New Zealand's Greenhouse Gas Inventory 1990-2013

Fulfilling reporting requirements under the United Nations Framework Convention on Climate Change and the Kyoto Protocol

New Zealand Government

Ministry for the Environment
Manatū Mō Te Taiao

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Executive summary

Key points

- New Zealand's total greenhouse gas emissions were 80,962 kt carbon dioxide equivalent (CO_2-e) in 2013, showing a 1.4 per cent decrease since 2012.
- The Agriculture and Energy sectors are the two largest contributors to New Zealand's emissions profile (approximately 48 per cent from the Agriculture sector and 39 per cent from the Energy sector of total emissions in 2013).
- Since 1990, New Zealand's total emissions have increased by 21 per cent. The four emission sources that contributed the most to this increase were:
  - road transport (carbon dioxide)
  - agricultural soils (nitrous oxide)
  - consumption of fluorinated compounds (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride)
  - enteric fermentation (methane).
- Emissions from the Energy, Agriculture and Waste sectors showed a slight reduction from 2012.
- New Zealand's net emissions were 54,200 kt CO_2-e in 2013.

ES.1 Background

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

The Inventory reports emissions and removals of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).[1] 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, SF_6 and NF_3) are reported in total emissions under the Climate Change Convention and accounted for under the Kyoto Protocol. The gases are reported under five sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); and Waste.

For Annex I Parties that have taken a target to reduce greenhouse gas emissions under the Kyoto Protocol, reporting of afforestation, reforestation and deforestation activities since 1990, and forest management, is mandatory during the second commitment period of the Kyoto Protocol. This is a change from the first commitment period, when reporting on forest management was voluntary for Annex I Parties. Reporting on cropland management, grazing land management, revegetation, and wetland drainage and

[1] Nitrogen trifluoride emissions do not occur in New Zealand and, therefore, they are not included in this report.

rewetting, are voluntary for the second commitment period (Kyoto Protocol Article 3.4). For the period 2013–2020, New Zealand has taken an unconditional target to reduce its greenhouse gas emissions under the UNFCCC. New Zealand will apply the Kyoto Protocol framework of rules towards its target, to ensure New Zealand's actions are transparent and have integrity. New Zealand remains a Party to the Kyoto Protocol and New Zealand will continue to meet the reporting requirements of the Kyoto Protocol for the period.

ES.2 National trends

Total (gross) emissions

Total (gross) emissions include those from the Energy, IPPU, 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 under the Climate Change Convention.[2]

1990–2013

In 1990, New Zealand's total greenhouse gas emissions were 66,720.16 kt carbon dioxide equivalent (CO_2-e). In 2013, total greenhouse gas emissions had increased by 14,241.48 kt CO_2-e (21.4 per cent above 1990 levels) to 80,961.64 kt CO_2-e (figure ES 2.1). From 1990 to 2013, the average annual growth in total emissions was 0.9 per cent per year.

The emission sources that contributed the most to this increase in total emissions were *Road transportation*, *Public electricity and heat production*, *Agricultural soils*, *Consumption of halocarbons and sulphur hexafluoride* (*SF_6*), and *Enteric fermentation*.[3]

2012–2013

Since 2012, New Zealand's total greenhouse gas emissions have decreased by 1,116.3 kt CO_2-e (1.4 per cent). This reflected emission reductions in the Energy, Agriculture and Waste sectors (3.2, 0.4 and 0.5 per cent respectively). Meanwhile, emissions from the IPPU sector have grown by 2.3 per cent.

The decrease in energy emissions reflected a decrease in emissions from electricity generation and fugitive emissions. This was driven by the high hydro inflows in 2013 in key catchment areas, leading to an increase in share of electricity generated from renewable energy sources. A higher contribution from renewable energy in the national grid resulted in a lower proportion of fossil fuels-based electricity generation over the year. Reductions from fugitive emissions are largely caused by reduced activity in underground coal mining and handling and, to a smaller degree, reductions in the natural gas and venting and flaring categories.

Total agricultural emissions in 2013 were lower than the 2012 level, which is attributable to the unfavourable weather conditions (widespread drought in 2013). There was a decrease in the population of non-dairy cattle and sheep that resulted in decreased emissions associated with these types of livestock.

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2 UNFCCC. 2013a. FCCC/CP/2013/10/Add.3. *Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013, Addendum; Decision 24/CP.19 Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention*.

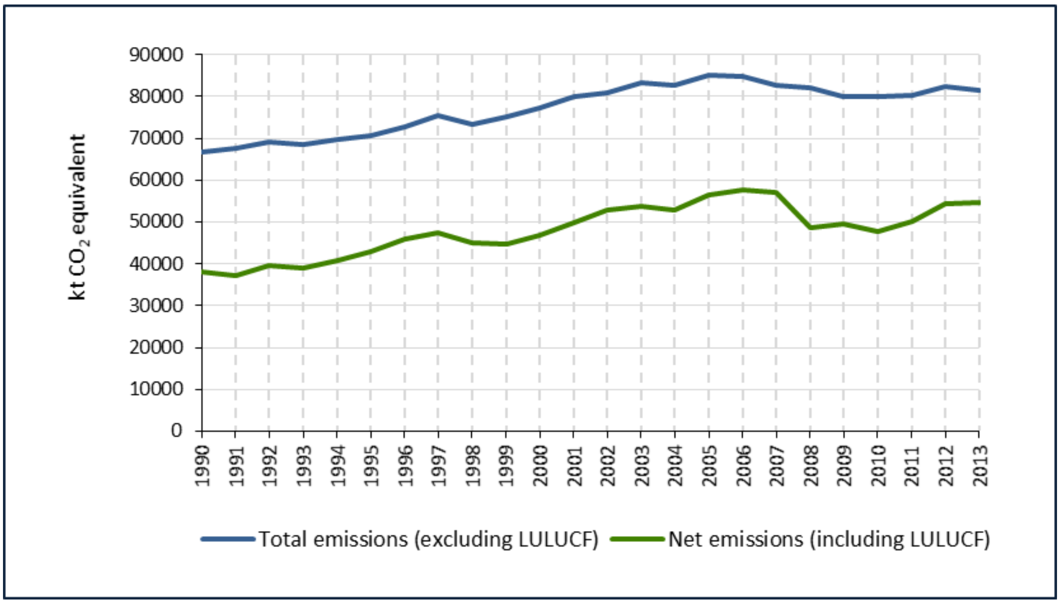
3 Methane emissions produced from ruminant livestock.

Net emissions – Climate Change Convention reporting

Net emissions include emissions from the Energy, IPPU, Agriculture and Waste sectors, together with emissions and removals from the LULUCF sector.

In 1990, New Zealand's net greenhouse gas emissions were 38,065.71 kt CO_2-e. In 2013, net greenhouse gas emissions had increased by 16,134.82 kt CO_2-e (42.4 per cent) to 54,200.53 kt CO_2-e (figure ES 2.1).

Figure ES 2.1 **New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2013**



Accounting under the Kyoto Protocol

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

In 2013, net removals were 21,195.1 kt CO_2-e from land subject to afforestation, reforestation, deforestation and forest management (see sections 1.12 and 2.5 for further detail).

New Zealand will continue to report on emissions and removals using the rules for reporting under the second commitment period. These rules have changed from those used for the first commitment period. Accounting for forest management is now under a business-as-usual reference level. Furthermore, emissions on land that meet the criteria for carbon equivalent forests and from natural disturbance events can now be excluded from accounting. This means the accounting quantity reported will fluctuate annually.

ES.3 Gas trends

The relative proportions of greenhouse gases emitted by New Zealand have changed since 1990. In 1990, CH_4 contributed the largest proportion of total emissions, while in 2013 CO_2 and CH_4 contributed nearly equal proportions to the total national emissions (table ES 3.1). This growth in emissions of CO_2 corresponds with growth in emissions from the Energy sector.

Table ES 3.1 New Zealand's total (gross) emissions by gas in 1990 and 2013

Direct greenhouse gas emissions	kt CO_2 equivalent 1990	kt CO_2 equivalent 2013	Change from 1990 (kt CO_2 equivalent)	Change from 1990 (%)
CO_2	25,392.3	34,610.9	+9,218.6	+36.3
CH_4	33,291.4	35,615.9	+2,324.6	+7.0
N_2O	7,294.7	9,052.8	+1,758.1	+24.1
HFCs	NO	1,615.2	+1,615.2	NA
PFCs	734.6	48.1	–686.4	–93.5
SF_6	7.3	18.7	+11.4	+157.7
Total	**66,720.2**	**80,961.6**	**+14,241.5**	**+21.4**

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

ES.4 Sector trends

The Agriculture sector contributed the largest proportion of total emissions in 1990 (table ES 4.1 and figure ES.4.1). The proportion of emissions from the Agriculture sector has generally been decreasing between 1990 and 2008. Emissions from agriculture have increased from 2009 to 2012 due to favourable growing conditions, a greater demand for New Zealand agricultural produce in the dairy sector and a favourable milk price. This led to an increase in the dairy cattle population and the amount of nitrogen applied as fertiliser to agricultural soils, resulting in an increase of CH_4 and N_2O emissions from the sector. In 2013, however, emissions from this sector decreased due to widespread drought in New Zealand.

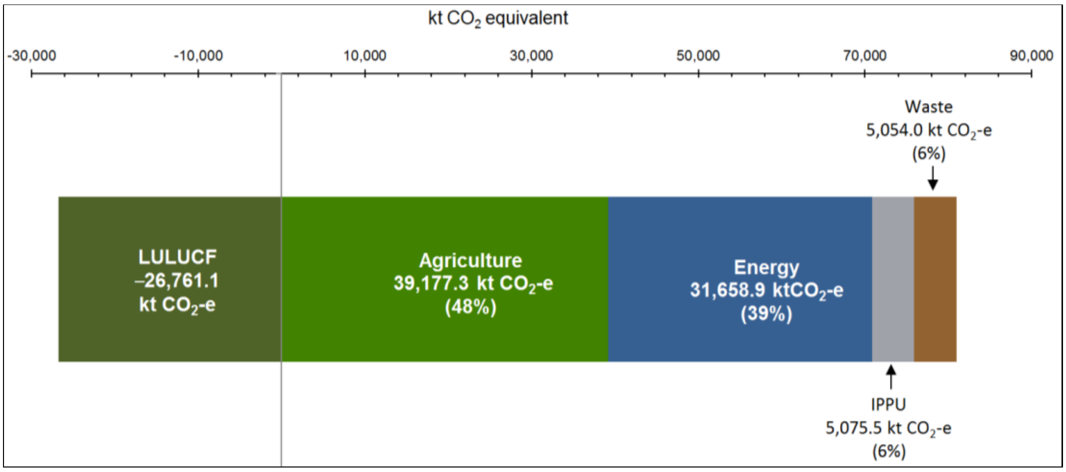
The Energy sector experienced the greatest increase in emissions over the period 1990–2008 (figure ES 4.2). Energy emissions have increased approximately two-and-a-half times as much as those from the Agriculture sector. In 2009–11 emissions from the Energy sector showed a decrease, resulting from the effects of the global recession, recent earthquakes and the closure of coal mines following accidents, as well as greater investment in renewable energy sources in New Zealand. A slight increase of emissions from the sector in 2012 (3.6 per cent) was mostly due to low hydro inflows and a subsequent reduction in the share of electricity production generated from renewable sources in the national energy grid. However, in 2013 there was an increase in hydro inflows in key catchment areas and a subsequent increase in the share of electricity produced from renewable sources in the national energy grid.

Table ES 4.1.1 New Zealand's emissions by sector in 1990 and 2013

Sector	kt CO_2 equivalent 1990	kt CO_2 equivalent 2013	Change from 1990 (kt CO_2 equivalent)	Change from 1990 (%)
Energy	23,994.6	31,658.9	+7,664.3	+31.9
Industrial Processes and Product Use	3,276.0	5,071.5	+1,795.5	+54.8
Agriculture	34,350.6	39,177.3	+4,826.7	+14.1
Waste	5,099.0	5,054.0	–45.0	–0.9
Total (excluding LULUCF)	**66,720.2**	**80,961.6**	**+14,241.5**	**+21.4**
LULUCF	–28,654.5	–26,761.1	+1,893.3	–3.9
Net total (including LULUCF)	**38,065.8**	**54,200.5**	**+16,134.8**	**+42.4**

Note: Net removals from the LULUCF sector are as reported under the Climate Change Convention (chapter 6). Columns may not total due to rounding.

Figure ES 4.1 New Zealand's emissions by sector in 2013



Note: The percentage numbers may not add up to 100 per cent due to rounding.

Figure ES 4.2 Proportion that sectors contributed to New Zealand's total emissions from 1990 to 2013

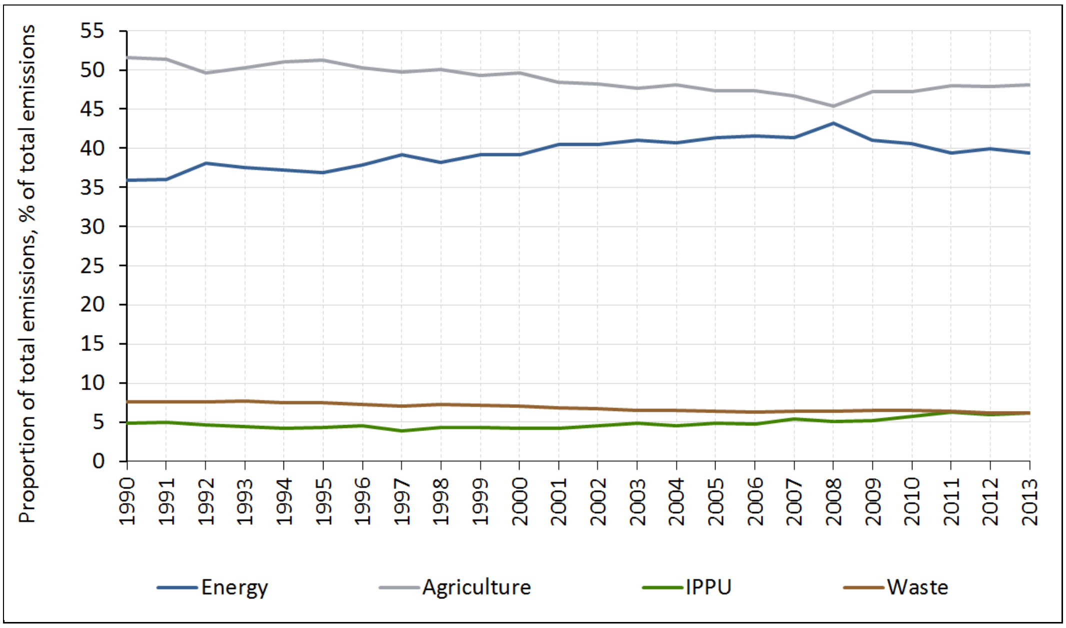


Figure ES 4.3 Change in New Zealand's emissions by sector in 1990 and 2013

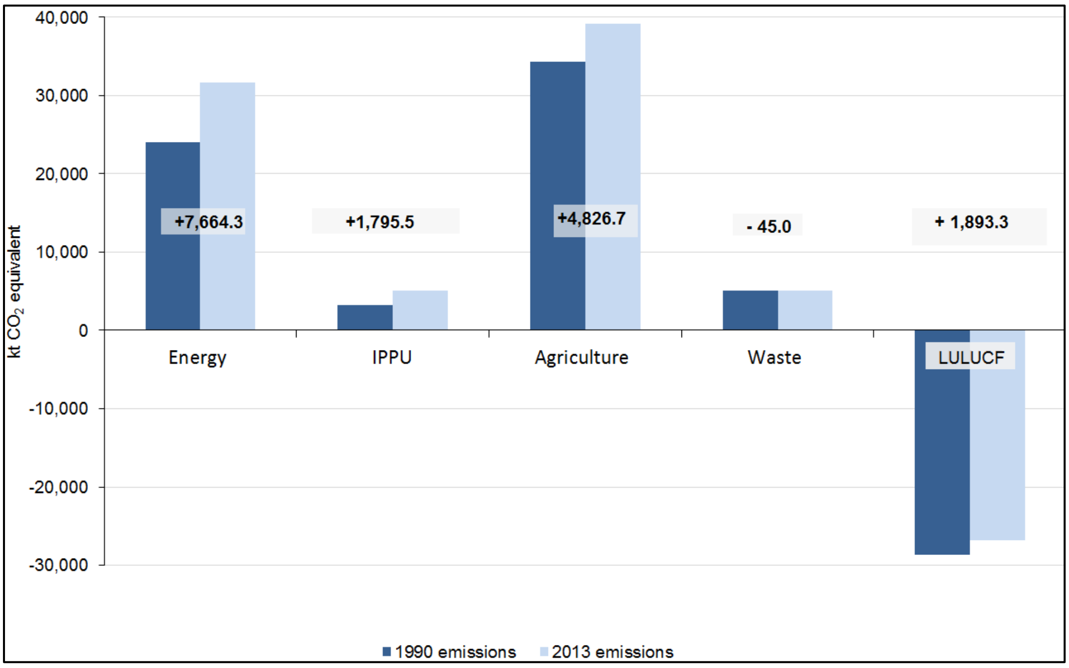
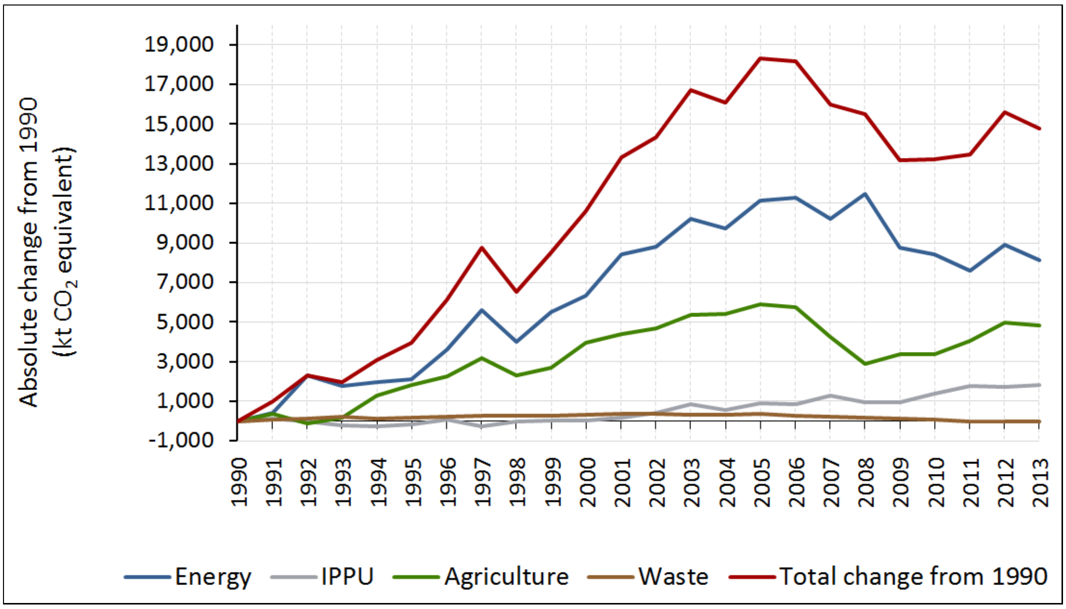


Figure ES 4.4 Absolute change in New Zealand's total emissions by sector from 1990 to 2013



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

Energy (chapter 3)

2013

In 2013, the Energy sector produced 31,658.9 kt CO_2-e, representing 39.1 per cent of New Zealand's total greenhouse gas emissions. The largest sources of emissions in the Energy sector were *Road transportation*, contributing 12,688 kt CO_2-e (40.2 per cent), and *Public electricity and heat production*, contributing 5,043 kt CO_2-e (16.0 per cent) to energy emissions.

1990–2013

In 2013, emissions from the Energy sector had increased by 31.9 per cent (7,664.3 kt) above the 1990 level of 23,994.6 kt CO_2-e. This growth in emissions is primarily from *Road transportation*, which increased by 5,197.0 kt CO_2-e (69.4 per cent), and *Public electricity and heat production*, which increased by 1,550.1 kt CO_2-e (44.4 per cent). Emissions from manufacture of solid fuels and other energy industries have decreased by 1,253.1 kt CO_2-e (49.9 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997.

2012–2013

Between 2012 and 2013, emissions from the Energy sector decreased by 1,036.3 kt CO_2-e (3.2 per cent). This decrease is primarily due to a decrease in emissions from *Public electricity and heat production*. Due to higher hydro inflows in 2013 compared to 2012, the share of electricity generated from renewable energy sources in the national energy grid increased from 73 per cent in 2012 to 75 per cent in 2013. This resulted in decreased gas and coal-based electricity generation over the year. Electricity generation from coal decreased 33 per cent from 2012.

There was also a 261 kt CO_2-e (11 per cent) decrease in fugitive emissions from the Energy sector. This was due to reduced activity in *Coal mining and handling*, as well as reductions in natural gas and venting and flaring.

Industrial processes and product use (chapter 4)

2013

In 2013, New Zealand's Industrial Processes and Product Use (IPPU) sector produced 5,071.5 kt CO_2-e, contributing 6.3 per cent of New Zealand's total greenhouse gas emissions. The largest source of emissions in this sector is the *Metal industry* category (CO_2 and a small amount of PFCs), contributing 45.9 per cent of emissions from the IPPU sector in 2013.

1990–2013

In 2013, emissions from the IPPU sector increased by 1,795.5 kt CO_2-e (54.8 per cent) above the 1990 level of 3,276.0 kt CO_2-e. This increase was largely driven by emissions from the *Product uses as substitutes for ODS*[4] category, with an increase in these emissions of 1,615.2 kt CO_2-e. This is driven by hydrofluorocarbon emissions, which have increased because of their use as a substitute for chlorofluorocarbons, as these were phased out under the Montreal Protocol. Also, CO_2 emissions from the *Mineral industry*, *Chemical industry* and *Metal industry* categories have gradually increased due to increasing product outputs. These increases have been partially offset by a reduction in emissions of PFCs from aluminium production, due to improved control of anode effects in aluminium smelting.

2012–2013

Since 2012, emissions from the IPPU sector increased by 115.9 kt CO_2-e (2.3 per cent). The change was the result of combined increases in emissions from the *Product uses as substitutes for ODS* (51.6 kt CO_2-e, 3.3 per cent increase), as well as small increases in CO_2 emissions from the *Metal industry* (42.0 kt CO_2-e, 1.8 per cent) and *Mineral industry* (19.7 kt CO_2-e, 2.6 per cent).

[4] ODS – Ozone Depleting Substances.

Agriculture (chapter 5)

2013

New Zealand has an unusual emissions profile amongst developed countries, with the Agriculture sector being the largest source of emissions. In 2013 this sector contributed 39,177.3 kt CO_2-e (48.4 per cent of total emissions). In Annex I countries, agricultural emissions average around 12 per cent of total emissions.

The largest sources of emissions from the Agriculture sector in 2013 were from *Enteric fermentation* (CH_4 emissions, 72.6 per cent of the total emissions from the sector) and from *Agricultural soils* (N_2O emissions, 21.5 per cent of the total emissions from the sector).

1990–2013

In 2013, New Zealand's Agriculture sector emissions increased by 4,826.7 kt CO_2-e (14.1 per cent) from the 1990 level of 34,350.6 kt CO_2-e. The increase is primarily due to a 2,130.9 kt CO_2-e (8.1 per cent) increase in methane (CH_4) emissions from the *Enteric fermentation* category and a 1,578.7 kt CO_2-e (23.0 per cent) increase in nitrous oxide (N_2O) emissions from the *Agricultural soils* category. The key drivers for this change in emissions are an increase of 88.4 per cent in the dairy cattle population since 1990 and a five-fold increase in synthetic fertiliser nitrogen (N) applied during this time. A decrease of 46.8 per cent in the sheep population partially offset these increases.

2012–2013

Total agricultural emissions in 2013 were 170.2 kt CO_2-e (0.4 per cent) lower than the 2012 level. This is most likely attributable to the drought during early 2013 that affected key pastoral areas.

The dairy cattle population increased between 2012 and 2013 (37,920, 0.6 per cent), compared with a larger population increase in the previous year (271,178, 4.4 percent). There was a 467.0 kt CO_2-e (2.7 per cent) increase in emissions from dairy cattle of 17,575.5 kt CO_2-e in 2013 compared with emissions of 17,108.5 kt CO_2-e in 2012.

There was a decrease in emissions of 468.1 kt CO_2-e (2.4 per cent) from non-dairy cattle, sheep and deer in 2013 compared with 2012. The populations of non-dairy cattle, sheep and deer decreased between 2012 and 2013. The longer-term increase in the dairy cattle population and the reduction in non-dairy cattle, sheep and deer numbers (figures 5.1.3a and b) are primarily due to higher relative returns being achieved in the dairy sector.

There was also a decrease of 142.6 kt CO_2-e (20.9 per cent) in emissions from agricultural liming in 2013 compared with 2012, which is consistent with the long-term trend of decreasing limestone use.

LULUCF (chapter 6)

The following information on Land Use, Land-Use Change and Forestry (LULUCF) summarises reporting under the Climate Change Convention. Article 3.3 and Article 3.4 LULUCF activities under the Kyoto Protocol are covered in ES.5 below.

2013

In 2013, net emissions from the LULUCF sector under the Climate Change Convention were –26,761.1 kt CO_2-e (figure ES 4.1.5). The highest contribution to removals in 2013 (21,299.0 kt CO_2-e) was from *Land converted to forest land*. This is largely due to the removals from the growth of first rotation forests.

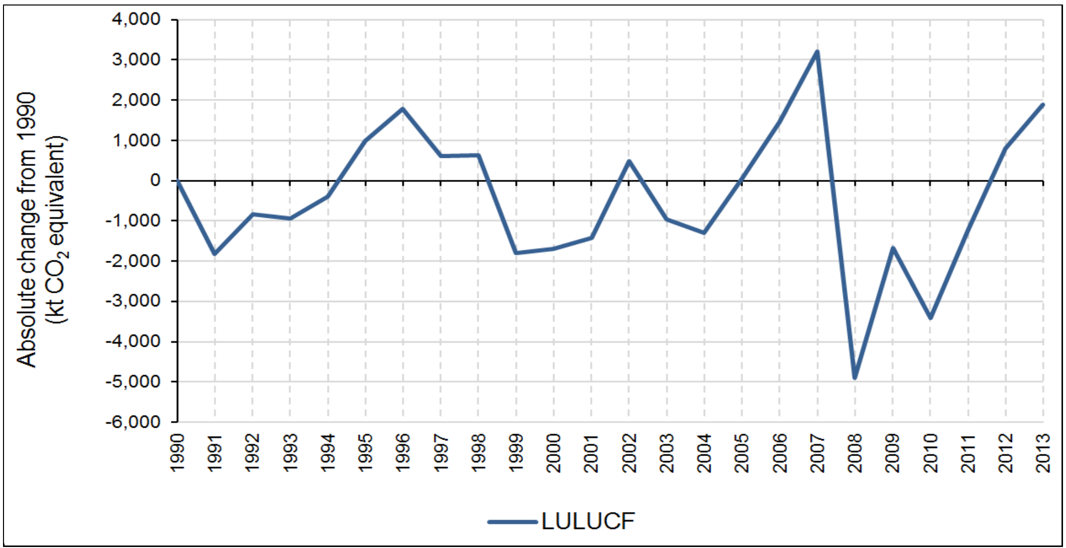
The largest source of emissions in LULUCF is from *Land converted to grassland*. In 2013, net emissions for *Land converted to grassland* contributed 4,874.2 kt CO_2-e. This is largely due to the emissions from loss of living biomass on land conversion.

1990–2013

From 1990 to 2013, net emissions from LULUCF increased by 1,893.3 kt CO_2-e (6.6 per cent) from the 1990 level of –28,654.5 kt CO_2-e. This increase in net emissions is largely the result of increased harvesting as a larger proportion of the production forest estate reaches harvest age.

The fluctuations in net emissions from LULUCF (figure ES 4.1.5) are influenced by harvesting and deforestation rates. Harvesting rates are driven by a number of factors, particularly tree age and log prices. Deforestation rates are driven largely by the relative profitability of forestry compared with alternative land uses. The increase in net emissions between 2004 and 2007 was largely due to the increase in planted forest deforestation that occurred leading up to 2008, before the introduction of the New Zealand Emissions Trading Scheme (NZ ETS).[5]

Figure ES 4.5 New Zealand's LULUCF sector net removals from 1990 to 2013



2012–2013

Between 2012 and 2013, net emissions from the LULUCF sector increased by 1,087.7 kt CO_2-e (3.9 per cent). The main contributor to the change occurred within the *Forest land* category, as a greater proportion of forest land reached harvest age in 2013 compared with 2012 (due to the age structure of New Zealand's production forests). Emissions have also increased for *Land converted to grassland* due to the area of forest land being converted to grassland being larger in 2013 than in 2012.

5 The NZ ETS included the Forestry sector as of 1 January 2008.

Waste (chapter 7)

The Waste sector contributed 5,054.0 kt CO_2-e (6.2 per cent) to total emissions in 2013.

Emissions from the Waste sector have decreased by 45.0 kt CO_2-e (0.9 per cent) from the 1990 level of 5,099.0 kt CO_2-e. This was the result of improved landfill management practices, particularly methane recovery. These improvements offset an increase in the total amount of solid waste disposed on land and increases in emissions from wastewater handling (in both the industrial and domestic sectors).

ES.5 Activities under Article 3.3 and 3.4 of the Kyoto Protocol (chapter 11)

Estimates of emissions and removals for activities under Article 3.3 and forest management under Article 3.4 of the Kyoto Protocol are included in the Inventory (table ES 5.1.1).

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2013 was 659,332 hectares. The net area is the total area of post-1989 forest (682,189 hectares) minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (22,857 hectares). Net removals from this land in 2013 were 17,057.4 kt CO_2-e.

Deforestation

The area deforested between 1 January 1990 and 31 December 2013 was 168,024 hectares. The area subject to deforestation in 2013 was 8,453 hectares. In 2013, deforestation emissions were 4,892.2 kt CO_2-e. Deforestation emissions include non-CO_2 emissions and lagged CO_2 emissions that occurred in 2013 as a result of deforestation since 1990.

Forest management

The net area reported under forest management as at the end of 2013 was 9,272,279 hectares. This represents 34.4 per cent of New Zealand's total land area. Removals for this area in 2013 are estimated as 9,029.9 kt CO_2-e. Reporting of emissions on forest management land is against a business-as-usual reference level, which means emissions below the reference level will be excluded from New Zealand's accounting during the period 2013 to 2020. Removals are also capped at 3.5 per cent of total emissions in the base year. Removals can only be claimed up to this level.

Natural disturbance

For the second commitment period countries who elect to, can exclude emissions from natural disturbance from their accounting. In accounting for its target under the Convention, New Zealand has chosen to elect this provision but is not excluding any emissions due to natural disturbance in 2013.

Table ES 5.1 New Zealand's net emissions and removals under Article 3.3 and 3.4 of the Kyoto Protocol

Activity	Gross area (ha) 1990–2013	Net area (ha) 2013	Emissions in 2013 (kt CO_2-e)
Afforestation/reforestation	682,189	659,332	–17,057.37
Deforestation	168,024	8,453	4,892.17
Forest management		9,272,279	–9,029.93
Net emissions			–21,195.12
Excluded emissions from natural disturbances		0	0
Forest management reference level			11,150
Forest management cap			2,333.8
Accounting quantity			–12,165.2

Note: The areas stated are as at 31 December 2013. Net 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. Deforestation includes deforestation of natural forest, pre-1990 planted forest and post-1989 forest. The accounting quantity is calculated by applying the accounting rules from Decision 2, CMP.7 to net emissions.

ES.6 Improvements introduced

According to the reporting requirements under the Climate Change Convention (UNFCCC, 2013a), the Inventory uses methodologies recommended by the IPCC 2006 Guidelines (IPCC, 2006). The new guidelines introduced some changes in methodology, categorisation of emission sources and the new set of the global warming potentials (as per the IPCC 4th Assessment Report). A web-based version of the UNFCCC compilation software (CRF Reporter) has also been introduced. This resulted in a significant amount of mandatory changes and recalculations in all inventory sectors.

In addition, following the 2013 submission and its review in September 2014,[6] improvements in the accuracy of emissions and removals were made in the Energy, Agriculture, IPPU, LULUCF and Waste sectors. Chapter 10 provides a summary of all recalculations made to the estimates.

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

Energy (section 3.3.1)

In addition to changes implemented in the Energy sector due to the shift to IPCC 2006 guidelines, a number of changes have been made to improve the accuracy, completeness and transparency of the Inventory. The most significant changes are:

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

[6] The Assessment Review Report resulted from the 2014 Inventory publication, and was not published until March 2015.

in 1.AA.2.C Chemicals. Further details are included chapter 4 (IPPU). The calculation of emissions resulting from combustion of the energy-use gas uses default emission factors.

Industrial Processes and Product Use (section 4.1.5)

Improvements in the IPPU sector that were not the result of alignment with the new IPCC 2006 guidelines were focussed on improving transparency in reporting emissions of fluorine-containing gases and resolving previously noted cross-sectoral issues.

- Further recalculation of emission estimates from HFC134a that was imported in 2011–2012 and used through 2013. The previous estimates have been revised now, since 2013 data is available.
- Implementation of changes in the activity data due to improved information on the increasing use of hydrocarbon and other alternative refrigerants in New Zealand (from the latest industry surveys).
- Improvement in activity data in the Other SF_6 Applications subcategory to include newly available information.
- Improvement in emission estimates of SF_6 from the electrical equipment subcategory, based on the reassessments of the SF_6 stock provided by New Zealand companies.
- Analysis and mitigation of small discrepancies between the data provided by companies in their NZ ETS returns and their returns to the Ministry of Business, Innovation and Employment for the purposes of the Inventory.

Agriculture (sections 5.1.4–5.1.6)

Two major changes to methodology included in the 2015 Inventory submission for the Agriculture sector are that the:

- country-specific N_2O emission factor for urea fertiliser has been amended from 0.01 to 0.0048 (the emission factor for non-urea synthetic fertiliser remains 0.01)
- parameter values for calculating nitrogen retention in cattle milk and deer velvet have been reduced.

New Zealand has also included additional data and reporting, for example, the data on CO_2 emissions from liming and urea, and has updated the modelling and emission factors in line with the requirement to meet IPCC 2006 guidelines (see section 5.1.5 for the detailed list).

LULUCF (section 6.1.5)

The main differences between this submission and estimates of New Zealand's LULUCF net removals reported in the 2014 Inventory are the result of (in decreasing order of magnitude):

- revised estimates of carbon stock change in pre-1990 natural forest, based on the first complete set of re-measurement data for these forests. This has accounted for an increase in emissions of around 10,000 kt CO_2-e annually for every year of the Inventory
- there has been a change to the pre-1990 planted forest age-class distribution. This has been recalibrated to more accurately reflect the latest available activity data
- the post-1989 and pre-1990 planted forest yield tables have been updated for the 2015 submission. The updates include reclassification of a small number of plots due

to mapping improvements, amendments to align with a revised estimate of net stocked area in both forest sub-categories, and the inclusion of a sub-set of previously unused plots in post-1989 planted forest

- continued improvements to the 1990, 2008 and 2012 land-use maps. Mapping data provided from the NZ ETS was integrated into the three maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest
- incorporating new data collected from post-1989 planted forests into the mineral soil organic carbon estimates. This changes not only the estimates for post-1989 planted forests but for other land uses also.

Waste (section 7.1.6)

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

- use of emission returns submitted under the NZ ETS in 2013 as the primary source for activity data for most landfills. This resulted in recalculation of activity data for 2010–12, since 2009 was the latest year for which surveyed data was available.
- ongoing use of waste placement data collected under the Waste Minimisation Act 2008 for other landfills and to improve the estimate of total waste disposal for New Zealand.

ES.7 National registry

In January 2008, New Zealand's national registry was issued with New Zealand's assigned amount of 309,564,733 metric tonnes CO_2-e. Table ES 7.1 summarises amounts of each type of units in the registry at the end of 2014. A detailed account of the transactions made to New Zealand's national registry during 2014 is presented in section 12.2 of the Inventory (table 2 (a), (b) and (c) in table 12.2.2).

Table ES 7.1 New Zealand's net emissions and removals under Article 3.3 and 3.4 of the Kyoto Protocol

Unit type	Amount in the New Zealand's registry in the end of 2014 *(metric tonnes)*
assigned amount units (AAUs)	305,777,516
emission reduction units (ERUs)	100,858,523
certified emission reduction units (CERs)	18,122,229
removal units (RMUs)	9,050,000

Executive summary: References

IPCC. 2006d. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1. General Guidance and Reporting.* IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan

UNFCCC. 2013a. FCCC/CP/2013/10/Add.3. *Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013, Addendum; Decision 24/CP.19 Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention.*

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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 AD) there has been a global increase in the atmospheric concentration of greenhouse gases, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (IPCC, 2013). This increase is attributed to human activity, particularly the burning of fossil fuels and land-use change. It is extremely likely that most of the global warming since the mid-20th century was caused by the increase in greenhouse gas concentrations and other human activities (IPCC, 2013). Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system.

1.1.1 United Nations Framework Convention on Climate Change

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

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

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

All countries that ratify the Climate Change Convention (the 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[7] to the Climate Change Convention commit to providing financial assistance to non-Annex I Parties (developing countries).

Annex I[8] 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

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

[8] 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'.

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 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 original objective of the Kyoto Protocol was to reduce the aggregate emissions of six greenhouse gases from Annex I Parties by at least 5 per cent below 1990 levels in the first commitment period (2008–2012). New Zealand's target in the first commitment period was to return emissions to 1990 levels[9] on average over the commitment period or otherwise take responsibility for the excess.

The eighth session of the Conference of the Parties, serving as the meeting of the Parties to the Kyoto Protocol (Doha, Qatar, November to December 2012), agreed amendments to the Kyoto Protocol for the second commitment period, including an amended Annex B for commitments for the second commitment period (2013–2020).

New Zealand took a target under the Climate Change Convention during the transition period to 2020 and therefore does not have a commitment listed in the amended Annex B of the Kyoto Protocol for the second commitment period. However, New Zealand will apply the Kyoto Protocol framework of rules to its 2020 target.

When reporting emissions from the LULUCF sector, New Zealand will continue to use a land-based approach, as required by Good Practice Guidance for LULUCF. For 2013–2020, as a Party to the Kyoto Protocol, New Zealand will complete activity-based reporting under Article 3.3 of the Kyoto Protocol for afforestation, reforestation and deforestation, and forest management under Article 3.4.

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, 2006d) and reporting guidelines agreed by the Conference of the Parties to the Climate Change Convention. The most recent reporting guidelines are FCCC/CP/2013/10/Add.3 (UNFCCC, 2013a). As per the UNFCCC reporting guidelines, New Zealand followed the IPCC 2006 guidelines in the preparation of the 2015 Inventory submission.

A complete inventory submission requires two components: the national Inventory report and the common reporting format tables. Inventories are subject to an annual two-stage

9 New Zealand's target under the Kyoto Protocol was 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 was based on total gross emissions from the Energy, Industrial Processes, Solvent and Other Product Use, Agriculture and Waste sectors.

international expert review process administered by the Climate Change Convention secretariat. The results of these reviews are available online (www.unfccc.int).

The Inventory reports emissions and removals of the gases CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). 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, SF_6 and NF_3) are reported in total emissions under the Climate Change Convention and accounted for under the Kyoto Protocol. The gases are reported under five sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); and Waste.

Reporting on afforestation, reforestation and deforestation activities since 1990 (Article 3.3 activities under the Kyoto Protocol) and forest management (under Article 3.4 of the Kyoto Protocol) are mandatory during the second commitment period of the Kyoto Protocol. Afforestation, reforestation, deforestation and forest management activities are defined below. The definitions are consistent with decision 16/CMP.1 (UNFCCC, 2005a).

1.1.4 Supplementary information required

Under Article 7.1 of the Kyoto Protocol, New Zealand is required to include supplementary information in its annual Inventory submission.

The supplementary information required includes:

- information on emissions and removals for each activity under Article 3.3, forest management under Article 3.4, 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 A description of the national inventory arrangements

1.2.1 Legal and procedural arrangements

The Climate Change Response Act 2002 (amended 1 January 2013) enables New Zealand to meet its international obligations under the Climate Change Convention and Kyoto Protocol. A Prime Ministerial directive for the administration of the Climate Change Response Act 2002 names the Ministry for the Environment (MfE) as New Zealand's 'Inventory Agency'. Part 3, section 32 of the Climate Change Response Act 2002 specifies the following functions and requirements:

1. The primary functions of the inventory agency, are to:
   - estimate annually New Zealand's anthropogenic emissions by sources and removals by sinks, of greenhouse gases
   - prepare the following reports for the purpose of discharging New Zealand's obligations:

i. New Zealand's annual Inventory report under Article 7.1 of the Protocol, including (but not limited to) the quantities of long-term certified emission reduction units and temporary certified emission reduction units that have expired or have been replaced, retired, or cancelled

ii. New Zealand's national communication (or periodic report) under Article 7.2 of the Kyoto Protocol and Article 12 of the Climate Change Convention

iii. New Zealand's report for the calculation of its initial assigned amount under Article 7.4 of the Kyoto Protocol, including its method of calculation.

2. In carrying out its functions, the inventory agency must:

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

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

1.2.2 Institutional arrangements, inventory management and planning

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

New Zealand has developed National Inventory System Guidelines that document the tasks required for making an official submission, starting from the submission of the previous year. The guidelines cover multiple aspects of the national Inventory production: planning, inventory process, quality assurance and control, communication and error management.

The MfE is New Zealand's single national entity for the Inventory, responsible for the overall development, compilation and submission of the inventory to the Climate Change Convention secretariat. The Ministry coordinates all of the government agencies and contractors involved in the Inventory. The national Inventory compiler is based at the MfE. 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 MfE calculates estimates of emissions for the IPPU sector, Waste sector, emissions and removals from the LULUCF sector and Article 3.3 and 3.4 activities under the Kyoto Protocol. Emissions of the non-CO_2 gases from the IPPU sector are obtained through industry surveys by consultants contracted by the MfE. The MfE compiles the various estimates for the IPPU sector.

The Ministry of Business, Innovation and Employment (MBIE) collects and compiles all emissions from the Energy sector and CO_2 emissions from the IPPU sector.

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

The MfE chairs a cross-agency Reporting Governance Group that provides leadership over the reporting, modelling and projections of greenhouse gas emissions and removals. Membership includes representation from the MfE, the Environmental Protection Authority (EPA), MPI and MBIE. The key roles and expectations of the Reporting Governance Group include:

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

New Zealand's national statistical agency, Statistics New Zealand, provides many of the official statistics for the Agriculture sector through regular agricultural censuses and surveys. Activity data on lime application and livestock slaughtering is also sourced from Statistics New Zealand. Population census data from Statistics New Zealand are used in the Waste and Industrial Processes and Product Use sectors.

The Climate Change Response Act 2002 establishes the requirement for a registry and a registrar. The EPA 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.

1.2.3 Quality assurance and quality control

Quality assurance and quality control are integral parts of preparing New Zealand's Inventory. The MfE developed a quality assurance and control plan in 2004, as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006; UNFCCC, 2013a) 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 2015 Inventory submission are discussed in the relevant sections below. Examples of quality-control checks are provided in the MS Excel spreadsheets accompanying this submission.

Quality control

For this submission, the completion of the IPCC 2006 Tier 1 quality control check sheets for each sector was the responsibility of the leading agency (MfE). The Tier 1 checks are based on the procedures suggested in the IPCC guidelines (IPCC, 2006d). All key categories for the 2015 Inventory year were checked.

Sectoral quality control processes and procedures have been revised and thoroughly documented in the updated version of New Zealand's National Systems Guidelines. Wherever possible, human checks have been replaced by automated electronic checks covering 100 per cent of the data in each checked data file.

All sector level data were entered into the web-based common reporting format database by sector compilers. This deadline allowed time for the agencies leading each sector to complete their own quality-control activities.

The sectoral contributions to the Inventory and Tier 1 quality-control checks were signed off by the responsible agency prior to final approval of the inventory and submission to the UNFCCC.

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

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.

For the 2015 Inventory, additional consultations with inventory experts from Australian, German and Austrian inventory agencies were conducted by means of bilateral meetings and follow-up document exchanges.

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

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

Prioritisation of improvements

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

Chapter 10 (section 10.2.1) details the five stages of New Zealand's planned improvement process, from identifying the improvement to acceptance into the Inventory.

Acceptance of improvements

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

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

Independent assessment

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

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

Independent agricultural inventory advisory panel

New Zealand has established an independent agricultural Inventory advisory panel to assess whether proposed changes are scientifically robust enough to be included in the Inventory. Reports and/or papers on proposed changes must be peer reviewed before they are presented to the panel. The panel advises the MPI of its recommendations. Refer to section 6.1.4 for further details.

Expertise

The technical competence of key contributors to the Inventory has continued to increase and with this comes the ability to provide more effective quality assurance on the Inventory before it is finalised for submission. One of the most effective ways that New Zealand experts improve their expertise is through participating in the Climate Change Convention inventory review process. During the reviews, experts can learn from each other and from the Party under review. New Zealand government officials who are UNFCCC-qualified inventory reviewers under the Climate Change Convention and the Kyoto Protocol include two lead reviewers, three Energy reviewers, two IPPU reviewers, one Agriculture reviewer, six LULUCF reviewers and two Waste reviewers. These experts are acting as sector compilers and, whenever possible, as peer reviewers before the sectoral Inventory chapters are finalised for the aggregate compilation by the national Inventory compiler.

The roles of the Agriculture and Energy sector compilers are well documented within respective sector-level manuals at the MPI and MBIE. There is also documentation for compiling the IPPU, LULUCF and Waste sectors. These are designed to help lower the risk of losing compiling knowledge.

Verification activities

Where relevant in a sector, verification activities are discussed under the appropriate section. Section 1.10 provides information about the verification that has become available for the Inventory from the New Zealand Emissions Trading Scheme (NZ ETS).

Treatment of confidentiality issues

Confidentiality issues largely apply to sources of emissions in the Energy and IPPU sectors. Confidential information is held by the EPA, the MfE and the MBIE. Each agency has security procedures (eg, restricted access to files on computers) to ensure this data is kept confidential.

UNFCCC annual inventory review

New Zealand's Inventory was reviewed in 2001 and 2002 as part of a pilot study of the technical review process (UNFCCC, 2001a; 2001b; 2001c; 2003). The Inventory was subject to detailed in-country, centralised and desk review procedures. The Inventories submitted for the years 2001 and 2003 were reviewed in a centralised review process. The 2006 Inventory submission was reviewed as part of the Kyoto Protocol initial review (UNFCCC, 2007). This was an in-country review held from 19–24 February 2007. The 2007–09 and 2011–13 Inventory submissions were reviewed during centralised reviews (UNFCCC, 2009; 2010; 2012; 2013; 2014). The 2010 Inventory submission was subject to an in-country review in August–September 2010 (UNFCCC, 2011). In all instances, the reviews were coordinated by the Secretariat and were conducted by an international team of experts nominated by Parties to the Climate Change Convention Roster of Experts. Review reports are available from the Climate Change Convention website (www.unfccc.int).

New Zealand has consistently met the reporting requirements under the Climate Change Convention and Kyoto Protocol. The submission of the Inventory to the Climate Change Convention secretariat has consistently met the required deadline under decision 15/CMP.1. The latest published expert review report (UNFCCC, 2014, pp 26–27) concluded that:

- *The inventory submission of New Zealand is complete (categories, gases, years and geographical boundaries and contains both an NIR and CRF tables for 1990–2011)*
- *The inventory submission of New Zealand has been prepared and reported in accordance with the UNFCCC reporting guidelines.*
- *The Party's inventory is in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories and the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry*
- *The ERT concluded that the Party's national system continues to be in accordance with the requirements of national systems outlined in decision 19/CMP.1.*
- *New Zealand's national registry continues to perform the functions set out in the annex to decision 13/CMP.1 and the annex to decision 5/CMP.1 and continues to adhere to the technical standards for data exchange between registry systems in accordance with relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP).*

New Zealand's consistency in meeting the reporting and national systems requirements (for the Inventory and the registry) enabled New Zealand to remain eligible to participate in the Kyoto Protocol mechanisms throughout the first commitment period.

1.2.4. Changes in the national inventory arrangements since previous annual GHG inventory submission

No changes have been made in the legal or institutional arrangements in the national Inventory system since the last Inventory submission, in 2014.

Although there were no major changes in the structure of the national system, operational improvements designed to facilitate better quality of New Zealand's Inventory reports have occurred during the year. The following sections present an update on further steps in improving quality assurance, automatisation in New Zealand's Inventory system and processes, and in developing Inventory expertise.

1.3 Inventory preparation, data collection, processing and storage

Consistent with the Climate Change Convention reporting guidelines, each Inventory is submitted 15 months after the conclusion of the calendar year reported, allowing time for data to be collected and analysed. Over the period October to January, sectoral data is calculated and entered into the Climate Change Convention common reporting format database, and then sectoral peer review and quality checking occurs. As per section 1.2, each agency involved in sectoral compilation organises the data collection, modelling and processing for the sectors under their mandate.

During the initial phase of the Inventory preparation process, each sector lead prepares a project plan to ensure that they can submit the sectoral contribution to the national Inventory on time (usually the second week of February). Sector leads make arrangements with peer reviewers, data checkers, and RGG managers to ensure thorough quality control of the sectoral data and chapters through the inventory production cycle.

The national Inventory compiler at the MfE coordinates work involved in calculation of the level and trend uncertainties in relation to the total national emissions and emission trends, key category assessment, further quality checking and finalising the Inventory. Once the Inventory is finalised, it is approved for publication by the Climate Change Director prior to submission 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 MfE in a controlled file system. The published Inventory is available from the websites of the MfE and the Climate Change Convention.

To provide data security and recovery for the national Inventory files in the event of a disaster, a distributive strategy for storage is in place. This includes storing the Inventory files using different types of storage devices (network drives and physical devices) in different geographic locations. The changes to all files are backed up on a daily basis, and the entire system is backed up on a weekly basis. For more detailed information on data archiving and storage please refer to chapter 13.

1.4 Methodologies and data sources used

The guiding documents in Inventory preparation are the Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003), 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006d), the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC, 2014a), 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014b), the revised UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (UNFCCC, 2013a) and the Kyoto Protocol (UNFCCC, 2012a, 2013b) guidelines on reporting and review (UNFCCC 2005a–k). The concepts contained in the good practice guidance are implemented in stages, according to sector priorities and national circumstances.

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

- Tier 1 methods apply IPCC default emission factors and use IPCC default models for emissions and/or removals calculations
- Tier 2 methods apply country-specific emission factors and use IPCC default models for emissions and/or removals calculations
- Tier 3 methods apply country-specific emission factors and use country-specific models for emissions and/or removals calculations.

Energy (chapter 3, Annex 4): Emissions from the Energy sector are calculated using IPCC Tier 1 and 2 methods. Activity data is compiled from industry-supplied information by the MBIE. New Zealand-specific emission factors are used for CO_2 emission calculations, where available. Applicable IPCC default factors are used for CO_2 and non-CO_2 emissions where New Zealand emission factors are not available.

Industrial Processes and Product Use (chapter 4): Activity data and most of the CO_2 emission estimates are supplied directly to the MBIE by industry sources. The remaining CO_2 estimates are either sourced from emission returns submitted to the New Zealand Emission Unit Register or directly provided by the industry to the inventory agency. IPCC Tier 1 and 2 approaches and a combination of New Zealand-specific and IPCC default parameters are applied in the IPPU sector for the CO_2 estimates. Activity data for non-CO_2 gases is collected via an industry survey, and emissions are estimated by CRL Energy (CRL Energy Ltd, 2013). Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach, and SF_6 emissions from large users are estimated with the Tier 3a approach (IPCC, 2006a).

