forest yield tables. FCPv3 contains new temperature-dependent decay functions and species-specific growth trajectory and biomass adjustments (Beets & Kimberley, 2011). New breast height pith-to-bark density functions and a stand tending module for improved estimation of past and future silvicultural events when stand records are incomplete are also included in the latest version of the Forest Carbon Predictor (Beets & Kimberley, 2011).

New Zealand has included new temperature-dependent deadwood and litter decay functions for the modelling of harvest residue decay in pre-1990 and post-1989 planted forest (Garrett et al, 2010). Previously, the 20-year linear IPCC default was used for harvest residue decay (IPCC, 2003).

Soil carbon stock

New Zealand has used Tier 1 default values to estimate soil organic carbon for mineral soils. The reference value for soils is based on the areas of each soil type found in each climate zone, and the default reference soil organic carbon stock under native vegetation for each climate/soil combination given in table 3.3.3 of GPG-LULUCF. Under Tier 1, it is assumed that the carbon stock in soil organic matter does not change, regardless of changes in forest management, types and disturbance regimes (IPCC, 2003). The mineral soil organic carbon stock under all forest land uses therefore reflects the reference value 92.59 t C ha^{-1} (table 7.1.7). The difference in stock values between low-producing grassland and forest land uses is –12.96 t C ha^{-1} (compared with the previous submission; –13.77 t C ha^{-1} for natural forest and –16.85 t C ha^{-1} for planted forest).

7.3.6 Category-specific planned improvements

Re-measurement of the natural forest permanent sample plot network is under way. After this re-measurement is completed, New Zealand will be better able to illustrate whether its natural forests are a net source or sink of carbon or whether they are carbon neutral.

Re-measurement of the post-1989 forest plot network is currently under way and will be completed by October 2012. Re-measurement of the plot network will provide a plot-based estimate of carbon stock change, reduce assumptions on future silviculture events and further validate the Forest Carbon Predictor model. Since the initial post-1989 forest inventory, 140 additional plots have been identified from updated forest mapping. The inclusion of these plots in the inventory will provide an unbiased and representative sample of post-1989 forests. The re-measurement data, including data from the additional plots, will be introduced from the 2013 submission.

Mapping of forest areas will be iteratively improved by comparison with other spatial forest data sets administered by the Ministry of Agriculture and Forestry. These include post-1989 forest areas lodged with the NZ ETS, pre-1990 planted forest areas lodged with the Forestry Allocation Scheme and new post-1989 forests planted through the Afforestation Grants Scheme and the Permanent Forest Sink Initiative.

The activity data used to estimate emissions from harvesting in pre-1990 planted forests will be improved. At present, there are differences in the definition of forest used for reporting of pre-1990 planted forest for Convention on Climate Change reporting, and the area included in the *National Exotic Forest Description* from which the harvesting statistics are sourced. The activity data associated with harvesting of pre-1990 planted forests will need to be adjusted to take account of these differences.

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:

- determination of how effectively LiDAR estimates carbon stock change with and without ground measurements
- increased accuracy in the estimates of carbon stock and change that is occurring within the commitment period.

Work to implement a recommendation from the review of New Zealand's 2010 submission to enable reporting by forest type within post-1989 forest is under way. This includes the following:

- the development of the methodology for reporting by forest type within the pre-1990 planted forests and post-1989 forests
- the expansion of the post-1989 forest inventory plot network to include the regenerating shrubland component of post-1989 forest to estimate carbon stock in this forest type
- improvements to the estimates of biomass burning following afforestation, reforestation and deforestation.

7.4 Cropland (CRF 5B)

7.4.1 Description

Cropland in New Zealand is separated into two subcategories: annual and perennial. In 2010, there were 334,865 hectares of annual cropland in New Zealand (1.2 per cent of total land area) and 102,901 hectares of perennial cropland (0.4 per cent of total land area).

Annual crops include cereals, grains, oil seeds, vegetables, root crops and forages. Perennial crops include orchards, vineyards and their associated shelterbelts except where these shelterbelts meet the criteria for forest land.

The amount of carbon stored in, emitted, or removed from permanent cropland depends on crop type, management practices and soil and climate variables. Annual crops are harvested each year, with no long-term storage of carbon in biomass. However, the amount of carbon stored in woody vegetation in orchards can be significant, with the amount depending on the species, density, growth rates, and harvesting and pruning practices.

In 2010, the net emissions from cropland were 392.1 Gg CO_2-e, comprising 344.2 Gg CO_2 from carbon stock change, 0.03 Gg N_2O (8.9 Gg CO_2-e) from the cultivation of land converted to cropland and 38.9 Gg CO_2 from liming.

Net emissions from cropland have decreased by 175.0 Gg CO_2-e (30.9 per cent) from the 1990 level when net emissions were 567.1 Gg CO_2-e (table 7.4.1). This decrease is largely due to the gradual reduction in the area of land in a state of conversion to cropland since 1990 as it transfers to the land remaining category.

Conversion to cropland category was identified as a key category for 2010 in CO_2 (trend assessment).

Table 7.4.1 New Zealand's land-use change within the cropland category from 1990 to 2010, and associated emissions

Cropland land-use category	Net area in 1990 (ha)	Net area in 2010 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$-e) 1990	2010	Change from 1990 (%)
Cropland remaining cropland	377,911	403,472	+6.8	334.6	311.3	–7.0
Land in conversion to cropland	36,764	34,293	–6.7	232.5	80.8	–65.2
Total	**414,675**	**437,765**	**+5.6**	**567.1**	**392.1**	**–30.9**

Note: 1990 and 2010 areas are as at 31 December. Land in conversion to cropland includes land that was converted prior to 1990. Net emission values are for the whole year indicated.

The cropland remaining cropland category is responsible for the majority of cropland emissions. This category comprised 92.2 per cent of all cropland area in 2010. The emissions for this land use are the result of annual cropland being converted to perennial cropland. Table 7.4.2 shows land-use change by cropland subcategory since 1990, and the associated CO_2 emissions from carbon stock change.

Table 7.4.2 New Zealand's land-use change within cropland subcategories from 1990 to 2010, and associated CO_2 emissions from carbon stock change

Cropland land-use subcategory	Net area in 1990 (ha)	Net area in 2010 (ha)	Change from 1990 (%)	Net emissions ($Gg\ CO_2$ only) 1990	2010	Change from 1990 (%)
Annual cropland	335,779	334,865	–0.3	419.6	252.6	–39.8
Perennial cropland	78,896	102,901	+30.4	105.7	91.7	–13.2
Total	**414,675**	**437,765**	**+5.6**	**525.3**	**344.3**	**–34.5**

Note: 1990 and 2010 areas are as at 31 December. Columns may not add due to rounding.

A summary of land-use change within the cropland category, by subcategory and land conversion status, is provided in table 7.4.3. This shows that land-use change within the croplands category has been dominated by conversions to perennial cropland, both from within the cropland category as well as from other land-use categories. This conversion has predominantly been for the establishment of vineyards (Davis and Wakelin, 2010).

Table 7.4.3 New Zealand's land-use change within the cropland category from 1990 to 2010

Cropland category	Subcategory	Net area in 1990 (ha)	Net area in 2010 (ha)	Change from 1990 (%)
Cropland remaining cropland	Annual remaining annual	306,694	323,764	5.6
	Perennial remaining perennial	68,122	74,397	9.2
	Annual to perennial	1,446	4,883	237.8
	Perennial to annual	1,649	428	-74.1
	Subtotal	*377,911*	*403,472*	*6.8*
Land in conversion to cropland	Annual cropland	27,436	10,673	-61.1
	Perennial cropland	9,328	23,620	+153.2
	Subtotal	*36,764*	*34,293*	*-6.7*
Total		**414,675**	**437,765**	**+5.6**

Carbon stock change within the cropland category is shown in table 7.4.4; from 1990 to 2010, the total carbon stock stored in cropland had decreased by 2,532.7 Gg C, equivalent to emissions of 9,286.7 Gg CO_2 from cropland since 1990. The majority of these emissions are from losses in the soil organic carbon pool.

Table 7.4.4 New Zealand's carbon stock change by carbon pool within the cropland category from 1990 to 2010

Crop land subcategory	Net carbon stock change 1990–2010 (Gg C)				Emissions 1990–2010 (Gg CO_2)
	Living biomass	Dead organic matter	Soils	Total	
Annual cropland	–2.4	NE	–1,899.8	–1,902.2	6,974.8
Perennial cropland	58.5	–4.4	–684.6	–630.5	2,311.8
Total	**56.1**	**–4.4**	**–2,584.4**	**–2,532.7**	**9,286.7**

Note: Dead organic matter (DOM) is not estimated (NE) as there is insufficient information to provide a basic approach with default parameters to estimate carbon stock change in this pool (IPCC, 2003). The reported DOM losses result from the loss of DOM of woody land-use classes on conversion to cropland. Columns may not add due to rounding.

7.4.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using IPCC Tier 1 emission factors for annual cropland, Tier 2 emission factors for perennial cropland (Davis and Wakelin, 2010) and activity data as described in section 7.2 – representation of land areas. Emissions and removals by the soil organic carbon pool are estimated using IPCC Tier 1 defaults for both mineral and organic soils. This is described in section 7.1.3 – soils.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for cropland is provided in table 7.4.5.

Table 7.4.5 Summary of New Zealand's carbon stock change emission factors for cropland

Cropland land-use subcategory	Carbon pool	Steady state carbon stock (t C ha^{-1})	Annual carbon stock change (t C ha^{-1})	Years to reach steady state	Source
Annual	**Biomass**				
	Living biomass	5.0	NA	1	IPCC default EF
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral		[1]	20	IPCC Tier 1 default parameters
	Organic	NE	–1.0 / –10.0		IPCC Tier 1 default parameters
Perennial	**Biomass**				
	Living biomass	18.76	0.67	28	NZ-specific EF
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral	97.76	[1]	20	IPCC Tier 1 default parameters
	Organic	NE	–1.0 / 10.0		IPCC Tier 1 default parameters

Note: EF = Emission factor. [1] Annual carbon stock change in mineral soils on land undergoing land-use change will depend on the land-use category the land has been converted to or from.

Cropland remaining cropland

For cropland remaining cropland, the Tier 1 assumption is that, for annual cropland, there is no change in carbon stocks after the first year (GPG-LULUCF, section 3.3.1.1.1.1, IPCC, 2003). The rationale is that the increase in biomass stocks in a single year is equal to the biomass losses from harvest and mortality in that same year. For perennial cropland, there is a change in carbon stocks associated with a land-use change. New Zealand has reported NA (not applicable) in the common reporting format tables where there is no land-use change at the subcategory level because no emissions or removals are assumed to have occurred. However, where there has been land-use change between the cropland subcategories, carbon stock changes are reported under cropland remaining cropland. Between 1990 and 2010, there were 5,311 hectares converted from one cropland subcategory to another.

Living biomass

To estimate carbon change in living biomass for annual cropland converted to perennial cropland, New Zealand is using Tier 1 defaults for biomass carbon stocks at harvest. The value being used for annual cropland is 5 t C ha^{-1} (see table 7.4.5). This is the carbon stock in living biomass after one year as given in GPG-LULUCF, table 3.3.8 (IPCC, 2003). The Tier 1 method for estimating carbon change assumes carbon stocks in biomass immediately after conversion are zero, that is, the land is cleared of all vegetation before planting crops (5 t C ha^{-1} is removed).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 t C ha^{-1} yr^{-1}. This value is based on the New Zealand-specific value of 18.76 t C ha^{-1} (Davis and Wakelin, 2010), sequestered over 28 years, which is the maturity period New Zealand uses for its lands to reach steady state.

The activity data available does not provide information on areas of perennial cropland temporarily destocked; therefore, no losses in carbon stock due to temporary destocking can be calculated.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation NE (not estimated) is used in the common reporting format tables. There is insufficient information to provide a basic approach with default parameters to estimate carbon stock change in dead organic matter pools in cropland remaining cropland (IPCC, 2003).

Soil organic carbon

Soil carbon stocks in cropland remaining cropland are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3 – soils. The steady state mineral soil carbon stock in annual cropland is estimated to be 59.82 t C ha^{-1} with an uncertainty of 96 per cent, and for perennial cropland is estimated to be 97.76 t C ha^{-1} with an uncertainty of 97 per cent.

Mineral soil carbon change for annual cropland converted to perennial cropland is estimated using a Tier 1 method with the change in soil carbon reflecting a linear rate of change over 20 years (the IPCC default method) from the steady state value for annual cropland to the steady state perennial cropland value.

The IPCC default emission factors for organic soils under cropland are 1.0 and 10.0 t C ha^{-1} per annum for cold temperate and warm temperate regimes respectively (table 7.1.8).

Liming

The calculation of carbon dioxide emissions from the liming of cropland soil is based on equation 3.4.11 in GPG-LULUCF (IPCC, 2003) as outlined in section 7.9.4 – liming. The total amount of agricultural lime (limestone) applied is provided by Statistics New Zealand (New Zealand's official statistics agency). This is split into lime and dolomite applied to cropland and grassland based on analysis of agricultural lime use by land use and farm type from the 2008 Agricultural Census. This analysis indicates that, each year, around 6 per cent of agricultural lime used in New Zealand is applied to cropland. The amount of lime applied to cropland is then converted to carbon emissions using a conversion factor of 0.12 from GPG-LULUCF, section 3.3.1.2.1.1 (IPCC, 2003).

Non-CO_2 emissions

Biomass burning

This is a relatively minor activity in New Zealand, and there is insufficient information to reliably report on this activity. The notation key NE (not estimated) is used in the common reporting format tables. Agricultural residue burning is reported in the agriculture sector.

Land converted to cropland

Living biomass

New Zealand uses a Tier 1 method, and a combination of IPCC default and New Zealand-specific emission factors to calculate emissions for land converted to cropland. The Tier 1 method multiplies the area of land converted to cropland annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass and dead organic matter immediately after conversion is zero, that is, the land is cleared of all vegetation before planting crops. The amount of biomass cleared when land at steady state is converted is shown in tables 7.1.3 and 7.1.4.

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

To estimate growth after conversion to annual cropland, New Zealand uses the IPCC default biomass accumulation rate of 5 t C ha^{-1} for the first year following conversion (GPG-LULUCF, table 3.3.8, IPCC, 2003). After the first year, any increase in biomass stocks in annual cropland is assumed equal to biomass losses from harvest and mortality in that same year and, therefore, after the first year there is no net accumulation of biomass carbon stocks in annual cropland remaining annual cropland (IPCC, 2003, section 3.3.1.1.1).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 t C ha^{-1} yr^{-1}. This value is based on the New Zealand-specific value of 18.76 t C ha^{-1} (Davis and Wakelin, 2010), sequestered over 28 years, which is the maturity period New Zealand uses for its lands to reach steady state.

Dead organic matter

New Zealand reports only losses in dead organic matter associated with the previous land use for this category. The losses are calculated based on the carbon in dead organic matter at the site prior to conversion to cropland. It is assumed that, immediately after conversion, dead organic matter is zero (all carbon in dead organic matter prior to conversion is lost). There is insufficient information to estimate gain in carbon stock in dead organic matter pools after land is converted to cropland (IPCC, 2003). Consequently, where there is no dead organic matter losses associated with the previous land use, the notation key NE (not estimated) is used in the common reporting format tables.

Soil organic carbon

Soil carbon stocks in land converted to annual and perennial cropland are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3 – 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.

The IPCC default emission factors for organic soils under cropland are also applied to land converted to cropland.

Non-CO_2 emissions

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

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland are described in section 7.9.3.

Biomass burning

Biomass burning with land conversion to cropland is not thought to be a significant activity in New Zealand, and there is no activity data available that would indicate otherwise. The notation key NE (not estimated) is reported in the common reporting format tables.

7.4.3 Uncertainties and time-series consistency

The uncertainty in mapping cropland is ± 6 per cent. Further details on this are given in section 7.2.5.

New Zealand uses IPCC default values for biomass accumulation in annual cropland. For perennial cropland, we use a New Zealand-specific emissions factor. As the perennial and annual cropland emission factors are based on only a limited number of biomass studies, the uncertainty in these figures is estimated as ± 75 per cent.

For soils, New Zealand uses IPCC default values for annual and perennial cropland. The uncertainty associated with the IPCC default values are 97 per cent and 96 per cent respectively (based on GPG-LULUCF, table 3.2.4, IPCC, 2003).

Uncertainty in liming emissions is based on activity data uncertainty (amount of lime applied) from Statistics New Zealand. This is estimated as ± 6 per cent for limestone and

± 21 per cent for dolomite. These values are then weighted to give overall uncertainty for liming emissions of ± 6.2 per cent.

As shown in table 7.4.6, while uncertainty in activity data is low, the uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand.

Table 7.4.6 Uncertainty in New Zealand's 2010 cropland estimates

Variable	**Uncertainty at a 95% confidence interval (%)**	
Land-use subcategory	Annual cropland	Perennial cropland
Activity data uncertainty		
Uncertainty in land area	6.0%	6.0%
Uncertainty introduced into net LULUCF emissions	0.1%	0.0%
Emission factor uncertainty		
Uncertainty in biomass accumulation rates	75.0%	75.0%
Uncertainty in soil carbon stocks	97%	96%
Uncertainty in liming emissions	6.2%	6.2%
Uncertainty introduced into net LULUCF emissions	1.0%	2.4%

7.4.4 Category-specific QA/QC and verification

Carbon dioxide emissions from 'conversion to cropland' were identified as a key category in the trend analysis for this submission. In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.4.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the cropland category is shown in table 7.4.7. Recalculations of the entire time series were carried out for this category as a result of:

- error correction to a formula used in the calculation of the area for N_2O disturbance to cropland – the change had only a small impact
- updated liming activity data following the release of the final results from the 2010 Agricultural Census
- revised soil carbon stock estimates. New Zealand has used Tier 1 default values to estimate soil organic carbon for mineral soils for the 2012 submission. The reference value for soils is based on the areas of each soil type found in each climate zone, and the default reference soil organic carbon stock under native vegetation for each climate/soil combination given in table 3.3.3 of GPG-LULUCF. Default stock change factors for cropland were selected from table 3.3.4 of GPG-LULUCF that reflect the management activities of cropland land uses in New Zealand. The current soil organic carbon stock values for annual and perennial cropland are 59.82 t C ha^{-1} and 97.76 t C ha^{-1} respectively. The difference in stock values between low-producing grassland and annual cropland is –45.73 t C ha^{-1} (compared with –14.81 t C ha^{-1} in the previous submission), and between low-producing grassland and perennial cropland is –7.79 t C ha^{-1} (compared with –4.57 t C ha^{-1} in the previous submission).

Table 7.4.7 Recalculations of New Zealand's net emissions from the cropland category in 1990 and 2009

Year	Net emissions (Gg CO_2-e)		Change from the 2011 submission	
	2011 submission	2012 submission	(Gg CO_2-e)	(%)
1990	395.3	567.1	171.7	43.4
2009	337.5	396.3	58.8	17.4

7.4.6 Category-specific planned improvements

The main improvement planned for this category is associated with a return to Tier 2 modelling for mineral soils. The Tier 2 model for mineral soils contained only 10 records for perennial cropland, which means the uncertainty associated with this land use is large (101.24 ± 11.83 t C ha^{-1}). New Zealand is currently trying to obtain additional data on carbon in soil under perennial cropland. If New Zealand does not return to Tier 2 modelling, because we cannot improve the model to the satisfaction of reviewers, this improvement will not be realised. Further detail on this is included in section 7.1.3 – soils.

7.5 Grassland (CRF 5C)

7.5.1 Description

In New Zealand, grassland covers a range of land-cover types. In this submission, three subcategories of grassland are used: high producing, low producing and with woody biomass.

High-producing grassland consists of intensively managed pasture land. Low-producing grassland consists of low-fertility grasses on hill country, areas of native tussock or areas composed of low, shrubby vegetation, both above and below the timberline. Grassland with woody biomass consists of grassland areas where the cover of woody species is less than 30 per cent and/or does not meet, nor have the potential to meet, the New Zealand forest definition due to either the current management regime (eg, periodically cleared for grazing) or the characteristics of the vegetation (eg, shrubland). A summary of land-use change within the grassland category is provided in table 7.5.1.

Land-use research indicates that, under business-as-usual grassland farming operations, areas of woody shrublands within farmland do not become forest over a 30- to 40-year timeframe (Trotter & MacKay, 2005). This is the case as long as the farmer's intention is to manage the land as grassland for grazing animals. When it becomes evident that the farmer has modified land management in a way that encourages sustained growth of woody vegetation, such as by removing stock, then these areas will be mapped as forest. A description of the land-management approaches that result in the sustained growth of woody vegetation is contained in the mapping interpretation guide (Dougherty et al, 2009).

In 2010, there were 5,795,395 hectares of high-producing grassland (21.5 per cent of total land area) 7,674,138 hectares of low-producing grassland (28.5 per cent of total land area) and 1,134,031 hectares of grassland with woody biomass (4.2 per cent of total land area).

The net emissions from grassland were 3120.8 Gg CO_2-e in 2010 (table 7.5.1). These emissions comprise 3,075.0 Gg CO_2 emissions from carbon stock change and agricultural lime application, and 2.0 Gg CH_4 emissions and 0.01 Gg N_2O emissions from biomass burning.

The grassland remaining grassland and conversion to grassland categories were identified as key categories for the level and trend assessment in 2010.

Net emissions from grassland have increased by 4,196.2 Gg CO_2-e (390.2 per cent) from the 1990 level of –1,075.4 Gg CO_2-e. This increase has occurred primarily on grassland remaining grassland and is due to the influence of land-use changes between grassland subcategories on mineral soil carbon.

Table 7.5.1 New Zealand's land-use change within the grassland category from 1990 to 2010

Grassland land-use category	Area in 1990 (ha)	Area in 2010 (ha)	Change from 1990 (%)	Net emissions ($Gg CO_2$-e) 1990	2010	Change from 1990 (%)
Grassland remaining grassland	14,615,978	14,436,382	–1.2	–966.0	2,104.6	317.9
Land in conversion to grassland	500,616	167,182	–66.6	–109.3	1,016.2	1,029.5
Total	**15,116,594**	**14,603,564**	**–3.4**	**–1,075.4**	**3,120.8**	**390.2**

Note: 1990 and 2010 areas are as at 31 December. Net emission estimates are for the whole year indicated. Land in conversion to grassland includes land converted up to 28 years prior to 1990. Columns may not add due to rounding.

The largest change is due to changes between grassland with woody biomass and high-producing grassland. The mineral soil carbon net stock change associated with this particular land-use change is 24.6 t C ha^{-1} (see table 7.1.7 and section 7.1.3 – soils for further information on mineral soil carbon stock estimates).

Land-use change by grassland subcategory is shown in table 7.5.2, together with the associated CO_2 emissions from carbon stock change.

Table 7.5.2 New Zealand's land-use change within grassland subcategories from 1990 to 2010, and associated CO_2 emissions from carbon stock change

Grassland land-use subcategory	Area in 1990 (ha)	Area in 2010 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2 only) 1990	2010	Change from 1990 (%)
Grassland – high producing	5,852,118	5,795,395	–1.0	–1,486.0	918.9	161.8
Grassland – low producing	7,999,790	7,674,138	–4.1	723.3	1,574.8	117.7
Grassland – with woody biomass	1,264,685	1,134,031	–10.3	–706.5	–11.2	98.4
Total	**15,116,594**	**14,603,564**	**–3.4**	**–1,469.1**	**2,482.5**	**269.0**

Note: 1990 and 2010 areas are as at 31 December. Net emission estimates are for the whole year indicated. Non-CO_2 emissions included in table 7.5.1 are not included here. Columns may not add due to rounding.

From 1990 to 2010, the net carbon stock change attributed to grassland was a decrease of –16,200.2 Gg C, equivalent to emissions of 59,400.6 Gg CO_2 from grassland since 1990.

The majority of these emissions are due to the loss of living biomass carbon stock, associated with forest land conversion to grassland.

Table 7.5.3 New Zealand's carbon stock change by carbon pool within the grassland category from 1990 to 2010

Grassland subcategory	Net carbon stock change 1990–2010 (Gg C)				Emissions 1990–2010 ($Gg\ CO_2$)
	Living biomass	Dead organic matter	Soils	Total	
Grassland – high producing	–11,150.3	–1,387.7	2,494.6	–10,043.3	36,825.5
Grassland – low producing	–5,687.2	–1,234.1	–295.1	–7,216.5	26,460.5
Grassland – with woody biomass	1,165.7	713.6	–819.6	1,059.7	–3,885.4
Total	**–15,671.8**	**–1,908.3**	**1,379.9**	**–16,200.2**	**59,400.6**

Non-CO_2 emissions from grassland in 2010 comprised 2.0 Gg CH_4 (41.4 Gg CO_2-e) and 0.01 Gg N_2O (4.5 Gg CO_2-e) from biomass burning, while emissions from liming of grassland accounted for 592.5 Gg CO_2-e (19.0 per cent) of net grassland emissions in 2010. Net liming emissions from grassland have increased by 241.7 Gg CO_2-e (68.9 per cent) compared with the 1990 level of 350.8 Gg CO_2-e.

Grassland remaining grassland

There were 14,436,382 hectares of grassland remaining grassland in 2010, equivalent to 53.6 per cent of New Zealand's total land area. Estimates of land-use change in this category have been split into three subcategories of grassland and the changes between them, as shown in table 7.5.4.

Table 7.5.4 New Zealand's land-use change between grassland subcategories from 1990 to 2010

Land-use changes within grassland remaining grassland	Net area in 1990 (ha)	Net area in 2010 (ha)	Change from 1990	
			(ha)	(%)
High producing remaining high producing	4,853,130	5,452,093	+598,963	+12.3
Low producing remaining low producing	7,679,180	7,566,340	–112,840	–1.5
With woody biomass remaining with woody biomass	968,369	1,084,821	+116,452	+12.0
Subtotal	*13,500,679*	*14,103,254*	*+602,576*	*+4.5*
High producing to low producing	0	0	0	NA
High producing to with woody biomass	438	9,192	+8,754	+2,000.0
Low producing to high producing	396,585	74,846	–321,739	–81.1
Low producing to with woody biomass	271,203	34,376	–236,828	–87.3
With woody biomass to high producing	408,060	165,170	–242,890	–59.5
With woody biomass to low producing	39,013	49,544	+10,531	+27.0
Subtotal	*1,115,299*	*333,127*	*–782,172*	*–70.1*
Total	**14,615,978**	**14,436,382**	**–179,596**	**–1.2**

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 2010. Columns may not add due to rounding.

Land undergoing land-use change from one land-use subcategory to another remains in a state of conversion for 28 years (the New Zealand maturity period), until it reaches steady state and transfers to the land remaining land category (or subcategory remaining subcategory). The most significant trend observable within the grassland remaining grassland category is the overall movement of land from a state of conversion between grassland subcategories – in particular, away from low-producing grassland – to a steady state as mature, high-producing grassland.

Land converted to grassland

Between 1990 and 2010, 90,995 hectares of land were converted to grassland, while 706,217 hectares of grassland were converted to other land-use categories, resulting in a net reduction in the total grassland area of 526,271 hectares. As at the end of 2010, however, there was a total of 167,182 hectares of land in a state of conversion to grassland, as areas of land converted prior to 1990 remain in a state of conversion for 28 years (New Zealand's land-use maturity period).

Much of New Zealand's grassland is grazed, with agriculture being the main land use. The majority of New Zealand's agriculture is based on extensive pasture systems, with animals grazed outdoors year-round. Increased profitability of dairy farming relative to other land uses has seen a recent trend for conversion of planted forest to pasture (deforestation).

The majority (95.0 per cent) of land converted to grassland since 1990 is land that was previously forest land. The 86,485 hectares of forest land converted to grassland since 1990 comprises an estimated 33,806 hectares of natural forest deforestation and 54,470 hectares of pre-1990 planted forest deforestation. A further 16,108 hectares of newly established, post-1989 forest (land that was not forest land at the start of 1990) has also been deforested and converted to grassland. (For more information on deforestation, see sections 7.2 and 7.3 and chapter 11.) Land-use change of forest land to grassland between 1990 and 2010 resulted in a net carbon stock loss of 101.3 Gg C, equivalent to net emissions of 371.5 Gg CO_2.

7.5.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using a combination of IPCC Tier 1 emission factors and country-specific factors. Emissions and removals from soils are estimated using a Tier 1 method as described in section 7.1.3 – soils, and the activity data used is described in section 7.2 – representation of land areas.

A summary of the New Zealand biomass emission factors and other parameters used to estimate greenhouse gas emissions for the grassland category is provided in table 7.5.5.

Table 7.5.5 Summary of New Zealand's biomass emission factors for grassland

Grassland subcategory	Carbon pool	Steady state carbon stock (t c ha^{-1})	Annual carbon accumulation (t c ha^{-1})	Years to reach steady state	Source
High producing	*Biomass*	6.75	6.75	1	IPCC default EF
	AGB	1.35	1.35	1	
	BGB	5.4	5.4	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
Low producing	*Biomass*	3.05	3.05	1	IPCC default EF
	AGB	0.8	0.8	1	
	BGB	2.25	2.25	1	

Grassland subcategory	Carbon pool	Steady state carbon stock (t c ha^{-1})	Annual carbon accumulation (t c ha^{-1})	Years to reach steady state	Source
	Dead organic matter	NE	NA	NA	No IPCC guidelines
With woody biomass	*Biomass*	29	1.04	28	NZ-specific EF
	AGB	16.0	0.57	28	
	BGB	4.0	0.14	28	
	Dead organic matter	9.0	0.32	28	NZ-specific EF
	Deadwood	3.0	0.11	28	
	Litter	6.0	0.21	28	

Note: AGB = above-ground biomass; BGB = below-ground biomass; NE = not estimated; NA = not applicable; EF = emissions factor.

Grassland remaining grassland

For grassland remaining grassland, the Tier 1 assumption is there is no change in carbon stocks (GPG-LULUCF, section 3.4.1.1.1.1, IPCC, 2003). The rationale is that, where management practices are static, carbon stocks will be in an approximate steady state, that is, carbon accumulation through plant growth is roughly balanced by losses. New Zealand has reported NA (not applicable) in the common reporting format tables where there is no land-use change at the subcategory level because no emissions or removals are assumed to have occurred. However, there is a significant area (333,127 hectares) in a state of conversion from one grassland subcategory to another. The carbon stock changes for these land-use changes are reported under grassland remaining grassland.

Living biomass

To calculate carbon change in living biomass on land converted from one subcategory to another (eg, high-producing grassland converted to low-producing grassland) it is assumed the carbon in living biomass immediately after conversion is zero, that is, the land is cleared of all vegetation. In the same year, carbon stocks in living biomass increase by the amount given in table 7.1.4 – annual growth in biomass for land converted to another land use. The values given in table 7.1.4 for high-producing and low-producing grassland are Tier 1 defaults. The value given for grassland with woody biomass is a country-specific factor based on Wakelin (2004).

Dead organic matter

New Zealand does not report estimates of dead organic matter for high-producing grassland or low-producing grassland because GPG-LULUCF states there is insufficient information to develop default coefficients for estimating the dead organic matter pool (IPCC, 2003). The notation key NE (not estimated) is used in the common reporting format tables.

For grassland with woody biomass, an estimate of dead organic matter is available from Wakelin (2004), and estimates of changes in dead organic matter stocks with conversion to and from this land use are given in the common reporting format tables.

Soil carbon

Soil carbon stocks in grassland remaining grassland are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3 – soils.

The mineral soil carbon values for the three grassland subcategories at equilibrium state are given in table 7.5.6.

Table 7.5.6 New Zealand's soil carbon stock values for the grassland subcategories

Land-use	Soil carbon stock density (t C ha^{-1})
High-producing grassland	117.16
Low-producing grassland	105.55
Grassland with woody biomass	92.59

The IPCC default emission factors for organic soils under grassland are 0.25 and 2.5 t C ha^{-1} per annum for cold temperate and warm temperate regimes respectively.

Liming

The calculation of carbon dioxide emissions from the liming of grassland soil is based on equation 3.4.11 in GPG LULUCF (IPCC, 2003) as outlined in section 7.9.4 – liming. The total amount of carbonate applied in the form of agricultural lime (eg, calcic limestone ($CaCO_3$)) and dolomite ($CaMg(CO_3)_2$) is provided by Statistics New Zealand. This is split into lime and dolomite applied to cropland and grassland based on analysis of agricultural lime use by land use and farm type from the 2007 Agricultural Census. This analysis indicates that, each year, around 94 per cent of agricultural lime used in New Zealand is applied to grassland. The amount of lime applied to grassland is then converted to carbon emissions using a conversion factor of 0.12 from GPG-LULUCF, section 3.3.1.2.1.1 (IPCC, 2003).

Non-CO_2 emissions

Biomass burning

Only non-carbon dioxide emissions from wildfires are reported in the grassland subcategory of 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 and from controlled burning are not reported because the subsequent regrowth is not captured in the inventory (GPG-LULUCF, section 3.2.1.4.2, IPCC, 2003). In these cases, the notation key IE (included elsewhere) is used.

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 30 April 1992. The average annual area burnt between May 1991 and April 2010 from this database is used as the estimate of area burnt for 1990 to 1991 because 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 50 per cent for above-ground live biomass and 100 per cent for above-ground dead biomass in high- and low-producing grassland and at 70 per cent of total above-ground biomass (made up of 65 per cent live and 35 per cent dead) 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 & Pearce, 2001) compiled by Wakelin et al, 2009. Different biomass quantity values are used for wildfire and controlled burning of grassland within the inventory. The different values reflect the assumption that grassland with woody biomass burnt during land conversion is of a lesser stature than other scrubland in this subcategory (Wakelin, 2004). Emissions from controlled burning of grassland during land conversion are reported in the land converted to forest category.

Land converted to grassland

Living biomass

New Zealand uses a Tier 1 method to calculate emissions for land converted to grassland. The Tier 1 method multiplies the area of land converted to grassland annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass immediately after conversion is zero, that is, the land is cleared of all vegetation at conversion. The amount of biomass cleared when land at steady state is converted is shown in table 7.1.3. The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place, as outlined in equation 3.3.8 of GPG-LULUCF (IPCC, 2003).

Dead organic matter

For land conversion to high- and low-producing grassland, New Zealand reports only losses in dead organic matter. The losses are calculated based on the carbon in dead organic matter at the site prior to conversion to grassland. It is assumed that, immediately after conversion, dead organic matter is zero (all carbon in dead organic matter prior to conversion is lost). There is insufficient information to estimate changes in carbon stock in dead organic matter pools after land is converted to high- or low-producing grassland (IPCC, 2003). Therefore, where there are no dead organic matter losses associated with the previous land use the notation key NE (not estimated) is used in the common reporting format tables.

For land converted to grassland with woody biomass, there is a country-specific value for carbon in dead organic matter. Where land is converted to grassland with woody biomass, dead organic matter accumulates to 9 t C ha^{-1} over 28 years (the maturity period New Zealand has chosen for land to reach steady state) (Wakelin, 2004).

Soil organic carbon

Soil carbon stocks in land converted to grassland are estimated using a Tier 1 method for both mineral and organic soils, as described in section 7.1.3 – 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 the new land use.

The IPCC default emission factors for organic soils under grassland are also applied to land converted to grassland.

Non-CO_2 emissions

Biomass burning

There is insufficient information to reliably report on biomass burning on land converted to grassland in New Zealand. Carbon dioxide emissions on land converted to grassland are captured by assuming instant biomass loss at the time of conversion. No attempt is made to quantify non-CO_2 emissions from burning deforestation residues due to a lack of activity data. The notation key IE (included elsewhere) is used for CO_2 emissions resulting from burning on land converted to grassland, and the notation key NE (not estimated) is used in the common reporting format tables for non-CO_2 emissions. New Zealand is currently investigating a data source for controlled burning on land converted to grassland for possible reporting in future submissions.

7.5.3 Uncertainties and time-series consistency

As shown in table 7.5.7, while the uncertainty introduced into the LULUCF net emissions by activity data is low, uncertainty in the IPCC default variables (GPG-LULUCF, table 3.4.2, IPCC, 2003) dominate the overall uncertainty in the estimate for grassland provided by New Zealand.

The uncertainty in mapping grassland is ± 6 per cent. Further details on this are given in section 7.2.5.

New Zealand uses IPCC default values for biomass accumulation in high-producing and low-producing grassland. The uncertainty in these figures is given as ± 75 per cent. New Zealand uses a New Zealand-specific value for biomass accumulation in grassland with woody biomass. No uncertainty is available for this so the uncertainty value used is the same as for the IPCC default.

The uncertainties in soil carbon stocks for the three grassland subcategories are given in table 7.5.7.

Uncertainty in liming emissions is based on activity data uncertainty (amount of lime applied) from Statistics New Zealand. This is estimated as ± 6 per cent for limestone and ± 21 per cent for dolomite. These values are then weighted to give overall uncertainty for liming emissions of ± 6.2 per cent.

Of the grassland subcategories, the largest per cent uncertainty is introduced into the net emissions by high-producing grassland.

Table 7.5.7 Uncertainty in New Zealand's 2010 estimates for the grassland category

Variable	**Uncertainty at a 95% confidence interval (%)**		
Grassland subcategory	**High producing**	**Low producing**	**With woody biomass**
Activity data uncertainty			
Uncertainty in land area	6.0%	6.0%	6.0%
Uncertainty introduced into net LULUCF emissions	0.3%	0.3%	0.0%
Emission factor uncertainty			
Uncertainty in biomass accumulation rates	75.0%	75.0%	75.0%
Uncertainty in soil carbon stocks	95.9%	95.5%	95.0%
Uncertainty in liming emissions	6.2%	6.2%	6.2%
Uncertainty introduced into net LULUCF emissions	7.9%	4.8%	3.5%

7.5.4 Category-specific QA/QC and verification

Carbon dioxide emissions from the ‘grassland remaining grassland’ and ‘land converted to grassland’ categories are key categories (level and trend, and level assessment respectively). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.5.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the grassland category is shown in table 7.5.8 below.

Table 7.5.8 Recalculations of New Zealand’s net emissions from the grassland category in 1990 and 2008

Grassland recalculations	Net emissions		Change from the 2011 submission	
	2011 submission (Gg CO_2-e)	2012 submission (Gg CO_2-e)	(Gg CO_2-e)	(%)
1990 estimate	+1,309.1	–1,075.4	–2,384.5	–182.1
2009 estimate	+2,529.4	+3,474.5	+945.0	+37.4

Further explanation of these recalculations is provided below.

Emissions factors

New Zealand has used Tier 1 default values to estimate soil organic carbon for mineral soils. The reference value for soils is based on the areas of each soil type found in each climate zone, and the default reference soil organic carbon stock under native vegetation for each climate/soil combination given in table 3.3.3 of GPG-LULUCF. Default stock change factors for the three grassland subcategories were selected from table 3.3.4 of GPG-LULUCF that reflect the management activities of grassland land uses in New Zealand.

The current soil organic carbon stock values for the three grassland subcategories are 117.16, 105.55 and 92.59 t C ha^{-1} for high-producing, low-producing and woody biomass grasslands respectively. The difference in stock values between low-producing grassland and high-producing grassland is 11.61 t C ha^{-1} (compared with –0.81 t C ha^{-1} in the previous submission), and between low-producing grassland and grassland with woody biomass is –12.96 t C ha^{-1} (compared with –7.38 t C ha^{-1} in the previous submission). Further information is provided in section 7.1.3 and chapter 10 – recalculations.

7.5.6 Category-specific planned improvements

Additional work to improve the mapping of the grassland with woody biomass land-use category will be carried out over the next two years.

7.6 Wetlands (CRF 5D)

7.6.1 Description

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

Section 3.5 of GPG-LULUCF defines wetlands as "land that is covered or saturated by water for all or part of the year (eg, peat land) and that does not fall into the forest land, cropland, grassland or settlements categories". This category can be further subdivided into managed and unmanaged wetlands according to national definitions. The definition includes reservoirs and flooded land as managed subdivisions, and natural rivers and lakes as unmanaged subdivisions. Flooded lands are defined in GPG-LULUCF as "water bodies regulated by human activities for energy production, irrigation, navigation, recreation, etc, and where substantial changes in water area due to water regulation occur. Regulated lakes and rivers, where the main pre-flooded ecosystem was a natural lake or river, are not considered as flooded lands". As the majority of New Zealand's hydro-electric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river, they are not defined as flooded lands.[36] As no other areas of New Zealand's wetlands qualify as 'managed' under the GPG-LULUCF wetlands definition, all of New Zealand's wetlands have been categorised as 'unmanaged', even though, more broadly, it can be said that all land in New Zealand is under some form of management and management plan (see section 11.4.1).

New Zealand's wetlands are mapped into two subcategories: 'wetland – open water', which includes lakes and rivers, and 'wetland – vegetated non-forest', which includes herbaceous vegetation that is periodically flooded, and estuarine and tidal areas. New Zealand has mapped its vegetated wetlands using existing land cover database (LCDB) data (see section 7.2 – representation of land areas, for more information). Areas of open water have been mapped using hydrological boundaries defined by Land Information New Zealand (LINZ).

There were 530,861 hectares of wetland – open water in 2010 and 132,691 hectares of wetland – vegetated non-forest. These two subcategories combined make up 2.5 per cent of the total New Zealand land area.

In 2010, there were no emissions from wetlands, compared with emissions of 165.7 Gg CO_2-e from wetlands in 1990. This is because carbon stock changes are not estimated for wetlands remaining wetlands (see section 7.6.2), and there were no new land conversions to wetlands in 2010.

Conversion to wetlands was a key category in 2010 in the trend assessment. Conversion to wetland shows up as a key category because there were no new land conversions to wetlands in 2010. The trend analysis compares 1990 emissions with the value of 0 for 2010 so a small change appears to be significant.

[36] For example, the Clyde Dam was created from the damming of the Clutha River in the South Island, creating Lake Dunstan. The area flooded was mostly low-producing grassland.

Table 7.6.1 New Zealand's land-use change for the wetlands category in 1990 and 2010, and associated CO_2-equivalent emissions

Wetlands land-use category	Net area in 1990 (ha)	Net area in 2010 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2-e) 1990	2010	Change from 1990 (%)
Wetlands remaining wetlands	649,861	659,955	+1.6	NE	NE	NA
Land in conversion to wetlands	13,872	3,597	–74.1	165.7	NE/NO	NA
Total	**663,733**	**663,552**	**–0.03**	**165.7**	**0.0**	**–100.0**

Note: 1990 and 2010 area values are as at 31 December. Net emission values are for the whole year indicated. Net emissions from the wetlands remaining wetlands land-use category are not estimated (NE); see section 7.6.2 for details. Land in conversion to wetlands consists of land converted to hydro lakes prior to 1990. NA = not applicable; NO = not occurring.

As at 2010, there were 3,597 hectares in a state of conversion to wetlands. These lands have been converted to wetlands during the previous 28 years but have not yet reached steady state and entered the wetlands remaining wetlands category.

Carbon stock change within the wetlands category is shown in table 7.6.2. From 1990 to 2010, the net carbon stock change for wetlands decreased by 451.9 Gg C, equivalent to emissions of 1657.0 Gg CO_2 in total since 1990. These carbon stock losses are from the historical (pre-1990) conversion of forest land to hydro-electric dams, the lagged effect of which continues to impact on soil organic carbon in the inventory period.

Table 7.6.2 New Zealand's carbon stock change by carbon pool within the wetlands category from 1990 to 20109

Wetlands subcategory	Net carbon stock change 1990–2010 (Gg C) Living Biomass	Dead organic matter	Soils	Total	Emissions 1990–2010 (Gg CO_2)
Wetland – vegetative non forest	0.0	0.0	0.0	0.0	0.0
Wetland – open water	0.0	0.0	–451.9	–451.9	1,657.0
Total	**0.0**	**0.0**	**–451.9**	**–451.9**	**1,657.0**

7.6.2 Methodological issues

Wetlands remaining wetlands

Living biomass and dead organic matter

A basic method for estimating CO_2 emissions in wetlands remaining wetlands is provided in appendix 3A.3 of GPG-LULUCF. The appendix covers emissions from flooded land and extraction from peat land. Recultivation of peat land is included under the agriculture sector.

Due to the current lack of data on biomass carbon stock changes in wetlands remaining wetlands, New Zealand has not prepared estimates for change in living biomass or dead organic matter for this category, as allowed for in the IPCC GPG-LULUCF, chapter 1.7. New Zealand reports the notation key NE (not estimated) in the common reporting format table for this category.