Agriculture (chapter 5, Annex 3a): Livestock population data are obtained from Statistics New Zealand through the Agricultural Production census and surveys. A Tier 2 (model) approach is used to estimate CH_4 emissions from dairy cattle, non-dairy cattle, sheep and deer. This methodology uses New Zealand animal productivity data from the MPI and independent organisations to estimate dry-matter intake and CH_4 production. The same dry-matter intake data are used to calculate N_2O emissions from animal excreta. The model is constantly being improved. New Zealand's modelling for the major livestock categories could be considered as approaching Tier 3, as country-specific data and monthly data intervals for livestock population, productivity and pasture quality are used.

A Tier 1 approach is used to calculate CH_4 and N_2O emissions from livestock species present in less significant numbers and emission contribution, with country-specific emission factors for swine and poultry. Activity data on liming are obtained from Statistics New Zealand and data on synthetic fertiliser are provided by the New Zealand Fertiliser Association. A Tier 2 (model) approach is used to calculate emissions from burning of agricultural residues. There is no rice cultivation in New Zealand or carbon dioxide emissions from other carbon-containing fertilisers.

Land Use, Land-Use Change and Forestry (LULUCF, chapters 6 and 11, Annex 3b): New Zealand uses a combination of Tier 1 and Tier 2 methodologies for estimating emissions and removals for the LULUCF sector under the Climate Change Convention, and Article 3.3 and 3.4 activities under the Kyoto Protocol. A Tier 2 approach has been used to estimate biomass carbon in the pools with the most living biomass at steady state; natural forest, pre-1990 planted forest, post-1989 forest, perennial cropland and grassland with woody biomass. A Tier 1 approach is used for estimating biomass carbon in all other land-use categories. A Tier 2 modelling approach has also been used to estimate carbon changes in the mineral soil component of the soil organic matter pool, while Tier 1 is used for organic soils.

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

- use of field plot measurements for natural and planted forests
- use of allometric equations and models to estimate carbon stock and carbon-stock change in natural and planted forests respectively (Holdaway et al, 2014; Beets et al, 2013; Paul et al, 2014)
- wall-to-wall land-use mapping for 1990, 2008 and 2012 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 7): Activity data for the Waste sector are estimated using waste survey data and information submitted under the NZ ETS and the Waste Management Act, combined with population data from Statistics New Zealand. Calculation of emissions from solid waste disposal uses the Tier 2 model from the IPCC 2006 guidelines. Methane and N_2O emissions from domestic and industrial wastewater handling are calculated using a refinement of the IPCC methodology (IPCC, 2006b). A combination of New Zealand-specific and IPCC default parameters are used for both the solid waste disposal and wastewater subcategories. There is no incineration of municipal waste in New Zealand. Emissions from incineration of medical, quarantine and hazardous wastes are estimated using the Tier 1 approach (IPCC, 2006b).

1.5 Key categories

1.5.1 Reporting under the Climate Change Convention

The IPCC *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2006d) identifies a key category as: “one that is prioritised within the national Inventory system because its estimate has a significant influence on a country’s total Inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both”. Key categories identified within the Inventory are used to prioritise Inventory improvements.

The key categories in the Inventory have been assessed using the Approach 1 level and trend methodologies from the IPCC 2006 guidelines (IPCC, 2006d). 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 2013 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 17.8 per cent
- CH_4 emissions from dairy cattle enteric fermentation; a contribution of 11.0 per cent
- CO_2 emissions from harvested wood products; a contribution of 8.5 per cent
- CH_4 emissions from sheep enteric fermentation; a contribution of 7.7 per cent.

The key categories that were identified as having the largest relative influence on the trend including LULUCF from 1990 to 2013, compared with the average change in net emissions from 1990 to 2013 (table 1.5.3(a)), were:

- CO_2 emissions from forest land remaining forest land; a contribution of 16.1 per cent
- CH_4 emissions from sheep enteric fermentation; contributed 13.4 per cent to the net emissions trend through a decrease
- CO_2 emissions from harvested wood products; contributed 13.0 per cent to the net emissions trend through an increase.
- CH_4 emissions from dairy cattle enteric fermentation; contributed 8.0 per cent to the net emissions trend through an increase

In the previous submission, CO_2 from *Ammonia production* was included as a key category based on a qualitative assessment. This assessment was based on the inclusion of CO_2 emitted when ammonia is processed into urea and used as fertiliser (see section 4.2.5 below). For this submission, fertiliser emissions are reported in the Agriculture sector, leaving a much smaller amount of CO_2 to be reported in the IPPU sector.

Table 1.5.1 Summary of New Zealand's key categories for the 2013 level assessment and the trend assessment for 1990 to 2013 (including and excluding LULUCF activities)

Quantitative method used: IPPC Tier 1			
CRF Code	**IPCC categories**	**Gas**	**Criteria for identification**
Energy			
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	level, trend
1.A.1.b	Energy Industries – Petroleum Refining – Gaseous Fuels	CO_2	trend
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	level, trend
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	level, trend
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	level, trend
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CO_2	level, trend
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CH_4	trend
1.B.1.a.i	Fugitive Emissions from Fuels – Coal Mining and Handling – Underground Mines	CH_4	trend
1.B.2.b.5	Fugitive Emissions from Fuels – Natural Gas – Distribution	CH_4	trend
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	level, trend
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at industrial plants and power stations	CH_4	level, trend
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	level, trend
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Gaseous Fuels	CO_2	level
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Liquid Fuels	CO_2	level
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Solid Fuels	CO_2	level
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	level, trend
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	level, trend

Quantitative method used: IPPC Tier 1			
CRF Code	**IPCC categories**	**Gas**	**Criteria for identification**
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Liquid Fuels	CO_2	trend
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Solid Fuels	CO_2	trend
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Gaseous Fuels	CO_2	level, trend
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Liquid Fuels	CO_2	level
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Solid Fuels	CO_2	level, trend
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	level, trend
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	level, trend
1.A.4.b	Other Sectors – Residential – Gaseous Fuels	CO_2	level, trend
1.A.4.b	Other Sectors – Residential – Solid Fuels	CO_2	trend
1.A.4.b	Other Sectors – Residential – Liquid Fuels	CO_2	level
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	level, trend
1.A.3.b	Transport – Road Transport – Gasoline	CO_2	level, trend
1.A.3.b	Transport – Road Transport – Liquefied Petroleum Gases	CO_2	trend
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	level, trend
1.A.3.b	Transport – Road Transport – Gaseous Fuels	CO_2	trend
1.B.1.a.ii	Fugitive Emissions from Fuels – Coal Mining and Handling – Surface Mines	CH_4	trend
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	level, trend
Agriculture			
3.D.A.4	Agricultural Soils – Direct N_2O Emissions – Crop Residues	N_2O	level
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	level, trend
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	level, trend
3.D.B.1	Agricultural Soils – Indirect N_2O Emissions – Atmospheric Deposition	N_2O	level
3.D.B.2	Agricultural Soils – Indirect N_2O Emissions – Nitrogen Leaching and Run-off	N_2O	level
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	level, trend
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	level, trend
3.A.4	Enteric Fermentation – Other – deer	CH_4	level
3.A.4	Enteric Fermentation – Other – goats	CH_4	trend
3.A.2	Enteric Fermentation – Sheep	CH_4	level, trend
3.G	Liming	CO_2	level, trend
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	level, trend
3.B.2	Manure Management – Sheep	CH_4	trend
3.H	Urea Application	CO_2	level, trend
IPPU			
2.B.10	Chemical industry – Other – Hydrogen Production	CO_2	level
2.C.3	Metal Industry – Aluminium Production	CO_2	level
2.C.3	Metal Industry – Aluminium Production	PFCs	trend
2.C.1	Metal Industry – Iron and Steel Production	CO_2	level, trend
2.A.1	Mineral Industry – Cement Production	CO_2	level
2.F.4	Product Uses as Substitutes for ODS – Aerosols	HFCs & PFCs	trend
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air	HFCs	level, trend

Quantitative method used: IPPC Tier 1			
CRF Code	**IPCC categories**	**Gas**	**Criteria for identification**
	Conditioning	& PFCs	
Waste			
5.A	Solid Waste Disposal	CH_4	level, trend
5.D	Wastewater Treatment and Discharge	CH_4	level
LULUCF			
4.B.1	Cropland Remaining cropland	CO_2	level
4.A.1	Forest Land Remaining Forest Land	CO_2	level, trend
4.C.1	Grassland Remaining Grassland	CO_2	level, trend
4.G	Harvested Wood Products	CO_2	level, trend
4.A.2	Land Converted to Forest Land	CO_2	level, trend
4.C.2	Land Converted to Grassland	CO_2	level, trend

Table 1.5.2 (a & b) **2013 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): 2013					
CRF Code	**IPCC categories**	**Gas**	**2013 estimate (kt CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
4.A.2	Land converted to forest land	CO_2	21,403.5	17.6	17.6
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	13,216.3	10.8	28.4
4.G	Harvested Wood Products	CO_2	10,295.6	8.4	36.9
3.A.2	Enteric Fermentation – Sheep	CH_4	9,223.3	7.6	44.4
1.A.3.b	Transport – Road Transport – Gasoline	CO_2	6,936.0	5.7	50.1
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	5,679.4	4.7	54.8
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	5,576.9	4.6	59.4
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	5,392.4	4.4	63.8
4.C.2	Land Converted to Grassland	CO_2	4,840.4	4.0	67.8
5.A	Solid Waste Disposal	CH_4	4,600.3	3.8	71.5
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	3,409.0	2.8	74.3
4.A.1	Forest Land Remaining Forest Land	CO_2	2,123.7	1.7	76.1
2.C.1	Metal Industry – Iron and Steel Production	CO_2	1,747.5	1.4	77.5
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	1,615.9	1.3	78.8
4.C.1	Grassland Remaining Grassland	CO_2	1,559.4	1.3	80.1
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air Conditioning	HFCs & PFCs	1,518.5	1.2	81.4
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Liquid Fuels	CO_2	1,313.4	1.1	82.4
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	1,295.6	1.1	83.5

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2013					
CRF Code	IPCC categories	Gas	2013 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Solid Fuels	CO_2	1,206.3	1.0	84.5
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	934.6	0.8	85.3
3.D.B.1	Agricultural Soils – Indirect N_2O Emissions – Atmospheric Deposition	N_2O	913.9	0.8	86.0
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	896.9	0.7	86.7
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	816.6	0.7	87.4
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	778.5	0.6	88.1
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CO_2	597.3	0.5	88.5
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	573.1	0.5	89.0
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Gaseous Fuels	CO_2	573.0	0.5	89.5
2.A.1	Mineral Industry – Cement Production	CO_2	568.6	0.5	89.9
3.A.4	Enteric Fermentation – Other – deer	CH_4	555.8	0.5	90.4
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	550.4	0.5	90.9
3.G	Liming	CO_2	540.1	0.4	91.3
2.C.3	Metal Industry – Aluminium Production	CO_2	533.8	0.4	91.7
3.D.B.2	Agricultural Soils – Indirect N_2O Emissions – Nitrogen Leaching and Run-off	N_2O	496.1	0.4	92.1
3.H	Urea Application	CO_2	490.0	0.4	92.5
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	411.7	0.3	92.9
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	374.7	0.3	93.2
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Liquid Fuels	CO_2	368.0	0.3	93.5
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	350.7	0.3	93.8
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	343.2	0.3	94.1
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	340.3	0.3	94.3
4.B.1	Cropland Remaining cropland	CO_2	339.5	0.3	94.6
1.A.2.d	Manufacturing Industries and	CO_2	327.5	0.3	94.9

(a) IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2013					
CRF Code	**IPCC categories**	**Gas**	**2013 estimate (kt CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
	Construction – Pulp, Paper and Print – Gaseous Fuels				
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	303.8	0.2	95.1

(b) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2013					
CRF Code	**IPCC categories**	**Gas**	**2013 estimate (kt CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	13216.3	16.3	16.3
3.A.2	Enteric Fermentation – Sheep	CH_4	9223.3	11.4	27.7
1.A.3.b	Transport – Road Transport – Gasoline	CO_2	6936.0	8.6	36.3
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	5679.4	7.0	43.3
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	5576.9	6.9	50.2
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	5392.4	6.7	56.8
5.A	Solid Waste Disposal	CH_4	4600.3	5.7	62.5
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	3409.0	4.2	66.7
2.C.1	Metal Industry – Iron and Steel Production	CO_2	1747.5	2.2	68.9
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	1615.9	2.0	70.9
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air Conditioning	HFCs & PFCs	1518.5	1.9	72.8
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Liquid Fuels	CO_2	1313.4	1.6	74.4
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	1295.6	1.6	76.0
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Solid Fuels	CO_2	1206.3	1.5	77.5
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	934.6	1.2	78.6
3.D.B.1	Agricultural Soils – Indirect N_2O Emissions – Atmospheric Deposition	N_2O	913.9	1.1	79.8
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	896.9	1.1	80.9
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	816.6	1.0	81.9
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	778.5	1.0	82.8
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production	CO_2	597.3	0.7	83.6

(b) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2013					
CRF Code	**IPCC categories**	**Gas**	**2013 estimate (kt CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
	– Other – Geothermal				
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	573.1	0.7	84.3
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Gaseous Fuels	CO_2	573.0	0.7	85.0
2.A.1	Mineral Industry – Cement Production	CO_2	568.6	0.7	85.7
3.A.4	Enteric Fermentation – Other – Deer	CH_4	555.8	0.7	86.4
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	550.4	0.7	87.1
3.G	Liming	CO_2	540.1	0.7	87.7
2.C.3	Metal Industry – Aluminium Production	CO_2	533.8	0.7	88.4
3.D.B.2	Agricultural Soils – Indirect N_2O Emissions – Nitrogen Leaching and Run-off	N_2O	496.1	0.6	89.0
3.H	Urea Application	CO_2	490.0	0.6	89.6
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	411.7	0.5	90.1
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	374.7	0.5	90.6
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Liquid Fuels	CO_2	368.0	0.5	91.0
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	350.7	0.4	91.5
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	343.2	0.4	91.9
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	340.3	0.4	92.3
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Gaseous Fuels	CO_2	327.5	0.4	92.7
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	303.8	0.4	93.1
1.A.4.b	Other Sectors – Residential – Gaseous Fuels	CO_2	301.6	0.4	93.5
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Solid Fuels	CO_2	293.1	0.4	93.8
5.D	Wastewater Treatment and Discharge	CH_4	272.4	0.3	94.2
2.B.10	Chemical industry – Other – Hydrogen Production	CO_2	252.4	0.3	94.5
3.D.A.4	Agricultural Soils – Direct N_2O Emissions – Crop Residues	N_2O	251.3	0.3	94.8
1.A.4.b	Other Sectors – Residential –	CO_2	187.4	0.2	95.0

(b) IPCC Tier 1 category level assessment – excluding LULUCF (total emissions): 2013					
CRF Code	IPCC categories	Gas	2013 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
	Liquid Fuels				

Table 1.5.3 (a & b) **1990–2013 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)							
CRF Code	IPCC categories	Gas	1990 estimate (kt CO_2-e)	2013 estimate (kt CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
4.A.1	Forest Land Remaining Forest Land	CO_2	9,539.4	2123.7	0.1	15.9	15.9
3.A.2	Enteric Fermentation – Sheep	CH_4	13,956.0	9223.3	0.1	13.2	29.1
4.G	Harvested Wood Products	CO_2	1,969.2	10295.6	0.1	13.0	42.1
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	5,951.6	13216.3	0.0	9.7	51.8
4.C.2	Land Converted to Grassland	CO_2	22.3	4840.4	0.0	7.9	59.7
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	1,423.8	5576.9	0.0	6.3	66.0
4.A.2	Land Converted to Forest Land	CO_2	18,858.2	21403.5	0.0	3.0	69.0
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	1,717.9	350.7	0.0	2.9	72.0
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	5,737.5	5392.4	0.0	2.8	74.7
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air Conditioning	HFCs & PFCs	0.0	1518.5	0.0	2.5	77.2
5.A	Solid Waste Disposal	CH_4	4,698.6	4600.3	0.0	2.0	79.2
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	474.8	1615.9	0.0	1.7	80.9
2.C.3	Metal Industry – Aluminium Production	PFCs	734.6	48.1	0.0	1.4	82.3
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	5,255.5	5679.4	0.0	1.3	83.6
1.A.2.g. viii	Manufacturing Industries and Construction – Other – Other non-specified – Solid Fuels	CO_2	731.1	167.8	0.0	1.2	84.9
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	217.7	934.6	0.0	1.1	85.9
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	531.3	1295.6	0.0	1.1	87.0
3.H	Urea Application	CO_2	39.2	490.0	0.0	0.7	87.7
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	390.1	896.9	0.0	0.7	88.4
1.A.4.b	Other Sectors – Residential – Solid Fuels	CO_2	344.9	30.6	0.0	0.7	89.1
4.C.1	Grassland Remaining Grassland	CO_2	964.5	1559.4	0.0	0.6	89.7
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and	CO_2	228.6	597.3	0.0	0.5	90.2

(a) IPCC Tier 1 category trend assessment – including LULUCF (net emissions)							
CRF Code	**IPCC categories**	**Gas**	**1990 estimate (kt CO_2-e)**	**2013 estimate (kt CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
	Other Emissions from Energy Production – Other – Geothermal						
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	2,999.6	3409.0	0.0	0.5	90.7
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	892.6	816.6	0.0	0.5	91.2
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	500.6	340.3	0.0	0.5	91.6
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Solid Fuels	CO_2	35.1	293.1	0.0	0.4	92.0
3.A.4	Enteric Fermentation – Other – Goats	CH_4	196.6	16.7	0.0	0.4	92.4
1.B.1.a.i	Fugitive Emissions from Fuels – Coal Mining and Handling – Underground Mines	CH_4	289.6	131.5	0.0	0.4	92.8
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	109.3	343.2	0.0	0.3	93.1
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	778.9	778.5	0.0	0.3	93.4
1.A.3.b	Transport – Road Transport – Gaseous Fuels	CO_2	140.3	0.0	0.0	0.3	93.7
1.B.2.b.5	Fugitive Emissions from Fuels – Natural Gas – Distribution	CH_4	277.5	185.2	0.0	0.3	94.0
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	331.5	550.4	0.0	0.2	94.2
2.C.1	Metal Industry – Iron and Steel Production	CO_2	1,306.7	1747.5	0.0	0.2	94.4
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	235.2	411.7	0.0	0.2	94.6
1.A.3.b	Transport – Road Transport – Liquefied Petroleum Gases	CO_2	102.1	17.0	0.0	0.2	94.8
1.A.1.b	Energy Industries – Petroleum Refining – Gaseous Fuels	CO_2	0.0	107.5	0.0	0.2	95.0
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	328.5	303.8	0.0	0.2	95.1

(b) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)							
CRF Code	**IPCC categories**	**Gas**	**1990 estimate (kt CO_2-e)**	**2013 estimate (kt CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
3.A.2	Enteric Fermentation – Sheep	CH_4	13,956.0	9223.3	0.1	21.9	21.9
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	5,951.6	13216.3	0.1	17.0	38.8
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	1,423.8	5576.9	0.0	10.9	49.7
1.A.1.c	Energy Industries – Manufacture of Solid Fuels	CO_2	1,717.9	350.7	0.0	4.9	54.7

(b) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)							
CRF Code	**IPCC categories**	**Gas**	**1990 estimate (kt CO_2-e)**	**2013 estimate (kt CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
	and Other Energy Industries – Gaseous Fuels						
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	5,737.5	5392.4	0.0	4.4	59.1
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air Conditioning	HFCs & PFCs	0.0	1518.5	0.0	4.3	63.4
5.A	Solid Waste Disposal	CH_4	4,698.6	4600.3	0.0	3.1	66.5
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	474.8	1615.9	0.0	2.9	69.5
2.C.3	Metal Industry – Aluminium Production	PFCs	734.6	48.1	0.0	2.4	71.9
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Solid Fuels	CO_2	731.1	167.8	0.0	2.0	73.9
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	5,255.5	5679.4	0.0	2.0	75.9
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	217.7	934.6	0.0	1.9	77.8
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	531.3	1295.6	0.0	1.8	79.6
3.H	Urea Application	CO_2	39.2	490.0	0.0	1.3	80.9
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	390.1	896.9	0.0	1.2	82.1
1.A.4.b	Other Sectors – Residential – Solid Fuels	CO_2	344.9	30.6	0.0	1.1	83.2
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CO_2	228.6	597.3	0.0	0.9	84.1
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	500.6	340.3	0.0	0.8	84.8
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	892.6	816.6	0.0	0.8	85.6
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Solid Fuels	CO_2	35.1	293.1	0.0	0.7	86.3
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	2,999.6	3409.0	0.0	0.7	87.0
3.A.4	Enteric Fermentation – Other – Goats	CH_4	196.6	16.7	0.0	0.6	87.6
1.B.1.a.i	Fugitive Emissions from Fuels – Coal Mining and Handling – Underground Mines	CH_4	289.6	131.5	0.0	0.6	88.2
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	109.3	343.2	0.0	0.6	88.8
1.A.3.b	Transport – Road Transport – Gaseous Fuels	CO_2	140.3	0.0	0.0	0.5	89.3
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	778.9	778.5	0.0	0.5	89.8
2.C.1	Metal Industry – Iron and Steel Production	CO_2	1,306.7	1747.5	0.0	0.5	90.2

(b) IPCC Tier 1 category trend assessment – excluding LULUCF (total emissions)							
CRF Code	IPCC categories	Gas	1990 estimate (kt CO_2-e)	2013 estimate (kt CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
1.B.2.b.5	Fugitive Emissions from Fuels – Natural Gas – Distribution	CH_4	277.5	185.2	0.0	0.4	90.6
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	331.5	550.4	0.0	0.4	91.1
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	235.2	411.7	0.0	0.4	91.4
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	382.9	573.1	0.0	0.3	91.7
1.A.1.b	Energy Industries – Petroleum Refining – Gaseous Fuels	CO_2	0.0	107.5	0.0	0.3	92.0
1.A.3.b	Transport – Road Transport – Liquefied Petroleum Gases	CO_2	102.1	17.0	0.0	0.3	92.3
3.G	Liming	CO_2	360.1	540.1	0.0	0.3	92.6
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Liquid Fuels	CO_2	52.0	163.6	0.0	0.3	92.9
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	328.5	303.8	0.0	0.3	93.2
1.A.3.b	Transport – Road Transport – Gasoline	CO_2	5,638.5	6936.0	0.0	0.3	93.5
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Gaseous Fuels	CO_2	347.3	327.5	0.0	0.3	93.7
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	232.9	374.7	0.0	0.3	94.0
2.F.4	Product Uses as Substitutes for ODS – Aerosols	HFCs & PFCs	0.0	91.6	0.0	0.3	94.2
1.B.1.a.ii	Fugitive Emissions from Fuels – Coal Mining and Handling – Surface Mines	CH_4	74.4	179.8	0.0	0.3	94.5
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CH_4	54.8	151.7	0.0	0.2	94.7
1.A.4.b	Other Sectors – Residential – Gaseous Fuels	CO_2	184.9	301.6	0.0	0.2	95.0
3.B.2	Manure Management – Sheep	CH_4	139.6	94.1	0.0	0.2	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 2013 year that correspond to the key categories for Article 3.3 or 3.4 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 and 3.4 activities under the Kyoto Protocol
Conversion to Forest Land	Afforestation and reforestation
Conversion to Grassland	Deforestation
Forest Land Remaining Forest Land	Forest Management

1.6 Inventory uncertainty

1.6.1 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, 2006d). Inventories prepared in accordance with IPCC guidelines (IPCC, 2006d) will typically contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable emissions such as N_2O fluxes from soils and waterways.

In this Inventory submission, New Zealand included a Tier 1 uncertainty analysis of the aggregated figures as required by the Climate Change Convention Inventory guidelines (UNFCCC, 2013) and IPCC good practice guidance (IPCC, 2006d). 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 A2.1.1). Table A2.1.2 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 2013 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 2013

The uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) is 13.1 per cent. This is a decrease of ± 0.2 per cent from 2012. Emissions of N_2O from agricultural soils (section 6.5), CH_4 from enteric fermentation and CH_4 from solid waste disposal contribute the highest levels of uncertainty. These categories accounted for ± 7.7 per cent, ± 5.6 per cent and ± 8.6 per cent, respectively, of New Zealand's total emissions uncertainty in 2013. The uncertainty in these categories reflects the inherent variability when estimating emissions from natural systems.

Uncertainty in the trend

The trend uncertainty in total emissions (excluding emissions and removals from the LULUCF sector) from 1990 to 2013 is ± 14.6 per cent. This is an increase of ± 3.5 per cent from the trend uncertainty for 2012. The increase in trend uncertainty is a result of revised activity and emission factor uncertainties.

Net emissions

Uncertainty in 2013

The calculated uncertainty for New Zealand's Inventory, including emissions and removals from the LULUCF sector in 2013 is ± 11.2 per cent. Emissions of CH_4 from solid waste disposal were a major contribution to the net uncertainty for 2013 at ± 5.7 per cent.

The overall uncertainty of national net emissions for 2013 has decreased by ± 6.6 per cent compared with the estimate provided for 2012 (±17.8 per cent). This change is mainly due to updated uncertainty estimates for activity data in many categories.

Uncertainty in the trend

When emissions and removals from the LULUCF sector are included, the overall uncertainty in the trend from 1990 to 2013 is ±11.2 per cent. This is an increase of ±2.2 per cent from the trend uncertainty calculated in 2012. Updated uncertainty estimates for activity data have contributed to this change.

1.6.2 LULUCF activities under the Kyoto Protocol

The combined uncertainty for emissions from afforestation and reforestation activities in 2013 was 6.3 per cent. The uncertainty introduced into net emissions from deforestation in 2013 was 2.4 per cent. The uncertainty introduced into net emissions from forest management in 2013 was 9.5 per cent. Combining these uncertainties gives a total uncertainty estimate for LULUCF activities under the Kyoto Protocol of 42.9 per cent.

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

1.7 Inventory completeness

1.7.1 Reporting under the Climate Change Convention

The Inventory for the period 1990–2013 is complete. In accordance with the IPCC guidelines (IPCC, 2006d), 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 MfE's website (www.mfe.govt.nz/publications/climate).

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

1.7.2 LULUCF activities under the Kyoto Protocol

New Zealand has included all carbon pools for Article 3.3 activities and Article 3.4 forest management activities under the Kyoto Protocol.

1.8 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 2014, New Zealand's national registry held 305,777,516 Assigned Amount Units (AAUs), 79,861,097 emissions reduction units, 10,854,195 certified emission reduction units and 9,050,000 removal units (table 1 in table 12.2.2).

At the end of 2014, there were 305,777,516 AAUs, 100,858,523 emission reduction units, 18,122,229 certified emission reduction units and 9,050,000 removal units held in the New Zealand registry (table 4 – a subpart of table 12.2.2). A detailed account of the transactions made to New Zealand's national registry during 2014 is presented in section 12.2 of the inventory (table 2 (a), (b) and (c) – all sub-parts in table 12.2.2).

New Zealand's national registry did not hold any temporary certified emission reduction units or long-term certified emissions reduction units during 2014 (table 4 in section 12.2.2).

During 2014, no Kyoto Protocol units expired or were replaced or cancelled.

1.9 New Zealand's Emissions Trading Scheme

The New Zealand Emissions Trading Scheme (NZ ETS) is New Zealand's principal policy response to climate change. The following sections explain how the domestic New Zealand Unit (NZU) relates to international units and how the data collected for the NZ ETS has been used to verify CO_2 emissions in the Energy and IPPU sectors.

1.9.1 The New Zealand Unit

In 2008, New Zealand established the NZ ETS. The NZ ETS places obligations on certain industries to account for the greenhouse gas emissions that result from their activities. The Climate Change Response Act 2002 (amended 2008) states which sectors are mandatory participants in the NZ ETS – those that generate emissions and that have an obligation to surrender emission units. The NZ ETS is based around a trade in units that represent a tonne of CO_2-e. The primary unit of trade is the NZU, which is the unit created and distributed by the New Zealand Government.

NZUs are issued into the New Zealand Registry by the New Zealand Government. New Zealand decided to leverage off and extend its Kyoto Protocol national registry to incorporate the requirements under the NZ ETS. Most significantly, this meant the issuance of NZUs into 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 to eligible individuals or firms in specific sectors, or awards them to individuals or firms conducting approved removal activities (such as the establishment of forests). The Government also has the ability to auction NZUs, but has not yet done so. When sectors enter the NZ ETS, participants are required to record and report the greenhouse gas emissions for which they have obligations or the removals for which they can claim NZUs. Participants with obligations are able to surrender NZUs or approved Kyoto units to cover their emissions. The methods for estimating emissions are set out in regulations prescribed under the Climate Change Response Act 2002 (and its amendments).

Trading NZUs for international units

NZUs can be traded within New Zealand. Under current legal settings (section 178C of the New Zealand's Climate Change Response Act (CCRA) 2002), 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.

1.9.2 Verification

For this submission, data collected for the NZ ETS was used to verify the Inventory estimates for CO_2 emissions in the Energy and IPPU sector (see chapters 3 and 4 for further detail of the verification), with the exception of the Waste sector. When sectors enter the NZ ETS, participants are required to record and report the greenhouse gas emissions for which they have obligations, or the removals for which they can claim NZUs. Participants with obligations are also required to surrender NZUs or other Kyoto units to cover their emissions annually. How participants estimate their emissions is set out in the regulations prescribed under the Climate Change Response Act 2002 (amended in 2012). The schedule for sectors entering the NZ ETS is detailed in table 1.10.1.

In the Waste sector, the ETS was used as a primary source for activity data on municipal waste disposal. Data reported under the Waste Minimisation Act has been used for verification, and as primary data for smaller landfill sites (see chapter 7 for details).

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

Sector	Voluntary reporting	Mandatory reporting	Obligations
Forestry	–	–	1 January 2008
Transport fuels	–	1 January 2010	1 July 2010
Electricity production	–	1 January 2010	1 July 2010
IPPU	–	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	

1.10 Improvements introduced

This Inventory submission includes improved estimates of emissions and removals compared with the 2014 Inventory submission, resulting in a number of recalculations to the estimates. Some changes and alterations have been made due to shifting to the 2006 IPCC guidelines. Recalculations of estimates reported in the previous Inventory were due to improvements in:

- activity data
- emission factors and/or other parameters
- methodology
- additional sources identified within the context of the good practice guidance (IPCC, 2000 and 2003), 2006 IPCC guidelines (IPCC, 2006d), 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use (IPCC, 2006c), 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1. General Guidance and Reporting (IPCC, 2006d), 2013

Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC, 2014a) and 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2014b)

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

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

The largest improvements in the accuracy of emissions and removals made to the Inventory following the 2014 Inventory submission and the Centralised Inventory review in September 2014 were made in the LULUCF, Agriculture, IPPU and Waste sectors. Chapter 10 provides a summary of all recalculations made to the estimates.

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

LULUCF (sections 6.1.5)

The main differences between this submission and previous estimates of New Zealand's LULUCF net removals reported in the 2014 Inventory submission are the result of (in decreasing order of magnitude):

- revised estimates of carbon stock change in pre-1990 natural forest based on the first complete set of re-measurement data for these forests. Carbon stock change estimates in this report are based on results of the latest analysis, presented in Holdaway et al (2014). This has accounted for an increase in emissions of around 10,000 kt CO_2-e annually for every year of the Inventory

- there has been a change to the pre-1990 planted forest age-class distribution. This has been recalibrated to more accurately reflect the latest available activity data (Wakelin and Paul, 2012; Paul et al, 2014)

- the post-1989 and pre-1990 planted forest yield tables have been updated for the 2015 submission. The updates include reclassification of a small number of plots due to mapping improvements, amendments to align with a revised estimate of net stocked area in both forest sub-categories, and the inclusion of a sub-set of previously unused plots in post-1989 planted forest

- continued improvements to the 1990, 2008 and 2012 land-use maps. Mapping data provided from the New Zealand Emissions Trading Scheme (NZ ETS) was integrated into the three maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest

- incorporating new data collected from post-1989 planted forests into the mineral soil organic carbon estimates. This changes not only the estimates for post-1989 planted forests but for other land uses also (McNeill and Barringer, 2014).

Energy (section 3.3.1)

In addition to changes implemented in the 2015 submission in the Energy sector due to the shift to IPCC 2006 guidelines, a number of changes have been made to improve the accuracy, completeness and transparency of the Inventory. The most significant changes are:

- Production of methanol has been moved from 1.AA.2.C Chemicals to 2. Industrial processes and Product Use. This is in response to the 2013 ERT recommendation.

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

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

Agriculture (sections 5.1.4–5.1.6)

Two major changes to the inventory methodology in the Agriculture sector are included in the 2015 Inventory submission:

- The country-specific N_2O emission factor for urea fertiliser has been amended from 0.01 to 0.0048 (the emission factor for non-urea synthetic fertiliser remains 0.01).
- The parameter values for calculating nitrogen retention in cattle milk and deer velvet have been reduced.
- New Zealand has also included additional data and reporting, for example, the data on CO_2 emissions from liming and urea, and has updated the modelling and emission factors in line with the requirement to meet IPCC 2006 guidelines (see section 5.1.5 for the detailed list).

Industrial Processes and Product Use (section 4.1.5)

Major improvements in the IPPU sector, which were not the result of alignment with the new IPCC 2006 guidelines, were focusing on improving transparency in reporting emissions of fluorine-containing gases, and resolving previously noted cross-sectoral issues.

- Further recalculation of emission estimates from HFC134a that were imported in 2011–2012 and used through 2013. The previous estimates of emissions in 2011–2012 have been revised since 2013 data are now available.
- Implementation of changes in the activity data due to improved information on the increasing use of hydrocarbons and other alternative refrigerants for household and industrial refrigeration in New Zealand (from the latest industry surveys).
- Improvement in activity data in the Other SF_6 Applications subcategory to include newly available information.
- Improvement in emission estimates of SF_6 from the electrical equipment subcategory, based on the reassessments of the SF_6 stock provided by New Zealand companies.
- Analysis and mitigation of discrepancies in CO_2 emissions in the metal industry, between the data provided by companies in their NZ ETS returns and those in their returns to MBIE for the purposes of the Inventory.

Waste (section 7.1.6)

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

- Use of emission returns submitted under the NZ ETS in 2013 as the primary source for activity data for most landfills. This resulted in recalculation of activity data for 2010–2012, since 2009 was the last year for which surveyed data on disposal to individual landfill sites was available.

- Ongoing use of waste placement data collected under the Waste Minimisation Act 2008 for smaller or remote landfills that are not NZ ETS participants, and to improve the estimates of total waste disposal for New Zealand.

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Chapter 2: Trends in greenhouse gas emissions

2.1 Emission trends for aggregated greenhouse gas emissions

This chapter describes trends for aggregated GHG emissions by gas. For each gas, interpretation of the emission trends is based on the contributing Inventory sectors and major categories. Emission trends for each Inventory sector can also be found in the Executive Summary (section ES4) and in chapters 3–7 of this report, as a part of each sector overview.

2.1.1 National trends

Total (gross) emissions

Total (gross) emissions include those from the Energy, Industrial Processes and Product Use (IPPU), 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 under the Climate Change Convention.

1990–2013

In 1990, New Zealand's total greenhouse gas emissions were 66,720.16 kt carbon dioxide equivalent (CO_2-e). Between 1990 and 2013, total greenhouse gas emissions had increased by 14,241.5 kt CO_2-e (21.4 per cent) to 80,961.6 kt CO_2-e in 2013 (figure 2.1.1). From 1990 to 2013, the average annual growth in total emissions was 0.9 per cent per year.

The emission sources that contributed the most to this increase in total emissions were road transportation, public electricity and heat production, agricultural soils, consumption of halocarbons and sulphur hexafluoride (SF_6), and enteric fermentation.[10]

2012–2013

Since 2012, New Zealand's total greenhouse gas emissions have decreased by 1,116.3 kt CO_2-e (1.4 per cent). This reflected emission reductions in the Energy, Agriculture and Waste sectors (3.2, 0.4 and 0.5 per cent respectively) that were partially offset by a 2.3 per cent increase of emissions from the IPPU sector.

Emission reduction in the Energy sector reflected a decrease in emissions from electricity generation and fugitive emissions. Emission reductions in electricity generation were driven by high hydro inflows in catchment areas in 2013, which led to an increase in the share of electricity generated from renewable energy sources. A higher contribution from renewable energy in the national grid resulted in a lower proportion of fossil fuels-based electricity generation over the year. Reductions from fugitive emissions are primarily caused by reduced activity in underground coal mining and handling category.

Total agricultural emissions in 2013 were lower than the 2012 level, which is attributable to the unfavourable weather conditions (drought in 2013). There was a decrease in the

[10] Methane emissions produced from ruminant livestock.

population of non-dairy cattle, sheep and deer that resulted in lower emissions associated with these types of livestock, and a decrease in emissions from agricultural liming.

Decreased emissions from the Waste sector were primarily due to improved landfill management, resulting in lower methane emissions from solid waste disposal on land in 2013, compared to 2012.

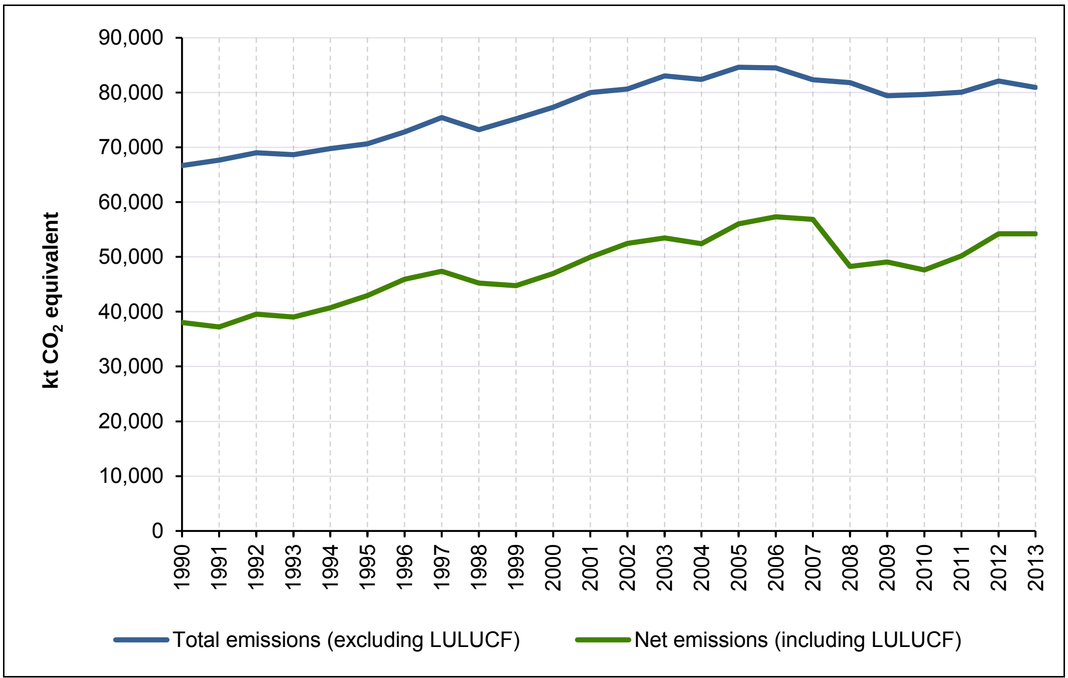
The increase in emissions from the IPPU sector was the result of combined increases in emissions from the product uses as substitutes for ODS, as well as small increases in CO_2 emissions from the metal industry and mineral industry.

Net emissions – Climate Change Convention reporting

Net emissions include emissions from the Energy, IPPU, Agriculture and Waste sectors, together with emissions and removals from the LULUCF sector.

In 1990, New Zealand's net greenhouse gas emissions were 38,065.7 kt CO_2-e. In 2013, net greenhouse gas emissions had increased by 16,134.8 kt CO_2-e (42.4 per cent) to 54,200.5 kt CO_2-e (figure 2.1.1). The four categories that contributed the most to the increase in net emissions between 1990 and 2013 were land converted to forest land, enteric fermentation from dairy cattle, road transportation and land converted to grassland.

Figure 2.1.1 New Zealand's total and net emissions (under the Climate Change Convention) from 1990 to 2013



Accounting under the Kyoto Protocol

New Zealand uses 1990 as a base year for accounting under the Kyoto Protocol. The total emissions in 1990 are currently estimated at 66,720.2 kt CO_2-e. This differs from previous estimates for the base year because the time series of emissions reported in each inventory submission are subject to continuous improvement.

In 2013, net removals were –21,195.1 kt CO_2-e from all land under Article 3.3 and forest management land under Article 3.4 of the Kyoto Protocol (see section 2.4 for further detail).

For the Kyoto Protocol second commitment period,[11] debits and credits on land reported under forest management are subject to new accounting rules. Specifically, not all emissions and removals on forest management land reported under Article 3.4 count towards a country's accounting quantity. These rules include:

- forest management being accounted for against a business-as-usual forest management reference level (FMRL). This means countries are not penalised for carrying out sustainable business-as-usual forest management activities like harvesting
- credits from forest management are capped at 3.5 per cent of base year greenhouse gas emissions excluding LULUCF
- countries are able to exclude from accounting emissions due to natural disturbance
- countries are able to exclude from accounting emissions and removals on land that meets the criteria for carbon equivalent forests.

The accounting rules are described in more detail in Decision 2/CMP7 and 2/CMP8.

Due to these rules, the accounting quantity reported will fluctuate annually. This is largely because the FMRL:

- is set as an annual average of the emissions projected to occur across the eight year commitment period, while emissions due to sustainable forest management activities such as harvesting will vary year to year during the commitment period. This means some years we expect emissions to be less than the FMRL and some years we expect emissions to be more than the FMRL
- will be subject to technical corrections during the 2013–2020 period to align the data and methodologies used in setting the FMRL with those used for accounting against it.

The accounting quantity for 2013 has been conservatively calculated as the sum of emissions and removals from land under Article 3.3 of the Kyoto Protocol. For 2013, this value is –12,165.2 kt CO_2-e.

2.2 Emission trends by gas

Inventory reporting under the Climate Change Convention covers seven direct greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride SF_6, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and nitrogen trifluoride (NF_3). However, NF_3 emissions do not occur in New Zealand and, therefore, are not included in this report.

Table 2.2.1 provides the change in each gas from 1990 to 2013. In 1990, CH_4 contributed the largest proportion of total emissions (figure 2.2.1); while in 2013 CO_2 and CH_4 contributed nearly equal proportions to the total national emissions (figure 2.2.2). Generally, the proportion of CH_4 has been decreasing over the time series, while the proportion of CO_2 has been increasing. This trend largely reflects the increase in emissions from the Energy sector since 88 per cent of New Zealand's CO_2 emissions come from that sector. Carbon dioxide showed the strongest influence on the trend in total emissions between 1990 and 2013 (figures 2.2.3 and 2.2.4). Meanwhile, CH_4 and N_2O emissions are contributed mainly by the Agriculture sector and, therefore, their trends predominantly reflect agricultural emission fluctuations.

[11] For the period 2013–2020, New Zealand has taken an unconditional target to reduce its greenhouse gas emissions under the UNFCCC. New Zealand will apply the Kyoto Protocol framework of rules towards its target, to ensure New Zealand's actions are transparent and have integrity.

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

Carbon dioxide

2013

Carbon dioxide contributed the largest proportion of total emissions in 2013 at 34,610.9 kt (42.7 per cent). The largest sources of total CO_2 emissions are from road transportation, and public electricity and heat production. In 2013, road transportation contributed 12,530.0 kt (36.2 per cent) to total CO_2 emissions, and public electricity and heat production contributed 5,024.9 kt (14.5 per cent).

Meanwhile, net emissions of CO_2 from the LULUCF sector (as reported under the Climate Change Convention) were –26,962.5 kt. The forest land category is the biggest contributor to the sector, with net emissions of –23,567.1 kt in 2013. This is similar to CO_2 emissions from afforestation and reforestation, and forest management as reported under the Kyoto Protocol, which were –25,474.3 kt in 2013.

Reporting of CO_2 emissions from the LULUCF sector has changed since the 2014 Inventory. The sector now includes reporting on emissions and removals by the harvested wood products pool. This means instead of assuming all carbon stored in trees is lost at time of harvest, the carbon is instead stored within wood products and decays over a longer time period, depending on the type of product the wood is turned into. Carbon dioxide removals in the harvested wood products pool were –10,295.6 kt in 2013.

1990–2013

Total CO_2 emissions have increased by 9,218.6 kt (36.3 per cent) from the 1990 level of 25,392.3 kt. The two largest sources of this growth were the increased emissions from road transportation, and public electricity and heat production.

Between 1990 and 2013, the net CO_2 emissions from LULUCF have increased by 1,957.6 kt CO_2 (6.8 per cent) from the 1990 level of –28,920.1 kt. This increase is largely the result of increased deforestation since 1990.

2012–2013

Between 2012 and 2013, total CO_2 emissions decreased by 994.0 kt (2.8 per cent of the total CO_2). The decrease in CO_2 emissions is the result of the emission reduction in the Energy sector. This is primarily due to a decrease in emissions from electricity generation due to higher hydro inflows in 2013 and, therefore, a higher proportion of the renewable energy in the sector portfolio. In turn, the contribution of the electricity generated from gas and coal in the national grid has decreased.

Between 2012 and 2013, net CO_2 emissions from the LULUCF sector increased by 1,087.7 kt (3.9 per cent). The main contributor to the change occurred within the forest land category as a greater proportion of forest was harvested in 2013.

Methane

2013

Methane contributed 35,615.9 kt CO_2-e (44.0 per cent) to total emissions in 2013. 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 2013, enteric fermentation CH_4 from all livestock contributed 28,441.1 kt CO_2-e (79.9 per cent) to total CH_4 emissions.

1990–2013

In 2013, CH_4 emissions increased by 2,324.6 kt CO_2-e (7.0 per cent) from the 1990 level of 33,291.4 kt CO_2-e. This is largely due to an increase in CH_4 emissions from enteric fermentation in the Agriculture sector. The decline in the population of sheep between 1990 and 2013 led to a decrease in CH_4 from enteric fermentation from sheep by 4,707.8 kt CO_2-e. However, the increase in the national dairy cattle herd over the same period has increased CH_4 from enteric fermentation from dairy cattle by 7,264.8 kt CO_2-e.

2012–2013

Between 2012 and 2013, CH_4 emissions decreased by 165.6 kt CO_2-e (0.5 per cent) primarily due to the decrease in emissions from underground mining activities (fugitive emissions) in the Energy sector, improvements made to landfill management in the Waste sector and a decrease of enteric fermentation emissions from non-dairy cattle in the Agriculture sector (due to decreases in livestock population following a widespread drought in 2013).

Nitrous oxide

2013

Nitrous oxide contributed 9,052.9 kt CO_2-e (11.2 per cent) to total emissions in 2013. The largest source of N_2O emissions is from agricultural soils. In 2013, the agricultural soils category contributed 8,453.4 kt CO_2-e (93.4 per cent) to New Zealand's total N_2O emissions.

1990–2013

In 2013, N_2O emissions increased by 1,758.1 kt CO_2-e (24.1 per cent) from the 1990 level of 7,294.7 kt CO_2-e. The growth in N_2O is largely from an increase in emissions from urine and dung deposited by grazing livestock (grazing manure) and the use of synthetic nitrogen fertilisers in the Agriculture sector.

2012–2013

Between 2012 and 2013, emissions of N_2O decreased by 9.3 kt CO_2-e (0.1 per cent). This is attributed to livestock population decreases following a widespread drought in 2013.

Fluorinated gases

2013

In 2013, aggregated fluorinated gases (HFCs, PFCs and SF_6) contributed 1,682.1 kt CO_2-e (2.1 per cent) to total emissions.

1990–2013

In 1990, no HFCs were used in New Zealand and, therefore, no percentage is shown in Table 2.2.1. In 2013, 1,615.24 kt CO_2-e of HFC emissions occurred. Hydrofluorocarbon emissions have increased because of their use as a substitute for chlorofluorocarbons, which were phased out under the Montreal Protocol.

Emissions of PFCs have decreased by 686.4 kt CO_2-e (93.4 per cent) from the 734.6 kt CO_2-e in 1990 to 48.1 kt CO_2-e in 2013. This decrease is the result of improvements in the aluminium smelting process.

Emissions of SF_6 have increased by 11.4 kt CO_2-e (157.3 per cent) from the 1990 level of 7.3 kt CO_2-e. The majority of SF_6 emissions are from use in electrical equipment.

Table 2.2.1 New Zealand's total (gross) emissions by gas in 1990 and 2013

Direct greenhouse gas emissions	kt CO_2 equivalent 1990	kt CO_2 equivalent 2013	Change from 1990 (kt CO_2 equivalent)	Change from 1990 (%)
CO_2	25,392.3	34,610.9	+9,218.6	+36.3
CH_4	33,291.4	35,615.9	+2,234.6	+7.0
N_2O	7,294.7	9,052.9	+1,758.1	+24.1
HFCs	NO	1,615.2	+1,615.2	NA
PFCs	734.6	48.1	–686.4	–93.5
SF_6	7.3	18.7	+11.4	+157.7
Total	**66,720.2**	**80,961.6**	**+14,241.5**	**+21.4**

Note: Total emissions exclude net removals from the LULUCF sector. The percentage 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 (gross) emissions by gas in 2013

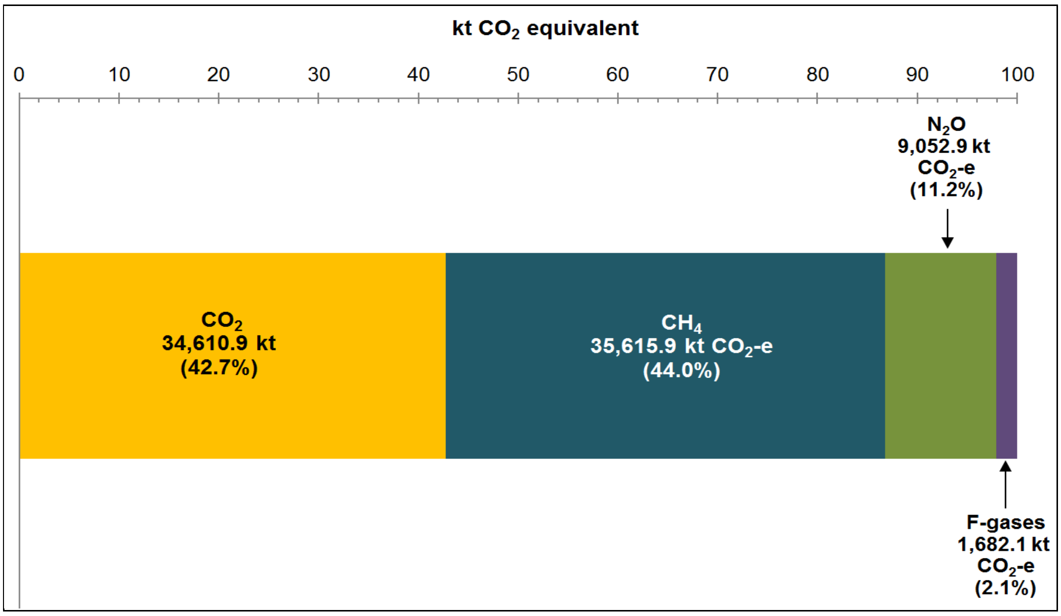


Figure 2.2.2 Proportion that gases contributed to New Zealand's total emissions from 1990 to 2013

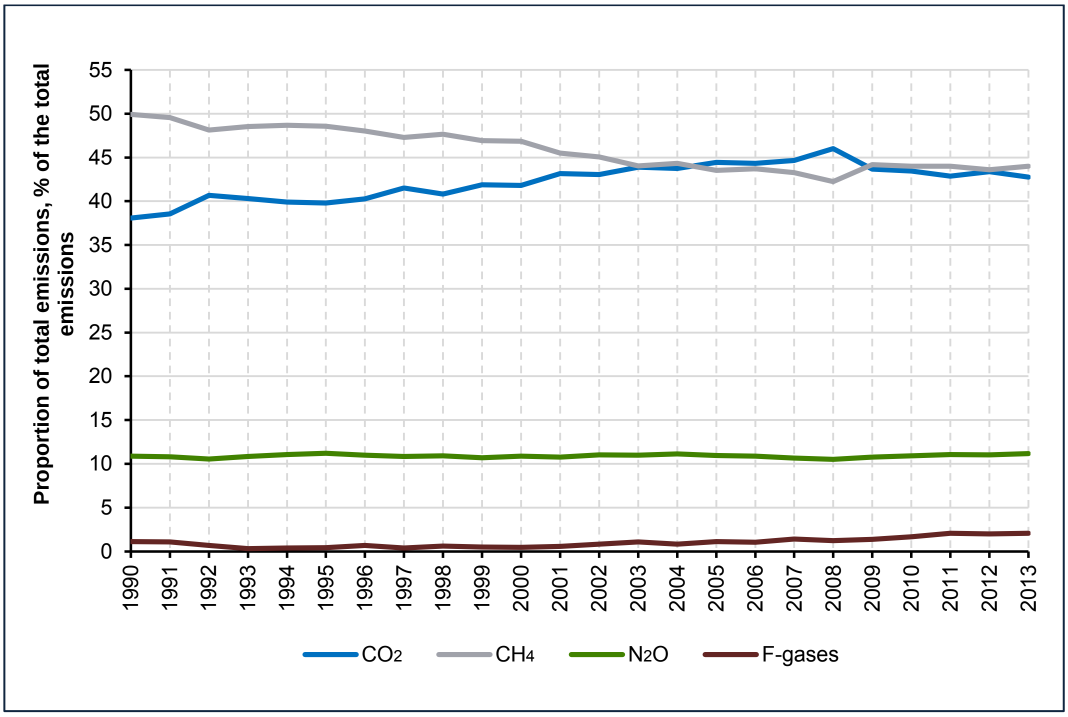


Figure 2.2.3 Change in New Zealand's total emissions by gas in 1990 and 2013

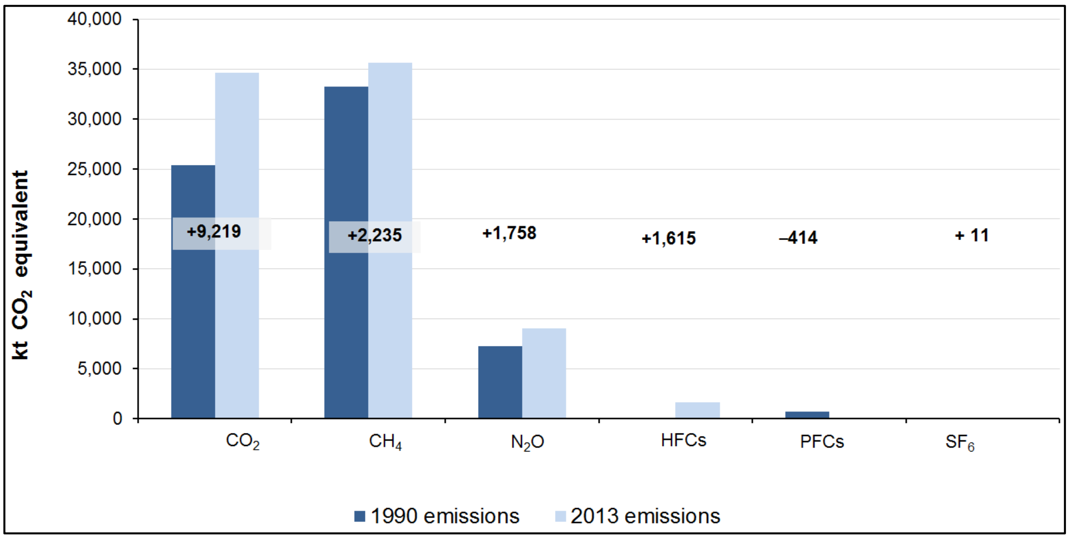
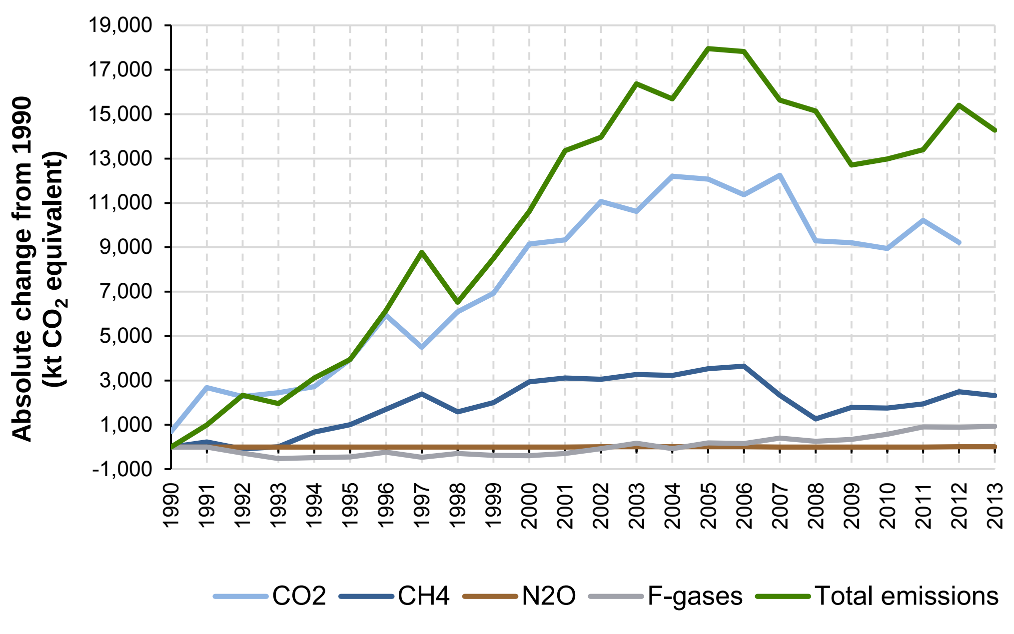


Figure 2.2.4 Change in New Zealand's total emissions by gas from 1990 to 2013



2.3 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 2013 are shown in table 2.4.1. Consistent with the Climate Change Convention reporting guidelines (UNFCCC, 2013), indirect greenhouse gases are not included in New Zealand's greenhouse gas emissions total.

Table 2.3.1 New Zealand's emissions of indirect greenhouse gases in 1990 and 2013

Indirect gas	kt of gas(es) 1990	2013	Change from 1990 (kt)	Change from 1990 (%)
NO_x	98.9	156.6	+57.6	+58.6
CO	620.4	703.3	+78.4	+13.0
NMVOCs	135.4	167.6	+32.2	+23.8
SO_2	51.9	68.9	+17.1	+32.9
Total	**906.6**	**1,096.4**	**+189.8**	**+20.9**

Note: Columns may not total due to rounding.

2.4 Article 3.3 and 3.4 activities under the Kyoto Protocol

In 2013, net removals from land subject to Article 3.3 and Article 3.4 activities under the Kyoto Protocol were –21,195.1 kt CO_2-e[12] (table 2.4.1). This estimate includes removals from the growth of all forest types, and emissions from:

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

- decay of harvested wood products from afforestation, reforestation and forest management land
- deforestation of all forest types
- conversion of land to post-1989 forest
- biomass burning
- soil disturbance associated with land-use conversion.

New Zealand's estimates under Article 3.3 of the Kyoto Protocol do not include emissions associated with nitrogenous fertiliser use on afforested and reforested land, because these are reported and accounted for in the Agriculture sector. The notation key IE (included elsewhere) is used for this in the common reporting format tables.

Afforestation and reforestation

The net area of post-1989 forest as at the end of 2013 was 659,332 hectares. The net area is the total area of new forest established since 1990 (682,189 hectares), minus the deforestation of post-1989 forest that has occurred since 1 January 1990 (22,857 hectares). Net removals for land included under afforestation and reforestation in 2013 were –17,057.4 kt CO_2-e, including –16.6 kt CO_2-e from the harvested wood products pool.

Deforestation

The area deforested between 1 January 1990 and 31 December 2013 was 168,024 hectares.[13] The area subject to deforestation in 2013 is estimated as 8,453 hectares. In 2013, deforestation emissions were 4,892.2 kt CO_2-e, compared with 4,642.6 kt CO_2-e in 2012 (a 5.4 per cent increase).

Forest management

From 2013 New Zealand is also reporting on forest management activities under Article 3.4 of the Kyoto Protocol. This reporting includes emissions and removals on land that was forest at 1 January 1990, and has not been deforested since 1990. The total area reported under forest management as at the end of 2013 was 9,272,279 hectares, equivalent to 34.4 per cent of New Zealand's total land area. Net removals on this land in 2013 were –9,029.9 kt CO_2-e, including removals of –3,225.5 kt CO_2-e from the harvested wood products pool.

Accounting quantity

From 2013 there are new rules for accounting under the Kyoto Protocol. These include:

- the ability to account for changes in the harvested wood products pool for afforestation, reforestation and forest management land
- the ability to exclude from accounting emissions and removals due to natural disturbance
- the ability to exclude from accounting emissions and removals on land that meets the criteria of carbon equivalent forests
- accounting for forest management against a forest management reference level (FMRL)

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

- the forest management cap set at 3.5 per cent of a country's base year emissions excluding LULUCF.

New Zealand's accounting quantity has been presented as the sum of emissions and removals from afforestation, reforestation and deforestation. This is due to changes in the forest management accounting rules and the potential for future changes to the forest management reference level (to align with current data and methodologies).

Table 2.4.1 New Zealand's net emissions and removals from land subject to activities under Article 3.3 and forest management under Article 3.4 of the Kyoto Protocol

		2013
Afforestation/reforestation		
	Net cumulative area since 1990 (ha)	659,332
	Area in calendar year (ha)	4,462
	Emissions in calendar year (kt CO_2-e)	–17,057.4
Deforestation		
	Net cumulative area since 1990 (ha)	168,024
	Area in calendar year (ha)	8,453
	Emissions in calendar year (kt CO_2-e)	4,892.2
Forest management		
	Area included (ha)	9,272,279
	Emissions in calendar year (kt CO_2-e)	–9,029.9
Total area included (ha)		10,099,635
Emissions in calendar year (kt CO_2-e)		–21,195.1
Accounting rules		
	Forest management reference level	11,150
	Forest management cap	2,333.9
Accounting quantity (kt CO_2-e)		**–12,165.2**

Note: The areas stated are as at 31 December 2013. 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.

The accounting quantity (–12,165.2) is calculated as the sum of emissions and removals from afforestation, reforestation and deforestation given the changes to the accounting rules for the second commitment period.

Chapter 2: References

UNFCCC. 2013. FCCC/CP/2013/10/Add.3. *Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013, Addendum; Decision 24/CP.19 Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention*.

Chapter 3: Energy

3.1 Sector overview

3.1.1 Introduction

In New Zealand, the Energy sector covers both:

- combustion emissions resulting from fuel being burnt to produce useful energy
- fugitive emissions resulting from:
  - production, transmission and storage of fuels
  - non-productive combustion
  - venting of carbon dioxide (CO_2) at gas treatment plants and
  - emissions from geothermal fields.

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

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

Electricity generation from the combustion of coal, oil and gas supports New Zealand's highly renewable electricity system. In 2013, fossil fuel thermal plants provided 25 per cent of New Zealand's total electricity supply, which is low by international standards due to the high proportion of demand met by hydro generation, as well as other renewable sources (eg, wind). While this provides a strong base in good hydro years, electricity emissions remain sensitive to rainfall in the key catchment areas.

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

2013

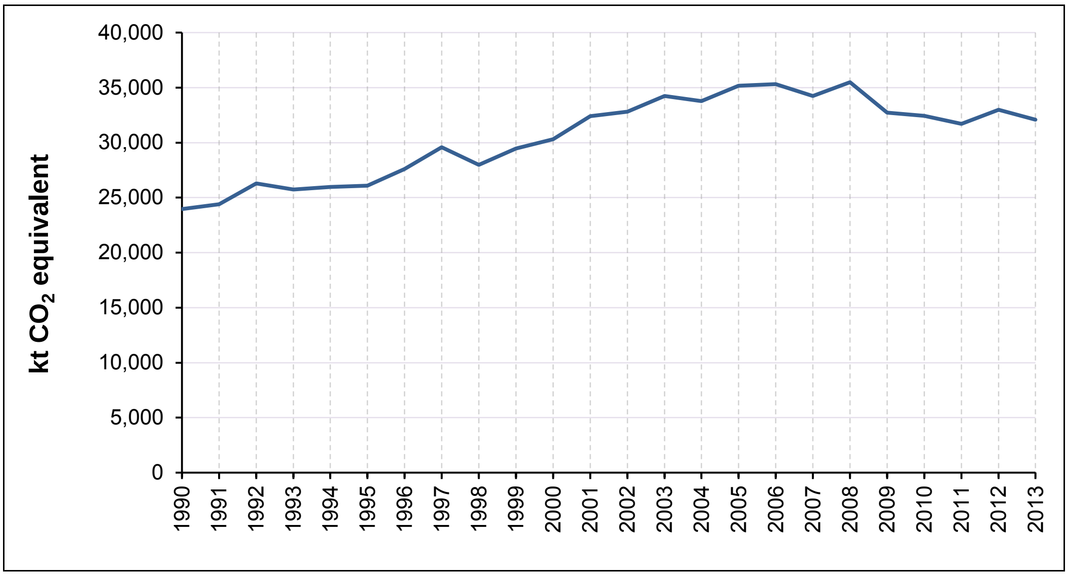
In 2013, the Energy sector produced 31,658 kt carbon dioxide equivalent (CO_2-e), representing 39.1 per cent of New Zealand's total greenhouse gas emissions. The largest sources of emissions in the Energy sector were road transportation, contributing 12,688 kt CO_2-e (40.0 per cent), and public electricity and heat production, contributing 5,043 kt CO_2-e (15.9 per cent) to energy emissions.

1990–2013

In 2013, emissions from the Energy sector had increased by 32 per cent (7,664 kt) above the 1990 level of 23,994 kt CO_2-e. Figure 3.1.1 shows the time series from 1990 to 2013. This growth in emissions is primarily from road transportation, which increased by 5,197 kt CO_2-e (69.4 per cent), and public electricity and heat production, which increased by 1,550 kt CO_2-e (44.4 per cent). Emissions from the subcategory 1.A.1.c

Manufacture of solid fuels and other energy industries have decreased by 1,320 kt CO_2-e (76.8 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997.

Figure 3.1.1 New Zealand's Energy sector emissions (1990–2013)



2012–2013

Between 2012 and 2013, emissions from the Energy sector decreased by 913 kt CO_2-e (2.8 per cent). This is primarily due to a 1,096 kt CO_2-e (17 per cent) decrease in emissions from subcategory 1.AA.1.A *Public electricity and heat production*, largely because the share of electricity generated from renewable energy sources was 75 per cent in 2013, up from 73 per cent in 2012, due to higher hydro inflows.

This resulted in decreased gas and coal-based electricity generation over the year. Electricity generation from coal decreased 33 per cent from 2012.

There was also a 261 kt CO_2-e (11 per cent) decrease in sector 1.B *Fugitive emissions*. This was due to reduced activity in subcategory 1.B.1.A *Coal mining and handling*, as well as reductions in the subcategories 1.B.2.B *Natural gas* and 1.B.2.C *Venting and flaring*.

3.1.2 Key categories in the Energy sector

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

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

CRF code	IPCC categories	Gas	Criteria for identification
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	level, trend
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	level, trend
1.A.3.b	Transport – Road Transport – Gaseous Fuels	CO_2	trend
1.A.3.b	Transport – Road Transport – Gasoline	CO_2	level, trend
1.A.3.b	Transport – Road Transport – Liquefied Petroleum Gases	CO_2	trend
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	level, trend
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	level, trend
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	level, trend
1.A.1.b	Energy Industries – Petroleum Refining – Gaseous Fuels	CO_2	trend
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	level, trend
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	level, trend
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	level, trend
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Liquid Fuels	CO_2	level
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Solid Fuels	CO_2	level
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Gaseous Fuels	CO_2	level
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	level, trend
1.A.2.g.vi ii	Manufacturing Industries and Construction – Other – Other non-specified – Solid Fuels	CO_2	trend
1.A.2.g.vi ii	Manufacturing Industries and Construction – Other – Other non-specified – Liquid Fuels	CO_2	trend
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	level, trend
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Gaseous Fuels	CO_2	level, trend
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Liquid Fuels	CO_2	level
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Solid Fuels	CO_2	level, trend
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	level, trend
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	level, trend
1.A.4.b	Other Sectors – Residential – Solid Fuels	CO_2	trend
1.A.4.b	Other Sectors – Residential – Liquid Fuels	CO_2	level
1.A.4.b	Other Sectors – Residential – Gaseous Fuels	CO_2	level, trend
1.B.1.a.i	Fugitive Emissions from Fuels – Coal Mining and Handling – Underground Mines	CH_4	trend
1.B.2.b.5	Fugitive Emissions from Fuels – Natural Gas – Distribution	CH_4	trend
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	level, trend
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CO_2	level, trend
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CH_4	trend
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	level, trend
1.B.1.a.ii	Fugitive Emissions from Fuels – Coal Mining and Handling –	CH_4	trend

	Surface Mines			

Note: level = level assessment (if not further specified – for the years 1990 and 2013); trend = trend assessment 2013.

3.1.3 Energy flows

This inventory includes energy flow diagrams (annex 4, section A4.5). These diagrams provide a snapshot of the flow of various fuels from the suppliers to the end users within New Zealand for the 2013 calendar year.

3.1.4 Ministry nomenclature

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

3.2 Background information

3.2.1 Reference approach versus sectoral approach

Greenhouse gas emissions from the Energy sector are calculated using a detailed sectoral approach. This bottom-up approach is demand based; it involves processing energy data collected on a regular basis through various surveys. For verification, New Zealand has also applied a reference approach to estimate CO_2 emissions from fuel combustion for the time series 1990–2013.

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

The apparent consumption for primary fuels in the reference approach is obtained from 'calculated' energy-use figures (see annex 4, section A4.4). These are derived as a residual figure from an energy balance equation comprising production, imports, exports, stock change and international transport on the supply side according to the Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 2006).

The majority of the CO_2 emission factors for the reference approach are specific to New Zealand. Most emission factors for liquid fuels are based on annual carbon content and the gross calorific value data provided by New Zealand's only oil refinery, Refining New Zealand. Where this data is not available, an IPCC default is used. The natural gas emission factor is based on a production-derived, weighted average of emission factors from all gas production fields. The CO_2 emission factors for solid fuels were updated for the 2014 submission following analysis to verify default emission factors used for the New Zealand Emissions Trading Scheme (NZ ETS). For more information on this improvement, see section 3.3.2.

The activity data used for the sectoral approach is referred to as 'observed' energy-use figures. These are based on surveys and questionnaires administered by the Ministry of Business, Innovation and Employment. The differences between 'calculated' and 'observed' figures are reported as statistical differences in the energy balance tables released along with *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2014a).

In some years, differences exist between the reference and sectoral approaches. Much of this difference is due to the statistical differences found in the energy balance tables (Ministry of Business, Innovation and Employment, 2014a) that are used as the basis for the reference and sectoral approach. Since 2000, the standard of national energy data has improved significantly due to increased resources and focus. In 2008, Statistics New Zealand delegated responsibility for the collection and analysis of national energy data to the Ministry of Business, Innovation and Employment. Before 2008, various energy statistics were collected by Statistics New Zealand or the Ministry of Business, Innovation and Employment. The change resulted in a more consistent and transparent approach to energy data collection as one agency collected data across the supply chain.

3.2.2 International bunker fuels

The data on fuel use by international transportation is collected and published online by the Ministry of Business, Innovation and Employment, 2014b. This data release uses information from oil company monthly survey returns provided to the Ministry of Business, Innovation and Employment.

Data on fuel use by domestic transport is sourced from the quarterly *Delivery of Petroleum Fuels by Industry* (DPFI) survey, conducted by the Ministry of Business, Innovation and Employment.

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

Consultation undertaken to review the method used to split international from domestic transport in civil aviation and navigation is covered in further detail in section 3.3.8.

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

3.2.3 Feedstock and non-energy use of fuels

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

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

- Much of the carbon in natural gas used to produce methanol is stored in the product and therefore has no associated emissions. The balance of the carbon is oxidised and results in CO_2 emissions reported under the associated sector.
- Emissions from the use of natural gas used in urea production (feedstock) are reported under the IPPU sector.
- Bitumen produced in New Zealand is not used as a fuel but rather by the companies Fulton Hogan and Downer EDi as a road construction material (non-energy use). Bitumen therefore has no associated emissions.
- Coal used in steel production at New Zealand Steel is used as a reductant, which is part of an industrial process. Therefore, emissions from this coal are reported under the IPPU sector rather than the Energy sector.

Emissions from synthetic petrol production are reported under the manufacture of solid fuels and other energy industries subcategory. Synthetic petrol production in New Zealand ceased in 1997.

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

There was no CO_2 capture from flue gases and subsequent CO_2 storage occurring in New Zealand between 1990 and 2013.

3.2.5 Country-specific issues

Reporting of the Energy sector presents some issues related to the IPCC guidelines (IPCC, 2000; 2006). The issues that exist are listed below.

Reference approach – Solid fuels in iron and steel manufacture

As mentioned in section 3.2.3, some of the coal production activity data in the reference approach is used in steel production. The IPPU sector accounts for the carbon dioxide emissions from this coal in the sectoral approach, as recommended by IPCC guidelines (IPCC, 2000); therefore they are not included in table 1.AA *Fuel combustion* – sectoral approach.

For simplicity, all feedstock carbon is excluded from reference approach according to the IPCC guidelines (IPCC, 2006). Without taking into account use by-product gases, this can create some discrepancies between the reference and sectoral approach.

Sectoral approach – Methanol production

The sector activity data excludes energy sources containing carbon that is later stored in manufactured products, specifically methanol. As a result, subtraction of emissions is not needed to account for this carbon sequestration. Also, due to confidentiality concerns raised by New Zealand's sole methanol producer, emissions from methanol production were previously reported under 1.AA.2.C *Chemicals*, rather than 2. *IPPU*. Following the 2013 expert review team (ERT) recommendation, the natural gas used for production of methanol was split into fuel gas and feedstock gas. The emissions from the fuel portion are reported in the CRF category 1.AA.2.C *Chemicals* in the Energy sector, and the emissions from the feedstock portion are described in chapter 4 (IPPU), section 4.3.2. The IPCC default emission factors were used for estimating emissions that resulted from combustion of gas for energy.

3.2.6 Energy balance

Energy in New Zealand (Ministry of Business, Innovation and Employment, 2014a) is an annual publication from the Ministry of Business, Innovation and Employment. It covers energy statistics, including:

- supply and demand by fuel types
- energy balance tables
- pricing information
- international comparisons.

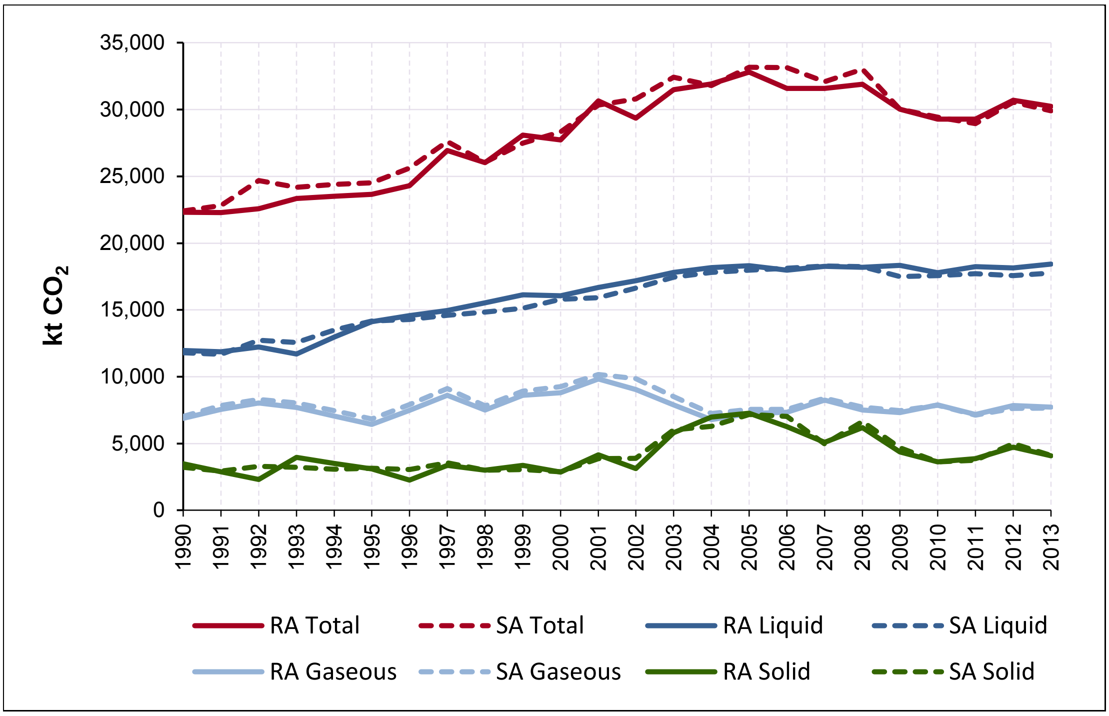
An electronic copy of this report is available online at: www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-in-new-zealand. Annex 4, section A4.4 provides an overview of the 2013 energy supply and demand balance for New Zealand.

3.3 Fuel combustion (CRF 1.A)

3.3.1 Comparison of the sectoral approach with the reference approach

In 2013, CO_2 emissions estimated in the sectoral approach were 2.4 per cent lower than those estimated in the reference approach. The following figure shows the results for the two approaches for the period 1990–2013.

Figure 3.3.1 Reference and sectoral approach carbon dioxide



Note: RA = Reference Approach; SA = Sectoral Approach.

Explanation of differences

- Gaseous fuels: Process emissions from ammonia and urea production are included in category 2.B.1 *Ammonia production*.

- Gaseous fuels: Field-specific emission factors are used for natural gas supplied for industrial processes, while the reference approach uses an average emission factor.
- Solid fuels: Stock change data for coal is not available for 1990 and 1991 resulting in a large statistical difference in 1992.
- Liquid fuels: The energy balance is mass balanced but not carbon balanced. Fuel category ‘other oil’ is an aggregation of several fuel types and so it is difficult to quantify a reliable carbon emission factor for the reference approach.
- Diesel and gasoline: In the reference approach, CO_2 emissions from diesel and gasoline are fully accounted for as fossil emissions, while in the sectoral the share of mixed biofuels is accounted for as biogenic.
- In the sectoral approach, sector- or even plant-specific net calorific values are taken to calculate the energy consumption, whereas in the reference approach, average (country-specific) calorific values are applied.

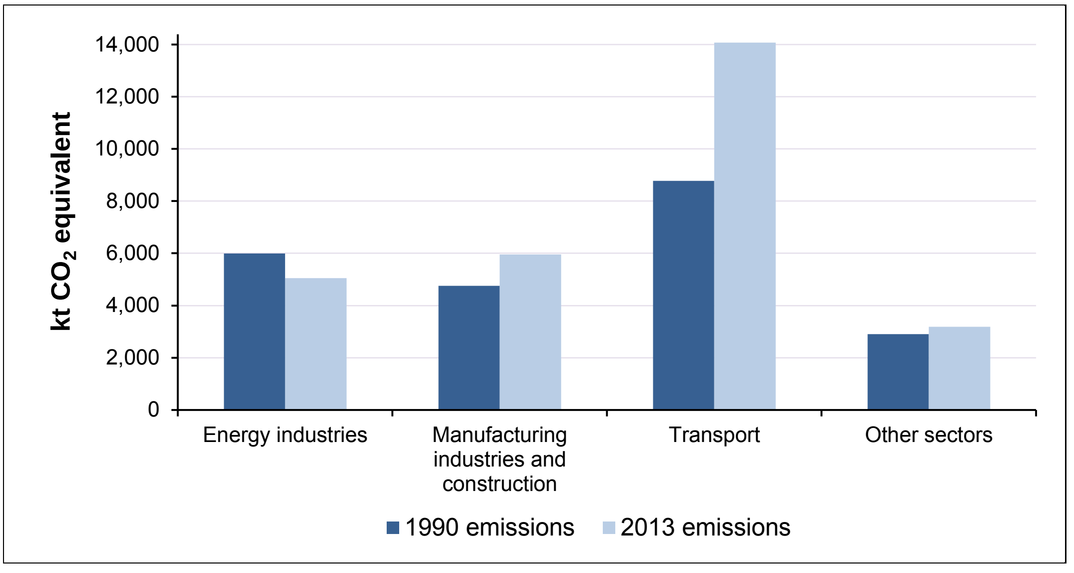
3.3.2 Sector-wide information

Description

The fuel combustion category reports all fuel combustion activities from 1.AA.1 *Energy industries*, 1.AA.2 *Manufacturing industries and construction*, 1.AA.3 *Transport* and 1.AA.4 *Other sectors* subcategories (figure 3.3.2). 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 for each of the subcategories is discussed below.

Figure 3.3.2 Change in New Zealand’s emissions from the fuel combustion categories (1990–2013)



Methodological issues

Energy emissions are compiled using the Ministry of Business, Innovation and Employment’s energy statistics along with relevant New Zealand-specific emission factors. Unless otherwise noted in the relevant section, CO_2 emissions are calculated by multiplying a country-specific emission factor for the given fuel by the relevant activity data using an IPCC 2006 Tier 2 method. Non-CO_2 emissions are calculated using IPCC 2006 default emission factors unless otherwise noted.

Activity data

Liquid fuels

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

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

Changes to note since the previous submission are listed below.

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

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

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

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

Solid fuels

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

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

All solid fuel used for iron and steel manufacture is reported under the IPPU sector, to avoid double counting.

Gaseous fuels

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

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

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

Biomass

Activity data for the use of biomass comes from a number of different sources. Electricity and co-generation data is received by the Ministry of Business, Innovation and Employment from electricity generators.

- New Zealand reports biogas emissions from landfill gas, sewage waste gas and cattle effluent (from the Tirau dairy processing facility), and commercial biogas use. Before 2013, New Zealand only reported emissions from landfill gas, sewage waste gas and commercial biogas use.
- New Zealand's biogas emissions are estimates based on electricity generation data (some of which is also estimated). No direct data is available on biogas emissions from landfills or sewage treatment facilities. See below for details of the estimation methodology of landfill gas and sewage gas.
- Biogas is also thought to be used by some local government councils, however, the Ministry of Business, Innovation and Employment has no information on this use. At some point, information was collected, but the small quantities and materially insignificant emissions mean that the Ministry has not focused on collecting this data for many years. A standing estimate (unchanged) has been included since 2006, but the source of this number is unknown. Emissions continue to be reported under this category to ensure there is no under reporting, given there is anecdotally some use outside of electricity generation and industry.
- No information is collected on flared biogas.

- The only biogas direct-use that data has been collected for is the Tirau dairy processing facility (and only one data point, which has been used for all years where it is believed the plant has emitted).

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

- Electricity generation data is collected for 15 individual plants. At 31 December 2012, New Zealand biogas generation was known to include the following.
  - Eleven landfill facilities, totalling 29.4 megawatts (MW). These facilities are electricity only (some landfill gas was used to heat a swimming pool in Christchurch before the Christchurch earthquake of February 2011, but that facility suffered major earthquake damage and has been removed).
  - Four wastewater treatment facilities, totalling 11.3 MW. These are all co-generation facilities, which provide heat and electricity for the processing of sewage.
  - Note: Accurate information is not available on the exact type of generation plant used at these individual facilities, although it is known to be a combination of gas turbines, internal combustion engines and some steam turbine facilities.
- Generation data is collected for each year ending 31 March, with generation assumed to be distributed equally across quarters to estimate December year-end generation.
  - Generation data is usually collected from all 15 plants. However, in some years estimates are made based on the previous year's generation.
- Fuel input information for generation is not collected for small generators (those less than 10 MW), to minimise the burden on respondents, and ensure the Ministry of Business, Innovation and Employment receives some information rather than nothing. Estimates of fuel input are made on the assumption of 30 per cent efficiency based on gross generation.
  - All generation data collected is assumed to be net generation – that is, parasitic load has already been taken off. It is then scaled up using default net to gross generation factors sourced from the International Energy Agency. For all thermal generation, the net to gross factor is assumed to be 1.07 (ie, an additional 7 per cent of generation is generated but used by the plant to generate more electricity). Fuel input estimates are then calculated based on the gross generation using a default electrical efficiency factor of 30 per cent. This estimated quantity of biogas is used as total biogas for energy purposes. Biogas use estimates for landfill gas and sewage gas are calculated and reported in petajoules (PJ).
  - Energy quantities of biogas are then converted into greenhouse gas emissions using default IPCC emissions factors. These factors are as follows:
    - CO_2 – 27.5 kt C/PJ or 100.98 kt CO_2/PJ (before and after oxidation). This is derived from the IPCC default net emission factor (it is assumed that the net emission factor is 10 per cent less than the gross emission factor)
    - methane (CH_4) – 1.080 t/PJ
    - nitrous oxide (N_20) – 2.070 t/PJ.
- Emissions from biogas are a very small part of New Zealand's emissions Inventory. Given this is the case, we believe the current process is sufficient for estimating emissions from biogas. Efforts to improve emissions quality would be better focused on other areas.

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

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

At the time of preparing this Inventory, complete data from the 2006 census was available, but only some data from the 2013 census had been released (see www.stats.govt.nz/Census/2006CensusHomePage.aspx). The census collects information on the heating fuels used for housing in New Zealand. For the latest data, see www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/quickstats-about-a-subject/housing/heating-fuels.aspx.

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

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

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

Electricity auto-production

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

Emission factors

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

- Gaseous fuels: Gross Emission Factor = 0.90 x Net Emission Factor

- Liquid and solid fuels: Gross Emission Factor = 0.95 x Net Emission Factor

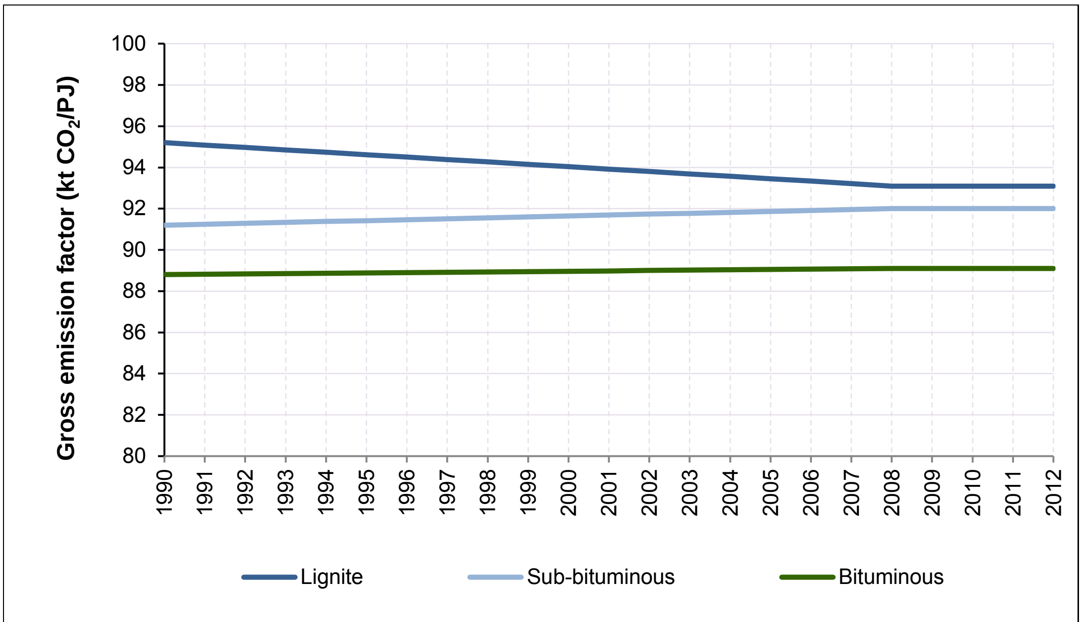
Liquid fuels

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

Solid fuels

Emission factors for solid fuels have been updated for this submission across the time series from 1990 to 2008, in response to a 2013 ERT recommendation. A comprehensive list of carbon content by coal mining is not currently available. A review of New Zealand's coal emission factors in preparation for the NZ ETS (CRL Energy Ltd, 2009) recommended re-weighting the current default emission factors to 2007 production rather than continue with those in the *New Zealand Energy Information Handbook* (Baines, 1993). However, following review of our 2013 submission, the ERT recommended interpolating the emission factors between 1990 and 2008. The updated emission factors are shown in figure 3.3.3.

Figure 3.3.3 Gross carbon dioxide emission factors for solid fuels



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

Gaseous fuels

New Zealand's gaseous fuel emission factors are above the IPCC 2006 default range, as New Zealand gas fields tend to have higher CO_2 content than most international gas fields. This is verified by regular gas composition analysis. Emission factors for 2012 from all fields, along with the production weighted average are included in annex 4 (section A4.1).

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

The Kapuni gas field has particularly high CO_2 content. Historically this field has been valued by the petrochemicals industry as a feedstock. However, most of the gas from this field is now treated, and the excess CO_2 is removed at the Kapuni gas treatment plant. Consequently, separate emission factors were used to calculate emissions from Kapuni treated and untreated gas, due to the difference in carbon content (refer to annex 4, table A4.1). Carbon dioxide removed from raw Kapuni gas then vented is reported under 1.B.2.B.2 *production/processing*.

Biomass

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

3.3.3 Sector-wide planned improvements

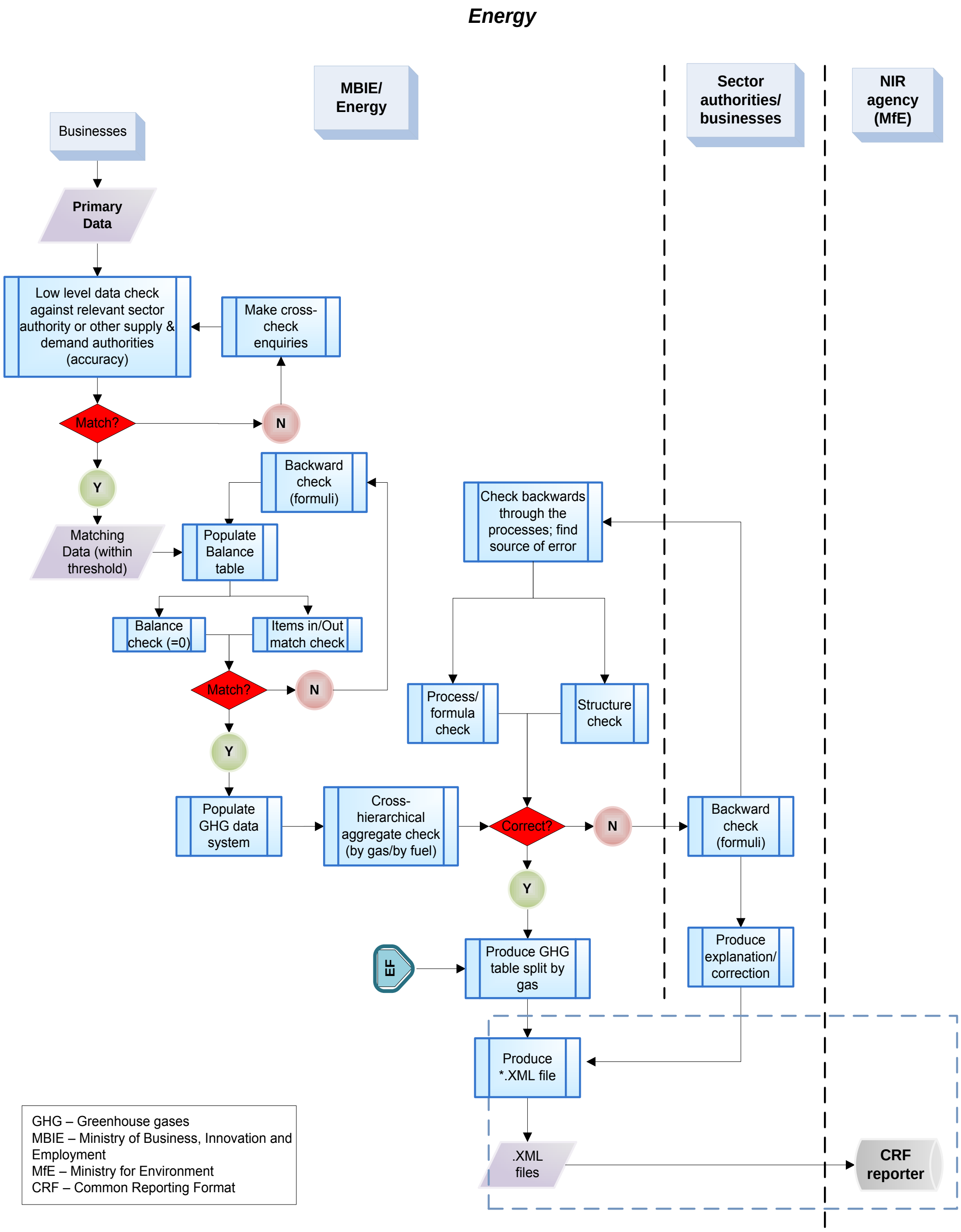
All source-specific planned improvements are discussed in their corresponding sections.

The Ministry of Business, Innovation and Employment will continue to examine the use of more specific solid fuel CO_2 emission factors.

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

In the preparation of this Inventory, the fugitive category underwent Tier 1 quality-assurance and quality-control checks as recommended in table 8.1 of *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). These include regular control sums throughout systems to verify system integrity, time-series consistency checks on activity data and consistency checks on implied emission factors at the industry–plant level where possible. Figure 3.3.4 describes the quality control process map for the Energy sector.

Figure 3.3.4 Energy sector quality control process map



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

Implied CO_2 emission factors for combustion of liquid, solid and gaseous fuels from this Inventory were compared with those in the IPCC Emission Factor Database, 2012, and converted to gross values for comparability with the New Zealand energy system.

Figures 3.3.5, 3.3.6 and 3.3.7 weight the upper, lower and middle IPCC 2006 emission factor ranges according to observed fuel consumption in New Zealand for the given year. For example, the top of the IPCC range for liquid fuels was calculated using the top of the IPCC 2006 emission factor range for each liquid fuel and observed New Zealand activity data for each liquid fuel.

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

With the exception of gaseous fuels (as discussed in section 3.3.2), each fuel type falls within the IPCC default range.

Figure 3.3.5 Carbon dioxide implied emission factor (IEF) – Liquid fuel combustion (1990–2012)

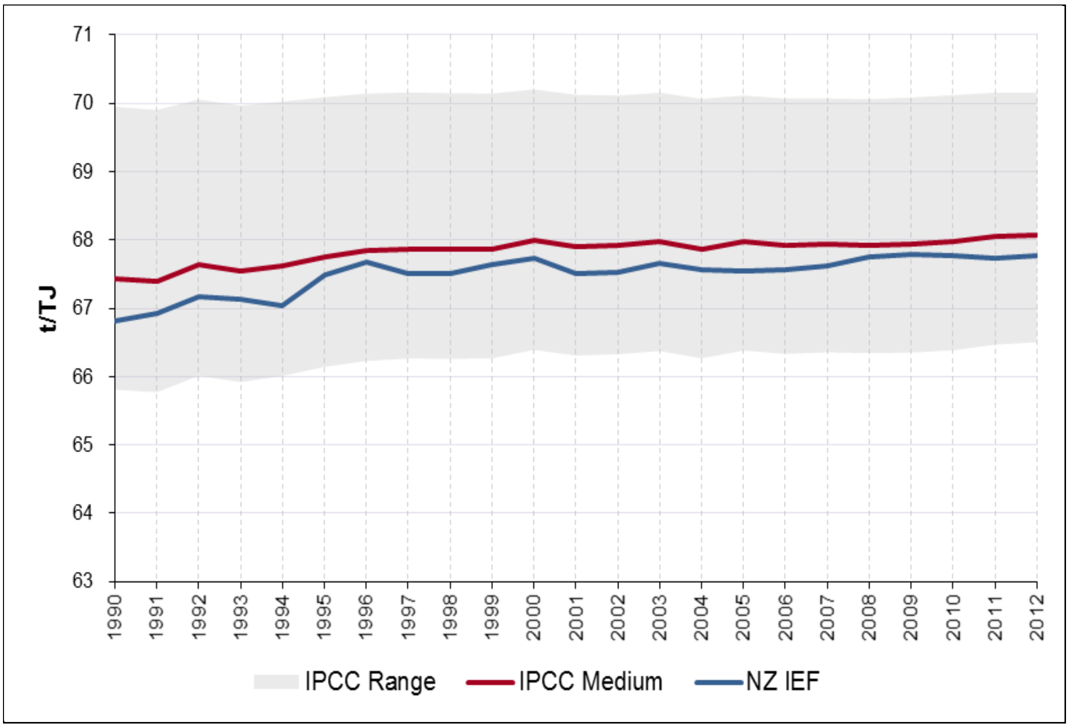


Figure 3.3.6 Carbon dioxide implied emission factor (IEF) – Solid fuel combustion (1990–2012)

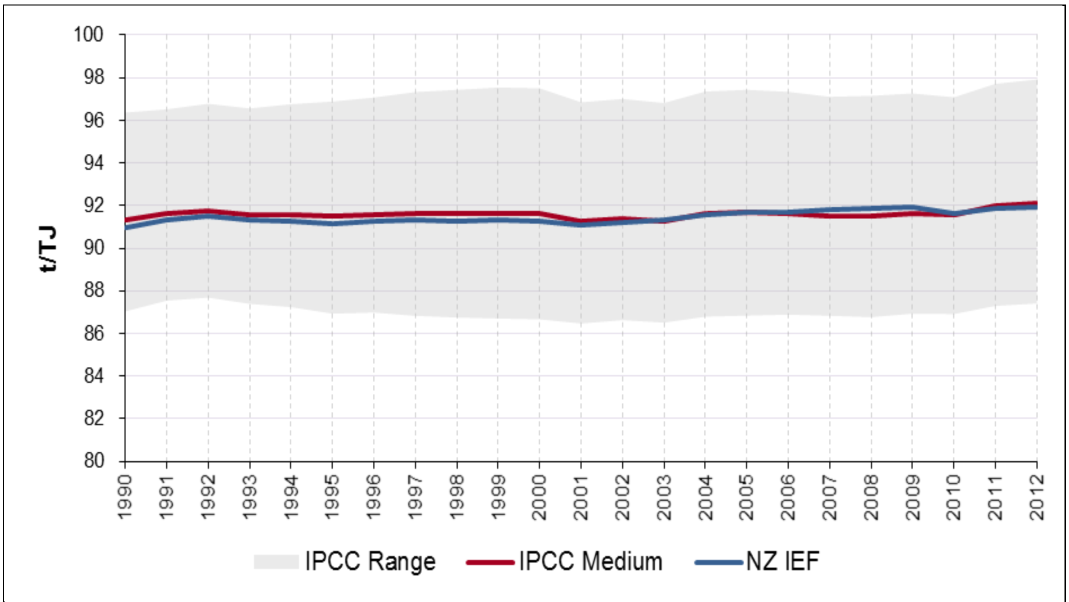
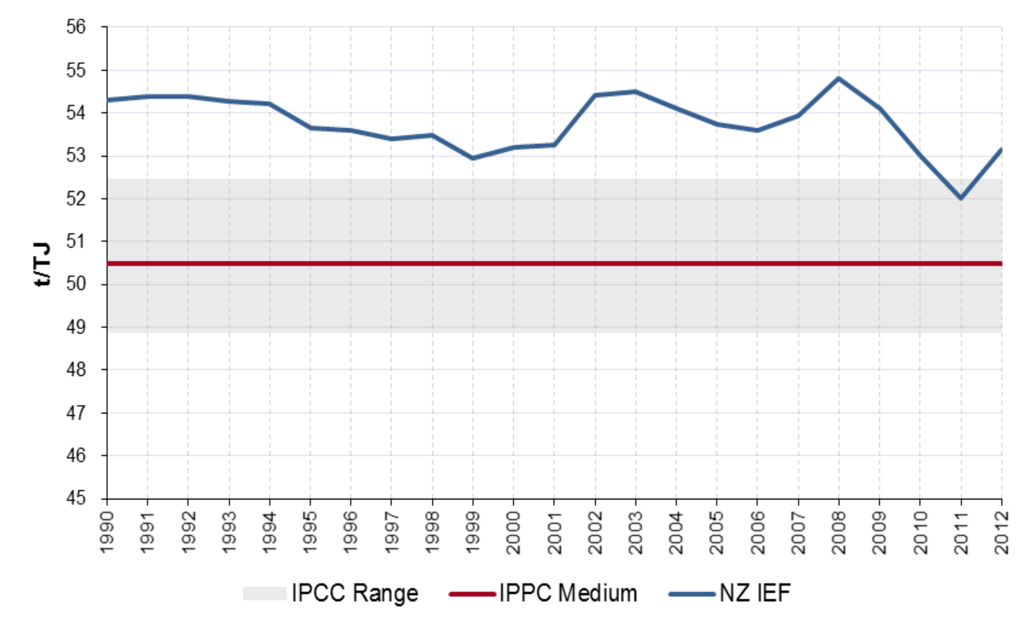


Figure 3.3.7 Carbon dioxide implied emission factor (IEF) – Gaseous fuel combustion (1990–2012)



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

3.3.5 Uncertainties and time-series consistency

Uncertainty in greenhouse gas emissions from fuel combustion varies, depending on the type of greenhouse gas. The uncertainty of CO_2 emissions is relatively low. This is important as CO_2 emissions made up over 98 per cent of CO_2-e emissions from fuel combustion in New Zealand in 2013. By comparison, emissions of the non-CO_2 gases are much less certain as emissions vary with combustion conditions. Uncertainties for CO_2, CH_4 and N_2O activity data and emission factors are supplied in table 3.3.4. Many of the non-CO_2 emission factors used by New Zealand are the IPCC default values. Further detailed information around uncertainties for each fuel type can be found in annex 2, sections A2.1, A2.2 and A2.3.

Table 3.3.4 Uncertainty for New Zealand's Energy sector emission estimates

		Activity data uncertainty (%)	Emission factor uncertainty (%)
CO_2	Liquid fuels	2.61	±0.5
	Solid fuels	10.89	±3.5
	Gaseous fuels	6.95	±2.4
	Fugitive – geothermal	5.00	±5.0
	Fugitive – venting/flaring	6.95	±2.4
	Fugitive – oil transport	5.00	±50.0
	Fugitive – transmission and distribution	6.95	±5.0
CH_4	Liquid fuels	2.61	±50.0
	Solid fuels	10.89	±50.0
	Gaseous fuels	6.95	±50.0
	Biomass	5.00	±50.0
	Fugitive – geothermal	5.00	±5.0
	Fugitive – venting/flaring	6.95	±50.0
	Fugitive – coal mining	10.89	±50.0
	Fugitive – transmission and distribution	6.95	±5.0
	Fugitive – other leakages	5.00	±50.0
	Fugitive – oil transportation	5.00	±50.0
N_2O	Liquid fuels	2.61	±50.0
	Solid fuels	10.89	±50.0
	Gaseous fuels	6.95	±50.0
	Biomass	5.00	±50.0

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

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

Description

This category includes combustion for public electricity and heat production, petroleum refining and the manufacture of solid fuels and other energy industries. The latter subcategory includes estimates for natural gas in oil and gas extraction and from natural gas in synthetic petrol production. The excess CO_2 removed from Kapuni gas at the Kapuni gas treatment plant has also been reported under the manufacture of solid fuels and other energy industries subcategory because of confidentiality concerns.