Soil carbon

Soil carbon stocks in wetlands remaining wetlands are estimated using a Tier 1 method for mineral soils as described in section 7.1.3 – soils. The mineral soil steady state carbon stock for wetland – vegetated non-forest is estimated to be 92.59 t C ha^{-1}, with a uncertainty of 95.0 per cent. For wetland – open water, the soil carbon stock at equilibrium is estimated to be 0.

For mineral soils, as with living biomass and dead organic matter, there are no emissions for wetlands in steady state so the notation key NE (not estimated) is used.

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with peat extraction, which is not a significant activity in New Zealand. It is therefore assumed that there are no carbon emissions from organic soils in wetlands remaining wetlands.

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

Since 1988, there have been no new conversion to wetlands so, from 2009 on (20 years after the last conversion), no emissions are estimated and the notation key NO (not occurring) is reported.

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). The Tier 1 method assumes carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place. For wetland – open water, the carbon stock in living biomass and dead organic matter following conversions are equal to zero. For wetland – vegetated non-forest, the carbon stock in living biomass and dead organic matter are not estimated as there is no guidance in GPG-LULUCF for estimating carbon stock following land use change to wetlands, and all emissions from land use change to wetlands from removal of the previous vegetation are instantly emitted. The notation keys NO (not occurring) and NE (not estimated) are reported in the CRF tables.

Soil carbon

Soil carbon stocks in land converted to wetlands are estimated using a Tier 1 method as described in section 7.1.3 – 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. The notation key NE (not estimated) is used in the common reporting format tables.

Biomass burning

Biomass burning on land converted to wetlands is a relatively minor activity in New Zealand, and there is insufficient information to reliably report on this activity. The notation key NE (not estimated) is used in the common reporting format tables.

7.6.3 Uncertainties and time-series consistency

The uncertainty in mapping wetlands is ± 6.0 per cent. Further details on this are given in section 7.2.5.

New Zealand uses the IPCC default value for biomass accumulation in wetlands, which is given as ± 75 per cent.

The uncertainties in soil carbon stocks for wetlands – open water is 0.0 per cent (as there is no soil carbon stock change for this land use) and 95.0 per cent for wetland – vegetated non-forest.

New Zealand's emissions from wetlands in 2010 were 0 so no uncertainty is introduced into the estimate by wetlands.

Table 7.6.3 Uncertainty in New Zealand's 2010 estimates for the wetlands category

Variable	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	
Uncertainty in land area	6.0%
Uncertainty introduced into net LULUCF emissions	*0.0%*
Emission factor uncertainty	
Uncertainty in biomass accumulation rates	75.0%
Uncertainty in soil carbon stocks	95.0%
Uncertainty introduced into net LULUCF emissions	*0.0%*

Note: The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC, 2003.

7.6.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data and emissions factor for carbon change underwent Tier 1 quality checks.

7.6.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the wetlands land-use category is shown in table 7.6.4. Recalculations were carried out for this category as a result of new activity data from the improved mapping process as described in section 7.2 – representation of land areas.

The carbon stock in soils at equilibrium state has also been recalculated since the last submission. Details of this process are described in section 7.1.3.

Table 7.6.4 Recalculations for New Zealand's net emissions from the wetlands category in 1990 and 2008

Wetlands recalculations	Net emissions 2011 submission ($Gg\ CO_2$-e)	Net emissions 2012 submission ($Gg\ CO_2$-e)	Change from the 2011 submission ($Gg\ CO_2$-e)	Change from the 2011 submission (%)
1990	164.7	165.7	1.0	0.6
2009	0.0	0.0	0.0	0

7.6.6 Category-specific planned improvements

For the 2012 submission, New Zealand has mapped wetlands into two subcategories: 'wetlands – open water' and 'wetlands – vegetated non-forest'. The estimates for these subcategories have been calculated separately but are reported in aggregate in the common reporting format tables.

No additional improvements to the estimates for the wetlands category are currently planned.

7.7 Settlements (CRF 5E)

7.7.1 Description

The settlements land-use category, as described in GPG-LULUCF chapter 3.6, includes "all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories". Settlements include trees grown along streets, in public and private gardens, and in parks associated with urban areas.

There were 207,169 hectares of settlements in 2010 in New Zealand, an increase of 3,709 hectares since 1990. This category was 0.8 per cent of New Zealand's total land area in 2010. The largest area of change to settlements between 1990 and 2010 was from high-producing grassland, with 2,264 hectares of high-producing grassland converted to settlements between 1990 and 2010.

In 2010, the net emissions from settlements were 34.9 Gg CO_2-e. These emissions are entirely from the subcategory of land converted to settlements.

Settlements were not a key category in 2010.

Table 7.7.1 New Zealand's land-use change within the settlements category from 1990 to 2010, and associated CO_2-equivalent emissions

Settlements land-use category	Net area as at 1990 (ha)	Net area as at 2010(ha)	Change from 1990 (%)	Net emissions ($Gg CO_2$-e) 1990	2010	Change from 1990 (%)
Settlements remaining settlements	180,852	198,002	9.5	NE	NE	NA
Land converted to settlements	22,608	9,167	–59.5	97.7	34.9	–64.3
Total	**203,460**	**207,169**	**1.8**	**97.7**	**34.9**	**–64.3**

Note: 1990 and 2010 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for the settlements remaining settlements land-use category are not estimated (NE) as New Zealand has insufficient activity data for this subcategory; see section 7.7.2 for details. NA = not applicable.

In 2010, there were 180,852 hectares of settlements remaining settlements. Carbon in living biomass and dead organic matter is not estimated for this land-use category. The carbon stock in soil for this land use is assumed to be in steady state.

There were 3,877 hectares of land converted to settlements between 1990 and 2010.

Carbon stock change within the settlements category is shown in table 7.7.2. From 1990 to 2010, the net carbon stock change for settlements decreased by 449.2 Gg C, equivalent to emissions of 1,647.0 Gg CO_2 in total since 1990. These carbon stock losses are predominantly due to the loss of soil carbon on land conversion to settlements (see table 7.7.3).

Table 7.7.2 New Zealand's carbon stock change by carbon pool within the settlements category from 1990 to 2010

Land-use category	Net carbon stock change 1990–20109 (Gg C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2010 (Gg CO_2)
Settlements	–121.7	–11.3	–316.1	–449.2	1,647.0

7.7.2 Methodological issues

Greenhouse gas emissions within the settlements land-use category derive principally from carbon stock changes within the living biomass pool. The IPCC notes that "while dead organic matter and soil carbon pools may also be sources or sinks of CO_2 in settlements, and CH_4 and N_2O emissions may result from urban land management practices, little is known about the role and magnitude of these pools in overall greenhouse gas fluxes" (GPG-LULUCF, section 3.6, IPCC, 2003).

Therefore, the focus of New Zealand's methodological approach to estimating greenhouse gas emissions for the settlements land-use category is on changes in carbon stock change in living biomass.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for settlements is provided in table 7.7.3.

Table 7.7.3 Summary of New Zealand emission factors for the settlements land-use category

Settlements greenhouse gas source category	Steady state carbon stock ($t\ C\ ha^{-1}$)	Years to reach steady state	Carbon stock change on conversion to settlements ($t\ C\ ha^{-1}$)	Reference
Biomass – all pools	NE	28	Instantaneous loss of previous land-use carbon stock	IPCC Tier 1 default (section 3.6.2, IPCC, 2003)
Soils – mineral	64.81	20	Linear change over the conversion period between new and previous stock values	Section 7.1.3 – soils
Biomass burning	NE	NA	NE	

Note: NE = not estimated; NA = not applicable.

Settlements remaining settlements

Living biomass and dead organic matter

A basic method for estimating CO_2 emissions in settlements remaining settlements is provided in appendix 3A.4 of GPG-LULUCF. The methods and available default data for this land use are preliminary and based on an estimation of changes in carbon stocks per tree crown cover area or carbon stocks per number of trees as a removal factor (IPCC, 2003). New Zealand does not have this level of activity data and is therefore unable to estimate emissions for this subcategory. The reporting of settlements remaining settlements is optional (GPG-LULUCF, chapter 1.7, IPCC, 2003).

Soil carbon

Soil carbon stocks in settlements remaining settlements are estimated using a Tier 1 method as described in section 7.1.3 – soils. The steady state mineral soil carbon stock in settlements is estimated to be 64.81 $t\ C\ ha^{-1}$ (table 7.1.7). In the absence of default stock change factors for this land use, the stock change factors for severely depleted unimproved grassland is used for this land use, which implies major long-term loss of productivity and vegetation cover.

Land converted to settlements

Living biomass and dead organic matter

New Zealand has applied a Tier 1 method for estimating carbon stock change with land conversion to settlements (GPG-LULUCF, equation 3.6.1, IPCC, 2003). This is the same as that used for other areas of land-use conversion (eg, land converted to cropland). The default assumptions for a Tier 1 estimate are that all living biomass and dead organic matter present before conversion are lost in the same year as the conversion takes place and that carbon stocks in living biomass and dead organic matter following conversion are equal to zero (GPG-LULUCF, section 3.6.2, IPCC, 2003).

Soil carbon

Soil carbon stocks in land converted to settlements are estimated using a Tier 1 method as described in section 7.1.3 – soils. In the absence of either country- or land-use specific data on the time rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and settlements for any given period.

Non-CO_2 emissions

Biomass burning

Biomass burning on land converted to settlements is a relatively minor activity in New Zealand, and there is insufficient information to reliably report on this activity. The notation key NE (not estimated) is used in the common reporting format tables.

7.7.3 Uncertainties and time-series consistency

The uncertainty in mapping settlements is ± 6 per cent. Further details on this are given in section 7.2.5.

New Zealand uses the IPCC default values for biomass accumulation. The uncertainty in these figures is given as ± 75 per cent.

New Zealand uses the IPCC default values for carbon accumulation in soils. The uncertainty in this figure is given as ± 107.4 per cent. This comprises of the uncertainty in the soil carbon reference value (92.6 per cent) and the uncertainty in the management regime factor (50.0 per cent).

Table 7.7.4 Uncertainty in New Zealand's 2010 estimates for the settlements category

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	6.0%
Emission factor uncertainty	131.0%
Uncertainty introduced into net LULUCF emissions	*0.006%*

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 for these emissions underwent Tier 1 quality checks.

7.7.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the settlements land-use category is shown in table 7.7.5. Recalculations were carried out for this category as a result of moving to Tier 1 methodology for estimation of soil carbon stock change. Details of this process are described in section 7.1.3.

Table 7.7.5 Recalculations for New Zealand's net emissions from the settlements category in 1990 and 2009

Settlements recalculations	Net emissions (Gg CO_2-e) 2011 submission	2012 submission	Change from the 2011 submission (Gg CO_2-e)	(%)
1990 estimates	–7.2	97.7	104.9	1,458.8
2009 estimates	2.5	34.9	32.4	1,301.9

7.7.6 Category-specific planned improvements

Activity data on the land area of settlements will be updated as new information on urban expansion becomes available.

No other changes to the settlements emission factors or methodology are planned.

7.8 Other land (CRF 5F)

7.8.1 Description

Other land is defined in GPG-LULUCF section 3.7 as including bare soil, rock, ice and all unmanaged land areas that do not fall into any of the other five land-use categories. It consists mostly of steep, rocky terrain at high elevation, often covered in snow or ice. This category is 3.3 per cent of New Zealand's total land area.

In 2009, the net emissions from other land were 10.8 Gg CO_2-e. These emissions occur in the land converted to other land category and are 4.3 Gg CO_2-e (67.3 per cent) higher than the 1990 level of 6.5 Gg CO_2-e. This is primarily due to the larger area of land estimated as having been converted to other land in 2009 than in 1990.

An analysis of change in area shows that most of the land converted to other land between 1990 and 2010 (489 hectares) was from the forest land category (table 7.2.3). Between 1990 and 2010, 220 hectares of natural forest and 269 hectares of pre-1990 planted forest were converted to other land. This is likely to be mainly due to conversion of forest land to roads, mines and quarries.

Other land was not a key category in 2010.

Table 7.8.1 New Zealand's land-use change within the other land land-use category from 1990 to 2010

Other land land-use category	Net area as at 1990 (ha)	Net area as at 2010 (ha)	Change from 1990 (%)	Net emissions (Gg CO_2-e) 1990	2010	Change from 1990 (%)
Other land remaining other land	898,889	892,326	–0.7	NE	NE	NA
Land in conversion to other land	25	873	3,359.0	6.5	10.8	67.3
Total	**898,914**	**893,199**	**–0.6**	**6.5**	**10.8**	**67.3**

Note: 1990 and 2010 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for other land remaining other land are not applicable (NA) as change in carbon stocks and non-CO_2 emissions are not assessed for this category; see section 7.8.2 for details. NA = not applicable.

7.8.2 Methodological issues

Other land remaining other land

The area of other land has been estimated based on LCDB2. The method used is described more fully in section 7.2 – representation of land areas.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for other land is provided in table 7.8.2.

Table 7.8.2 Summary of New Zealand emission factors for the other land land-use category

Other land greenhouse gas source category	Steady state carbon stock (t C ha^{-1})	Years to reach steady state	Carbon stock change on conversion to other land (t C ha^{-1})	Reference
Biomass	NE	NA	Instantaneous loss of previous land-use carbon stock	IPCC Tier 1 default assumption (equation 3.7.1, GPG-LULUCF, IPCC, 2003)
Soils (mineral)	92.59	20	Linear change over the conversion period between new and previous stock values	Section 7.1.3 – soils
Biomass burning	NE	NA	NE	

Note: NE = not estimated; NA = not applicable.

Living biomass and dead organic matter

All of New Zealand's land area in the other land category is classified as 'managed'. New Zealand considers all land to be managed as all land is under some form of management plan, regardless of the intensity and/or type of land-management practices. No guidance is provided in GPG-LULUCF for estimating carbon stocks in living biomass or dead organic matter for other land that is managed, and, as a result, the change in carbon stocks and non-CO_2 emissions is not assessed for this category.

Soil carbon

Soil carbon stocks in other land remaining other land are estimated using a Tier 1 method for mineral soils as described in section 7.1.3 – soils. The steady state mineral soil carbon stock in other land is estimated to be 92.59 t C ha^{-1}, with an associated uncertainty of 95 per cent. In the absence of default stock change factors for this land use, it is assumed that other land represents native conditions, and the reference soil organic stock value is used.

Land converted to other land

Living biomass and dead organic matter

New Zealand uses a Tier 1 method to calculate emissions for land converted to other land (GPG-LULUCF, equation 3.7.1, IPCC, 2003). This is the same as that used for other areas of land-use conversion (eg, land converted to cropland). The Tier 1 method assumes carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place and that carbon stock in living biomass and dead organic matter following 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 1 method as described in section 7.1.3 – soils. The IPCC default method of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and other land for any given period.

Non-CO_2 emissions

Biomass burning

Biomass burning on land converted to other land is a relatively minor activity in New Zealand, and there is insufficient information to reliably report on this activity. The notation key NE (not estimated) is used in the common reporting format tables.

7.8.3 Uncertainties and time-series consistency

Uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. Uncertainty in other land introduces 0.003 per cent uncertainty into the LULUCF net carbon emissions. This is low because the area in other land and the emissions from other land are low.

Table 7.8.3 Uncertainty in New Zealand's 2010 estimates for the other land land-use category

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	6.0%
Emission factor uncertainty	95.0%
Uncertainty introduced into net LULUCF emissions	*0.003%*

Note: The activity data and combined emissions factor uncertainty are weighted values and have been calculated using equation 5.2.2 from GPG-LULUCF, IPCC, 2003.

7.8.4 Category-specific QA/QC and verification

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

7.8.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emissions estimates for the other land category is shown in table 7.8.4. Recalculations were carried out for this category as a result of new activity data and error corrections to the mapping data as explained in section 7.1.5.

Table 7.8.4 Recalculations for New Zealand's net emissions from the other land land-use category in 1990 and 2009

	Net emissions		Change from the 2011 submission	
	2011 submission ($Gg\ CO_2$-e)	2012 submission ($Gg\ CO_2$-e)	($Gg\ CO_2$-e)	(%)
1990	31.9	6.5	–25.4	–79.7
2009	7.2	17.7	10.4	143.9

Activity data

New Zealand has reviewed its mapping of forest land converted to other land which is due to erosion. Land within the forest land category that was eroded was removed from the other land category because erosion results in a change in land cover (but is not a land-use change) and the emissions from the change in land cover are estimated on harvest or when the land undergoes land-use change.

7.8.6 Category-specific planned improvements

There are no category-specific planned improvements for other land.

7.9 Non-CO_2 emissions (CRF 5(I-V))

7.9.1 Direct N_2O emissions from nitrogen fertilisation of forest land and other (CRF 5.I)

New Zealand's activity data on nitrogen fertilisation is not currently disaggregated by land use, and therefore all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the category 'direct soils emissions' (CRF 4D). The notation key IE (included elsewhere) is reported in the CRF tables for the LULUCF sector.

7.9.2 Non-CO_2 emissions from drainage of soils and wetlands (CRF 5.II)

New Zealand has not prepared estimates for this voluntary reporting category as allowed for in the IPCC good practice guidance for LULUCF, chapter 1.7, IPCC, 2003. The notation key NE (not estimated) is reported in the CRF tables for the LULUCF sector.

7.9.3 N_2O emissions from disturbance associated with land-use conversion to cropland (CRF 5.III)

Description

Nitrous oxide emissions result from the mineralisation of soil organic matter with conversion to cropland. This mineralisation results in an associated conversion of nitrogen previously in the soil organic matter to ammonium and nitrate. Microbial activity in the soil converts some of the ammonium and nitrate present to N_2O. An increase in this microbial substrate caused by a net decrease in soil organic matter can therefore be expected to give an increase in net N_2O emissions (GPG-LULUCF, section 3.3.2.3, IPCC, 2003).

Nitrous oxide emissions from disturbance associated with land-use conversion to croplands are minor in New Zealand, estimated at 0.03 Gg N_2O in 2010, and 0.9 Gg N_2O (285.4 Gg CO_2-e) in total since 1990 (table 7.9.1). This reflects the relatively small area of land converted to croplands since 1990 and the moderately high carbon stocks of New Zealand's cropland soils (section 7.1.3).

Table 7.9.1 N_2O emissions from disturbance associated with land-use conversion to cropland

Area and associated emissions	1990	2010	Change since 1990
Area of land in conversion to cropland (ha)	36,764	34,293	–6.7%
Emissions from disturbance (Gg N_2O)	0.06	0.03	–52.6%

Methodological issues

To estimate N_2O emissions from disturbance associated with land-use conversion to cropland, New Zealand uses the method outlined in GPG-LULUCF, equations 3.3.14 and 3.3.15, to estimate these emissions (IPCC, 2003). The inputs to these equations are:

- change in carbon stocks in mineral soils, and estimated carbon losses from organic soils, on land converted to cropland: these values are calculated from the land converted to cropland soil carbon calculations
- EF1: the emission factor for calculating emissions of N_2O from nitrogen in the soil. New Zealand uses a country-specific value of 0.01 kg N_2O – N/kg N (Kelliher & de Klein, 2006)
- C:N ratio: the IPCC default ratio of carbon to nitrogen in soil organic matter (1:15) is used (IPCC, 2003)
- where an area of land converted to cropland has a lower mineral soil organic carbon stock than the subcategory of cropland it has been converted to, no N_2O emissions have been estimated as occurring because there is no associated loss of soil organic carbon. For instance, forest land converted to cropland is accordingly estimated not to result in net N_2O emissions because this land-use conversion is associated with a net gain in soil organic carbon in New Zealand (see section 7.1.3). In these situations, the notation key NO (not occurring) is reported in the CRF tables.

Uncertainties and time-series consistency

New Zealand uses a country-specific value for calculating N_2O emissions from nitrogen in soil. This value has a high level of uncertainty, which is estimated at 40.0 per cent.
New Zealand uses the IPCC default values for carbon accumulation in soils. The uncertainty in this figure is given as 97 per cent.

Table 7.9.2 Uncertainty in New Zealand's 2010 estimates for N_2O emissions from disturbance associated with land-use conversion to cropland

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	5.0%
Emission factor uncertainty	137.0%

Source-specific recalculations

There has been a small error correction to the spreadsheet in which the N_2O emissions from disturbance associated with land-use conversion to cropland are calculated. This has been corrected for the 2012 submission.

Source-specific planned improvements

No additional improvements are currently planned to New Zealand's estimation of emissions from disturbance associated with land-use conversion to cropland.

7.9.4 Liming (CRF 5(IV))

Description

In New Zealand, agricultural lime is mainly applied to acidic grassland and cropland soils to maintain or increase the productive capability of soils and pastures.

Emissions from the application of lime in 2010 were 631.4 Gg CO_2, down 5.6 per cent from emissions of 669.1 Gg CO_2 in 2009 but up 68.9 per cent from 373.8 Gg CO_2 in 1990.

Methodological issues

Information on agricultural lime (limestone and dolomite) application is collected by the national statistics agency, Statistics New Zealand, as part of its annual Agricultural Production Survey. The Agricultural Production Survey has gaps in its time series. No survey was carried out in 1991, or between 1997 and 2001. Linear interpolation has been used to represent the data for these years. 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 Agricultural Production Survey indicates that, each year, around 94 per cent of agricultural lime used in New Zealand is applied to grassland, with the remaining 6 per cent applied to cropland. Emissions associated with liming are estimated using a Tier 1 method (GPG-LULUCF equation 3.4.11, IPCC, 2003) and the IPCC default emission factor for carbon conversion of 0.12.

Uncertainties and time-series consistency

The uncertainty in LULUCF net emissions introduced by liming has been reported under the relevant land use, namely cropland and grassland.

Source-specific QA/QC and verification

In the preparation of this inventory, the data for liming underwent Tier 1 quality checks. Statistics New Zealand, which collects the activity data for liming, also carries out a series of quality-assurance and quality-control procedures as part of the Agricultural Production Survey carried out each year.

Source-specific recalculations

Emissions from liming in 2009 have been updated as a result of the activity data from the Agricultural Production Survey being finalised.

Source-specific planned improvements

New Zealand will continue to update activity data on liming as it becomes available from Statistics New Zealand. No other future improvements are currently planned.

7.9.5 Biomass burning (CRF 5.V)

Description

Biomass burning may occur as a result of wildfires or controlled burning, and results in emissions of CO_2, CH_4, N_2O, CO and NO_x. The general approach for estimating greenhouse gas emissions from biomass burning is the same regardless of the specific land-use type.

Biomass burning is not a significant source of emissions for New Zealand as the practice of controlled burning is limited and wildfires are not common due to New Zealand's temperate climate and vegetation.

Emissions of CO_2 are reported as either IE (included elsewhere) (when associated with a land-use change or where subsequent regrowth is not captured in the inventory) or NE (not estimated) (where no data exists) in the CRF tables. The reason for this is explained below under methodological issues. Non-CO_2 emissions from biomass burning in 2010 were 2.6 Gg CH_4 (53.8 Gg CO_2-e) and 0.02 Gg N_2O (5.7 Gg CO_2-e).

Table 7.9.3 Non-CO_2 emissions from biomass burning

Emissions	1990	2009	Change since 1990
CH_4 emissions (Gg CH_4)	2.4	2.6	8.8%
N_2O emissions (Gg N_2O)	0.02	0.02	7.0%

Methodological issues

New Zealand reports on emissions from wildfire in forest land and grassland, and controlled burning associated with land-use change from grassland to forest land based on activity data and an assumption of the proportion of these areas burnt. Emissions from controlled burning in land converted to grassland are not reported in the inventory because there is insufficient information on the proportion of land burnt during this change. Emissions from the burning of crop stubble and controlled burning of savanna are reported in the agriculture sector (chapter 6).

Tier 2 methodologies are employed to estimate emissions from biomass burning in New Zealand. Country-specific emission factors are employed along with IPCC equations to derive emissions (sections 3.4.2.1.1.2 and 3A.1.12, IPCC 2003). Activity data (area of land-use change) for the grassland with woody biomass converted to forest category is based on annual land-use changes as estimated in section 7.2 – representation of land areas. For the land remaining land categories, activity data is sourced from the NRFA database, which has data from 1992 onwards.

The average area burnt between 1992 and 2009 from this database is used as the estimate of area burnt for 1990 to 1991 as the estimates for this period are inaccurate because of incomplete coverage in data collection. The April year data is then converted to calendar years for use in the inventory (Wakelin et al, 2009).

There has not been a significant change in wildfire activity since 1990 (Wakelin et al, 2009). Natural disturbance (lightning) induced wildfires are estimated to account for only 0.1 per cent of burning in grassland and forest land in New Zealand (Wakelin, 2006; Doherty et al, 2008). Non-CO_2 emissions from these events are reported in the inventory because the NRFA does not distinguish between anthropogenic and natural wildfire events in the data. Given the small incidence of natural disturbance induced wildfires in New Zealand, this is not regarded as a significant source of error. The emission of CO_2 from the combustion of biomass due to wildfires in forest land is not estimated at the time of burning. In planted forest, burnt stands are either harvested or left to grow on at reduced stocking. CO_2 emissions are reported when the stand is harvested or deforested (with no reduction in stock when compared with an un-burnt stand). Given the few incidences of wildfire in New Zealand's planted forest lands, this is not regarded as a significant source of error. Carbon dioxide lost in natural forest wildfires can be ignored since these fires do not result in land-use change and regrowth is not reported in the inventory (IPCC, 2003).

A single weighted biomass density is used to estimate non-CO_2 emissions from wildfire in the forest land remaining forest land subcategory. Wildfire activity data is attributed to each subcategory by proportion of forest type estimated to be burned over the time series. This is split by 87.5 per cent to planted forest with the remaining to natural forest (Wakelin et al, 2009). The planted forest activity data are further split into pre-1990 and post-1989 forest by the proportion of area each subcategory makes up of the total planted forest area. In planted forest, it is assumed that the carbon stock affected by wildfire is equivalent to the carbon stock at the average stand age in each subcategory (Wakelin, 2011). The individual forest subcategory estimates that make up the single weighted figure are derived from the national plot network described in section 7.3.

Non-CO_2 emissions from wildfires in land converted to forest land are reported under the post-1989 forest subcategory for the first time in the 2012 submission. The activity data does not distinguish between forest land subcategories. Therefore, non-CO_2 emissions resulting from wildfire are attributed to the post-1989 forest subcategory by the proportion of area post-1989 forest makes up of the total planted forest area. An age-based carbon yield table is then used to estimate non-CO_2 emissions in post-1989 forest. This approach assumes that the carbon stock affected by wildfire is equivalent to the carbon stock at the average stand age each year throughout the time series (Wakelin, 2011). Carbon dioxide emissions resulting from wildfire events are not reported, as the methods applied do not capture subsequent regrowth (GPG-LULUCF, section 3.2.1.4.2, IPCC, 2003).

In New Zealand, it is assumed that 25 per cent of grassland with woody biomass converted to forest land is cleared using controlled burning. New Zealand is currently investigating a data source to refine the assumption for this activity.

Different biomass-density values for wildfire and controlled burning on grassland with woody biomass are used in the inventory. The differences are due to the vegetation that is typically converted to forest, which is generally of a lesser stature when compared with other shrubland (Wakelin, 2008). The inventory does not report on-site preparation burning activities on forest land remaining forest. Although this practice is not thought to be significant, New Zealand is investigating a data source for this activity. Controlled burning of grassland with woody biomass for the establishment or re-establishment of pasture has also not been included. Conversions of planted forest land to grassland (pasture) have increased between 2004 and 2008. New Zealand is investigating sources of information to quantify emissions from this activity for possible reporting in future submissions.

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. The biomass burning statistics have gaps in the time series where data collection did not occur or survey methodologies changed. Assumptions are made for some emission factors and burning fractions where insufficient data exists.

Table 7.9.4 Uncertainty in New Zealand's 2009 estimates for CH_4 and N_2O emissions from biomass burning

Uncertainty source	Uncertainty at a 95% confidence interval (%)
Activity data uncertainty	5.0%
Emission factor uncertainty	42.4%

Source-specific QA/QC and verification

Quality-control and quality-assurance measures are applied to the biomass burning activity data and emission factors. The biomass burning dataset is scientifically verified whenever new data are supplied. In 2006 and 2009, the biomass burning parameters (emission factors, burning and emissions factors), assumptions and dataset were scientifically reviewed and updated. Data validation rules and plausibility tests were then applied to the activity data (Wakelin et al, 2009).

Source-specific recalculations

New Zealand has updated the country-specific emission factor for wildfire in forest land remaining forest land derived from the national plot network described above under methodological issues. The affect of the changes in this category is small due to the relatively minor incidences of wildfire in New Zealand.

Source-specific planned improvements

Emissions from controlled burning of planted forest harvesting residues are not reported in the inventory. New Zealand is investigating sources of information to quantify emissions from this activity for possible reporting in future submissions.

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

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Chapter 8: Waste

8.1 Sector overview

In 2010, the waste sector contributed 1,991.8 Gg carbon dioxide equivalent (CO_2-e) (2.8 per cent) of New Zealand's total greenhouse gas emissions. The largest source of waste sector emissions in 2010 was the solid waste disposal on land category, which contributed 1,345.5 Gg CO_2-e (or 67.5 per cent of waste sector emissions). The wastewater handling category contributed 644.1 Gg CO_2-e (32.3 per cent) of waste sector emissions and the waste incineration category contributed the remaining 2.2 Gg CO_2-e (0.1 per cent).

Emissions from the waste sector are predominantly methane emissions (90.8 per cent), followed by nitrous oxide emissions (9.1 per cent) and then carbon dioxide emissions (0.05 per cent).

Changes to emissions between 1990 and 2010

Emissions from the waste sector were 61.4 Gg CO_2-e (3.0 per cent) below the 1990 baseline value of 2,053.2 Gg CO_2-e (figure 8.1.1). This reduction, despite an increase in New Zealand's population and economic activity occurred largely in the solid waste disposal on land category as a result of initiatives to improve solid waste management practices. Emissions from municipal solid waste disposal on land decreased by 168.9 Gg CO_2-e (11.2 per cent) between 1990 (1,514.4 Gg CO_2-e) and 2010 (1,345.5 Gg CO_2-e) and by 46.0 Gg CO_2-e (3.3 per cent) since 2009.

Figure 8.1.1 New Zealand's waste sector emissions from 1990 to 2010

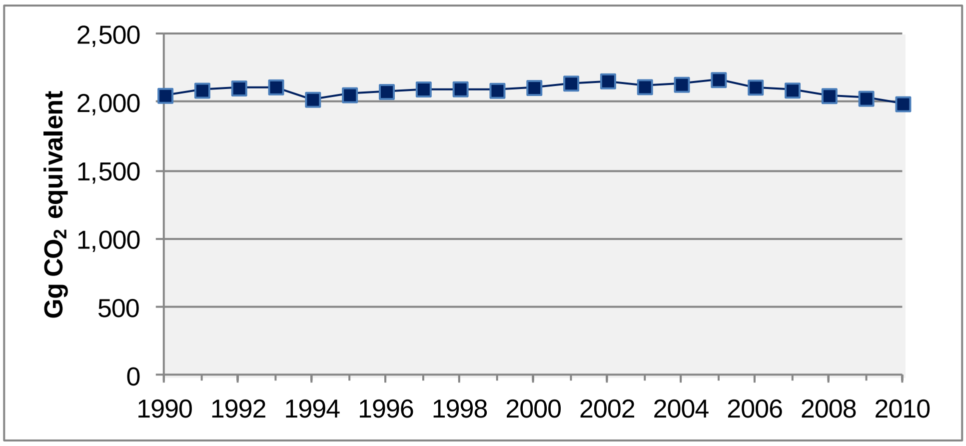
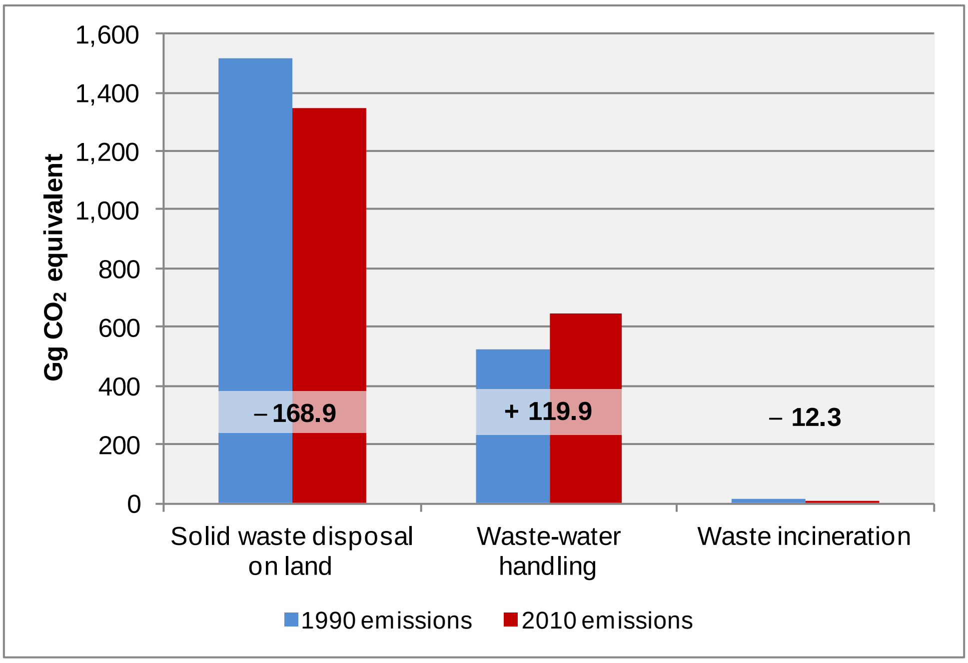


Figure 8.1.2 Change in New Zealand's emissions from the waste sector from 1990 to 2010



Changes to emissions between 2009 and 2010

Total waste emissions in 2010 were 40.0 Gg CO_2-e (2.0 per cent) lower than the 2009 level. This was largely due to the increase in emissions recovered from solid waste disposal sites.

8.1.1 Summary of improvements

The estimates for the waste sector have been recalculated. This is largely due to improved methodologies for calculating emissions from wastewater handling by the meat industry and domestic sector. These improvements have come from:

- using actual meat industry output figures from 1990 to 2010. Earlier submissions interpolated and extrapolated many of these values
- applying more appropriate biochemical oxygen demand correction factors for some wastewater treatment plants.

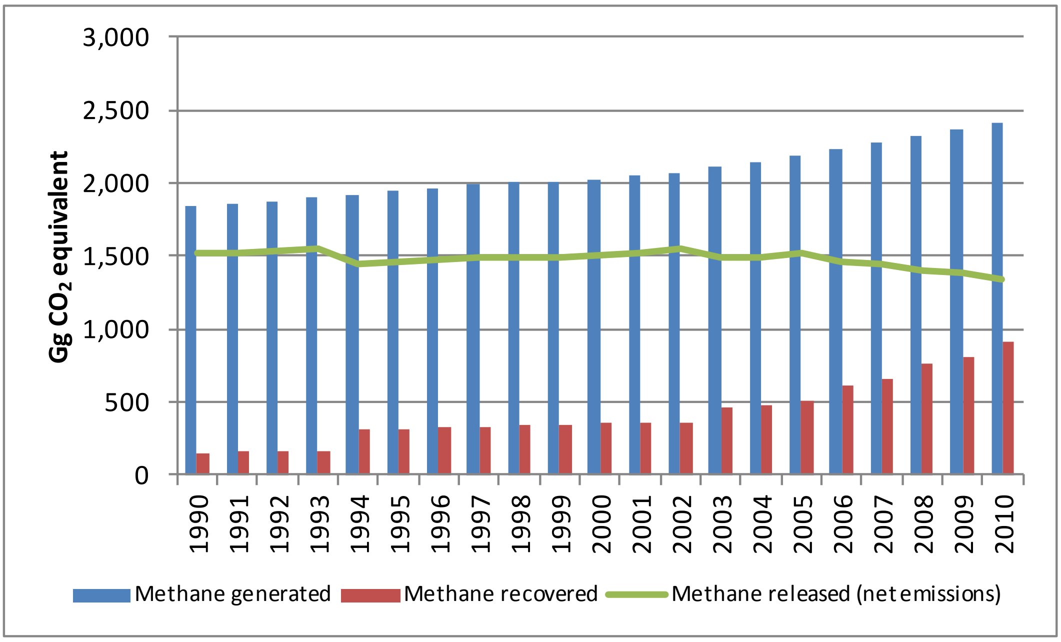
8.2 Solid waste disposal on land (CRF 6A)

8.2.1 Description

In 2010, solid waste disposal on land contributed 1,345.5 Gg CO_2-e (67.6 per cent) of total emissions from the waste sector. Solid waste disposal emissions in 2010 were 168.9 Gg CO_2-e (11.2 per cent) below the 1990 level of 1,514.4 Gg CO_2-e.

In 2010, the amount of methane recovered from solid waste disposal on land was 913.3 Gg CO_2-e. Methane recovered in 2010 was 758.2 Gg CO_2-e above the 1990 level of 155.1 Gg CO_2-e and 98.9 Gg CO_2-e (12.1 per cent) above the 2009 level (see figure 8.1.3).

Figure 8.1.3 New Zealand's solid waste disposal to land emissions from 1990 to 2010



Methane emissions from solid waste disposal were identified as a key category in the 2010 level assessment and in the 1990–2010 trend assessment.

Organic waste in solid waste disposal sites is broken down by bacterial action in a series of stages that result in the formation of carbon dioxide and methane. The carbon dioxide from aerobic decomposition is not reported in the inventory as it is assumed to be reabsorbed in the following year. The amount of methane generated depends on a number of factors including waste disposal practices (eg, managed versus unmanaged landfills), the composition of the waste and physical factors, such as the moisture content and temperature of landfills. The methane produced can go directly into the atmosphere via venting or leakage, or it can be flared off and converted to carbon dioxide.

Solid waste management in New Zealand

In New Zealand, managing solid wastes has traditionally meant disposing of solid waste in landfills. In 1995, a national landfill census showed there were 327 legally operating landfills or solid waste disposal sites in New Zealand that accepted approximately 3.18 million tonnes of solid waste (Ministry for the Environment, 1997).

Since 1995, there have been a number of initiatives to improve solid waste management practices in New Zealand. These include the release of guidelines for:

- the development and operation of landfills
- the management of closing and closed landfills
- landfill resource consent conditions under New Zealand's Resource Management Act 1991.

As a result of these initiatives, a number of poorly located and substandard landfills have been closed and communities are relying increasingly on modern regional disposal facilities for disposal of their solid waste. The *National 2006/07 Landfill Census* reported that there were 60 legally operating municipal landfills in New Zealand, a reduction of

82 per cent from 1995 (Ministry for the Environment, 2007). The same census reported that 3.156 million tonnes of solid waste were disposed of to landfills in 2006.

In March 2002, the Government released the *New Zealand Waste Strategy* (Ministry for the Environment, 2002a). The strategy, which was revised in 2010, sets out the Government's long-term priorities for waste management and minimisation (Ministry for the Environment, 2010). The strategy's two goals provide direction to local government, businesses (including the waste industry) and communities on where to focus their efforts to deliver environmental, social and economic benefits to all New Zealanders. The goals are:

- reducing the harmful effects of waste
- improving the efficiency of resource use.

As part of the implementation and monitoring of the waste strategy, the Government developed the *Solid Waste Analysis Protocol*, which provided a classification system, sampling regimes and survey procedures to measure the composition of solid waste streams (Ministry for the Environment, 2002b).

In 2008, the Government passed the Waste Minimisation Act, which imposes a levy of $10 per tonne of municipal solid waste from 1 July 2009, extends product stewardship regimes and enables regulations to require landfill operators and others to report on various waste targets and measures. Reporting required under this Act significantly improves New Zealand's knowledge of solid waste volumes. Work will be undertaken to attempt to determine a method to back-cast this information so it can be incorporated into future inventory submissions (see section 8.2.7.)

8.2.2 Methodological issues

New Zealand has applied a Tier 2 approach by using the IPCC first order decay model to report emissions from solid waste disposal in the inventory (IPCC, 2006a). The 2006 IPCC guidelines (IPCC, 2006a) are used because New Zealand considers them to contain the most appropriate and current methodologies, particularly regarding default methane generation rates, for estimating emissions from solid waste disposal.

The following discusses the parameters for each type of landfill (ie, landfills with methane recovery systems and those without methane recovery systems) where they differ and then discusses the common parameters used for both types of landfills.

Landfills with methane recovery systems

In 2010, 21 landfills had operational methane recovery systems, with a known further three landfills expecting to have methane recovery systems operating by 2012. For each of these 24 landfills, a landfill-specific first order decay model, based on the model contained within the IPCC 2006 guidance, was used to develop estimates of net methane emissions from waste disposal. In 2010, these 24 landfills accepted approximately 63 per cent of waste disposed to municipal landfills in New Zealand.

Waste placement

Landfill-specific information on annual solid waste placement was determined for the 24 landfills with methane recovery systems (or with plans to install methane recovery systems by 2012) through direct contact with landfill operators (SKM, Unpublished (a)).

Methane correction factor

The methane correction factor accounts for the different amounts of methane produced by the different levels of management of landfills. A methane correction factor of 1.0 is applied for all years to all landfills with methane recovery systems, as all these landfills are considered to be managed solid waste disposal sites.

Methane generation rate/half-life

The methane generation rate/half-life is the time taken for the degradable organic carbon in waste to decay to half of its initial mass. Methane generation rates/half-life values for waste disposed of to the 24 landfills with methane recovery systems (or with plans to install methane recovery systems by 2012) were determined based on local rainfall information and the values used in the Inventory of US Greenhouse Gas Emissions and Sinks 1990–2007 (SKM, Unpublished (a)). These values were then adjusted to reflect the management practices at each landfill. The practices considered were leachate collection, leachate recirculation, leachate treatment and quality of capping (SKM, Unpublished (a)).

Recovery

In the 21 landfills identified as having methane recovery systems in 2010, estimates of methane recovery efficiency were developed either through the use of metered system data (for four landfills) or through consideration of landfill capping quality, landfill lining, well placement, active or passive gas control and retrofitted or original wells (SKM, Unpublished (a)). To check that the modelling approach was accurate, modelled results were determined for the four landfills with metered data and the two sets of results were compared. The modelled results and the metered data were, on average, very similar, although the modelled results had a very slight tendency to underestimate recovery efficiency (by approximately 3 per cent).

Efficiencies ranged from 42 per cent to 90 per cent, with an average efficiency of 61.1 per cent.

Landfills without methane recovery systems

In 2010, landfills without methane recovery systems accepted approximately 37 per cent of waste disposed to municipal landfills in New Zealand. A first order decay model was used to estimate net methane emissions from this waste.

Waste placement

Annual total waste placement to all landfills has been estimated based on national surveys for the years 1995, 1998, 2002 and 2006. For the years between surveys, when data is not available, solid waste-placement per person is estimated by interpolation. For the years before the earliest survey and after the latest survey, the closest survey-based waste-placement per person value (1995 and 2006 respectively) is used (table 8.2.1). The solid waste-placement per person estimate is then multiplied by population estimates to determine the total waste placement to all landfills. The reduction in solid waste per person per year since 1995 is assumed to be due to waste minimisation initiatives from central and local government and increased recycling.

The annual solid waste placement for landfills without methane recovery systems is the difference between the sum of the estimated annual solid waste placement for the 24 landfills with methane recovery systems (or with plans to install methane recovery systems) (SKM, Unpublished (a)) and the total annual solid waste placement discussed above.

Table 8.2.1 New Zealand's generation rate of solid waste to landfill

Year	Generation rate (kilograms per person per year)	Source
1950–1994	857.9	1995 figure applied retrospectively
1995	857.9	Ministry for the Environment (1997)
1996	812.6	Interpolation
1997	767.4	Interpolation
1998	722.1	Ministry for the Environment (2000)
1999	730.9	Interpolation
2000	739.8	Interpolation
2001	748.6	Interpolation
2002	757.5	Ministry for the Environment (2003)
2003	757.1	Estimated using population growth and waste composition analysis
2004	774.4	Estimated using population growth and waste composition analysis
2005	761.9	Interpolation
2006	749.4	Ministry for the Environment (2007) and Waste Not Consulting (Unpublished)
2007–2010	749.4	2006 figure applied

Methane correction factor

In 1997, it was estimated that 90 per cent of New Zealand's waste in 1995 was disposed to managed solid waste disposal sites and 10 per cent disposed to uncategorised sites (Ministry for the Environment, 1997). However, it was estimated that 100 per cent of solid waste would be disposed to managed sites by 2010, due to the closure of unmanaged landfills. Consequently, the methane correction factor for landfills without methane recovery systems has increased from 0.90 in 1995 to a value of 1.00 from 2010.