In 2013, emissions in category 1.AA.1 *Energy industries* totalled 6,768 kt CO_2-e (21 per cent of the Energy sector emissions). Emissions from energy industries have increased 775 kt CO_2-e (13 per cent) since the 1990 level of 5,993 kt CO_2-e. Subcategory 1.AA.1.A *Public electricity and heat production* accounted for 5,521 kt CO_2-e (82 per cent) of the emissions from the energy industries category in 2013. This is an increase of 2,028 kt CO_2-e (58 per cent) from the 1990 level of 3,493 kt CO_2-e.

Changes in emissions between 2012 and 2013

Between 2012 and 2013, there was a decrease of 1,096 kt CO_2-e (17 per cent) in emissions from 1.AA.1.A *Public electricity and heat production*. This was largely because the share of electricity generated from renewable energy sources was 75 per cent in 2013, up from 73 per cent in 2012, due to higher hydro inflows.

This resulted in decreased gas and coal generation over the year. Generation from coal decreased 33 per cent from 2012.

Key categories identified in the 2013 level assessment from the energy industry category include CO_2 emissions from:

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

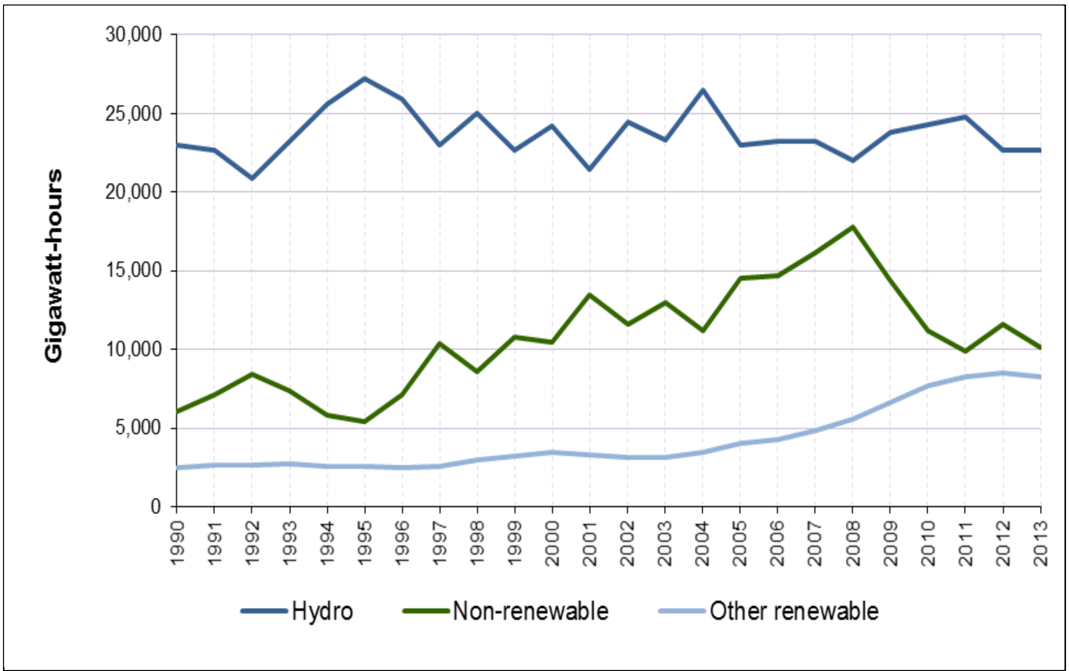
Key categories identified in the 2013 trend assessment from the energy industry category include CO_2 emissions from:

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

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2013 calendar year, hydro generation provided 54 per cent of New Zealand's electricity generation. A further 14 per cent came from geothermal, 5 per cent from wind and 1 per cent from biomass. The remaining 25 per cent was provided by fossil fuel thermal generation plants using gas, coal and oil (Ministry of Business, Innovation and Employment, 2013).

Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations between 1990 and 2013. These fluctuations can also be seen over the time series for New Zealand's total emissions. The fluctuations are influenced by the close inverse relationship between thermal and renewable generation (figure 3.3.8). In a dry year, where low rainfall affects the majority of New Zealand's hydroelectric lake levels, the shortfall is made up by thermal electricity generation. New Zealand's hydro resources have limited storage capacity, with around 10 per cent of New Zealand's annual demand of reservoir storage (Electricity Technical Advisory Group and Ministry of Business, Innovation and Employment, 2009). Electricity generation in a 'normal' hydro year requires lower gas and coal use, while a 'dry' hydro year requires higher gas and coal use.

Figure 3.3.8 New Zealand's electricity generation by source (1990–2012)



Methodological issues

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

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

Activity data

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

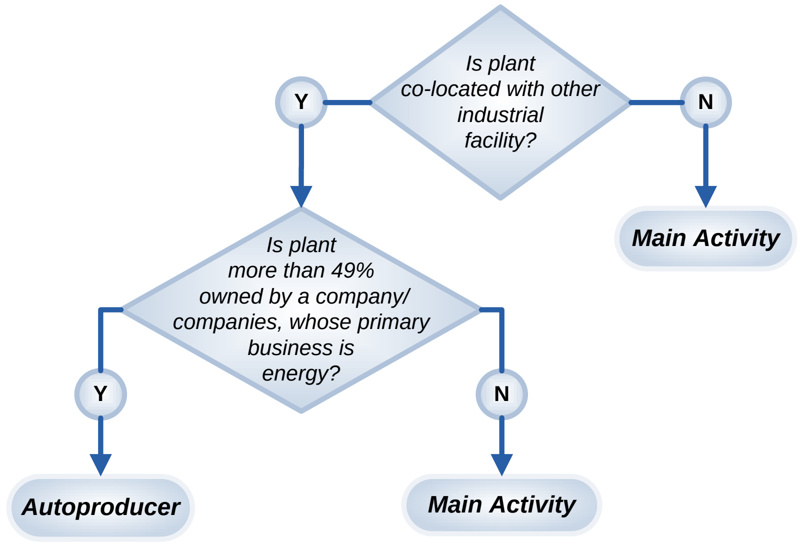
All thermal electricity generators provide figures to the Ministry of Business, Innovation and Employment for the amount of coal, gas and oil used for electricity generation. Greenhouse gas emissions from geothermal electricity generation are reported under 1.B.2.D.

Around 6 per cent of New Zealand's electricity is supplied by co-generation (also known as combined heat and power) (Ministry of Business, Innovation and Employment, 2013). Most of the major co-generation plants are attached to large industrial facilities that consume most of the electricity and heat generated.

There are six co-generation plants that fit the IPCC, 2006, definition of public electricity and heat production that produce electricity as their primary purpose. The emissions from these plants are included under the public electricity and heat production subcategory, while emissions from other co-generation plants are included within the manufacturing industries and construction category (section 3.3.2).

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

Figure 3.3.9 Decision tree to identify an autoproducer



1.AA.1.B Petroleum refining

Refining New Zealand provides annual activity data and emission factors for each type of fuel being consumed at the site. The fuel-type specific emission factors were adopted under the Government's Projects to Reduce Emissions in 2003 (Ministry for the Environment, 2009). As no data is available concerning non-CO_2 emissions from the refinery, the IPCC, 1996, default emission factors for industrial boilers have been applied.

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

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

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

Emission factors

Gaseous fuels

As mentioned in section 3.3.2, New Zealand's natural gas emission factor fluctuates from year to year, mainly due to the different mixture of gas fields that were used in that year. New Zealand gas fields also have higher CO_2 content than most international gas fields. This is particularly evident in the public electricity and heat production subcategory.

Uncertainties and time-series consistency

Uncertainties in emissions and activity data estimates for this category are relevant to the entire fuel combustion sector (refer to table 3.3.4).

Source-specific QA/QC and verification

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

Source-specific recalculations

As discussed in section 3.3.2, emission factors for solid fuels were updated for the previous submission in response to a 2013 ERT recommendation. This resulted in changes in emissions from solid fuel combustion across all sectors, including *Public electricity and heat production*. In addition, the previous submission implemented updated emission factors for solid fuel combustion for electricity generation to include the effect of imported coal use reported by the operator of the country's only primary producer of coal-fired electricity generation.

The net effect was a decrease in CO_2 emissions in the *Public electricity and heat production* sector across the time series. A full time series of the emission factor for sub-bituminous coal used for electricity generation can be found in annex 4 (table A4.2).

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

Description

This category comprises emissions from fossil fuels combusted in iron and steel, other non-ferrous metals, chemicals, pulp, paper and print, food processing, beverages and tobacco, and other uses. Emissions from co-generation plants that do not meet the definition of co-generation as provided in the IPCC guidelines (IPCC, 2006) are included in this category.

In 2013, emissions from 1.AA.2 *Manufacturing industries and construction* subcategory accounted for 5,959 kt CO_2-e (19 per cent) emissions from the Energy sector. Emissions were 1,201 kt CO_2-e (25 per cent) above the 1990 level of 4,758 kt CO_2-e. A decline in methanol production in 2003–04 caused a significant reduction in emissions from this category. Methanol production is the largest source of emissions in subcategory 1.AA.2.C *Chemicals*.

Changes in emissions between 2012 and 2013

Between 2012 and 2013, emissions from the manufacturing industries and construction sector increased by 600 kt CO_2-e (11 per cent). This is primarily due to a 255 kt CO_2-e (14 per cent) increase in emissions from solid fuels in the sector as a result of the increased economic activity.

Key categories identified in the 2013-level assessment from the manufacturing industries and construction category include CO_2 emissions from:

- *Chemicals – Gaseous Fuels*
- *Food Processing, Beverages and Tobacco – Gaseous Fuels*
- *Food Processing, Beverages and Tobacco – Liquid Fuels*
- *Food Processing, Beverages and Tobacco – Solid Fuels*
- *Other – Mining and Quarrying – Liquid Fuels*
- *Other – Non-metallic Minerals – Solid Fuels*

- *Pulp, Paper and Print – Gaseous Fuels.*

Key categories, identified in the 2013 trend assessment from the manufacturing industries and construction category, include CO_2 emissions from:

- *Chemicals – Gaseous Fuels*
- *Other – Mining and Quarrying – Liquid Fuels*
- *Other – Other non-specified – Solid Fuels*
- *Other – Non-metallic Minerals – Solid Fuels*
- *Pulp, Paper and Print – Gaseous Fuels.*

Methodological issues

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

Activity data

The previous submission further disaggregated emissions formerly reported under subcategory 1.AA.2.g *Manufacturing industries and construction – other* into specific subcategories. This resulted in the ‘other’ subcategory becoming much smaller.

Energy balance tables released with *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2014) split out industrial uses of energy using the Australia New Zealand Standard Industrial Classification 2006. This was possible because of the collection of more detailed information from the various surveys used to compile the energy balance tables since 2009.

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

Solid fuels

In 2010, the disaggregation of the ‘manufacturing industries’ category for coal was implemented within the energy greenhouse gas data system. This was the first time this category has been disaggregated and applied from 2009. These percentage splits, based on 2009 data, were applied to activity data for the annual inventory submission across the whole time series (back to 1990). However, during 2014 the coal data system at the Ministry of Business, Innovation and Employment was revised to internally disaggregate manufacturing industries based on a 2011 survey of major coal users. Therefore, the disaggregation procedure previously used within the greenhouse gas data system is no longer necessary.

From 2009 onwards, the coal sales survey conducted by the Ministry of Business, Innovation and Employment provides data at a more disaggregated level.

Solid biomass

The Bioenergy Association of New Zealand conducted a 2006 Heat Plant Survey of New Zealand (Bioenergy Association of New Zealand, 2008) to gain information on heat plant (boiler) capacity and use in New Zealand. One area this survey examined was solid biomass use in New Zealand industrial companies (see table 3.3.6). The survey shows that most solid biomass in New Zealand is used by the wood processing industry. The industrial splits from the survey were used to separate out solid biomass activity data for the New Zealand Greenhouse Gas Inventory. These splits were applied across the whole time series (back to 1990) for activity data and CO_2, CH_4 and N_2O emissions.

Table 3.3.6 Solid biomass splits for 2006 that were used to disaggregate the manufacturing industries and construction category between 1990 and 2013

Manufacturing industries and construction subcategory	Per cent
1.AA.2.A Iron and steel	NO
1.AA.2.B Non-ferrous metals	NO
1.AA.2.C Chemicals	NO
1.AA.2.D Pulp, paper and print	99.94
1.AA.2.E Food processing, beverages and tobacco	0.05
1.AA.2.F Other – mining and quarrying	NO
1.AA.2.F Other – textiles	NO
1.AA.2.F Other – non-metallic minerals	NO
1.AA.2.F Other – mechanical/electrical equipment	NO
1.AA.2.F Other – non-specified	0.01

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

Gaseous biomass

During the 2012 centralised review, it was discovered that the national inventory was not capturing emissions from the combustion of biogas produced at the Tirau dairy processing facility. Cattle effluent is utilised to produce biogas that is used to raise heat for the milk processing facility, which is open from September through to December each year. See section 3.3.2 (Biomass) for further information.

Biogas is not metered or analysed at the site, but estimates of flow rate and CH_4 content were obtained from the facility manager for the 2011 reporting year. The Ministry of Business, Innovation and Employment then used these to calculate an estimate of the total energy content, which was then confirmed by the facility manager.

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

Liquid fuels (diesel, gasoline and fuel oil)

As mentioned in section 3.3.2 (Liquid fuels), New Zealand uses the *Annual Liquid Fuel Survey* to capture sales by small independent distributors. With this information, some liquid fuel demand that would otherwise be allocated to national transport is reallocated to the correct sectors' demand. In terms of the Energy sector emission estimates, emissions attributed to category 1.AA.3 *Transport* decrease by around 20 per cent as a result of this reallocation, and emissions attributed to other categories, such as 1.AA.4.C *Agriculture/forestry/fishing* increase significantly.

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

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

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

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

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

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

Figure 3.3.10 Splits used for manufacturing industries and construction category – Gasoline (1990–2013)

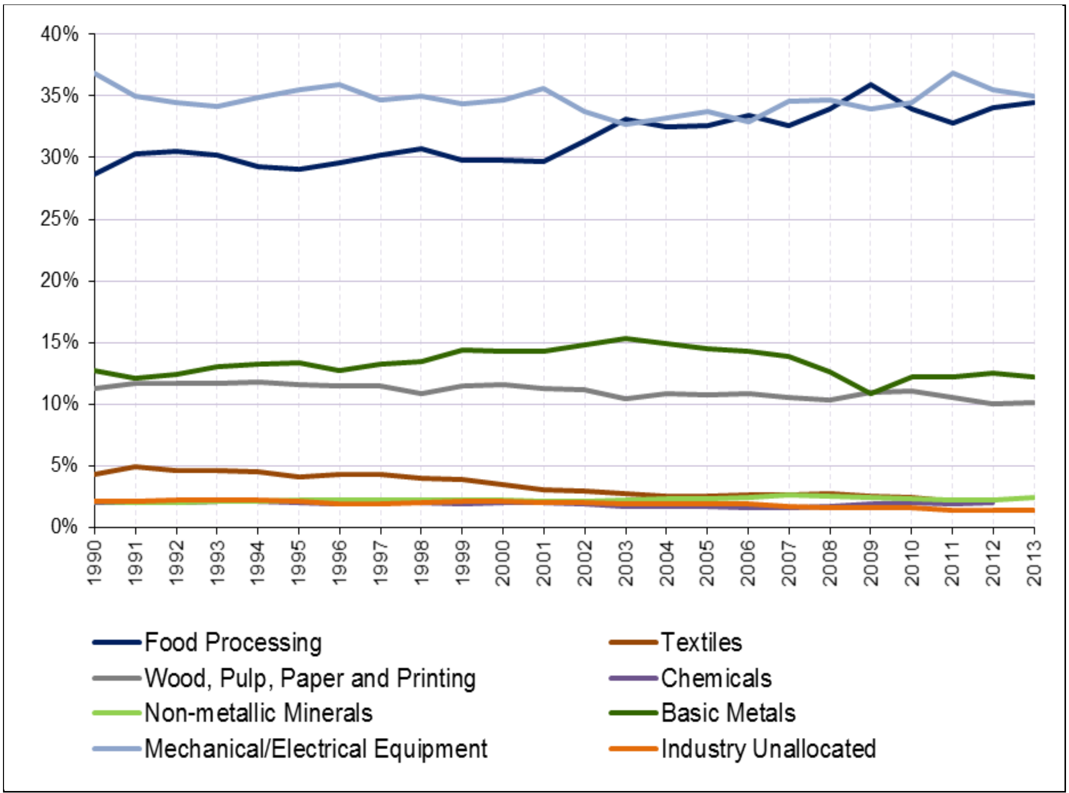


Figure 3.3.11 Splits used for manufacturing industries and construction category – Diesel (1990–2013)

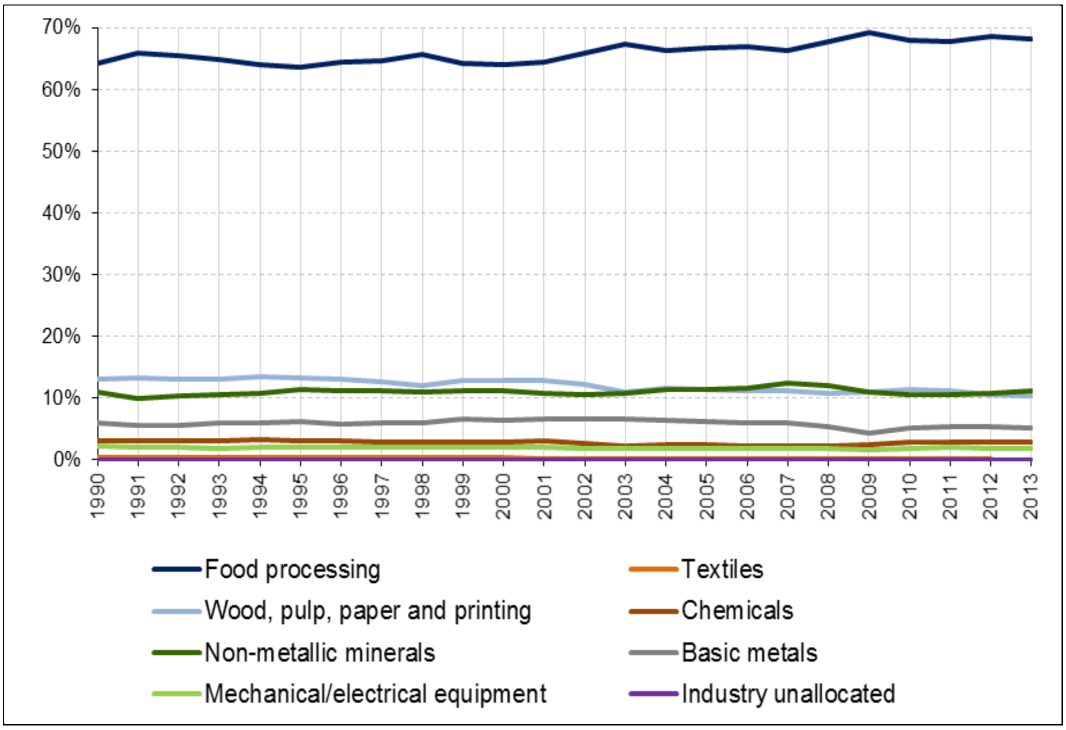
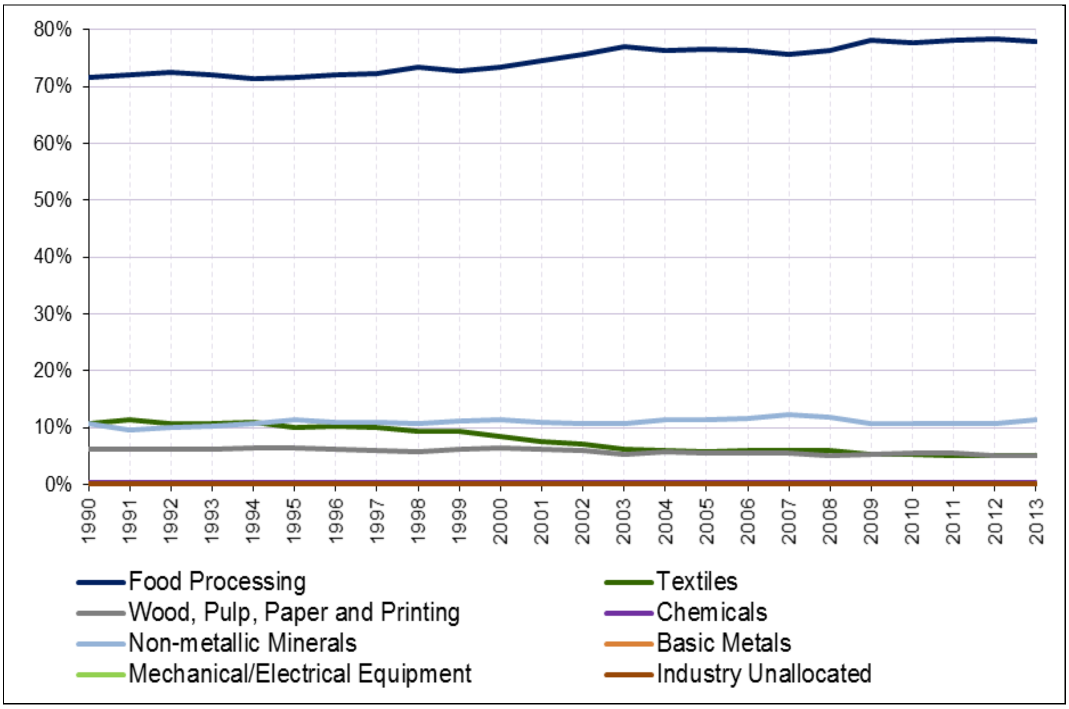


Figure 3.3.12 Splits used for manufacturing industries and construction category – Fuel oil (1990–2013)



Gaseous fuels

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

Method used in order of preference based on available data:

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

1.AA.2.A Iron and steel

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

1.AA.2.C Chemicals

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

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

Two important improvements since the previous submission should be noted:

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

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

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

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

On-site electricity generation

As mentioned in section 3.3.2, on-site electricity generation is allocated to either public electricity and heat production or the sector in which the associated plant operates, using the decision in figure 3.3.9.

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Source-specific recalculations

As mentioned under activity data, during 2014 the coal data system at the Ministry of Business, Innovation and Employment was revised to internally disaggregate manufacturing industries based on a 2011 survey of major coal users. Therefore, the disaggregation procedure previously used within the greenhouse gas data system is no longer necessary. Note that this change in activity data has not resulted in any change in total emissions, only a reallocation between subsectors.

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

Description

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

In 2013, category 1.AA.3 *Transport* was responsible for 13,995 kt CO_2-e (43.6 per cent of emissions from the Energy sector), or 17.2 per cent of total emissions. Emissions increased 5,220 kt CO_2-e (59.5 per cent) from the 8,775 kt CO_2-e emitted in 1990. The transport emissions profile in 2013 was dominated by emissions from subcategory 1.AA.3.B *Road transportation*. In 2013, road transport accounted for 12,688 kt CO_2-e (90.1 per cent) of total transport emissions. This was an increase of 5,197 kt CO_2-e (69.4 per cent) from the 1990 level of 7,492 kt CO_2-e.

Changes in emissions between 2012 and 2013

Between 2012 and 2013, emissions from transport increased by 219 kt CO_2-e (1.6 per cent).

Key categories identified in the 2013 level assessment from the transport category include CO_2 emissions from:

- *Domestic aviation – jet kerosene*
- *Road transport – gasoline*
- *Road transport – diesel oil*
- *Domestic navigation – residual fuel oil.*

Key categories identified in the 2013 trend assessment from the transport category include CO_2 emissions from:

- *Domestic aviation – jet kerosene*
- *Road transport – diesel oil*
- *Road transport – gasoline*
- *Road transport – gaseous fuels*
- *Domestic navigation – residual fuel oil*
- *Road transport – liquefied petroleum gases.*

Methodological issues

1.AA.3.A Civil aviation

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

1.AA.3.B Road transportation

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

Since the 2012 submission, New Zealand has used a Tier 2 (IPCC, 2000) methodology to estimate CH_4 and N_2O emissions from road transport. Data collected by New Zealand's Ministry of Transport provides comprehensive information on vehicle-kilometres-travelled by vehicle class and fuel type from 2001–10. Before 2001, insufficient data was available, so 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 evenly between vehicles:

- manufactured in New Zealand[14] or imported for sale as new vehicles
- produced and used in Japan and then imported into New Zealand.

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

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

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

- vehicle type
- fuel type
- vehicle weight class

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

- year of manufacture.

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

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

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

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

The Ministry of Business, Innovation and Employment and Ministry for the Environment met with the Australian inventory reporting team in July 2011 to conduct a review of proposed methodologies for calculating emissions of CH_4 and N_2O emissions associated with road transport. New Zealand's Tier 2 approach for road transport was presented, resulting in a recommendation from the Australian team that the new methodology be adopted for the 2012 submission and that New Zealand attempt to use the IPCC good practice guidance (IPCC, 2000) to choose an appropriate splicing method.

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

Figure 3.3.13 Methane emissions from road transport from 2001 to 2012 – Gasoline

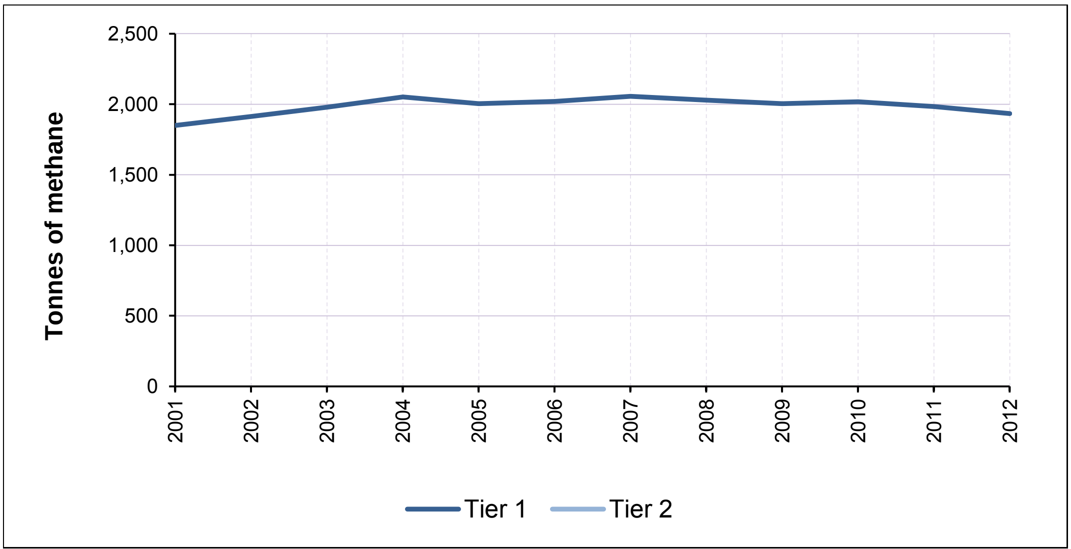
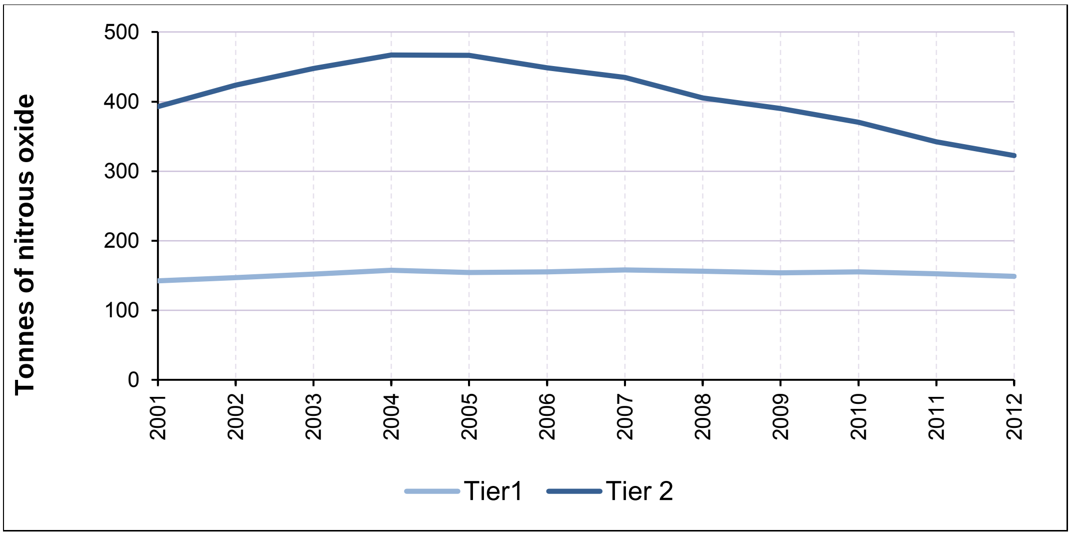


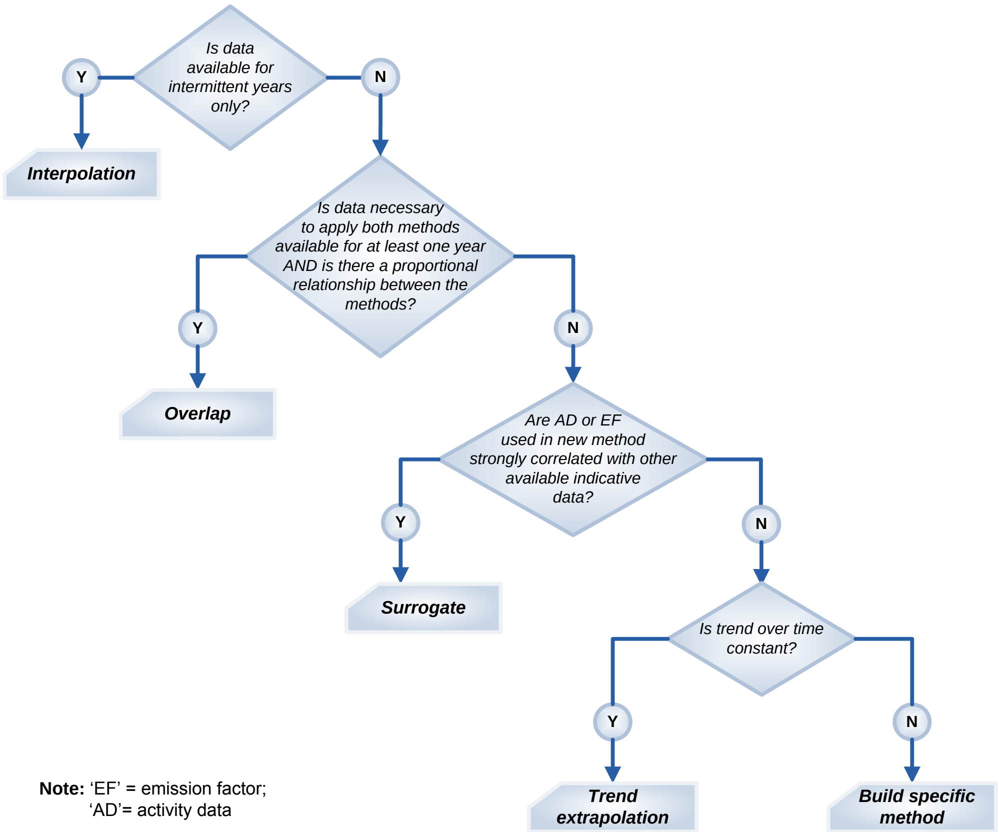
Figure 3.3.14 Nitrous oxide emissions from road transport from 2001 to 2012 – Gasoline



Time-series consistency

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

Figure 3.3.15 Splicing method decision tree for gasoline emissions



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

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

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

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

Where:

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

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

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

Where:

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

In the case of CH_4, the relationship is decreasing over the entire overlap period (2001–10), as would be expected with the increasing uptake of emissions control technology. This relationship was extrapolated back to the beginning of the time series to derive a factor by which to multiply the Tier 1 estimate for a given year.

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

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

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

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

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

Figure 3.3.16 Nitrous oxide implied emission factors from 1990 to 2012 – Gasoline road transport

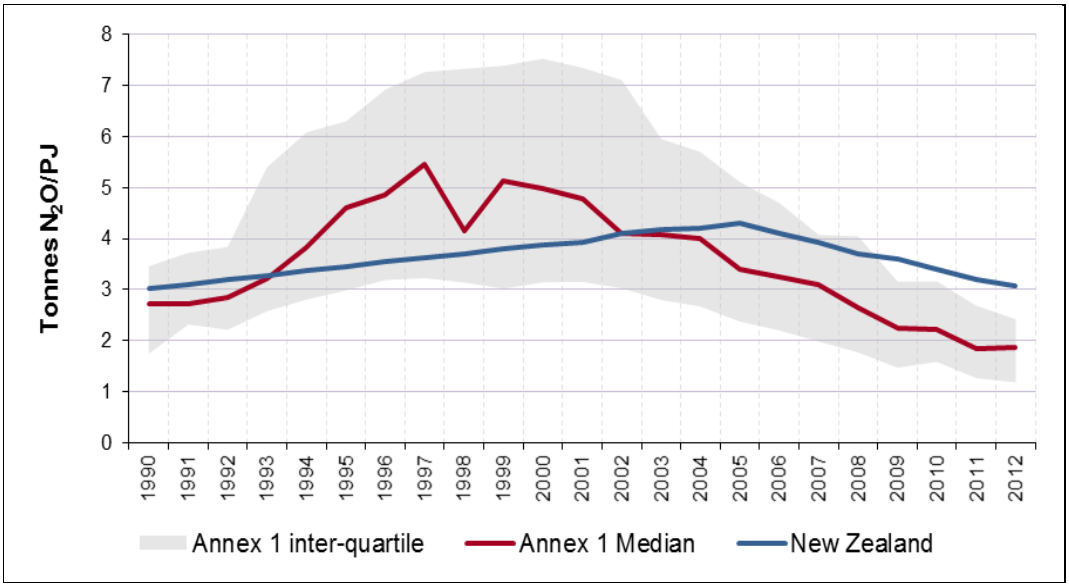
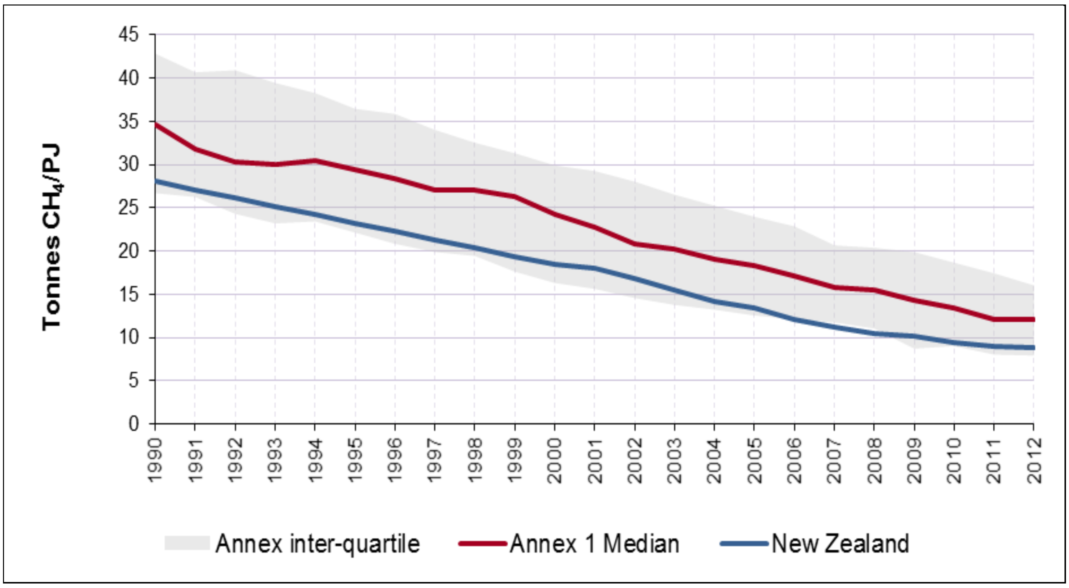


Figure 3.3.17 Methane implied emission factors from 1990 to 2012 – Gasoline road transport



Dual-fuel vehicles

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

The amount of natural gas used in vehicles on New Zealand roads was significantly larger in 1990 than it was in 2012, when almost all natural gas in road transport was used in buses. For the purposes of time-series consistency, the new methodology was considered incomparable with the previous methodology due to fundamental differences in the type of activity that the two methods represent. The CH_4 emission factors (t CH_4/PJ) from a purpose-built natural gas (CNG) bus are known to be significantly lower than those from a light passenger vehicle built to run on petrol then converted to use natural gas.

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

Blended biofuels

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

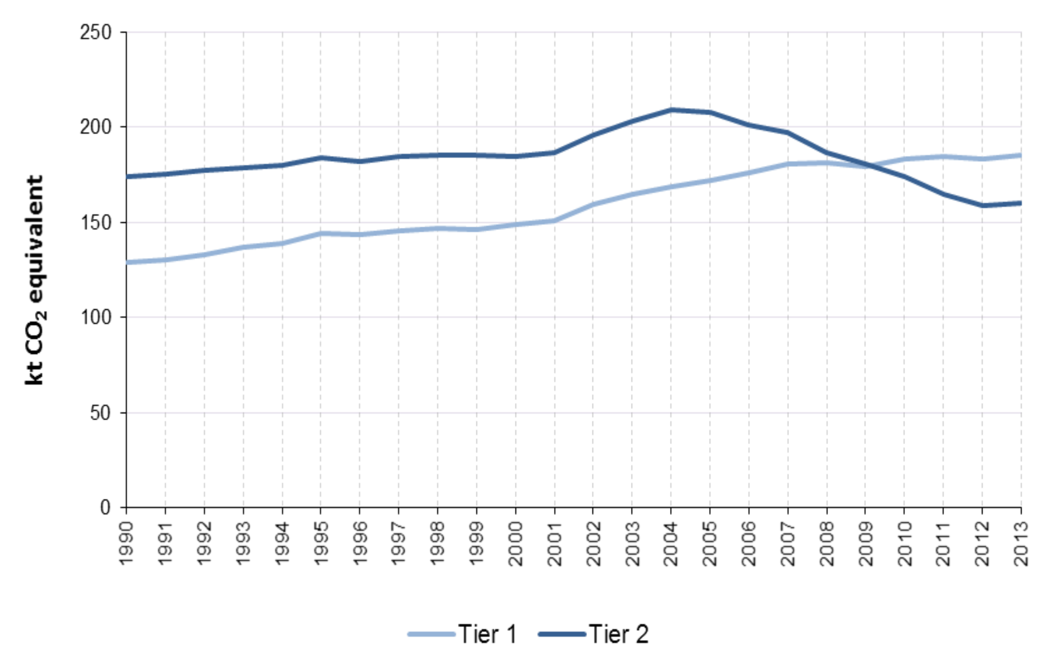
Overall effect of moving to Tier 2 methodology

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

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

As more advanced emissions-control technologies entered the fleet, the difference between N_2O estimates from the Tier 2 methodology and Tier 1 methodology reduced, while the differences between the CH_4 emissions continued to increase. From 2010, the combined CO_2-e emissions from N_2O and CH_4 in road transport are lower under the Tier 2 methodology than under the previous Tier 1 methodology, reflecting continued improvements in emission-control technology entering the fleet (see figure 3.3.18).

Figure 3.3.18 Total methane and nitrous oxide road transport emissions from 1990 to 2013



1.AA.3.C Railways

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

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

Emissions from the navigation subcategory in New Zealand were estimated using a Tier 1 approach (IPCC, 2006).

Activity data

1.AA.3.A Civil aviation

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

The distinction between domestic and international flights is based on refuelling at the domestic and international terminals of New Zealand airports. The allocation of aviation fuels between domestic and international segments has previously been raised by the ERT. A previous centralised review stated (UNFCCC, 2009):

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

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

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

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

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

1.AA.3.B Road transportation

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

Activity data on the consumption of fuel by the transport sector was sourced from the DPFI conducted by the Ministry of Business, Innovation and Employment. Liquefied petroleum gas and compressed natural gas consumption figures are reported online by the Ministry of Business, Innovation and Employment.

As mentioned in section 3.3.2, this Inventory continues to use the results of the *Annual Liquid Fuel Survey* that began in 2009. The purpose of this survey is to capture the allocation of fuel resold by small independent resellers. These independent resellers account for nearly 18 per cent of national diesel sales and 3 per cent of national gasoline sales.

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

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

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

1.AA.3.C Railways

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

1.AA.3.D Domestic Navigation

Fuel oil activity data on fuel use by domestic transport is sourced from the quarterly DPFI conducted by the Ministry of Business, Innovation and Employment. The DPFI provides monthly marine diesel supply figures that are added to automotive diesel consumption data provided by KiwiRail, operators of diesel ferries, to obtain total diesel consumption in the Navigation sector. New Zealand-specific emission factors have been used to estimate CO_2 emissions and, because of insufficient data, the IPCC 1996 default emission factors have been used to estimate CH_4 and N_2O emissions.

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

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

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Comparison of international implied emission factors across the time series (1990–2012), and those resulting from the new Tier 2 methodology for CH_4 and N_2O emissions from road transport, were made using the IPCC Locator Tool (version 3.4).

Source-specific recalculations

Some revisions to historical data have been made within the oil data system at the Ministry of Business, Innovation and Employment. This was in response to the ERT recommendation to endeavour to reconcile the differences between the MOS and the DPFI. The most significant revisions were made to the MOS for jet fuel and heavy fuel oil between 2003–08 for both domestic and international consumption. Some errors were also corrected in the DPFI were some exports had incorrectly been coded as international bunkers or vice versa.

Source-specific planned improvements

There are no planned improvements currently in this sector.

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

Description

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

In 2013, fuel combustion of the other sectors category accounted for 3,183 kt CO_2-e (9.9 per cent of the emissions from the Energy sector). This is an increase of 281 kt CO_2-e (9.7 per cent) from the 1990 value of 2,902 kt CO_2-e.

Changes in emissions between 2012 and 2013

Between 2012 and 2013, emissions from 1.AA.4 *Other sectors* decreased by 168 kt CO_2-e (5.0 per cent).

Key categories identified in the 2013 level assessment from the other sectors category include CO_2 emissions from:

- *Agriculture/forestry/fishing – Liquid Fuels*
- *Agriculture/forestry/fishing – Solid Fuels*
- *Commercial/Institutional – Gaseous Fuels*
- *Commercial/Institutional – Liquid Fuels*
- *Residential – Gaseous Fuels*
- *Residential – Liquid Fuels.*

Key categories identified in the 2013 trend assessment from the other sectors category include CO_2 emissions from:

- *Agriculture/forestry/fishing – Solid Fuels*
- *Commercial/Institutional – Gaseous Fuels*
- *Commercial/Institutional – Liquid Fuels*
- *Residential – Solid Fuels*
- *Residential – Liquid Fuels.*

Methodological issues

There are no notable methodological issues in this category.

Activity data

Liquid fuels

As mentioned in section 3.3.2, this Inventory continues to use the results of the *Annual Liquid Fuel Survey* that began in 2009. The purpose of this survey is to capture the allocation of fuel resold by small independent resellers. In 2013, these independent resellers accounted for nearly 26 per cent of national diesel deliveries and 7 per cent of national gasoline deliveries.

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

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

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

Table 3.3.7 Split of ‘other primary industry’

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

Solid fuels

In 2010, it was discovered that some coal reported as sold to the commercial sector was in fact being on-sold. As a result, some activity previously reported under the Commercial sector has been reallocated to the Agriculture sector. This on-selling is assumed to continue across the time series 1990–2013.

Solid biomass

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

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

Gaseous fuels

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

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

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

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

Uncertainties and time-series consistency

Uncertainties in emission estimates for data from other sectors are relevant to the entire Energy sector (table 3.3.4).

Source-specific QA/QC and verification

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

Source-specific recalculations

Some recalculations may have occurred across the time series due to revisions of activity data.

Source-specific planned improvements

There are no current planned improvements for this specific category.

3.4 Fugitive emissions from fuels (CRF 1.B)

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

In 2013, fugitive emissions from fuels accounted for 2,116 kt CO_2-e (6.6 per cent) of emissions from the Energy sector. This is an increase of 577 kt CO_2-e (37 per cent) from the 1990 level of 1,540 kt CO_2-e.

Changes in emissions between 2012 and 2013

Between 2012 and 2013, fugitive emissions from fuels decreased by 252 kt CO_2-e (11 per cent). This was primarily the result of decreased activity in subcategory 1.B.1.A *Coal mining and handling.*

Key categories identified in the 2013 level assessment from fugitive emissions include CO_2 emissions from:

- *Oil and Natural Gas and Other Emissions from Energy production – Other – Geothermal*
- *Natural Gas – Processing*

Key categories identified in the 2013 level assessment from fugitive emissions include CH_4 emissions from:

- *Oil and Natural Gas and Other Emissions from Energy production – Other – at industrial plants and power stations*

Key categories identified in the 2013 trend assessment from fugitive emissions include CO_2 emissions from:

- *Oil and Natural Gas and Other Emissions from Energy production – Other – Geothermal*
- *Natural Gas – Processing.*

Key categories identified in the 2013 trend assessment from fugitive emissions include CH_4 emissions from:

- *Coal Mining and Handling – Surface mines*
- *Natural Gas – Distribution*
- *Coal Mining and Handling – Underground*

- *Oil and Natural Gas and Other Emissions from Energy production – Other – Geothermal*
- *Oil and Natural Gas and Other Emissions from Energy production – Other – at industrial plants and power stations.*

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

Description

In 2013, fugitive emissions from the solid fuels subcategory produced 247 kt CO_2-e (12 per cent) of emissions from the fugitive emissions category. This is a decrease of 91 kt CO_2-e (27 per cent) from the 337 kt CO_2-e reported in 1990.

Between 2012 and 2013, fugitive emissions from solid fuels decreased by 102 kt CO_2-e (29 per cent) as a result of decreased production from underground mines. Production at Spring Creek Mine was suspended in 2012 pending a business review. As a result, 2013 production from underground mines in New Zealand was 44 per cent lower than in 2012, leading to a similar reduction in fugitive emissions in the subcategory.

New Zealand's fugitive emissions from the solid fuels subcategory are a by-product of coal-mining operations. Methane is created during coal formation. The amount of CH_4 released during coal mining is dependent on the coal grade and the depth of the coal seam. In 2011, 66.7 per cent of the CH_4 from coal mining came from underground mining. This includes the emissions from post-underground mining activities such as coal processing, transportation and use. In 2013, New Zealand coal production was 4.6 million tonnes, a 6.1 per cent decrease from the 2012 production level.

At the end of 2013, there was no known flaring of CH_4 at coalmines in New Zealand, and CH_4 captured for industrial use is negligible. Pilot schemes of both coal seam gas and underground coal gasification began in 2012, but these projects have not progressed.

Methodological issues

The underground mining subcategory dominates fugitive emissions from coal mining. The New Zealand-specific emission factor for underground mining of sub-bituminous coal is used to calculate CH_4 emissions (Beamish and Vance, 1992). Emission factors for the other subcategories, for example, surface mining, are sourced from the IPCC, 2006, guidelines.

Activity data

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

Uncertainties and time-series consistency

Uncertainties in fugitive emissions are relevant to the entire Energy sector (table 3.3.4).

Source-specific QA/QC and verification

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

Source-specific recalculations

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

Source-specific planned improvements

There are no current planned improvements for this specific category.

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

Description

In 2013, fugitive emissions from the oil and natural gas subcategory contributed 1,120 kt CO_2-e (88 per cent) to emissions from the fugitive emissions category. This is an increase of 667 kt CO_2-e (55 per cent) from 1,203 kt CO_2-e in 1990.

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

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

Carbon dioxide is also produced when natural gas is flared at the wellheads of other fields. The combustion efficiency of flaring is 95 to 99 per cent, leaving some fugitive CH_4 emissions as a result of incomplete combustion.

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

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

In 2013, emissions from geothermal operations were 749 kt CO_2-e, an increase of 466 kt CO_2-e (164 per cent) since the 1990 level of 283 kt CO_2-e.

Between 2012 and 2013, emissions from geothermal have decreased by 0.2 per cent.

Methodological issues

1.B.2.A.3 Oil transport

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

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

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

Ozone precursors and sulphur dioxide from oil refining

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

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

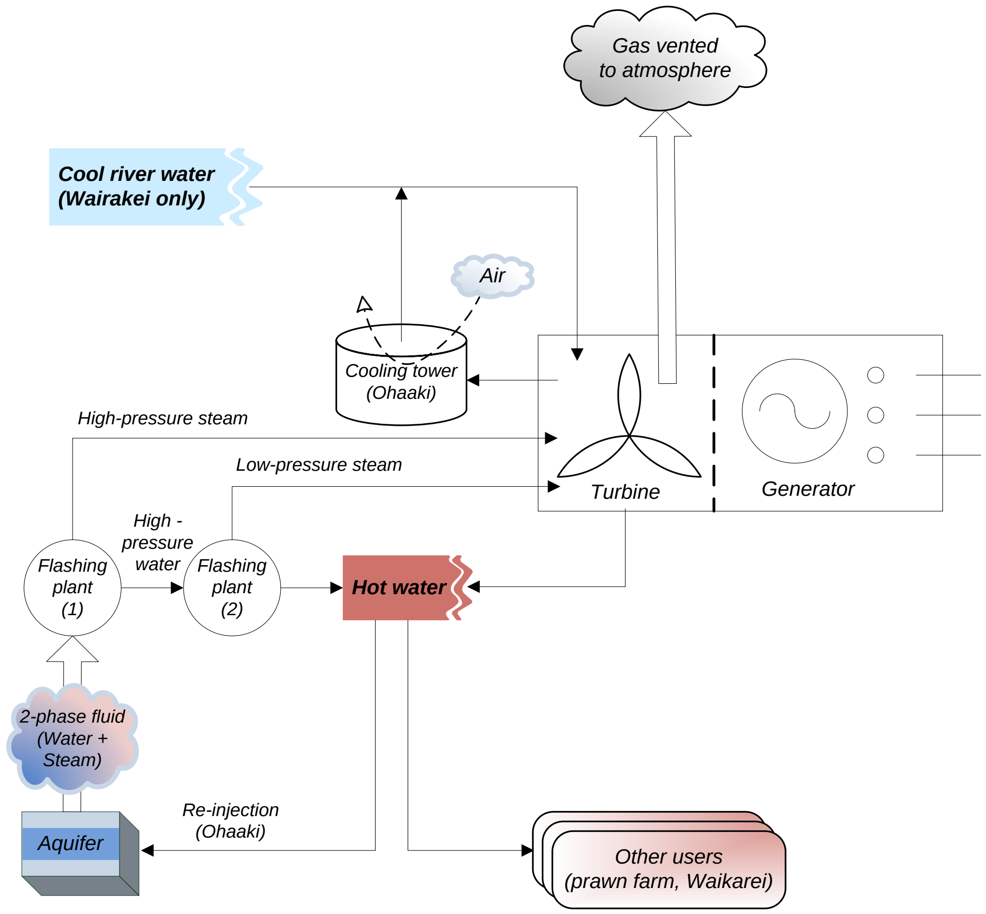
Emissions for other leakages of natural gas are estimated using a Tier 1 method. Methane emissions are estimated for leakages at both 'industrial plants and power stations' and 'residential and commercial sectors'. For this inventory, all gas supplied to industrial plants, including both energy-use gas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

1.B.2.D Geothermal

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

Estimates of CO_2 and CH_4 emissions for the geothermal subcategory are obtained directly from the geothermal power companies. There are currently 13 geothermal power stations – most of these are owned (or partly owned) by two major power companies. Two examples of methodologies used to estimate emissions by these companies are explained below.

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



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

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

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

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

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

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

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

Geothermal methodology for Company A

At Company A, quarterly gas sampling analysis is conducted to measure the amount of CO_2 and CH_4 in the steam. Gas samples are collected at the inlet to the electricity generation station and at the extraction process when gas is dissolved in the condensate (wastewater).

The concentration of CO_2 (eg, 0.612 per cent) and CH_4 (eg, 0.0029 per cent) by weight of discharged steam is then calculated by carrying out a mass balance.

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

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

Therefore, to work out CO_2 emissions discharged to atmosphere:

Average discharge per hour is calculated as:

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

And the total discharge per year is:

$$by\ weight\ of\ steam = 3.565 \frac{tonnes\ of\ CO_2}{hour} x8760 \frac{hours}{year}$$ = 31,230 tonnes of CO_2.

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

Geothermal methodology for Company B

At Company B, spot measurements of both CO_2 and CH_4 concentrations are taken at the inlet steam when the power stations are operating normally. The net megawatt-hours of electricity generated that day are then used to calculate the emission factor. This implied emission factor is then multiplied by the annual amount of electricity generated to work out the annual emissions for each power station.

Activity data

Venting and flaring from oil and gas production

Data on the amount of CO_2 released through flaring was supplied directly by the gas field. Vector Ltd, operator of the Kapuni gas treatment plant, supplies estimates of CO_2 released during the processing of the natural gas.

New Zealand has improved the data split between natural gas flaring and venting since its 2013 submission, in response to previous ERT recommendations. These items are now disaggregated and reported separately.

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

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

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

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

Of the gas entering the low-pressure distribution system, 1.75 per cent (which is based on consultation between the Government and the Gas Association of New Zealand (an industry group)) is assumed to be lost through leakage. Consequently, activity data from the low-pressure distribution system is based on 1.75 per cent of the gas entering the distribution system, and CO_2 and CH_4 emissions are based on gas composition data.

1.B.2.A.3 Oil transport

The activity data is New Zealand's total production of crude oil reported in the Ministry of Business, Innovation and Employment's online energy data tables (Ministry of Business, Innovation and Employment, 2013a). The CO_2 emission factor is the IPCC, 2000, default for oil transport using tanker trucks and rail cars, while the CH_4 emission factor is the mid-point of the IPCC (1996) default value range. A different source was chosen for the CO_2 fugitive emissions because the IPCC good practice guidance (IPPC, 2000) has an emissions factor that more closely aligns to the way oil is transported in New Zealand. The specific factor chosen was for oil transport in 'tanker trucks and rail cars' (table 2, page 112, IPCC, 2000).

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

Activity data is based on oil intake at New Zealand's single oil refinery. The CH_4 emission factor for oil refining is the same as that for oil transport. The emission factor for oil storage is 0.14 tonnes of CH_4/PJ, and the fugitive CH_4 emission factor for oil refining is 0.745 tonnes of CH_4/PJ. These emission factors are the mid-point of the IPCC default range from the IPCC guidelines (IPCC, 1996), for Western Europe (table 1-58, page 1.121). The combined emissions factor for oil refining and storage is 0.885 tonnes of CH_4/PJ.

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

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

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

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

Emission factors

1.B.2.A.3 Oil transport

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

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

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

Ozone precursors and sulphur dioxide from oil refining

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

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

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

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

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

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

Source-specific planned improvements

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

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Chapter 4: Industrial Processes and Product Use (IPPU)

4.1 Sector overview

4.1.1 The IPPU sector in New Zealand

New Zealand has a relatively small number of industrial processing plants emitting non-energy-related greenhouse gases. Carbon dioxide (CO_2) methane (CH_4) and nitrous oxide (N_2O) emissions from eight distinct industrial processes in New Zealand are reported in the IPPU sector. These are:

- calcination of limestone in cement production
- calcination of limestone in burnt and slaked lime production
- production of ammonia, which is further processed into urea
- production of methanol
- production of hydrogen, in oil refining and for making hydrogen peroxide
- production of steel, from iron sand and from scrap steel
- oxidation of anodes in aluminium smelting
- use of soda ash in glass making.

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are used in a large number of products and in refrigeration and air conditioning equipment. Some recovered HFCs are exported for destruction. Perfluorocarbons are also emitted as a result of anode effects in aluminium smelting. Sulphur hexafluoride (SF_6) is used in the electricity distribution sector and for medical and some other applications. There is no production of any fluorinated chemicals in New Zealand; they are all imported.

4.1.2 Emissions summary

The IPPU sector in New Zealand produces CO_2 emissions (65.7 per cent), fluorinated gases (31.8 per cent) and small amounts of CH_4 and N_2O. Coal and natural gas are used on a significant scale for energy in the *Mineral industry*, *Chemical industry* and *Metal industry* source categories. Carbon dioxide and any other emissions from combustion of fuels in these industries are reported under the Energy sector.

2013

In 2013, emissions in the IPPU sector contributed 5,071.5 kt carbon dioxide equivalent (CO_2-e) or 6.3 per cent of New Zealand's total greenhouse gas emissions.

The emissions by source category are shown in table 4.1.1. The largest source category is the *Metal industry* category, with substantial CO_2 emissions from *Steel production* and aluminium smelting. The *Metal industry* category also contributes a small amount of PFC emissions from anode effects in aluminium smelting.

1990–2013

Total IPPU sector emissions in 2013 were 1,795.5 kt CO_2-e higher than emissions in 1990 (3,276.0 kt CO_2-e). This increase was mainly driven by increasing emissions from the *Product uses as substitutes for ODS* source category, which had no emissions in 1990 and 1,615.2 kt CO_2-e in 2013. These emissions have continued to increase, due to increasing use of air conditioning and other products containing refrigerants.

In addition, CO_2 emissions from the *Mineral industry*, *Chemical industry* and *Metal industry* categories have increased due to increasing production rates in these industries. This was partly offset by a substantial reduction in PFC emissions, achieved by improvements in management of anode effects in aluminium smelting.

Emissions from the *Other product manufacture and use* category have also increased due to the use of imported N_2O in medical and other applications.

2012–2013

Total IPPU sector emissions in 2013 were 115.9 kt CO_2-e (2.3 per cent) higher than emissions in 2012. This change was a result of ongoing gradual increases from the *Product uses as substitutes for ODS* source category (51.6 kt CO_2-e or 3.3 per cent), due to increasing use of air conditioning and other products. In addition there have been small increases in CO_2 emissions in the *Mineral industry* (19.7 CO_2-e or 2.6 per cent) and in the *Metal industry* (42.0 kt CO_2-e or 1.8 per cent) categories due to ongoing increases in production.

Table 4.1.1 New Zealand's greenhouse gas emissions for the IPPU sector by source category

	Emissions (kt CO_2-e)		Difference (kt CO_2-e)	Change (percentage)	Share (percentage)	
Source category	**1990**	**2013**	**1990–2013**	**1990–2013**	**1990**	**2013**
Mineral industry (2.A)	561.9	771.5	209.7	37.3%	17.4%	15.2%
Chemical industry (2.B)	176.7	276.8	100.1	56.6%	5.5%	5.5%
Metal industry (2.C)	2,490.3	2,329.4	–160.8	–6.5%	77.0%	45.9%
Product uses as substitutes for ODS (2.F)	–	1615.2	1615.2	–	–	31.8%
Other product manufacture and use (2.G)	47.2	78.4	31.2	66.1%	1.5%	2.4%
Total	**3,276.0**	**5,071.5**	**1,795.5**	**54.8%**	**–**	**–**

Note: No emissions are reported for the electronics industry (2.E) or non-energy products from fuels and solvents use (2.F) source categories. Colums may not sum due to rounding.

Figure 4.1.1 New Zealand's annual emissions from the IPPU sector from 1990 to 2013

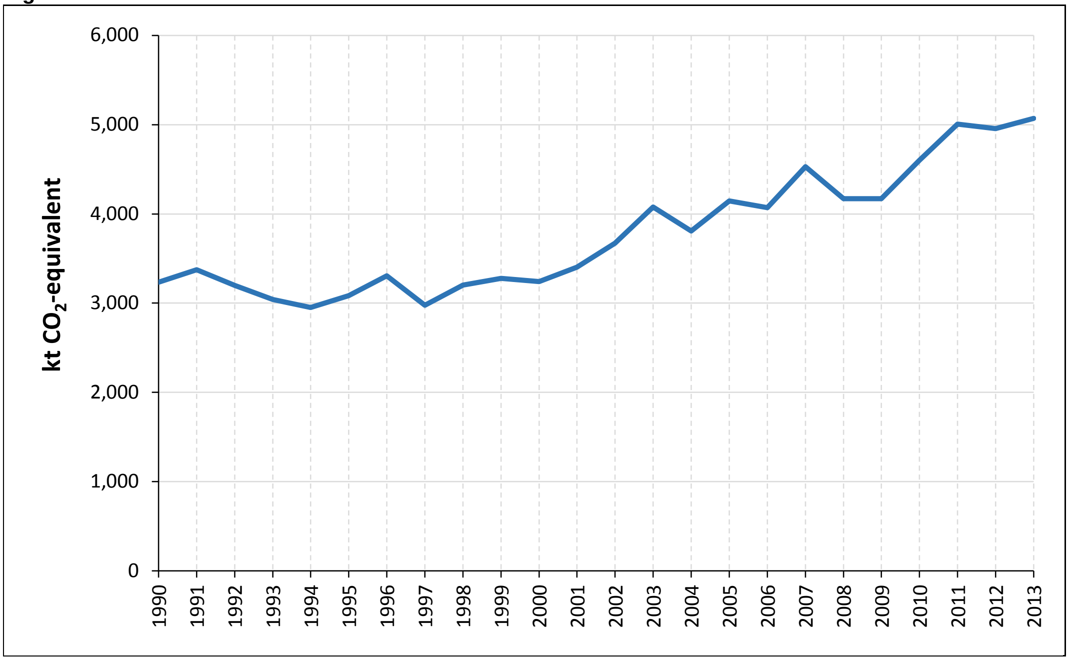
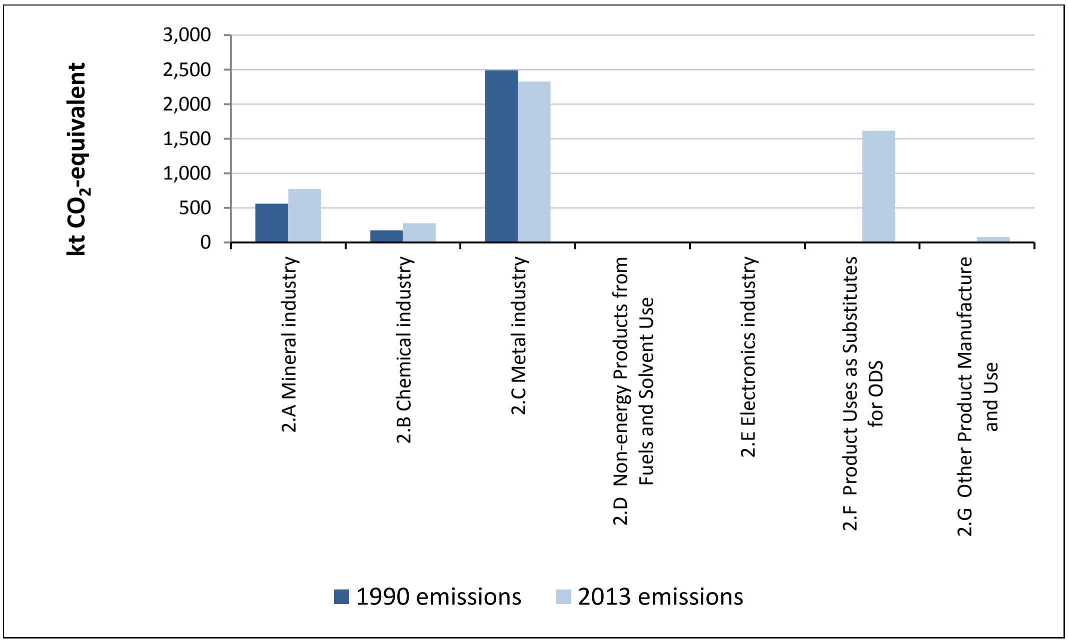


Figure 4.1.2 Change in New Zealand's emissions from the IPPU sector from 1990 to 2013



4.1.3 Key categories for IPPU sector emissions

Details of New Zealand's key category analysis are in section 1.5. The key categories in the IPPU sector are listed in table 4.1.2 below.

Table 4.1.2 Key categories in the Industrial Processes and Product Use sector

CRF code	IPCC categories	Gas	Criteria for identification
2.A.1	Mineral Industry – Cement Production	CO_2	level
2.B.10	Chemical industry – Other – Hydrogen Production	CO_2	level
2.C.1	Metal Industry – Iron and Steel Production	CO_2	level, trend
2.C.3	Metal Industry – Aluminium Production	CO_2	level
2.C.3	Metal Industry – Aluminium Production	PFCs	trend
2.F.4	Product Uses as Substitutes for ODS – Aerosols	HFCs & PFCs	trend
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air Conditioning	HFCs & PFCs	level, trend

Note: Ammonia production was a key category in previous submissions (level assessment and qualitative assessment) due to the inclusion of emissions from the use of urea, made from ammonia, as a fertiliser. These emissions are now reported in the Agriculture sector.

4.1.4 Methodological issues for the IPPU sector

Activity data in the IPPU sector has been derived from a variety of sources. In the *Mineral industry* category, the primary data source is emissions data reported under the New Zealand Emissions Trading Scheme (NZ ETS). For the *Chemical industry* and *Metal industry* categories, data (including activity data) is provided to the Ministry of Business, Innovation and Employment (MBIE) in response to an annual survey. For some large-scale activities in these categories, which are carried out by only one or two companies in New Zealand, activity data is reported as confidential in the CRF tables.

For the *Product uses as substitutes for ODS* category, updated activity data has been obtained by a detailed annual survey covering the electrical, refrigeration, and other industry participants (CRL Energy, 2014).

For small amounts of indirect greenhouse gas emissions reported in the *Chemical industry* category, and in *Other product manufacture and use*, data was obtained by a detailed industry survey and analysis (CRL Energy, 2006a). This data has been extrapolated for the years since 2006.

New Zealand uses a combination of Tier 1 and Tier 2 methodologies for the IPPU sector. Tier 2 methods are used for all key categories.

Country-specific emission factors have been used where available, including for emissions of Non-Methane Volatile Organic Compounds (NMVOCs) from solvent use in roading.

4.1.5 Uncertainties

The uncertainties are discussed under each category. IPCC default uncertainties have been used in nearly all cases. For previous submissions, an uncertainty of ±100 per cent was reported for lime manufacture, due to apparent uncertainty in the activity data – there was a possibility of emissions from unidentified production. This has been changed as the inventory agency is satisfied there is no such production occurring.

4.1.6 Verification

The inventory agency verified information on CO_2 emissions reported in the *Production of iron and steel* against information provided by these industries as participants in the NZ ETS.

For PFCs in *Aluminium production*, and for the *Mineral industry* category, the ETS is used as a primary data source. Verification will be done over time as these ETS returns are verified, but this has not been possible for this submission.

All data supplied in response to annual surveys (for the *Chemical industry*, *Metal industry*, and *Product uses as substitutes for ODS* categories) was verified against national totals where possible and anomalous data followed up and checked.

4.1.7 Recalculations and improvements

There were no recalculations for the *Mineral industry* or *Metal industry* source categories.

For the *Chemical industry* category, the only recalculation necessary was for compliance with IPCC 2006 guidelines. Emissions from urea used as fertiliser are now reported in the Agriculture sector. Only on-site process emissions associated with ammonia and urea manufacture are now in the IPPU sector.

A number of recalculations and improvements have been made in the *Product uses as substitutes for ODS* category. These have resulted from improved information on the import and use of stockpiled refrigerants and N_2O, and the increasing use of alternative refrigerants (such as hydrocarbons).

Expert review team comments

Following review of previous submissions, the Expert Review Team (ERT) recommended that New Zealand continue efforts to improve the transparency of activity data in the *Mineral industry*, *Chemical industry* and *Metal industry* categories. This relates to activity data that is reported as confidential, and to the use of ETS returns in which some activity data (eg *Cement production*) is not transparently reported.

Commercial confidentiality remains an issue for this and future submissions. The inventory agency will continue to work with industry to allow inclusion of activity data in reporting. In addition, early provision of confidential activity data to future review teams will assist in allowing more rigorous review.

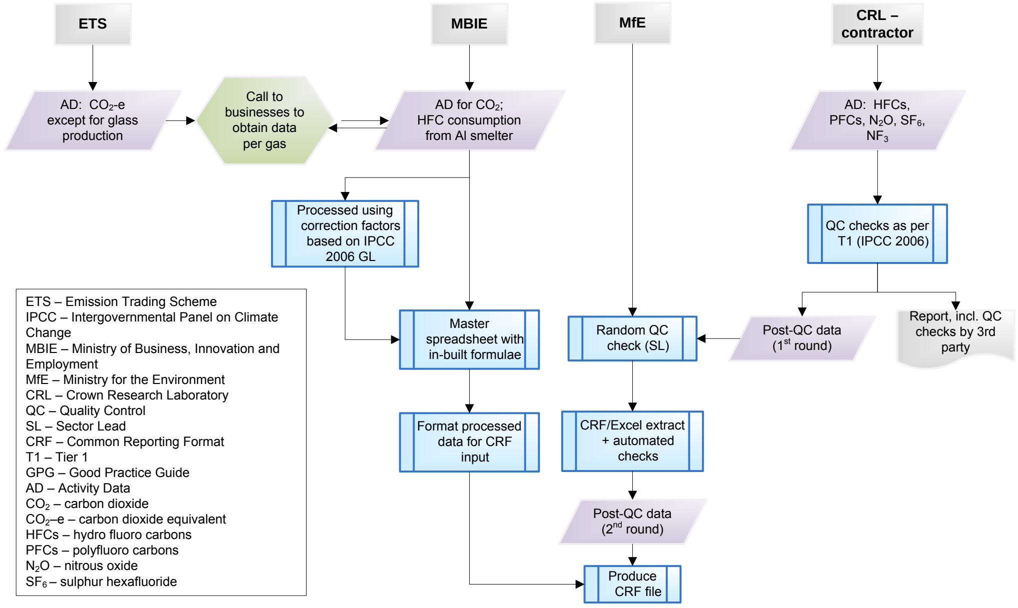
Although verification of ETS returns has not been possible for this submission, over time verification will improve the transparency of reporting in the *Mineral industry* category.

New Zealand makes significant use of import data to estimate emissions of PFCs used in the *Refrigeration and air conditioning* category. The ERT recommended that New Zealand try to obtain information necessary to calculate emissions at time of use. For this submission, data obtained from industry surveys has not allowed a change in this methodology. However, improved data has allowed more accurate assessment of the time of use for refrigerants, and the reported emissions for 2010–12 have been recalculated.

The ERT also recommended that New Zealand reassess the uncertainty value of ±100 per cent assigned to activity data for the *Lime production* category, by investigating the possibility of unreported production. This has been completed and the default uncertainty is used in this submission.

4.1.8 Quality assurance and quality control (QA/QC) processes

Figure 4.1.3 Tier 1 quality checks for the IPPU sector



4.2 Mineral industry (2.A)

4.2.1 Description

Emissions from the *Mineral industry* source category include emissions of CO_2 from the calcination of limestone for cement and lime, and from the use of soda ash and limestone in the production of iron and steel, glass, and aluminium. Only CO_2 from calcination is reported here. Any emissions from the combustion of fuel to provide heat for these activities are reported in the Energy sector.

Small amounts of indirect emissions (SO_2 only) from the *Cement production* category are also reported.

There are two cement production facilities operating in New Zealand. Holcim New Zealand Ltd has a dry-process plant near Whangarei, and Golden Bay Cement Ltd has a wet-process cement plant at Cape Foulwind, on the west coast of the South Island. Another, smaller cement company (Lee Cement Ltd) also operated from 1995 to 1998. These facilities produce clinker from the calcination of limestone, and process it into Portland cement and general purpose cement.

There are three companies (McDonalds Ltd, Websters Hydrated Lime Ltd and Perrys Group Ltd) making burnt and slaked lime at five different facilities in New Zealand.

Soda ash and limestone are used under the G*lass production* category by two manufacturers. O-I New Zealand makes container glass and Tasman Insulation New Zealand Ltd makes glass for building insulation products. Limestone and soda ash are also used in the steel and aluminium industries. Emissions from this use are reported in the *Mineral industry* category to protect the confidentiality of the data.

The only key category is CO_2 emissions from the *Cement production* category (level assessment). No sources were identified as key categories in the 2013 trend assessment.

In 2013, the *Mineral industry* category accounted for 771.5 kt CO_2-e (15.2 per cent) of emissions from the IPPU sector. This is 209.7 kt (37.3 per cent) above the 1990 emissions, driven by increasing production of cement, lime and other products.

Changes in the national standards for cement, in 1995 and 2010, have allowed increasing amounts of other minerals to be added to clinker in cement. Partly due to these changes, the increase in emissions has not been in proportion to cement and lime production, both of which have increased by approximately 60% over the time series.

4.2.2 Methodological issues

Use of NZ ETS data

Firms that use limestone or soda ash in the production of clinker (for cement), burnt or slaked lime, or glass have had emission reporting obligations under the NZ ETS since 2010. The emission returns submitted by participants in the NZ ETS are now the primary source of data for all CO_2 emissions from mineral products.

The Environmental Protection Authority (EPA) administers and audits the emission returns submitted by participants. Data submitted by NZ ETS participants is protected by stringent provisions relating to commercial confidentiality. However, under section 149 of the Climate Change Response Act 2002, the inventory agency (the Ministry for the Environment) may request information from the EPA for the purpose of compiling New Zealand's annual Inventory report.

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

For all NZ ETS reporting in the *Mineral industry* category, the methodologies used are specified in regulations (Parliamentary Counsel Office 2015). These methods require participants to report CO_2 emissions calculated from the amount of pure product or input material. For cement, this means pure calcium oxide (CaO) and magnesium oxide (MgO) in clinker produced. Participants are not required to report the gross amounts of clinker or cement produced, with impurities included. This information only becomes available when ETS returns are verified by the EPA.

Cement production

In 2013, *Cement production* accounted for 568.6 kt CO_2-e (73.7 per cent) of emissions from the *Mineral industry* category.

For years up to 2009, emissions data was supplied by the cement companies to MBIE and based on the methodology specified in the *Cement CO_2 Protocol* (World Business Council for Sustainable Development, 2005), which uses plant-specific emission factors based on the CaO and MgO content of clinker produced. It also includes an adjustment for emissions due to cement kiln dust. This is consistent with the IPCC Tier 2 method (IPCC, 2006).

Due to commercial sensitivity, individual company data has been kept confidential. Also, as indicated above, from 2010 ETS returns have been used and companies do not report activity data every year. For both of these reasons, activity data for *Cement production* has not been included in the CRF tables.

Small amounts of sulphur dioxide (SO_2) are also emitted in *Cement production*. SO_2 originates from sulphur in the limestone used, and approximately 75 to 95 per cent of the SO_2 generated is absorbed into the clinker produced. The emission factor for SO_2 used by New Zealand is 0.64 kg SO_2 per tonne of clinker produced. This was estimated from a mass balance study on one of the two cement plants in the country (CRL Energy, 2006a).

Some additional SO_2 is derived from sulphur in the fuel used in cement kilns, and is reported in the Energy sector.

Lime production

In 2013, *Lime production* accounted for 132.5 kt (17.2 per cent) of emissions from the *Mineral industry* category.

Emissions data was supplied annually by the lime companies to MBIE until 2009. This included the amount of burnt lime produced each year. Emissions for these years were calculated using the IPCC Tier 1 method and the default emission factor of 0.75 t CO_2 per tonne of burnt lime produced.

From 2010 lime companies have reported their emissions in ETS returns. As indicated above, these do not incorporate data on the amount of burnt or slaked lime produced or its purity. However, the companies do carry out regular analyses to develop the data to report in the ETS, and the use of ETS data represents an improvement in accuracy. For this submission, the activity data for 2010 to 2013 has been back-estimated using the default emission factor.

The emissions of SO_2 from *Lime production* have been estimated using an emission factor of 0.5 kg SO_2 per tonne of burnt lime produced. This was derived from plant measurements carried out in 2005 (CRL Energy, 2006a). Any SO_2 from sulphur in fuel used for *Lime production* is reported in the Energy sector.

Glass production and other uses of carbonates

Activity data for *Glass production* is considered confidential by the two companies that produce glass in New Zealand and is not provided in the CRF tables. Emissions from the use of soda ash and limestone in *Glass production* are reported in *Other process uses of carbonates* (CRF 2.A.4) to aggregate this with other small-scale emission sources in the *Mineral industry* category.

Emissions from limestone used by New Zealand Steel Ltd are also reported in CRF 2.A.4, not in the *Metal industry* category, so that they can be aggregated with other limestone and soda ash uses. This preserves the confidentiality of the data provided by New Zealand Steel Ltd. Because the limestone emissions cannot be fully disaggregated in the data provided by the company, a small amount of CO_2 from coke and electrode use at the steel plant is also included (see section 4.4.2).

Emissions of CO_2 from soda ash used by New Zealand Aluminium Smelters Ltd (in reduction cells in the aluminium smelter) are also reported in CRF 2.A.4 for aggregation, as the data is also considered to be confidential.

For these emission sources, historical data for the years up to 2006 was provided by the companies (CRL Energy, 2006a) and updated for the years 2007–2009 by survey requests from MBIE. Data on limestone and soda ash use was based on the companies' records where available. In the case of one glass-making facility, some historical data had to be estimated based on glass production rates, as actual limestone and soda ash use was not recorded before 2006.

For 2010– 2013, the companies' ETS returns are used.

Emissions from ground limestone used in liming agricultural soils are reported in the Agriculture sector.

4.2.3 Uncertainties and time-series consistency

The IPCC default uncertainties have been used for CO_2 emissions (see table 4.2.1). Uncertainties in non-CO_2 emission factors (table 4.2.1) were assessed from survey questionnaires and correspondence with industry sources (CRL Energy, 2006a).

For previous submissions, an estimated uncertainty of ±100 per cent was used for *Lime production* activity data. This was on the basis that there would be a possibility of non-market production of lime that may not be reported. The inventory agency is satisfied that there is no unreported, non-market production of burnt or slaked lime occurring in New Zealand, so for this submission the default uncertainty is used (IPCC, 2006a).

Table 4.2.1 Uncertainty in emissions from mineral products

Mineral product	Uncertainty in AD	Uncertainty in EFs
Cement: CaO content of clinker	± 1%	± 1%
Cement: kiln dust	± 1%	± 5%
Cement (SO_2)	± 1%	± 40%
Lime (CO_2)	± 2%	± 2%
Lime (SO_2)	± 2%	± 80%
Glass (SO_2)	± 5%	± 5%
Glass (NMVOC)	± 5%	± 50%
Glass (SO_2)	± 5%	± 10%

4.2.4 Source-specific quality assurance and quality control and verification

Emissions from *Cement production* were a key category, and data for these emissions underwent Tier 1 quality checks in the preparation of this Inventory. Verification of activity data from independent sources is not currently possible.

4.2.5 Source-specific recalculations

There were no recalculations for the *Mineral industry* category.

4.2.6 Source-specific planned improvements

NZ ETS returns in the *Mineral industry* category are not verified every year, but the EPA carries out verification of NZ ETS participants' submitted data on a rotating basis. As these verifications occur over time, the inventory agency will make use of the resulting information to verify the emissions data used in the Inventory.

In addition, the verifications will allow more accurate calculation of activity data, particularly clinker or cement in *Cement production*. The inventory agency will also consider approaching the sector directly for updated activity data. However, confidentiality will remain a problem for reporting detailed activity data in future Inventory submissions.

4.3 Chemical industry (2.B)

4.3.1 Description

The main chemical processes occurring in New Zealand are the production of urea, methanol, superphosphate fertiliser, hydrogen peroxide and formaldehyde. In addition, a significant amount of hydrogen is made at the Marsden Point oil refinery and CO_2

emissions from this process are reported in the *Chemical industry* category. No other chemical products (such as nitric acid, adipic acid, ethylene or coke) are produced in New Zealand.

Ammonia is made at one site in Taranaki by the catalytic steam reforming of natural gas. Essentially all of the ammonia produced is further processed into urea, and all urea produced is used as a fertiliser in New Zealand.

Methanol is made from natural gas feedstock at two sites in Taranaki. When built, one of these plants processed methanol into synthetic gasoline for transport use in New Zealand. Synthetic gasoline production stopped in 1997, and from that time both sites have only made chemical methanol for export. Emissions associated with production of synthetic gasoline (1990–1997) are reported in the Energy sector.

Formaldehyde is made at five sites in New Zealand.

Emissions from the *Chemical industry* category in 2013 were 276.8 kt CO_2-e (5.5 per cent) of emissions from the IPPU sector.

Carbon dioxide emissions from hydrogen production were identified as a key category (level assessments) in 2013. In the previous submission, CO_2 from the *Ammonia production* category was included as a key category, based on a qualitative assessment. This assessment was based on the inclusion of CO_2 emitted when ammonia is processed into urea and used as fertiliser (see section 4.3.5 below). For this submission, fertiliser emissions are reported in the Agriculture sector, leaving a much smaller amount of CO_2 to be reported in the IPPU sector.

4.3.2 Methodological issues

Ammonia and urea

Data on the natural gas feedstock supplied to the ammonia-urea production plant is supplied to MBIE by Ballance Agri-Nutrients Limited, which operates the plant. The CO_2 emissions are estimated from a carbon balance: emissions are from the total carbon in the feedstock gas used, less carbon recovered for urea production and remaining in the urea product (IPCC, 2006a). Note that only gas used as feedstock is included in this calculation. Gas used for combustion is reported in the Energy sector under the *Manufacturing industries and construction* source category (CRF 1.A.2).

Methanol

Data on the natural gas used for methanol production is also supplied to MBIE by the plant operators. However, the available data on gas supplied to the methanol plants does not allow for feedstock to be clearly distinguished from gas used for combustion. Also, close to 100 per cent of the carbon in feedstock gas is converted to methanol. Therefore, no significant CO_2 emissions can be clearly related to the process. Any small amount of process CO_2 emissions is included in the Energy sector (CRF 1.A.2), along with the much larger amount of combustion-related emissions from the methanol plants. Fugitive methane from the methanol manufacturing process is estimated using the default emission factor.

Hydrogen

Most of the hydrogen produced in New Zealand is made by Refining New Zealand Ltd at the Marsden Point oil refinery. Another company, Degussa Peroxide Ltd, produces a small amount of hydrogen, which is converted to hydrogen peroxide. In both cases the hydrogen is produced from CH_4 (from natural gas) and steam. Carbon dioxide is a by-product of the reaction and is vented to the atmosphere.

Emissions of CO_2 from hydrogen production are calculated using a Tier 2 methodology. The required data is supplied directly to MBIE by the two production companies. Field-specific emission factors are used to determine the CO_2 emissions from the feedstock gas used in the production of hydrogen. In 2013, the implied emission factor was 6.0 tonnes of CO_2 per tonne of hydrogen produced.

Formaldehyde

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

Fertiliser

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

Activity data supplied in 2005 has been used for 2006–2013. Emission estimates are based on site-specific emission factors supplied by industry. The combined implied emission factor is 1.5 kilograms of SO_2 per tonne of sulphuric acid.

Ethanol

NMVOCs are also emitted from three ethanol plants (excluding ethanol produced for beverages). These are estimated using a country-specific emission factor of 6 grams NMVOCs per litre of ethanol made (CRL Energy, 2006a). Due to data unavailability, the estimates have remained unchanged since 2006.

4.3.3 Uncertainties and time-series consistency

The IPCC default uncertainties are used as detailed in table 4.3.1 below.

Table 4.3.1 Uncertainty in emissions from chemical industry

Chemical industry	Uncertainty in AD	Uncertainty in EFs
Ammonia	± 2%	± 6% (CO_2)
Formaldehyde	± 2%	± 50% (NMVOCs)
Methanol	± 2%	± 50% (NO_x and CO) ± 30% (NMVOCs) ± 80% (CH_4)
Superphosphate	± 10%	± 25-60% (varies by site)
Sulphuric acid	± 10%	± 15%

4.3.4 Source-specific quality assurance and quality control and verification

Emissions from hydrogen production were identified as a key category (level assessment). Data for this source underwent Tier 1 quality checks in the preparation of this Inventory. Verification of activity data and emissions from independent sources is not currently possible.

4.3.5 Source-specific recalculations

In the previous submission, emissions of the carbon in the urea product (emitted when urea is used as a fertiliser) were included in the reported emissions for the *Chemical industry* category (IPCC 1996). Under the 2006 IPCC guidelines (IPCC 2006b) all emissions from use of urea fertiliser are reported in the Agriculture sector. For New Zealand, this includes imported and domestically made urea. Therefore, carbon incorporated in urea is excluded from the emissions reported in the *Chemical industry* category for this submission. Also, methane emissions from methanol production are now estimated and reported in the *Chemical industry* category.

There were no recalculations for the *Chemical industry* category, apart from these changes required to comply with the 2006 IPCC guidelines.

4.3.6 Source-specific planned improvements

The inventory agency will work with MBIE and the industry to improve transparency as far as possible in this category, while recognising that confidentiality concerns may continue to limit the ability to report all activity data.

4.4 Metal industry (2.C)

4.4.1 Description

The main *Metal industry* activities in New Zealand are the *Production of iron and steel* (from iron sand and from recycled scrap steel) and aluminium smelting. New Zealand has no production of coke, sinter, or ferroalloys.

There are two steel producing sites in New Zealand. New Zealand Steel Limited produces iron using an 'alternative iron-making process', from titanomagnetite iron sand (Ure, 2000). The iron produced is then processed into steel. Pacific Steel Limited operates an electric arc furnace at a separate site, which processes recycled scrap metal into steel.

In 2014 it was announced that the owners of New Zealand Steel Limited were buying the Pacific Steel Limited assets and that, from the end of 2015, all New Zealand's steel-making capacity is likely to be concentrated on one site.

There is one aluminium smelter in New Zealand, operated by New Zealand Aluminium Smelters Limited. The plant produces aluminium by smelting imported bauxite using centre-work prebake technology.

4.4.2 Methodological issues

Iron and steel production

There are two steel producers in New Zealand, New Zealand Steel Ltd and Pacific Steel. The production data from the two steel producers is provided to MBIE. However, this production data is regarded as commercially confidential and is reported as such in the CRF tables.

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

New Zealand Steel Ltd

The majority of 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

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:

$$CO_2 \text{ emissions} = \text{mass of reducing agent} \times \text{EF reducing agent} - \text{mass C in finished steel.}$$

All CO_2 emissions associated with coal use for the *Iron and steel production* category are reported in the IPPU sector, regardless of the end use (IPCC, 2006a). Following the calculation of CO_2, New Zealand Steel Ltd provides a plant-specific analysis of the proportions of coal and natural gas that contribute to the chemical transformation and to combustion. This ensures there is no double counting between the Energy and IPPU sectors.

The data on limestone could not be separated from those on coke and electrodes. Therefore, CO_2 emissions 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.4). These emissions are reported in section 4.2.

Pacific Steel

Emissions from the production of steel by Pacific Steel arise from the combustion of the carbon charge to the electric arc furnace. Each of the carbon-containing charges input to the electric arc furnace is weighed, and each charge is multiplied by its carbon content (see table 4.4.2). The average carbon content (0.20 per cent by mass) in the finished product is then subtracted from the total carbon charge to obtain the carbon emitted. The result is multiplied by the molar mass ratio of CO_2 to C to obtain the CO_2 emissions.

Table 4.4.2 Approximate carbon content of carbon-containing charges input to the electric arc furnace (provided by Pacific Steel)

Charge	Carbon content (%)
20'' electrode	98.00
12'' electrode	98.00
Scrap metal	0.59
Lime	12.00
Mag-Carb	Up to 30.00
Diajetta	99.90
Recarburiser	98.00

Emissions exclude the carbon component of vanadium, manganese or silicon that is subsequently added to the ladle. The amount of carbon is considered negligible and is likely to be sequestered in the final steel product.

Due to limited process data at Pacific Steel, emissions between 1990 and 1999 are calculated using the average of the implied emission factors for 2000–2008 based on production volume. Emissions from 2000 onwards are reported using the IPCC, 2006a, Tier 2 method. Pacific Steel provides this data directly to MBIE.

Aluminium production

There is one aluminium smelter in New Zealand, operated by New Zealand Aluminium Smelters Ltd (NZAS). The smelter produces aluminium by smelting imported raw material using centre-work prebake technology. CO_2 and perfluorocarbon (PFC) are emitted during the aluminium production process.

Carbon dioxide is emitted during the oxidation of the carbon anodes. The two PFCs, tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6), are emitted from the reduction cells used for smelting during anode effects. An anode effect occurs when the aluminium oxide concentration in the cell 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.

Estimates of CO_2 and PFC emissions were supplied by NZAS to MBIE until 2010. From 2011 to 2013, the CO_2 and PFC emissions have been sourced from the company's NZ ETS returns.

Carbon dioxide

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

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

Perfluorocarbons

The two PFCs, CF_4 and C_2F_6, are emitted from the reduction cells used for smelting during anode effects. An anode effect occurs when the aluminium oxide concentration in the cell is low.

PFC emissions from aluminium smelting are calculated using the IPCC–International Aluminium Institute 2006 Tier 2 methodology:

$$\text{Perfluorocarbon emissions (t } CO_2\text{-e)} = \text{hot metal production (t)} \times \text{slope factor} \times \text{anode effect duration (min/cell-day)} \times \text{global warming potential}$$

The smelter captures every anode effect 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 CF_4 and 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-worke prebake technology and are sourced from the International Aluminium Institute, 2006. The global warming potentials of CF_4 and C_2F_6 are 7,390 and 12,200 respectively.

Anode effect durations were not recorded in 1990, 1991 and 1992. Consequently, a Tier 1 method (IPCC, 2006a) 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.

The implied emission factors for emissions from aluminium production fluctuated over the time series between 1990 and 1998. Since 1998, emissions have been lower than previously, and relatively stable, due to much better control of anode effects (see table 4.4.3).

4.4.3 Uncertainties and time-series consistency

The IPCC default uncertainties have been used.

Table 4.4.3 Uncertainty in emissions from metal products

Mineral product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Iron and steel	± 5%	±7 (CO2)
		±20–30 (CO)
		±70 (NOx)
Aluminium	± 5%	±2 (CO2)
		±30 (PFCs)[1]
		±40 (CO)

[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 IPCC guidelines, and in the absence of measurement data and precision measures, the total uncertainty is assessed to be ±30 per cent (CRL Energy, 2006b).

Table 4.4.4 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 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. An industry-supplied value of 110 kilograms of CO per tonne of product was based on measurements and comparison with Australian CO emission factors.

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[15] as sources of non-CO_2 emissions. However, no details or emission factors were 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 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

[15] IPCC, 1996.

factors for the *Iron and steel production* category include ±5 per cent uncertainty for the carbon content of the steel (IPCC, 2000) and ±5 per cent for the reducing agent.

The default uncertainty[16] of ±2 per cent has been applied to CO_2 emission factors from the *Aluminium production* category. Uncertainties in non-CO_2 emissions were assessed by the contractor from questionnaires and correspondence with industry sources (CRL Energy, 2006a). These are documented in table 4.4.4.

4.4.4 Source-specific QA/QC and verification

Carbon dioxide emissions from the *Iron and steel production* and *Aluminium production* categories (2013 level assessment), and PFC emissions from the *Aluminium production* category (trend assessment) underwent IPCC Tier 1 quality checks. There were no significant findings from these checks.

Verification with the NZ ETS

New Zealand followed a Tier 2 quality assurance and quality control (QA/QC) check for the *Iron and steel production* category. Reported estimates of CO_2 emissions from this category were verified with data provided by the two steel producers under the NZ ETS for the 2010–2013 calendar years.

The verification process concluded there that were no significant discrepancies between the reported emissions from these sources for the two steel companies.

4.4.5 Source-specific recalculations

There were no recalculations for this category.

4.4.6 Source-specific planned improvements

There are no planned improvements for this category.

4.5 Non-energy products from fuels and solvent use (2.D)

New Zealand has no known emission sources in this category. Indirect greenhouse gas emissions from the use of solvents in applications such as painting are reported in the *Other product manufacture and use* category (CRF 2.G).

4.6 Electronics industry (2.E)

New Zealand does not manufacture electronic products.

4.7 Product uses as substitutes for ODS (2.F)

4.7.1 Description

In 2013 net emissions of HFCs and PFCs (the *Product uses as substitutes for ODS* category) totalled 1,615.2 kt CO_2-e, 31.8 per cent of emissions from the IPPU sector. This was an increase of 51.6 kt CO_2-e (3.3 per cent) from the 2012 level of 1,563.7 kt CO_2-e. There was no consumption of HFCs or PFCs in 1990. The first consumption of HFCs in New Zealand was reported in 1992 and the first consumption of PFCs in 1995.

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16 IPCC, 2006a.

Emissions from the consumption of HFCs and PFCs from the *Refrigeration and air conditioning* and *Aerosols* subcategories were identified as key categories in the 2013 trend assessment. Emissions from the consumption of HFCs and PFCs from the *Refrigeration and air conditioning* subcategory were also a key category in the 2013 level 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 in New Zealand. Perfluorocarbons are also emitted from the aluminium-smelting process and are reported in the *Metal industry* category (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 2006 IPCC guidelines, emissions of HFCs and PFCs are separated into seven subcategories:

- *Refrigeration and air conditioning*
- *Foam blowing agents*
- *Aerosols*
- *Solvents*
- *Fire protection*
- *Other*.

4.7.2 Methodological issues

Activity data on the bulk imports and end use of HFCs and PFCs in New Zealand is collected through an annual survey of 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. In surveys up to 2001, the Ministry of Economic Development compiled a detailed breakdown of bulk HFCs using this data and information from import licences for a range of mixtures such as HFCs and HCFCs. This analysis has not been carried out in recent years due to restricted access to commercially sensitive import data. Consequently there is no longer an accurate independent check on the total imports reported by bulk chemical suppliers.

Imports of HFCs in products, and bulk imports of PFCs, are more difficult to determine as import tariff codes are not specific enough to identify these chemicals. However, the availability of import (and export) statistics for *Refrigeration and air conditioning* equipment from July 2013 should provide a significant improvement in Inventory quality for that sector.

New Zealand uses the IPCC Tier 2 approach to calculate emissions from the consumption of HFCs and PFCs (IPCC, 2006a). 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 IPCC reporting guidelines (IPCC, 2006a). Potential emissions for HFCs and PFCs have been calculated using the IPCC, 2006a, 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, 2014).

Table 4.7.1 New Zealand's halocarbon methods and emission factors

HFC Source	Calculation method	Emission factor
Stationary refrigeration/ air conditioning	IPCC, 2006 equation 7.9	Not applicable
Mobile air conditioning	IPCC, 2000 equation 3.44	Top-down approach First fill: 0.5 per cent
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
Aerosols	IPCC, 2006 equation 7.6	IPCC default factor of 50 per cent of the initial charge per year (but 100 per cent for metered dose inhalers)
Fire protection	IPCC, 2006	Top-down approach using an annual emission rate of 1.5 per cent

Refrigeration and air conditioning

Stationary refrigeration and air conditioning

Emissions from the use of HFCs and PFCs in stationary refrigeration and air conditioning were 1,316.7 kt CO_2-e in 2013. This is an increase of 1,315.2 kt CO_2-e from the 1992 level of 1.4 kt CO_2-e. In 2013, stationary refrigeration and air conditioning accounted for 81.5 per cent of emissions from the *Product uses as substitutes for ODS* category. In 1992, only HFC-134a was used, while in 2013, HFCs -32, -134a, -125 and -143a were consumed. There was no use of HFCs and PFCs before 1992. A small amount of C_2F_6 (in the form of a mix) was used in 2010 only.

The increase in emissions from 1992 to 2013 is due to HFCs and PFCs used as replacement refrigerants for CFCs and HCFCs in *Refrigeration and air conditioning* equipment.

For the current Inventory of 2013 emissions, Fisher & Paykel staff revealed the complexity of their business as the key New Zealand manufacturer as well as the main importer and exporter of household refrigerators and freezers. Most of their manufacturing base shifted to a new plant in Thailand during 2012 and 2013 and the transition to hydrocarbon refrigerants is further advanced than previously reported. It was concluded only 50 per cent of household refrigerator/freezer imports in 2013 contained HFC and the hydrocarbon proportions for 2011 and 2012 were revised to 5 per cent and 15 per cent respectively (CRL Energy, 2014).

New Zealand uses the top-down IPCC, 2006a Tier 2b approach (Box 4.2) and New Zealand-specific data to obtain actual emissions from stationary refrigeration and air conditioning. This approach is equivalent to the IPCC, 2000 Tier 2 top-down approach. Table 4.7.2 provides a summary of results for the time series 1990–2013.

Table 4.7.2 HFC and PFC emissions from stationary refrigeration in New Zealand (CRL Energy, 2014)

Year	Annual sales of new refrigerant (tonnes)	Total charge of new equipment sold in NZ (tonnes)	Emissions from retiring NZ equipment (tonnes)	Amount of intentional destruction (tonnes)	Emissions (tonnes)
1990	0.0	0.0	0.0	0	0.0
1991	0.0	0.0	0.0	0	0.0
1992	1.2	0.2	0.0	0	1.0
1993	2.8	0.8	0.0	0	2.0
1994	49.5	10.0	0.0	0	39.5
1995	111.5	24.1	0.0	0	87.4
1996	173.3	41.6	0.0	0	131.7
1997	73.2	44.3	0.0	0	28.9
1998	226.1	58.9	0.0	0	167.1
1999	207.7	70.9	0.0	0.0	136.9
2000	201.8	79.0	0.0	0.0	122.9
2001	209.2	79.8	0.0	0.0	129.4
2002	246.2	62.5	0.0	0.0	183.7
2003	310.9	73.7	0.1	0.0	237.4
2004	228.3	100.7	1.0	0.0	128.6
2005	376.6	162.5	0.8	0.0	215.0
2006	390.4	197.6	6.6	0.0	199.4
2007	510.8	239.6	9.7	0.0	280.9
2008	471.8	268.9	15.3	0.0	218.2
2009	470.2	251.5	21.8	0.0	240.5
2010	579.4	256.8	29.3	0.0	351.9
2011	715.2	246.3	45.4	0.0	514.3
2012	712.1	263.4	42.5	0.0	491.1
2013	675.9	210.5	53.0	0.0	518.4

To estimate HFC and PFC emissions, all refrigeration equipment is split into two groups: factory-charged equipment and all other equipment that is charged with refrigerant on site. 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 in factory-charged equipment and 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). This includes 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 estimate includes schools, factories, offices and hotels. 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.

Detailed information on the assumptions used to build models of refrigerant consumption and banks can be found in CRL Energy, 2014.

Mobile air conditioning

In 2013, HFC-134a emissions from mobile air conditioning were 201.5 kt CO_2-e, an increase of 200.2 kt CO_2-e from the 1994 level of 1.3 kt CO_2-e. Emissions from mobile air conditioning accounted for 12.5 per cent of emissions from halocarbon and SF_6 consumption in 2013. 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 the 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 through bulk chemical importers and distributors and within the air-conditioning systems of imported vehicles. Industry sources report that air-conditioning systems were retrofitted (with ‘aftermarket’ units) to new trucks and buses and to second-hand cars (mainly around the year 2000). Refrigerated transport is included in the stationary refrigeration and air-conditioning subcategory.

New Zealand has used the IPCC 2000 Tier 2b method, mass-balance approach (box 4.3). This approach does not require emission factors (except for the minor first-fill component) as it is based on chemical sales and not equipment leak rates.

IPCC, 2000, Equation 3.44

Annual Emissions of HFC-134a = First-Fill Emissions +
Operation Emissions + Disposal Emissions — Intentional Destruction

First-fill emissions are calculated from imported vehicle fleet numbers provided by Statistics New Zealand and the New Zealand Transport Registry Centre. Assumptions are made 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 CRL Energy, 2014.

Foam

In 2013, emissions from the use of HFCs in the *Foam blowing* category were 2.9 kt CO_2-e, an increase of 2.8 kt CO_2-e from the 2000 level of 0.1 kt CO_2-e.

The HFC-245fa/365mfc mixture is known to have only been used in New Zealand in *Foam blowing* from 2004 to 2012. These emissions are estimated to have increased from 0.1 tonnes in 2004 to 2.71 tonnes in 2013. Emissions of the two gases in this mixture are assessed independently and reported accordingly.

For the current study of 2013 emissions, the same methodology for foam manufacture and for imported foam was used. Suppliers have continued to provide detailed information on the supply of *Foam blowing agents*. At a very late stage of the current study, a new supplier of foam HFCs was identified. It is estimated they imported 0.5 tonnes, although this will be reviewed when new information becomes available (CRL Energy, 2014).

Fire protection

HFC-227ea emissions from *Fire protection* equipment were 2.2 kt CO_2-e in 2013, or 0.1 per cent of emissions from the *Product uses as substitutes for ODS* category. This is an increase of 2.1 kt CO_2-e from the 1994 level of 0.1 kt 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 further major importer of *Fire protection* equipment was identified in the last report and provided HFC-227ea import figures from 2009 (when they commenced imports).

A Tier 1a approach (with country specific emissions factors) was used to estimate emissions for this category. 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 HFCs from any retirements were totally recovered for use in other systems.

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 can be attributed to HFC-134a being used as a substitute propellant for HCFCs and CFCs (as discussed above).

Aerosols

Emissions from *Aerosols* contributed 23.6 kt CO_2-e in 2013, or 1.5 per cent of emissions from the *Product uses as substitutes for ODS* category. This is an increase of 22.0 kt CO_2-e from the 1996 level of 1.6 kt CO_2-e. Aerosols containing HFCs were not widely used in New Zealand until 1996. Therefore, emissions from *Aerosols* are estimated from 1996 onwards. The initial charge is expected to be emitted within the first two years of sale.

Activity data on aerosol use 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

Emissions from metered dose inhalers contributed 67.9 kt CO_2-e in 2013, or 4.2 per cent of emissions from the *Product uses as substitutes for ODS* category. This is an increase of 67.4 kt CO_2-e from the 1995 level of 0.5 kt CO_2-e. The consumption of HFCs in metered dose inhalers is not known to have occurred in New Zealand before 1995.

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

Data on the total number of doses contained in metered dose inhalers used from 1999 to 2013 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. HFC-134a propellant was first used in metered dose inhalers in 1995. Pharmac's figures for total doses demonstrate a relatively small increase in activity from 1999 to 2013 with the HFC proportion steadily increasing to 100 per cent by 2012 (as CFCs were phased out).

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, 2014).

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 4.7.3. 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 4.7.3 New Zealand's uncertainties in the consumption of HFCs (CRL Energy, 2014)

HFC Source	Uncertainty estimates (%)
Stationary refrigeration/air conditioning	Combined uncertainty ±50
Mobile air conditioning	Combined uncertainty ±32
Foam	Combined uncertainty ±49
Aerosols	Combined uncertainty ±56
Metered dose inhalers	Combined uncertainty ±10
Fire protection	Combined uncertainty ±32

4.7.4 Source-specific QA/QC and verification

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

4.7.5 Source-specific recalculations

Stationary refrigeration and air-conditioning equipment

Several improvements in the estimation of emissions from Stationary Refrigeration and Air Conditioning (SRAC) have been made for this submission. An adjustment has been applied to account for stockpiling before the 2013 ETS introduction for HFCs. Without detailed information on supplier stock changes, all imports have to be assumed emitted in the import year. Therefore SRAC emissions in 2011, 2012 and 2013 appeared to be 832, 620 and 72 tonnes respectively. By averaging those three years of supply for all SRAC HFCs, the total emissions balance out to more realistic levels of 490 to 520 tonnes (and 2014 emissions appear to have returned to pre-2011 levels).