Methane generation rate/half-life

New Zealand applies the IPCC default methane generation rate (referred to as the half-life value (k)) for a wet temperate climate (IPCC, 2006a). Default half-life values are applied to these landfills as there is no New Zealand-specific data on the half-life values of the solid waste within these landfills. This climate type is considered the best fit for New Zealand's complex climate systems and geography.[37]

The New Zealand waste composition categories do not match the definition categories required for the IPCC methane generation and degradable organic carbon calculations (IPCC, 2006a). The difference is that New Zealand's putrescibles category combines the food waste stream and the garden waste stream for the methane generation rate and degradable organic carbon calculation. A separation of the combined waste stream into the two IPCC categories was not possible given the available data. New Zealand applies a conservative approach to estimating the combined food and garden stream by applying

[37] Mean average temperatures vary from 10 degrees Celsius in the south to 16 degrees Celsius in the north. Mean annual precipitation ranges from 600 to 1,600 millimetres (National Institute of Water and Atmospheric Research, 2010). Mean annual potential evapo-transpiration ranges from 200 millimetres to 1,100 millimetres.

the half-life for food waste to the combined food and garden waste category. For consistency, the degradable organic carbon content for food waste has also been applied to the combined category. This approach results in the garden waste component of the category biodegrading sooner and, therefore, producing emissions sooner than if it was in its own category. It also results in a lower degradable organic carbon for the garden waste component than if it was in its own category.

The 2011 inventory submission advised methane generation rates would be developed for each landfill without a methane recovery system. The current methodology uses a combined waste-placement value for all these landfills as individual landfill placement data is not available. While this information has been collected under the Waste Minimisation Act since July 2009, the use of this information is not possible due to confidentiality reasons. As the use of individual landfill methane generation rates is not practical without individual landfill placement information, the planned improvement did not proceed.

Landfills with and without methane recovery systems

The following parameters are applied to both landfills with and without methane recovery systems.

Waste class

New Zealand has insufficient data to categorise solid waste as either municipal solid waste or industrial solid waste, because many municipal landfills accept industrial waste. All national data is therefore reported in the municipal solid waste class and industrial waste is included in the composition estimates for this class.

Waste composition

Activity data on solid waste composition was estimated in the national surveys for 1995 and 2004 (Ministry for the Environment, 1997; Waste Not Consulting, Unpublished). Linear interpolations were used to provide estimates for the years between the two national surveys. The 1995 estimate is used for preceding years, and the 2004 estimate is used for subsequent years, including 2010. Table 8.2.2 shows the measured and calculated proportions each waste category has contributed to the total waste stream from 1950 to 2010.

As discussed above, New Zealand uses a putrescibles category that combines the IPCC food waste category and the garden waste category.

Table 8.2.2 Composition of New Zealand's waste

Year	Food (%)	Garden (%)	Paper (%)	Wood (%)	Textile (%)	Nappies (%)	Inert (%)	Source
1950–1994	28	0	16	7	1	3	45	1995 proportions applied retrospectively
1995	28	0	16	7	1	3	45	Ministry for the Environment (1997)
1996	28	0	16	8	1	3	45	Interpolation
1997	27	0	16	9	1	3	44	Interpolation
1998	27	0	16	9	2	3	44	Interpolation
1999	26	0	16	10	2	3	43	Interpolation

Year	Food (%)	Garden (%)	Paper (%)	Wood (%)	Textile (%)	Nappies (%)	Inert (%)	Source
2000	25	0	16	11	2	3	43	Interpolation
2001	25	0	15	12	3	3	43	Interpolation
2002	24	0	15	12	3	3	42	Interpolation
2003	24	0	15	13	4	3	42	Interpolation
2004	23	0	15	14	4	3	41	Waste Not Consulting (Unpublished)
2005–2010	23	0	15	14	4	3	41	2004 proportions applied

Degradable organic carbon

The combined degradable organic carbon (DOC) value varies across the time series according to the New Zealand-specific composition data, discussed above. The default IPCC values of the degradable organic carbon in the different waste composition categories are used – the exception being the combined food and garden category, which uses the food category DOC value.

The combined DOC value has remained constant since 2004, as there is no new data available for solid waste composition. The estimate of degradable organic carbon content in 1995 was 0.146 Gg C/Gg waste. This estimate has been applied to preceding years. The estimate increased over time to 0.170 Gg C/Gg waste in 2004, and this has been applied to subsequent years, including 2009. This increase was mainly due to an increase in the proportion of wood in each tonne of waste going to landfills.

Default parameters applied

New Zealand uses the IPCC default values for the starting year, the delay time, the fraction of degradable organic carbon that actually decomposes and the fraction of methane in landfill gas (table 8.2.2) (IPCC, 2006a).

An oxidation factor of 0.1 is applied to all landfills as landfills in New Zealand are capped at the end of operational life and have daily cover applied, and are categorised as well managed (IPCC, 2006a). However, prior to 2010, there was a small proportion of landfills that were considered not well managed and were accommodated through the adjusted methane correction factor, discussed above.

Summary of parameters used

Table 8.2.3 provides a summary of the parameter values applied for estimating methane emissions from solid waste disposal to land.

Table 8.2.3 Parameter values applied by New Zealand for estimating solid waste disposal to land

Parameter	Value	Source	Reference
Landfills with methane recovery systems			
Methane generation rate/half-life (year^{-1})	Range of 0.038–0.090	New Zealand specific	SKM (Unpublished (a))
Methane correction factor	1.0	IPCC default	IPCC (2006a)
Methane recovery efficiencies (%)	Range of 42–90	New Zealand specific	SKM (Unpublished (a))

Parameter	Value	Source	Reference
Landfills without methane recovery systems			
Methane generation rate/half-life ($year^{-1}$):			
Food and garden	0.185	IPCC default for food	IPCC (2006a)
Paper	0.060	IPCC default	IPCC (2006a)
Wood and straw	0.030	IPCC default	IPCC (2006a)
Textiles	0.060	IPCC default	IPCC (2006a)
Disposable nappies	0.100	IPCC default	IPCC (2006a)
Sewage sludge	0.185	IPCC default	IPCC (2006a)
Methane correction factor	Range of 0.90–1.0	New Zealand specific	Ministry for the Environment (1997)
All landfills			
Starting year	1950	IPCC default	IPCC (2006a)
Delay time	6 months	IPCC default	IPCC (2006a)
Fraction of DOC that decomposes	0.50	IPCC default	IPCC (2006a)
Fraction of methane in landfill gas	0.50	IPCC default	IPCC (2006a)
Oxidation correction factor	0.10	IPCC default	IPCC (2006a)
Degradable organic carbon (Gg C/Gg waste)	Range of 0.146–0.170	New Zealand specific	Ministry for the Environment (1997); Waste Not Consulting (Unpublished)

8.2.3 Uncertainties and time-series consistency

The overall level of uncertainty is estimated at ±40 per cent. The uncertainty is based on the uncertainty provided for the recovery modelling (SKM, Unpublished (a)), and sits within the IPCC default uncertainty range for methane recovery, as some metered data is used.

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or parameters have occurred, the entire time series was recalculated (see section 8.2.5).

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

In the preparation for this inventory submission, the data for this category underwent Tier 1 quality checks.

8.2.5 Source-specific recalculations

Emission estimates between 2007 and 2010 have been recalculated to reflect a landfill operating a methane recovery system earlier than previously assumed. The amount of untreated sewage sludge disposed of to landfills has been amended based on corrections to the amount of sludge produced (see section 8.3.5).

8.2.6 Source-specific planned improvements

Waste-placement information is collected under the Waste Minimisation Act 2008. The Act provides a robust framework for collecting data on waste disposal to municipal landfills. This information has been collected from July 2009. Data collected prior to this date was collected using a variety of methods and has high uncertainties.

The waste-placement data collected under the Act for 2010 is approximately 25 percent less than the waste-placement data used in this submission. The differences between the two datasets are still being investigated. If an inconsistent time series approach was used, a sudden decrease in the waste placement and emissions from solid waste disposal would be reported.

As the time period of waste-placement information collected under the Act increases, work will be undertaken to attempt to determine a method to back-cast this information so it can be incorporated into future inventory submissions.

8.3 Wastewater handling (CRF 6B)

8.3.1 Description

In 2010, wastewater handling produced 644.1 Gg CO_2-e (32.3 per cent) of emissions from the waste sector. This was an increase of 119.9 Gg CO_2-e (22.9 per cent) from the 1990 level of 524.2 Gg CO_2-e and is due to increases in emissions from both the industrial and domestic sectors.

Methane emissions from wastewater handling were identified as a key category in the 2010 level assessment, but only in the analysis of total emissions.

Domestic and commercial wastewater

Domestic and commercial wastewater contributed 274.3 Gg CO_2-e (42.6 per cent) of the 2010 emissions from the wastewater handling category.

Wastewater from almost every town in New Zealand with a population over 1,000 is collected and treated in community wastewater treatment plants. There are approximately 317 municipal wastewater treatment plants in New Zealand and approximately a further 50 government or privately owned treatment plants serving populations of more than 100 people (SCS Wetherill Environmental, 2002).

Although most of the wastewater treatment processes are aerobic, there are a significant number of wastewater treatment plants that use partially anaerobic processes such as oxidation ponds or septic tanks. Small communities and individual rural dwellings are served mainly by simple septic tanks, followed by ground soakage trenches.

Industrial wastewater

Industrial wastewater contributed 369.9 Gg CO_2-e (57.4 per cent) of the 2010 emissions from the wastewater handling category. The major sources of industrial wastewater in New Zealand are the meat and pulp and paper industries. Most of the industrial wastewater treatment is aerobic and most methane from anaerobic treatment is flared. However, there are a number of anaerobic ponds that do not have methane collection, particularly serving the meat industry. This is discussed further below in methodological issues.

8.3.2 Methodological issues

Methane emissions from domestic wastewater treatment

Method

Methane emissions from domestic wastewater handling have been calculated using the default IPCC method (IPCC, 1996).

Activity data

Estimates are derived from applying information on the number of treatment plants in New Zealand, the population connected to each treatment plant and the treatment methods of each plant (Beca, Unpublished).

Population served by municipal wastewater treatment plants

The population using each municipal treatment plant and an estimation of the population using septic tanks has been determined (SCS Wetherill Environmental, 2002; Beca, Unpublished). In 2010, the total connected population was estimated to be 4.1 million. This is a minor difference between the estimated official 2010 population of 4.3 million. The relative difference is similar to other years and is considered unlikely to be significant within the accuracy of the calculations (Tonkin and Taylor, Unpublished). The connected population includes an estimated 429,000 people connected to rural septic tanks.

The population treated by each plant is updated each year based on the population growth rate of the district in which the plant is located. This information is obtained from Statistics New Zealand (Statistics New Zealand, 2011a).

Methane conversion factors for handling systems

Methane conversion factors for the different handling systems in New Zealand have been determined by SCS Wetherill Environmental, 2002. These factors range from zero, for the different types of aerobic treatment, and up to 0.65 for the different types of anaerobic treatment.

Biochemical oxygen demand

New Zealand uses a value of 26 kilograms biochemical oxygen demand per person per year. This is equivalent to the IPCC high-range default value for the Oceania region of 70 grams per person per day (IPCC, 1996). This value has been determined as a typical value for wastewater treatment methods adopted in New Zealand (Beca, Unpublished). This value has been increased by 25 per cent for most treatment plants to allow for commercial and industrial activity within a municipal area. Ten treatment plants have been identified to accept much larger amounts of industrial and/or commercial activity and the increases in the biochemical oxygen demand value for these plants range from 77 per cent to 1,490 per cent (Beca, Unpublished).

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

Methane removal via flaring or for energy production is known to occur at eight plants in New Zealand. All methane generated at these plants is flared or used for energy production and consequently the net result is zero methane emissions (Beca, Unpublished).

Summary of parameters used

Table 8.3.1 provides a summary of the parameter values applied for estimating methane emissions from domestic wastewater treatment.

Table 8.3.1 Parameter values applied by New Zealand for estimating methane emissions for domestic wastewater treatment

Parameter	Value	Source	Reference
Methane conversion factors (MCF)			
Handling systems MCF	Range of 0–0.65	New Zealand specific	SCS Wetherill Environmental (2002)
Aggregated MCF	Range of 0.35–0.37	New Zealand specific	Derived from SCS Wetherill Environmental (2002)
Biochemical oxygen demand (BOD) (kg BOD/person/year)	26	New Zealand specific	Beca (Unpublished)
Correction factor for BOD	Range of 1.25–14.9	New Zealand specific	Beca (Unpublished)
Maximum methane producing capacity (kgCH_4/kgBOD)	0.625	IPCC default	IPCC (1996)

Methane emissions from industrial wastewater treatment

The IPCC default method is used to calculate methane emissions from industrial wastewater treatment (IPCC, 1996).

The following industries were identified as having organic-rich wastewaters that are treated anaerobically (in order of significance): meat processing, pulp and paper, and dairy processing. Emissions from wine production and wool scouring wastewater have also been included to ensure all industries known to have wastewater treatment facilities are accounted for.

Meat processing industry

Activity data

An estimate of the wastewater output from meat processing is based on the total production (kills) from the different producers of the meat industry – beef, sheep/lambs, goats, pigs (obtained from Statistics New Zealand, 2011b), venison (obtained from Deer Industry New Zealand, pers. comm., 2011) and poultry (obtained from Poultry Industry Association of New Zealand, pers. comm., 2011).

The total organic wastewater from meat rendering was determined in 2006 (Beca, Unpublished). Using the 2006 figure, a ratio of wastewater from rendering to kills has been determined and has been applied to all years.

Degradable organic component

SCS Wetherill Environmental (2002) determined there was a range of 50 to 123 kilograms of chemical oxygen demand per tonne of product for the different producers within the meat industry.

Methane conversion factor

The meat processing methane conversion factor for all of the different producers is 0.55, as reported by SCS Wetherill Environmental (2002).

Default parameters applied

New Zealand uses the 1996 default IPCC value for both the maximum methane producing capacity and the methane conversion factor for the rendering calculations.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.2 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the meat industry.

Table 8.3.2 Parameter values applied by New Zealand for estimating methane emissions from wastewater treatment by the meat industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	Range of 0.05–0.12	New Zealand specific	SCS Wetherill Environmental (2002)
Methane conversion factors			
Processing	0.55	New Zealand specific	SCS Wetherill Environmental (2002)
Rendering	1.0	IPCC default	IPCC (1996)
Maximum methane producing capacity ($kgCH_4/kgCOD$)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand.

Pulp and paper industry

Activity data

An estimate of the pulp and paper wastewater output is based on the paper, paperboard and pulp production from the industry. This information is obtained from the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2011).

Degradable organic component

The degradable organic component was derived from the chemical oxygen demand (COD)/t product, which is determined from industry data for biochemical oxygen demand (Beca, Unpublished).

Methane conversion factor

The methane conversion factor of 0.02 was determined by SCS Wetherill Environmental, 2002. This same conversion factor was also determined by Beca (Unpublished) in 2006.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.3 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the pulp and paper industry.

Table 8.3.3 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the pulp and paper industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	0.03	New Zealand specific	Beca (Unpublished)
Methane conversion factor	0.02	New Zealand specific	SCS Wetherill Environmental (2002), Beca (Unpublished)
Maximum methane producing capacity ($kgCH_4/kgDC$)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand.

Dairy industry

The dairy industry predominantly uses aerobic treatment. There is only one factory that uses anaerobic treatment. The wastewater is covered and the majority of the captured biogas (consisting of 55 per cent methane) is used to operate the boilers. The remainder is flared. Consequently, there are no emissions from this industry (Beca, Unpublished).

Wine industry

Emissions from the wine industry have been estimated using expert judgement and are based on total industry output values and values of methane production in septic tanks (Savage, Unpublished). These estimates are then extrapolated for the time series. Work is under way to improve the reporting of wastewater emissions from the wine industry (see section 8.3.5).

Wool scouring industry

Activity data

Emissions from wastewater for the wool scouring industry are based on the outputs obtained and projected by SCS Wetherill Environmental (2002).

Methane conversion factor

The methane conversion factor of the wool scouring industry is 0.29, as determined by SCS Wetherill Environmental (2002).

Degradable organic component

SCS Wetherill Environmental (2002) determined there were 22 kilograms of chemical oxygen demand per tonne of product for the wool scouring industry.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.4 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the meat industry.

Table 8.3.4 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the wool scouring industry

Parameter	Value	Source	Reference
Methane conversion factor	0.29	New Zealand specific	SCS Wetherill Environmental (2002)
Degradable organic component (kg COD/tonne of product)	0.02	New Zealand specific	SCS Wetherill Environmental (2002)
Maximum methane producing capacity ($kgCH_4$/kgCOD)	0.25	IPCC default	IPCC (1996)

Note: COD = chemical oxygen demand.

Methane emissions from domestic sludge treatment

In large domestic wastewater treatment plants in New Zealand, sludge is handled anaerobically and the methane is almost always flared or used (Tonkin and Taylor, Unpublished). Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds (SCS Wetherill Environmental, 2002).

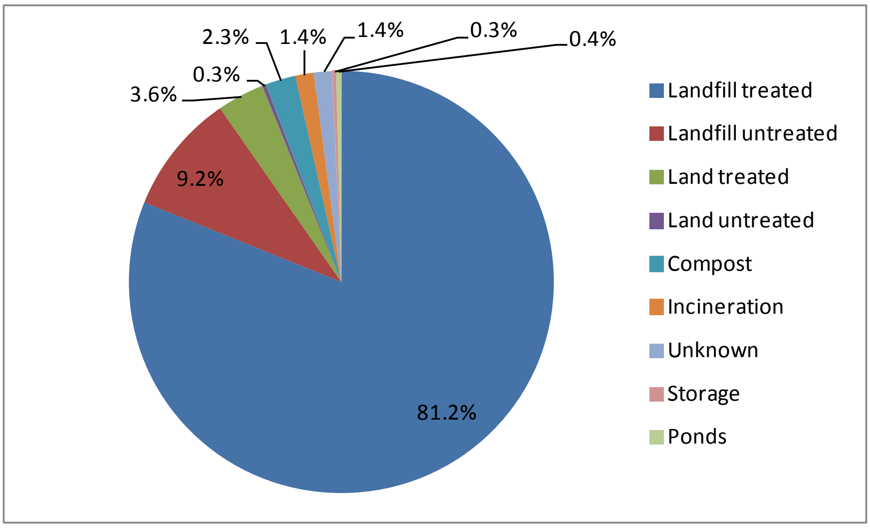
Oxidation ponds accumulate sludge on the pond floor. In New Zealand, these are typically only de-sludged every 20 years. The sludge produced is well stabilised with an average age of approximately 10 years. It has a low, biodegradable organic content and is considered unlikely to be a significant source of methane (SCS Wetherill Environmental, 2002).

Sludge from septic tank clean-out, known as 'septage', is often removed to the nearest municipal treatment plant. In those instances, it is included in the methane emissions from domestic wastewater treatment. There are a small number of treatment lagoons specifically treating septage. These lagoons are likely to produce a small amount of methane and their effect is included in the calculations (SCS Wetherill Environmental, 2002).

Disposal

In New Zealand, the majority of sludge from domestic wastewater treatment plants is sent to landfills. In 2006, 90.4 per cent of sludge disposed of was sent to landfills – 81.2 per cent of this sludge was treated and 9.2 per cent was untreated (Figure 8.3.1) (Tonkin & Taylor, Unpublished). The treated sludge sent to landfill is considered inert and therefore no emissions are produced, while untreated sludge emissions are included in the estimates for solid waste disposal to land (section 8.2).

Figure 8.3.1 Domestic sludge disposal in New Zealand, 2006



Method

The IPCC (1996) Tier 1 method is used to calculate emissions from domestic sludge treatment.

Activity data

Estimates are derived from applying information on the number of treatment plants in New Zealand, the population connected to each treatment plant and the treatment methods of each plant (Beca, Unpublished; Tonkin and Taylor, Unpublished).

Population served by municipal wastewater treatment plants, biochemical oxygen demand and biochemical oxygen demand correction factors

These values have been determined (and adjusted in the case of population) as discussed above in the methane emissions from domestic wastewater treatment section.

Fraction of degradable organic component removed as sludge

The fraction of degradable organic component removed as sludge for the different types of wastewater treatment plants has been based on the average ranges reported in Metcalf and Eddy (1992), as recommended by Tonkin & Taylor (Unpublished). These fractions range from 0 to 0.88.

Methane conversion factors

A methane conversion factor of 1 has been used for anaerobic treatment systems, and a methane conversion factor of 0 used for aerobic treatment/handling systems.

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

In 2010, anaerobic digestion treats approximately 59 per cent of total domestic sludge in New Zealand. Of the sludge treated by anaerobic digestion, 96 per cent is treated by plants that utilise or flare methane.

A methane recovery value of 90 per cent is used for anaerobic digesters with known utilisation or flaring. This is a conservative method as much higher destruction efficiency is expected. In accordance with the IPCC method, where the fate of the gas from an anaerobic digester is unknown, no methane recovery is assumed.

Summary of parameters used

Table 8.3.5 provides a summary of the parameter values applied for estimating methane emissions from domestic wastewater sludge treatment.

Table 8.3.5 Parameter values applied by New Zealand for estimating methane emissions from domestic wastewater sludge treatment

Parameter	Value	Source	Reference
Fraction of degradable organic component removed as sludge	Range of 0–0.88	New Zealand specific	Tonkin & Taylor (Unpublished)
Methane conversion factors			
Anaerobic treatment systems	1	IPCC default	IPCC (1996)
Aerobic treatment systems	0	IPCC default	IPCC (1996)
Biochemical oxygen demand (BOD) (kg BOD/person/year)	26	New Zealand specific	Beca (Unpublished)
Correction factor for BOD	Range of 1.25–14.9	New Zealand specific	Beca (Unpublished)
Maximum methane producing capacity ($kgCH_4/kgDC$)	0.25	IPCC default	IPCC (1996)
Methane recovery factor for anaerobic digestion treatment with utilisation or flaring	0.9	New Zealand specific	Tonkin & Taylor (Unpublished)

Methane emissions from industrial sludge treatment

Method

The IPCC (1996) Tier 1 method is used to calculate emissions from industrial sludge treatment.

Activity data

In New Zealand, the pulp and paper industry has been determined as the only industry to produce a source of methane from sludge treatment (Tonkin and Taylor, Unpublished).

An estimate of the pulp and paper wastewater output is based on the paper, paperboard, and pulp production (tonnes) from the industry. This information is updated quarterly by the Ministry of Agriculture and Forestry (Ministry of Agriculture and Forestry, 2011).

The meat industry typically uses anaerobic treatment processes – mostly anaerobic lagoons with no sludge discharges. Emissions from these processes have been accounted for under the wastewater category. The dairy industry uses a variety of typically aerobic processes for treatment. Any sludge removed from these treatment processes is generally treated aerobically and discharged to land.

Fraction of degradable organic component removed as sludge

An 80 per cent chemical oxygen demand removal as sludge has been assumed (Tonkin and Taylor, Unpublished).

Methane conversion factor

A methane conversion factor of 0.6 has been used for the pulp and paper industry as not all pulp and paper plants in New Zealand treat their sludge anaerobically. This figure is likely to be conservative as conversion factors are expected to be lower (Tonkin and Taylor, Unpublished).

Default parameters applied

New Zealand uses the 1996 default IPCC value for the maximum methane producing capacity.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.6 provides a summary of the parameter values applied for estimating methane emissions from waste sludge treatment by industry.

Table 8.3.6 Parameter values applied by New Zealand for estimating methane emissions from industry wastewater sludge treatment

Parameter	Value	Source	Reference
Fraction of degradable organic component removed as sludge	0.8	New Zealand specific	Tonkin & Taylor (Unpublished)
Methane conversion factor	0.6	New Zealand specific	Tonkin & Taylor (Unpublished)
Maximum methane producing capacity (kgCH_4/kgDC)	0.25	IPCC default	IPCC (1996)

Nitrous oxide emissions from domestic wastewater

There are no methodologies to estimate these nitrous oxide emissions from domestic wastewater within New Zealand.

Nitrous oxide emissions from industrial wastewater treatment

The IPCC states that, compared with domestic wastewater, the nitrous oxide emissions from industrial wastewater are insignificant and can therefore be ignored (IPCC, 2006a). However, this guidance does not take into account the significance of the meat industry in New Zealand in relation to nitrogenous-rich wastewaters. Due to the prevalence of anaerobic treatment plants within the meat industry, New Zealand has chosen to report nitrous oxide emissions from this source for completeness.

Method

The IPCC does not have a method for calculating nitrous oxide emissions from industrial wastewater; consequently, a New Zealand-derived method has been applied. The total nitrogen is calculated by adopting the chemical oxygen demand load from the methane emission calculations, and using a ratio of chemical oxygen demand to nitrogen in the wastewater for each of the different producers in the meat industry.

Activity data

The meat industry activity is consistent with the activity data used for calculating methane emissions from the meat industry under the industrial wastewater treatment section.

Ratio of nitrogen to total organic wastewater

New Zealand uses a ratio of 0.08 to determine the amount of nitrogen in the total organic wastewater from the meat industry.

Emission factor

An emission factor of 0.02 is used to calculate the emissions from the total nitrogen in wastewater (SCS Wetherill, 2002).

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.7 provides a summary of the parameter values applied for estimating nitrous oxide emissions from wastewater sludge treatment by the meat industry.

Table 8.3.7 Parameter values applied by New Zealand for estimating nitrous oxide emissions for wastewater treatment for the meat industry

Parameter	Value	Source	Reference
Ratio of nitrogen to total organic wastewater	0.08	New Zealand specific	SCS Wetherill Environmental (2002)
Emission factor	0.02	New Zealand specific	SCS Wetherill Environmental (2002)

Nitrous oxide emissions from domestic wastewater sludge treatment/human sewage treatment

Method

To estimate nitrous oxide emissions from domestic wastewater sludge/human sewage treatment, New Zealand uses the IPCC Tier 1 method, which calculates nitrogen production based on average per capita protein intake (IPCC, 2006a).

Activity data

Nitrous oxide emissions from domestic wastewater sludge/human sewage treatment are updated based on population data from Statistics New Zealand (Statistics New Zealand, 2011a).

Per capita protein consumption

A value of 36.135 kilograms of protein per person per year is used. This figure was reported by New Zealand to the Food and Agriculture Organization, United Nations. It is the maximum value reported by New Zealand between 1990 and 2010.

Default parameters applied

New Zealand uses the default IPCC values for the fraction of nitrogen in protein, fraction of non-consumption protein, the fraction of industrial and commercial co-discharged protein, nitrogen removed with sludge, emission factor and the emissions from wastewater treatment plants.

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 8.3.8 provides a summary of the parameter values applied for estimating nitrous oxide emissions from domestic and commercial wastewater sludge treatment.

Table 8.3.8 Parameter values applied by New Zealand for estimating nitrous oxide emissions from domestic and commercial wastewater sludge treatment

Parameter	Value	Source	Reference
Per capita protein consumption (kg/person/year)	36.135	New Zealand specific	Beca (Unpublished)
Fraction of nitrogen in protein	0.16	IPCC default	IPCC (2006a)
Fraction of non consumption protein	1.4	IPCC default	IPCC (2006a)
Fraction of industrial and commercial co-discharged protein	1.25	IPCC default	IPCC (2006a)
Nitrogen removed with sludge (kg)	0	IPCC default	IPCC (2006a)
Emission factor	0.005	IPCC default	IPCC (2006a)
Emissions from wastewater treatment plants	0	IPCC default	IPCC (2006a)

Nitrous oxide emissions from industrial sludge treatment

There are no methodologies to estimate these emissions within New Zealand.

8.3.3 Uncertainties and time-series consistency

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or emission factors have occurred, the entire time series has been recalculated.

Methane emissions from domestic wastewater treatment

The domestic wastewater methane emissions have an accuracy of ±40 per cent (SCS Wetherill Environmental, 2002; Beca, Unpublished). It is not possible to perform rigorous statistical analyses to determine uncertainty levels for domestic wastewater because of biases in the data collection methods (SCS Wetherill Environmental, 2002). This uncertainty stems from:

- uncertainties in the factors used to calculate emissions from the different wastewater treatment processes
- uncertainties in the quantities of wastewater handled by the different wastewater treatment plants
- uncertainties in the accuracy and completeness of the data relating to each plant.

Methane emissions from industrial wastewater treatment

Total methane production from industrial wastewater has an estimated accuracy of ±40 per cent (SCS Wetherill Environmental, 2002; Beca, Unpublished). This uncertainty stems from:

- uncertainties in the factors used to calculate the degradable organic content in the wastewater
- uncertainties in the wastewater treatment methods.

Methane emissions from domestic sludge treatment

The uncertainty of methane from domestic sludge is assessed as being ±50 per cent. This uncertainty stems from:

- uncertainties in the factors used to calculate emissions from the sludge
- uncertainties in the quantities of sludge produced from different wastewater treatment processes
- using average removal efficiencies
- uncertainties in the accuracy and completeness of the data relating to each plant.

Methane emissions from industrial sludge treatment

The uncertainty is assessed as being +100 per cent to –50 per cent. This uncertainty stems from:

- uncertainties in the method and factors used to calculate emissions from the sludge

- uncertainties in the quantities of sludge produced
- the use of average removal efficiencies.

Nitrous oxide emissions from domestic sludge and industrial wastewater treatment

There are very large uncertainties associated with nitrous oxide emissions from wastewater treatment, and no attempt has been made to quantify this uncertainty. The IPCC default emissions factor, EF_6, has an uncertainty of –80 per cent to +1,200 per cent (IPCC, 1996), which means the estimates have only order of magnitude accuracy.

8.3.4 Source-specific QA/QC and verification

In the preparation for this inventory submission, the data for the domestic and industrial sludge component of this category underwent Tier 1 quality checks. The largest improvement recommended by the Tier 1 quality checks was an improvement in the transparency of the compilation. This will be addressed in future submissions.

8.3.5 Source-specific recalculations

Methane emissions from domestic and commercial wastewater and sludge treatment

The time series for methane emissions from domestic wastewater treatment and from domestic sludge were recalculated to reflect corrections made to the activity data. This has improved the consistency of datasets within the wastewater handling category.

Amendments were made specifically to the correction factors for additional industrial biochemical oxygen demand discharged into sewers for certain treatment plants.

Methane and nitrous oxide emissions from industrial wastewater treatment

The time series for methane and nitrous oxide emissions from industrial wastewater were recalculated to include improved information on the total annual output for the different meat industry producers. Previously, there was incomplete information on total annual output and extrapolation and interpolation were applied. The improved information was sourced directly from the meat producers.

8.3.7 Source-specific planned improvements

Further work is under way to refine the methane emissions from industrial sludge. This work intends to refine production rates and reassess disposal methods for the pulp and paper, wine and wool scouring industries.

The development of New Zealand-specific parameters for the pulp and paper industry is also under way. Parameters include the methane producing capacity and the industrial degradable organic component removed as sludge.

8.4 Waste incineration (CRF 6C)

8.4.1 Description

In 2010, waste incineration accounted for 2.2 Gg CO_2-e (0.1 per cent) of waste emissions. This was a decrease of 12.3 Gg CO_2-e (84.9 per cent) from the 1990 level of 14.6 Gg CO_2-e. Emissions have remained fairly constant since 2007 and have not changed from 2009.

Waste incineration management in New Zealand

There is no incineration of municipal waste in New Zealand. The only incineration is for small specific waste streams, including medical, quarantine and hazardous wastes. The practice of incinerating these waste streams has declined since the early 1990s due to environmental regulations and alternative technologies, primarily improving sterilisation techniques. Resource consents under New Zealand's Resource Management Act 1991 control non-greenhouse gas emissions from these incinerators.

Further, in 2004, New Zealand introduced a national environmental standard for air quality. The standard effectively required all existing, low temperature waste incinerators in schools and hospitals to obtain resource consent by 2006, irrespective of existing planning rules. Incinerators without consents are prohibited.

8.4.2 Methodological issues

Method

Estimates of direct emissions from the incineration of waste are made using the default Tier 1 methodology (IPCC, 2006a). The 2006 IPCC guidelines (IPCC, 2006a) are used because New Zealand considers the guidelines to contain the most appropriate and current methodologies for estimating emissions from waste incineration.

Activity data

Information on the annual amount of waste burnt per facility, per year is used to estimate waste incineration emissions. Limited information was provided by some individual sites, and some activity data had to be interpolated or extrapolated from the available data. There is generally no detailed information about the actual composition of the waste incinerated, only the consented types of waste allowed (SKM, Unpublished (b)).

Incineration devices that do not control combustion to maintain adequate temperature and that do not provide sufficient residence time for complete combustion are considered as open burning systems (IPCC, 2006a). Applying this definition excluded potential emissions from many small facilities that may have burned plastics and other mixed waste, such as at schools.

Only carbon dioxide emissions resulting from the burning of carbon in waste that is fossil in origin is included by the IPCC, such as in plastics, synthetic textiles, rubber, liquid, solvents and waste oil (IPCC, 2006a). Biogenic carbon dioxide, such as that from paper, cardboard and food, is excluded in accordance with the IPCC (2006a). Also excluded are emissions from waste to energy incineration facilities, as they are reported within the energy sector of the inventory.

Quarantine waste

Many incinerators in New Zealand are quarantine waste incinerators. The IPCC does not have a default category for quarantine incinerators. However, for the purposes of the calculations, the composition of quarantine was assumed to be more closely aligned with clinical waste than with the other categories (SKM, Unpublished (b)).

Hazardous waste

All parameters applied are default parameters.

Default IPCC hazardous waste compositional values are used to estimate the dry-matter content and the fossil carbon fraction in the total carbon in the waste incinerated. The default IPCC 2006 incineration oxidation value is used. New Zealand uses the mid-point where these values are presented as ranges.

The default IPCC 2006 emission factor for industrial waste is used for calculating methane emissions from incinerating hazardous waste. As the methane factors are presented as kg/TJ, the calorific value for the relevant waste is needed to convert the figures to Gg/year. The calorific value was sourced from the *New Zealand Energy Information Handbook* (Baines, 1993). Only the gross calorific value was available from this handbook, so that value is used, although it is noted this is inconsistent with the IPCC approach, which uses net values (IPCC, 2006a; 2006b).

The default IPCC 2006 emission factor for industrial waste incineration is used for calculating nitrous oxide emissions from incinerating hazardous waste (SKM, Unpublished (b)).

Clinical waste

All parameters applied are default parameters.

The default IPCC 2006 clinical waste compositional value is used to estimate the dry-matter content in the waste incinerated. The default IPCC 2006 clinical waste incineration values for the fraction of carbon in the dry matter, fossil carbon fraction in the total carbon and oxidation factor are used.

The default IPCC 2006 emission factor for municipal/industrial waste is used for calculating methane emissions from incinerating clinical waste. As for hazardous waste, calorific values from the *New Zealand Energy Information Handbook* (Baines, 1993) are used.

The default IPCC 2006 emission factor for municipal solid waste – batch type incinerators is used for calculating nitrous oxide emissions from incinerating clinical waste (SKM, Unpublished (b)).

Sewage sludge

All parameters applied are default parameters.

The default IPCC 2006 domestic sludge compositional value is used to estimate the dry-matter content. The default IPCC 2006 sewage sludge incineration values for the fraction of carbon in the dry matter, fossil carbon fraction in the total carbon and oxidation factor are used. New Zealand uses the mid-point where these values are presented as ranges.

The Japanese emission factor for sludge, provided in the IPCC 2006 guidelines, is used to calculate methane emissions from incinerating sewage sludge. The IPCC 2006 guidelines note that the most detailed observations of methane emissions from waste incineration have been made in Japan (IPCC, 2006a).

The default IPCC 2006 emission factor for sewage sludge incineration is used for calculating nitrous oxide emissions from incinerating sewage sludge (SKM, Unpublished (b)).

Summary of parameters

Table 8.4.1 provides a summary of the parameter values applied for estimating emissions from incineration.

Table 8.4.1 Parameter values applied by New Zealand for estimating emissions from incineration

Parameter	Hazardous waste	Clinical waste	Sewage sludge
Dry matter content in the waste incinerated (%)	0.5	0.65	0.1
Fraction of carbon in the dry matter	N/A	0.6	0.45
Fraction of fossil carbon in the total carbon	0.275	0.4	1.0
Oxidation factor	1.0	1.0	1.0
Methane emission factor	2.34	1.79	9.7
Nitrous oxide emission factor	100	60	900
Source			All IPCC defaults
Reference			All IPCC (2006a; 2006b)

8.4.3 Uncertainties and time-series consistency

As per the IPCC recommendation for uncertainties relating to activity data (IPCC, 2006a), estimated uncertainty for the amount of wet waste incinerated ranges from ±10 per cent to ±50 per cent and uncertainty of ±50 per cent is applied.

The data collected for the composition of waste is not detailed. Therefore, as per the recommendation for uncertainties relating to emission factors (IPCC, 2006a), the estimated uncertainty for default CO_2 factors is ±40 per cent. Default factors used in the calculation of methane and nitrous oxide emissions have a much higher uncertainty (IPCC, 2006a); hence, the estimated uncertainty for default methane and nitrous oxide factors is ±100 per cent (SKM, Unpublished (b)).

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or emission factors have occurred, a full time-series recalculation is conducted.

8.4.4 Source-specific QA/QC and verification

As there were minimal recalculated values in this sector, quality-assurance and quality-control efforts were focused on the solid waste disposal on land and wastewater handling categories.

8.4.5 Source-specific recalculations

An error has been corrected in the calculation of methane emissions from clinical waste incineration. This correction resulted in a very minor decrease across the time series.

8.4.6 Source-specific planned improvements

No improvements are planned for this category.

Chapter 8: References

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Chapter 9: Other

New Zealand does not report any emissions under the United Nations Framework Convention on Climate Change category 7, 'Other'.

Chapter 10: Recalculations and improvements

This chapter summarises the recalculations and improvements made to the New Zealand's greenhouse gas inventory following the 2011 submission. Further details on the recalculations for each sector are provided in chapters 3 to 8 and chapter 11.

Recalculations of estimates reported in the previous inventory can be due to improvements in:

- activity data
- emission factors and/or other parameters
- methodology
- additional sources identified within the context of the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003)
- activity data and emission factors that become available for sources that were previously reported as NE (not estimated) because of insufficient data.

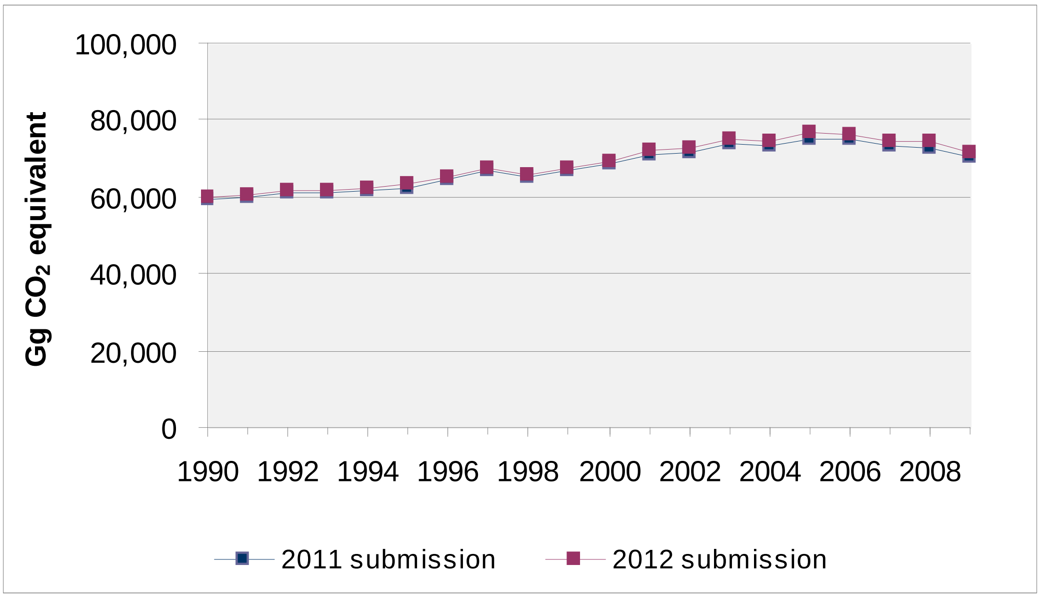
It is good practice to recalculate the whole time series from 1990 to the current inventory year to ensure a consistent time series. This means estimates of emissions in a given year may differ from emissions reported in the previous inventory submission for the same year. There may be exceptions to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

10.1 Implications and justifications

The overall effect of all recalculations in the 2012 inventory submission is shown in figure 10.1.1. There was a 1.2 per cent (685.1 Gg carbon dioxide equivalent (CO_2-e)) increase in total (gross) emissions for the base year, 1990, and a 1.3 per cent (919.1 Gg CO_2-e) increase in total emissions for the 2009 year. In New Zealand's 2011 inventory submission (1990–2009), emissions were 19.4 per cent above the level reported in 1990. As a result of the recalculations in the 2012 inventory submission, total emissions for 2009 were 19.5 per cent above 1990. The greatest influence for recalculations of total emissions was the improvements made in the agriculture sector. The improvements that made the largest change in emissions in the agriculture sector are the changes to the Tier 2 model used to estimate emissions from dairy, beef, sheep and deer.

The following section details the effect of recalculations for each sector and summarises the improvements that resulted in the recalculations.

Figure 10.1.1 Effect of recalculations on New Zealand's total (gross) greenhouse gas emissions from 1990 to 2009



10.1.1 Energy

The improvements made in the energy sector have resulted in a 0.4 per cent (99.3 Gg CO_2-e) increase in energy emissions in 1990, and a 0.7 per cent (233.4 Gg CO_2-e) increase in energy emissions in 2009 (figure 10.1.2). The most significant improvements introduced to the energy sector were revisions to coal consumption and mining data and the inclusion of waste oil. There was also a significant change in methodology – the adoption of a Tier 2 approach for estimating methane (CH_4) and nitrous oxide (N_2O) emissions from road transport. This has resulted in the recalculation of road transport emissions across the time series. The new methodology is a more accurate reflection of the effect of emission control technology on CH_4 and N_2O emissions from road transport. For further information on the methodology please see section 3.3.3.

In the 2012 submission, other significant improvements include the disaggregation of liquid fuel consumption in the manufacturing industries and construction category, the revision of gas activity data and the results of quality-control procedures. The explanations and justifications for all recalculations to New Zealand's energy estimates in the 2012 submission are summarised in table 10.1.1.