HFC-134a imports in household refrigerators, freezers and refrigerator/freezers were each reduced by 5 per cent instead of the previous 1 per cent in 2011, and 15 per cent instead of the previous 3 per cent in 2012. This accounts for the major increase in equipment imports with hydrocarbon refrigerants.

With increasing evidence of alternative refrigerants in the coolstore sector, it was assumed that 3 tonnes of R407F was installed in 2012 instead of R404A.

Errors were corrected in figures for re-exports in household refrigeration for 1994 to 2005 and 2008.

The other refrigerated equipment category was reassessed. This resulted in improved simplicity and a more consistent approach for future calculations.

The average refrigerant charge was reassessed. Seven kilograms is now used for imports, New Zealand-manufactured units and other exports. This compares with an average of 4 kg for manufactured exports.

Temperzone had indicated its manufacturing emissions were as low as 0.1 per cent of filled R410A (no measurements), but this has been amended in this study to a more realistic 1 per cent for all years.

The net effect of the changes (not including the first three changes listed above) ranged from reducing 2005 calculated HFC-134a emissions for the SRAC sector by 1.3 tonnes, to increasing emissions by 0.9 tonnes in 2010. The most significant changes for calculated HFC-125 and HFC-143a emissions were 2 to 4 tonnes increases each for 2004 and 2005 (related to R404A wrong calculations). HFC-32 changes were small by comparison.

4.8 Other product manufacture and use (2.G)

4.8.1 Description

In 2013 net emissions of SF_6 and N_2O from the *Other product manufacture and use* category totalled 78.4 kt CO_2-e or 1.5 per cent of emissions from the IPPU sector.

The emissions Inventory for SF_6 is broken down into two subcategories: *Electrical equipment*, and *Other*. The majority of SF_6 emissions are from use in *Electrical equipment*. In New Zealand, the main electricity distribution company accounts for 70 per cent of total SF_6 used in *Electrical equipment*. The majority of N_2O emissions in this category are from medical applications. A minor amount of N_2O is also used in dairy products, motor sports and in scientific analyses.

In 2013, SF_6 emissions totalled 18.7 kt CO_2-e. This is an increase of 6.9 kt CO_2-e (58.8 per cent) from the 1990 level of 11.8 kt CO_2-e, and a decrease of 0.7 kt CO_2-e (3.6 per cent) from 2012.

Other emission sources reported in this category are NMVOCs emitted from the use of solvents in paint application, degreasing, printing, and for general domestic and commercial applications, and in beverage manufacture. Also, indirect greenhouse gases including NMVOCs and SO_2 are emitted in the manufacture of wood products (particle board and fibre boards) and in the use of bitumen for road paving and roofing.

4.8.2 Methodological issues

Electrical equipment

Emissions of SF_6 in 2013 were 16.0 kt CO_2-e, an increase of 7.0 kt CO_2-e from the 1990 level of 9.0 kt 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.

IPCC, 2006a, recommends a minimum Tier 1 approach using default emission factors. However, detailed information of the equipment used in this industry was only available from the major provider (70 per cent of SF6 used in *Electrical equipment*) since 2003. Actual emissions are calculated using the IPCC, 2000, Tier 3a approach for the utility responsible for 70 per cent of the total SF6 held in electrical switchgear equipment. The

IPCC, 2000, Tier 1 approach was used for the rest of the industry and all companies prior to 2003 (CRL Energy, 2014).

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. One importer exited the market and exported remaining stocks to Australia early in 2012, causing a drop in potential emissions (CRL Energy, 2014).

The IPCC, 2000, Tier 1 method is used to calculate potential emissions of SF_6 (including estimates for SF6 for 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 (CRL Energy, 2014). The high ratio of potential to actual emissions for SF_6 is a result of the long lifespan of *Electrical equipment* (IPCC, 2006: more than 30 to 40 years) and the expansion of the electricity transmission system.

Other SF_6 applications

Emissions from *Other SF_6* applications in 2013 were 2.7 kt CO2-e. In New Zealand, other applications include medical uses for eye surgery, tracer gas studies, magnesium casting, plumbing services, tyre manufacture and industrial machinery equipment. A Tier 1 method (IPCC, 2006) is applied and a 50 per cent emission factor is used as it is assumed to be emitted over two years.

On the basis of the supplier figures, the scientific use of SF_6 is reassessed to be at a highly uncertain level of 50 kg per year (a major change from the 1 kg assumed in earlier years). Total medical usage of SF_6 is reassessed to be at a highly uncertain level of 30 kg per year (a major change from the 10 kg assumed in earlier years for eye surgery). Other unidentified usage of SF_6 is assessed to be at a highly uncertain level of 40 kg per year (none assumed in earlier years).

Activity data for 2005 to 2013 was provided by one main supplier for eye surgery, scientific use, plumbing, tyre manufacture and industry. Scientific use was also discussed with the National Institute of Water and Atmospheric Research, AgResearch and GNS Science.

Table 4.8.1 New Zealand's SF_6 methods and emission factors

SF6 Source	Calculation method	Emission factor
Electrical equipment	IPCC, 2000, equation 3.17	Tier 3 approach based on overall consumption and disposal. Company-specific emission factors measured annually and averaging 1 per cent for the main utility (representing 70 per cent of total holdings) and an equipment manufacturer This was supplemented by data from other utilities and users using the IPCC default emission factor of 2 per cent (Tier 2a approach)
Other applications	IPCC, 2006, equation 8.23	No emission factor required as 100 per cent is emitted within two years

N_2O from other product use

In 2013 N_2O emissions from product uses totalled 59.8 kt CO_2-e.

The majority of N_2O in this category (assumed to be 90 per cent) is imported by one supplier (BOC Medical) and most is used in medical applications with small amounts used in dairy products, motor sports and in scientific analyses.

Surveys indicated that BOC Medical imported a number of large containers of nitrous oxide in 2002 (CRL Energy, 2014). Further data was acquired from Statistics New Zealand as Customs began recording imported nitrous oxide from 2005. Initially, data suggested over-reporting by Statistics New Zealand. However, production figures were consistent with Statistics New Zealand data from 2008. A correction factor of 0.9 has been applied from 2008 to 2013, a factor of 0.45 is applied to 2006 and a factor of 0.55 is applied to 2007 (CRL Energy, 2014).

Wood products

Both Kraft and mechanical pulp production occur in New Zealand, and NMVOC emissions from these processes are estimated using an industry-supplied emission factor (CRL Energy, 2006a). Any emissions of CO and NO_x from the pulp industry are considered to be related to fuel use and are not reported in the IPPU sector.

NMVOCs are also emitted in the manufacture of wood panel products (particle board and medium density fibre board). These are also estimated using industry-supplied emission factors (CRL Energy, 2006a).

Data for NMVOCs emitted in wood products manufacture has been extrapolated for the years 2007 to 2013.

Asphalt paving and roofing

There are three main bitumen production companies operating in New Zealand, providing materials for road paving. Data on bitumen production and emission rates was provided by these companies, and activity data on the amount of bitumen used for road paving was confirmed by the New Zealand Bitumen Contractors' Association (CRL Energy, 2006a). There is also one company manufacturing asphalt roofing in New Zealand.

The bitumen content of road paving used in New Zealand is about six per cent, which is lower than commonly used in most countries. The NMVOC emissions from road paving are calculated using a country-specific method based on the fraction of bitumen in asphalt used in road paving material, the fraction of solvent added to bitumen, and the assumption that 75 per cent of the solvent added will be emitted.

Calculation of NMVOC emissions from road paving
NMVOC emitted = A × B × C × D Where: A = road paving material used (kt) B = fraction by weight of bitumen in asphalt C = fraction of solvent added to bitumen (0.04) D = fraction of solvent emitted (0.75)

The fraction of bitumen in asphalt used in road paving materials was reduced over time as methods of laying roading improved (see table 4.8.2).

Table 4.8.2 Fraction bitumen in road paving material

Reporting years	Fraction of bitumen in asphalt (B above)
1990–2001	0.80
2002–2003	0.65
2004–2013	0.60

For asphalt used as roofing material, IPCC default emission factors of 0.05 kg MNVOCs and 0.0095 kg CO per tonne of product have been used.

For both of these sources, data for the years up to 2005 has been extrapolated for 2006–13 in the absence of any updated information.

Food and drink

Emissions of NMVOCs occur in the fermentation of cereals and fruits in the manufacture of alcoholic beverages, and in the 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 (CRL Energy, 2006a). Subsequent NMVOC estimates from food and drink have been estimated using linear extrapolation, as no industry survey was conducted.

4.8.3 Uncertainties and time-series consistency

Uncertainties associated with the calculation of emissions factors, estimation of activity data, actual emissions, and potential emissions, are combined to provide a level of uncertainty for each category.

Table 4.8.3 Uncertainties for Other product manufacture and use

SF_6 Source	Uncertainty estimates (%)
Electrical equipment	Combined uncertainty ±37
Other applications (SF_6)	Combined uncertainty ±60
Other product use (N_2O)	±15 in 2013, ±30 for all other years
Road paving with asphalt	± 10%

4.8.4 Source-specific QA/QC and verification

During data collection and calculation for the electrical and medical sectors, activity data provided by industry was verified against national totals where possible. Furthermore, unreturned questionnaires and anomalous data were followed up and verified to ensure a complete and accurate record of activity data. Detailed maintenance records form the utilities industry has also improved the quality of SF_6 data in recent Inventories.

4.8.5 Source-specific recalculations

Electrical equipment

Improved information was provided by several utilities, resulting in changes to the total SF_6 nameplate capacity in *Electrical equipment* for 2000 to 2012. This resulted in small changes in calculated emissions from stocks.

These changes had a very small impact on the calculation of actual emissions for 2010–2012: +3 kg for 2010, +1 kg for 2011 and +5 kg for 2012, compared with figures calculated in last year's report.

N_2O from other product use

Improved information was provided by BOC Medical (supplies majority of industrial and medial nitrous oxide). Furthermore, it is now assumed that half of all nitrous oxide purchased is released during the purchase year and half in the following year.

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Chapter 5: Agriculture

5.1 Sector overview

In 2013, the Agriculture sector contributed 39,177.3 kilotonnes of carbon dioxide-equivalent emissions (kt CO_2-e) (48.4 per cent) of New Zealand's total emissions. Emissions have increased by 4,826.7 kt CO_2-e (14.1 per cent) from the 1990 level of 34,350.6 kt CO_2-e (figure 5.1.1).

The increase since 1990 is primarily due to a 2,130.9 kt CO_2-e (8.1 per cent) increase in methane (CH_4) emissions from the *Enteric fermentation* category and a 1,578.7 kt CO_2-e (23.0 per cent) increase in nitrous oxide (N_2O) emissions from the *Agricultural soils* category (figure 5.1.2). The key drivers for this change in emissions are: an increase of 26.7 per cent in total cattle population since 1990, and a six-fold increase in synthetic fertiliser nitrogen (N) applied during this time. A decrease of 46.8 per cent in the sheep population partially offset these increases.

In 2013, 72.6 per cent (28,441.1 kt CO_2-e) of the total emissions from the Agriculture sector were from *Enteric fermentation*, followed by 21.5 per cent (8,453.3 kt CO_2-e) from *Agricultural soils*, 3.1 per cent from *Manure management*, 1.4 per cent from *Liming*, 1.3 per cent from *CO_2 emissions from the application of urea fertiliser*, and 0.1 per cent from field burning of agricultural residues (table 5.1.1). Methane emissions from *Enteric fermentation* were 35.1 per cent of New Zealand's total emissions, and nitrous oxide emissions from the *Agricultural soils* category were 10.4 per cent of New Zealand's total emissions.

Figure 5.1.1 New Zealand's Agriculture sector emissions from 1990 to 2013

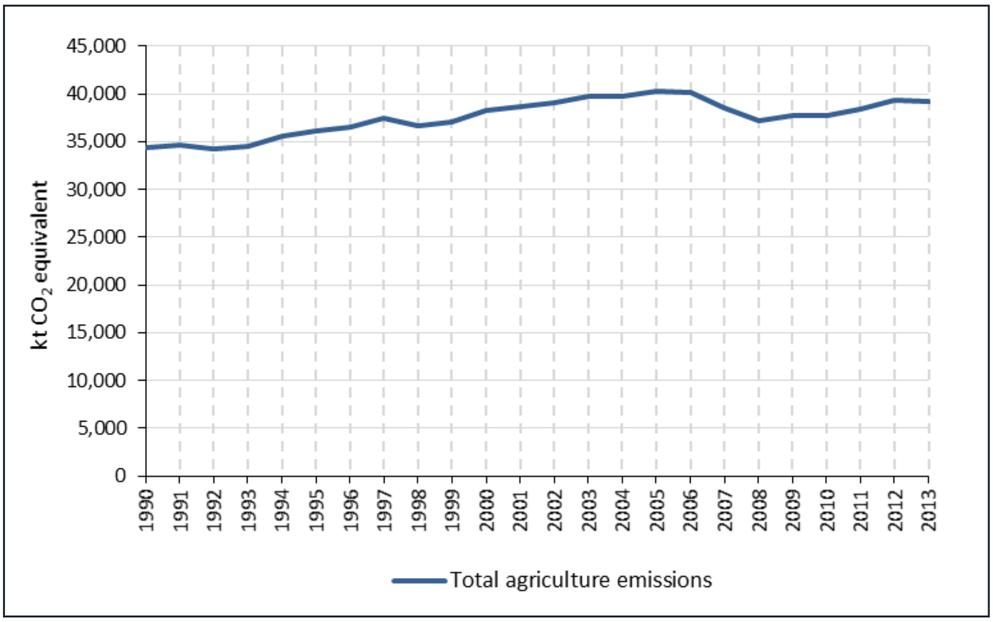
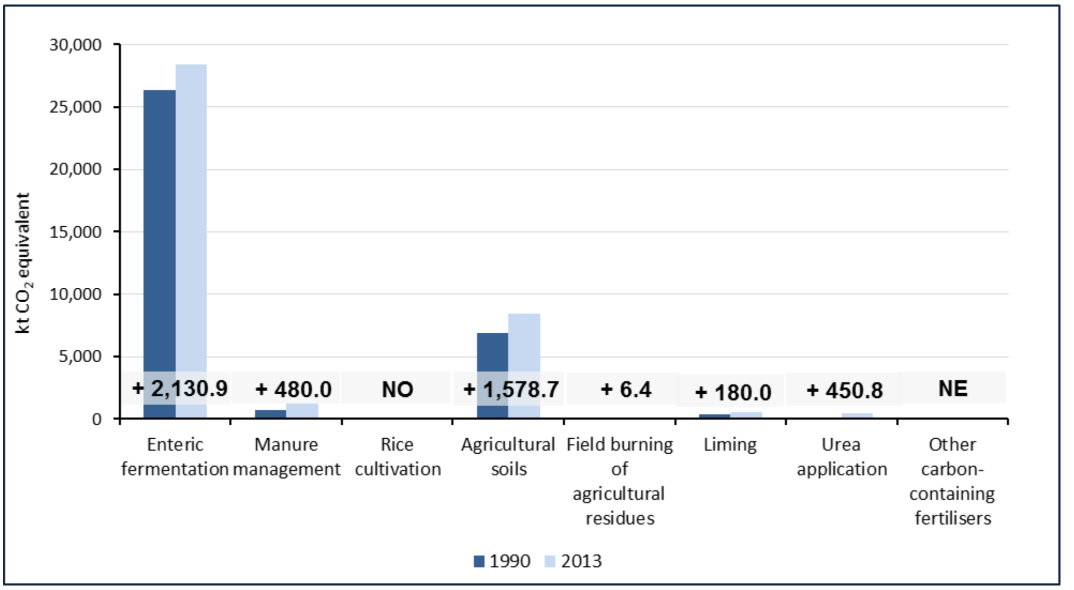


Figure 5.1.2 Change in New Zealand's emissions from the Agriculture sector from 1990 to 2013



Note: Rice cultivation does not occur (NO) in New Zealand. Emissions from other carbon-containing fertilisers are unlikely to be significant and are not estimated (NE).

Table 5.1.1 Trends and relative contribution of New Zealand's agricultural greenhouse gas emissions by category between 1990 and 2013

	Emissions (kt CO_2-e)		Change from 1990		Percentage share of Agriculture sector	
Category	1990	2013	%	Difference (kt CO_2-e)	1990	2013
Enteric fermentation	26,310.2	28,441.1	8.1	2130.9	76.6	72.6
Manure management	739.0	1,219.0	64.9	480.0	2.2	3.1
Rice cultivation	NO	NO	–	–	–	–
Agricultural soils	6,874.7	8,453.4	23.0	1578.7	20.0	21.6
Prescribed burning of savanna	IE	IE	–	–	–	–
Field burning of agricultural residues	27.4	33.8	23.3	6.4	0.1	0.1
Liming CO_2 emissions	360.1	540.0	50.0	180.0	1.0	1.4
Urea application CO_2 emissions	39.2	490.0	1150.2	450.8	0.1	1.3
Other carbon-containing fertilisers	NE	NE	–	–	–	–

Note: Rice cultivation does not occur (NO) in New Zealand. Prescribed burning of savanna is included elsewhere (IE) under the Land Use, Land-Use Change and Forestry (LULUCF) sector. Emissions from other carbon-containing fertilisers are unlikely to be significant and are not estimated (NE).

Agriculture is a major component of the New Zealand economy and agricultural products comprise 64 per cent of the total value of merchandise exports (Ministry for Primary Industries, 2014). This is helped by the favourable temperate climate, the abundance of agricultural land and the farming practices used in New Zealand. These practices include the use of year-round extensive outdoor pastoral grazing systems and more reliance on nitrogen fixation by legumes rather than nitrogen fertiliser as the nitrogen source.

Dairy cattle, non-dairy cattle (beef), sheep and deer are largely grazed outside all year round. This means that New Zealand has a much lower proportion of agricultural emissions from manure management compared with other Annex 1 Parties, as intensive housing of major livestock species is generally not practised in New Zealand, although a small number of dairy farms use housing systems. For further information about New Zealand's agricultural growing conditions see chapters 1 and 2 (Executive summary and National Circumstances) of New Zealand's Sixth National Communication (http://mfe.govt.nz/publications/climate/nz-sixth-national-communication/index.html).

5.1.1 Trends in the Agriculture sector

Since 1990, the *Enteric fermentation* and *Agricultural soils* categories have contributed significantly to New Zealand's total agricultural emissions (table 5.1.1). In 1990 and 2013 respectively, 96.0 and 93.0 per cent of agricultural emissions originated from dairy cattle, non-dairy cattle, sheep and deer, so trends in Agriculture sector emissions are largely driven by the populations of these livestock classes.

During this time there have been changes in the proportions of the main livestock species farmed in New Zealand (figures 5.1.3 a and b), as the relative profitability of dairy products has risen compared with that of sheep and beef products. Pastoral land used by dairy cattle has increased and pastoral land used for sheep and, to a lesser extent, beef has decreased (inferred from livestock numbers and Statistics New Zealand land-use data). Since 1990, there has also been an overall trend for forestry to be established in areas that were previously in grassland (see chapter 6).

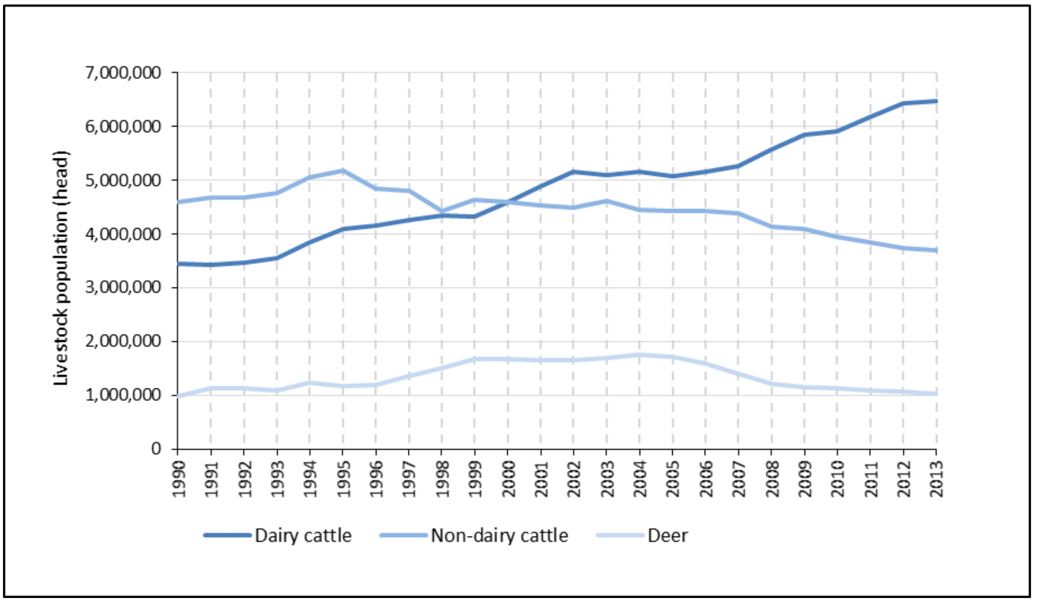
There was a gradual increase in the implied emission factors per head for dairy cattle and non-dairy cattle that reflects the increased levels of productivity (milk and meat yield per head) achieved by New Zealand farmers between 1990 and 2013. Increases in animal liveweight and milk yield per animal require increased feed intake per 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 both livestock numbers and productivity, resulting in lower livestock emissions, which are reflected in overall agricultural emissions (figure 5.1.1). The livestock population and implied emission factors started to increase again once seasonal growing conditions improved. A drought in 2013 also reduced livestock emissions, but to a lesser extent than in 2008, as farmers were better prepared for drought and high profits in the dairy sector that year meant more on-farm resilience against drought.

Agriculture uses 48 per cent of New Zealand's land area, mostly for grazing (Coriolis, 2014). The land area used for cropland has increased since 1990 and the type of produce grown has changed (Statistics New Zealand table builder and Infoshare database, 2014). Overall, there is now less cultivated land area for crops such as oats and vegetables and more for wheat and grapes (for wine production) than in 1990, and productivity per hectare has increased during this time.

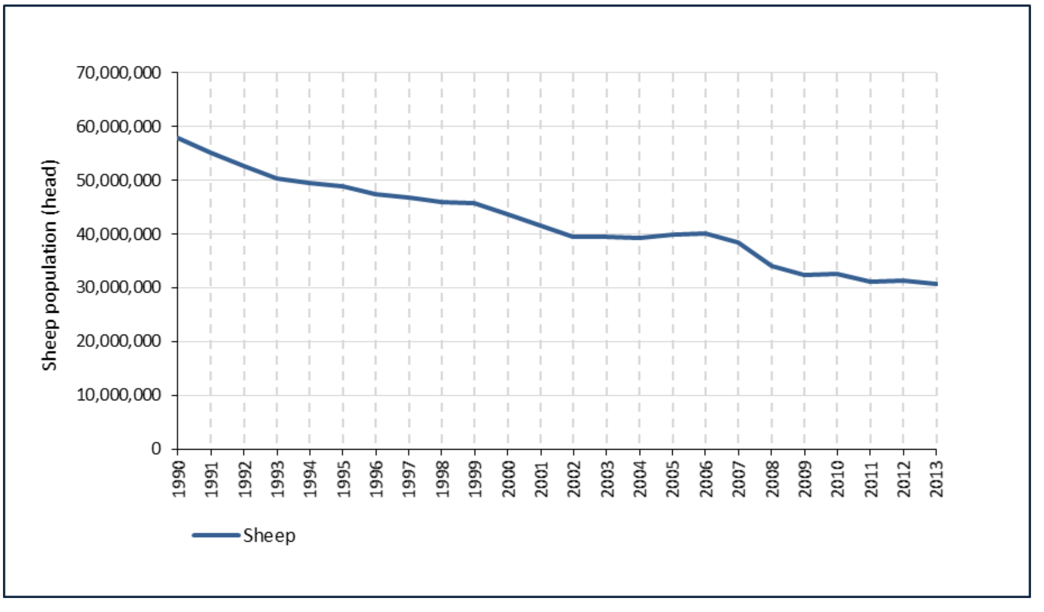
Although synthetic nitrogen fertiliser applied to agricultural land has increased since 1990, this activity still contributes a relatively small proportion towards New Zealand's agricultural emissions (table 5.1.1). In 1990 and 2013 respectively, 0.8 and 3.0 per cent of agricultural emissions originated from N_2O from synthetic fertilisers, and 0.1 and 1.3 per cent from CO_2 from synthetic urea fertiliser (urea CO_2 being reported under the Agriculture sector for the first time in the 2015 submission under the 2006 IPCC guidelines).

Figure 5.1.3a Population of New Zealand's dairy cattle, non-dairy cattle and deer from 1990 to 2013 (June year ending)



Source: Statistics New Zealand

Figure 5.1.3b Population of New Zealand's sheep from 1990 to 2013 (June year-ending)



Source: Statistics New Zealand

Changes in emissions between 2012 and 2013

Total agricultural emissions in 2013 were 170.2 kt CO_2-e (0.4 per cent) lower than the 2012 level. This is most likely attributable to the drought during early 2013 which affected key pastoral areas. The dairy cattle population increased between 2012 and 2013 (37,920, 0.6 per cent), compared with a larger population increase in the previous year (271,178, 4.4 percent). There was a 467.0 kt CO_2-e (2.7 per cent) increase in emissions from dairy cattle of 17,575.5 kt CO_2-e in 2013 compared with emissions of 17,108.5 kt CO_2-e in 2012.

There was a decrease in emissions of 468.1 kt CO_2-e (2.4 per cent) from non-dairy cattle, sheep and deer in 2013 compared with 2012. The populations of non-dairy cattle, sheep and deer decreased between 2012 and 2013. The longer-term increase in the dairy cattle population and the reduction in non-dairy cattle, sheep and deer numbers (figures 5.1.3 a and b) are primarily due to higher relative return on investment being achieved in the dairy sector.

There was also a decrease of 142.6 kt CO_2-e (20.9 per cent) in emissions from agricultural liming in 2013 compared with 2012, which is consistent with the long-term trend of decreasing limestone use (section 5.8).

5.1.2 Key categories in agriculture

Full details of New Zealand's key category analysis are presented in section 1.5. Key Agriculture sector categories identified in the 2013 level assessment include:

- methane from *Enteric fermentation – dairy cattle*
- methane from *Enteric fermentation – non dairy cattle*
- methane from *Enteric fermentation – sheep*
- methane from *Enteric fermentation – other – deer*
- methane from *Manure management – cattle – dairy cattle*
- nitrous oxide from *Agricultural soils – direct N_2O emissions – Inorganic N Fertilisers*
- nitrous oxide from *Agricultural soils – direct N_2O emissions – crop residues*
- nitrous oxide from *Agricultural soils – direct N_2O emissions – urine and dung deposited by grazing animals*
- nitrous oxide from *Agricultural soils – indirect N2O emissions – atmospheric deposition*
- nitrous oxide from *Agricultural soils – indirect N_2O emissions – nitrogen leaching and run-off*
- carbon dioxide from *Liming*
- carbon dioxide from *Urea application*.

Key Agriculture sector categories identified in the 2013 trend assessment include:

- methane from *Enteric fermentation – dairy cattle*
- methane from *Enteric fermentation – non dairy cattle*
- methane from *Enteric fermentation – sheep*
- methane from *Enteric fermentation – other – goats*
- methane from *Manure management – sheep*
- methane from *Manure management – cattle – dairy cattle*
- nitrous oxide from *Agricultural soils – direct N_2O emissions – Inorganic N Fertilisers*
- nitrous oxide from *Agricultural soils – direct N_2O emissions – urine and dung deposited by grazing animals*
- carbon dioxide from *Liming*
- carbon dioxide from *Urea application*.

5.1.3 Methodological issues for the Agriculture sector

New Zealand uses a range of models and tiers appropriate to the size of the different emission categories. In 2013, 93.0 per cent of New Zealand's agriculture emissions were due to four grazed livestock categories: dairy cattle, non-dairy cattle, sheep and deer (referred to in this chapter as the 'major' livestock categories). New Zealand uses a detailed livestock population characterisation (table A3.1.1.1) and a complex nutritional and energy model to support the calculation of emissions from these livestock.

Other livestock species (swine, goats, horses, llama and alpaca, mules and asses, and poultry) account for only 0.5 per cent of New Zealand agriculture emissions, and these are estimated using Tier 1 methods (referred to as the 'minor' livestock categories). Where possible, New Zealand has used country-specific emission methods and factors to estimate emissions for the minor livestock species.

Direct and indirect N_2O emissions from synthetic fertiliser account for 3.0 per cent of New Zealand's agricultural emissions and are calculated using country-specific emission factors. Carbon dioxide emissions from liming and urea, which are reported under the Agriculture sector for the first time in the 2015 submission, contribute 2.6 per cent towards 2013 total agricultural emissions. The remaining 0.9 per cent of New Zealand's agriculture emissions is due to organic fertiliser, crop residue returned to the soil, cropland cultivation (histosols and N mineralisation) and cropland burning. Emissions from crop residues and the burning of some agriculture residues are calculated using a Tier 2 method.

Further technical detail is provided in the Inventory methodology document on the Ministry for Primary Industries website (http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/) and in the methodological issues sections for each category. The approach for determining livestock nutritional and energy requirements is described next.

Tier 2 model for determining energy requirements for major livestock categories

The Tier 2 Inventory model was developed to calculate emissions from the major ruminant livestock categories (Clark et al, 2003), in line with good practice guidance (IPCC, 2000 and IPCC, 2006). The model is constantly being improved upon. New Zealand's modelling for the major livestock categories could be considered as approaching Tier 3, as country-specific data and monthly data intervals for livestock population, productivity and pasture quality are used.

The main emissions from ruminant livestock are methane from enteric fermentation and nitrous oxide from manure (urine and dung). The level of these emissions is a function of livestock energy requirements and the energy concentration of the feed which determine the level of feed intake (dry-matter intake, DMI), where:

$$DMI = \frac{ME_{TOTAL}}{E}$$

Where: DMI is the dry-matter intake (kg),

ME_{TOTAL} is the total metabolisable energy requirement of the animal (kJ), and,

E is the energy concentration in the feed (kJ/kg DM).

Metabolisable energy requirement (ME_{TOTAL}) calculation: For dairy cattle, non-dairy cattle and sheep, the approach for calculating the total metabolisable energy requirement (ME) was developed in Australia (CSIRO, 1990). These algorithms are chosen because they specifically include methods to estimate the energy requirements of grazing animals, which is the predominant feeding method used in New Zealand. All calculations are performed on a monthly basis. The equation below is derived from the general equation used in the Australian feeding standards and adjusted to suit New Zealand conditions.

This method includes a maintenance requirement (a function of the animal's liveweight and stage of maturity), a production energy requirement needed for a given level of productivity (milk yield and liveweight gain), physiological state (eg, pregnant or lactating), and the amount of energy expended on the grazing process):

$$ME_{TOTAL} = ME_{BASAL} + 0.1ME_P + ME_{GRAZE}$$

Where: ME_{BASAL} is the energy requirement for maintenance,

ME_P is the energy used directly for production (meat, milk, wool, gestation etc), and,

ME_{GRAZE} is the additional energy required by grazing livestock.

Thus:

$$ME_{TOTAL} = \frac{KSM(0.28W^{0.75}\exp(-0.03A))}{k_m} + 0.1ME_P + \frac{E_{GRAZE}}{k_m}$$

Where: K, S and M are constants defined in CSIRO (1990); K = 1.0 for sheep and 1.4 for cattle, S = 1.0 for females and castrates and 1.15 for entire males, M = 1 for all animals except milk-fed animals. M has been removed from the New Zealand calculations and an adjustment for milk-fed animals is carried out through a milk adjustment factor detailed later.

W is the live weight (kg),

A is the age in years, up to a maximum value of 6,

k_m is the net efficiency of use of ME for maintenance, and,

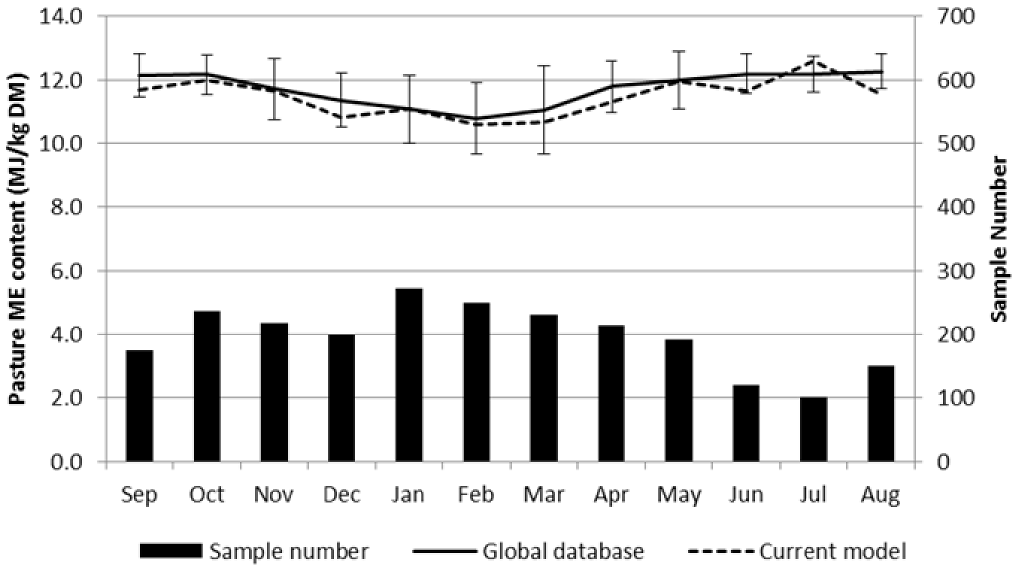
E_{GRAZE} is the additional energy expenditure of livestock in cold stress.

The CSIRO (1990) algorithms take into account animal liveweight and production requirements based on the rate of liveweight gain, sex, milk yield and physiological state. For further details, see the Inventory methodology document of Pickering and Wear (2013), which is available on the Ministry for Primary Industries website (http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/).

Monthly diet energy (E) concentration: Dairy cattle, non-dairy cattle, sheep and deer are predominantly fed on pasture year round. Datasets of estimated monthly energy concentrations of pasture consumed by different livestock are used for all years. These data are reported in the Inventory methodology document (Pickering and Wear, 2013, appendices 3, 9 and 19, http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/). There are no comprehensive published data available that allow the estimation of a time series dating back to 1990. The data used are derived from published and unpublished research trial data, and supplemented with additional data from farm surveys on commercial cattle and sheep farms.

Bown et al, 2013, were commissioned to review and collate data held around New Zealand on the energy and nitrogen content of pasture. Pasture measurements from eight research studies and a commercial testing laboratory were collated, analysed and compared with the national monthly average values used in the current Inventory model. The collated database (defined as the ‘Global database’ in figure 5.1.4) was collected from 1996 to 2011 from dairy cattle, non-dairy cattle and sheep farms all over New Zealand. The graph in figure 5.1.4 shows, as an example using the dairy farm data, how the assumed values in the New Zealand Inventory for energy in dairy pasture compare with 2,371 dairy pasture samples from the Global database, and that they are in reasonable agreement.

Figure 5.1.4 Comparison of mean measured pasture ME content in 2,371 New Zealand dairy pasture samples with current Inventory model values



Source: Bown et al (2013)

To ensure consistency, a single livestock population characterisation and feed-intake estimate is produced by the Tier 2 model, and is used in different parts of the calculations for the Inventory 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.

5.1.4 Activity data

Major livestock categories

The Tier 2 methodology developed by New Zealand uses detailed population characterisation and livestock productivity data to calculate livestock energy requirements, or metabolisable energy (ME). Population data are collected by Statistics New Zealand every five years (the Agricultural Production census) and annually between censuses (the Agricultural Production survey). Productivity data are available from the New Zealand Livestock Improvement Corporations (LIC, dairy statistics), Beef and Lamb New Zealand and Deer Industry New Zealand. Slaughter statistics are collected by the Ministry for Primary Industries.

Most of these data are collected on a June year-end basis but the Inventory is calculated on a calendar year. New Zealand uses a June year for animal statistics as this reflects the natural biological cycle for animals in the southern hemisphere. New Zealand's Tier 2 model has been developed to estimate livestock emissions on a monthly time step, beginning on 1 July of one year and ending on 30 June of the next year. To calculate emissions for a single calendar year (January–December), the calculated emission data from the last six months of a July–June year is combined with the first six months' emissions of the next July–June year. This is carried out so that New Zealand's Inventory is on a calendar year basis and meets IPCC good practice as it is comparable with the inventories of other countries.

Population data

Statistics New Zealand collects population data on a territorial authority basis. Territorial authorities are the lowest political division in New Zealand. Territorial authorities are then aggregated up to regional council boundaries by Statistics New Zealand. In 1993, the regional council boundaries changed. Therefore, dairy population data for 1990–1993 were collected from Statistics New Zealand at a territorial authority level and then aggregated up to the regional council boundaries currently used. From 1993, Statistics New Zealand supplied livestock population data at the required regional council delineation, so no further aggregation of data was required. Further details about the scope and accuracy of Statistics New Zealand Agricultural Production data collection are provided in annex 3.1.

The New Zealand Inventory uses a different population characterisation for pasture-based livestock compared with that recommended in IPCC (2000) and IPCC (2006). The full list of subcategories for the major livestock populations can be found in annex 3.1.1 and in the Inventory methodology document on the Ministry for Primary Industries website (http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/).

Dairy cattle encompass all cattle that are required to support the milking dairy herd. This includes calves, young growing non-lactating heifers, dry cows and dairy 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 non-dairy cattle. These include non-dairy breeding lactating cows used for producing slaughter animals from calves, dry cows, bulls and all slaughter classes. Female calves not required for dairy, and dairy bull calves also go into the non-dairy herd.

The detailed livestock population characterisation for each livestock type (dairy cattle, non-dairy, sheep and deer) is subdivided in the population models (table A3.1.1.2). The population models estimate population and age changes on a monthly time step throughout the year for the subcategories of the livestock. This delineation is required by the Inventory model and has been developed by using industry knowledge and assumptions as detailed in Clark (2008a), Thomson et al, (2010), Thomson et al (2012) and Suttie (2012). The populations within a year are adjusted on a monthly basis to account for births, deaths and transfers between age groups. This is necessary because the livestock population numbers present and recorded at one point in time may not accurately reflect the numbers present at other times of the year. For example, the majority of lambs are born and slaughtered between August and May, so do not appear in the June census or survey data. Also, male and female dairy calves not wanted as replacements are usually slaughtered at four days of age, or transferred to the non-dairy herd. It also ensures that the calculated feed demand accurately reflects the status of each livestock category at a particular time of the year.

Dairy livestock numbers are calculated on a regional basis, so regional dairy population numbers are used to take into account regional differences in production (Clark, 2008b).

Productivity data

Productivity data are obtained from the Livestock Improvement Corporation Ltd (LIC, 2013), Beef and Lamb New Zealand (Beef and Lamb New Zealand, 2013, table 8) and Deer Industry New Zealand, which are industry-good organisations providing services to the dairy cattle, non-dairy cattle, sheep and deer industries. Slaughter statistics are collected by the Ministry for Primary Industries http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/agriculture/livestock-slaughter-statistics/ and used as a proxy for changes in animal liveweight over time. Animal liveweight is then derived from published slaughter statistics and from killing-out percentages (Clark, 2003; Muir et al, 2008; Muir and Thomson, 2010). To ensure consistency, the same data sources are used each year. 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.

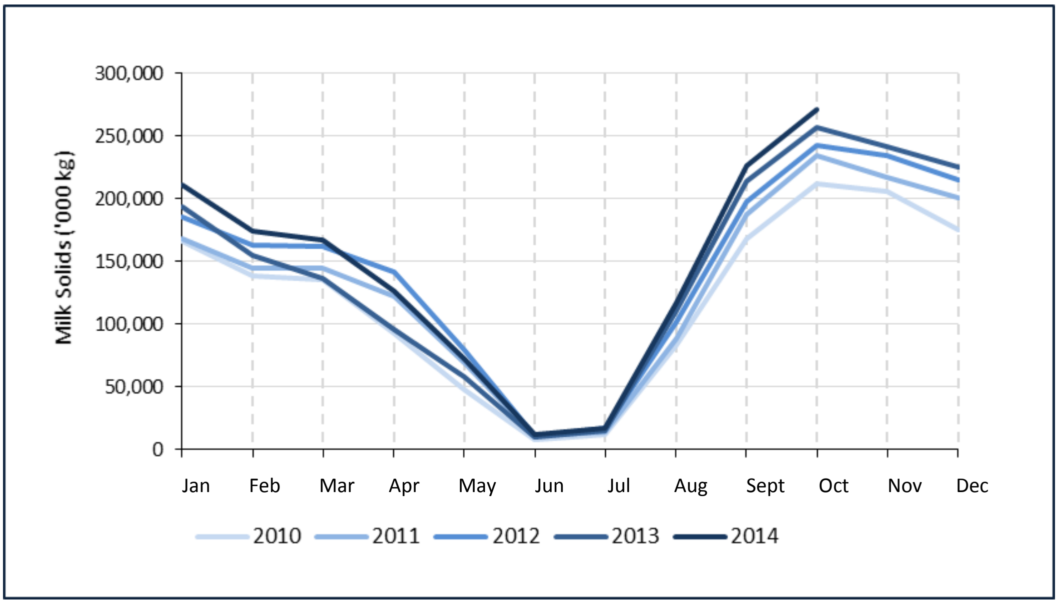
Dairy cattle: Regional data on milk production, proportions of dairy cattle breeds and average animal weight is provided by the Livestock Improvement Corporation (LIC, a dairy herd improvement company owned by New Zealand dairy farmers). These data are collectively compiled by the LIC and DairyNZ (a non-Government, industry-good organisation funded through a compulsory levy on milk solids) and are published annually.

Data on New Zealand's total milk production originates from the amount of milk processed through New Zealand dairy factories for both the export and domestic markets. These data are available from DairyNZ through its collection of the levy on milk solids. Data on individual animal production is sourced from the Dairy Core Database, the regulated portion of LIC's database that holds core production data from cows herd tested in New Zealand. Dairy farmers are paid on the basis of milk solids collected (and not on a volume basis). Tankers that collect the milk also meter the milk collected from individual farms, and these meters are regularly calibrated and audited. Milk samples from individual farms are also independently tested for milk solids, milk fat and protein content.

The LIC provides annual milk production data (milk yield and composition), but the Tier 2 livestock model operates on a monthly time-step. Monthly milk production is therefore determined by multiplying the total annual milk production by the proportion of milk yield each month (table A3.1.2.1 from Pickering and Wear, 2013, appendix 4). Milk production occurs from late July to early August every year, peaking around October/November and drying-off during Autumn (April, May and June in the southern hemisphere); the production in June and July is low (figure 5.1.5).

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

Figure 5.1.5 National monthly milk production in New Zealand for 2010–2014



Source: www.DCANZ.com/statistics

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 the LIC data. Dairy cow liveweights are only available from the Livestock Improvement Corporation from 1996 onwards for six livestock improvement regions that have the largest number of dairy animals, each region comprising several territorial local authorities. As there are 16 regional council regions, the data from the six livestock improvement regions were apportioned appropriately. Due to the lack of liveweight data before 1996, liveweights prior to 1996 were estimated using the trend in liveweights from 1996 to 2008, together with data on the breed composition of the national herd (LIC, 2014).

In the model, replacement dairy animals (calves) are assumed to be 9 per cent of the weight of the average cow at birth and reach 90 per cent of the weight of the average adult cow at calving (at two years of age) (Clark et al, 2003). Growth between birth and calving is divided into two periods: birth to weaning and weaning to calving. Higher growth rates are applied in the model between birth and weaning, when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

No data are available on the liveweights and performance of most breeding dairy bulls, which can range from small Jerseys through to larger European beef breeds. It is assumed, based on expert opinion and taking into account industry data (Clark et al, 2003), that the average mature weight at 1 January is 500 kilograms and that they are growing at 0.5 kilograms per day. This gives an average weight (at the mid-point of the year) of 592 kilograms. This is almost 25 per cent higher than the average weight of a breeding dairy cow but is realistic given that some of the bulls will be of a heavier breed (eg, Friesian and some beef breeds). Total emissions are not highly sensitive to these assumed liveweight values because breeding bulls in the dairy herd contribute less than 0.1 per cent of emissions from the dairy sector.

Prior to 1993, no productivity data were available at a territorial authority level, so these data were estimated by extrapolating from the trends observed in existing data from 1994 to 2008. Before 2004, not all productivity data required could be collected from the LIC at a territorial authority level. Therefore, from 1993–2003, annual milk yield per cow was determined by the following equation:

$$Litres\ per\ cow = \frac{Mean\ milk\ fat\ (kg/cow) \cdot 100}{per\ cent\ milk\ fat}$$

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

Approximately 70 per cent of all cattle (LIC Statistics 2012/2013) are tested by LIC for liveweight, milk production, milk fat and milk protein. LIC also does genetic testing to identify key breeding stock and their genetic background. Genetic improvement has contributed significantly to the per animal productivity improvements in the New Zealand dairy cattle herd.

New Zealand's dairy production per animal is lower compared with some other parts of the world. This is a reflection of New Zealand's predominantly pasture-based system compared with dairy cattle in intensively housed and grain-fed systems. In 2013, the New Zealand dairy herd comprised breeds including a Holstein–Friesian/Jersey crossbreed (42.6% of the national cow population in 2013), Holstein–Friesian (37.0%), Jersey (11.7%), Ayrshire (8.1%) and other (0.7%) (LIC, 2013). The Holstein–Friesian/Jersey crossbreed has been developed specifically for New Zealand's pasture-based systems. This cow is approximately 10 per cent lighter than a Holstein–Friesian (LIC, 2013) with less maintenance feed requirements and does less damage to pasture during wet periods due to its lower liveweight compared to larger cattle breeds. It also has higher milk volumes than the Jersey breed while maintaining a good percentage of milk solids.

Non-dairy cattle: The principal source of information for estimating productivity for non-dairy (beef) cattle is livestock slaughter statistics provided by the Ministry for Primary Industries. All growing beef animals are assumed to be slaughtered at two years of age and the average weight at slaughter for the three subcategories (heifers, steers and bulls) is estimated from the carcass weight at slaughter. Liveweights at birth are assumed to be 9 per cent of an adult cow weight for heifers and 10 per cent for steers and bulls (Clark et al, 2003). As with dairy cattle, growth rates of all growing animals are divided into two periods in the model: birth to weaning and weaning to slaughter. Higher growth rates are applied before weaning when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

The carcass weights obtained from the Ministry for Primary Industries slaughter statistics do not separate carcass weights of adult dairy cows and adult beef cows. Therefore, a number of assumptions[17] are made to estimate the liveweights of breeding beef cows. A total milk yield of 800 litres per breeding beef cow is assumed and is consumed by beef calves (Clark et al, 2003).

Sheep: Livestock slaughter statistics from the Ministry for Primary Industries are used to estimate the liveweights of adult sheep and lambs at slaughter, assuming killing-out percentages[18] of 40 per cent for ewes and 45 per cent for lambs (Thomson et al, 2010). Lamb liveweights at birth are assumed to be 9 per cent of the adult ewe weight, with all lambs assumed to be born on 11 September (Thomson et al, 2010). Growing breeding and non-breeding ewe hoggets are assumed to reach full adult size when subsequently mated at age 20 months. Adult wethers are assumed to be the same weight as adult breeding females. No within-year pattern of liveweight change is assumed for either adult wethers or adult ewes. All ewes rearing a lamb are assumed to have a total milk yield of 100 litres. Breeding rams are assumed to weigh 40 per cent more than adult ewes (Clark et al, 2003). Wool growth (greasy fleece growth) is assumed to be 5 kilograms per annum in mature sheep (ewes, rams and wethers) and 2.5 kilograms per annum in growing sheep and lambs. Beef and Lamb New Zealand, the industry body representing the non-dairy cattle and sheep industry, provides estimates of the total wool production from 1990 to 2013 from which the individual fleece weight is estimated (eg, Beef and Lamb New Zealand, 2013).

Deer: Liveweights of growing hinds and stags are estimated from Deer Industry New Zealand statistics, assuming a killing-out percentage of 55 per cent. A fawn birth weight of 9 per cent of the adult female weight and a common birth date of mid-November are assumed. Liveweights of breeding stags and hinds are based on a report by Suttie (2012). It is assumed there is no pattern of liveweight change within any given year. The lactation assumptions are 204 litres over 120 days, an average daily lactation yield of 1.7 litres per day (Suttie, 2012).

Minor livestock categories

A Tier 1 methodology is used for goats, horses, mules and asses, swine, poultry and alpaca (IPCC, 2006), using a combination of country-specific and IPCC default emissions factors (annex A3.1.2, table A3.1.2.2).

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17 The number of beef cows slaughtered is assumed to be 17 per cent of the total beef cow herd, with other adult cows slaughtered assumed to be dairy cows. The carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing-out percentage of 42 per cent (Thomson et al, 2010). 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.

The populations of goats, horses and swine are reported using data from the Statistics New Zealand Agricultural Production census and survey. The population of alpacas is provided by Henderson and Cameron (2010) based on the Alpaca Association New Zealand (AANZ) and, when available, Statistics New Zealand data on alpaca are used from 2010 onwards.

During 2012, it was determined there are small herds of buffalo and donkeys in New Zealand. Statistics New Zealand advised that in 2011 there were 192 buffalo and 141 donkeys. Buffalo were brought into New Zealand around 2007 as a trial (approximately 60 head) and since then the herd has averaged around 200. The buffalo are used for milking to produce mozzarella cheese for the restaurant industry. Given the highly specialised nature of the product the herd size is not expected to increase. The buffalo farm has been reporting its livestock within the dairy herd so the notation key included elsewhere (IE) is used for buffalo. Mules and asses are not farmed commercially or used as beasts of burden in New Zealand. A small donkey population supports breeding for pets and children's rides at parks. A constant population of 141 donkeys has been included in the Inventory under mules and asses. The emissions from this small population of animals are extremely small relative to the major livestock categories.

Statistics New Zealand provides estimates of average annual broiler flock sizes using industry data on the numbers of broilers processed every year since 1990, mortality rates and days alive. Statistics New Zealand also obtains estimates of the number of layers and other poultry (eg, ducks, turkeys and breeder) from the Agricultural Production census or survey.

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

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

5.1.5 Recalculations

Agriculture emissions research

Two parallel national inter-institutional expert groups, New Zealand Methanet and New Zealand NzOnet, have been running for over 10 years. The groups were formed to identify the key strategic directions of research into the CH_4 and N_2O inventory and mitigation, and to develop a collaborative approach to improve the certainty of CH_4 and N_2O emission data. These expert groups are supported through the Ministry for Primary Industries. The implementation of the Tier 2 approach for livestock, development of country-specific emission factors and parameters, improved activity data and uncertainty analyses are a consequence of the research identified, conducted and peer-reviewed by the expert groups.

New Zealand established the Pastoral Greenhouse Gas Research Consortium in 2003 to carry out research, primarily into mitigation technologies and management practices for ruminants but also to provide information to improve on-farm inventories. The Consortium is funded from both public and private sector sources.

New Zealand has also set up the New Zealand Agricultural Greenhouse Gas Research Centre, comprising eight of New Zealand's research providers, including the Pastoral Greenhouse Gas Research Consortium. The aim of the Centre is to contribute to the agricultural greenhouse gas mitigation strategy through research programmes and international collaboration. It also seeks to enhance New Zealand's research capability and infrastructure in this area. Funding is made available through the Ministry for

Primary Industries' Primary Growth Partnership. The results of research by the Centre feed into improving the national Inventory.

Recalculation and improvement approval process in the Agriculture sector

The process for developing improvements and agreeing methodological changes in the Agriculture Inventory are shown in the flow chart figure 5.1.6.

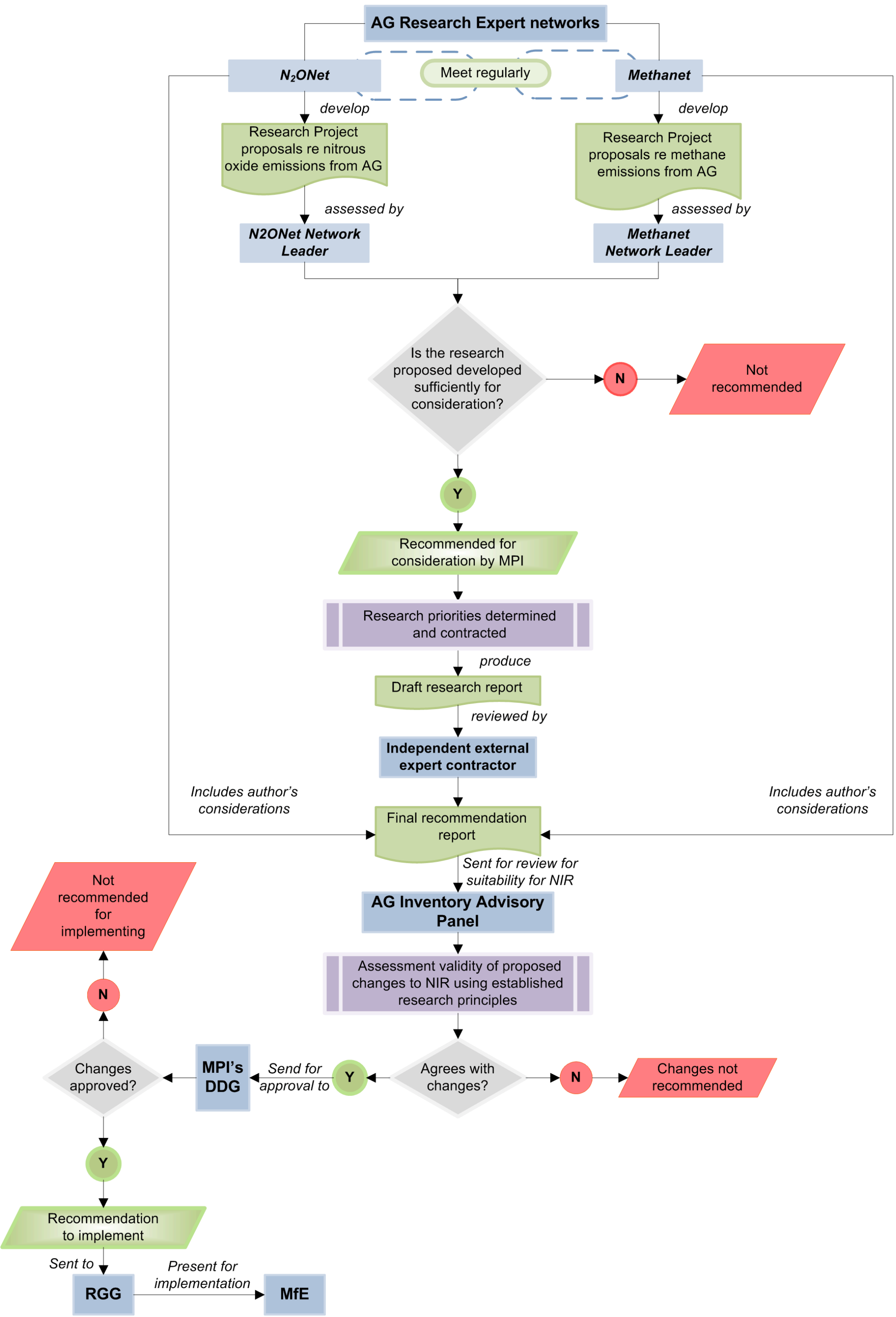
The New Zealand Methanet and New Zealand NzOnet networks meet annually and present their research findings. New research proposals raised by the two networks provide the basis for determining future research. Final decisions on research priorities are made following discussions between the network leaders and Ministry for Primary Industries staff. Research is contracted to address specific questions related to gaps in New Zealand's knowledge, and to review and test current parameters used. The draft research reports are reviewed by a least one external independent expert with knowledge in the field and are assessed for their scientific robustness and for their suitability to be included in the Inventory. The final report must address the reviewer's comments and demonstrate the author's consideration of the comments.

A briefing and the final report are sent to the Agriculture Inventory Advisory Panel (the Panel) who meet annually to review proposed changes to the Inventory. The Panel, formed in 2009, comprises expert representatives from the Ministry for Primary Industries, the Ministry for the Environment and science representatives from the Royal Society of New Zealand, New Zealand Methanet and New Zealand NzOnet expert advisory groups. The Panel is independent of policy and industry influences and has been formed to give advice on whether changes to New Zealand's agricultural section of the national Inventory are scientifically justified. The Panel assesses if the proposed changes have been appropriately researched, using recognised scientific principles, and if there is sufficient scientific evidence to support the recommended change(s). The 2014 meeting of the Panel was held on 20 November 2014 where an update to the emission factor for urea fertiliser was recommended for inclusion in the 2014 submission, as well as incorporation of updated nitrogen retention values for dairy and non-dairy (beef) cattle milk, sheep wool and deer velvet. The briefs, reports and minutes of the Panel meeting are all publically available and have been posted on the Ministry for Primary Industries website: http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/agricultural-inventory-advisory-panel/.

Once changes are agreed by the Panel they are sent to the Deputy Director-General (Policy and Trade) of the Ministry for Primary Industries. The Deputy Director-General then recommends which changes should be presented to the Ministry for the Environment for implementation into the annual Inventory. During the course of the year, recalculations being considered by all sectors are proposed to the Reporting Governance Group, which is chaired by the Ministry for the Environment, and leads the reporting, modelling and projections of greenhouse gas emissions and removals across government. Further details of the Reporting Governance Group are provided in section 1.2.2.

The changes recommended by the Panel are detailed in the relevant recalculation and methodology sections of the national Inventory report.

Figure 5.1.6: Agriculture sectoral approval process for recalculations and improvements



Note: AG = agriculture; DDG – Deputy Director-General; MfE = Ministry for the Environment; MPI = Ministry for Primary Industries; NIR = National Inventory Report; RGG = Reporting Governance Group (for the NIR).

Recalculations approved for the 2015 Inventory submission in the Agriculture sector

New Zealand has made a number of improvements in its 2015 annual submission, arising from the changes recommended by the Agriculture Inventory Advisory Panel and a number of corrections and improvements to its modelling. New Zealand has also ensured that its submission meets the IPCC (2006) guidelines and has updated the default emission factors and parameters whose values have changed in its modelling.

The 2014 Agriculture Inventory Advisory Panel agreed to two changes to the Inventory methodology for the 2015 annual submission:

- the country-specific N_2O emission factor for urea fertiliser has been amended from 0.01 to 0.0048 (the emission factor for non-urea synthetic fertiliser remains 0.01); and
- the parameters for calculating nitrogen retention in cattle milk and deer velvet have been reduced, and the parameter for sheep wool was verified and remains unchanged.

Two additional changes were presented to the 2014 Agriculture Inventory Advisory Panel as information papers:

- Changes to the reporting in the Agriculture Inventory in line with the UNFCCC Conference of the Parties decision (15/CP17) that from the 2015 submission onwards the annual Greenhouse Gas Inventory must meet the requirements stipulated in the IPCC (2006) guidelines.
- The implementation of the IPCC (2006) method to update the methodology for calculating methane emissions from dairy shed effluent ponds.

New Zealand has included additional data and reporting and has updated the modelling in line with the requirement to meet IPCC (2006) guidelines:

- Units have been changed from Gg to kt in the 2015 Inventory submission.
- The emission factors for horse, mules and asses, and poultry (other) and the emission factor for manure management of goats have been changed to IPCC (2006) default values.
- Emission from camelids (alpaca and llama) are now reported under the 'Camels' category (there are no Middle-Eastern camels in New Zealand).
- N_2O emissions from manure management are reported by livestock category.
- A report to investigate activity data for application of non-manure organic N fertiliser on agricultural land has been commissioned and produced (van der Weerden et al, 2014). The report found that this is not a significant activity in New Zealand. A small quantity of sewerage sludge applied to agricultural land continues to be reported under the Waste sector.
- Indirect N_2O emissions are now calculated for *Manure management* and *Agricultural soils* categories.
- A report has been produced on pasture renewal (Thomas et al, 2014) and this activity is now included under the calculation for N_2O released from crop residues.
- The proportion of synthetic fertiliser that is applied as urea has been calculated using annual synthetic fertiliser N sales figures from the Fertiliser Association of New Zealand, a non-government industry-representative organisation, which are adjusted using the proportion of urea fertiliser reported on the International Fertilizer Industry Association. These data are used to meet the new requirement to report CO_2 emissions from urea fertiliser, and to calculate N_2O emissions from urea and

non-urea synthetic fertiliser using an updated country-specific emission factor for urea fertiliser.

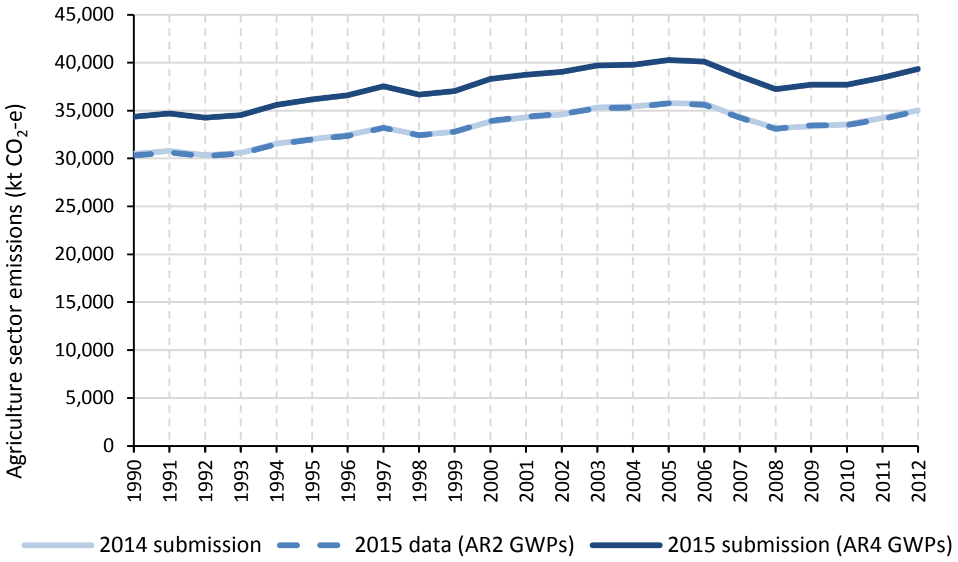
- Mineralisation associated with loss of soil organic matter for *Cropland remaining Cropland* land use is included under the Agriculture sector via data provided by the LULUCF sector.
- CO_2 emissions from *Liming* are now reported under the Agriculture sector (formerly provided under the LULUCF sector).
- Savanna burning is now reported under the LULUCF sector.
- The IPCC (1996) and IPCC (2000) guidelines erroneously recommended that $Frac_{GAS}$ be deducted before applying the Direct N_2O emission factor. This has been rectified.
- The global warming potentials (GWPs) have been updated to values recommended in the IPCC Fourth Assessment Report (AR4) (CH_4 GWP = 25; N_2O GWP = 298), in line with UNFCCC decision 24/CP. 19 (Annex III).
- All Agriculture model outputs have been updated into a format compatible with the online CRF Reporter.

These activities will result in recalculations in *Enteric fermentation*, *Manure management*, and *Agricultural soils* categories, and sections have been added in the 2015 Inventory submission to include the reporting of *Liming, Urea application* and *Other carbon-containing fertilisers*. These are discussed in further detail in the relevant sector recalculation sections. A summary of recalculations is also provided in section 10.1.3.

To quantify the effect of the changes made in the Agriculture sector calculations due to the improvements and the migration to IPCC (2006) guidelines, New Zealand has compared the 2015 submission with the previous submission using the AR2 GWPs. These improvements and methodological changes have resulted in 0.5 per cent (164.2 kt CO_2-e) decrease in agricultural emissions in 1990, and a 0.1 per cent (12.4 kt CO_2-e) decrease in agricultural emissions in 2012.

The 2015 submission is the first in which the IPCC AR4 GWPs have been used. The conversion of non-CO_2 emissions to CO_2-e using the AR4 GWPs have resulted in a relative increase of 12.7 per cent (3879.6 kt CO_2-e) in reported CO_2-e emissions for 1990, and a relative increase of 12.4 per cent (4327.4 kt CO_2-e) for 2013. Figure 5.1.7 shows a comparison of emission estimates for 1990 to 2012 between the 2014 and 2015 Inventory submissions.

Figure 5.1.7 Effect of including improvements, revised and additional reporting arising from the migrating to the IPCC (2006) guidelines, and IPCC AR4 global warming potentials on New Zealand's Agriculture sector reporting from 1990 to 2012



5.1.6 Quality assurance and quality control (QA/QC)

The compilation of the agriculture Greenhouse Gas Inventory is performed by the team responsible for the Agriculture Inventory preparation and for LULUCF technical advice, while liaising with the team responsible for primary industries (agriculture, forestry and fishing) data collation that is located on the same floor within the Ministry for Primary Industries' headquarters. The latter team's role includes liaising with Statistics New Zealand and forecasting primary industries activity and performance. This arrangement provides for a good understanding and quantitative judgement of activity data and agriculture performance. The connection with Statistics New Zealand ensures that the statistical collection work keeps pace with the changes in the primary industries sector and provides for the tracking of possible new activities and management practices in the primary industries sector. There are also strong connections with secondary data sources such as Beef and Lamb New Zealand, the Livestock Improvement Corporation (LIC), Deer Industry New Zealand (DINZ), Poultry Industry Association New Zealand (PIANZ) and the Fertiliser Association of New Zealand.

The draft national Inventory report is reviewed by Ministry for Primary Industries personnel with expertise in climate change policy, climate change science, livestock and cropping policy. This ensures that activity trends and emissions trends are reviewed at a high level and that the results from the national Inventory are used to inform domestic climate change policy.

The Agriculture Inventory experts meet regularly at the Ministry for the Environment with the team responsible for coordinating the annual national Inventory submission. The Ministry for the Environment monitors the Ministry for Primary Industries' progress in implementing recommendations from previous expert review reports and on meeting timelines during the year.

The Ministry for the Environment also manages an internal guidance document 'New Zealand's National Inventory System Guidelines for compiling New Zealand's Greenhouse Gas Inventory'. This document provides domestic guidelines for Sector leaders to follow, including the decisions under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, and the application of these decisions within the Kyoto Protocol. The document also includes New Zealand's QA/QC plan followed by all Sector leads.

The Ministry for Primary Industries participates in the annual Inventory debrief coordinated by the Ministry for the Environment to ensure the national Inventory compiler and each Sector lead understands what is working well and where improvements could be made.

During the compilation of the 2012 submission, an external audit firm (Deloitte), with specialist skills in QA and QC management, was engaged to advance and improve QA/QC processes for the Agriculture Inventory. New Zealand has used this feedback to update and improve the QA/QC methodology.

The scope of the Deloitte review included:

- A review of the existing QA/QC tools including: analytical testing of results, sample testing calculations against stated methodology, reviewing the reconciliation of outputs from the previous Delphi-based model with the current model and sample testing formulae for consistency across different time periods.
- A review of the QA/QC process including assessing: controls, the QA/QC plan and procedures, observing data input processes and calculation processes, and making recommendations for potential process improvements.
- A review of record-keeping and archiving processes.

A process of quality control checks is mandated in the internal compilation process and is provided below.

Activity data

- Records of data inputs and checks are recorded in a data check table which is signed by the individual staff members performing the data input and the checks.
- A comprehensive list of all external data to be collected annually from internal and external sources is included as a part of the data check sheet.
- New activity data are cross-checked for accuracy and completeness by someone not involved in the data input and primary compilation.
- New data on activity and year-to-year time variance is reviewed by commodity analysts and economic modellers to ensure the data are consistent and reflect the domestic situation.
- Where practical, key historical data are re-checked concurrently with updating the latest data.
- The data check table is included with the managerial sign-off materials before delivery to Ministry for the Environment.

Emissions

- Implied emissions factors are checked over time (1990 to most recent year) and against previous submissions. Any anomalies are investigated.
- Key category emissions are compared against Tier 1 default methodologies and against similar Parties, particularly Australia. A challenge for New Zealand is the lack of countries with similar agricultural circumstances and management practices. For example, New Zealand's Tier 2 livestock are almost all outdoors on pasture in all seasons.

- Total emissions and key activity data from the common reporting format (CRF) are checked for accuracy against total emissions and activity in the workbooks. Sub-sector totals are also checked.

Recalculations

- Recalculations are agreed with the Ministry for the Environment and the Reporting Governance Group every year before the Inventory compilation commences.
- Recalculations are compared with previous submissions and, as far as possible, explained and confirmed by the changes in method or activity data.
- Anomalous results from recalculations are checked and, if necessary, corrected.
- The Agriculture Inventory compiler completes recalculation forms, signs the forms and forwards them to the Ministry for the Environment.[19]

Periodic reviews

Periodic reviews are completed on different aspects of the Inventory.

- In recent years, the livestock population models and productivity parameters have been reviewed (eg, Thomson et al, 2010) and used to update and improve the Tier 2 model. During 2013 the nitrogen retention rates in liveweight gains, milk protein and fibre, and pasture quality were reviewed, but the reviews were not completed in time to be submitted to the 2013 Agriculture Inventory Advisory Panel meeting for approval. The results are expected to be incorporated in the 2016 Inventory submission.
- During the 2012 submission, new crops were included for the first time and a new complex methodology was implemented. For the 2013 submission, Plant and Food Research, which has expertise in this area, was hired to review the workbooks, check the formulae and model parameters.
- During the 2015 submission, a mutual bilateral Greenhouse Gas Inventory review was held between Australia and New Zealand, which included the Agriculture sector (Australian Government, 2014).

Model improvements

- The original model for calculating Tier 2 livestock emissions in the Agriculture sector dates back to 2003. It had been developed using the computer language Delphi, which is not in common use. During 2011 and 2012, the model for calculating Tier 2 livestock emissions was converted from Delphi to Excel VBA. The advantage of Excel VBA language is that it is more widely understood and available. During the conversion, any noted errors in formulas and processes were addressed and documented. Once the conversion was complete, a parallel run of the data between the new and the original model could be done to test the data integrity.
- The results obtained from running the same data set between the Delphi-based model and the Excel VBA-based model as part of the model testing were used for the reconciliation and validation process during development. Deloitte independently reviewed the results of the reconciliation process undertaken by the model developer as a part of its 2012/2013 review of the QA/QC practices for the Agriculture sector.

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[19] As there have been a number of changes arising from the migration to reporting to the IPCC (2006) guidelines and applying AR4 GWPs to calculate CO_2-e for non-CO_2 gases, this has not been completed for the 2015 submission.

- The model has been updated to include the recalculations approved for the 2015 Inventory submission.

Error checking and reporting

- Errors confirmed during the year are recorded and the national Inventory compiler is notified. The factors contributing to the error are assessed.
- As part of a review of QA/QC procedures by Deloitte, a sample of workbooks was tested with proprietary diagnostic tools to test formulae consistency across time periods.
- An issues register was maintained throughout the QA/QC review process by Deloitte, which includes a description of agreed actions to resolve each issue.
- An issues, risks and enhancements register is kept up-to-date and is used to prioritise the resolution of key sources of risk to the Agriculture Inventory compilation and results.
- A checklist of QC activities is followed during data collection and entry into the model, data upload to the CRF reporting tool, and Inventory chapter preparation.
- The Agriculture chapter of the National Inventory Report and the data exported to the Common Reporting Format reporter are signed off by the chapter compiler, persons involved in data checking and the manager responsible for the staff.

Documentation

- Internal working instructions are maintained to allow for staff movements.
- Workbooks and calculation sheets are kept on an electronic archiving and management system, enabling wider team access to all workbooks.
- Hyperlinks between check sheets, sign off documents and workbooks are used to link relevant files on the document management system.

Training and development

- Staff involved with the compilation of the Agriculture Greenhouse Gas Inventory are encouraged to complete the UNFCCC and Kyoto Protocol national system training and to participate in expert review teams to develop review experience and learn from what other countries are doing.

5.1.7 Planned improvements

Short-term improvements include:

- A review of the partitioning of nitrogen in excreta between dung and urine in grazing livestock.
- Including the effect of land slope on N_2O emissions from excreta (non-dairy cattle, sheep and deer) (and possibly fertiliser) deposited on grazed hill country.
- A review of the treatment of uncertainty and including an update to the uncertainty analysis for the Agriculture sector.
- Inclusion of activity data for barn and free-range poultry provided by the Poultry Industry Association of New Zealand (PIANZ).

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

- The relationship between DMI and CH_4 emissions from lactating dairy cattle.

- The direct N_2O emissions factor (EF_1) and ammonium emissions for urea nitrogen fertiliser and dairy shed effluent under a range and combination of treatments with nitrogen inhibitors including urease inhibitors.
- The direct N_2O emissions from grazing livestock manure (EF_3) to address knowledge gaps for deer, manure deposited on irrigated land and different soils types.
- Trials on N_2O emissions from very steep slopes (greater than 25 degrees).
- Trials on N_2O emissions under different environmental conditions.
- Updating national estimates of pasture quality especially for metabolisable energy, nitrogen and dry matter digestibility.
- Revisiting enteric emissions factors for sheep including the results of recent trials using new calorimeters based at New Zealand's Agriculture Greenhouse Gas Research Centre.

These specific planned improvements are discussed in further detail in the relevant sector recalculation sections 5.2.5 (*Enteric fermentation* (CRF 3A)), 5.3.5 (*Manure management* CRF 3B) and 5.5.5 (*Agricultural soils* CRF 3D).

5.2 Enteric fermentation (CRF 3.I.A)

5.2.1 Description

Methane is a by-product of digestion in ruminants, for example in cattle and sheep, and in some non-ruminant animals, such as swine and horses. Within the Agriculture sector, ruminants are the largest source of CH_4. The amount of CH_4 released depends on the quantity of feed consumed, which is determined by the type, age and weight of the animal, animal production, feed quality and the energy expenditure of the animal.

In 2013, enteric fermentation contributed 28,441.1 kt CO_2-e. This represented 34.9 per cent of New Zealand's total CO_2-e emissions and 72.6 per cent of agricultural emissions. Dairy and non-dairy cattle contributed 18,608.7 kt CO_2-e (65.4 per cent) of emissions from the *Enteric fermentation* category and sheep contributed 9,223.3 kt CO_2-e (32.4 per cent) of emissions from this category. Emissions from the *Enteric fermentation* category in 2013 were 2,130.9 kt CO_2-e (8.1 per cent) above the 1990 level of 26,310.2 kt CO_2-e.

Methane emissions from the *Enteric fermentation* category from dairy cattle and sheep were identified as the largest key categories for New Zealand in the 2015 level assessment, and were also assessed as key categories for trend assessment. In accordance with IPCC good practice guidance (IPCC, 2000), the methodology used by New Zealand for calculating CH_4 emissions from enteric fermentation in domestic livestock is a Tier 2 modelling approach.

Since 1990, there have been changes in the relative sources of emissions within the *Enteric fermentation* category (table 5.2.1). The largest increase came from emissions from dairy cattle. In 2013, dairy cattle were responsible for 13,216.3 kt CO_2-e, an increase of 7,264.7 kt CO_2-e (122.1 per cent) from the 1990 level of 5,951.6 kt CO_2-e. Meanwhile, there have been decreases in emissions from non-dairy cattle, sheep and minor livestock populations, such as goats, horses and swine.

Table 5.2.1 Trends and relative contribution of enteric fermentation from livestock categories between 1990 and 2013

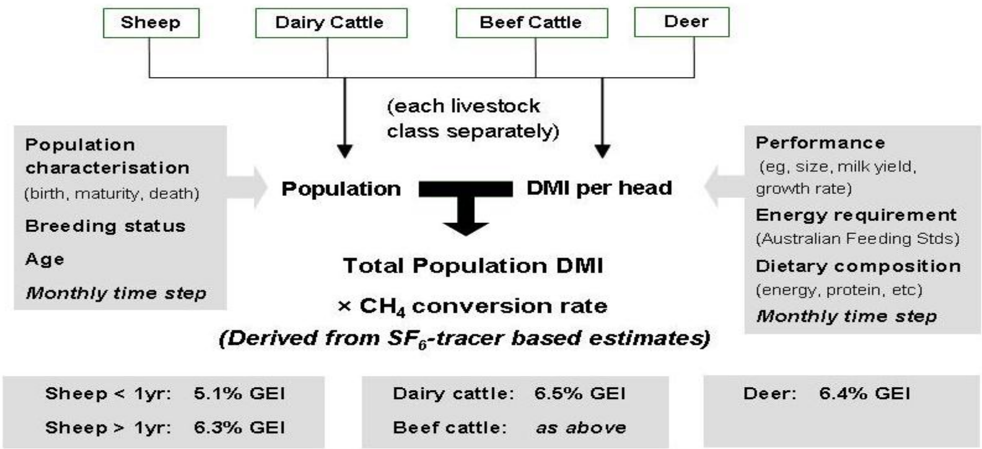
Livestock category	Emissions ($kt\ CO_2$-e) 1990	Emissions ($kt\ CO_2$-e) 2013	Change from 1990 %	Change from 1990 Difference ($kt\ CO_2$-e)	Share of Enteric fermentation category 1990 (%)	Share of Enteric fermentation category 2013 (%)	Share of total Agriculture sector 1990 (%)	Share of total Agriculture sector 2013 (%)
Dairy cattle	5,951.6	13,216.3	122.1	7,264.7	22.6	46.5	15.2	38.5
Non-dairy cattle	5,737.5	5,392.4	–6.0	–345.1	21.8	19.0	14.6	15.7
Sheep	13,956.0	9,223.3	–33.9	–4,732.7	53.0	32.4	35.6	26.9
Deer	415.6	555.8	33.7	140.2	1.6	2.0	1.1	1.6
Minor livestock	249.5	53.4	–78.6	–196.2	0.9	0.2	0.6	0.2

5.2.2 Methodological issues

Emissions from major livestock categories (cattle, sheep and deer)

Using the population characterisation and DMI per head calculated by New Zealand's Tier 2 Inventory model (section 5.1.3), the total amount of CH_4 emitted is calculated using a CH_4 conversion rate for emissions per unit of feed intake per livestock type (figure 5.2.1).

Figure 5.2.1 Schematic diagram of how New Zealand's emissions from enteric fermentation are calculated



Note: DMI is the dry-matter intake and GEI is the gross energy intake.

The equation for the total production of enteric methane for cattle, sheep and deer is:

$$CH_{4-enteric} = \sum_{\substack{livestock\\type}} \frac{n.DMI \cdot CH_4 conversion\ rate}{1000}$$

Where: $CH_{4\text{-enteric}}$ is the methane from enteric fermentation (kg CH_4/year),

Livestock type is cattle, deer, sheep (< 1 year old) and (sheep > 1 year old),

n is the population of each livestock category (head),

DMI is the dry-matter intake (kg dry matter per head/year), and,

CH_4 conversion rate is the CH_4 emissions per unit of feed intake (g CH_4/kg DM) (table 5.2.2).

There are a number of published algorithms and models[20] of ruminant digestion for estimating CH_4 emissions per unit of feed intake. The data requirements of the digestion models make them difficult to use in generalised national inventories and none of the methods have high predictive power when compared against empirical experimental data. Additionally, the relationships in the models have been mainly derived from animals fed indoors on diets unlike those consumed by New Zealand's grazing ruminants.

Since 1996, New Zealand scientists have been measuring CH_4 emissions from grazing cattle and sheep using the sulphur hexafluoride (SF_6) tracer technique (Lassey et al, 1997; Ulyatt et al, 1999). New Zealand now has one of the largest data-sets in the world of CH_4 emissions determined using the SF_6 technique on grazing ruminants. More recent research has moved to using respiration chambers, which are considered the gold standard for assessing emissions from livestock (see planned improvements). To obtain New Zealand-specific values, published and unpublished data on CH_4 emissions from New Zealand were collated and average values for CH_4 emissions from different categories of livestock were obtained (Clark et al, 2003). Sufficient data were available to obtain values for adult dairy cattle, sheep more than one year of age, and growing sheep (less than one year of age). These data are presented in table 5.2.2 together with the IPCC (2006, tables 10.12 and 10.13) default values for per cent gross energy intake (GEI) used to calculate CH_4. The New Zealand values fall within the IPCC range and are applied in this submission. Table 5.2.3 shows a time series of CH_4 implied emission factors for dairy cattle, non-dairy cattle and sheep.

Table 5.2.2 Methane emissions and gross energy intake (GEI) from New Zealand measurements and IPCC (2006) default values

	Adult cattle	Adult sheep (> 1 year)	Sheep < 1 year
New Zealand methane emission rates from Clark et al (2003) (g CH_4/kg DM)	21.6	20.9	16.8
New Zealand data (GEI, %)	6.5	6.3	5.1
IPCC (2006) default Y_m values (GEI, %)	6.5 ± 1.0	6.5 ± 1.0	4.5 ± 1.0

The adult dairy cattle value is applied to all dairy and non-dairy cattle, irrespective of age, and the adult ewe value is applied to all sheep more than one year of age. The average of the adult cow and adult ewe value (21.25 g CH_4/kg DMI) is assumed to apply to all deer (Clark et al, 2003). In very young animals receiving a milk diet, no CH_4 is assumed to arise from the milk portion of the diet.

[20] 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 5.2.3 New Zealand's implied emission factors for enteric fermentation from 1990 to 2013

Year	Dairy cattle (kg CH_4 per animal per annum)	Non-dairy cattle (kg CH_4 per animal per annum)	Sheep, all (kg CH_4 per animal per annum)	Deer (kg CH_4 per animal per annum)
1990	69.2	50.0	9.6	17.0
1991	72.2	51.4	9.9	17.6
1992	72.7	52.2	9.9	18.4
1993	73.7	53.0	10.1	18.8
1994	72.3	53.4	10.2	18.3
1995	72.0	52.9	10.0	19.2
1996	74.3	54.7	10.5	19.6
1997	75.2	55.6	10.9	19.8
1998	73.1	55.7	10.9	19.8
1999	74.6	54.4	10.9	19.9
2000	76.2	56.4	11.3	20.2
2001	77.1	57.4	11.3	20.2
2002	76.6	57.2	11.4	20.3
2003	79.5	56.8	11.5	20.1
2004	78.3	57.8	11.8	20.6
2005	78.8	58.4	11.9	20.9
2006	78.6	59.5	11.7	21.2
2007	77.6	58.1	11.3	21.2
2008	76.5	57.4	11.5	21.4
2009	77.0	57.8	11.9	21.6
2010	78.9	57.6	11.5	21.6
2011	80.0	58.5	11.9	21.7
2012	79.9	59.3	12.1	21.8
2013	80.2	58.5	11.9	21.2

Emissions from minor livestock categories

A Tier 1 approach is adopted for the minor livestock categories of goats, horses, swine, alpaca and mules and asses, using either IPCC (2006) default emission factors (horses, alpaca and mules and asses) or New Zealand country-specific emission factors (goats and swine). These minor species comprised less than 0.2 per cent of total enteric CH_4 emissions in 2013. The populations of goats, horses, pigs, alpacas and mules and asses are reported using the statistics and assumptions described in section 5.1.4.

Goats: From 1990 to 2009, the population declined from 1,062,900 to 82,229. Most of the decline in the herd was in the non-milking goat population. New Zealand uses a country-specific emission factor for enteric fermentation of 7.4 kg CH_4/head for 1990 and 8.5 kg CH_4/head for 2009 based on the differing population characteristics for those two years (Lassey, 2011). For the intermediate years between 1990 and 2009 and for 2010 to 2013, the emission factor was calculated based on the goat population, with the assumption that the dairy goat population has remained in a near constant numbers over time while the rest of the goat population has declined.

Swine: New Zealand uses a country-specific emission factor of 1.06 kg CH_4/head/year, which was derived from the IPCC (1996) Tier 2 methodology using a country-specific value for gross energy intake of 26.9 MJ per animal per day (Hill, 2012). The value of gross energy intake (GEI) and the composition of the swine diet are based on a survey of

56 farms accounting for 59 per cent of New Zealand pork production. Swine feed formulation is similar across farms as swine diets are controlled in New Zealand and limited ingredients are available for feed (Hill, 2012). Nutritional information was available for different age classes and categories, and the average value of gross energy intake was adjusted for population and further verified against national animal welfare standards. The New Zealand value is lower than the IPCC (1996) default for developed countries[21], which is based on average values derived from 1980s Western German production and population statistics. This is not representative of New Zealand swine systems and changes in production due to: improvements in genetic selection, reproductive cycle performance, housing and feed, animal husbandry and herd management (Hill, 2012).

Horses: In the absence of data to develop country-specific emission factors, the IPCC (2006) default value (18 kilograms CH_4/head/year) was used to determine emissions from enteric fermentation from horses.

Alpacas: In the absence of further work carried out on alpacas in New Zealand, the IPCC (2006) default value (8 kilograms CH_4/head/year) has been used to estimate emissions from this category.

Mules and asses: The IPCC default value from the IPCC (2006) guidelines was used (10 kilograms CH_4/head/year).

5.2.3 Uncertainties and time-series consistency

To ensure consistency, a single livestock population characterisation and feed-intake estimate is produced by the Tier 2 model (table A3.1.1.2), and is used in different parts of the calculations for the Inventory 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.

Livestock numbers

The calculations for total enteric fermentation require livestock population numbers. Information on uncertainties and time-series consistency for the livestock population data is included in section 5.1.4 and in annex 3.1.

Methane emissions from enteric fermentation

In the 2003 Inventory submission, the CH_4 emissions data from domestic livestock in 1990 and 2001 were subjected to Monte Carlo analysis using the software package @RISK to determine the uncertainty of the annual estimate (Clark et al, 2003). In subsequent submissions, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value.

In 2009, the Ministry for Primary Industries (then the Ministry of Agriculture and Forestry) commissioned a report that recalculated the uncertainty of the enteric fermentation CH_4 emissions for sheep and cattle (Kelliher et al, 2009). Since the Monte Carlo analysis carried out in 2003, there had been significant research in New Zealand on measuring enteric CH_4 emissions and feed intake from sheep and cattle. The initial analysis expressed the coefficient of variation (CV) according to the standard deviation of the CH_4 yield. The report (Kelliher et al, 2009) investigated calculating the uncertainty by expressing the CV according to the standard deviation of the CH_4 yield with the larger sample of measurements available by then. The analysis was restricted to one diet type;

[21] The IPCC (2006) default emission factor for swine is identical to the IPCC (1996) emission factor.

grass–legume pasture, the predominant diet of sheep and cattle in New Zealand. The new overall uncertainty of the enteric CH_4 emissions Inventory, expressed as a 95 per cent confidence interval, is ±16 per cent (Kelliher et al, 2009), see table 5.2.4.

Table 5.2.4 New Zealand's uncertainty in the annual estimate of enteric fermentation emissions for 1990 and 2013, estimated using the 95 per cent confidence interval (±16 per cent)

Year	Enteric CH_4 emissions (kt CH_4/annum)	95% confidence interval minimum (kt CH_4/annum)	95% confidence interval maximum (kt CH_4/annum)
1990	1,052.4	884.0	1,220.8
2013	1,137.6	955.6	1,319.6

Note: The CH_4 emissions used in the Monte Carlo analysis exclude those from swine, horses, goats, mules and asses, and alpacas, which represent a small proportion of total methane emissions.

Uncertainty in the annual CH_4 estimate is dominated by variance in the measurements of the 'methane per unit of intake' factor. This uncertainty is predominantly due to natural variation from one animal to the next. Uncertainties in the estimates of livestock energy requirements, herbage quality and population data are much smaller (0.005–0.05).

5.2.4 Source-specific QA/QC control and verification

In 2015, 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 trials were 329 (±153) grams CH_4/day/cow compared with 365 (±61) grams CH_4/day/cow for the scaled-up measurements reported by Waghorn et al (2002; 2003) using the SF_6 technique. Methane emissions from lactating dairy cows have also been measured using the New Zealand SF_6 tracer method and respiration chamber techniques (Grainger et al, 2007). Total CH_4 emissions were similar, 322 and 331 grams CH_4/day/cow, when measured using respiration chambers or the SF_6 tracer technique respectively.

The calculations in New Zealand's model for cattle, sheep and deer are Tier 2 and are based on IPCC (2000) good practice guidance and IPCC (2006) guidelines. Table 5.2.5 shows a comparison of the New Zealand-specific 2012 implied emission factor for enteric fermentation with the IPCC (2006) Oceania and the Australian implied emission factors for dairy cattle, non-dairy cattle and sheep.

Table 5.2.5 Comparison of IPCC default emission factors and country-specific implied emission factors (IEFs) for methane from enteric fermentation for dairy cattle, non-dairy cattle and sheep

	Dairy cattle (kg CH_4/head/year)	Non-dairy cattle (kg CH_4/head/year)	Sheep (kg CH_4/head/year)
IPCC (1996) Oceania default value	68.0	53.0	8.0
IPCC (2006) Oceania default value	90.0	60.0	8.0
Australian-specific IEF 2012 value	113.5	71.9	6.7
New Zealand-specific IEF 2012 value[22]	79.8	59.2	12.1

Source: UNFCCC (http://unfccc.int/di/FlexibleQueries.do) downloaded 24 January 2015.

Note: All values except for New Zealand include lambs in the implied emission factor calculation. IPCC (2006) value for sheep is for developed countries.

For non-dairy cattle, the implied emission factor is similar to the IPCC (2006) default. Differences such as feed type and quality, breed and which animals are characterised as non-dairy will, however, influence the IEF.

New Zealand's emission factor for sheep is higher than the IPCC default and higher than Australia's implied emission factor. New Zealand takes into account lambs when determining actual CH_4 emissions but not when estimating the implied emission factor. Therefore, a lower IEF is calculated than when the lamb population is also taken into account.

New Zealand has a slightly lower implied emission factor for dairy than the IPCC (2006) Oceania default and Australia's IEF. Although the predominantly pasture-based system in New Zealand is similar to Australian dairy cattle management, this lower IEF value may be due to the difference in cattle breeds between these countries. The Australian dairy herd comprises 80 per cent Holstein, 11 per cent Jersey breeds and 9 per cent other, including the Brown Swiss (according to http://www.austrex.com.au/dairy-cattle, accessed 24 January 2015). In 2013, 42.6 per cent of New Zealand's cow population comprised a Holstein–Friesian/Jersey crossbreed which is, on average, 90 per cent of the live weight of New Zealand's Holstein–Friesian cows (LIC, 2013). Also, in New Zealand's Tier 2 Inventory model, dairy cattle encompass all cattle that are required to support the milking dairy herd. This includes calves, young growing non-lactating heifers, dry cows and bulls. By taking the emissions from these animals into account, the implied emission factor will be lower than if only mature milking cows had been taken into account.

5.2.5 Source-specific recalculations

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

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

Migration from the revised IPCC (1996) guidelines to the IPCC (2006) guidelines

The methodology was updated to reflect the reporting requirements for national inventories in the IPCC (2006) guidelines, in line with the UNFCCC Conference of the Parties decision (15/CP17). For the *Enteric fermentation* category, this included changing the Tier 1 default values for horses and mules and asses.

22 As reported in *New Zealand's Greenhouse Gas Inventory 1990–2012* (Ministry for the Environment, 2014).

5.2.6 Source-specific planned improvements

Pasture quality nationwide sampling measurements

A review by Bown et al (2013) of values of the pasture metabolisable energy concentration and nitrogen content provided updated national estimates of pasture quality. An independent peer review of this report concluded that New Zealand should consider collecting more measurements before changing the values used in its national Agriculture Inventory (Stevens, 2014).

Bown et al, (2013) had identified further improvements that could be made to sampling pasture quality, particularly of hill country pasture grazed by non-dairy cattle, sheep and deer, and further work to support regional disaggregation of pasture quality data. New Zealand organised a workshop in November 2014 to bring together industry associations and researchers. A smaller working group was formed and is due to meet in 2015 to discuss and commission a multiyear study to improve the sampling, especially where gaps were identified by Bown et al (2013).

Emission factor lactating cattle

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

Emission factor sheep

Enteric emissions factors for sheep are being reviewed. This will include the results of recent trials using the respiration chambers based at New Zealand's Agriculture Greenhouse Gas Research Centre. Results from these trials are undergoing detailed statistical analysis for future publishing and inclusion in the national Inventory.

5.3 Manure management (CRF 3.B)

5.3.1 Description

In 2013, emissions from the *Manure management* category contributed 1,219.0 kt CO_2-e (3.1 per cent of emissions from the Agriculture sector). Emissions from *Manure management* have increased by 480.0 kt CO_2-e (64.9 per cent) from the 1990 level of 739.0 kt CO_2-e. Methane from *Manure management* from dairy cattle was identified as a key category for New Zealand in the 2015 level and trend assessment and methane from *Manure management* from sheep was identified as a key category in a trend assessment.

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 (ie relates to how the manure is stored) (table 5.3.1). In 2013, CH_4 emissions contributed 1129.6 kt CO_2-e (92.7 per cent of the *Manure management* category) (table 5.3.1).

The *Manure management* category also includes N_2O emissions related to manure handling before it is added to agricultural 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 sub-category contributed a relatively small amount of N_2O in 2013 (89.4 kt CO_2-e, 0.2 per cent of the Agriculture sector) (table

5.3.1). In comparison, the combined N_2O emissions from organic fertilisers (spreading of animal manure) and pasture, range and paddock manure (deposited directly by grazing livestock) reported under the *Agricultural soils* category totalled 8,453.4 kt CO_2-e in 2013 (15.5 per cent of emissions from the Agriculture sector).

Table 5.3.1 Trends and relative contribution of methane and nitrous oxide emissions under the *Manure management* category between 1990 and 2013

Manure management sub-category	Emissions (kt CO_2-e)		Change from 1990		Share of Manure management category		Share of total Agriculture sector	
	1990	2013	%	Difference (kt CO_2-e)	1990 (%)	2013 (%)	1990 (%)	2013 (%)
Methane	685.5	1,129.6	64.8	444.1	92.8	92.7	2.0	2.9
Nitrous oxide	53.5	89.4	67.1	35.9	7.2	7.3	0.2	0.2

For the major livestock categories in New Zealand, only dairy cows have their excreta stored in anaerobic lagoon waste systems (table 5.3.2). This stored excreta represents a small proportion (5 per cent) of the total dairy effluent produced (Ledgard and Brier, 2004). The remaining 95 per cent of excreta from dairy cattle is deposited directly onto pasture. This relates to the proportion of time dairy cattle spend on pasture compared with the time they spend in the milking shed. Non-dairy cattle, sheep and deer graze outdoors all year and deposit all of their faecal material (dung and urine) directly onto pastures (table 5.3.2).

For the minor livestock species: goats, horses, mules and asses, and alpacas are assumed to graze outdoors all year and deposit all of their manure directly onto pastures. Estimates of the proportions of different waste management systems for swine and poultry broilers in the manure management systems in New Zealand have been provided by Hill (2012) and Fick et al (2011) respectively (table 5.3.2).

Nitrous oxide emissions from the spreading of animal manure and from manure deposited directly to pasture by grazing livestock are reported under the *Agricultural soils* category (under sections: *Organic nitrogen fertilisers* and *Urine and dung deposited by grazing animals* respectively).

Table 5.3.2 Distribution of livestock waste across animal waste management systems in New Zealand

Livestock	Anaerobic lagoon (%)	Daily spread[23] (%)	Pasture, range and paddock[24] (%)	Solid storage and dry-lot (%)	Other (%)
Dairy cattle[25]	5	–	95	–	–
Non-dairy cattle	–	–	100	–	–
Sheep	–	–	100	–	–
Deer	–	–	100	–	–
Goats	–	–	100	–	–
Horses	–	–	100	–	–
Swine[26]	20.5	25.7	8.9	42.5	2.4
Poultry – Broilers[27]	0	–	4.9	–	95.1
Poultry – Layers[27]	–	–	5.8	–	94.2
Poultry – Other[28]	–	–	3	–	97
Alpaca	–	–	100	–	–
Mules and asses	–	–	100	–	–

5.3.2 Methodological issues

Methane from manure management systems (CRF 3.B.1)

A Tier 2 approach, which is consistent with the IPCC (2000) good practice guidance and the IPCC (2006) guidelines, is used to calculate CH_4 emissions from ruminant animal wastes from the major livestock categories in New Zealand (cattle, sheep and deer). This approach is based on the methods recommended by Saggar et al (2003).

In the 2015 submission, the IPCC (2006) Tier 2 methodology for dairy anaerobic lagoons has been implemented. The Tier 1 methodology for the minor livestock categories uses country-specific and IPCC (2006) default emission factors.

Manure methane from the major livestock categories

The approach for calculating CH_4 emissions from the major livestock categories 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 (based on the distributions in table 5.3.2); and

(3) the development of New Zealand-specific emission factors for the quantity of CH_4 produced per unit of faecal dry matter (for the component deposited directly onto pastures and for that stored in anaerobic lagoons).

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[23] Reported under Agricultural soils, under *Organic nitrogen fertilisers (CRF 3.D.1.2).*

[24] Reported under Agricultural soils, under *Urine and dung deposited by grazing animals (CRF 4.D.1.3).*

[25] 95 per cent of faecal manure from dairy cows is assumed to be deposited directly onto pastures (Ledgard and Brier, 2004).

[26] Hill (2012).

[27] Fick et al (2011) and pers. comm. (2010).

[28] IPCC (1996) default waste management proportions for Oceania.

The faecal dry-matter output (FDM) is calculated monthly for each livestock category (dairy cattle, non-dairy cattle, sheep and deer) from the following equation:

$$FDM = DMI \times (1-DMD)$$

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

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

DMD = dry-matter digestibility (decimal proportion).

The dry-matter intake and dry-matter digestibility estimates in this calculation are the same as are used to calculate the enteric fermentation CH_4 and nitrogen in excreta. These Tier 2 model calculations are based on livestock performance statistics (section 5.1.4).

Methane from dairy effluent anaerobic lagoons

An estimated five per cent of manure from dairy cows is stored in anaerobic lagoons (Ledgard and Brier, 2004). A Tier 2 methodology derived from IPCC (2006, equations 10.23 and 10.24) linking volatile solids to faecal dry matter (FDM) is used for calculating methane emissions from this activity:

$$CH_{4-MM} = FDM \cdot (1 - ASH) \cdot B_0 \cdot 0.67 \cdot MCF \cdot MS$$

Where: FDM is the faecal dry-matter excreted by dairy cows (on pasture and stored in anaerobic lagoons) (kg/head/month),

ASH is the ash content of manure, 0.08 (IPCC, 2006, default value),

B_0 is the maximum methane-producing capacity of manure, 0.24 (IPCC, 2006, Oceania default value, verified by Pratt et al, 2012),

The factor, 0.67, is the conversion factor of m^3 CH_4 to kg CH_4 (IPCC, 2006),

MCF is the methane conversion factor, 0.74 (IPCC, 2006, table 10.17, default for uncovered anaerobic lagoon, average annual temperature 15º, verified by Pratt et al, 2012), and,

MS is the percentage of manure from the dairy herd (6 per cent from lactating cattle which is equivalent to 5 per cent of the total dairy herd, Ledgard and Brier, 2004).

Methane from manure directly deposited to pasture

Dairy cattle: Ninety five per cent of faecal material arising from dairy cows is assumed to be deposited directly onto pastures (Ledgard and Brier, 2004), and the faecal dry matter (FDM) is derived monthly from the equation above. The quantity of CH_4 produced per kg of faecal dry matter is 0.98 grams CH_4/kg. This value is obtained from New Zealand studies on dairy cows and ranges from approximately 0.92 to 1.04 g CH_4/kg (Saggar et al, 2003; Sherlock et al, 2003).

Non-dairy cattle: Non-dairy (beef) cattle are not housed in New Zealand, and all faecal material is deposited directly onto pasture. 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).

Sheep: Sheep are not housed in New Zealand, and all faecal material is deposited directly onto pasture. 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 sampling periods (Carran et al, 2003).

Deer: Deer are not housed in New Zealand, and all faecal material is deposited directly onto pasture. 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).

Manure methane from minor livestock categories

Manure methane emissions from the minor livestock categories are calculated per head, using country-specific and default emission factors.

Swine: New Zealand uses a country-specific emission factor of 5.94 kilograms CH_4/head/year (Hill, 2012) for estimating emissions from swine manure management.

Poultry: Methane emissions from poultry manure management use New Zealand-specific emission factor values derived from Fick et al (2011). These are based on New Zealand-specific volatile solids and proportions of poultry faeces in each manure management system for each production category. The poultry population has been disaggregated into three different categories and the values for each are: broiler birds – 0.022 kilograms CH_4/head/year; layer hens – 0.016 kilograms CH_4/head/year; and other – 0.117 kilograms CH_4/head/year. The value for other poultry (turkeys, ducks and other species) is the IPCC (1996) default.

Goats, horses, and mules and asses: New Zealand-specific emission factors are not available for CH_4 emissions from manure management for goats, horses, mules and asses. These are minor livestock categories in New Zealand, and IPCC (2006) default emission factors for temperate developed countries (goats 0.20 kilograms CH_4/head/year, horses 2.34 kilograms CH_4/head/year, mules and asses 1.10 kilograms CH_4/head/year) are used to calculate emissions. All faecal material from these livestock is deposited directly onto pasture. Until country-specific information is available for these categories, the IPCC default value will continue to be used.

Alpacas: 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 are no data indicating that alpaca have gained the kind of productivity increases that have been seen in sheep.

Nitrous oxide from manure management systems (CRF 3.B.2)

Nitrous oxide emissions from manure are calculated for each livestock category from:

(1) livestock population characterisation data (consistent with section 5.1.3)

(2) average nitrogen excretion rate per head

(3) an estimation of the total quantity of faecal material produced (consistent with the calculations in the previous section for methane from manure management)

(4) the partitioning of this faecal material between manure management systems (based on the distributions in table 5.3.2), and

(5) multiplication of the total amount of N managed in each system by an emission factor (IPCC, 2006).

Direct and indirect N_2O emissions are calculated. Direct N_2O emissions are assumed to be generated by the combined nitrification and denitrification of nitrogen contained in the manure (IPCC, 2006). Indirect N_2O emissions result from volatile nitrogen losses in the forms of ammonia and NO_x and are emitted via diffusion into the surrounding air (volatilisation) or via leaching and runoff.

Nitrogen excretion rates for the major livestock categories

The nitrogen excretion rates for the main livestock classes in New Zealand (cattle, sheep and deer) are calculated from the nitrogen intake less the nitrogen retained in animal products, such as liveweight gain, gestation, milk, wool, velvet. Nitrogen intake is determined from the dry-matter 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 5.1.4). The nitrogen content of feed is estimated from a review of over 6,000 pasture samples from dairy systems and sheep and non-dairy (beef) systems (Ledgard et al, 2003).

The nitrogen content of animal products is derived from industry data. For lactating dairy cows, the nitrogen content of milk is derived from the protein content of milk published annually by the LIC (nitrogen = 1.03 x protein/6.38; equation from CSIRO, 1990). The nitrogen content of sheep meat, milk and wool, non-dairy meat and milk, and the nitrogen retained in deer velvet, are taken from New Zealand-based research (Pickering and Wear, 2012; Bown et al, 2013).