Figure 10.1.2 Effect of recalculations on New Zealand's energy sector from 1990 to 2009

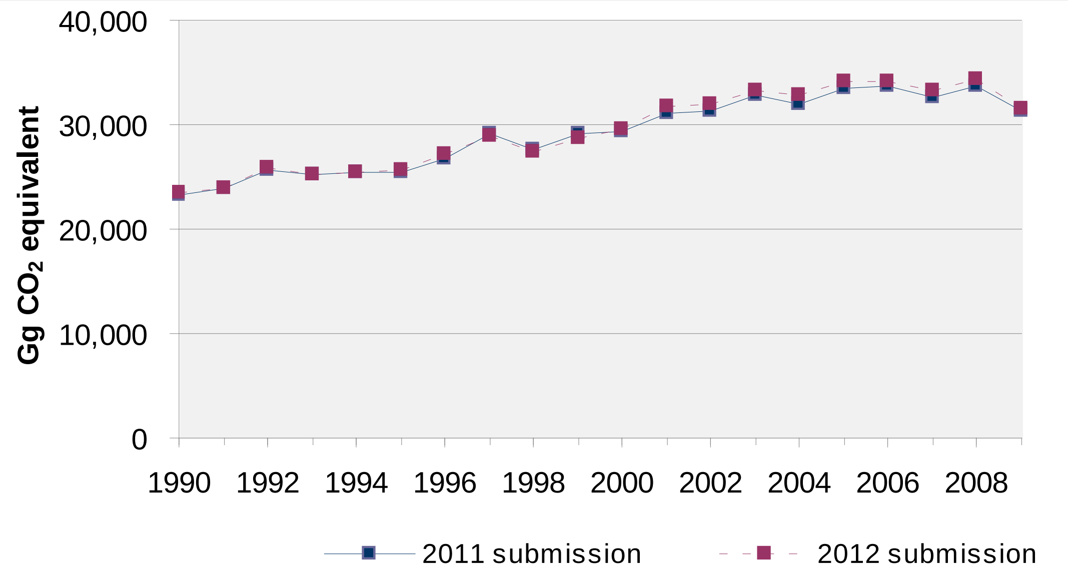


Table 10.1.1 Explanations and justification for recalculations in the energy sector

Explanation of recalculation	Good practice principle that was improved	Additional information
Small revisions to historic (1990–1998) liquid fuel activity data have been made following data cleansing of national energy data. Reported consumption was found to be inconsistent with reported electricity generation. As electricity generation was considered to be the more reliable data, new estimates of fuel consumption were made using electricity generation data and plant efficiencies. See section 3.3.1	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes
Revisions in activity data for gaseous fuels in public electricity and heat production were made as a result of a miscalculation in the reconciliation of monthly and annual data from electricity generation companies and the decision to reclassify the Whareroa co-generation facility as a main activity producer. See section 3.3.1	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes
Additional biogas plants have been captured in this inventory, leading to recalculations in biomass activity data in public electricity and heat production. See section 3.3.1	Completeness	Correction identified and resolved through quality-assurance and quality-control processes
Natural gas mining own-use activity data has been revised following the discovery of incorrect reporting. See section 3.3.1	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes
There have been small activity data revisions in some energy industry categories due to revisions in solid fuels data sources. See section 3.3.1	Accuracy	Corrections made by industry
Natural gas activity data in manufacturing industries and construction has been revised across the time series due to inconsistent sector reporting. New estimates were made using the following data sources in order of preference: • actual consumer data • sales data • regression against sector gross domestic product See section 3.3.2	Consistency	Correction identified and resolved through quality-assurance and quality-control processes

Explanation of recalculation	Good practice principle that was improved	Additional information
Continued disaggregation of liquid fuel activity data in manufacturing industries and construction previously reported as ‘other non-specified’ using Statistics New Zealand’s Energy End Use Surveys. As a result, recalculations have been made across the time series in all sub-sectors. See section 3.3.2	Completeness and consistency	Expert review team recommendation for a key category
Prior to 2009, liquid fuels sold to mining were captured as ‘other primary industry’. As part of the disaggregation mentioned above, these volumes were split between forestry and logging and mining using Statistics New Zealand’s *Energy End Use Survey of Primary Energy Sectors 2008*, resulting in increases in emissions from liquid fuels in the manufacturing industries and construction sector across the time series. See section 3.3.2	Accuracy and consistency	Correction identified and resolved through quality-assurance and quality-control processes
Some sales of coal previously reported as commercial were found to be resold to the manufacturing industries and construction sector. For time-series consistency, a split was applied to historical activity data, resulting in reallocations from commercial to manufacturing industries and construction. See section 3.3.2	Accuracy	Correction identified and resolved through quality-assurance and quality-control processes
Woody biomass combustion in industry was estimated using a model driven by the production of a number of different wood products. For this inventory, additional wood products were captured in the model, resulting in recalculations in activity data across the time series. See section 3.3.2	Accuracy and completeness	Correction identified and resolved through quality-assurance and quality-control processes
There have been small activity data revisions in the manufacturing industries and construction due to revisions in liquid fuels, natural gas and solid fuels data sources. See section 3.3.2	Accuracy	Corrections made by industry
Following expert review team recommendations, New Zealand has moved to a Tier 2 (IPCC, 2000) methodology for estimating methane and nitrous oxide emissions from road transport. The new methodology was developed by the Ministry of Transport in consultation with the Ministry of Economic Development based on fleet data collected in the national six-monthly vehicle inspection system from 2001–2010. For time-series consistency, new estimates were made of emissions prior to 2001 based on analyses of the relationship between the new and previous methodologies. See section 3.3.3	Accuracy	Expert review team recommendation for non-key categories
New Zealand has corrected the emissions factor previously used for methane emissions from the combustion of aviation gas and jet kerosene leading to recalculations across the time series. See section 3.3.3	Accuracy	Expert review team question during the 2011 submission review for a non-key category
There have been small activity data revisions in some transport categories due to revisions in liquid fuels activity data provided by companies. See section 3.3.3	Accuracy	Corrections made by industry
Liquid fuel activity data in the residential and commercial sectors has been slightly revised across the times series based on new data becoming available from small independent distributors. See section 3.3.4	Accuracy and completeness	Correction identified and resolved through quality-assurance and quality-control processes
Some sales of coal previously reported as commercial were found to be resold to the agriculture, forestry and fisheries and residential sectors. For time-series consistency, a split was applied to historical activity data resulting in reallocations from commercial to manufacturing industries and construction. See section 3.3.4	Consistency	Correction identified and resolved through quality-assurance and quality-control processes

Explanation of recalculation	Good practice principle that was improved	Additional information
Historical coal production data has been slightly revised due to revisions in data provided by companies. This has resulted in slight revisions in activity data and corresponding emissions for some years. See section 3.4.1	Accuracy	Corrections made by industry
Historical venting and flaring activity data has been revised slightly due to historical data revisions provided by companies. See section 3.4.2	Accuracy	Corrections made by industry
The split between underground and surface mining has been revised due to historical data revision provided by mining companies. See Section 3.4.1	Accuracy	Corrections made by industry

10.1.2 Industrial processes

The improvements made in the industrial processes sector have resulted in a 0.2 per cent (6.2 Gg CO_2-e) increase in industrial processes emissions in 1990, and a 0.1 per cent (4.8 Gg CO_2-e) increase in industrial processes emissions in 2009. These were minor recalculations for the sector. An overall effect of recalculations on New Zealand's industrial processes sector from 1990 to 2009 is presented in figure 10.1.3.

The improvement that had the largest impact on emissions in the 2009 year was the improvement made to the assumptions for HFC-134a emissions from refrigeration and air conditioning (please see section 4.7.5 for further information). Other improvements are summarised in table 10.1.2 below.

Figure 10.1.3 Effect of recalculations on New Zealand's industrial processes sector from 1990 to 2009

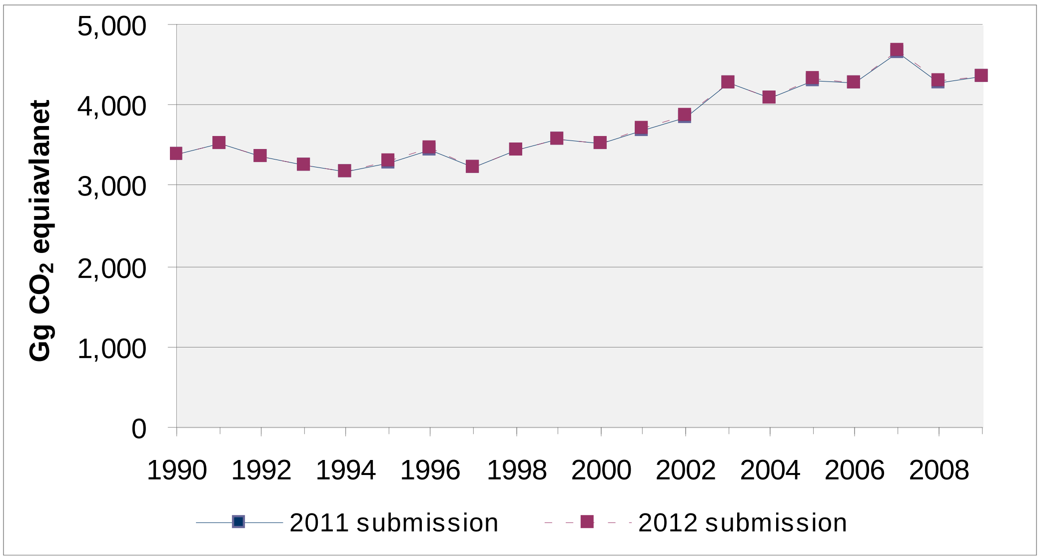


Table 10.1.2 Explanations and justifications for recalculations of New Zealand's previous industrial processes estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
The addition of two sources of limestone use emissions for the first time, and the reallocation of soda ash use emissions to the soda ash use category. See section 4.2.5 for further detail.	Completeness	Results from verification with the New Zealand Emissions Trading Scheme (NZ ETS)
Reallocating soda ash use emissions from the limestone use and aluminium production categories to the soda ash use category. An additional source of soda ash use emissions was added to the inventory for the first time. See section 4.2.5 for further detail.	Transparency and completeness	Expert review team recommendation and results from verification with the NZ ETS
Due to revised ammonia production data from industry, the weighted average emission factor was revised. See section 4.3.5 for further detail.	Accuracy	Corrections made by industry
Reallocation of soda ash emissions from aluminium Production to the soda ash use category and revised emissions for 2009. See section 4.4.5 for further detail.	Transparency and accuracy	Expert review team recommendation and a correction provided by industry
Improved assumptions for the refrigeration and air conditioning estimates. See section 4.7.5 for further detail.	Accuracy	To account for recent rise in R134A stocks and to reflect information from industry
Inclusion of <1000cc cars for the first time in the estimate of mobile air conditioning emissions. See section 4.7.5 for further detail.	Completeness	Correction identified and resolved through quality-assurance and quality-control processes
New information on new and retired equipment for electrical equipment has been included. See section 4.7.5 for further detail.	Accuracy	Industry supplied information

10.1.3 Solvent and other product use

There have been no recalculations made to this sector.

10.1.4 Agriculture

The improvements made in the agriculture sector have resulted in a 1.9 per cent (577.7 Gg CO_2-e) increase in agricultural emissions in 1990, and a 2.0 per cent (667.5 Gg CO_2-e) increase in agricultural emissions in 2009 (figure 10.1.4). The improvement that made the largest change in emissions in the agriculture sector is the change to the Tier 2 model used to estimate emissions from dairy, beef, sheep and deer. All other recalculations made within the agriculture sector are summarised in table 10.1.3 below.

Figure 10.1.4 Effect of recalculations on New Zealand's agriculture sector from 1990 to 2009

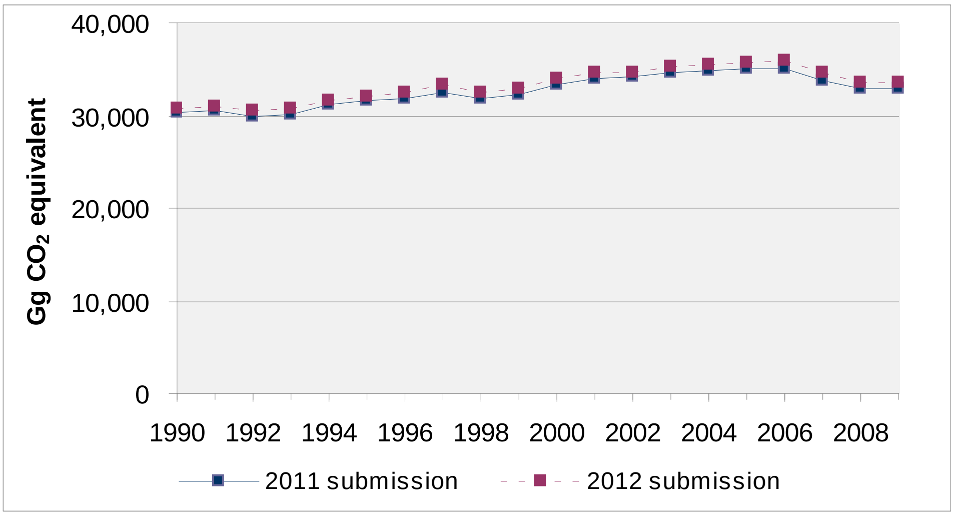


Table 10.1.3 Explanations and justifications for recalculations of New Zealand's previous agriculture estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Enhancements to New Zealand's Tier 2 inventory model have resulted in recalculations of dairy, sheep, non-dairy and deer emissions from enteric fermentation, manure management and agricultural soils. See sections 6.2.5, 6.3.5 for further detail.	Transparency, consistency and accuracy	Planned improvement for key categories
Corrections identified in the Tier 2 model through recoding the inventory programme and population models into Visual Basic. The recoding will ensure the model is more transparent and accessible for quality assurance and quality control. See sections 6.2.5, 6.3.5 for further detail.	Transparency, consistency and accuracy	Correction identified and resolved through quality-assurance and quality-control processes
Improvements to the methodology used to estimate ewe and non-dairy cow liveweight have been included. Liveweights now reflect the national breeding ewe and cow liveweight more accurately. See sections 6.2.5, 6.3.5 for further detail.	Accuracy	Planned improvement for key categories
Country-specific emission factors have been implemented for minor species, swine and poultry. See sections 6.2.5, 6.3.5 and 6.5.5 for further detail.	Transparency, accuracy, completeness and consistency	Planned improvement for non-key categories
The country-specific emission factors for goats have been refined to include assumptions on the population make up. See sections 6.2.5 and 6.5.5 for further detail.	Transparency and accuracy	Planned improvement for a non-key category
A new methodology has been applied along the entire time series, 1990 to 2010, for all crop-related emissions. The improvement adds additional crops for estimates of emissions from crop residue and N-fixing crops, improves the data and consistency for crop burning and savanna burning. The improvement also moves New Zealand from using a Tier 1 method with default emission factors for crop residue, crop burning and savanna burning to a Tier 2 method with country-specific emission factors. New crops	Transparency, accuracy, completeness and consistency	Expert review team recommendation from an in-country review of the 2010 annual submission

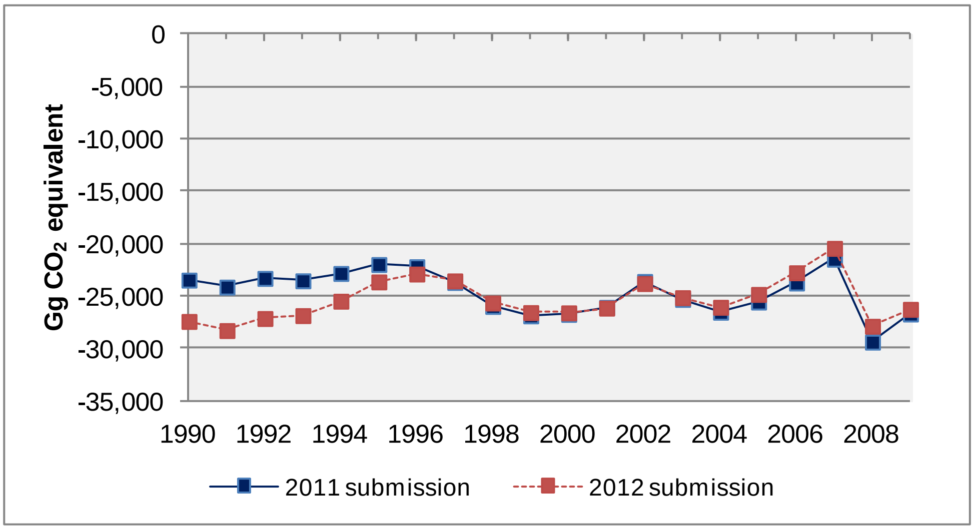
Explanation of recalculation	Good practice principle that was improved	Additional justification
added were sweet corn, onions, squash, brassica seeds, legume seeds and herbage seeds. See section 6.5.5 and 6.7.5 for further detail.		
The methodology used to estimate the area of cultivated histosols has been revised to provide a more robust transparent estimate. The area of cultivated histosols was formerly based on expert judgement. The review by Dresser et al (2011) also clarifies definitions used in land use and land-use change and forestry and agriculture. See section 6.5.5 and 6.7.5 for further detail.	Transparency and accuracy	Expert review team recommendation from an in-country review of the 2010 annual submission

10.1.5 Land use, land-use change and forestry

Improvements made to the land use, land-use change and forestry (LULUCF) sector have resulted in a 16.8 per cent (3,937.2 Gg CO_2-e) increase in net LULUCF removals in 1990, and a 1.7 per cent (448.6 Gg CO_2-e) decrease in net LULUCF removals in 2009 (figure 10.1.5). These recalculations are the result of a third year of significant enhancements to the LULUCF inventory following the introduction in the 2010 submission of a new data collection and modelling programme for the New Zealand LULUCF sector – the Land Use and Carbon Analysis System (LUCAS). Further improvements and recalculations are expected to be introduced into the reporting in the LULUCF sector for the remainder of the first commitment period (see chapter 7 for details).

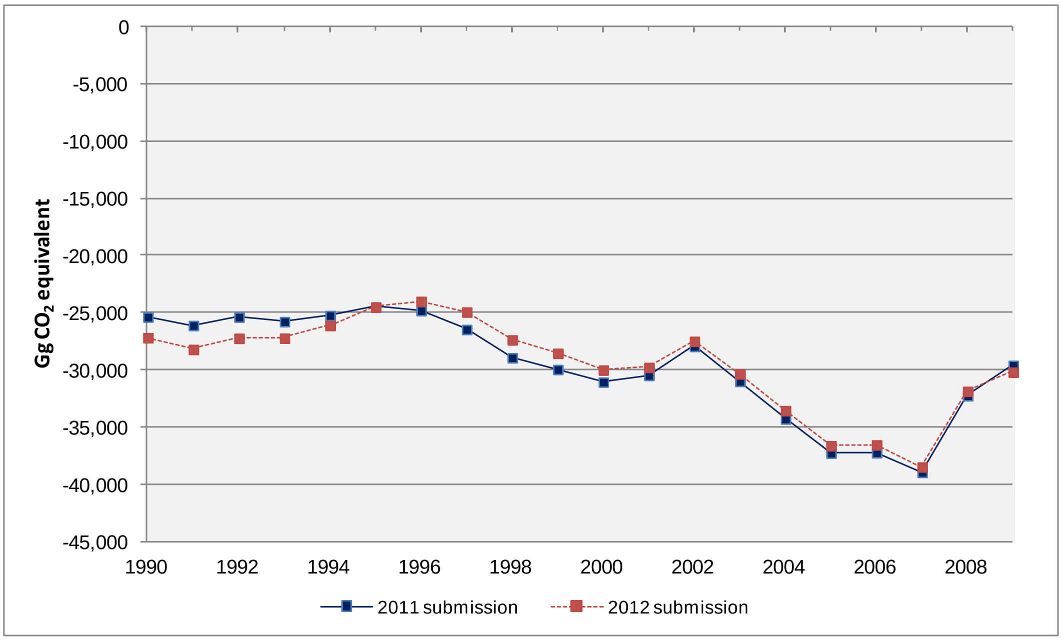
In the 2012 submission, significant improvements include a return to Tier 1 methodologies for estimating mineral soil carbon emissions with land-use change, new mapping of deforestation and the incorporation of a new yield table for pre-1990 planted forests based on plot information collected under LUCAS. Further detail on these changes is provided in section 7.1.5. The effect of recalculations to the forest land and grassland categories are shown in figures 10.1.6 and 10.1.7. The explanations and justifications for all recalculations to New Zealand's LULUCF estimates in the 2012 submission are summarised in table 10.1.4.

Figure 10.1.5 Effect of recalculations on net removals from New Zealand's LULUCF sector from 1990 to 2009



Note: Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

Figure 10.1.6 Effect of recalculations on net removals from New Zealand's forest land category from 1990 to 2009



Note: Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

Figure 10.1.7 Effect of recalculations on net emissions from New Zealand's grassland category from 1990 to 2009

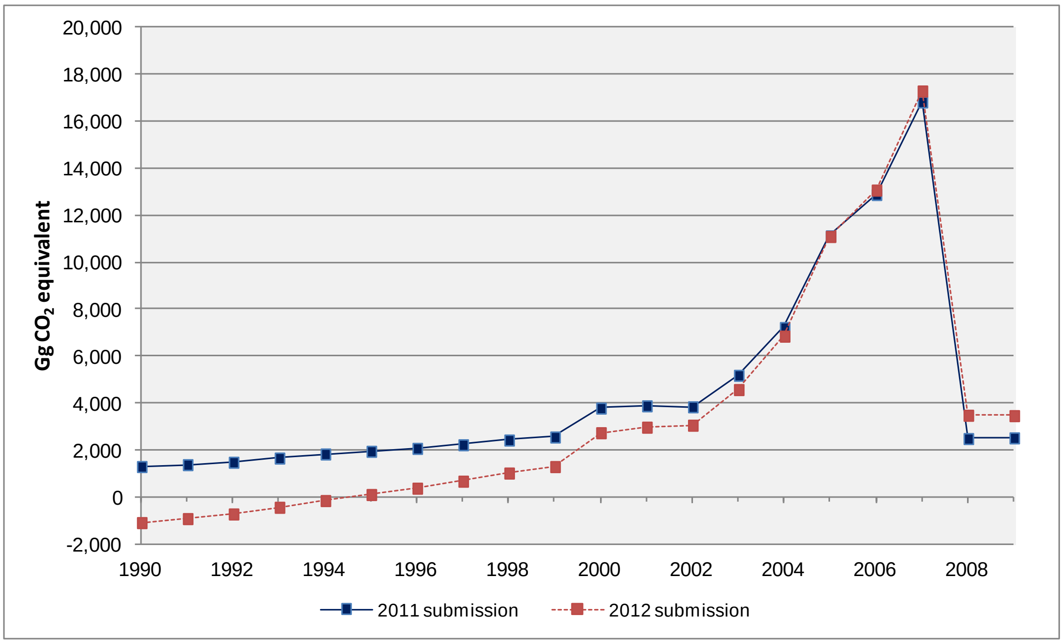


Table 10.1.4 Explanations and justifications for recalculations of New Zealand's previous LULUCF estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Changes to previous deforestation estimates. In this submission, we include improved estimation of deforestation through polygon-specific mapping (IPCC Approach 2) of deforestation from high-resolution (SPOT) satellite imagery in priority areas and	Accuracy	Key category improvement (*Land converted to grassland*)

Explanation of recalculation	Good practice principle that was improved	Additional justification
uncertainty analysis to provide a more accurate estimate of total annual deforestation occurring since the start of the first commitment period (1 January 2008). See section 7.2.2 for further detail.		
Estimates of mineral soil carbon change are now based on Tier 1 methodology. In the 2010 and 2011 submissions, New Zealand reported mineral soil carbon change using a Tier 2 method. In the report from the in-country review of the 2010 submission, the review team questioned the "statistical validity of estimating soil carbon change from these estimates [estimates based on the tier 2 system], particularly for some poorly represented (i.e. sampled) land use transitions". New Zealand has not been able to obtain enough additional data to improve the uncertainty in the estimates based on the Tier 2 methodology and, consequently, has reverted to using Tier 1 methodology. See section 7.1.3 for further detail.	Accuracy	Expert review team feedback from in-country review 2010
Updated activity data on dolomite and liming emissions, sourced from Statistics New Zealand. See section 7.9.4 for further detail.	Accuracy	Use of latest data
Pre-1990 planted forest yield table has been revised based on plot data collected specifically for carbon inventory reporting. This aligns the method used for estimating biomass changes in the pre-1990 planted forest to that used for the post-1989 forest using the plot data collected in 2010 and 2011. See section 7.3.2 – Pre-1990 planted forest for further detail.	Accuracy/consistency	Key category improvement (*Forest land remaining forest land*) To align the methodology used across forest types
Mapping improvements to better distinguish pre-1990 planted forest from post-1989 forest, identify young newly planted post-1989 forest and update areas of perennial cropland. See section 7.2.6 for further detail.	Accuracy	Key category improvement (*Land converted to forest land and Forest land remaining forest land*)
An error correction made to N_2O emissions associated with disturbance to cropland as the formula used to calculate emissions for this source previously was summing a cumulative area.	Accuracy	Correction identified through quality-assurance and quality-control processes
The use of the Forest Carbon Predictor (FCP) version 3 in the development of the pre-1990 and post-1989 planted forest yield tables. Version 3 of the FCP contains new temperature-dependent decay functions and species-specific growth trajectory and biomass adjustments (Beets & Kimberley, 2011). New breast height pith-to-bark density functions, and a stand-management module for improved estimation of past and future silvicultural events when stand records are incomplete, are also included since the previous submission (Beets & Kimberley, 2011). See sections 7.3.2 and 7.3.5 for further detail.	Accuracy	Key category improvement (*Forest land remaining forest land* and *Land converted to forest land*) Expert review team feedback from in-country review 2010
Inclusion of temperature-dependent deadwood and litter decay functions into the Calculation and Reporting Application for the decay of harvest residues in pre-1990 and post-1989 planted forest (Garrett et al, 2010). Previously, the 20-year linear IPCC default was used for harvest residue decay. See section 7.3.5 for further detail.	Accuracy	Key category improvement (*Forest land remaining forest land* and *Land converted to forest land*)
A new emission factor for wildfire in forest land remaining forest land based on New Zealand's national permanent sample plot network. See section 7.9.5 for further detail.	Accuracy, consistency	So biomass present at burning are consistent with biomass from plot-based yield table
Correction of an equation to estimate non-carbon emissions from carbon released during burning.	Accuracy	Correction identified through quality-assurance and quality-control processes

10.1.6 Waste

The methodological improvements made in the waste sector have resulted in a 0.1 per cent (1.9 Gg CO_2-e) increase in calculated waste emissions in 1990, and a 0.7 per cent (13.4 Gg CO_2-e) increase in waste emissions in 2009 (figure 10.1.8). This is largely due to an improved understanding of the activity data for the meat industry (see section 8.3.5) and a correction of the commencement of operation of a methane recovery system at one landfill (see section 8.2.5). Other recalculations are provided in table 10.1.5.

Figure 10.1.8 Effect of recalculations on New Zealand's waste sector from 1990 to 2009

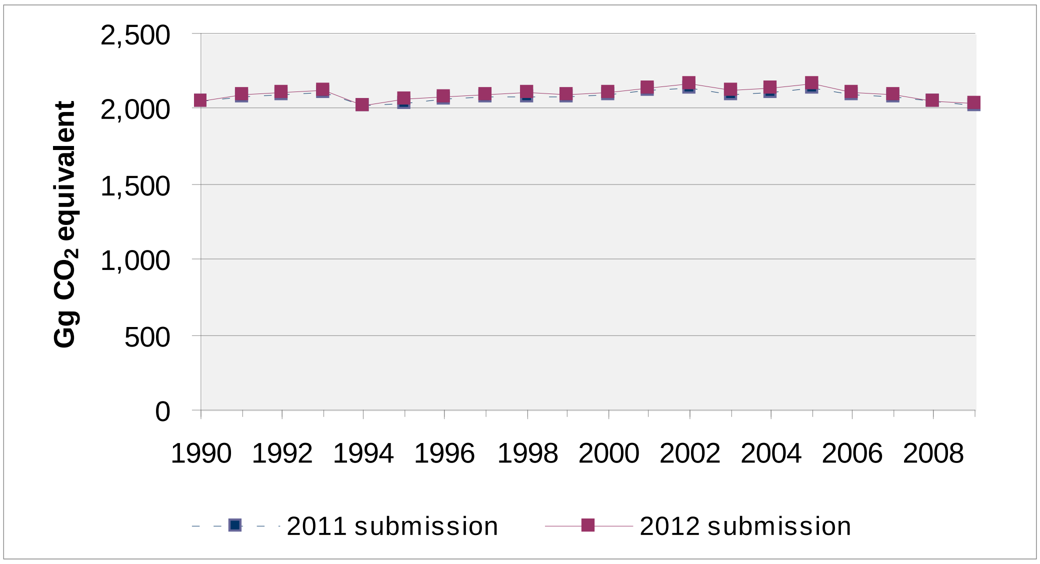


Table 10.1.5 Explanations and justifications for recalculations of New Zealand's previous waste estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
The operating commencement date of the methane recovery system at one landfill was corrected (see section 8.2.5).	Accuracy	Key category improvement (*Solid waste disposal on land*)
The amount of untreated sewage sludge disposed to landfills has been amended based on corrections to the amount of sludge produced, detailed below (see section 8.2.5 and 8.3.5).	Accuracy Consistency	Key category improvement (*Solid waste disposal on land*)
Activity data for the wastewater treatment plants was corrected, resulting in recalculations of emissions from both domestic and commercial wastewater treatment and sludge treatment (see section 8.3.5).	Accuracy Consistency	Corrections identified through quality-assurance and quality-control processes
Amendments were made to some of the correction factors for additional industrial biochemical oxygen demand discharged into sewers for specific treatment plants resulting in recalculations of methane emissions from both domestic and commercial wastewater treatment and sludge treatment (see section 8.3.5).	Accuracy Consistency	Corrections identified through quality-assurance and quality-control processes
Introduction of total annual output for the different meat industry producers, resulting in recalculations of methane and nitrous oxide	Accuracy	Use of latest and annual data

emissions from industrial wastewater (see section 8.3.5).		
Correcting a minor error in one of the emission factors used for calculating methane emissions from waste incineration (see section 8.4.5).	Accuracy	Correction identified through quality-assurance and quality-control processes

10.1.7 Article 3.3 activities under the Kyoto Protocol

New Zealand's greenhouse gas estimates for activities under Article 3.3 of the Kyoto Protocol have been recalculated since the previous submission (table 10.1.6, table 10.1.7 and table 10.1.8). The recalculations incorporate improved New Zealand-specific methods, activity data and emission factors, as detailed in sections 7.1 and 7.2 and table 10.1.7.

The largest improvement made to the estimates for Article 3.3 activities under the Kyoto Protocol has been the revision of the post-1989 yield table. This has utilised an updated version of the Forest Carbon Predictor (FCP v3), which contains new temperature-dependent decay functions and species-specific growth trajectory and biomass adjustments (Beets & Kimberley, 2011). The greatest percentage change has been due to a recalculation of the 2008 and 2009 deforestation areas (chapter 11, table 11.3.3). This is because of improvements in deforestation mapping using higher resolution imagery than was used for mapping prior to the 2012 submission.

Table 10.1.6 Explanations and justifications for recalculations of New Zealand's previous Kyoto Protocol estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Changes to previous deforestation estimates. This submission includes improved estimation of deforestation through polygon-specific mapping (IPCC Approach 2) of deforestation from high-resolution (SPOT) satellite imagery in priority areas and uncertainty analysis to provide a more accurate estimate of total annual deforestation occurring since the start of the first commitment period (1 January 2008). See section 7.2.2 for further detail.	Accuracy	Key category improvement (*Land converted to grassland*)
Estimates of mineral soil carbon change are now based on Tier 1 methodology. In the 2010 and 2011 submissions, New Zealand reported mineral soil carbon change using a Tier 2 method. In the report from the in-country review of the 2010 submission, the review team questioned the "statistical validity of estimating soil carbon change from these estimates [estimates based on the Tier 2 system], particularly for some poorly represented (i.e. sampled) land use transitions". New Zealand has not been able to obtain enough additional data to improve the uncertainty in the estimates based on the Tier 2 methodology so has, instead, reverted to using Tier 1 methodology. See section 7.1.3 for further detail.	Accuracy	Expert review team feedback from in-country review 2010
Updated activity data on dolomite and liming emissions, sourced from Statistics New Zealand. See section 7.9.4 for further detail.	Accuracy	Use of latest data
Pre-1990 planted forest yield table has been revised based on plot data collected specifically for carbon inventory reporting. This aligns the method used for estimating biomass changes	Accuracy/Consistency	Key category improvement (*Forest land remaining forest land*)

Explanation of recalculation	Good practice principle that was improved	Additional justification
in the pre-1990 planted forest to that used for the post-1989 forest. See section 7.3.2 for further detail.		To align the methodology used across forest types
Mapping improvements to better distinguish pre-1990 planted forest from post-1989 forest, identify young newly planted post-1989 forest and update areas of perennial cropland. See section 7.2.6 for further detail.	Accuracy	Key category improvement (*Land converted to forest land* and *Forest land remaining forest land*)
Nitrous oxide emissions associated with disturbance to cropland. This is an error correction as the formula used to calculate emissions for this source previously was summing a cumulative area.	Accuracy	Correction identified through quality-assurance and quality-control processes
The use of the Forest Carbon Predictor (FCP) version 3 in the development of the pre-1990 and post-1989 planted forest yield tables. Version 3 of the FCP contains new temperature-dependent decay functions and species-specific growth trajectory and biomass adjustments (Beets & Kimberley, 2011). New breast height pith-to-bark density functions, and a stand-management module for improved estimation of past and future silvicultural events when stand records are incomplete, are also included since the previous submission (Beets & Kimberley, 2011). See section 7.3.2 for further detail.	Accuracy	Key category improvement (*Forest land remaining forest land* and *Land converted to forest land*) Expert review team feedback from in-country review 2010
Inclusion of temperature-dependent deadwood and litter decay functions into the Calculation and Reporting Application for the decay of harvest residues in pre-1990 and post-1989 planted forest (Garrett et al, 2010). Previously, the 20-year linear IPCC default was used for harvest residue decay. See section 7.3.5 for further detail.	Accuracy	Key category improvement (*Forest land remaining forest land* and *Land converted to forest land*)
A new emission factor for wildfire in forest land remaining forest land based on New Zealand's national permanent sample plot network. See section 7.9.5 for further detail.	Accuracy, consistency	So biomass present at burning is consistent with biomass from plot-based yield table
Correction of an equation to estimate non-carbon emissions from carbon released during burning.	Accuracy	Correction identified through quality-assurance and quality-control processes
Allocation of a proportion of emissions from wildfire to the post-1989 forest subcategory. See section 7.9.5 for further detail.	Completeness	

Table 10.1.7 Impact of the recalculations of New Zealand's net emissions under Article 3.3 of the Kyoto Protocol in 2009

Activity under Article 3.3 of the Kyoto Protocol	2009 net emissions ($Gg\ CO_2$-e) 2011 submission	2012 submission	Change from 2011 submission (%)
Afforestation/reforestation	–17,624.3	–19,210.5	–9.0
Forest land not harvested since the beginning of the commitment period	–17,701.3	–19,336.7	–9.2
Forest land harvested since the beginning of the commitment period	77.0	126.1	63.8
Deforestation since the beginning of the commitment period	355.9	1,375.2	286.4%
Total	**–17,268.4**	**–17,835.3**	**–3.3**

Note: Net removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

Table 10.1.8 Recalculations to New Zealand's 2009 activity data under Article 3.3 of the Kyoto Protocol

Activity under Article 3.3 of the Kyoto Protocol	2009 areas (ha)		Change from 2011 submission (%)
	2011 submission	2012 submission	
Afforestation/reforestation	591,202	589,041	–0.4
Forest land not harvested since the beginning of the commitment period	589,052	586,441	–0.4
New planting	4,000	4,300	7.5
Forest land harvested since the beginning of the commitment period	2,150	2,600	20.9
Deforestation	1,644	3,259	98.2
Natural forest	462	506	9.5
Pre-1990 planted forest	449	1652	267.9
Post-1989 forest	734	1101	50.0

10.2 Recalculations in response to the review process and planned improvements

10.2.1 Response to the review process

Many of the recommendations made by the expert review team during the centralised review of New Zealand's greenhouse gas inventories submitted in 2007 and 2008 have been implemented. Due to prioritisation and limited resourcing, some of the recommendations have been partially implemented and some are ongoing. However, New Zealand does have the full implementation of the recommendations planned for in the risk register (see section 1.6.2 for further detail on the risk register). The recommendations made in UNFCCC (2011) and New Zealand's responses are included below in table 10.2.1. There were no recommendations made for solvent and other product use sectors. The expert review team report for the 2011 submission was not published in time to be taken into account for this submission.

Table 10.2.1 New Zealand's response to expert review team recommendations from the individual review of the greenhouse gas inventory submitted by New Zealand in 2010

Sector	Expert review team recommendation	New Zealand response
General	Continue to estimate and report the missing minor non-key category emissions in its next annual submission.	**Implemented.**
General	Elaborate the Quality Assurance and Quality Control plan by including specific procedures for the documentation and archiving of confidential information with a view to ensuring that all the confidential information used for inventory preparation is appropriately treated and archived.	**Work in progress.**
General	Ensure the notation keys in the common reporting format tables are applied according to reporting guidelines across	**Implemented.**

Sector	Expert review team recommendation	New Zealand response
	all categories.	
Registry	Report changes to hosting providers.	**Implemented.**
Energy: 'other' industries and construction	Make efforts to further disaggregate the 'other' (manufacturing industries and construction) by following the revised 1996 IPCC guidelines and the IPCC good practice guidance.	**Partially implemented.** Further work has been done on disaggregating the manufacturing and construction sectors. Additional data is becoming available in energy end-use surveys that will allow further disaggregation in the next submission.
Geothermal energy production	Provide more detailed information on methodologies and data utilised for the estimation of carbon dioxide (CO_2) and methane emissions from geothermal energy production (for example, emission factors calculated by one of the major geothermal operators based on data obtained from spot measurements).	**Implemented.** A more comprehensive treatment of the methods of calculating the emission factors at two geothermal fields is included in this submission.
Road transportation	Apply the Tier 2 approach for methane and nitrous oxide emissions from road transportation to reflect the national circumstances of New Zealand's transportation fleet.	**Implemented.** This inventory uses a Tier 2 methodology to estimate emissions from road transport. Further information can be found in section 3.3.3.
Industrial processes and solvent and other product use	Provide more explanation about quality-control procedures and its results, as well as on the methods and data used for each category.	**Implemented.**
Industrial processes and solvent and other product use	Reassess the uncertainty estimates for activity data, reporting uncertainty estimates for each emission factor and providing a more detailed description of the uncertainty estimates at least for every key category.	**Implemented.**
Consumption of halocarbons and sulphur hexafluoride (SF_6)	Reconsider and correct the use of notation keys.	**Implemented.**
Cement production – CO_2	Improve the transparency of the national inventory report by discussing which tier method has been used and how the method is consistent with the IPCC good practice guidance.	**Implemented.**
Ammonia production – CO_2	Provide a more thorough and correct explanation of the method and assumption used to estimate emissions from this category, including an explanation of the consumption of natural gas as a raw material and how double counting with the energy sector was prevented.	**Implemented.**
Iron and steel production – CO_2	Explain more transparently the method and data used by companies (eg, plant-specific emission factors for reducing agents, carbon content of raw materials and steel products, carbon content of additives) in its next annual submission.	**Implemented.**
Iron and steel production – CO_2	Correct the emission estimates for 1990–1999 using the updated emission factors in its next annual submission.	**Implemented.**
Iron and steel production – CO_2	Provide more information in the section on iron and steel production so as to make it clear which flux elements are included and how their emissions are reported in the common reporting tables.	**Implemented.**
Aluminium production – perfluorocarbons	Make further analysis of why the implied emission factors are so remarkably lower than other countries as well as	**Not implemented.** New Zealand does not have implied emission factors that are lower than other Parties.

Sector	Expert review team recommendation	New Zealand response
(PFCs)	IPCC default values, and that New Zealand provide more explanation about it in the national inventory report in its next annual submission.	
Aluminium production – PFCs	Report 'Anode effect minutes per pot day' in the national inventory report following table 3.11 in the IPCC good practice guidance, with a view to demonstrating the low occurrence of anode effects.	**Not implemented.** This data is considered confidential by the smelter.
Consumption of halocarbons and SF_6 – hydrofluorocarbons (HFCs)	Improve the transparency of its explanation in the national inventory report by including the data used for the calculation (eg, annual sales of new refrigerant) that are given in the background report.	**Implemented.**
Consumption of halocarbons and SF_6 – HFCs	Provide a transparent explanation of the improved models used for emissions estimation in its next annual submission	**Implemented.**
Aluminium production – CO_2	Reallocating the reporting of CO_2 emissions from soda ash use in the flue gas scrubbing process under aluminium production to the soda ash production and use category, in accordance with the revised 1996 IPCC guidelines.	**Implemented.**
Agriculture	Improve the transparency of the national inventory report by further expanding the discussion on methodologies, activity data and emission factors, and including the equations, where possible, and presenting this information in an orderly and consistent manner across the chapter.	**Implemented.** The agriculture section of the national inventory report in the 2011 and 2012 submissions has been substantively rewritten and now follows the annotated outline.
Manure management	Change the allocation for manure from goats to Pasture, Range, and Paddock in table 4B(a) of the 2008 common format reporting tables from 0 to 100 per cent.	**Implemented.** The allocation for manure from goats to pasture, range and paddock was corrected in the 2011 submission for all years 1990 to 2009.
Agriculture soils	Change the notation key 'not estimated' used for rye to 'not applicable' in table 4.F.	**Implemented.** The notation key for rye burning was changed to 'not occurring' (NO) as this is a more accurate notation key because there is no activity or process (burning of rye). Notation keys for crop burning lentils and pea were similarly corrected from 'not applicable' (NA) to 'not occurring' (NO).
Agriculture soils	Include the additional nitrogen inputs to the soils such as other organics (tankage/ slaughterhouse waste, blood meal, bone meal, compost, brewery waste, etc).	**Work in progress.** A scoping study was commissioned during 2011 to assess if these sources were occurring in New Zealand and to determine the availability of data and methodologies to estimate these possible emissions. Assessment of this area is ongoing in preparation for application of the revised reporting guidelines from 2015 onwards.
Agriculture soils	Continue its efforts to improve its estimates from agricultural soils by accounting for all types of crops grown.	**Implemented.** The 2012 submission has re-estimated all crop-related emissions from 1990 to 2010. A Tier 2 methodology based on Curtin et al (2011) has been used to estimate emissions from crop residues, crop burning and savanna burning. Sweet corn, onions, squash, brassica seeds, legume seeds and herbage seeds have been included in the 2012 submission. This is fully documented in sections 6.5.2, 6.6.2, 6.6.5, 6.7.2 and 6.7.5.

Sector	Expert review team recommendation	New Zealand response
Agriculture and LULUCF: definitions	Harmonise the definitions and activity data used for organic soils within the agriculture and LULUCF sectors.	**Partially implemented.** This work was completed during 2011, but the results of this work have not been included in the LULUCF sector estimates as the spatial layer resulting from this work was not available at the time this submission was prepared. This will be implemented for the 2013 submission.
LULUCF	Expand methodological description for the estimation and provide a rationale for the selection of country-specific emission factors in the national inventory report.	**Implemented.** Section 7.2.3 now contains additional detail on how country-specific emission factors for forest land have been derived.
LULUCF: Sector overview	Ensure, to the extent possible, the inclusion in its next annual submission, of emissions for categories currently reported as 'not estimated' and for which methods exist for these categories in the revised 1996 IPCC guidelines and/or the IPCC good practice guidance, and if emissions for a given category cannot be estimated then the Party is to provide sufficient explanation in the national inventory report as to why it cannot be estimated.	**Partially implemented.** Work ongoing for the LULUCF sector. For the 2011 submission, New Zealand reported emissions from organic soils, and N_2O emissions associated with land-use conversion to cropland for the first time. For the 2012 submission, New Zealand has reported non-CO_2 emissions from biomass burning within the KP-LULUCF sector for the first time.
LULUCF: Organic soils	Apply the IPCC Tier 1 method for reporting organic soil emissions in the LULUCF sector in its next annual submission.	**Implemented.** In the 2011 submission, New Zealand has introduced reporting of emissions from organic soils using IPCC Tier 1 default emissions factors, and recalculated the LULUCF time-series. See section 7.1.3.
LULUCF: Information on models for calculations	Document or attach to appendices more detailed information on models (functionality, parameterisation and quality assurance and quality control)	**Implemented.** Additional information has been included on the Forest Carbon Predictor model in the 2012 submission. A scientific paper publishing the approach used for post-1989 forest has been published (Beets et al, 2011). A scientific paper is currently being prepared for publication on the pre-1990 planted forests approach. See section 7.3.5 – Pre-1990 planted forest.
LULUCF: Cropland disturbance reassessment	Reassess the occurrence of cropland disturbance, and if the activity does not occur, report N_2O emission estimates as 'NO' 'not occurring'.	**Implemented.** The notation keys for N_2O emissions were corrected for the 2011 submission. See section 7.9.3.
LULUCF: Back-casting	Undertake 'back-casting' studies to define land use back to the year 1963 and follow the IPCC good practice guidance for LULUCF for land use disaggregation to estimate lagged emissions/removals for pre-1990 land cover conversions.	**Implemented.** New Zealand identified land areas in transition as at the start of 1990 and recalculated the entire LULUCF time series for the 2011 submission. Further information on this change was provided in the 2011 national inventory report.
LULUCF: Tier 2 method for estimating change in mineral soil carbon	There were a number of comments about the Tier 2 methodology New Zealand was using to estimate change in mineral soil carbon associated with land-use change. As the approach New Zealand is using has changed (now using a Tier 1 methodology), these recommendations have been grouped below. 1. The expert review team recommends that New Zealand includes uncertainty analysis of soil stock changes. 2. Undertake further work to improve and validate the soil carbon monitoring system	**Change of approach.** Some of the comments were addressed in the 2011 submission, for instance, more information from the uncertainty analysis was included. This information is not included in the 2012 submission as New Zealand has changed back to a Tier 1 methodology as it has not been able to improve the uncertainty in the estimates enough to address concerns raised in the 2010 in-country review. Work to improve the Tier 2 methodology continues, but this work may not be completed in time for the 2014 submission.

Sector	Expert review team recommendation	New Zealand response
	3. New Zealand used a paired plot sampling approach to measure and model changes in soil carbon stocks associated with land-use change. The expert review team commends this improvement, but questions the statistical validity of this approach, particularly in some poorly represented land-use transitions. 4. It is not clear whether or not the currently adopted methodology can, with any certainty (statistical significance of the mean reference soil values used for different land uses), detect significant changes in soil carbon stock changes for different land uses. The expert review team encourages New Zealand to re-examine the methodological approach used for reporting mineral soil carbon changes following land use change. 5. To reduce the level of uncertainty in soil-climate and land-use classes New Zealand is encouraged to include increased sampling in land-use classes (particularly croplands, post-1989 forest and wetlands), which are currently under represented in the national sample.	1. Additional information on uncertainties was included in the 2011 submission. 2. Further work to validate the model was completed in 2011. This included paired plot work and looking at a significant land-use change (low-producing grassland to planted forest). 3. Additional data for annual cropland has been added to the dataset though this data is not used in the 2012 submission as the Tier 1 methodology has been used instead. 4. Now using Tier 1 methodology. 5. Additional data for annual cropland has been added to the dataset though this data is not used in the current Tier 1 methodology. Additional data for post-1989 forest and wetlands has not been collected. See section 7.1.3.
LULUCF: Transition of natural to planted forest	Estimate the emissions associated with the land cover transition from natural to plantation forest.	**Implemented.** Included in the 2011 submission.
LULUCF: Species specific modelling	Estimate biomass carbon stock changes using the newly developed models of growth and biomass allocation for Douglas fir and eucalyptus to avoid underestimation of biomass carbon stock changes in minor plantation species.	**Partially implemented.** For the 2012 submission, New Zealand has used Forest Carbon Predictor (FCP) version 3 in the development of the pre-1990 and post-1989 planted forest yield tables. Improvements made to version 3 of the FCP include, amongst other things, species-specific growth trajectory and biomass adjustments (Beets & Kimberley, 2011). New Zealand is investigating further improvements in this area. Work to identify options for making species-specific improvements has been contracted out to Scion (New Zealand Forest Research Institute). A decision on what of these improvements can be achieved within budget will be made in 2012. See section 7.3.5.
LULUCF: Improve disaggregation of areas into land converted to and land remaining categories	Follow the IPCC good practice guidance and use the higher tier method to estimate emissions from land converted to grassland category and further improve disaggregation.	**Partially implemented.** New Zealand has now implemented the 'back-casting' project, and has reported areas of land in transition at 1990, in accordance with GPG-LULUCF, for the 2011 submission. Land converted to grassland is a key category due to the emissions reported in this category from deforestation. New Zealand uses Tier 2 methods to estimate all carbon stock changes from land-use conversions from woody land-use subcategories (ie, all forest land subcategories and the grassland with woody biomass subcategory). Only where non-woody subcategories are converted to grassland are Tier 1 methods (ie, default emission factors) used. Because conversions from these

Sector	Expert review team recommendation	New Zealand response
		categories are not a significant source of emissions, New Zealand considers that the current use of Tier 1 methods and default emission factors for non-woody classes is appropriate, however, it will investigate whether there is potential for improvement in this area of the LULUCF estimates. See New Zealand's 2011 submission for further detail on this.
LULUCF: Perennial cropland	Report the results of the use of a country-specific value for carbon stock in perennial cropland in the annual submission.	**Implemented.** This was included in the 2011 submission.
LULUCF: Cultivated organic soils	Estimate lagged CO_2 removals/emissions for conversions that occurred before 1990 and CO_2 emissions in cultivated organic soils that were not estimated previously and reported as 'NE' 'not estimated'.	**Implemented.** These changes were made for the 2011 submission. New Zealand has introduced reporting of emissions from organic soils using IPCC Tier 1 default emissions factors and recalculated the time series.
LULUCF: Biomass burning	Estimate CH_4 and N_2O emissions from biomass burning of all land-use conversion following the IPCC good practice guidance for LULUCF.	**Not implemented.** New Zealand has investigated potential additional sources of activity data on biomass burning and has not been able to gather the information needed for this reporting. Some progress has been made on estimating emissions for land included under the Kyoto Protocol with a survey of owners undertaken in 2011. The cost of carrying out this survey for all land uses is prohibitive so only land uses with the most dry matter available for burning have been included.
Waste	Disaggregate and accurately account for the fraction of gas used for energy recovery under the energy sector and the fraction of gas that is flared under memo items as biomass combustion.	**Work in progress.**
Waste: Solid waste disposal on land – CH_4	Continue to use or improve the approach of applying the k-value of food to the New Zealand-specific situation of a grouped food and garden waste category.	**Implemented.**
Non-key categories: Wastewater handling – CH_4 and N_2O	Investigate and verify the wastewater treatment systems and report on this to ensure transparency of its reporting in its next annual submission.	**Implemented.**
Non-key categories: Wastewater handling – CH_4 and N_2O	Continue to include emissions estimates from all industrial wastewater and sludge handling activities, including wool scouring and wine processing.	**Implemented.**
KP-LULUCF	Further refine the procedure, allowing full confirmation of deforestation in the last reporting years.	**Not yet implemented.** New Zealand is investigating improvements in this area and will report on refinements to the procedure in the next (2013) submission.
KP-LULUCF	Provide estimates of estimated CO_2 emissions in organic soils associated with reforestation and deforestation separately from mineral soils.	**Implemented.** New Zealand introduced reporting of emissions from organic soils in the 2011 submission.
KP-LULUCF	Provide estimates of N_2O and CH_4 emissions from biomass burning due to wildfire on reforested and deforested lands.	**Implemented.** Emissions of N_2O and CH_4 from biomass burning due to wildfire on reforested and deforested lands is included in the 2012 submission. See section 7.9.5.

Sector	Expert review team recommendation	New Zealand response
KP-LULUCF	Provide estimates of N_2O and CH_4 emissions from controlled burning on deforested land.	**Not implemented.** Emissions of N_2O and CH_4 from biomass burning due to controlled burning on deforested lands are not reported as there is currently no data on this activity. Potential sources of activity data are being investigated, and if sourced, will be reported in the next submission.
KP-LULUCF	Implement planned improvements such as the development of Douglas-fir and eucalyptus growth and biomass allocation models.	**Implemented.** For the 2012 submission, New Zealand has used FCP version 3 in the development of the pre-1990 and post-1989 planted forest yield tables. Improvements made to version 3 of the FCP include amongst other things species-specific growth trajectory and biomass adjustments (Beets & Kimberley, 2011). See section 7.3.5.
KP-LULUCF	The lagged emissions from soil carbon on lands that deforested before the reporting year were estimated, but were not transparently described in the national inventory report. The expert review team recommends that New Zealand enhance transparency in reporting these emissions in its next annual submission.	**Implemented.** This change was made to the 2011 submission. New Zealand now reports the total area of deforestation since 1990 in the Kyoto Protocol common reporting format tables and includes information on this in the national inventory report. See section 11.1.
KP-LULUCF	Refine methodology to distinguish between deforested and harvested land during 2008–2012.	**Implemented**. New Zealand is going to achieve this using a combination of methods, including mapping based on satellite imagery, information from other sources for instance, the New Zealand Emissions Trading Scheme, and review of areas of interest using aerial photography as completed in the four priority areas in 2011 to distinguish deforestation, harvesting and land awaiting a land-use determination (see section 11.4.3).
KP-LULUCF	Report emissions from decay of below-ground biomass pool in the dead organic matter pool.	**Implemented**. This change was made to the 2011 submission.

10.2.2 Planned improvements

Priorities for inventory development are guided by the analysis of key categories (level and trend), uncertainty surrounding existing emission and removal estimates, and recommendations received from previous international reviews of New Zealand's inventory. The inventory improvement 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.

Chapter 10 References

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PART II: SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7.1

Chapter 11: KP-LULUCF

11.1 General information

In 2010, net removals from land subject to afforestation, reforestation and deforestation were 18,307.1 Gg carbon dioxide equivalent (CO_2-e) (table 11.1.1). This value is the net total of all emissions and removals from activities under Article 3.3 of the Kyoto Protocol, and includes removals from the growth of post-1989 forest and emissions from the conversion of land to post-1989 forest, the harvesting of forests planted on non-forest land after 31 December 1989, emissions from deforestation of all forest types, as well as emissions from liming, biomass burning and soil disturbance associated with land-use conversion to cropland of any land subject to afforestation, reforestation and deforestation since 1990.

These net emissions are reported separately for the North Island and South Island for the five carbon pools (figure 11.1.1). Afforestation, reforestation and deforestation are key categories for New Zealand (table 1.5.4).

For reporting under Article 3.3 of the Kyoto Protocol, New Zealand has categorised its forests into three subcategories: natural forest, pre-1990 planted forest and post-1989 forest. These subcategories are also used for greenhouse gas inventory reporting on the land use, land-use change and forestry (LULUCF) sector under the Climate Change Convention (see chapter 7). For the first commitment period, New Zealand has not elected any of the activities under Article 3.4 of the Kyoto Protocol.

All forest land that existed on 31 December 1989 has been categorised as either natural forest or pre-1990 planted forest. For these forests, only emissions from deforestation activities are reported in this chapter. For the post-1989 forests, emissions and removals from carbon losses and gains due to afforestation, reforestation and deforestation are reported for the first three years of the commitment period: 2008, 2009 and 2010.

Table 11.1.1 New Zealand's net emissions from land subject to afforestation, reforestation and deforestation as reported under Article 3.3 of the Kyoto Protocol in 2010

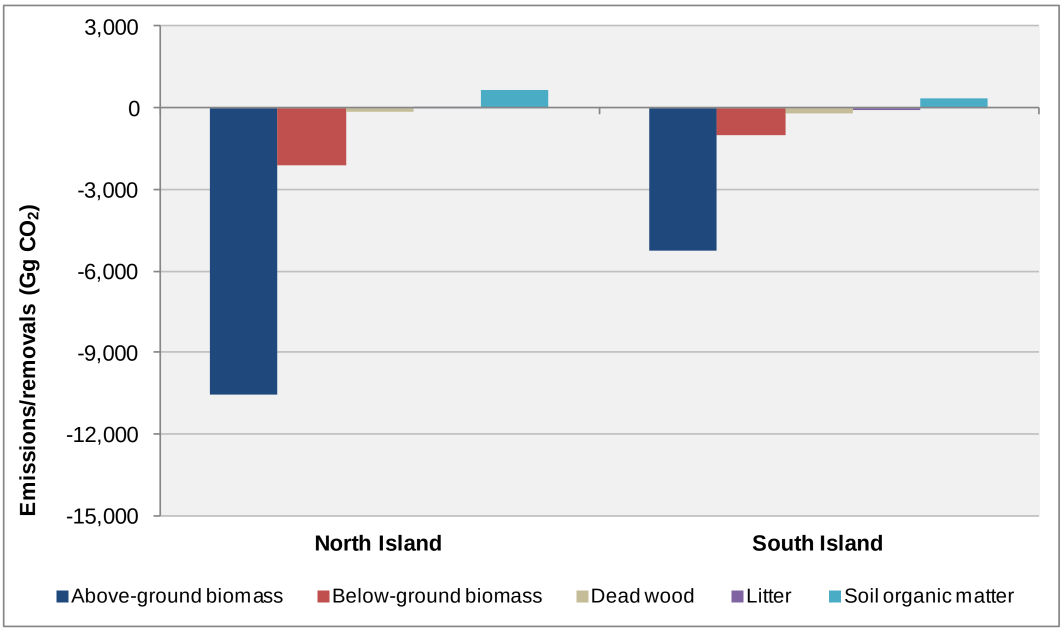
Source	Gross area (ha) 1990–2010	Net area (ha) 2010	Emissions in 2010 (Gg CO_2-e)
Afforestation/reforestation	611,149	593,821	–19,357.0
Forest land not harvested since the beginning of the commitment period	–	593,221	–19,512.4
Forest land harvested since the beginning of the commitment period	1,800	600	155.4
Deforestation	106,906	2,616	1,049.9
Total	**–**	**–**	**–18,307.1**

Note: Removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission. Afforestation/reforestation refers to new forest established since 1 January 1990. The gross afforestation/reforestation area includes 17,327 hectares of land in transition to post-1989 forest that has subsequently been deforested. The 2009 areas are as at 31 December 2010. Columns may not total due to rounding.

Between 1990 and 2010, 611,149 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities – an average of 29,000 hectares per year (refer to figure 7.3.1 and table 11.1.1). During 2010, an estimated 6,000 hectares of new forest was planted, an increase from 4,300 hectares in 2009 and 1,900 hectares in 2008.

Deforestation of all subcategories of forest land (post-1989, pre-1990 planted and natural forest) during 2010 was estimated at 2,616 hectares. Since 1990, the area of deforestation of all subcategories of forest is estimated as 106,906 hectares. This deforestation has resulted in 3,998.5 Gg CO_2-e emissions for the commitment period so far.

Figure 11.1.1 New Zealand's net CO_2 emissions by carbon pool associated with afforestation, reforestation and deforestation activities in 2010



Note: Emissions shown are the result of changes in carbon stock only and do not include non-CO_2 emissions. Removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

A breakdown of New Zealand's net emissions under Article 3.3 of the Kyoto Protocol by greenhouse gas source category is provided in table 11.1.2.

Table 11.1.2 New Zealand's net emissions under Article 3.3 of the Kyoto Protocol by greenhouse gas source category

	Net emissions in 2010 (Gg)		
Greenhouse gas source category	**Source form**	**Source emission**	**CO_2-equivalent**
Carbon stock change	CO_2	–18,328.5	–18,328.5
Disturbance associated with forest conversion to cropland	N_2O	NO	NO
Agricultural lime application on deforested land	C	4.5	16.3
Biomass burning of afforestation/reforestation land	CH_4	0.2	4.6
Biomass burning of afforestation/reforestation land	N_2O	0.0015	0.5
Total			**–18,307.1**

Note: NO = not occurring.

Nitrous oxide (N_2O) emissions from disturbance associated with forest conversion to cropland is reported as NO (not occurring) as there is a net gain in soil organic carbon with land-use change to cropland using the IPCC default methodology. This would result in New Zealand reporting a net gain in N_2O with disturbance to cropland. NO is reported instead.

New Zealand is not reporting:

- Carbon dioxide emissions from areas burnt by wildfire prior to forest harvesting or deforestation. Carbon dioxide emissions associated with wildfire are captured by, and reported under, the general carbon stock change calculation for forests at the time of harvest or deforestation
- liming of afforested and reforested land, as this activity does not occur
- non-CO_2 emissions from controlled burning on harvested and deforested land, as there is currently insufficient data to quantify the emissions from these activities. New Zealand is investigating sources of information to quantify emissions from controlled burning for possible reporting in future submissions
- emissions associated with nitrogen fertiliser use on deforested land, as these are reported in the agriculture sector.

Afforestation and reforestation

Between 1990 and 2010, it is estimated that 611,149 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities (table 11.1.3). The net area of post-1989 forest as at the end of 2010 was 593,821 hectares. The net area is the total area of new forest planted since 31 December 1989 minus the deforestation of post-1989 forest since 1 January 1990.

The new planting rate (land reforested or afforested) between 1990 and 2010 was, on average, 29,000 hectares per year. While new planting rates were high from 1992 to 1998 (averaging 61,000 hectares per year), the rate of new planting declined rapidly from 1998 and reached a low of 1,900 hectares in 2008. The planting rate has slowly recovered over the past two years with an estimated 4,300 hectares in 2009 and 6,000 hectares in 2010.

Table 11.1.3 New Zealand's estimated annual net area of afforestation/reforestation since 1990

	Annual area of post-1989 forest (ha)			
Year	New forest planting	Harvesting	Deforestation	Net cumulative area
1990	13,925	0	0	13,925
1991	13,572	0	0	27,497
1992	44,241	0	0	71,738
1993	54,288	0	0	126,026
1994	86,558	0	0	212,584
1995	65,020	0	0	277,604
1996	73,840	0	0	351,444
1997	56,203	0	0	407,647
1998	45,039	0	0	452,687
1999	35,087	0	0	487,774
2000	29,409	0	0	517,182
2001	26,391	0	0	543,573
2002	19,318	0	721	562,169
2003	17,385	0	2,273	577,281
2004	9,190	0	2,089	584,383

Year	Annual area of post-1989 forest (ha) New forest planting	Harvesting	Deforestation	Net cumulative area
2005	5,197	200	2,376	587,203
2006	2,252	600	2,037	587,419
2007	2,034	600	4,889	584,564
2008	1,900	600	622	585,842
2009	4,300	600	1,101	589,041
2010	6,000	600	1,220	593,821
Total	**611,149**	**3,200**	**17,327**	**593,821**

In 2008 and 2009, the New Zealand Government introduced legislation and government initiatives to encourage forest establishment and discourage deforestation of planted forests. These include:

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

The New Zealand Emissions Trading Scheme (NZ ETS) has been introduced under the Climate Change Response Act 2002. Forest land was introduced into the scheme on 1 January 2008. Under the scheme, owners of post-1989 forest land may voluntarily participate in the NZ ETS and receive emission units for any increase in carbon stocks in their forests from 1 January 2008. The annual area of new planting is expected to further increase with the implementation of the NZ ETS, Permanent Forest Sinks Initiative and Afforestation Grant Scheme.

New Zealand’s post-1989 forests are described in further detail in section 7.2.

Deforestation

In 2010, deforestation emissions were 1,049.9 Gg CO_2-e, compared with 1,375.3 Gg CO_2-e in 2009 and 1,573.3 Gg CO_2-e in 2008. These emissions are from the carbon stock loss caused by deforestation since 1990 that occurred in each year.

The area of deforestation in 2010 was 2,616 hectares, slightly lower (11.7 per cent) than the 3,259 hectares deforested in 2009. The lower emissions in 2010 are a result of the higher proportion of the deforested area that was post-1989 forest (46.6 per cent of the total, compared with 33.8 per cent in 2009), which is on average younger and has a lower carbon stock than pre-1990 planted or natural forest. The higher proportion of post-1989 forest deforestation in 2010 compared with pre-1990 planted forest may reflect the deforestation liabilities that have been imposed on pre-1990 forest land since the introduction of the NZ ETS on 1 January 2008.

Table 11.1.4 shows the areas of forest land subject to deforestation since 1990, by forest subcategory, and total emissions from deforestation in 2010.

Table 11.1.4 New Zealand's forest land subject to deforestation in 2010, and associated emissions from carbon stock change

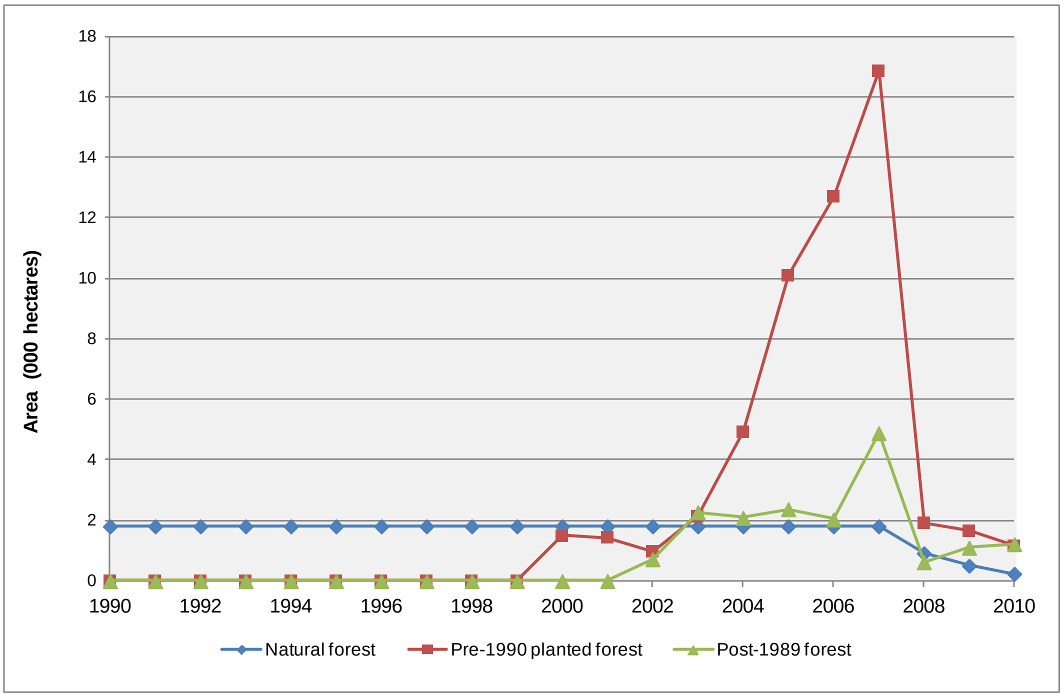
Forest land subcategory	Since 1990	Area of deforestation (ha) 2008	2009	2010	Emissions from carbon stock change in 2010 (Gg CO_2)
Natural forest	34,209	919	506	240	
Pre-1990 planted forest	55,369	1,926	1,652	1,157	
Post-1989 forest	17,327	622	1,101	1,220	
Total	**106,906**	**3,467**	**3,259**	**2,616**	**1049.9**

Note: 2008, 2009 and 2010 areas as at 31 December. Columns may not total due to rounding

Figure 11.1.2 shows the annual areas of deforestation since 1990, by forest subcategory. This illustrates the increase in pre-1990 planted forest deforestation that occurred in the four years leading up to 2008.

While the conversion of land from one land use to another is not uncommon in New Zealand, plantation forest deforestation on the scale seen between 2004 and 2008 was a new phenomenon. Most of the area of planted forest that was deforested from the mid-2000s onwards has subsequently been converted to grassland. This conversion is due in part to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry, as well as to the anticipated introduction of the NZ ETS.

Figure 11.1.2 New Zealand's annual areas of deforestation from 1990 to 2010



There are no emissions from deforestation of pre-1990 planted forest or post-1989 forest before 2000 are estimated as this activity was not significant and insufficient data exists to reliably report the small areas of deforestation that may have occurred.

Since the introduction of the NZ ETS in 2008, owners of pre-1990 planted forest are now able to deforest only 2 hectares in any five-year period without having to surrender emission units. Above this level of deforestation, they are required to surrender units equal to the reported emissions, with some exemptions for smaller forest owners

(Ministry of Agriculture and Forestry, 2009b). This has led to a significant reduction in the rate of deforestation of pre-1990 planted forest since the inception of the scheme. Post-1989 forest owners who are registered in the scheme also have legal obligations to surrender units if the carbon stocks in their registered forest area fall below a previously reported level (for example, due to deforestation, harvesting or fire).

The area of deforestation of natural forests prior to 2008 has been estimated by linear interpolation from the average land-use change mapped between 1 January 1990 and 1 January 2008. As there was no quantitative information on the annual rate of natural forest deforestation between 1990 and 2007, the same annual rate of change was assumed for the entire period (1,818 hectares per year). However, a number of factors suggest that the rate of natural forest deforestation is unlikely to have been constant over the 18-year period between 1990 and 2007, but instead mostly occurred prior to 2002. The area available for harvesting (and potentially deforestation) was higher before amendments were made to the Forests Act 1949 in 1993. Further restrictions to the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand from that time on. Both of these developments are likely to have reduced natural forest deforestation since 2002.

The estimated rate of natural forest deforestation has decreased since the start of the commitment period. This reduced rate of natural forest deforestation has been confirmed in 2008, 2009 and 2010 through satellite image mapping of deforestation (see figure 7.2.6 under land-use mapping for details of the mapping process).

Deforestation in New Zealand is described more fully in sections 7.2.1, 11.3.1 and 11.4.2.

11.1.1 Definitions of forest and any other criteria

New Zealand has used the same forest land definition as for the LULUCF sector under the Climate Change Convention reporting (chapter 7) and as defined in *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006). Table 11.1.5 provides the defining parameters for forest land.

Table 11.1.5 Parameters defining forest in New Zealand

Forest parameter	Kyoto Protocol range	New Zealand selected value
Minimum land area (ha)	0.05–1	1
Minimum crown cover (%)	10–30	30
Minimum height (m)	2–5	5

Note: The range values represent the minimum forest definition values as defined under the Kyoto Protocol, decision 16/CMP.1.

New Zealand also uses a minimum forest width of 30 metres, which removes linear shelterbelts from the forest category. The width and height of linear shelterbelts can vary as they are trimmed and topped from time to time. Further, they form part of non-forest land uses, namely cropland and grassland as shelter to crops and/or animals.

The definition used for reporting to the Food and Agriculture Organization is different from that used for Climate Change Convention and Kyoto Protocol reporting. New Zealand has not adopted a formal definition of forest type for reporting to the Food and Agriculture Organization. New Zealand has instead used the international definition proposed in the United Nations Economic Commission for Europe/Food and Agriculture Organization *Temperate and Boreal Forest Resources Assessment 2000*: "…an association of trees and other vegetation typical for a particular site or area and commonly described by the predominant species, for example, spruce/fir/beech" (UNECE/FAO, 2000). For reporting to the Food and Agriculture Organization, New Zealand subdivided forests into two estates based on their biological characteristics, the management regimes applied to the forests and their respective roles and national objectives (Ministry of Agriculture and Forestry, 2002). The two estates are indigenous and planted production forest. The former estate largely equates to natural forest as reported in this submission, and the latter largely equates to pre-1990 planted forest and post-1989 forest. There is an overlap where post-1989 forest has been established with native species or is the result of growth of native species following a change in management regime, for example, retirement of pasture land.

11.1.2 Elected activities under Article 3.4

As stated in *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006), New Zealand has not elected any of the activities under Article 3.4 of the Kyoto Protocol for the first commitment period.

11.1.3 Implementation and application of activities under Article 3.3

The area of afforestation/reforestation reported under the Kyoto Protocol is equal to the net area of post-1989 forest reported for land-use change to forest land reported in the LULUCF sector. Between 1990 and 2010, 611,149 hectares were reforested and 6,000 hectares of this occurred in 2010. Of the total area afforested or reforested between 1990 and 2010, an estimated 17,327 hectares were deforested between 1990 and 2010. Once an area has been identified as deforested it remains in this category for the first commitment period. Therefore, all subsequent stock changes and emissions and removals on this land are reported against units of land deforested.

Tracking of these deforestation areas during the calculation and land-use mapping processes (annex 3.2) ensures that land areas, once deforested, cannot be reported as afforestation or reforestation land and that the emissions and removals are reported under the land use the area is converted to.

New Zealand's intention is to account for all activities under Article 3.3 of the Kyoto Protocol at the end of the commitment period (Ministry for the Environment, 2006).

11.2 Land-related information

11.2.1 Spatial assessment unit

New Zealand is mapping land use to 1 hectare.

11.2.2 Methodology for land transition matrix

Mapping of land use as at the start of 1990 and of 2008 focused on the classes containing woody biomass (natural forest, pre-1990 planted forest, post-1989 forest and grassland with woody biomass). Satellite imagery was used to map woody classes as at 1 January 1990 and 1 January 2008. The mapping of land-use change prior to 2008 was based on these maps, high-resolution photography and field visits.

For 2008 and 2009, deforestation was mapped across all of New Zealand from 22 metre resolution DMC satellite imagery. For 2010, only a partial mapping was completed based on higher resolution 10 metre SPOT satellite imagery. Deforestation occurring in the unmapped areas was estimated based on the spatial distribution of deforestation that was observed in 2008 and 2009.

The use of higher resolution imagery for 2010 mapping highlighted that there were areas of 2008 and 2009 deforestation that had been missed in the earlier mapping activity. These areas were added to the deforestation totals for 2008 and 2009, and a further estimate was made of the remaining area of unmapped 2008 and 2009 deforestation that has occurred outside the area covered by high-resolution SPOT satellite imagery.

For the 2008, 2009 and 2010 years, afforestation was estimated from the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2011). For the non-forest land uses, change was estimated based on the average annual change between 1 January 1990 and 1 January 2008. This is further explained in section 7.2.

Land-use change during the first commitment period will be confirmed following mapping at the end of 2012.

11.2.3 Identifying geographical locations

New Zealand has used Reporting Method 1 for preparing estimates of emissions and removals from afforestation, reforestation and deforestation, and has used a combination of Approaches 2 and 3 to map land-use change.

The geographic units chosen by New Zealand to report by are: the North Island, including Great Barrier and Little Barrier Islands; and the South Island, including Stewart Island, the Chatham Islands and New Zealand’s offshore islands.

New Zealand’s uninhabited offshore islands include the Kermadec Islands, Three Kings Islands and the sub-Antarctic Islands (Auckland Islands, Campbell Island, Antipodes Islands, Bounty Islands and Snares Islands) and are reported in a steady state of land use. These protected conservation areas total 74,052 hectares and are not subject to land-use change.

11.3 Activity-specific information

11.3.1 Carbon stock change and methods

Description of the methodologies and the underlying assumptions used

The methodologies and assumptions used for reporting under the Kyoto Protocol Article 3.3 activities are the same as those used for Climate Change Convention reporting and are described fully in chapter 7.

Carbon stock change

Emissions and removals from afforestation and reforestation are determined at the national scale. Carbon analyses based on a national forest plot network are performed to estimate the average amount of carbon per hectare per pool and are described in section 7.3.2.

For the 2011 submission, emissions from deforestation have been calculated based on mapped polygons of deforestation using satellite imagery and plot network based estimates of carbon density and stock for each subcategory of forest (natural forest, pre-1990 planted forest and post-1989 forest) as described in section 7.3.2.

Natural forest deforestation has been further sub-classified according to species composition, to identify the proportion of deforestation that was tall forest as opposed to younger or immature natural forest (shrubland that will meet the forest definition) areas (table 11.3.1). This has been determined using the ECOSAT spatial layer, which enables more accurate reporting of the dominant natural forest species within the deforested area, resulting in more accurate emission factors. For further information on the ECOSAT layer refer to: http://www.landcareresearch.co.nz/services/informatics/ecosat/about.asp

Table 11.3.1 New Zealand's areas of natural forest deforestation by sub-classification in 2008, 2009 and 2010

	Area of deforestation since 2008 (ha)			
Natural forest sub-classification	**2008**	**2009**	**2010**	**Total**
Shrub	838	441	210	1489
Tall forest	81	65	30	176
Total	919	506	240	1665
Percent tall forest (%)	**8.8%**	**12.8%**	**12.5%**	**10.6%**

The carbon yield tables for all three subcategories of forest (natural forest, pre-1990 planted forest and post-1989 forest) will be updated following scheduled re-measurement of these forests as described in section 7.3.2.

Following deforestation, carbon on the new land use then accumulates at rates given in table 7.1.4.

Liming

Liming of afforestation land does not occur in New Zealand so the notation key 'NO' is used in the CRF tables. Emissions from liming of deforestation land are reported based on the same methodology as used for the LULUCF sector and described in section 7.9.4.

Non-CO_2 emissions

Direct N_2O emissions from nitrogen fertilisation

New Zealand's activity data on nitrogen fertilisation is not currently disaggregated by land use, and therefore all N_2O emissions from nitrogen fertilisation are reported in the agriculture sector under the category 'direct soils emissions' (CRF 4D). The notation key IE (included elsewhere) is reported in the common reporting format (CRF) tables for the KP-LULUCF sector.

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

Nitrous oxide emissions result from the mineralisation of soil organic matter with conversion of land to cropland. This mineralisation results in an associated conversion of nitrogen previously in the soil organic matter to ammonium and nitrate. Microbial activity in the soil converts some of the ammonium and nitrate present to N_2O. An increase in this microbial substrate caused by a net decrease in soil organic matter can therefore be expected to give an increase in net N_2O emissions (GPG-LULUCF, section 3.3.2.3, IPCC, 2003).

With deforestation to cropland, the change in soil organic carbon is estimated to be a net gain. Calculating the net N_2O emissions based on this would result in removals of N_2O with mineralisation of soil organic matter with land-use change, which is not appropriate, so the notation key NO (not occurring) is reported within the CRF tables instead.

Biomass burning

Non-CO_2 emissions from wildfires in land converted to forest land are reported under the post-1989 forest subcategory for the first time in the 2012 submission. The activity data does not distinguish between forest land subcategories; therefore, non-CO_2 emissions resulting from wildfire are attributed to the post-1989 forest subcategory by the proportion of area the post-1989 forest makes up of the total planted forest area. An age-based carbon yield table is then used to estimate non-CO_2 emissions in post-1989 forest. This approach assumes that the carbon stock affected by wildfire is equivalent to the carbon stock at the average stand age each year throughout the time series (Wakelin, 2011). Carbon dioxide emissions resulting from wildfire events are not reported as the methods applied do not capture subsequent regrowth (IPCC, 2003, GPG-LULUCF, section 3.2.1.4.2).

For calculating the emissions from controlled burning, New Zealand assumes that 25 per cent of grassland with woody biomass converted to forest land is cleared using controlled burning. New Zealand is currently investigating a data source to refine the assumption for this activity.

Conversions of planted forest land to grassland (pasture) have increased between 2004 and 2008. New Zealand is investigating sources of information to quantify emissions from this activity for possible reporting in future submissions.

Justification when omitting any carbon pool or greenhouse gas emissions from activities under Article 3.3 and elected activities under Article 3.4

New Zealand has accounted for all carbon pools from activities under Article 3.3. New Zealand has not elected any activities under Article 3.4 for the first commitment period.

New Zealand has not estimated methane or N_2O emissions from controlled burning on land subject to deforestation under Article 3.3 as there is currently no data on this activity. New Zealand is investigating sources of information to quantify emissions from this activity for possible reporting in future submissions.

Direct N_2O emissions from the application of nitrogen fertiliser to land subject to afforestation and reforestation are reported as IE (included elsewhere) as these emissions are reported in the agriculture sector under the category direct soil emissions.

Factoring out information

New Zealand does not factor out emissions or removals from:

- elevated carbon dioxide concentrations above pre-industrial levels
- indirect nitrogen deposition
- the dynamic effects of age structure resulting from activities prior to 1 January 1990.

Recalculations

New Zealand's greenhouse gas estimates for activities under Article 3.3 of the Kyoto Protocol have been recalculated since the previous submission to incorporate improved New Zealand-specific methods, activity data and emission factors, as detailed in sections 7.1, 7.2 and chapter 10. The impact of the recalculations on New Zealand's 2009 Kyoto Protocol estimates is shown in table 11.3.2.

Table 11.3.2 Impact of the recalculations of New Zealand's net emissions under Article 3.3 of the Kyoto Protocol in 2009

Activity under Article 3.3 of the Kyoto Protocol	2009 net emissions ($Gg CO_2$-e) 2011 submission	2012 submission
Afforestation/reforestation	–17,624.3	–19,210.5
Forest land not harvested since the beginning of the commitment period	–17,701.3	–19,336.7
Forest land harvested since the beginning of the commitment period	77.0	126.1
Deforestation	355.9	1,375.2
Total	–17,268.4	–17,835.3

Note: Removals are expressed as a negative value to help the reader in clarifying that the value is a removal and not an emission.

The largest factor in the recalculations has been the revision of the post-1989 yield table. This has utilised an updated version of the Forest Carbon Predictor (FCP v3), which contains new temperature-dependent decay functions and species-specific growth trajectory and biomass). The greatest percentage change has been due to a recalculation of the 2009 deforestation areas (table 11.3.3). This is because deforestation areas reported in the 2011 submission were based on lower resolution (22 metre) satellite image mapping. Improved mapping in 2011, from higher resolution imagery, has allowed more areas of 2009 deforestation to be identified in the four most active areas of deforestation in New Zealand, and an estimation to be made of further areas of 2009 deforestation that are yet to be mapped outside the of the most active areas. Deforestation mapping from 2008 to 2010 is described in more detail in section 7.2.2.

Table 11.3.3 Recalculations to New Zealand's 2009 activity data under Article 3.3 of the Kyoto Protocol

Activity under Article 3.3 of the Kyoto Protocol	2009 areas (ha) 2011 submission	2012 submission	Change from 2011 submission (%)
Afforestation/reforestation	591,202	589,041	–0.4
Forest land not harvested since the beginning of the commitment period	589,052	586,441	–0.4
New planting	4,000	4,300	7.5
Forest land harvested since the beginning of the commitment period	2,150	2,600	20.9
Deforestation	1,644	3,259	98.2
Natural forest	462	506	9.5
Pre-1990 planted forest	449	1,652	267.9
Post-1989 forest	734	1,101	50.0

Uncertainty and time-series consistency

The uncertainty in net emissions from afforestation and reforestation is 80.4 per cent, based on the uncertainty in emissions from post-1989 forest (refer to section 7.3.3 and table 7.3.9 for further details). The uncertainty in emissions from deforestation units is determined by the type of forest land deforested. This may be natural forest, pre-1990 forest or post-1989 forest (table 11.1.4). Further detail on the uncertainty in emissions for natural forest and pre-1990 forest is provided in section 7.3.

Table 11.3.4 Uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2010

Source of emissions	Uncertainty with a 95% confidence interval (%) Afforestation/ reforestation	Deforestation			
Land-use subcategory	Post-1989 forest	Natural forest	Pre-1990 forest	Post-1989 forest	Total
Activity data uncertainty	7.0%	15.8%	10.2%	10.9%	7.9%
Emission factor uncertainty	80.1%	2,485.9%	202.4%	92.0%	156.1%
Total uncertainty	**80.4%**				**156.3%**

Note: All land that has been afforested/reforested since 1 January 1990 is defined as post-1989 forest. Land deforested since 1 January 1990 may be natural forest, pre-1990 forest or post-1989 forest.

If uncertainty and emissions from soils is excluded then the uncertainties associated with afforestation and deforestation are much lower, as shown in table 11.3.5.

Table 11.3.5 Uncertainty in New Zealand's estimates for afforestation, reforestation and deforestation in 2010 excluding the soils pool

Source of emissions	Uncertainty with a 95% confidence interval (%) Afforestation/ reforestation	Deforestation
Activity data uncertainty	7.5%	11.8%
Emission factor uncertainty	11.0%	25.5%
Total uncertainty	**13.4%**	**28.1%**

New Zealand forests are actively managed, with thinning and pruning activities undertaken in both pre-1990 planted forests and post-1989 forests. The majority of these activities are completed before trees reach the age of 13. Thus there is a gradual increase in the size of the dead wood and litter pools from these management practices leading up to this age. This is followed by a decline in these pools after age 13 where pruning and thinning ceases and decay exceeds inputs. Due to the age-class structure of post-1989 forest in New Zealand, this can be seen as a rapid increase in the dead wood and litter pools between consecutive years.

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 7.3.4.

Year of the onset of an activity

Paragraph 18 of the annex to 16/CMP.1 (land use, land-use change and forestry) requires that New Zealand account for emissions and removals from Article 3.3 activities beginning with the onset of the activity or the beginning of the commitment period, whichever is later. In practical terms, paragraph 18 means there is a need to differentiate activities that occurred between 1 January 1990 and 31 December 2007 from those after this period.

During 2010, an estimated 6,000 hectares of post-1989 forest were established and 2,616 hectares of forest (natural forest, pre-1990 planted forest and post-1989 forest) were deforested.

The afforestation area is estimated from the *National Exotic Forest Description* survey, the Afforestation Grants Scheme and the East Coast Forestry Project (Ministry of Agriculture and Forestry, 2011). This information ensures that the activity is attributed to the correct year of onset.

The deforestation area is based on mapping from satellite imagery acquired in the summers of 2009–2010 and 2010–2011. To distinguish between deforestation events occurring in 2008 and 2009, other available imagery sources such as Landsat 7 are used.

11.4 Article 3.3

11.4.1 Demonstration that activities apply

The United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines require that countries provide information which demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and that these activities are direct human-induced.

All land in New Zealand is under some form of management and management plan. Land is managed for a variety of reasons, including agriculture and/or forestry production, conservation, biodiversity, fire risk management (eg, fire breaks) and scenic and cultural values. Most land-use changes occur in agriculture and forestry landscapes. All land-use change, including deforestation, is therefore a result of human decisions to either change the vegetation cover and/or change the way land is managed. The only notable exception to this is the loss of natural forest due to erosion, which can be a non-anthropogenic land-use change.

New Zealand has used satellite imagery collected around the start of 1990 and 2008 to detect changes in land use between these two periods.

To estimate land-use change in 2008, 2009 and 2010, Land Use and Carbon Analysis System (LUCAS) mapping was augmented with data from the Ministry of Agriculture and Forestry's Afforestation Grants Scheme, the NZ ETS and the *National Exotic Forest Description* (Ministry of Agriculture and Forestry, 2010). This was used to estimate afforestation and reforestation during 2009. Deforestation occurring during 2008, 2009 and 2010 was mapped and estimated from satellite imagery (see section 7.2.2). Where non-anthropogenic destocking was identified during deforestation mapping it was delineated but not reported as deforestation.

Following the mapping of land use at the end of 2012, New Zealand will recalculate the area of land-use change due to afforestation, reforestation and deforestation during the first commitment period.

11.4.2 Distinction between harvesting and deforestation

The UNFCCC reporting guidelines require that countries provide information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation.

New Zealand has used the IPCC (2003) definition of deforestation: "Deforestation is the direct human-induced conversion of forested land to non-forested land". Deforestation is different from harvesting, in that harvesting is part of usual forest management practice and involves the removal of biomass from a site followed by reforestation (replanting or revegetation, ie, no change in land use).

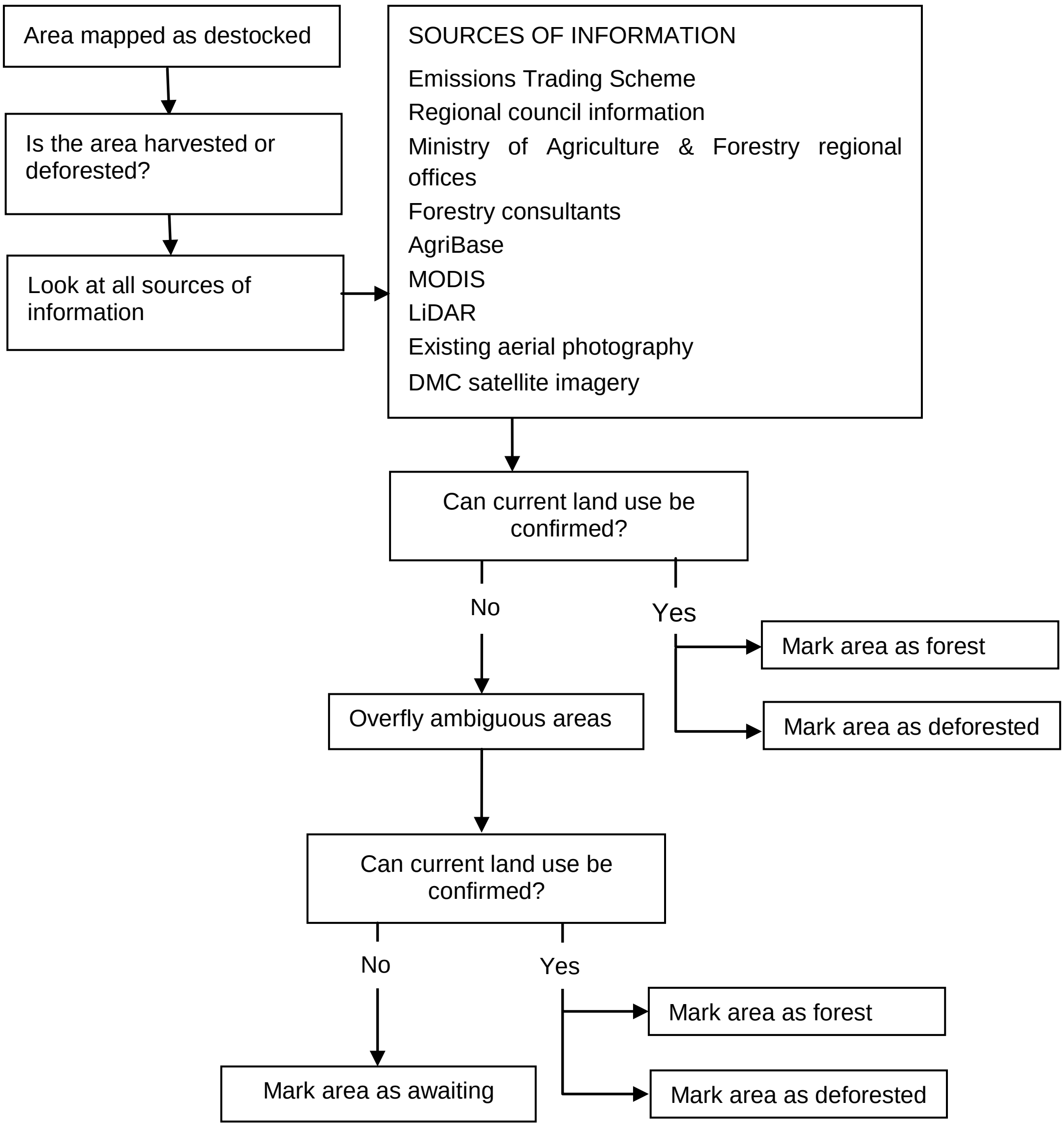
In New Zealand, temporarily unstocked or cleared areas of forest (eg, harvested areas and areas subject to disturbances) remain designated as forest land unless there is a confirmed change in land use or if, after four years, no reforestation (replanting or revegetation) has occurred. The four-year time period was selected because, in New Zealand, the tree grower and landowner are often different people. Forest land can be temporarily unstocked for a number of years while landowners decide what to do with land after harvesting.

Prior to the four-year time period, there are a number of activities that will be carried out to confirm if land-use change has occurred, including the analysis of satellite imagery and oblique aerial photography. These activities are detailed in section 7.2 – representation of land areas.

Under the NZ ETS, owners of pre-1990 planted forest and owners of post-1989 forest who are participants in the scheme are required to notify the Government of any deforestation activity (Ministry of Agriculture and Forestry, 2009a). There is a data-sharing agreement that the Ministry of Agriculture and Forestry, the agency that administers the forestry aspects of the NZ ETS, will provide the Ministry for the Environment with regular updates of the area of confirmed deforestation.

Areas identified as destocked are monitored until future land-use intentions can be confirmed. There are a number of approaches to this monitoring and confirmation including: satellite image interpretation, evidence from the Ministry of Agriculture and Forestry's ETS mapping database, oblique aerial photography, digital orthophotography, field visits and searching for information held either by regional councils, Ministry of Agriculture and Forestry district offices, or forestry consultants. This process is shown in figure 11.4.1.

Figure 11.4.1 Verification of deforestation in New Zealand



Note: MODIS = Moderate Resolution Imaging Spectroradiometer; LiDAR = Light Detection and Ranging; DMC = Disaster Monitoring Constellation.

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 at individual sites where areas are harvested within four years of the end of the first commitment period. To establish the total area of deforestation at the end of 2012, New Zealand will use a combination of the ratio of area harvested to area deforested over the first part of the commitment period, the total area of destocking mapped from high-resolution SPOT 5 (or similar high-resolution optical imagery) acquired at the end of the commitment period and deforestation information from the NZ ETS.

Once a land-use change is mapped and confirmed, the deforestation emissions will be reported in the year of forest clearance. This is based on the assumption that, at the time of forest clearance, the intention was to deforest the land and that associated emissions to the atmosphere occurred in that year.

11.4.3 Unclassified deforestation

The UNFCCC reporting guidelines require that countries provide information on the size and geographical location of forest areas that have lost forest cover but that are not yet classified as deforested.

In order to identify these areas, the 2010 deforestation mapping methodology was modified to allow destocked land to be mapped into three classes: Harvested (H), Deforested (D) and Awaiting (A). The Awaiting areas are those areas where there is no clear evidence to support harvesting (replanting activity, forestry context) or deforestation (confirmed land-use change, such as pasture establishment, fences and stock). The areas are therefore awaiting a land-use determination.

Deforestation mapping for 2010 was carried out over four priority areas based on SPOT 5 10 metre resolution satellite imagery (section 7.2.2 – land-use mapping). All areas destocked during 2010 were identified, and an initial classification into H, D and A was made based on satellite image interpretation. A stratified sample of the areas mapped was then assessed by acquiring oblique aerial photography from light aircraft. Results from this verification process were used to derive uncertainty estimates for the mapped areas of H, D and A. From this uncertainty analysis, it was possible to derive estimates of the total awaiting land within the four priority areas as a percentage of total destocked area. The Awaiting area was estimated to be 13.3 per cent of the total destocked area (4,422 hectares). Table 11.3.6 shows how this area is split between forest types.

Table 11.3.6 Estimate of land destocked in 2010 awaiting a land-use determination within four priority areas

	Natural forest	Pre-1990 forest	Post-1989 forest	Total
2010 Awaiting land within four priority areas (ha)	796	2911	715	4422

At present, there are insufficient data to extrapolate this to an estimate of the Awaiting area for all of New Zealand. Mapping and monitoring of the Awaiting area will continue over the next two years to ensure that a complete snapshot of this area, and the anticipated rate of conversion to deforestation, is available for the 2014 submission.

11.5 Article 3.4

New Zealand has not elected any activities under Article 3.4 of the Kyoto Protocol (Ministry for the Environment, 2006).

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities

Conversion to forest land (afforestation and reforestation) and conversion to grassland (deforestation) are key categories in both the level and trend analysis.

11.7 Information relating to Article 6

New Zealand is not involved in any LULUCF activities under Article 6 of the Kyoto Protocol.

Chapter 11: References

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Chapter 12: Information on accounting of the Kyoto Protocol units

12.1 Background information

Assigned amount and commitment period reserve

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

The commitment period reserve of 278,608,260 metric tonnes (CO_2-e) is 90 per cent of the assigned amount, fixed after the initial review in 2007.

Holdings and transactions of Kyoto Protocol units

Please refer to the standard reporting format tables below (table 12.2.2). These tables are also provided in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/ publications/climate).

General note

Abbreviations used in this chapter include:

AAUs	Assigned amount units
CDM	Clean Development Mechanism
CERs	Certified emission reduction units
ERUs	Emission reduction units
ICERs	Long-term Certified Emission Reduction units
NO	Not occurring
NZEUR	New Zealand Emission Unit Register
RMUs	Removal units
tCERS	Temporary Certified Emission Reduction units

For *Table 2b Annual external transactions* in table 12.2.2 in the column 'Transfers and acquisitions':

AT	Austria
AU	Australia
CDM	Clean Development Mechanism
CH	Switzerland
FR	France
GB	United Kingdom of Great Britain and Northern Ireland
JP	Japan
NL	Netherlands

12.2 Summary of the standard electronic format tables for reporting Kyoto Protocol units

At the beginning of the calendar year 2011, New Zealand's national registry held 307,259,426 assigned amount units, 20,328 emissions reduction units and 531,020 certified emission reduction units. There were no removal units held in the registry at the beginning of the 2011 calendar year (table 1 in table 12.2.2).

At the end of 2011, there were 306,248,485 assigned amount units, 530,346 emission reduction units, 2,935,654 certified emission reduction units and 3,900,000 removal units held in the New Zealand registry (table 4 in table 12.2.2).

New Zealand's national registry did not hold any temporary certified emission reduction units and long-term certified emissions reduction units during 2011 (table 4 in table 12.2.2).

The transactions made to New Zealand's national registry during 2011 (tables 2 (a), (b), (c) in table 12.2.2) are summarised below.

- There were 18,530 assigned amount units added to New Zealand's national registry from the United Kingdom of Great Britain and Northern Ireland. Seven thousand assigned amount units were subtracted from the registry and were transferred to Switzerland (3,000), Japan (3,000) and the United Kingdom of Great Britain and Northern Ireland (1,000).
- There were 1,731,931 emission reduction units added to New Zealand's national registry and 1,221,913 were subtracted. The main additions were in respect to New Zealand-verified projects under Article 6 of the Kyoto Protocol. The biggest external addition of emission reduction units was 576,000 units from the United Kingdom of Great Britain and Northern Ireland. There were six external subtractions of emission reduction units, with the largest being 529,991 to the Netherlands. There were no internal subtractions.
- There were 4,396,232 certified emission reduction units added to New Zealand's national registry and 1,991,598 were subtracted. The greatest addition was 2,958,042 certified emission reduction units from the United Kingdom of Great Britain and Northern Ireland. The greatest subtraction was 1,726,593 certified emission reduction units made to the United Kingdom of Great Britain and Northern Ireland. There were no internal transactions.
- There was one external addition of 3,900,000 removal units from the United Kingdom of Great Britain and Northern Ireland.
- There were no transactions of temporary certified emission reduction units and long-term certified emissions reduction units.

During 2011, no Kyoto Protocol units were expired, replaced or cancelled.

Table 12.2.1 New Zealand's submission of the standard electronic format

Annual submission item	New Zealand's national registry response
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	The Standard Electronic Format report for 2011 has been submitted to the UNFCCC Secretariat electronically and is included in this section (table 12.2.2).

Table 12.2.2 Copies of the standard report format tables (ie, tables 1–6) from New Zealand's national registry

Party	New Zealand
Submission year	2012
Reported year	2011
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	307098445	NO	NO	NO	NO	NO
Entity holding accounts	158292	20328	NO	530220	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	2689	NO	NO	800	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	307259426	20328	NO	531020	NO	NO

Party	New Zealand
Submission year	2012
Reported year	2011
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		1022471					1022471		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							8517	NO	NO	NO	NO	NO
Sub-total		1022471	NO				1030988	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 2012
Reported year 2011
Commitment period 1

Add registry Delete registry

Table 2 (b). Annual external transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Transfers and acquisitions												
AT	NO	NO	NO	NO	NO	NO	NO	19715	NO	NO	NO	NO
AU	NO	NO	NO	5	NO	NO	NO	NO	NO	30005	NO	NO
CDM	NO	NO	NO	798254	NO	NO	NO	NO	NO	NO	NO	NO
CH	NO	NO	NO	NO	NO	NO	3000	116515	NO	NO	NO	NO
FR	NO	NO	NO	205000	NO	NO	NO	45315	NO	NO	NO	NO
GB	18530	576000	3900000	2958042	NO	NO	1000	450377	NO	1726593	NO	NO
JP	NO	133460	NO	324931	NO	NO	3000	60000	NO	NO	NO	NO
NL	NO	NO	NO	110000	NO	NO	NO	529991	NO	235000	NO	NO
Sub-total	18530	709460	3900000	4396232	NO	NO	7000	1221913	NO	1991598	NO	NO

Additional information

Independently verified ERUs								NO				

Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	18530	1731931	3900000	4396232	NO	NO	1037988	1221913	NO	1991598	NO	NO

Party	New Zealand
Submission year	2012
Reported year	2011
Commitment period	1

Table 3. Expiry, cancellation and replacement

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

Party	New Zealand
Submission year	2012
Reported year	2011
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	305642697	NO	NO	133150	NO	NO
Entity holding accounts	594582	530346	3900000	2801704	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	11206	NO	NO	800	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	306248485	530346	3900000	2935654	NO	NO

Party	New Zealand
Submission year	2012
Reported year	2011
Commitment period	1

Table 5 (a). Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Issuance pursuant to Article 3.7 and 3.8	309564733											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	309564733	NO		NO			NO	NO	NO	NO		
Annual transactions												
Year 0 (2007)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 1 (2008)	NO	120000	NO	25108	NO	NO	120000	NO	NO	15800	NO	NO
Year 2 (2009)	1000	496567	NO	401000	NO	NO	1068018	568469	NO	401000	NO	NO
Year 3 (2010)	1	419880	NO	621002	NO	NO	1120979	447650	NO	100090	NO	NO
Year 4 (2011)	18530	1731931	3900000	4396232	NO	NO	1037988	1221913	NO	1991598	NO	NO
Year 5 (2012)	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	19531	2768378	3900000	5443342	NO	NO	3346985	2238032	NO	2508488	NO	NO
Total	309584264	2768378	3900000	5443342	NO	NO	3346985	2238032	NO	2508488	NO	NO

Table 5 (b). Summary information on replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Previous CPs			NO	NO	NO	NO	NO	NO
Year 1 (2008)		NO	NO	NO	NO	NO	NO	NO
Year 2 (2009)		NO	NO	NO	NO	NO	NO	NO
Year 3 (2010)		NO	NO	NO	NO	NO	NO	NO
Year 4 (2011)		NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO

Table 5 (c). Summary information on retirement

	Retirement					
	Unit type					
Year	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Year 1 (2008)	NO	NO	NO	NO	NO	NO
Year 2 (2009)	NO	NO	NO	NO	NO	NO
Year 3 (2010)	NO	NO	NO	NO	NO	NO
Year 4 (2011)	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO

Party	New Zealand
Submission year	2012
Reported year	2011
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

12.2 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 2011. 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 2011. 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 2011. 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 2011. For completeness, the report R-5 is included with 'Nil' invalid units notification received during the reporting period.
15/CMP.1 annex I.E, paragraph 1 17: Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.

12.4 Publicly accessible information

New Zealand's national registry list of publicly accessible information is available at www.eur.govt.nz. Search the Register tab. A list of publicly accessible information is provided in table 12.4.1.

Table 12.4.1 List of the publicly accessible information in New Zealand's national registry

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
44. Each national registry shall make non-confidential information publicly available and provide a publicly accessible user interface through the Internet that allows interested persons to query and view it.			
45. The information referred to in paragraph 44 above shall include up-to-date information for each account number in that registry on the following:			
(a) Account name: the holder of the account.	Yes (refer Search the Register: Accounts).	Up to date (real-time).	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(b) Account type: the type of account (holding, cancellation or retirement).	Yes (refer Search the Register: Accounts).	Up to date (real-time).	n/a
(c) Commitment period: the commitment period with which a cancellation or retirement account is associated.	Yes (refer Search the Register: Accounts: Click on Account Number hyperlink to access Account Information Report).	Up to date (real-time).	n/a
(d) Representative identifier: the representative of the account holder, using the Party identifier (the two-letter country code defined by ISO 3166) and a number unique to that representative within the Party's registry.	No – the representative identifiers for primary representatives are not publicly available as it is classified as confidential.	n/a	Section 27(1)(a) of the Climate Change Response Act 2002 does not require this information to be made publicly available. Only the holding account number for each account in the registry is publicly available under this section.
(e) Representative name and contact information: the full name, mailing address, telephone number, facsimile number and email address of the representative of the account holder.	Yes, available during the reporting period. Partial from 12 February 2011 – the publication of the personal email addresses of the representatives has been withdrawn given the recent security issues encountered by some overseas registries. (Refer Search the Register: Accounts: Click on Account Number hyperlink to access Account Information Report: Representative Details.)	Up to date (real-time).	Section 13 of the Climate Change Response 2002 permits the Registrar to withhold access to the email address of account holder's representatives on the grounds of security or integrity of the registry.
46. The information referred to in paragraph 44 shall include the following Article 6 project information, for each project identifier against which the Party has issued ERUs:			
(a) Project name: a unique name for the project.	Yes (refer Search the Register: Joint Implementation (JI) Projects).	Up to date (real-time).	n/a
(b) Project location: the Party and town or region in which the project is located.	Yes (refer Search the Register: Joint Implementation (JI) Projects).	Up to date (real-time).	n/a
(c) Years of ERU issuance: the years when ERUs have been issued as a result of the Article 6 project.	Yes (this information can be accessed either by clicking on the project ID under the Unit Conversions tab or through the Ministers' Directions	Joint Implementation (JI) Projects annually by 31 January for the previous calendar year.	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
	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).	Ministers' directions - Up to date (real-time).	
(d) Reports: downloadable electronic versions of all publicly available documentation relating to the project, including proposals, monitoring, verification and issuance of ERUs, where relevant, subject to the confidentiality provisions in decision 9/CMP.1.	Partial – this information is published on the Ministry for the Environment's website for Joint Implementation Projects at http://www.mfe.govt.nz/issues/climate/policies-initiatives/joint-implementation/notice.html and is not replicated on the New Zealand's national registry website (www.eur.govt.nz). The following information for each JI project is published on the Ministry for the Environment website: • project description • non-host party project approval • annual reports • verification reports. Project proposals are not included as they contain financial information that is considered to be commercially sensitive and confidential.	This information becomes publicly available once New Zealand gives its approval to the JI project. The information is then updated when necessary and annual reports are added annually.	n/a
47. The information referred to in paragraph 44 shall include the following holding and transaction information relevant to the national registry, by serial number, for each calendar year (defined according to Greenwich Mean Time):			

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(a) The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year.	Partial – aggregate unit holdings of ERUs, CERs, AAUs and RMUs for the previous calendar year are disclosed by 31 January of each year (refer Search the Register: NZEUR Holding & Transaction Summary). Total quantity of unit holdings in each account within the most recent calendar year is considered to be confidential information, therefore the total quantity of unit holdings in each account provided is only that completed more than one year in the past. (Refer Search the Register: NZEUR Kyoto Unit Holdings by Account: Use Search Criteria to find information pertaining to more than one year in the past.)	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year. 1 January for the beginning of the previous calendar year.	Section 27(2) of the Climate Change Response Act 2002 only requires total holdings of AAUs, ERUs, CERs, ICERs, tCERs and RMUs to be publicly available by 31 January of each year for the previous calendar year. Section 27(3) of the Climate Change Response Act 2002 only requires holdings of Kyoto units by each holding account for the beginning of the previous calendar year to be made publicly available.
(b) The total quantity of AAUs issued on the basis of the assigned amount pursuant to Article 3, paragraphs 7 and 8.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	n/a
(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 Section 27(j) of the Climate Change Response Act 2002 requires that only the following be made publicly available: • total quantity of units transferred; and • total quantity and type of unit transferred; and • the identity of the transferring overseas

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
	The identity of the individual transferring accounts is not available as it is considered to be confidential information.		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.
(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

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48		Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(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). Total quantity of unit holdings in each account within the most recent calendar year is considered to be confidential information, therefore the total quantity of unit holdings in each account provided is only that completed more than one year in the past. (refer Search the Register: NZEUR Kyoto Unit Holdings by Account: Use Search Criteria to find information pertaining to more than one year in the past).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1January of each year. 1 January for the beginning of the previous calendar year.	Section 27(2) of the Climate Change Response Act 2002 only requires total holdings of AAUs, ERUs, CERs, ICERs, tCERs and RMUs to be publicly available by 31 January of each year for the previous calendar year. Section 27(3) of the Climate Change Response Act 2002 only requires holdings of Kyoto units by each holding account for the beginning of the previous calendar year to be made publicly available.

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
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 is 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*.[38]

The commitment period reserve level as at 31 December 2011 is:

Commitment period reserve limit:	278,608,260
Units held:	313,602,479
Commitment period Reserve level:	313,602,479
Commitment period reserve level = (% of assigned amount):	101.30%

CPR level comprises of the following units:	
AAUs	306,237,279
ERUs (converted from AAUs)	530,346
CERs	2,934,854
RMUs	3,900,000
Total units	313,602,479

New Zealand's commitment period reserve level is also available at: www.eur.govt.nz, and is updated on a daily basis.

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

Chapter 13: Information on changes to the national system

Development of expertise

New Zealand has continued to develop the expertise of the main inventory contributors. For this submission, an additional government expert learnt how to compile the national inventory. Additional sector experts for the energy and agriculture sectors were also trained as the lead sector compilers.

Two government officials passed their exams under the Climate Change Convention for the energy and land use, land-use change and forestry (LULUCF) sectors. One government official passed their exams under the Kyoto Protocol as a LULUCF reviewer, another one passed their exams to qualify as a lead reviewer and two government officials participated in their first expert review of an Annex I inventories.

Governance

The Terms of Reference for the Reporting Governance Group were reviewed to reflect improved clarity for modelling and projections, updated membership and to specify engagement with wider climate change governance. The next review of the Terms of Reference is due in late 2012. See section 1.2.2 for further detail on the Reporting Governance Group.

Quality assurance

New Zealand and Australia participated in a mutual exchange in August 2011. This included reviewing aspects of each other's inventories, including the energy, agriculture and LULUCF sectors. This contributed to our quality-assurance activities for the 2012 submission.

Other significant changes to the national system that relate to specific sectors include the following.

- Verification with data provided under the New Zealand Emissions Trading Scheme was a significant improvement to the quality assurance of estimates for carbon dioxide in the industrial processes sector (refer to chapter 4).
- The Tier 1 quality-control procedures were improved for the LULUCF sector to better reflect the compilation process, and the development of a LULUCF compilation manual was started.
- Documentation to demonstrate how estimates for the waste sector are compiled was significantly improved.

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 2011 submission are included in table 14.1.

New Zealand's response to the most recent recommendation made by the expert review team is included in table 14.2.

A list of reference documents included in the submitted zip file 'Chapter 14 2012' is provided in table 14.3.

Table 14.1 Changes made to New Zealand's national registry

Section subheading	New Zealand's response
15/CMP.1 Annex II.E, paragraph 32.(a): Change in the name or contact for the national registry	In 2011, the contact details for the national registry have been changed. Changes have been made to the Administrator, the Main Contact, the Alternative Contact and the Release Manager. Refer to the table 14.4 below for details. The National Focal Point advised UN/ITL of these changes. The changes have taken effect from 5 December 2011.
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	During 2011 (19/20 August 2011), New Zealand has changed the NZEUR Hosting providers. The application software has not been changed, only the hosting environment has been transitioned. The Readiness Documentation package has been provided to UN/ITL (and it is also attached to this submission). Refer to table 14.3 below. There were changes made to the Database and Application Backup (changes to the content of the backup procedures, no changes to the backup retention periods, no changes to the frequency of the database backups), changes made to the Disaster Recovery Plan, changes made to the Security Plan, changes made to the Application Logging Documentation, changes made to the Time Validation Plan, no changes made to the Version Change Management and changes made to the Operational Plan. New Zealand undertook Annex H testing for the new hosting environment change over and the relevant documentation has been provided to UN/ITL. Also, as part of this transition for the new hosting environment New Zealand has successfully performed the ITL VPN and ITL SSL testing. The documentation has been provided to UN/ITL. Refer to the documentation listed in table 14.3 below.
15/CMP.1 Annex II.E, paragraph 32.(d): Change in the conformance to technical standards	During 2011, New Zealand changed the hosting environment. There were no changes made to the application software. There were no changes made to the Version Change Management. The changes made were to the test plan and test report areas. Also, there were updates to the test plan and test completion report for the Business Acceptance (this was the testing business performed as part of the hosting transition), see attached documentation (items 1–6 and under item 9 in table 14.3 below). There were changes made to other areas under the Readiness Documentation, see above (item 9 in the table 14.3).

Section subheading	New Zealand's response
15/CMP.1 Annex II.E, paragraph 32.(e): Change in the discrepancy procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 Annex II.E, paragraph 32.(f): Change in security	No change occurred under the security. The only changes were the ones for the new hosting environment.
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. The changes to the Disaster Recovery are captured as part of the readiness documentation submitted, see attached NZEUR DR Plan document (part of item 9 in table 14.3 below).
15/CMP.1 Annex II.E paragraph 32.(j) – Change of the test results	No changes occurred in the test results during this reporting period. The changes to the test plans and test reports that have been made for the hosting transition have been captured; please refer to the attached NZEUR Test Report and NZEUR Test Plan submitted as part of the readiness package as well as the documentation relating to the NZEUR Business Acceptance Test Report and Completion Report. For this hosting change, the New Zealand national registry updated the Business Acceptance Test Plan, the test scripts (by creating additional tests for the additional representative 'types') and Business Acceptance Test Completion Report. These documents (including a sample test script and the test log) are attached (items 1 to 6 and part of item 9 in table 14.3 below).

Table 14.2 Previous recommendations for New Zealand from the expert review team

Previous annual review recommendations	New Zealand addressed the recommendation as follows
2010 report of the individual review of the annual submission of New Zealand	During the 2010 in-country review, New Zealand agreed to conduct performance testing on the new hosting environment. See attached the NZEUR Performance Test Report for details (item 5 in table 14.3 below).
2010 Standard Independent Assessment Report (SIAR)	No recommendations were made that require a response from the New Zealand national registry.

Table 14.3 Reference documents list – all zipped under 'Chapter 14 2012.zip'

ID	Document name	Document description
1	NZEUR Business Acceptance Test Plan – Hosting Changeover.doc	NZEUR Business Acceptance test plan for testing the hosting changeover
2	NZEUR Business Acceptance Test Completion Report – Hosting Changeover.doc	NZEUR Business Acceptance test report at the end of testing the preparer/approver functionality
3	TestSummaryJuly2011.doc	Test Summary
4	TS-00010.doc	NZEUR test script sample, more test scripts available on request
5	TCL Prod and Preprod July 2011 Test Log v6.0.xls	NZEUR test results log
6	Acc Holder Type and Activity Summ July 2011.xls	Supporting documentation for test activities

ID	Document name	Document description
7	GoLive Tick List v6.0.doc	Checklist for Hosting Changeover Go Live
8	NZEUR Hosting Changeover August 2011 v3.4	Change Plan for Hosting Changeover Go Live
9	UN Readiness Assessment package which includes: • Registry Readiness Document • NZEUR Backup plan • NZEUR DR Plan • TCL Data centre template • NZEUR Security Plan • NZEUR Time Validation Plan • NZEUR Test Plan • NZEUR Test Report	United Nations Readiness Assessment package provided to United Nations and updated as required
10	ITL Recertification data March 2011	Available on request
11	NZEUR Operations Manual v3.03	Available on request
12	NZEUR System Administrator Guide 2012	Available on request
13	ITL VPN Connectivity Testing	
14	ITL SSL Connectivity Testing	
15	NZEUR Performance Test Report v1.7	Test report from the NZEUR Performance testing

Table 14.4 Contact details

Organisation designated as the administrator of New Zealand's national registry	Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 462 4289 Fax: +64 4 978 3661 Web: http://www.epa.govt.nz
Main Contact	Chris Ballantyne Manager, Emissions Trading Scheme, Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 474 5511 Fax: +64 4 978 3661 Email: chris.ballantyne@epa.govt.nz
Alternative Contact	Andrea Gray General Manager, Emissions Trading Scheme, Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 910 9239 Fax: +64 4 978 3661 Email: andrea.gray@epa.govt.nz
Release Manager	Anca Slusanschi Project Manager, Emissions Trading Scheme, Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 474 5509 Fax: +64 4 978 3661 Email: anca.slusanschi@epa.govt.nz

Chapter 15: Information on minimisation of adverse impacts

This chapter provides information on New Zealand's implementation of policies and measures that minimise adverse social, environmental and economic impacts on non-Annex I Parties, as required under Article 3.14 of the Kyoto Protocol.

Most of this information is the same or very similar to that provided in the 2011 submission. However, some revised information is provided in connection with the Pacific Islands Forum (see section 15.1), carbon capture and storage technology development (see section 15.5), improvements in fossil fuel efficiencies (see section 15.6) and assistance provided to non-Annex I Parties that are dependent on the export and consumption of fossil fuels in diversifying their economies (see section 15.7).

15.1 Overview

New Zealand's Cabinet and legislative processes to establish and implement climate change response measures include consultation with the Ministry of Foreign Affairs and Trade and with members of the public. The Ministry of Foreign Affairs and Trade provides advice to the Government on international aspects of proposed policies. During the public consultation phase, concerns and issues about the proposed measure can be raised by any person or organisation.

Through the New Zealand Government's regular trade, economic and political consultations with other governments, including some non-Annex I Parties, there are opportunities for those who may be concerned about the possible or actual impacts of New Zealand policies to raise concerns and have them resolved within the bilateral relationship. To date, there have been no specific concerns raised about any negative impact of New Zealand's climate change response policies.

The New Zealand Government, through the New Zealand Aid Programme (www.aid.govt.nz), has regular Official Development Assistance programming talks with partner country governments, where partners have the opportunity to raise concerns about any impacts and to ask for or prioritise assistance to deal with those impacts. From these discussions, New Zealand works closely with the partner country to prepare a country strategic framework for development. These engagement frameworks are relatively long term (five or 10 years) and convey New Zealand's development assistance strategy in each country in which it provides aid. They are aligned to the priorities and needs of the partner country, while also reflecting New Zealand's priorities and policies.

On many of the issues related to the implementation of Article 3.14, New Zealand gives priority to working with countries broadly in the Pacific region. The New Zealand Aid Programme also works with partner developing countries to strengthen governance and improve their ability to respond to changing circumstances.

Climate change, including adaptation and finance, was a key part of discussions by leaders at the 42nd Pacific Island Forum meeting held in Auckland, New Zealand, in September 2011. New Zealand, as current Chair of the Pacific Islands Forum, is working closely with non-Annex I Parties in the Pacific in a wide range of technical, economic and political fields, addressing the climate change concerns raised by leaders.

New Zealand maintains a liberalised and open trading environment, consistent with the principles of free trade and investment, ensuring that both developed and developing countries can maximise opportunities in New Zealand's market regardless of the response measures undertaken.

15.2 Market imperfections, fiscal incentives, tax and duty exemptions and subsidies

Annex I Parties are required to report any progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities.

New Zealand does not have any significant market imperfections, fiscal incentives, tax and duty exemptions or subsidies in greenhouse-gas-emitting sectors of this nature.

15.3 Removal of subsidies

Annex I Parties are required to report information concerning the removal of subsidies associated with the use of environmentally unsound and unsafe technologies. New Zealand does not have any subsidies of this nature. To support international efforts, New Zealand is a member of "the Friends of Fossil Fuel Subsidy Reform", an informal group of non-G20 countries that encourages and supports the G20 countries to meet their commitments. The group is committed to supporting the reform of inefficient fossil-fuel subsidies, based on the essential notion that it is incoherent to continue to underwrite the costs of emissions from fossil fuels at the same time as making concerted efforts to mitigate those emissions through actions elsewhere.

15.4 Technological development of non-energy uses of fossil fuels

Annex I Parties are required to report on cooperation in the technological development of non-energy use of fossil fuels and support provided to non-Annex I Parties. The New Zealand Government has not actively participated in activities of this nature as yet.

15.5 Carbon capture and storage technology development

Annex I Parties are required to report on cooperation in the development, diffusion and transfer of less-greenhouse-gas-emitting advanced fossil fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouragement of their wider use; and on facilitating the participation of non-Annex I Parties.

New Zealand is a member of the United States-led Carbon Sequestration Leadership Forum (www.cslforum.org), the Australian-led Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC – www.co2crc.com.au), Global Carbon Capture and Storage Institute (www.globalccsinstitute.com) and the International Energy Agency Greenhouse Gas Research and Development Programme (www.ieaghg.org).

15.6 Improvements in fossil fuel efficiencies

Annex I Parties are required to report how they have strengthened the capacity of non-Annex I Parties identified in Article 4.8 and 4.9 of the Climate Change Convention, by improving the efficiency in upstream and downstream activities related to fossil fuels and by taking into consideration the need to improve the environmental efficiency of these activities.

An example is New Zealand's commitment to a major energy programme in Tonga. Working closely alongside other development partners, New Zealand is at the forefront of supporting practical implementation of Tonga's Energy Roadmap, an ambitious 10-year sector-wide plan to improve Tonga's energy efficiency and energy self-reliance. As part of an NZ$8.5 million commitment, support has initially focused on upgrading Tonga's power distribution network.

Similar work is currently being planned in the energy sectors in Tuvalu and Tokelau – two of the most vulnerable island countries in the Pacific. Work reported in the 2011 submission on the upgrade of the Cook Islands energy supply network is ongoing.

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 for 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.

According to the International Monetary Fund, Timor-Leste is the world's most oil-dependent economy. In 2009, petroleum income accounted for almost 80 per cent of gross national income. New Zealand is helping to provide new economic opportunities in Timor-Leste through: rehabilitating the coffee sector to increase the quality, quantity and value of coffee products; and providing capacity and capability building for small business in rural areas, particularly those run by women. New Zealand's aim is to target one third of its development assistance in Timor-Leste to support sustainable economic development through private sector investment.

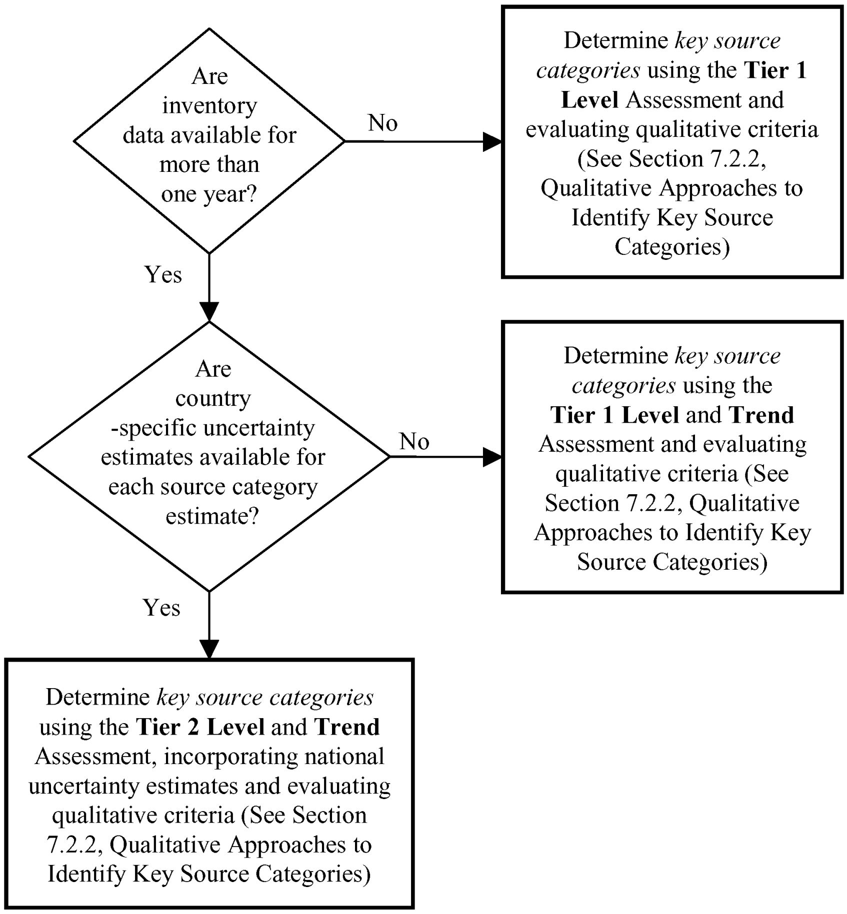
Annexes to New Zealand's National Inventory Report for 2009

Annex 1: Key categories

A1.1 Methodology used for identifying key categories

The key categories in the New Zealand inventory have been assessed according to the methodologies provided in the good practice guidance (IPCC, 2000). The methodology applied was determined using the decision tree shown in figure A1.1.1.

Figure A1.1.1 Decision tree to identify key source categories (Figure 7.1 (IPCC, 2000))



For this inventory submission, the Tier 1 level and trend assessment were applied, including the land use, land-use change and forestry (LULUCF) sector and excluding the LULUCF sector (IPCC 2000, 2003). The ‘including LULUCF’ level and trend assessments are calculated as per equations 5.4.1 and 5.4.2 of *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (GPG-LULUCF). The ‘excluding LULUCF’ level and trend assessments are calculated as per equations 7.1 and 7.2 of the good practice guidance (IPCC, 2000). Key categories are defined as those categories whose cumulative percentages, when summed in decreasing order of magnitude, contributed 95 per cent of the total level or trend.

A1.2 Disaggregation

The classification of categories follows the classification outlined in table 7.1 of the good practice guidance (IPCC, 2000) by:

- identifying categories at the level of Intergovernmental Panel on Climate Change (IPCC) categories using carbon dioxide (CO_2) equivalent emissions and considering each greenhouse gas from each category separately
- aggregating categories that use the same emission factors
- including LULUCF categories at the level shown in GPG-LULUCF table 5.4.1.

There was one modification to the suggested categories to reflect New Zealand's national circumstances. The 'fugitive emissions from the oil and natural gas category' was divided into two categories: 'fugitive emissions from oil and gas operations' and 'fugitive emissions from geothermal operations'. This is to reflect that New Zealand generates a significant amount of energy from geothermal sources that cannot be included as oil or gas operations.

A1.3 Tables 7.A1–7.A3 of the IPCC good practice guidance

Table A1.3.1 Results of the key category level analysis for 99 per cent of the net emissions and removals for New Zealand in 2010

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2010				
IPCC categories	Gas	2010 estimate (Gg CO_2-e)	Level assessment (%)	Cumulative total (%)
Conversion to forest land	CO_2	29,992.1	26.9	26.9
Enteric fermentation – dairy cattle	CH_4	9,849.2	8.8	35.7
Enteric fermentation – sheep	CH_4	7,772.9	7.0	42.6
Transport – road transport – gasoline	CO_2	7,177.2	6.4	49.1
Forest land remaining forest land	CO_2	6,439.3	5.8	54.8
Agricultural soils – pasture, range and paddock	N_2O	5,649.6	5.1	59.9
Enteric fermentation – other	CH_4	5,518.5	4.9	64.8
Transport – road transport – diesel oil	CO_2	5,089.5	4.6	69.4
Energy industries – public electricity and heat production – gaseous fuels	CO_2	4,138.1	3.7	73.1
Agricultural soils – indirect emissions	N_2O	2,520.9	2.3	75.4
Grassland remaining grassland	CO_2	2,058.7	1.8	77.2
Manufacturing industries and construction – solid fuels	CO_2	1,925.0	1.7	78.9
Manufacturing industries and construction – gaseous fuels	CO_2	1,900.5	1.7	80.6
Agricultural soils – direct emissions	N_2O	1,734.7	1.6	82.2
Other sectors – liquid fuels	CO_2	1,726.4	1.5	83.7
Metal production – iron and steel production	CO_2	1,646.9	1.5	85.2
Solid waste disposal on land	CH_4	1,345.5	1.2	86.4
Energy industries – public electricity and heat production – solid fuels	CO_2	1,221.0	1.1	87.5
Manufacturing industries and construction – liquid fuels	CO_2	1,072.2	1.0	88.5

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2010				
IPCC categories	**Gas**	**2010 estimate ($Gg\ CO_2$-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to grassland	CO_2	1,016.2	0.9	89.4
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	1,006.7	0.9	90.3
Transport – civil aviation – jet kerosene	CO_2	951.3	0.9	91.1
Energy industries – Petroleum refining – liquid fuels	CO_2	809.5	0.7	91.9
Fugitive emissions – flaring – combined	CO_2	803.1	0.7	92.6
Other sectors – gaseous fuels	CO_2	760.2	0.7	93.3
Manure management	CH_4	668.8	0.6	93.9
Fugitive emissions – geothermal	CO_2	642.2	0.6	94.4
Mineral products – cement production	CO_2	582.0	0.5	94.9
Metal production – aluminium production	CO_2	575.0	0.5	95.5
Fugitive emissions – coal mining and handling	CH_4	552.2	0.5	96.0
Waste-water handling	CH_4	463.8	0.4	96.4
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	393.9	0.4	96.7
Chemical industry – ammonia production	CO_2	386.2	0.3	97.1
Fugitive emissions – natural gas	CH_4	379.3	0.3	97.4
Other sectors – solid fuels	CO_2	349.3	0.3	97.7
Cropland remaining cropland	CO_2	311.3	0.3	98.0
Transport – navigation – residual oil	CO_2	254.6	0.2	98.2
Chemical industry – hydrogen production	CO_2	243.8	0.2	98.4
Wastewater handling	N_2O	180.4	0.2	98.6
Transport – railways – liquid fuels	CO_2	141.0	0.1	98.7
Mineral products – lime production	CO_2	131.1	0.1	98.9
Fugitive emissions – geothermal	CH_4	115.2	0.1	99.0

Note: Key categories are those that comprise 95 per cent of the total.

Table A1.3.2 Results of the key category level analysis for 99 per cent of the net emissions and removals for New Zealand in 1990

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990				
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Conversion to forest land	CO_2	22,556.5	25.4	25.4
Enteric fermentation – sheep	CH_4	11,822.6	13.3	38.6
Enteric fermentation – other	CH_4	5,588.2	6.3	44.9
Transport – road transport – gasoline	CO_2	5,570.7	6.3	51.2
Agricultural soils – pasture, range and paddock	N_2O	5,385.5	6.1	57.2
Enteric fermentation – dairy cattle	CH_4	5,011.0	5.6	62.9
Forest land remaining forest land	CO_2	4,605.3	5.2	68.0
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	3.4	71.4
Manufactuing industries and construction – solid fuels	CO_2	2,161.7	2.4	73.8
Agricultural soils – indirect emissions	N_2O	2,056.6	2.3	76.1

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990				
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	1.9	78.1
Other sectors – liquid fuels	CO_2	1,626.7	1.8	79.9
Manufactuing industries and construction – gaseous fuels	CO_2	1,599.5	1.8	81.7
Solid waste disposal on land	CH_4	1,514.4	1.7	83.4
Transport – road transport – diesel oil	CO_2	1,417.3	1.6	85.0
Metal production – iron and steel production	CO_2	1,306.7	1.5	86.5
Grassland remaining grassland	CO_2	1,009.0	1.1	87.6
Manufactuing industries and construction – liquid fuels	CO_2	849.0	1.0	88.6
Transport – civil aviation – jet kerosene	CO_2	842.5	0.9	89.5
Energy industries – Petroleum refining – liquid fuels	CO_2	773.9	0.9	90.4
Metal production – aluminium production	PFCs	629.9	0.7	91.1
Other sectors – gaseous fuels	CO_2	520.7	0.6	91.7
Other sectors – solid fuels	CO_2	511.8	0.6	92.2
Manure management	CH_4	487.5	0.5	92.8
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	0.5	93.3
Agricultural soils – direct emissions	N_2O	449.2	0.5	93.8
Metal production – aluminium production	CO_2	449.0	0.5	94.3
Mineral products – cement production	CO_2	444.7	0.5	94.8
Fugitive emissions – natural gas	CH_4	438.1	0.5	95.3
Waste-water handling	CH_4	381.5	0.4	95.7
Cropland remaining cropland	CO_2	334.6	0.4	96.1
Chemical industry – ammonia production	CO_2	277.9	0.3	96.4
Fugitive emissions – coal mining and handling	CH_4	274.5	0.3	96.7
Transport – road transport – liquefied petroleum gases	CO_2	237.8	0.3	97.0
Transport – navigation – residual oil	CO_2	235.8	0.3	97.3
Fugitive emissions – flaring – combined	CO_2	228.9	0.3	97.5
Fugitive emissions – geothermal	CO_2	228.6	0.3	97.8
Conversion to cropland	CO_2	213.7	0.2	98.0
Conversion to wetland	CO_2	165.7	0.2	98.2
Chemical industry – hydrogen production	CO_2	152.3	0.2	98.4
Wastewater handling	N_2O	142.7	0.2	98.5
Transport – road transport – gaseous fuels	CO_2	139.6	0.2	98.7
Conversion to grassland	CO_2	109.3	0.1	98.8
Conversion to settlement	CO_2	97.7	0.1	98.9
Mineral products – lime production	CO_2	82.6	0.1	99.0

Note: Key categories are those that comprise 95 per cent of the total.

Table A1.3.3 Results of the key category trend analysis for 99 per cent of the net emissions and removals for New Zealand in 2010

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

IPCC categories	Gas	1990 estimate (Gg CO_2-e)	2010 estimate (Gg CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
Enteric fermentation – sheep	CH_4	11,822.6	7,772.9	0.050	22.0	22.0
Enteric fermentation – dairy cattle	CH_4	5,011.0	9,849.2	0.025	11.1	33.0
Transport – road transport – diesel oil	CO_2	1,417.3	5,089.5	0.024	10.3	43.3
Energy industries – Manufacture of solid fuels and other energy industries – gaseous fuels	CO_2	1,717.4	393.9	0.013	5.5	48.8
Conversion to forest land	CO_2	22,556.5	29,992.1	0.012	5.2	54.0
Enteric fermentation – other	CH_4	5,588.2	5,518.5	0.011	4.6	58.7
Agricultural soils – direct emissions	N_2O	449.2	1,734.7	0.008	3.6	62.3
Agricultural soils – pasture, range and paddock	N_2O	5,385.5	5,649.6	0.008	3.4	65.8
Consumption of halocarbons and SF_6 – refrigeration and air conditioning	HFCs & PFCs	0.0	1,006.7	0.007	3.1	68.9
Conversion to grassland	CO_2	109.3	1,016.2	0.006	2.7	71.6
Grassland remaining grassland	CO_2	1,009.0	2,058.7	0.006	2.5	74.1
Manufacturing industries and construction – solid fuels	CO_2	2,161.7	1,925.0	0.006	2.4	76.5
Metal production – aluminium production	PFCs	629.9	40.6	0.005	2.3	78.9
Forest land remaining forest land	CO_2	4,605.3	6,439.3	0.005	2.0	80.9
Energy industries – public electricity and heat production – solid fuels	CO_2	465.3	1,221.0	0.005	2.0	82.9
Solid waste disposal on land	CH_4	1,514.4	1,345.5	0.004	1.7	84.6
Fugitive emissions – flaring – combined	CO_2	228.9	803.1	0.004	1.6	86.2
Energy industries – public electricity and heat production – gaseous fuels	CO_2	2,984.6	4,138.1	0.003	1.2	87.4
Fugitive emissions – geothermal	CO_2	228.6	642.2	0.003	1.1	88.5
Other sectors – liquid fuels	CO_2	1,626.7	1,726.4	0.002	1.0	89.5
Other sectors – solid fuels	CO_2	511.8	349.3	0.002	0.9	90.4
Transport – road transport – liquefied petroleum gases	CO_2	237.8	71.6	0.002	0.7	91.1
Conversion to wetland	CO_2	165.7	0.0	0.001	0.6	91.8
Fugitive emissions – coal mining and handling	CH_4	274.5	552.2	0.001	0.6	92.4
Conversion to cropland	CO_2	213.7	71.9	0.001	0.6	93.0
Transport – road transport – gasoline	CO_2	5,570.7	7,177.2	0.001	0.6	93.6
Transport – road transport – gaseous fuels	CO_2	139.6	1.6	0.001	0.5	94.2

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)						
IPCC categories	**Gas**	**1990 estimate (Gg CO_2-e)**	**2010 estimate (Gg CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
Fugitive emissions – natural gas	CH_4	438.1	379.3	0.001	0.5	94.7
Energy industries – Petroleum refining – liquid fuels	CO_2	773.9	809.5	0.001	0.5	95.2
Cropland remaining cropland	CO_2	334.6	311.3	0.001	0.3	95.5
Manufacturing industries and construction – gaseous fuels	CO_2	1,599.5	1,900.5	0.001	0.3	95.9
Other sectors – gaseous fuels	CO_2	520.7	760.2	0.001	0.3	96.2
Transport – civil aviation – jet kerosene	CO_2	842.5	951.3	0.001	0.3	96.5
Energy industries – Petroleum refining – gaseous fuels	CO_2		93.1	0.001	0.3	96.8
Conversion to settlement	CO_2	97.7	34.9	0.001	0.3	97.1
Consumption of halocarbons and SF_6 – foam blowing	HFCs & PFCs	0.0	78.9	0.001	0.2	97.3
Agricultural soils – indirect emissions	N_2O	2,056.6	2,520.9	0.000	0.2	97.5
Fugitive emissions – geothermal	CH_4	46.0	115.2	0.000	0.2	97.7
Manure management	CH_4	487.5	668.8	0.000	0.2	97.9
Chemical industry – hydrogen production	CO_2	152.3	243.8	0.000	0.2	98.0
Transport – railways – liquid fuels	CO_2	77.6	141.0	0.000	0.1	98.2
Transport – road transport – gasoline	CH_4	50.5	21.7	0.000	0.1	98.3
Transport – navigation – residual oil	CO_2	235.8	254.6	0.000	0.1	98.4
Transport – road transport – gaseous fuels	CH_4	31.4	0.0	0.000	0.1	98.6
Chemical industry – ammonia production	CO_2	277.9	386.2	0.000	0.1	98.7
Mineral products – limestone and dolomite use	CO_2	24.7	59.6	0.000	0.1	98.8
Mineral products – lime production	CO_2	82.6	131.1	0.000	0.1	98.8
Other sectors – solid fuels	CH_4	23.4	3.9	0.000	0.1	98.9
Mineral products – cement production	CO_2	444.7	582.0	0.000	0.1	99.0

Note: Key categories are those that comprise 95 per cent of the total.

Annex 2: Methodology and data collection for estimating emissions from fossil fuel combustion

New Zealand emission factors are based on gross calorific value. Energy activity data and emission factors in New Zealand are conventionally reported in gross terms, with some minor exceptions. The convention adopted by New Zealand to convert gross calorific value to net calorific value follows the Organisation for Economic Co-operation and Development and International Energy Agency assumptions:

$$\text{Net calorific value} = 0.95 \times \text{gross calorific value for coal and liquid fuels}$$
$$\text{Net calorific value} = 0.90 \times \text{gross calorific value for gas.}$$

Emission factors for gas, coal, biomass and liquid fuels used by New Zealand are shown in tables A2.1–A2.3. Where Intergovernmental Panel on Climate Change (IPCC) default emission factors are used, a net-to-gross factor as above is used to account for New Zealand activity data representing gross energy figures:

$$Gross\ EF = Net\ EF \times Factor.$$

Table A2.1 Gross carbon dioxide emission factors used for New Zealand's energy sector in 2010 (before oxidation)

	Emission factor (t CO_2/TJ)	Emission factor (t C/TJ)	Source
Gas			
Maui	52.40	14.29	1
Kapuni	53.24	14.52	1
McKee	84.10	14.71	3
Kaimiro	53.30	15.01	3
Ngatoro	62.44	15.01	3
TAWN	83.97	14.38	3
Mangahewa	55.90	14.53	3
Turangi	55.67	14.81	3
Pohokura	51.91	14.64	1
Rimu/Kauri	52.72	14.13	3
Maari	52.61	14.13	3
Weighted Average Distributed Gas	54.05	14.54	
Kapuni Low Temperature Separation (LTS)	54.11	22.94	1
Methanol – Mixed Feed – to 94	51.25	17.03	3
Methanol – LTS – to 94	53.98	22.90	3

	Emission factor ($t\ CO_2/TJ$)	Emission factor (t C/TJ)	Source
Liquid fuels			
Crude oil	69.81	19.04	5
Regular petrol	66.59	18.16	4
Petrol – premium	66.79	18.22	4
Diesel (10 parts (sulphur) per million)	69.64	18.99	4
Jet kerosene	68.57	18.70	4
Av gas	65.89	17.97	4
LPG	59.24	16.16	2
Heavy fuel oil	73.68	20.09	4
Light fuel oil	72.91	19.89	4
Power station fuel oil	74.09	20.21	4
Bitumen (asphalt)	76.90	20.97	4
Biomass			
Biogas	100.98	27.54	5
Wood (industrial)	104.15	28.41	5
Bioethanol	64.20	17.33	6
Biodiesel	62.40	16.85	6
Wood (residential)	104.15	28.41	5
Coal			
All sectors (sub-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* (Baines, 1993)
3. Specific gas field operator
4. New Zealand Refinery Company
5. IPCC guidelines (1996)
6. *New Zealand Energy Information Handbook: Energy data conversion factors and definitions* (Eng, Bywater & Hendtlass, 2008)

Table A2.2 IPCC (1996) methane emission factors used for New Zealand's energy sector for 1990 to 2010

	Emission factor t CH_4/PJ	Source
Natural gas		
Electricity – boilers	.09	IPCC Tier 2 (table 1–15) natural gas boilers
Electricity – large turbines	5.40	IPCC Tier 2 (table 1–15) large gas-fired turbines > 3MW
Commercial	1.08	IPCC Tier 2 (table 1–19) natural gas boilers
Residential	0.90	IPCC Tier 2 (table 1–18) gas heaters
Domestic transport (CNG)	567.00	IPCC Tier 2 (table 1–43) passenger cars (uncontrolled)
Other stationary (mainly industrial)	1.26	IPCC Tier 2 (table 1–16) small natural gas boilers
Liquid fuels		
Stationary sources		
Electricity – residual oil	0.86	IPCC Tier 2 (table 1–15) residual oil boilers – normal firing
Electricity – distillate oil	0.86	IPCC Tier 2 (table 1–15) distillate oil boilers – normal firing
Industrial (including refining) – residual oil	2.85	IPCC Tier 2 (table 1–16) residual oil boilers
Industrial – distillate oil	0.19	IPCC Tier 2 (table 1–16) distillate oil boilers
Industrial – LPG	1.05	IPCC Tier 2 (table 1–18) propane/butane furnaces
Commercial – residual oil	1.33	IPCC Tier 2 (table 1–19) residual oil boilers
Commercial – distillate oil	0.67	IPCC Tier 2 (table 1–19) distillate oil boilers
Commercial – LPG	1.05	IPCC Tier 2 (table 1–18) propane/butane furnaces
Residential – distillate oil	0.67	IPCC Tier 2 (table 1–18) distillate oil furnaces
Residential – LPG	1.05	IPCC Tier 2 (table 1–18) propane/butane furnaces
Agriculture – stationary	0.19	IPCC Tier 2 (table 1–49) diesel engines (agriculture)
Mobile sources		
LPG	28.50	IPCC Tier 2 (table 1–44) passenger cars (uncontrolled)
Petrol	18.53	IPCC Tier 2 (table 1–27) passenger cars (uncontrolled – mid-point of average g/MJ)
Diesel	3.8	IPCC Tier 2 (table 1–32) passenger cars (uncontrolled – g/MJ)
Navigation (fuel oil and diesel)	6.65	IPCC Tier 2 (table 1–48) ocean-going ships
Aviation fuel/kerosene	0.48	IPCC Tier 2 (table 1–48) jet and turboprop aircraft
Coal		
Combustion		
Electricity generation	0.67	IPCC Tier 2 (table 1–15) pulverised bituminous combustion – dry bottom, wall fired
Cement	0.95	IPCC Tier 2 (table 1–17) cement, lime coal kilns
Lime	0.95	IPCC Tier 2 (table 1–17) cement, lime coal kilns
Industry	0.67	IPCC Tier 2 (table 1–16) dry bottom, wall fired coal boilers
Commercial	9.50	IPCC Tier 2 (table 1–19) coal boilers
Residential	285.00	IPCC Tier 1 (table 1–7) coal – residential
Biomass		
Wood stoker boilers	14.25	IPCC Tier 2 (table 1–16) wood stoker boilers
Wood – fireplaces	285.00	IPCC Tier 1 (table 1–7) wood – residential
Bioethanol	18.00	IPCC Tier 1 (table 3.2.2) – ethanol, cars, Brazil
Biodiesel	18.00	IPCC Tier 1 (table 3.2.2) – ethanol, cars, Brazil
Biogas	1.08	IPCC Tier 2 (table 1–19) gas boilers

Table A2.3 IPCC (1996) nitrous oxide emission factors used for New Zealand's energy sector for 1990 to 2010

	Emission factor t N_2O/PJ	Source
Natural gas		
Electricity generation	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Commercial	2.07	IPCC Tier 2 (table 1–19) natural gas boilers
Residential	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Domestic transport (CNG)	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Other stationary (mainly industrial)	0.09	IPCC Tier 1 (table 1–8) natural gas – all uses
Liquid fuels		
Stationary sources		
Electricity – residual oil	0.29	IPCC Tier 2 (table 1–15) residual oil boilers – normal firing
Electricity – distillate oil	0.38	IPCC Tier 2 (table 1–15) distillate oil boilers – normal firing
Industrial (including refining) – residual oil	0.29	IPCC Tier 2 (table 1–16) residual oil boilers
Industrial – distillate oil	0.38	IPCC Tier 2 (table 1–16) distillate oil boilers
Commercial – residual oil	0.29	IPCC Tier 2 (table 1–19) residual oil boilers
Commercial – distillate oil	0.38	IPCC Tier 2 (table 1–19) distillate oil boilers
Residential (all oil)	0.19	IPCC Tier 2 (table 1–18) furnaces
LPG (all uses)	0.57	IPCC Tier 1 (table 1–8) oil – all sources except aviation
Agriculture – stationary	0.38	IPCC Tier 2 (table 1–49) diesel engines – agriculture
Mobile sources		
LPG	0.57	IPCC Tier 1 (table 1–8) oil – all sources except aviation
Petrol	1.43	IPCC Tier 2 (table 2.7 in GPG (IPCC, 2000))
		US gasoline vehicles (uncontrolled)
Diesel	3.71	IPCC Tier 2 (table 2.7 in GPG (IPCC, 2000)) all US diesel vehicles
Fuel oil (ships)	1.90	IPCC Tier 2 (table 1–48) ocean-going ships
Aviation fuel/kerosene	1.90	IPCC Tier 1 (table 1–8) oil – aviation
Coal		
Electricity generation	1.52	IPCC Tier 2 (table 1–15) pulverised bituminous combustion – dry bottom, wall fired
Cement	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Lime	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Industry	1.52	IPCC Tier 2 (table 1–16) dry bottom, wall fired coal boilers
Commercial	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Residential	1.33	IPCC Tier 1 (table 1–8) coal – all uses
Biomass		
Wood (all uses)	3.80	IPCC Tier 1 (table 1–8) wood/wood waste – all uses
Biogas	2.07	IPCC Tier 2 (table 1–19) natural gas boilers

A2.1 Emissions from liquid fuels

A2.1.1 Activity data and uncertainties

The *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Economic Development is run as a census, meaning there is no sampling error. The only possible sources or error are non-sample error (such as respondent error and processing error). The 2010 statistical difference for liquid fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2011) was 0.17 per cent. This is used as the activity data uncertainty for liquid fuels in 2010.

A2.1.2 Emission factors and uncertainties

The 2010 carbon dioxide emission factors are described in table A2.1. Table A2.4 shows a complete time series of gross calorific values, while table A2.5 shows a complete time series of carbon content of liquid fuels. This information is supplied by the New Zealand Refinery Company and is used in the calculation of annual emission factors for liquid fuels.

A 2009 consultant report (Hale and Twomey, 2009) to the Ministry for the Environment estimates the uncertainty of carbon dioxide emission factors for liquid fuels at ±0.5 per cent. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

Table A2.4 Gross calorific values (MJ/kg) for liquid fuels for 1990 to 2010

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Av gas	Heavy fuel oil	Light fuel oil	Power station fuel oil	Bitumen (asphalt)
1990	47.24	47.22	45.76	46.37	47.30	43.07	44.12	42.71	41.30
1991	47.17	47.17	45.73	46.38	47.30	43.02	44.07	42.70	41.30
1992	47.18	47.14	45.75	46.41	47.30	43.03	44.14	42.72	41.30
1993	47.09	47.14	45.74	46.36	47.30	43.01	44.13	42.75	41.31
1994	47.10	47.11	45.75	46.34	47.30	43.03	44.16	42.70	41.30
1995	47.07	47.14	45.59	46.31	47.30	43.03	44.01	42.69	41.30
1996	46.91	47.14	45.54	46.26	47.30	43.00	43.98	42.68	41.30
1997	46.93	47.17	45.58	46.32	47.30	42.92	43.92	42.56	41.30
1998	46.89	47.12	45.64	46.27	47.30	43.06	44.02	42.79	41.27
1999	46.92	47.13	45.56	46.29	47.30	43.09	43.93	42.79	41.28
2000	46.91	47.12	45.58	46.22	47.30	43.07	43.90	42.74	41.27
2001	46.92	47.15	45.64	46.25	47.30	43.08	43.96	42.76	41.27
2002	46.90	47.16	45.62	46.29	47.30	43.03	43.84	42.79	41.26
2003	46.87	47.11	45.61	46.23	47.30	43.06	43.79	42.77	41.27
2004	46.91	47.10	45.59	46.25	47.30	43.04	43.90	42.79	41.30
2005	46.95	47.10	45.73	46.28	47.30	43.11	43.94	42.78	41.30
2006	46.97	47.09	45.79	46.23	47.30	42.93	43.68	42.65	41.30
2007	46.97	47.10	45.77	46.23	47.30	42.97	43.72	42.66	41.30
2008	46.93	47.06	45.72	46.19	47.30	42.86	43.72	42.56	41.30
2009	46.95	47.03	45.72	46.17	47.30	42.89	43.75	42.56	41.29
2010	46.96	47.03	45.69	46.17	47.30	42.95	43.70	42.62	41.29

Table A2.5 Carbon content (per cent mass) for liquid fuels for 1990 to 2010

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Av gas	Heavy fuel oil	Light fuel oil	Power station fuel oil	Bitumen (asphalt)
1990	84.87	84.92	86.28	85.92	85.00	86.22	86.67	86.03	86.57
1991	85.04	85.04	86.33	85.89	85.00	86.26	86.30	86.04	86.57
1992	85.03	85.13	86.29	85.84	85.00	86.25	86.18	86.03	86.57
1993	85.25	85.13	86.32	85.94	85.00	86.27	86.20	86.00	86.56
1994	85.21	85.19	86.30	85.99	85.00	86.25	86.13	86.04	86.57
1995	85.30	85.13	86.63	86.05	85.00	86.25	86.39	86.05	86.57
1996	85.66	85.13	86.73	86.16	85.00	86.28	86.45	86.05	86.57
1997	85.63	85.04	86.64	86.04	85.00	86.35	86.55	86.16	86.58
1998	85.72	85.17	86.52	86.14	85.00	86.22	86.39	85.97	86.63
1999	85.65	85.15	86.69	86.10	85.00	86.20	86.53	85.96	86.63
2000	85.67	85.16	86.64	86.25	85.00	86.22	86.58	86.01	86.63
2001	85.65	85.09	86.53	86.18	85.00	86.21	86.49	85.98	86.64
2002	85.68	85.06	86.57	86.10	85.00	86.25	86.68	85.96	86.66
2003	85.76	85.19	86.58	86.23	85.00	86.23	86.76	85.98	86.63
2004	85.66	85.22	86.62	86.20	85.00	86.24	86.58	85.97	86.58
2005	85.58	85.22	86.62	86.12	85.00	86.18	86.52	85.97	86.57
2006	85.54	85.25	86.57	86.24	85.00	86.34	86.93	86.08	86.57
2007	85.54	85.23	86.61	86.24	85.00	86.30	86.87	86.07	86.57
2008	85.63	85.32	86.70	86.32	85.00	86.39	86.87	86.16	86.57
2009	85.56	85.38	85.85	86.36	85.00	86.37	86.83	86.16	86.60
2010	85.54	85.40	85.91	86.35	85.00	86.31	86.90	86.11	86.59

A2.2 Emissions from solid fuels

A2.2.1 Activity data and uncertainties

The *New Zealand Quarterly Statistical Return of Coal Production and Sales* conducted by the Ministry of Economic Development has full coverage of the sector, meaning there is no sampling error. The only possible sources or error are non-sample error (such as respondent error and processing error). The 2010 statistical difference for solid fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2011) was 0.7 per cent. This is used as the activity data uncertainty for solid fuels in 2010.

A2.2.2 Emission factors and uncertainties

The estimated uncertainty in carbon dioxide emission factors for solid fuels is ±3.5 per cent. This is based on the difference between the range of emission factors for the three different ranks of coal used in New Zealand. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

A2.3 Emissions from gaseous fuels

A2.3.1 Activity data

Through the various surveys and information collected by the Ministry of Economic Development, it has full coverage of the natural gas sector. This means that there is no sampling error in natural gas statistics and the only possible sources or errors are non-sample error (such as respondent error and processing error). The 2009 statistical difference for gaseous fuels in the balance table of the *New Zealand Energy Data File* (Ministry of Economic Development, 2011) was 9.2 per cent. This is used as the activity data uncertainty for gaseous fuels in 2010.

A2.3.2 Emission factors

The estimated uncertainty in carbon dioxide emission factors for gaseous fuels is ±2.9 per cent. This is based on the difference between the range of emission factors for the three largest gas fields in New Zealand. Together, these gas fields made up over 75 per cent of New Zealand's total gas supply in 2010. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

Table A2.6 Emission factors for European gasoline and diesel vehicles – COPERT IV model

	N_2O emission factors (mg/km)				CH_4 emission factors (mg/km)			
	Urban		**Rural**	**Highway**	**Urban**		**Rural**	**Highway**
	Cold	**Hot**			**Cold**	**Hot**		
Passenger car								
Gasoline								
pre-Euro	10	10	6.5	6.5	201	131	86	41
Euro 1	38	22	17	8	45	26	16	14
Euro 2	24	11	4.5	2.5	94	17	13	11
Euro 3	12	3	2	1.5	83	3	2	4
Euro 4	6	2	0.8	0.7	57	2	2	0
Diesel								
pre-Euro	0	0	0	0	22	28	12	8
Euro 1	0	2	4	4	18	11	9	3
Euro 2	3	4	6	6	6	7	3	2
Euro 3	15	9	4	4	7	3	0	0
Euro 4	15	9	4	4	0	0	0	0
LPG								
pre-ECE	0	0	0	0	80	80	35	25
Euro 1	38	21	13	8	80	80	35	25
Euro 2	23	13	3	2	80	80	35	25
Euro 3 and later	9	5	2	1	80	80	35	25

	N_2O emission factors (mg/km)				CH_4 emission factors (mg/km)			
	Urban		Rural	Highway	Urban		Rural	Highway
	Cold	Hot			Cold	Hot		
Light duty vehicles								
Gasoline								
pre-Euro	10	10	6.5	6.5	201	131	86	41
Euro 1	122	52	52	52	45	26	16	14
Euro 2	62	22	22	22	94	17	13	11
Euro 3	36	5	5	5	83	3	2	4
Euro 4	16	2	2	2	57	2	2	0
Diesel								
pre-Euro	0	0	0	0	22	28	12	8
Euro 1	0	2	4	4	18	11	9	3
Euro 2	3	4	6	6	6	7	3	2
Euro 3	15	9	4	4	7	3	0	0
Euro 4	15	9	4	4	0	0	0	0
Heavy duty truck and bus								
Gasoline – all technologies	6	6	6	6	140	140	110	70
Diesel								
GVW<16t	30	30	30	30	85	85	23	20
GVW>16t	30	30	30	30	175	175	80	70
Urban busses and coaches	30	30	30	30	175	175	80	70
CNG								
pre Euro 4					5,400	5,400	5,400	5,400
Euro 4 and later					900	900	900	900
Power two wheeler								
Gasoline								
<50 cm3	1	1	1	1	219	219	219	219
>50 cm3 2-stroke	2	2	2	2	150	150	150	150
>50 cm3 4stroke	2	2	2	2	200	200	200	200

A2.4 Energy balance for year ended December 2010

Table A.2.7 New Zealand energy balance for year ended December 2010 (Ministry of Economic Development, 2011)

	Converted into Petajoules using Gross Calorific Values	Coal			Oil								Natural Gas	Renewables								Electricity	Waste Heat	
		Bituminous & Sub-bitum.	Lignite	Total	Crudes/ Feedstocks/ NGL	LPG	Petrol	Diesel	Fuel Oil	Av. Fuel Kero	Others	Total	Total	Hydro	Geothermal	Solar	Wind	Liquid Biofuels	Biogas	Wood	Total	Total	Total	TOTAL
SUPPLY	Indigenous Production	134.02	4.51	138.53	115.87	7.50						123.37	179.34	88.97	152.57	0.36	5.88	0.18	3.18	59.10	310.25		1.32	752.81
	+ Imports	5.84	0.00	5.85	232.65	0.38	42.89	26.21	-	2.73	6.58	311.43												317.28
	- Exports	75.27	-	75.27	110.57	0.71	1.63	0.01	2.75	-	-	115.67												190.94
	- Stock Change	11.06	0.04	11.11	1.67	0.14	0.92	-3.45	-1.74	-0.24	-0.09	-2.79	5.87											14.19
	- International Transport						-	1.40	13.08	33.95	0.01	48.43												48.43
	TOTAL PRIMARY ENERGY	53.53	4.47	58.00	236.29	7.03	40.34	28.25	-14.09	-30.98	6.65	273.50	173.47	88.97	152.57	0.36	5.88	0.18	3.18	59.10	310.25		1.32	816.54
	ENERGY TRANSFORMATION	-32.67	-0.28	-32.95	-237.09	-0.43	65.25	81.33	22.75	45.11	14.00	-9.07	-88.56	-88.97	-143.09		-5.88	-0.18	-2.90	-5.09	-246.12	145.31	-1.32	-232.70
	Electricity Generation	-13.66	-	-13.66				-0.02	-0.00			-0.02	-62.58	-88.97	-141.78		-5.88		-2.00		-238.64	151.52		-163.38
	Cogeneration	-7.84	-0.28	-8.12									-18.61		-1.31				-0.90	-5.09	-7.29	9.83	-1.32	-25.51
	Oil Production				-236.64		64.50	81.74	22.68	45.93	15.03	-6.76	-					-0.18			-0.18			-6.94
	Other Transformation	-10.58	-	-10.58																				-10.58
	Losses and Own Use	-0.59	-	-0.59	-0.45	-0.43	0.75	-0.39	0.07	-0.81	-1.03	-2.30	-7.37									-16.04		-26.29
	Non-energy Use										-20.66	-20.66	-25.47											-46.13
	CONSUMER ENERGY (calculated)	20.86	4.19	25.05	-0.81	6.60	105.59	109.59	8.66	14.14	-	243.77	59.44		9.48	0.36	-	-	0.28	54.01	64.14	145.31	-	537.71
DEMAND	Agriculture, Forestry and Fishing	1.89	0.02	1.91			1.38	13.27	2.44	0.06		17.14	1.47		0.73						0.73	6.65		27.90
	Agriculture	1.89	0.02	1.91			1.37	8.93	-	0.05		10.35	1.46		0.73						0.73	5.90		20.34
	Forestry and Logging	-	-	-			0.01	2.57	-	0.00		2.59	0.01									0.25		2.85
	Fishing	-	-	-			0.00	1.77	2.44	0.00		4.21	-									0.50		4.72
	Industrial	18.32	2.97	21.29		2.22	0.09	11.29	1.27	0.11		14.98	39.59		6.10					46.49	52.60	55.79		184.24
	Mining	0.01	-	0.01			0.00	3.63	-	0.00		3.63	0.01									1.83		5.48
	Food Processing	11.38	2.91	14.29			-	-	-	-		-	9.62									7.82		31.73
	Textiles	0.24	-	0.24									0.38									0.43		1.04
	Wood, Pulp, Paper and Printing	0.64	0.05	0.69									4.85									11.82		17.36
	Chemicals	-	-	-									18.85									2.39		21.25
	Non-metallic Minerals	4.14	0.01	4.15									0.83									0.79		5.77
	Basic Metals	-	-	-			-	-	-	-		-	3.00									24.26		27.26
	Mechanical/Electrical Equipment	0.02	-	0.02									1.39									0.70		2.11
	Building and Construction	0.08	-	0.08			0.01	3.97	0.02	0.10		4.10	0.03									0.68		4.90
	Unallocated	1.80	-	1.80		2.22	0.08	3.69	1.25	0.01		7.25	0.63		6.10					46.49	52.60	5.07		67.33
	Commercial	0.89	0.54	1.43		1.27	0.05	4.43	0.09	0.05		5.88	6.87		2.34				0.28		2.62	32.50		49.32
	Transport	0.05	-	0.05		1.16	108.81	75.87	3.51	14.53		203.88	0.03						-		-	0.36		204.32
	Residential	0.24	0.30	0.54		1.95	0.04	0.30	-	-		2.29	5.99		0.31	0.36				7.52	8.19	48.04		65.05
	CONSUMER ENERGY (observed)	21.39	3.83	25.21	-	6.60	110.36	105.15	7.31	14.75	-	244.18	53.95	-	9.48	0.36	-		0.28	54.01	64.14	143.34	-	530.83
	Statistical Differences	-0.53	0.36	-0.17	-0.81	-	-4.77	4.43	1.35	-0.62	-	-0.41	5.49		-	-	-		-	-	-	1.97	-	6.87

A2.5 Fuel Flow Diagrams for year ended December 2010

Figure A2.1 New Zealand coal energy flow summary for 2010

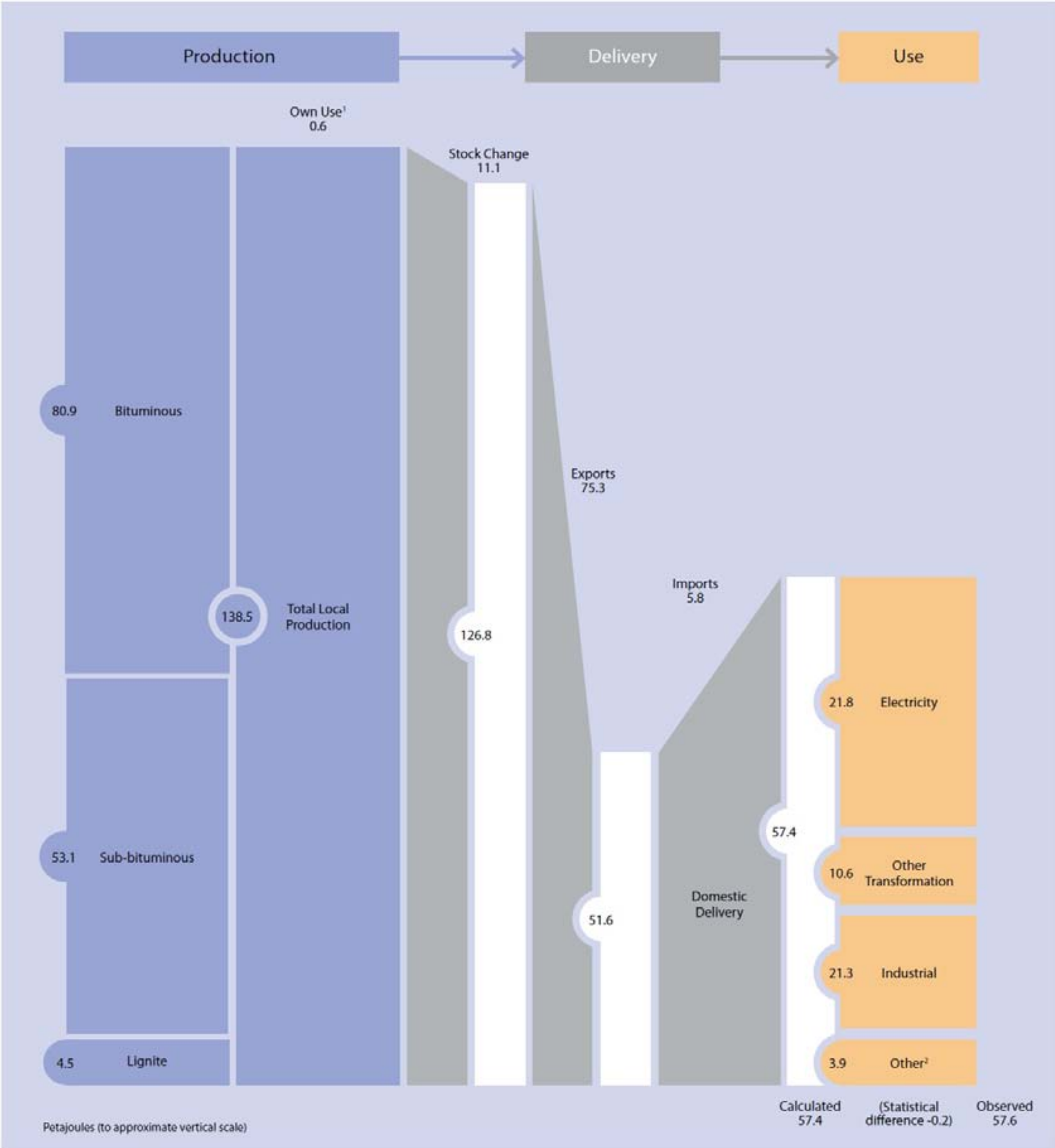


Figure A2.2 New Zealand oil energy flow summary for 2010

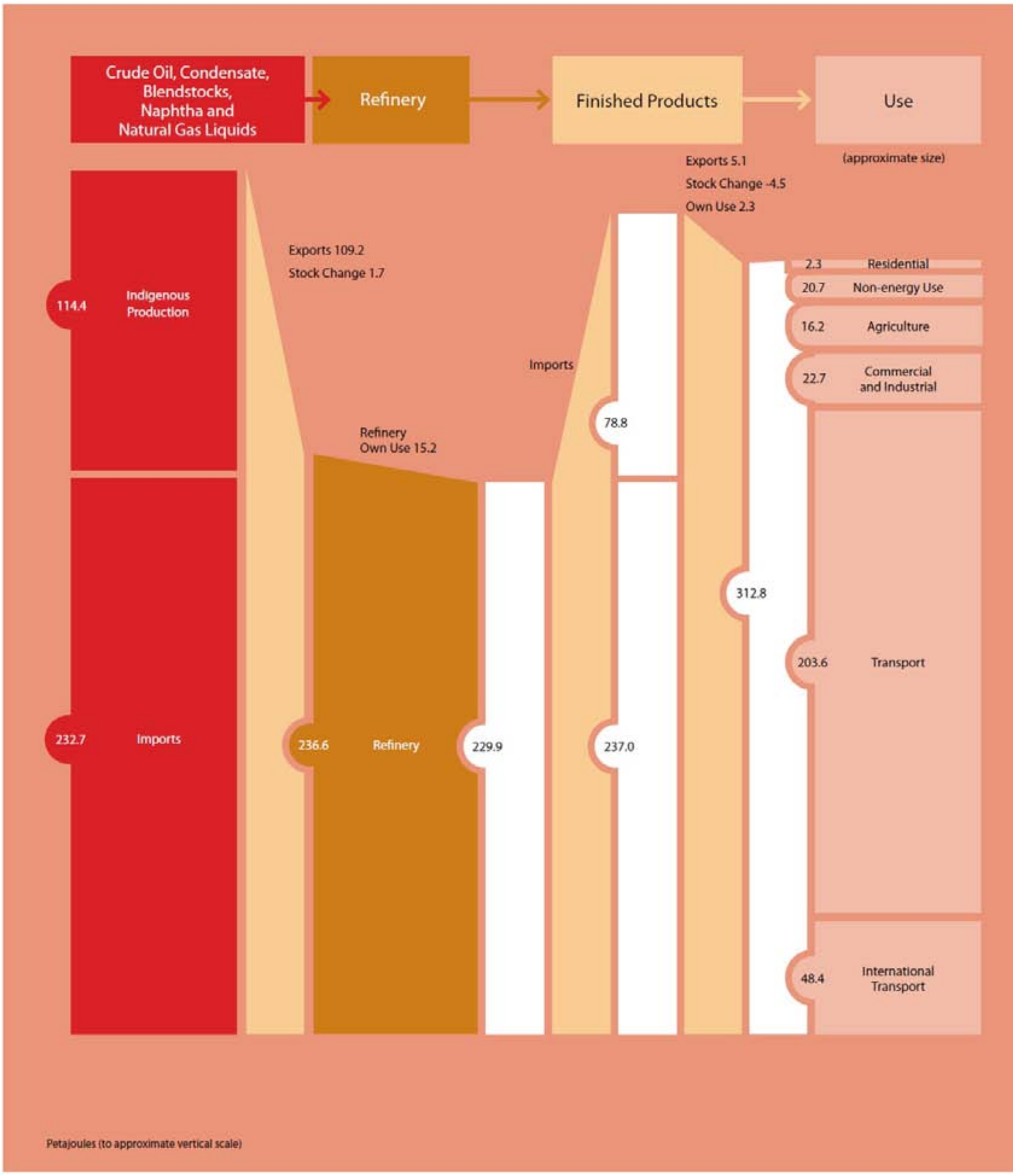
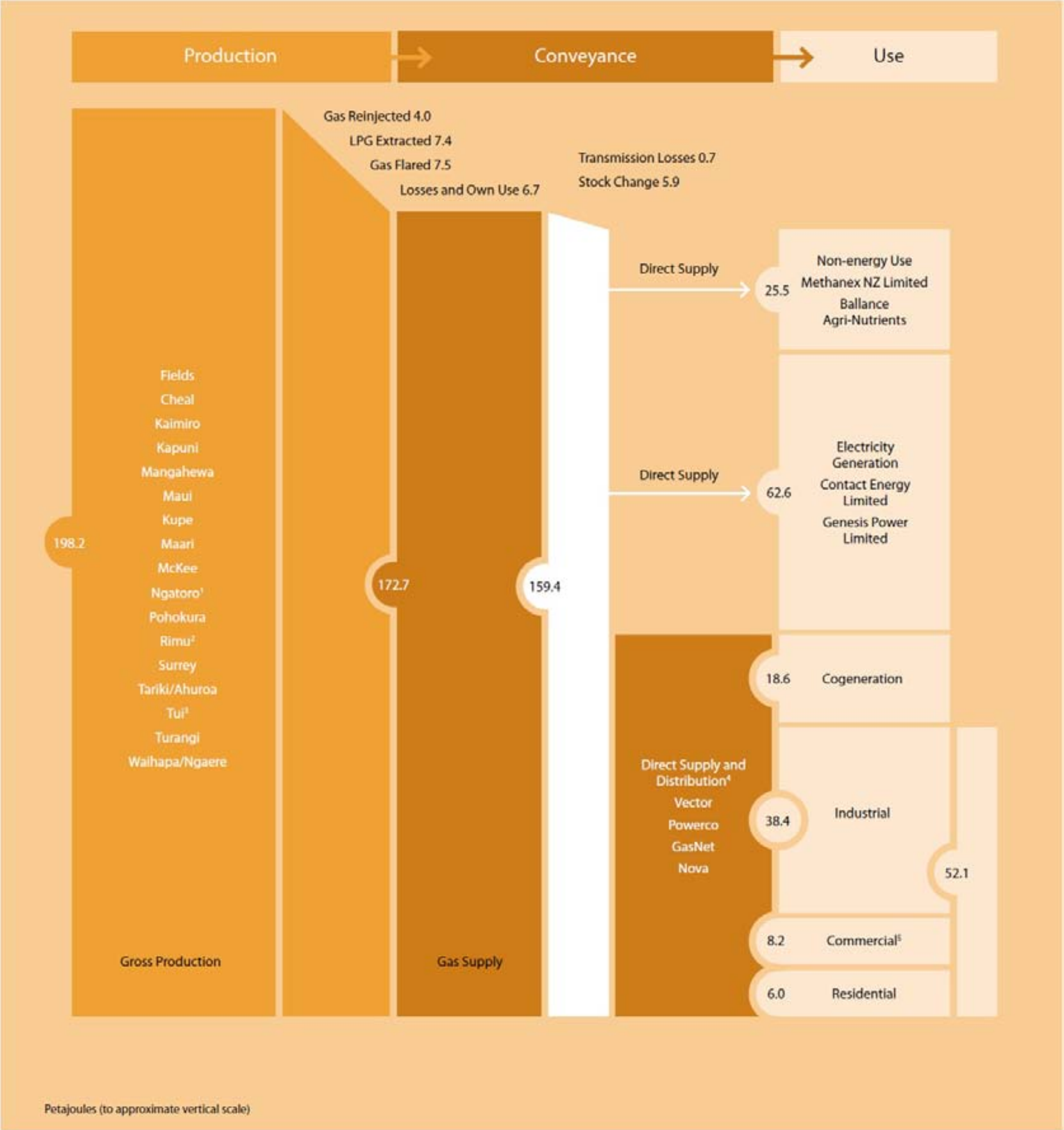


Figure A2.3 New Zealand natural gas energy flow summary for 2010



Notes:

1. Includes the Goldie well
2. Includes the Kauri well.
3. All gas from Tui field was flared.
4. Gas supplied through distribution systems is used by industry (including cogeneration) and the commercial, residential and transport sectors. Some co-generators and other industrial and commercial users are supplied directly.
5. Includes Transport, Agriculture, Forestry and Fishing.

Annex 3: Detailed methodological information for other sectors

A3.1 Agriculture

A3.1.1 Uncertainty of animal population data

Details of the surveys and census are included to provide an understanding of the livestock statistics process and uncertainty values. The information documented is from Statistics New Zealand. Full details of the surveys are available from Statistics New Zealand's website. For information about surveys and census see: **http://www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/info-releases.aspx**

Agricultural production surveys

The target population for the *2010 Agricultural Production Survey* was all units that were engaged in agricultural production activity (including livestock, cropping, horticulture and forestry) or owned land that was intended for agricultural activity during the year ended 30 June 2010. The response rate was 85 per cent. These businesses represent 86 per cent of the total estimated value of agricultural output. Statistics New Zealand imputes using a random 'hot deck' procedure for values for farmers and growers who did not return a completed questionnaire. The imputation levels for the *2010 Agricultural Production Survey* are provided in table A3.1.1.

The *2010 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 *2010 Agricultural Production Survey*

Statistic	Proportion of total estimate imputed (%)	Sample error (%)
Ewe hoggets put to ram	18	9
Breeding ewes, two tooth and over	18	3
Total number of sheep	19	3
Lambs marked and/or tailed from ewe hoggets	16	13
Lambs marked and/or trailed from ewes	18	3
Beef cows and heifers (in calf) two years and over	18	4
Beef cows and heifers (in calf) one to two years	20	7
Total number of beef cattle	18	3
Calves born alive to beef heifers/cows	18	4
Dairy cows and heifers, in milk or calf	21	4
Total number of dairy cattle	21	4

Statistic	Proportion of total estimate imputed (%)	Sample error (%)
Calves born alive to dairy heifers/cows	20	4
Female deer mated	13	8
Total number of deer	13	7
Fawns born on farm and alive at four months	13	8
Area of wheat harvested	26	10
Area of barley harvested	21	8

A3.1.2 Key parameters and emission factors used in the agriculture sector

Table A3.1.2 Parameter values for New Zealand's agriculture N_2O emissions

Parameter (fraction)	Fraction of the parameter	Source	Parameter value
$Frac_{BURN}$ (kg N/kg crop-N)	Crop residue burned in fields	See 6.7.2	Crop specific survey data
$Frac_{BURNL}$ (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

Table A3.1.3 Parameter values for New Zealand's cropping emissions

Crop	HI	dmf	AG_N	RatioBG	BG_N
Wheat	0.46	0.86	0.005	0.1	0.009
Barley	0.46	0.86	0.005	0.1	0.009
Oats	0.3	0.86	0.005	0.1	0.009
Maize grain	0.5	0.86	0.007	0.1	0.007
Field Seed peas	0.5	0.21	0.02	0.1	0.015
Lentils	0.5	0.86	0.02	0.1	0.015
Peas fresh and process	0.45	0.86	0.03	0.1	0.015
Potatoes	0.9	0.22	0.02	0.1	0.01
Onions	0.8	0.11	0.02	0.1	0.01
Sweet corn	0.55	0.24	0.009	0.1	0.007
Squash	0.8	0.2	0.02	0.1	0.01
Herbage seeds	0.11	0.85	0.015	0.1	0.01
Legume seeds	0.09	0.85	0.04	0.1	0.01
Brassica seeds	0.2	0.85	0.01	0.1	0.008

Source: Curtin et al. (2011)

Table A3.1.4 Emission factors for New Zealand's agriculture emissions N_2O emissions

Emission factor	Emissions	Source	Parameter value
EF_1 (kg N_2O-N/kg N)	Direct emissions from nitrogen input to soil	Kelliher and de Klein (2006)	0.01
EF_2 (kg N_2O-N/ha-yr)	Direct emissions from organic soil mineralisation due to cultivation	IPCC (2000) Table 4.17	8
EF_{3AL} (kg N_2O-N/kg N excreted)	Direct emissions from waste in the anaerobic lagoons animal waste management systems	IPCC (2000) Table 4.12	0.001
EF_{3SSD} (kg N_2O-N/kg N excreted)	Direct emissions from waste in the solid waste and drylot animal waste management systems	IPCC (2000) Table 4.12	0.02
EF_{3PRP} (kg N_2O-N/kg N excreted)	Direct emissions from urine in the pasture range and paddock animal waste management systems for cattle, sheep and deer, and direct emissions from manure waste in the pasture range and paddock animal waste management systems for all other species	Carran et al. (1995); Muller et al. (1995); de Klein et al .(2003)	0.01
$EF_{3(PRP\ DUNG)}$ (kg N_2O-N/kg N excreted)	Direct emissions from dung in the pasture range and paddock animal waste management systems for cattle, sheep and deer.	Luo et al. (2009)	0.0025
EF_{3OTHER} (kg N_2O-N/kg N excreted)	Direct emissions from waste in other animal waste management systems	IPCC (2000) Table 4.13	0.005
EF_4 (kg N_2O-N/kg NH_x-N)	Indirect emissions from volatising nitrogen	IPCC (2000) Table 4.18	0.01
EF_5 (kg N_2O-N/kg N leached & runoff)	Indirect emissions from leaching nitrogen	IPCC (2000) Table 4.18	0.025

Table A3.1.5 Emission factor for Tier 1 enteric fermentation livestock and manure management

Emission factor	Emissions	Source	Parameter value (kg/head/yr)
EF_{GOATS}	Enteric fermentation – goats	Lassey (2011)	8.5[39]
EF_{HORSES}	Enteric fermentation – horses	IPCC (1996) Table 4.3	18
EF_{SWINE}	Enteric fermentation – swine	Hill et al. (2012)	1.5
EF_{ALPACA}	Enteric fermentation – alpaca	IPCC (2006) Table 10.10	8
MM_{GOATS}	Manure management – goats	IPCC (1996) Table 4.5	0.18
MM_{HORSES}	Manure management – horses	IPCC (1996) Table 4.5	2.1
MM_{SWINE}	Manure management – swine	Hill et al. (2012)	20
$MM_{BROILERs}$	Manure management – broilers	Fick et al. (2011)	0.022
MM_{LAYERS}	Manure management – layer hens	Fick et al., 2011	0.016
$MM_{OTHER\ POULTRY}$	Manure management – other poultry	IPCC (1996) Table 4.5	0.117
MM_{ALPACA}	Manure management – alpaca	New Zealand 1990 sheep value[40]	0.091

A3.2 Supplementary information for the LULUCF sector: The Land Use and Carbon Analysis System (LUCAS)

A3.2.1 LUCAS Data Management System

The LUCAS Data Management System stores, manages and archives data for international greenhouse gas reporting for the LULUCF sector. These systems are used for managing the land-use spatial databases, plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting (figure A3.2.1).

The data collected is stored and manipulated within three systems: the Geospatial System, the Gateway and the Calculation and Reporting Application.

The key objectives of these systems are to:

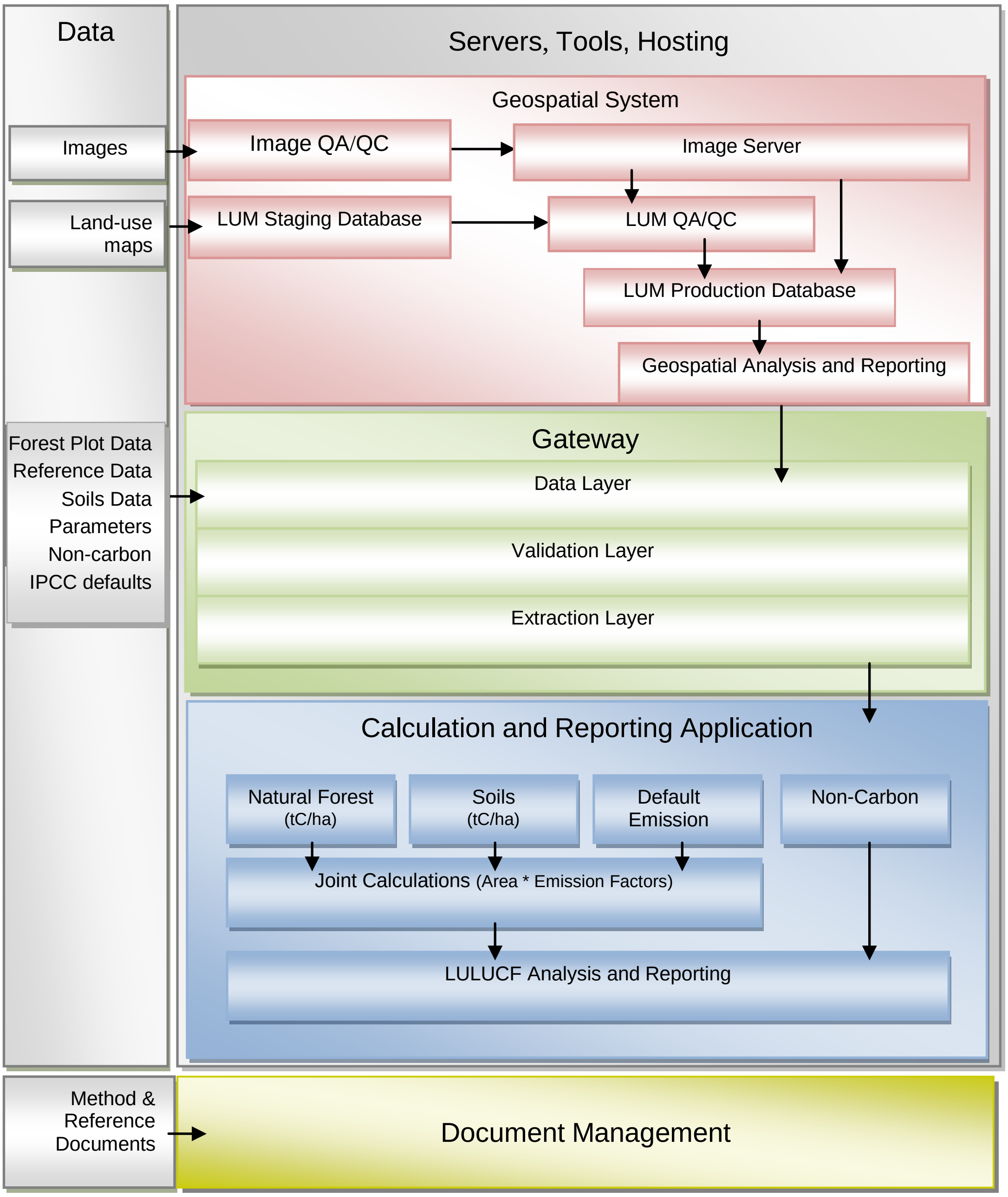
- provide a transparent system for data storage and carbon calculations
- provide a repository for the versioning and validation of plot measurements and land-use data
- calculate carbon stocks, emissions and removals per hectare for land uses and carbon pools based on the plot and spatial data collected

39 Value is for 2009. In 1990, the value was EF 7.4 kg CH_4/head/yr. Values for the intermediate years between 1990 and 2009 and for 2010 are interpolated and extrapolated based on assumption that the dairy goat population has remained in a near constant state over time.

40 As was reported in the first year that alpacas were included in *New Zealand's Greenhouse Gas Inventory* (Ministry for the Environment, 2010).

- calculate biomass burning and liming emissions by land use based on spatial and emission factors stored in the Gateway.
- produce the outputs required for the LULUCF sector reporting under the Climate Change Convention and the Kyoto Protocol.
- archive all inputs and outputs used in reporting.

Figure A3.2.1 New Zealand's LUCAS Data Management System



Note: LUM = land-use map. Joint calculations are described below.

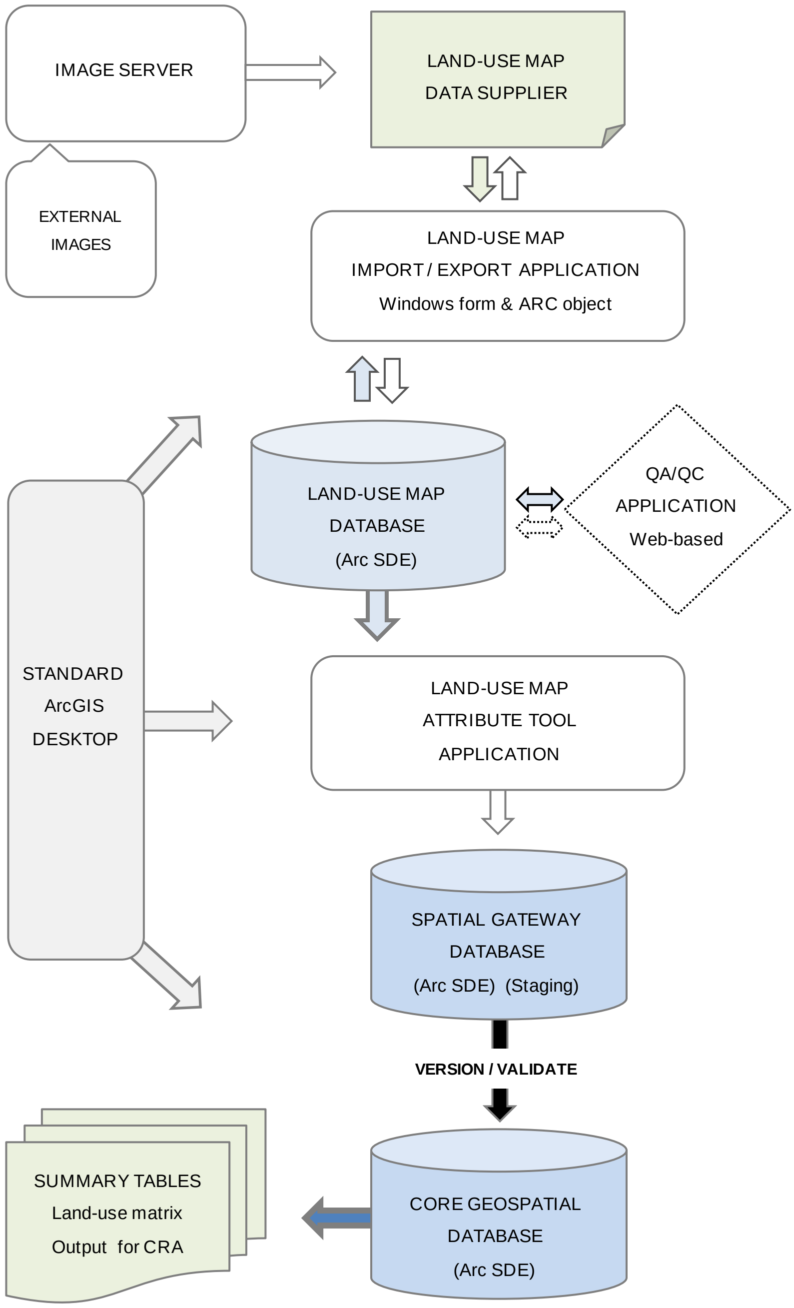
The module Joint Calculations refers to the process New Zealand uses to estimate national average carbon values by carbon pool for each land-use category and subcategory.

The Joint Calculation process is performed within the Calculation and Reporting Application. Within the Joint Calculations interface, the user selects the appropriate area data and emission factors. The results of the calculations are carbon gains, losses and net change for all land-use subcategories whether in a conversion state or land remaining land, by year, by carbon pool, and stratified by North or South Island.

The Geospatial System

The Geospatial System consists of hardware and specific applications designed to meet LULUCF reporting requirements. The hardware largely comprises servers for spatial database storage, management, versioning and running web mapping applications. The core components of the Geospatial System are outlined below.

Figure A3.2.2 New Zealand's Geospatial System components



Land-use mapping functionality

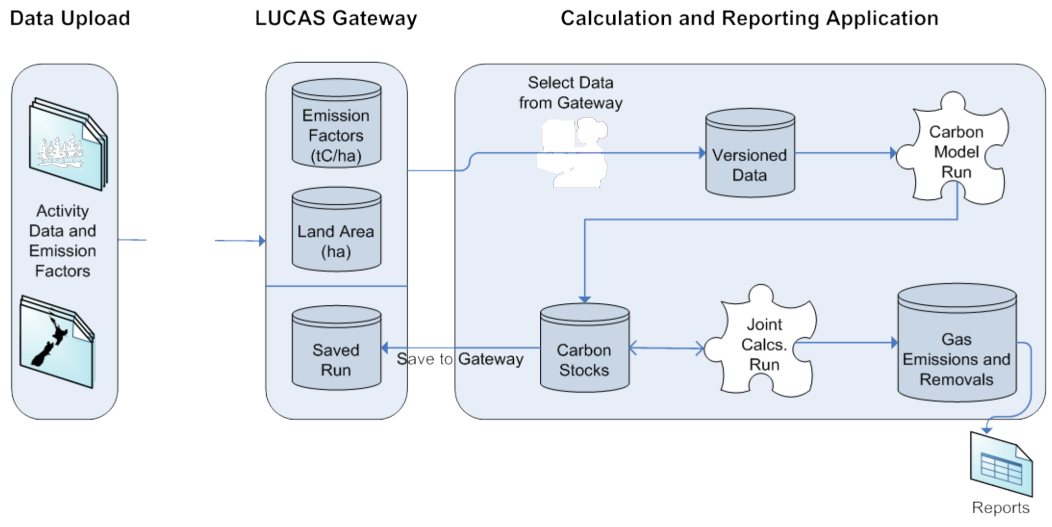
The land-use mapping (LUM) functionality of the Geospatial System largely involves the editing and maintenance of time-stamped land-use mapping data. There are five components within the LUM functionality, as described below:

- LUM Import/Export Application – provides functionality for managing the importing and exporting of land-use mapping information into and out of the database
- LUM Attribute Tool Application – an extension to the standard ArcGIS Desktop software that facilitates maintenance and updates to the land-use mapping data by external contractors
- LUM Database – a non-versioned GIS database for interim land-use mapping data and related quality assurance and control observation data
- Spatial Gateway Application – used to validate and version data from the LUM database prior to loading into the Core Geospatial Database. Spatial gateway rules are stored in the Spatial Gateway Database
- Core Geospatial Database – stores final versioned geospatial datasets that are used by the Summary Calculation application to generate land-use matrix data. It also stores the summary tables produced.

The LUCAS Management Studio

The LUCAS Management Studio is the package of applications used to store activity data and calculate and report New Zealand's emissions and removals for LULUCF. The LUCAS Gateway is a data warehouse with the purpose of storing, versioning and validating activity data and emissions factors. The Calculation and Reporting Application sources all data from the Gateway and calculates and outputs New Zealand's emissions and removals for LULUCF for land remaining land and land converted to another land use, by pool and year.

Figure A3.2.3 LUCAS Management Studio



The LUCAS Gateway

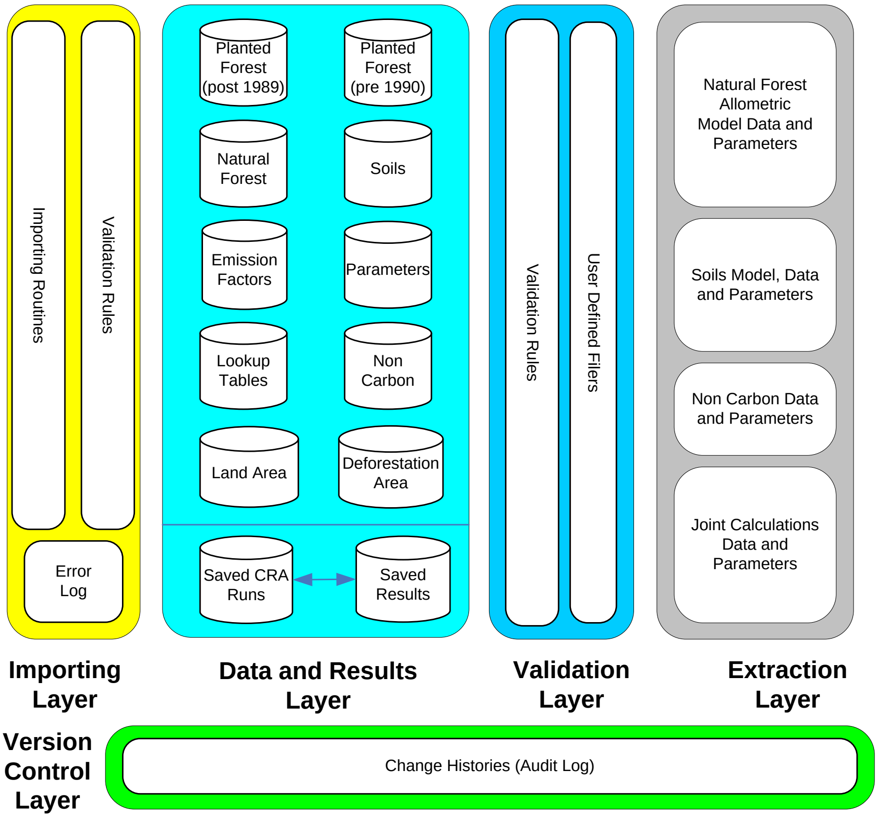
The LUCAS Gateway enables the storage of activity data such as: field plot data, land-use area, biomass burning, liming and other data, such as IPCC defaults, needed by the Calculation and Reporting Application.

The LUCAS Gateway provides a viewing, querying and editing interface to the source (plot, land-use area, carbon and non-carbon) data. The Gateway also stores any published or saved results from running the Calculation and Reporting Application.

All activity data and emission factors are stored within the Gateway database (figure A3.2.4). Below is a description of the key components:

- a data and results layer contains all activity data (natural, planted forest, soils, default carbon, non-carbon, land-use areas, land-use change and reference tables). The user has the ability to create a 'snapshot' in time (a dataset archiving system) of the data held in the Gateway. This enables users of the Calculation and Reporting Application to select from a range of data snapshots and also ensures past results can be replicated over time
- a validation layer allows users to judge the suitability of data for use in the Calculation and Reporting Application calculations, subsequent to passing primary validation. Where records are deemed not acceptable for use within published reports, they are tagged as 'invalid' in the LUCAS Gateway database
- an audit trail provides a history of any changes to the database tables within the Gateway
- versioning at a number of levels ensures any changes to data, schema or the database itself are logged and versioned, while providing the user with the ability to track what changes have been applied, and roll back to a previous version if required. The results of saved or published reports within the Calculation and Reporting Application are also stored within the Gateway for repeatability and reference
- primary data validation, both during data capture and during import of the data into the Gateway, ensures only data that has passed acceptability criteria are available for a publishable Calculation and Reporting Application run
- hosting and application support provides hosting services, system security, backup and restore, daily maintenance and monitoring for the Gateway and Calculation and Reporting Application.

Figure A3.2.4 LUCAS Gateway database

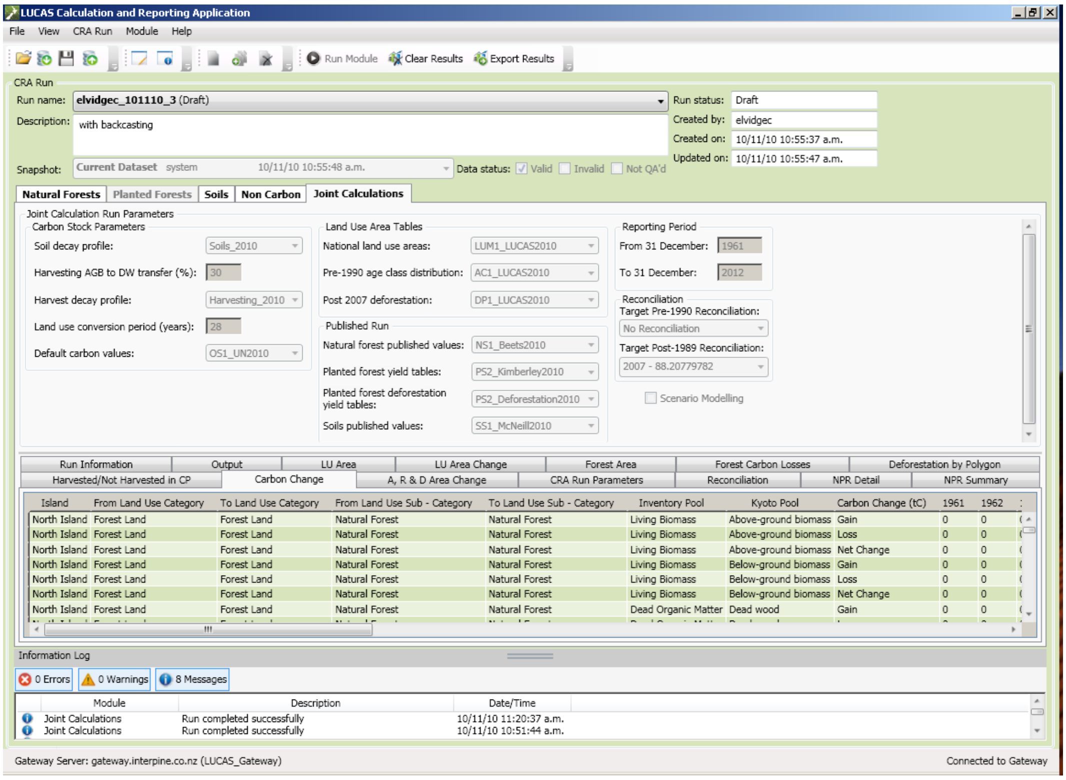


Calculation and Reporting Application

The Calculation and Reporting Application enables users to import carbon and non-carbon data from the Gateway and, by running the various modules, determine emissions and removals by New Zealand's forests, cropland, grassland and other land-use types. This information, combined with land-area data, enables New Zealand to meet its reporting requirements under the Climate Change Convention and Kyoto Protocol.

The Calculation and Reporting Application allows for the inclusion of other datasets, models and calculations without the complete redesign of the applications. All models, data and results are versioned, and the Calculation and Reporting Application allows the user to alter specific key values within a model or calculation (parameters) without the intervention of a programmer or technical support officer. The Calculation and Reporting Application is deployed as a client-based application that sources the required data from the Gateway.

Figure A3.2.5 Calculation and Reporting Application



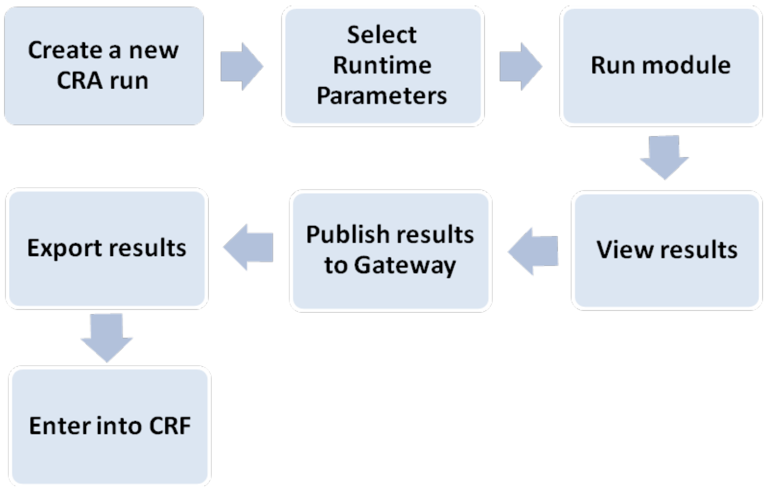
The Calculation and Reporting Application comprises of four modules: natural forest, soils, non-carbon, and joint calculations. Any of these modules can be run independently or as a group. The results are provided as 'views' to the user at the completion of the run.

To activate the module, the user selects the module to run within the Calculation and Reporting Application, the version of the dataset to be used, the model version and other calculation parameters. The natural forest and soil carbon modules use R statistical language as the base programme language, while the non-carbon module and joint calculations module are developed in C Sharp programming language (C#).

Within the joint calculations module, the user has the option of using the carbon results from running the modules, or using default carbon estimates (based on published reports) stored within the Gateway. The joint calculations module combines the carbon estimates with the land-use area to calculate carbon stock and change. The results represent carbon stock and change for every 'from' and 'to' land-use combination outlined by the IPCC since 1990.

On completion of running a module, the results can be saved or published back to the Gateway. This provides a versioned and auditable record of the results used for reporting. If the results are saved or published, other information, such as the time created, the user's identification and the module-particular parameters that were used, is also saved for tracking and audit control.

Figure A3.2.6 How New Zealand used the Calculation and Reporting Application for entry into the common reporting format database



The Calculation and Reporting Application is maintained and supported by Interpine Forestry Limited, a New Zealand-based company that specialises in forestry inventories and related information technology development. Interpine Forestry Limited also provides support services, such as database and application back-ups and system security (firewalls and virus control), day-to-day issue resolution and enhancement projects to the Gateway or the Calculation and Reporting Application, as required.

Any changes to the data or table structure within the Gateway, or to people accessing the Gateway or Calculation and Reporting Application, are tracked via audit logs. For any changes to the data within the Gateway, the person making the change, the date, reason for change and the version are logged and reports are made available to the users for review.

Annex 4: Carbon dioxide reference approach and comparison with sectoral approach, and relevant information on the national energy balance

Information on the carbon dioxide reference approach and a comparison with sectoral approach is provided in section 3.2.1. A table of the national energy balance for the 2010 calendar year is provided in annex 2.

Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

An assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in section 1.8.

Annex 6: Additional information and supplementary information under Article 7.1

All supplementary information required under Article 7.1 of the Kyoto Protocol is provided in chapters 11 to 15.

Annex 7: Uncertainty analysis (Table 6.1 of the IPCC good practice guidance)

Uncertainty estimates are an essential element of a complete emissions inventory. The purpose of uncertainty information is not to dispute the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice (IPCC, 2000). The good practice guidance also notes that inventories prepared following the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003) will typically contain a wide range of emission estimates. This range varies from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable nitrous oxide (N_2O) fluxes from soils and waterways (IPCC, 2000).

New Zealand has included a Tier 1 uncertainty analysis as required by the Climate Change Convention inventory guidelines (UNFCCC, 2006) and IPCC good practice guidance (IPCC, 2000 and 2003). Uncertainties in the categories are combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. Land use, land-use change and forestry sector (LULUCF) categories have been included using the absolute value of any removals of carbon dioxide (CO_2) (table A7.1.1). Table A7.1.2 calculates the uncertainty only in emissions, that is, excluding LULUCF removals.

A7.1 Tier 1 uncertainty calculation

The uncertainty in activity data and emission and or removal factors shown in table A7.1.1 and A7.1.2 are equal to half the 95 per cent confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95 per cent confidence interval is that the value corresponds to the familiar plus or minus value when uncertainties are loosely quoted as ‘plus or minus x per cent’.

Where uncertainty is highly asymmetrical, the larger percentage difference between the mean and the confidence limit is entered. Where only the total uncertainty is known for a category, then:

- if uncertainty is correlated across years, the uncertainty is entered as the emission or the removal factor uncertainty and as zero in the activity data uncertainty
- if uncertainty is not correlated across years, the uncertainty is entered as the uncertainty in the activity data and as zero in the emission or the removal factor uncertainty.

In the Tier 1 method, uncertainties in the trend are estimated using two sensitivities:

- Type A sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and a greenhouse gas in both the base year and the current year.

- Type B sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and gas in the current year only.

Uncertainties that are fully correlated between years are associated with Type A sensitivities, and uncertainties that are not correlated between years are associated with Type B sensitivities.

In tables A7.1.1 and A7.1.2, the figure labelled ‘Uncertainty in the trend’ is an estimate of the total uncertainty in the trend in emissions since the base year. This is expressed as the number of percentage points in the 95 per cent confidence interval in the per cent change in emissions since the base year. The total uncertainty in the trend is calculated by combining the contribution of emissions factor uncertainty and activity data uncertainty to the trend across all categories using equation 3.1 (IPCC, 2000).

The values for individual categories are an estimate of the uncertainty introduced into the trend by the category in question.

Table A7.1.1 The uncertainty calculation (including LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2010* (IPCC, Tier 1)

IPCC source category	Gas	1990 emissions or absolute value of removals, Gg CO_2-e	2010 emissions or absolute value of removals, Gg CO_2-e	Activity data uncertainty, %	Emission or removal factor uncertainty, %	Combined uncertainty, %	Combined uncertainty as a per cent of the national total in 2010, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty, %	Uncertainty in trend in national total introduced by activity data uncertainty, %	Uncertainty introduced into the trend in the national total, %	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – liquid fuels	CO_2	11,690.69	17,334.99	0.2	0.5	0.5	0.1	0.0489	0.1948	0.0244	0.0463	0.1	R	M
Energy – solid fuels	CO_2	3,146.01	3,499.58	0.7	3.5	3.6	0.1	0.0001	0.0393	0.0003	0.0378	0.0	M	M
Energy – gaseous fuels	CO_2	6,961.82	7,287.35	9.2	2.4	9.5	0.7	–0.0050	0.0819	–0.0120	1.0699	1.1	M	M
Energy – fugitive – geothermal	CO_2	228.58	642.22	5.0	5.0	7.1	0.0	0.0044	0.0072	0.0218	0.0510	0.1	D	D
Energy – fugitive – venting/flaring	CO_2	228.88	803.14	2.6	2.4	3.5	0.0	0.0062	0.0090	0.0149	0.0329	0.0	M	M
Energy – fugitive – oil transport	CO_2	0.01	0.01	5.0	50.0	50.2	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – fugitive – transmission and distribution	CO_2	1.46	1.06	2.6	5.0	5.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	M
Industrial processes – mineral production	CO_2	557.80	778.03	100.0	7.0	100.2	0.8	0.0018	0.0087	0.0125	1.2367	1.2	D	D
Industrial processes – chemical industry	CO_2	430.20	630.02	2.0	6.0	6.3	0.0	0.0017	0.0071	0.0103	0.0200	0.0	D	D
Industrial processes – metal production	CO_2	1,755.71	2,221.89	5.0	7.0	8.6	0.2	0.0031	0.0250	0.0214	0.1766	0.2	D	D
LULUCF – forest land	CO_2	27,161.8	23,552.8	10.8	44.4	45.7	10.9	–0.0740	0.2647	–3.2861	4.0434	5.2	M	R
LULUCF – non-forested land	CO_2	1,936.5	3,503.9	3.6	73.3	73.4	2.6	0.0152	0.0394	1.1152	0.2005	1.1	M	R
Waste – waste incineration	CO_2	12.9	0.9	50.0	40.0	64.0	0.0	–0.0002	0.0000	–0.0060	0.0007	0.0	D	D

IPCC source category	Gas	1990 emissions or absolute value of removals, Gg CO_2-e	2010 emissions or absolute value of removals, Gg CO_2-e	Activity data uncertainty, %	Emission or removal factor uncertainty, %	Combined uncertainty, %	Combined uncertainty as a per cent of the national total in 2010, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty, %	Uncertainty in trend in national total introduced by activity data uncertainty, %	Uncertainty introduced into the trend in the national total, %	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – liquid fuels	CH_4	56.85	30.83	0.2	50.0	50.0	0.0	–0.0004	0.0003	–0.0181	0.0001	0.0	D	M
Energy – solid fuels	CH_4	23.79	4.38	0.7	50.0	50.0	0.0	–0.0002	0.0000	–0.0124	0.0000	0.0	D	M
Energy – gaseous fuels	CH_4	56.41	40.55	9.2	50.0	50.8	0.0	–0.0002	0.0005	–0.0124	0.0060	0.0	D	M
Energy – biomass	CH_4	57.38	60.59	5.0	50.0	50.2	0.0	0.0000	0.0007	–0.0018	0.0048	0.0	D	D
Energy – fugitive – geothermal	CH_4	46.02	115.20	5.0	5.0								D	D
Energy – fugitive – venting/flaring	CH_4	54.29	66.45	9.2	50.0	50.8	0.0	0.0001	0.0007	0.0035	0.0098	0.0	D	M
Energy – fugitive – coal mining and handling	CH_4	274.47	552.22	0.7	50.0	50.0	0.3	0.0028	0.0062	0.1391	0.0060	0.1	D	M
Energy – fugitive – transmission and distribution	CH_4	235.16	156.67	9.2	5.0	10.5	0.0	–0.0012	0.0018	–0.0059	0.0230	0.0	D	M
Energy – fugitive – other leakages	CH_4	202.9	222.6	5.0	50.0	50.2	0.1	0.0000	0.0025	–0.0015	0.0177	0.0	D	D
Energy – fugitive – oil transportation	CH_4	4.8	6.0	5.0	50.0								D	D
Agriculture – enteric fermentation	CH_4	22,421.8	23,140.7	0.0	16.0	16.0	3.7	–0.0197	0.2601	–0.3147	0.0000	0.3	M	M
Agriculture – manure management	CH_4	454.7	623.0	5.0	30.0	30.4	0.2	0.0013	0.0070	0.0398	0.0495	0.1	M	M
Agriculture – prescribed burning	CH_4	22.2	6.5	20.0	60.0	63.2	0.0	–0.0002	0.0001	–0.0123	0.0021	0.0	D	R
Agriculture– burning of residues	CH_4	19.7	20.3	0.0	40.0	40.0	0.0	0.0000	0.0002	–0.0007	0.0000	0.0	D	R
LULUCF	CH_4	49.5	53.8	5.0	42.4									

IPCC source category	Gas	1990 emissions or absolute value of removals, Gg CO_2-e	2010 emissions or absolute value of removals, Gg CO_2-e	Activity data uncertainty, %	Emission or removal factor uncertainty, %	Combined uncertainty, %	Combined uncertainty as a per cent of the national total in 2010, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty, %	Uncertainty in trend in national total introduced by activity data uncertainty, %	Uncertainty introduced into the trend in the national total, %	Emission/ removal factor quality indicator	Activity data quality indicator
Waste – solid waste disposal	CH_4	1,514.4	1,345.5	0.0	40.0	40.0	0.5	–0.0038	0.0151	–0.1510	0.0000	0.2	M	R
Waste – wastewater handling	CH_4	381.5	463.8	0.0	100.0	100.0	0.5	0.0005	0.0052	0.0452	0.0000	0.0	D	R
Waste – waste incineration	CH_4	0.0	0.0	50.0	100.0	111.8	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – liquid fuels	N_2O	118.14	186.53	0.2	50.0	50.0	0.1	0.0006	0.0021	0.0311	0.0005	0.0	D	M
Energy – solid fuels	N_2O	16.24	18.21	0.7	50.0	50.0	0.0	0.0000	0.0002	0.0001	0.0002	0.0	D	M
Energy – gaseous fuels	N_2O	8.26	7.74	9.2	50.0	50.8	0.0	0.0000	0.0001	–0.0008	0.0011	0.0	D	M
Energy – biomass	N_2O	46.25	71.48	5.0	50.0	50.2	0.0	0.0002	0.0008	0.0113	0.0057	0.0	D	D
Solvents – N_2O use	N_2O	41.5	31.0	10.0	0.0	10.0	0.0	–0.0002	0.0003	0.0000	0.0049	0.0	R	
Agriculture – agricultural soils	N_2O	7,891.3	9,905.2	0.0	74.0	74.0	7.4	0.0128	0.1113	0.9503	0.0000	1.0	M	M
Agriculture – manure management	N_2O	32.8	45.8	5.0	100.0	100.1	0.0	0.0001	0.0005	0.0106	0.0036	0.0	R	R
Agriculture – prescribed burning	N_2O	8.1	2.4	20.0	60.0	63.2	0.0	–0.0001	0.0000	–0.0045	0.0007	0.0	D	R
Agriculture – burning of residues	N_2O	4.6	4.7	6.0	40.0	40.4	0.0	0.0000	0.0001	–0.0002	0.0004	0.0	D	R
LULUCF	N_2O	24.1	14.6	3.6	85.8	85.9	0.0	–0.0001	0.0002	–0.0117	0.0008	0.0	R	R
Waste – wastewater handling	N_2O	142.7	180.4	25.0	1200.0	1200.3	2.2	0.0002	0.0020	0.2951	0.0717	0.3	D	R
Waste – waste incineration	N_2O	1.6	1.3	50.0	100.0	111.8	0.0	0.0000	0.0000	–0.0006	0.0010	0.0	D	D

IPCC source category	Gas	1990 emissions or absolute value of removals, Gg CO_2-e	2010 emissions or absolute value of removals, Gg CO_2-e	Activity data uncertainty, %	Emission or removal factor uncertainty, %	Combined uncertainty, %	Combined uncertainty as a per cent of the national total in 2010, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty, %	Uncertainty in trend in national total introduced by activity data uncertainty, %	Uncertainty introduced into the trend in the national total, %	Emission/ removal factor quality indicator	Activity data quality indicator
Industrial processes	HFCs	0.0	1,087.17	16.0	5.0	16.8	0.2	0.0122	0.0122	0.0611	0.2765	0.3	R	R
Industrial processes – aluminium production	PFCs	629.9	40.59	5.0	30.0	30.4	0.0	–0.0074	0.0005	–0.2221	0.0032	0.2	M	M
Industrial processes – consumption of hydrofluorocarbons	PFCs	0	0.22	20.0	5.0	20.6	0.0	0.0000	0.0000	0.0000	0.0001	0.0	R	R
Industrial processes	SF_6	15.2	20.16	23.0	10.0	25.1	0.0	0.0000	0.0002	0.0004	0.0074	0.0	R	R
Total emissions/removals		**88,969.0**	**98,782.3**		**Uncertainty in the year**		**14.2%**		**Uncertainty in the trend**			**5.7%**		

Table A7.1.2 The uncertainty calculation (excluding LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2010* (IPCC, Tier 1)

IPCC source category	Gas	1990 emissions or absolute value of removals	2010 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	Type A sensitivity	Type B sensitivity	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty	Uncertainty in trend in national total introduced by activity data uncertainty	Uncertainty introduced into the trend in the national total	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – liquid fuels	CO_2	11,690.69	17,334.99	0.2	0.5	0.5	0.1	0.0555	0.2899	0.0278	0.0690	0.1	R	R
Energy – solid fuels	CO_2	3,146.01	3,499.58	0.7	3.5	3.6	0.2	–0.0045	0.0585	–0.0159	0.0562	0.1	R	R
Energy – gaseous fuels	CO_2	6,961.82	7,287.35	9.2	2.4	9.5	1.0	–0.0176	0.1219	–0.0425	1.5918	1.6	R	R
Energy – fugitive – geothermal	CO_2	228.58	642.22	5.0	5.0	7.1	0.1	0.0062	0.0107	0.0308	0.0759	0.1	D	D
Energy – fugitive – venting/flaring	CO_2	228.88	803.14	2.6	2.4	3.5	0.0	0.0088	0.0134	0.0213	0.0489	0.1	R	R
Energy – fugitive – oil transport	CO_2	0.01	0.01	5.0	50.0	50.2	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – fugitive – transmission and distribution	CO_2	1.46	1.06	2.6	5.0	5.6	0.0	0.0000	0.0000	–0.0001	0.0001	0.0	R	R
Industrial processes – mineral production	CO_2	557.80	778.03	100.0	7.0	100.2	1.1	0.0018	0.0130	0.0128	1.8401	1.8	D	D
Industrial processes – chemical industry	CO_2	430.20	630.02	2.0	6.0	6.3	0.1	0.0019	0.0105	0.0115	0.0298	0.0	D	D
Industrial processes – metal production	CO_2	1,755.71	2,221.89	5.0	7.0	8.6	0.3	0.0020	0.0372	0.0138	0.2627	0.3	D	D
Waste – waste incineration	CO_2	12.9	0.9	50.0	40.0	64.0	0.0	–0.0002	0.0000	–0.0097	0.0011	0.0	D	D
Energy – liquid fuels	CH_4	56.85	30.83	0.2	50.0	50.0	0.0	–0.0006	0.0005	–0.0312	0.0001	0.0	D	D
Energy – solid fuels	CH_4	23.79	4.38	0.7	50.0	50.0	0.0	–0.0004	0.0001	–0.0202	0.0001	0.0	D	D
Energy – gaseous fuels	CH_4	56.41	40.55	9.2	50.0	50.8	0.0	–0.0005	0.0007	–0.0226	0.0089	0.0	D	D
Energy – biomass	CH_4	57.38	60.59	5.0	50.0	50.2	0.0	–0.0001	0.0010	–0.0068	0.0072	0.0	D	D
Energy – fugitive – geothermal	CH_4	46.02	115.20	5.0	5.0								D	D
Energy – fugitive – venting/flaring	CH_4	54.29	66.45	9.2	50.0	50.8	0.0	0.0000	0.0011	0.0012	0.0145	0.0	R	R

IPCC source category	Gas	1990 emissions or absolute value of removals	2010 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	Type A sensitivity	Type B sensitivity	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty	Uncertainty in trend in national total introduced by activity data uncertainty	Uncertainty introduced into the trend in the national total	Emission/ removal factor quality indicator	Activity data quality indicator
Energy – fugitive – coal mining & handling	CH_4	274.47	552.22	0.7	50.0	50.0	0.4	0.0037	0.0092	0.1867	0.0089	0.2	R	R
Energy – fugitive – transmission and distribution	CH_4	235.16	156.67	9.2	5.0	10.5	0.0	–0.0021	0.0026	–0.0105	0.0342	0.0	R	R
Energy – fugitive – other leakages	CH_4	202.9	222.6	5.0	50.0	50.2	0.2	–0.0003	0.0037	–0.0172	0.0263	0.0	D	D
Energy – fugitive – oil	CH_4	4.8	6.0	5.0	50.0								D	D
Agriculture – enteric fermentation	CH_4	22,421.8	23,140.7	0.0	16.0	16.0	5.2	–0.0621	0.3870	–0.9938	0.0000	1.0	M	M
Agriculture – manure management	CH_4	454.7	623.0	5.0	30.0	30.4	0.3	0.0013	0.0104	0.0392	0.0737	0.1	M	M
Agriculture – prescribed burning	CH_4	22.2	6.5	20.0	60.0	63.2	0.0	–0.0003	0.0001	–0.0202	0.0031	0.0	D	R
Agriculture– burning of residues	CH_4	19.7	20.3	0.0	40.0	40.0	0.0	–0.0001	0.0003	–0.0022	0.0000	0.0	D	R
Waste – solid waste disposal	CH_4	1,514.4	1,345.5	0.0	40.0	40.0	0.8	–0.0078	0.0225	–0.3138	0.0000	0.3	M	R
Waste – wastewater handling	CH_4	381.5	463.8	0.0	100.0	100.0	0.6	0.0001	0.0078	0.0111	0.0000	0.0	D	R
Waste – waste incineration	CH_4	0.0	0.0	50.0	100.0	111.8	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – liquid fuels	N_2O	118.14	186.53	0.2	50.0	50.0	0.1	0.0008	0.0031	0.0376	0.0007	0.0	D	D
Energy – solid fuels	N_2O	16.24	18.21	0.7	50.0	50.0	0.0	0.0000	0.0003	–0.0010	0.0003	0.0	D	D
Energy – gaseous fuels	N_2O	8.26	7.74	9.2	50.0	50.8	0.0	0.0000	0.0001	–0.0018	0.0017	0.0	D	D
Energy – biomass	N_2O	46.25	71.48	5.0	50.0	50.2	0.1	0.0003	0.0012	0.0134	0.0085	0.0	D	D
Solvents – N_2O use	N_2O	41.5	31.0	10.0	0.0	10.0	0.0	–0.0003	0.0005	0.0000	0.0073	0.0	R	
Agriculture – agricultural soils	N_2O	7,891.3	9,905.2	0.0	74.0	74.0	10.2	0.0075	0.1656	0.5547	0.0000	0.6	M	M
Agriculture – manure management	N_2O	32.8	45.8	5.0	100.0	100.1	0.1	0.0001	0.0008	0.0110	0.0054	0.0	R	R
Agriculture – prescribed	N_2O	8.1	2.4	20.0	60.0	63.2	0.0	–0.0001	0.0000	–0.0074	0.0011	0.0	D	R

IPCC source category	Gas	1990 emissions or absolute value of removals	2010 emissions or absolute value of removals	Activity data uncertainty	Emission or removal factor uncertainty	Combined uncertainty	Combined uncertainty as a per cent of the national total in 2009	Type A sensitivity	Type B sensitivity	Uncertainty in the trend in national total introduced by emission or removal factor uncertainty	Uncertainty in trend in national total introduced by activity data uncertainty	Uncertainty introduced into the trend in the national total	Emission/ removal factor quality indicator	Activity data quality indicator
burning														
Agriculture – burning of residues	N_2O	4.6	4.7	6.0	40.0	40.4	0.0	0.0000	0.0001	–0.0006	0.0007	0.0	D	R
Waste – wastewater handling	N_2O	142.7	180.4	25.0	1200.0	1200.3	3.0	0.0002	0.0030	0.1870	0.1066	0.2	D	R
Waste – waste incineration	N_2O	1.6	1.3	50.0	100.0	111.8	0.0	0.0000	0.0000	–0.0011	0.0015	0.0	D	D
Industrial processes	HFCs	0.0	1,087.17	16.0	5.0	16.8	0.3	0.0182	0.0182	0.0909	0.4114	0.4	R	R
Industrial processes – aluminium production	PFCs	629.9	40.59	5.0	30.0	30.4	0.0	–0.0119	0.0007	–0.3583	0.0048	0.4	M	M
Industrial processes – consumption of hydrofluorocarbons	PFCs	0	0.22	20.0	5.0	20.6	0.0	0.0000	0.0000	0.0000	0.0001	0.0	R	R
Industrial processes	SF_6	15.2	20.16	23.0	10.0	25.1	0.0	0.0000	0.0003	0.0003	0.0110	0.0	R	R
Total emissions		**59,797.2**	**71,657.2**		**Uncertainty in the year**		**12.0%**		**Uncertainty in the trend**			**2.8%**		

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