Table 5.3.3 shows the nitrogen excretion rates for the major livestock classes. Note that these increase over time, reflecting the increases in animal productivity in New Zealand since 1990. For full details of how nitrogen excretion rates are derived for each livestock class, see the Inventory methodology document on the Ministry for Primary Industries website (http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/).

Table 5.3.3 Nitrogen excretion (N_{ex}) rates for New Zealand's major livestock classes from 1990 to 2013

Year	Dairy N (kg/head/year)	Non-dairy cattle N (kg/head/year)	Sheep N (kg/head/year)	Deer N (kg/head/year)
1990	104.1	64.3	13.8	25.2
1991	108.1	66.1	14.3	26.1
1992	108.8	67.1	14.3	27.1
1993	110.1	68.3	14.5	27.7
1994	108.0	68.9	14.6	26.8
1995	107.6	68.3	14.5	28.1
1996	110.7	70.8	15.0	28.7
1997	111.7	72.1	15.7	28.8
1998	109.2	72.1	15.6	28.8
1999	111.1	70.3	15.6	28.9
2000	112.7	72.8	16.3	29.4
2001	113.8	74.1	16.2	29.4
2002	113.1	73.6	16.4	29.5
2003	117.2	73.2	16.4	29.0
2004	115.7	74.5	16.8	29.4
2005	116.3	75.4	17.1	29.7
2006	115.5	76.9	16.8	29.8
2007	114.2	74.8	16.3	29.4
2008	112.5	73.9	16.5	29.5
2009	113.3	74.5	17.0	29.5
2010	115.9	74.3	16.5	29.4
2011	116.9	75.4	16.9	29.7
2012	116.9	76.5	17.2	29.7
2013	118.9	75.2	17.1	29.5

Nitrogen excretion rates for the minor livestock categories

Swine: A New Zealand-specific nitrogen excretion rate for swine is calculated for each year (table 5.3.4) based on the 2010 value of 10.8 kilograms N/head/year (Hill, 2012). This is based on the weighted average of the animal distribution of animal weights by swine subcategory. Estimates of nitrogen excretion rates for all other years are indexed relative to 2009 for the average pig kill weights for each year.

Goats: New Zealand uses country-specific nitrogen excretion rates for goats to estimate N_2O emissions of 10.6 kilograms N/head/year for 1990 and 12.1 kilograms N/head/year for 2009 based on the differing population characteristics for those two years (Lassey, 2011). As explained in section 5.2.2 for enteric fermentation, for the intermediate years between 1990 and 2009 and for later years, the excretion rate was interpolated based on assumptions that the dairy goat population has remained in a near constant state over time, while the rest of the goat population has declined (table 5.3.4).

Poultry: New Zealand-specific and IPCC default nitrogen excretion rates are used for poultry (Fick et al, 2011). These are the country-specific values of 0.39 kilograms N/head/year for broiler birds and 0.42 kilograms N/head/year for layer hens. Ducks and turkeys make up approximately 1 per cent of New Zealand's poultry population and flock sizes are unclear as they are reported by Statistics New Zealand under 'other Poultry'. Therefore, the value of 0.60 kilograms N/head/year for ducks and turkeys recommended by Fick et al (2011) is retained. These values are used for all years.

Horses, mules and asses: New Zealand-specific nitrogen excretion rates are not available for horses, mules and asses, and the default nitrogen excretion rate for Oceania of 0.3 kg N/1000 kg mass/day is used, in line with the guidelines (IPCC, 2006; table 10.19).

Alpaca: There is no IPCC default value available for nitrogen excretion rate for alpacas. Therefore, this was calculated by assuming a default nitrogen excretion rate for alpacas for all years that is equal to the per-head value of the average sheep in 1990 (ie, total sheep emissions per total sheep population). The alpaca emission factor is not indexed to sheep over time because there are 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 result in the overestimation of N_{ex} for alpacas.

Table 5.3.4 Nitrogen excretion (N_{ex}) rates for New Zealand's swine and goats from 1990 to 2013

Year	Swine N (kg/head/year)	Goat N (kg/head/year)	Year	Swine N (kg/head/year)	Goat N (kg/head/year)
1990	9.0	10.6	2002	10.2	11.4
1991	9.2	10.7	2003	10.1	11.3
1992	9.3	10.8	2004	10.5	11.5
1993	9.5	10.9	2005	10.6	11.5
1994	9.5	11.0	2006	10.7	11.5
1995	9.6	10.9	2007	10.8	11.7
1996	9.8	11.2	2008	10.8	11.9
1997	9.9	11.1	2009	10.8	12.1
1998	9.9	11.1	2010	10.8	11.8
1999	9.9	11.3	2011	11.0	12.0
2000	10.2	11.3	2012	11.0	11.9
2001	10.5	11.4	2013	11.1	12.0

Direct nitrous oxide from manure management

Major livestock categories: For the major livestock categories (cattle, sheep and deer), the majority of manure is deposited directly to pasture by grazing animals (table 5.3.2). Direct and indirect nitrous oxide emissions from the manure deposited by grazing animals are reported under the *Agricultural soils* category (*Urine and dung deposited by grazing animals CRF 4.D.1.3*).

The remainder of dairy manure is managed in anaerobic lagoons. The IPCC (2006) guidelines note that the production of emissions of direct N_2O from managed manure require aerobic conditions for the formation of oxidised forms of nitrogen, but assumes that negligible direct nitrous oxide emissions occur during storage in anaerobic lagoons (IPCC 2006, table 10.21). Direct nitrous oxide emissions from dairy effluent anaerobic lagoons are reported under the *Agricultural soils* category (*Organic nitrogen fertiliser CRF 4.D.1.2*) when the stored effluent is spread onto agricultural land.

Swine: Swine manure is managed under various types of waste management system (table 5.3.2). The IPCC (2006) guidelines (table 10.21) assume that negligible direct nitrous oxide emissions occur in anaerobic lagoons and daily spread. Nitrous oxide emissions from manure from these systems occur once the stored effluent is spread onto agricultural land and are reported under the *Agricultural soils* category (*Organic nitrogen fertiliser CRF 4.D.1.2*). Nitrous oxide from manure management of swine for the solid storage, dry lot and other manure management systems is estimated using the IPCC (2006) default values for EF_3 of 0.02 and 0.005 kilograms N_2O-N/kg N respectively.

Poultry: Direct nitrous oxide emissions from poultry manure deposited directly on pasture are reported under the *Agricultural soils* category (*Urine and dung deposited by grazing animals CRF 4.D.1.3*). For other manure management systems, the IPCC (2006, table 10.21) default emission factor for EF_3 of 0.001 kilograms N_2O-N/kg N for poultry manure with and without litter is assumed.

Goats, horses, alpaca, and mules and asses: All faecal material from these livestock is deposited directly onto pasture and direct nitrous oxide emissions from grazing animals are reported under the *Agricultural soils* category (*Urine and dung deposited by grazing animals CRF 4.D.1.3*).

Indirect nitrous oxide from manure management

Indirect N_2O emissions from manure management result from diffusion into the surrounding air (volatilisation) and from leaching and runoff. All indirect N_2O emissions for the pasture, range and paddock manure management systems are reported under the *Agricultural soils* category.

The IPCC (2006) Tier 1 methodology is used for calculating N_2O emissions resulting from volatilisation:

$$N_2O_{MM-volatiliasation} = \frac{44}{12}(N_{volatilisation-MMS} \cdot EF_4)$$

And:

$$N_{volatilisation-MMS} = \sum_S \left[\sum_T \left[(N_T \cdot Nex_T \cdot MS_{T,S}) \cdot \left(\frac{Frac_{GasMS}}{100} \right)_{T,S} \right] \right]$$

Where: $N_{volatilisation\text{-}MMS}$ is the amount of manure N that is lost due to volatilisation (kg/year),

EF_4 is the emission factor for N_2O emissions from volatilisation, the IPCC (2006) default value of 0.01 kg N_2O-N/(kg NH_3-N + NO_x-N volatilised) is used,

N_T is the number of livestock per category (head), detailed in section 5.1.4,

Nex_T is the average nitrogen excretion for each livestock category, T, detailed above,

$MS_{T,S}$ is the fraction of total nitrogen excretion per livestock category, T, per manure management system, S, derived from table 5.3.2, and,

$Frac_{GasMS}$ is the percent of managed manure N for each livestock category, T, which volatilises as NH_3 and NO_x per manure management system, S. New Zealand uses default values for $Frac_{GasMS}$ detailed in table 5.3.5.

The IPCC (2006) Tier 1 methodology for determining indirect N_2O emissions does not provide a methodology for leaching and runoff. There have been no country-specific emission factors derived for leaching and runoff from manure management systems in New Zealand (eg, Hill, 2012), and there are extremely limited measurement data available generally (IPCC, 2006). Leaching and runoff from dairy anaerobic lagoons is likely to be an insignificant activity in New Zealand (T Wilson, pers. comm. 2014). Therefore, all indirect N_2O emissions from leaching and runoff are reported under the *Agricultural soils* category.

Table 5.3.5 IPCC default values for the fraction of managed manure N that volatilises as NH_3 and NO_x ($Frac_{GasMS}$/100) for livestock categories per manure management system in New Zealand (table 5.3.5)

Manure management system	Livestock category	Value	Source
Anaerobic lagoons	Dairy	0.35	IPCC (2006) table 10.22
	Swine	0.4	
Daily spread	Swine	0.07	
Solid storage and dry lot	Swine	0.3	
Other	Swine	0.25	
	Poultry – broilers	0.25	
	Poultry – layers	0.25	
	Poultry – other	0.25	

5.3.3 Uncertainties and time-series consistency

To ensure consistency, a single livestock population characterisation and feed-intake estimate is produced by the Tier 2 model for the major livestock categories, and is used in different parts of the calculations for the Inventory 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 grazing manure subcategory.

Methane emissions

The major sources of uncertainty in CH_4 emissions from manure management are the accuracy of emission factors for manure management system distribution, the activity data on the livestock population and the use of the various manure management systems (IPCC, 2006).

New Zealand does not currently have country-specific uncertainty values for CH_4 from manure management, although the ranges for measured emissions for the major livestock categories have been stated where available. For all livestock manure emissions, the IPCC (2006) default values of ± 20 per cent for Tier 2 methodologies and ± 30 per cent for Tier 1 methodologies have been used.

Uncertainties for the livestock characterisation are discussed in section 5.1.4 and annex A3.1.1. The uncertainty range for the various manure management systems is under investigation for future inclusion in the national Inventory.

Nitrous oxide emissions

The main factors causing uncertainty in direct and indirect N_2O emissions from manure management are the nitrogen excretion rates, the emission factors from manure and manure management systems, activity data on the livestock population and the use of the various manure management systems (IPCC, 2006).

Uncertainty ranges for the default nitrogen excretion values are estimated at about ± 50 per cent (IPCC, 2006), and may be substantially smaller for the values for the livestock whose N excretion rates were derived from in-country statistics on productivity. New Zealand uses the default values for EF_3 for direct N_2O emissions from the manure management of swine and poultry, which have uncertainties of –50 per cent to +100 per cent. New Zealand uses the default value for EF_4, which has an uncertainty range of 0.002 to 0.05 (IPCC, 2006, table 11.3).

As above, uncertainties for the livestock characterisation are discussed in section 5.1.4 and annex A3.1.1. The uncertainty range for use of the various manure management systems is under investigation for future inclusion in the national Inventory.

5.3.4 Source-specific QA/QC and verification

Methane from *Manure management* from dairy cattle was identified as a key category for New Zealand in the 2015 level and trend assessment and methane from *Manure management* from sheep was identified as a key category in a trend assessment.

In the preparation for this Inventory submission, the data for this category underwent Tier 1 and Tier 2 quality checks.

Table 5.3.6 shows a comparison of the New Zealand-specific 2012 implied emission factor for CH_4 from *Manure management* with the IPCC (2006) Oceania default values and Australia's implied emission factors for dairy cattle, non-dairy cattle and sheep.

New Zealand has a lower implied emission factor for CH_4 from *Manure management* than the IPCC (2006) Oceania default. Differences between New Zealand's implied emission factors and the IPCC default factors are due to the reasons outlined in the *Enteric fermentation* section, that is, size and productivity of the animals, the age classes of livestock included in New Zealand's modelling, and the use of different algorithms to determine energy intake as well as values used for nitrogen content of feed and digestibility.

Table 5.3.6 Comparison of IPCC default emission factors and country-specific implied emission factors for methane from *Manure management*

	Dairy cattle (kg CH_4/head/year)	Non-dairy cattle (kg CH_4/head/year)	Sheep (kg CH_4/head/year)
IPCC (1996) developed temperate/Oceania default value	32.00	6.00	0.28
IPCC (2006) Oceania average temperature 15º (cattle) /developed temperate default value (sheep)	27.00	2.00	0.28
Australian-specific IEF 2012 value	8.59	0.04	0.00
New Zealand-specific 2012 value[29]	3.48	0.80	0.12

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

Note: IEF = implied emission factor.

5.3.5 Source-specific recalculations

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

Changes to the Tier 2 model for livestock population, productivity and energy equations are explained in section 5.2.5, and will flow through to the emissions from *Manure management* and result in recalculations.

A report was commissioned and completed during 2013 to review nitrogen retention rates in wool, milk, deer velvet and animal liveweight gain (Bown et al, 2013) and updated nitrogen retention values for dairy and non-dairy (beef) cattle milk, for sheep wool and for deer velvet became available. These are used in the Tier 2 calculation of the nitrogen excretion rates.

Migration from the revised IPCC (1996) guidelines to the IPCC (2006) guidelines

The methodology was updated to reflect the reporting requirements for national inventories in the IPCC (2006) guidelines, in line with the UNFCCC Conference of the Parties decision (15/CP17). For the *Manure management* category, this included:

- updating the Tier 1 default values for methane emissions for goats, horses and mules and asses
- nitrogen excretion for horses, mules and asses
- direct nitrous oxide emissions for swine and poultry (other); and,
- the values for the parameter, $Frac_{GasMS}$.

Direct and indirect nitrous oxide emissions were reported separately, ensuring that no double-counting of N_2O emissions between the *Manure management* and *Agricultural soils* categories is occurring.

[29] As reported in *New Zealand's Greenhouse Gas Inventory 1990–2012* (Ministry for the Environment, 2014).

5.3.6 Source-specific planned improvements

Improved manure management methodology

A long-term improvement to the disaggregation of dairy effluent into different manure management systems is being investigated by New Zealand scientists. Findings may be incorporated in future submissions.

Partitioning nitrogen in excreta between dung and urine

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

Pasture quality nationwide sampling measurements

As above for *Enteric fermentation*, a review by Bown et al (2013) provided updated national estimates of pasture quality. An independent peer review of this report concluded that New Zealand should consider collecting more measurements before changing the values used in its national Agriculture Inventory (Stevens, 2014).

Bown et al (2013) had identified further improvements that could be made to sampling pasture quality, particularly of hill country pasture grazed by non-dairy cattle, sheep and deer, and further work to support regional disaggregation of pasture quality data. New Zealand organised a workshop in November 2014 to bring together industry associations and researchers. A smaller working group was formed and is due to meet in 2015 to discuss and commission a multiyear study to improve the sampling, especially where gaps were identified by Bown et al (2013).

2006 IPCC guidelines

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

5.4 Rice cultivation (CRF 3.C)

5.4.1 Description

At present, no commercial rice cultivation is being carried out in New Zealand. This has been confirmed with experts from Plant and Food Research, a New Zealand-based scientific research company. The ‘NO’ notation is reported in the common reporting format tables.

5.5 Agricultural soils (CRF 3.D)

5.5.1 Description

In 2013, the *Agricultural soils* category contributed 8,453.4 kt CO_2-e (10.4 per cent) to New Zealand’s total emissions and 93.4 per cent to New Zealand’s total N_2O emissions. Emissions were 1,578.7 kt CO_2-e (23.0 per cent) above the 1990 level of 6,874.7 kt CO_2-e.

Several sub-categories contribute to emissions from agricultural soils from direct and indirect pathways (table 5.5.1). Direct N_2O emissions occur directly from the soils to which N has been added or released; indirect emissions arise from volatilisation (evaporation or sublimation) and subsequent redeposition of ammonia (NH_3) or mono-nitrogen oxides (NO_x), or result from leaching and runoff of soil N within water (IPCC, 2006).

In order of significance to New Zealand's agricultural emissions in 2013 these are as outlined below.

- Direct N_2O emissions from urine and dung deposited by grazing livestock (grazing manure). In 2013, N_2O emissions from grazing manure contributed 5,679.4 kt CO_2-e (67.2 per cent) to emissions from the *Agricultural soils* category and 14.5 per cent of emissions under the total Agriculture sector. This is an increase of 423.8 kt CO_2-e (8.1 per cent) from the 1990 level of 5,255.5 kt CO_2-e. *Direct N_2O emissions* from grazing manure were identified as a key category (trend and level assessment).
- Direct N_2O emissions as a result of adding synthetic nitrogen fertilisers to agricultural soils. In 2013, N_2O emissions from synthetic nitrogen fertilisers contributed 934.6 kt CO_2-e (11.1 per cent) to emissions from the *Agricultural soils* category. This is an increase of 716.9 kt CO_2-e (329.4 per cent) from the 1990 level of 217.7 kt CO_2-e. *Direct N_2O emissions* from synthetic fertiliser were identified as a key category (trend and level assessment).
- Indirect N_2O emissions through volatilisation, which in 2013 contributed 913.9 kt CO_2-e (10.8 per cent) to emissions from the *Agricultural soils* category. This was an increase of 187.2 kt CO_2-e (25.8 per cent) from the 1990 level of 726.8 kt CO_2-e. *Indirect N_2O emissions from atmospheric deposition* were identified as a key category (level assessment).
- Indirect N_2O emissions through leaching and runoff, which in 2013 contributed 496.1 kt CO_2-e (5.9 per cent) to emissions from the *Agricultural soils* category. This was an increase of 105.4 kt CO_2-e (27.0 per cent) from the 1990 level of 390.8 kt CO_2-e. Nitrous oxide emissions from *Nitrogen leaching and run-off* were identified as a key category (level assessment).
- Direct N_2O emissions from agricultural soils as a result of adding nitrogen in the form of: organic nitrogen fertilisers (predominantly in the form of animal manure), inputs from above- and below-ground crop residues and from forages during pasture renewal, mineralisation of cropland soil organic matter loss, and cultivation of organic soils. These combined direct N_2O soil emissions contributed 429.3 kt CO_2-e (5.1 per cent) to emissions from the *Agricultural soils* category in 2013. This was an increase of 145.3 kt CO_2-e (51.1 per cent) from the 1990 level of 284.0 kt CO_2-e.

Table 5.5.1 Trends and relative contribution of emissions from *Agricultural soils* sub-categories between 1990 and 2013

Agricultural soils sub-category		Emissions ($kt CO_2$-e) 1990	Emissions ($kt CO_2$-e) 2013	Change from 1990 %	Change from 1990 Difference ($kt CO_2$-e)	Share of Agricultural soils category 1990 (%)	Share of Agricultural soils category 2013 (%)	Share of total Agriculture sector 1990 (%)	Share of total Agriculture sector 2013 (%)
Direct	Synthetic fertilisers	217.7	934.6	329.4	716.9	3.2	11.1	0.6	2.4
	Organic fertilisers (manure spreading)	78.5	147.8	88.4	69.3	1.1	1.7	0.2	0.4
	Grazing manure	5,255.5	5,679.4	8.1	423.8	76.4	67.2	15.3	14.5
	Crop residue	175.5	251.3	43.2	75.9	2.6	3.0	0.5	0.6
	Cropland N mineralisation from soil organic matter loss	0.03	0.2	570.6	0.2	Negl.	0.002	Negl.	Negl.
	Cultivation of organic soils	30.0	30.0	0.0	0.0	0.4	0.4	0.1	0.1
Indirect	Volatilisation	726.8	913.9	25.8	187.2	10.6	10.8	2.1	2.3
	Leaching and run-off	390.8	496.1	27.0	105.4	5.7	5.9	1.1	1.3

Indirect emissions from livestock waste management systems are reported under section 5.3 (*Manure management*) in line with IPCC (2006). Carbon dioxide emissions from lime and dolomite fertilisers are reported in section 5.8 (*Liming*).

5.5.2 Methodological issues

The largest inputs of nitrogen to agricultural soils are manure from grazing livestock, synthetic N fertilisers and volatilisation, which contribute 89.1 per cent of emissions from the *Agricultural soils* category. New Zealand uses methodologies based on the IPCC guidelines and, where applicable, using the outputs of the Tier 2 livestock population characterisation and livestock nutrition and energy requirements modelling. Methodological issues for individual subcategories under the *Agricultural soils* category follow this section.

New Zealand applies a combination of default and country-specific emission factors and parameters to calculate N_2O emissions from agricultural soils. Several country-specific emission factors and parameters have been developed and are used in the Inventory (tables 5.5.2 and 5.5.3; tables A3.1.2.3 and A3.1.2.4). Further refinements are applied where mitigation technologies are used (table 5.5.4).

As the majority of livestock waste is excreted directly onto pasture during grazing (table 5.3.2), and as manure contributes 14.5 per cent of emissions to the total Agriculture sector, considerable research effort has gone into establishing New Zealand-specific emission factors for EF_3 (described in detail below), including a disaggregation for emissions from urine and dung from the major livestock categories (dairy and non-dairy cattle, sheep and deer; table 5.5.2).

Two country-specific emission factors have been established for the application of synthetic N fertiliser to agricultural soils, EF_1. The country-specific value for $EF_{1\text{-UREA}}$ for urea-derived fertiliser (0.0048 kgN_2O-N/kg N) is based on a statistical analysis by Kelliher et al (2014) of 22 field trials in New Zealand. The IPCC default value of 0.01 was verified for New Zealand conditions by Kelliher and de Klein (2006) and is used for all other N fertiliser (including synthetic, organic, crop residue etc). New Zealand also commissioned a desktop review of New Zealand and international studies of EF_5 for rivers, lakes and estuaries (Clough and Kelliher, 2014), which concluded that further research would be required to develop a country-specific value.

New Zealand has also developed country-specific parameters for volatilisation, leaching, N input from crop residue burning and pasture renewal (table 5.5.3), and has also incorporated emission factors, as well as parameters for the use of mitigation technologies: nitrification inhibitor dicyandiamide (DCD) and urease inhibitor, N-(n-butyl) thiophosphoric triamide (nBTPT, sold as ‘Agrotain’) (table 5.5.4).

Table 5.5.2 N_2O emission factors for agricultural soils in New Zealand

Category		Emission factor		Source
3.D.1 Direct N_2O Emissions				
Synthetic fertiliser (urea)	$EF_{1\text{-UREA}}$	0.0048	kg N_2O-N/kg N	Kelliher et al (2014)
Synthetic fertiliser (other), organic fertiliser, crop residue, N loss due to soil organic matter mineralisation, organic soil mineralisation due to cultivation	EF_1	0.01	kg N_2O-N/kg N	Kelliher and de Klein (2006)
Cultivation of organic soils	EF_2	8	kg N_2O-N/ha/kg N	IPCC (2006), table 11.1
Manure (urine and dung) from grazing animals in pasture, range and paddock systems	EF_{3PRP}	0.01	kg N_2O-N/kg N	Carran et al (1995); Muller et al (1995); de Klein et al (2003)
Dung from grazing cattle, sheep and deer in pasture, range and paddock systems	$EF_{3PRP\text{-DUNG}}$	0.0025	kg N_2O-N/kg N	Luo et al (2009)
3.D.2 Indirect N_2O Emissions				
Volatisation	EF_4	0.010	kg N_2O-N/kg N	IPCC (2006), table 11.3
Leaching and runoff	EF_5	0.0075	kg N_2O-N/kg N	IPCC (2006), table 11.3

Table 5.5.3 Parameters for indirect N_2O emissions from agricultural soils in New Zealand

Category		Parameter		Source
3.D.2 Indirect N_2O Emissions				
Fraction of volatilisation from synthetic fertiliser	$Frac_{GASF}$	0.1	kg NH_3-N + NO_x-N/kg N	IPCC (2006) verified by Sherlock et al (2008)
Fraction of volatilisation from organic N additions including pasture manure	$Frac_{GASM}$	0.1	kg NH_3-N + NO_x-N/kg N	Sherlock et al (2008)
Fraction of leaching/runoff from all N applied to soil	$Frac_{LEACH-(H)}$	0.07	kg N/kg N	Thomas et al (2003; 2005)
Fraction of crop residue burned in the field	$Frac_{BURN}$	Crop-specific	kg N/kg crop-N	Thomas et al (2008, table 14)
Fraction of legume crop residue burning in the field	$Frac_{BURNL}$	0	kg N/kg crop-N	Thomas et al (2008)
Fraction of land undergoing pasture renewal	$Frac_{RENEW}$	Year-specific		Beare et al (2012), Thomas et al (2014)
Fraction of N in above-ground residues removed for bedding, feed or construction	$Frac_{REMOVE}$	0	kg N/kg crop-N	Thomas et al (2014)

Table 5.5.4 Emission factors and parameter values for use of mitigation technologies

Category	Parameter		Source
Urine from grazing dairy cattle in pasture, range and paddock systems with application of dicyandiamide (DCD)	$EF_{3PRP\text{-}DCD}$	See table 5.5.4	Clough et al (2008)
Fraction of N from leaching/runoff with application of dicyandiamide (DCD)	$Frac_{LEACH-(H)\text{-}DCD}$	See table 5.5.4	Clough et al (2008)
Volatilisation from synthetic fertiliser including urease inhibitor (nBTPT)	$Frac_{GASF\text{-}UI}$	0.045 (scalar of 0.55 used)	Saggar et al (2013)

Direct nitrous oxide emissions from managed soils (3.D.1)

Nitrous oxide emissions from the direct soils emissions subcategory arise from:

- synthetic fertiliser use (F_{SN})
- organic fertilisers (which are predominantly the spreading of animal waste, F_{AM})
- manure deposited by grazing livestock in pasture, range and paddock (F_{PRP})
- decomposition of crop residues left on fields (F_{CR}), and
- N mineralisation associated with loss of soil organic matter (F_{SOM}).

Emissions from the non-manure components of organic nitrogen additions to soils (F_{ON}) (ie, dairy processing wastewater, compost sold to the rural sector, meat processing wastewater sand sludge, grape marc from the wine industry, vegetable processing wastewater applied to land) are not significant activities in New Zealand (van der Weerden et al, 2014). Many of these subcategories have N_2O emissions from indirect pathways as well, and these calculations are described in detail in the later section on indirect N_2O emissions from agricultural soils.

Where N_{ex} values and allocation to animal waste management systems are used to determine nitrogen inputs to soils (for F_{AM} and F_{PRP}), these are the same as are discussed in section 5.3. These 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 5.1.1). This ensures the same base DMI values are used for both the CH_4 and N_2O emission calculations. Further details can be found in the Inventory methodology document on the Ministry for Primary Industries' website (http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/).

Synthetic nitrogen fertiliser (CRF 3.D.1.1)

Anthropogenic N_2O emissions from nitrogen from synthetic fertiliser are a relatively small proportion of total N_2O emissions, although still significant. The majority of synthetic N fertiliser used in New Zealand is urea fertiliser applied to dairy pasture land to boost pasture growth during spring and autumn.

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-based fertiliser. As recommended by IPCC (2006), the adjustment for NH_3 and NO_x emissions from volatilisation is no longer applied:

$$N_2O\ emissions = \frac{44}{28} \cdot \left[\left(F_{SN(UREA)} \cdot EF_{1(UREA)}\right) + \left(F_{SN(OTHER)} \cdot EF_1\right)\right]$$

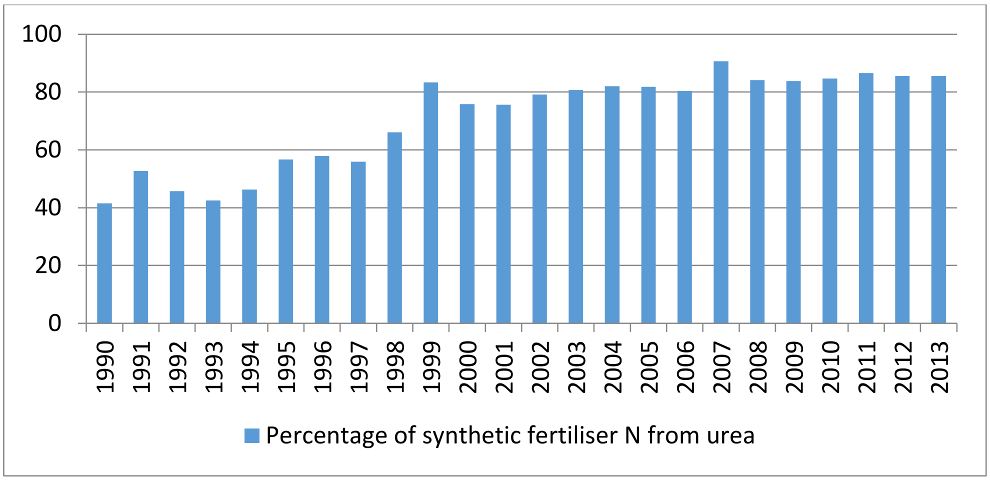
Where: F_{SN} is the total annual amount of synthetic fertiliser nitrogen applied to soils (urea-based and other fertilisers),

$EF_{1(UREA)}$ = proportion of direct N_2O emissions from nitrogen input to the soil for urea fertilisers (0.0048; table 5.5.2), and,

EF_1 = proportion of direct N_2O emissions from nitrogen input to the soil (0.01; table 5.5.2).

Data on synthetic fertiliser use is provided by the Fertiliser Association of New Zealand from sales records for 1990 to 2013. Data on the percentage of urea-derived synthetic fertiliser is sourced from the International Fertilizer Industry Association (IFA) online database. During this time there has been a six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser, from 59,265 tonnes in 1990 to 359,412 tonnes in 2013, and at the same time, the proportion of urea fertiliser applied has increased to over 80 per cent of all synthetic fertiliser (figure 5.5.1).

Figure 5.5.1 Percentage of synthetic fertiliser nitrogen derived from urea, 1990–2013



The increase in synthetic N fertiliser use since 1990 has resulted in an increase of direct N_2O emissions, from 217.7 kt CO_2-e in 1990 (0.6 per cent of agricultural emissions) to 934.6 kt CO_2-e in 2013 (2.4 per cent of agricultural emissions).

Organic nitrogen fertilisers (CRF 3.D.1.2)

Organic nitrogen applied as fertiliser in New Zealand is predominantly animal manure that is spread after storage in manure management systems. The IPCC (2006) guidelines recommend that non-manure components of organic N applied to agricultural soils, such as compost, sewerage sludge and rendering waste are included under organic fertilisers. New Zealand has commissioned a report on sources of organic waste, which include dairy processing wastewater, compost sold to the rural sector, blood and bone fertiliser, meat processing wastewater and sludge, grape marc from the wine industry, vegetable processing wastewater and sewage sludge applied to land (van der Weerden et al, 2014). The report found that these activities are not significant for New Zealand and account for ~0.024 per cent of the 2012 national total greenhouse gas emissions. No brewery waste is applied to soils in New Zealand, as spent yeast is used in the food industry to manufacture a yeast spread, and application of sewerage sludge to agricultural land is reported under the Waste sector.

The majority of animal manure in New Zealand is excreted directly onto pasture, but some manure is kept in manure management systems and is applied to soils as an organic fertiliser (table 5.3.2). Some manure is also collected but not stored; rather, it is spread onto pasture daily (eg, swine manure). 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 calculation excludes manure deposited directly by grazing livestock on pasture, range and paddock land, which is covered in the next section (urine and dung deposited by grazing animals (CRF 3.D.1.3)).

Animal manure is not used for feed, fuel or construction in New Zealand. 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 manure to soil. As recommended by IPCC (2006), the adjustment for NH_3 and NO_x emissions from volatilisation is no longer applied:

$$N_2O\ emissions = \frac{44}{28} \cdot (F_{AM} \cdot EF_1)$$

Where: F_{AM} is the total amount of animal manure nitrogen applied to soils from manure management systems (other than pasture, range and paddock), which is derived as a fraction of the nitrogen excretion rates, N_{ex}, described in section 5.3.2, and,

EF_1 is the proportion of direct N_2O emissions from nitrogen input to the soil (0.01; table 5.5.2).

The output of the Tier 2 livestock population characterisation and feed-intake estimate (section 5.1.3) and nitrogen excretion calculation (section 5.3.2) is used to calculate national manure N quantities per livestock category, which are allocated per manure management system as detailed in table 5.3.2. This ensures the same base values are used for the N_2O emission calculations throughout New Zealand's Inventory. Further details can be found in the Inventory methodology document (http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/).

Because the majority of livestock manure in New Zealand is excreted directly onto pasture, emissions from the organic N fertiliser subcategory are relatively small. However, emissions from this source have almost doubled since 1990 due to the increase in dairy population numbers. In 1990, manure fertiliser emissions were 78.5 kt CO_2-e (0.2 per cent of agricultural emissions) and in 2013 this had increased to 147.8 kt CO_2-e (0.4 per cent of agricultural emissions).

Urine and dung deposited by grazing animals (CRF 3.D.1.3)

The majority of livestock in New Zealand are grazed outdoors on pasture. This system is the predominant regime for managing animal manure, with 95 per cent of dairy cattle excreta and 100 per cent of non-dairy cattle, sheep, deer and other livestock manure allocated to it (table 5.3.2).

In line with good practice guidance (IPCC, 2006), the following equations are used to determine direct N_2O emissions from grazing livestock manure:

For sheep, cattle and deer urine only, and urine and dung for all other livestock categories:

$$N_2O\ emissions = \frac{44}{28}(N_2O - N) = \frac{44}{28}\left(\sum_T N_T \cdot Nex_T \cdot MS_T\right) \cdot EF_{3PRP}$$

For sheep, cattle and deer dung only:

$$N_2O\ emissions = \frac{44}{28}(N_2O - N) = \frac{44}{28}\left(\sum_T N_T \cdot Nex_T \cdot MS_T\right) \cdot EF_{3PRP-DUNG}$$

Where: N_T is the population of livestock category, T (population as calculated in section 5.1.3),

Nex_T is the annual average nitrogen excretion per head by each livestock category (kg N/head/year) (section 5.3),

MS_T is the proportion of manure excreted directly onto pasture, range and paddock by each livestock category (table 5.3.2), and

$EF_{3PR\&P}$ and $EF_{3PR\&P\text{-}DUNG}$ are the emission factors for manure from grazing animals in pasture, range and paddock (table 5.5.2).

New Zealand uses a country-specific emission factor for EF_{3PRP} of 0.01 (Carran et al, 1995; Muller et al, 1995; de Klein et al, 2003; Kelliher et al, 2003) for the urine of cattle, sheep and deer and the manure from all other livestock classes. For the dung of cattle, sheep and deer, a country-specific emission factor for $EF_{3PRP\text{-}DUNG}$ of 0.0025 has been implemented (table 5.5.2).

There has been, and continues to be, an extensive research programme aimed at establishing New Zealand-specific emission factors for EF_{3PRP}. Field studies have been performed as part of a collaborative research effort called NzOnet. The EF_{3PRP} parameter has been measured by NzOnet researchers in the Waikato (Hamilton), Manawatu (Palmerston North), Canterbury (Lincoln) and Otago (Invermay) regions for pastoral soils of different drainage classes (de Klein et al, 2003). These regional data are comparable because the same measurement methods were used at the four locations.

The percentage of applied nitrogen emitted as N_2O and relevant environmental variables were measured in four separate trials in autumn 2000, summer 2002, spring 2002 and winter 2003. Measurements were carried out for up to 250 days at each trial site or until urine-treated pasture measurements dropped back to background emission levels. Kelliher et al (2003, 2005), assessed all available EF_{3PRP} data and their distribution to pastoral soil drainage class, to determine an appropriately weighted (using proportions of land area by soil drainage class) national annual mean value. The complete EF_{3PRP} data set of NzOnet were synthesised using the national assessment of three pastoral soil drainage classes. These studies recognise that:

- environmental (climate) data are not used to estimate N_2O emissions using the methodology in the *revised* 1996 IPCC guidelines (IPCC, 1996)
- the N_2O emission rate can be strongly governed by soil water content
- soil water content depends on drainage that can moderate the effects of rainfall and drought
- drainage classes of pastoral soils, as a surrogate for soil water content, can be assessed nationally using a geographic information system.

An earlier analysis in New Zealand showed that the distribution of drainage classes for pasture land is highly skewed, with 74 per cent well drained, 17 per cent imperfectly drained and 9 per cent poorly drained (Sherlock et al, 2001).

The research and analysis to date has suggested that cattle and sheep excreta emissions could be separated into urine and dung components. As with the EF_{3PRP} parameter, considerable further research effort has gone into establishing a New Zealand-specific value for dung, $EF_{3PR\&P\text{-}DUNG}$. This included field studies ranging over eight years being performed in regions across New Zealand (Waikato, Southern Hawke's Bay, Manawatu, Canterbury and Otago) on free and poorly drained soils in the spring, summer, autumn and winter. These field studies used the methodologies developed during the research into the original New Zealand-specific parameter for $EF_{3PRP.}$ Luo et al (2009) assessed all available $EF_{3PR\&P\text{-}DUNG}$ data and their distribution to the pastoral soil drainage class, and carried out a further trial to confirm data during the spring, to determine an appropriately weighted national annual mean value. This review confirmed that a disaggregation of $EF_{3PR\&P\text{-}DUNG}$ between dung and urine is warranted and EF_3 decreases as follows: cattle urine > cattle dung > sheep dung. However, when seasonal data were pooled, there was no significant difference between cattle and sheep dung.

It was recommended that the N_2O emission factor for cattle and sheep urine remain at the country-specific value of 1 per cent and the N_2O emission factor for cattle and sheep dung be reduced to 0.25 per cent (Luo et al, 2009).

The output of the Tier 2 livestock population characterisation and feed-intake estimate (section 5.1.3) and nitrogen excretion calculation (section 5.3.2) is used to calculate national manure N quantities per livestock category, which are allocated per manure management system as detailed in table 5.3.2. This ensures the same base values are used for the N_2O emission calculations throughout New Zealand's Inventory. Further details can be found in the Inventory methodology document (http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/).

In 2013, N_2O emissions from manure from grazing livestock contributed 5,679.4 kt CO_2-e (67.2 per cent of emissions from agricultural soils, 14.5 per cent of total agricultural emissions). This is an increase of 423.8 kt CO_2-e (8.1 per cent) from the 1990 level of 5,255.5 kt CO_2-e. Emissions per livestock category are given in table 5.5.5. Direct N_2O emissions from *Urine and dung deposited by grazing animals* were identified as a key category (trend and level assessment).

Table 5.5.5 Trends and relative contribution of direct N_2O emissions from urine and dung deposited by grazing animals per livestock category between 1990 and 2013

	Emissions (kt CO_2-e)		Change from 1990		Share of Agricultural soils category		Share of total Agriculture sector	
Livestock category	1990	2013	%	Difference (kt CO_2-e)	1990 (%)	2013 (%)	1990 (%)	2013 (%)
Dairy cattle	1,274.0	2,741.0	115.1	1,467.0	18.5	32.4	3.7	7.0
Non-dairy cattle	1,028.6	969.3	–5.8	–59.3	15.0	11.5	3.0	2.5
Sheep	2,783.3	1,839.1	–33.9	–944.2	40.5	21.8	8.1	4.7
Deer	88.8	106.6	20.0	17.8	1.3	1.3	0.3	0.3
Minor livestock	80.8	23.4	–71.0	–57.4	1.2	0.3	0.2	0.1

Nitrous oxide from crop residue returned to soil (CRF 3.D.1.4)

This sub-category includes emissions from nitrogen added to soils by above- and below-ground crop residue (including residue left behind by crop burning), and the N added as a result of mineralisation of forages during pasture renewal. The latter is included for the first time in the 2015 submission, in line with IPCC (2006). This activity includes both nitrogen-fixing and non-nitrogen-fixing crop species. The direct emissions from agricultural residue burning are reported under section 5.7.

Thomas et al, 2008, recommend that New Zealand does not include an adjustment for crop residue removed for feed and bedding in this calculation until activity data are available.

Nitrogen from crop residue: The non-nitrogen-fixing crops grown in New Zealand are barley, wheat, oats, potatoes, maize seed, and other seed crops. For the 2012 submission onwards, New Zealand has reported emissions from additional cropping activity not previously estimated, such as onions, squash and sweetcorn (Thomas et al, 2011). The nitrogen-fixing crops grown in New Zealand include peas grown for both processing and seed markets, as well as lentil production and legume seeds grown for pasture production.

A country-specific methodology is used to calculate emissions from crop residue (Thomas et al, 2008):

$$N_2O_{FCR}\ emissions = \frac{44}{28}(N_2O - N)_{FCR} = \frac{44}{28}(AG_N + BG_N) \cdot EF_1$$

Where: AG_N and BG_N are the annual nitrogen residue returned to soils from above- and below-ground crop residue, and crop-specific values are given in table A3.1.3.

$$AG_N = AG_{DM} \cdot N_{AG}$$

$$BG_N = (AG_{DM} + Crop_T) \cdot R_{BG} \cdot N_{BG}$$

Where: AG_{DM} and BG_{DM} are the mass of the above- and below-ground residue dry matter,

$Crop_T$ is the crop yield, or mass removed during harvest,

N_{AG} and N_{BG} are the above- and below-ground crop-specific nitrogen concentration factors, and,

R_{BG} is the crop-specific root:shoot ratio of below-ground dry matter against the total above-ground crop biomass (crop gathered $Crop_T$ plus above-ground residue dry matter AG_{DM}), 0.1 (table A3.1.2.5).

The country-specific value of EF_1 of 0.01 is used (table 5.5.2).

$$AG_{DM} = \left(\frac{Crop_T}{HI}\right) - Crop_T \cdot Frac_{BURN} \cdot C_f$$

Where: HI is the crop-specific harvest index, or fraction of the crop that is harvested (table A3.1.3),

$Frac_{BURN}$ is the fraction of residue burned in the field (table 5.5.3), and,

C_f is the combustion factor; a value of 0.7 is recommended (Thomas et al, 2008).

The country-specific value for $Frac_{BURN}$ was derived from Statistics New Zealand data and farmer surveys (Thomas et al, 2011). The parameters used to estimate the N added by above- and below-ground crop residues were compiled from published and unpublished reports for New Zealand-grown crops (Cichota et al, 2010) and 'typical' values derived for use in the OVERSEER® nutrient budget model for New Zealand. The OVERSEER® model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems (http://www.overseer.org.nz/).

The tonnage produced per year of most non-nitrogen fixing crops in New Zealand is supplied by Statistics New Zealand from its Agricultural Production census and survey. Additional information on potatoes is provided by PotatoesNZ and updated information on seed crops is provided by AsureQuality, which certifies seeds in New Zealand (Thomas, 2010; S. Thomas, pers. comm. 2014). The tonnage of nitrogen-fixing crops is supplied by Statistics New Zealand from its Agricultural Production census and survey (lentils and legumes) and HortNZ (peas) (S. Thomas, pers. comm. 2014).

Nitrogen from pasture renewal: Of the four categories of perennial forage that the IPCC (2006) list for pasture renewal, only two categories are appropriate for New Zealand (Thomas et al, 2014): these are grass-clover pastures and lucerne, a nitrogen-fixing perennial forage. New Zealand has calculated emissions from pasture renewal per plant species type, T, separately:

$$F_{CR-Renew} = \sum_T \left[Crop_T \cdot Area_T \cdot Frac_{Renew(T)} \cdot \left[R_{AG(T)} \cdot N_{AG(T)} \cdot \left(1 - Frac_{Remove(T)}\right) + R_{BG(T)} \cdot N_{BG(T)} \right] \right]$$

Where: $Area_T$ is the total annual area harvested (ha/year). No burning is used for pasture renewal in New Zealand,

$Frac_{Renew(T)}$ is the fraction of the area under each crop that is renewed,

$R_{AG(T)}$ is the ratio of above-ground residue dry matter (DM) to harvested yield (kg N/kg DM),

$N_{AG(T)}$ is the N content of above-ground residue (kg N/kg DM),

$Frac_{Remove\ (T)}$ is the fraction of above-ground residue removed annually for feed, assumed zero for New Zealand,

$R_{AG(T)}$ is the ratio of below-ground residue DM to harvest yield (kg N/kg DM), and,

$N_{BG(T)}$ is the N content of below-ground residue (kg N/kg DM).

The areas for each perennial forage crop were obtained from the Statistics New Zealand Agricultural Production census and survey which include the area of grassland and annual crops (Thomas et al, 2014). The disaggregation of grass-clover systems was considered, but there is insufficient activity data for pastures of different compositions in New Zealand, as the proportion of clover varies widely in high N inputs systems, meaning disaggregated data on the N content are not presently available.

The contribution of crop residues and pasture renewal to overall agricultural emissions is small, with 175.5 kt CO_2-e (0.5 per cent of agricultural emissions) in 1990 and, in 2013, 251.3 kt CO_2-e (0.6 per cent of agricultural emissions).

Nitrogen mineralisation from loss of soil organic matter in mineral soils (CRF 3.D.1.5)

Most of New Zealand's reporting of emissions due to nitrogen mineralised during the loss of soil organic matter through land-use change or management is covered under the LULUCF sector, except for activities under the 'cropland remaining cropland' land-use category, which are reported under Agriculture (IPCC, 2006).

Total nitrous oxide emissions from this activity are determined as follows (IPCC, 2006):

$$N_2O_{FSOM} = \frac{44}{28}(F_{SOM} \cdot EF_1) \cdot 10^{-6}$$

Where: N_2O_{FSOM} is the nitrous oxide emitted as a result of N mineralisation from loss of soil organic matter in mineral soils (kt), and,

F_{SOM} is the N mineralisation from loss of soil organic matter in mineral soils through land management for cropland remaining cropland (kg).

The emission factor EF_1 is 0.01 (Kelliher and de Klein, 2006).

And:

$$F_{SOM} = \frac{\Delta C_{Mineral,CrC}}{R} \cdot 10^3$$

Where: $\Delta C_{Mineral,CrC}$ is the loss of soil carbon (C) in mineral soil during management of cropland (kt), and,

R is the C:N ratio, the IPCC (2006) default value of 10 is used.

Activity data on the soil carbon loss associated with cropland since 1990 was provided by calculations under the LULUCF sector.

Cultivation of organic soils (CRF 3.D.1.6)

The area of managed organic soils (histosols) in New Zealand includes the area of cultivated organic soil (as reported under the LULUCF sector) and the area of mineral agricultural soils with a peaty layer that is cultivated (Dresser et al, 2011). Mineral soils with a peaty layer are included in the definition of organic soils as it was determined that these soils will have similar emissions behaviour to that 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.

The total area of managed cultivated organic soils in New Zealand is 160,385 ha with 135,718 ha being organic soils and 24,667 ha mineral soils with a peaty layer. Dresser et al (2011) determined that the assumed 5 per cent of organic soils (plus mineral soils with a peaty layer) under agricultural pasture is cultivated on an annual basis (Kelliher et al, 2002) should be retained until further information has been gathered. This results in 8,019 hectares of 'organic agricultural soils' being cultivated annually.

Direct N_2O emissions from organic soils are calculated using the Tier 1 methodology for all years of the time series, by multiplying the area of cultivated organic soils by the default value of emission factor, EF_2, of 8 kg N_2O-N/kg N (IPCC, 2006). The annual contribution of organic soils (plus mineral soils with a peaty layer) to the overall agricultural emissions is relatively small and has remained at 30.0 kt CO_2-e (0.1 per cent of agricultural emissions) since 1990 to the present.

Indirect nitrous oxide emissions from managed soils (CRF 3.D.2)

In addition to direct N_2O emissions from managed soils, emissions of N_2O also occur through two indirect pathways: via volatilisation and via leaching and runoff.

Volatilisation (CRF 3.D.2.1)

Some of the nitrogen deposited or spread on agricultural land is emitted into the atmosphere as NH_3 and NO_x through volatilisation. A fraction of this volatilised nitrogen returns to the ground during rainfall and is then re-emitted as N_2O. The fraction of nitrogen that is deposited or spread on land that then indirectly becomes N_2O through this process is calculated using the fractions $Frac_{GASF}$ for synthetic fertiliser and $Frac_{GASM}$ for organic inputs from animal excreta. New Zealand uses country-specific values for $Frac_{GASF}$ and $Frac_{GASM}$.

In New Zealand, nitrogen added to agricultural soils from synthetic fertiliser (F_{SN}), organic N fertiliser from the spreading of managed manure (F_{ON}), and excreta from grazing livestock on pasture, range and paddock (F_{PRP}) contribute to N_2O emissions from volatilisation. The collection of activity data for F_{SN}, F_{ON} and F_{PRP} is described above under *Direct emissions (nitrous oxide) (CRF 3.D.1)*.

From the 2015 submission onwards, volatilisation from manure stored in manure management systems (prior to application to land) is reported under the *Manure management* category (section 5.3.2), as is recommended by the 2006 IPCC guidelines. New Zealand uses a Tier 1 methodology with the country-specific emission factors for $Frac_{GASF}$ and $Frac_{GASM}$ and a default value for EF_4 emission factor to calculate indirect emissions from nitrogen volatilisation:

$$N_2O_{ATD}\ emissions = \frac{44}{28}(N_2O_{ATD} - N) = \frac{44}{28}\left[(F_{SN} \cdot Frac_{GASF}) + \left((F_{ON} + F_{PRP}) \cdot Frac_{GASM}\right)\right] \cdot EF_4$$

Where: N_2O_{ATD}–N is the annual amount of N_2O-N produced by atmospheric deposition of volatilised n from agricultural soils (kg N_2O-N/year),

F_{SN}, F_{ON} and F_{PRP} are defined above (kg N/year),

$Frac_{GASF}$ is the fraction of N from synthetic fertiliser that volatilises as NH_3 and NO_x (table 5.5.3),

$Frac_{GASM}$ is the fraction of N from manure spreading and grazing manure that volatilises as NH_3 and NO_x (table 5.5.3), and,

EF_4 is the emission factor for N_2O emissions from atmospheric deposition of N on soils and water (kg N_2O-N/kg N)

Seventeen peer-reviewed papers covering 79 individual trials were 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, 2008). As this is almost identical to the IPCC default value of 0.1, this value of 0.1 has been adopted by New Zealand as a country-specific value for $Frac_{GASF}$.

A literature review of international and New Zealand-based scientific research showed that the recommended default value of 0.2 for $Frac_{GASM}$ (IPCC 2006) is too high for New Zealand conditions (Sherlock et al, 2008). In most European countries, ammonia emitted from pasture soils following grazing is just one of several sources contributing to their reported $Frac_{GASM}$ inventory values, whereas in New Zealand, 97 per cent of all livestock urine and dung is deposited directly on soils during grazing. Excluding studies on nitrification inhibitors, eight international papers covering 45 individual trials and nine New Zealand papers covering 19 individual trials were considered. On the basis of these, the authors recommended a value of 0.1 for $Frac_{GASM}$ was more appropriate for New Zealand conditions (Sherlock et al, 2008). This value has been adopted and is used for all years as it best reflects New Zealand's national agricultural circumstances.

In 2013, N_2O emissions from volatilisation made up 2.3 per cent (913.9 kt CO_2-e) of total agricultural emissions, an increase of 25.8 per cent from the 1990 value of 726.8 kt CO_2-e.

Leaching and runoff (CRF 3.D.2.2)

Nitrous oxide emissions from leaching and runoff originate from applied nitrogen from synthetic fertiliser (F_{SN}), organic N additions from the spreading of managed manure (F_{ON}), above- and below-ground crop residues (F_{CR}), N mineralisation associated with loss of soil organic matter from cropland land management (F_{SOM}), and excreta from grazing livestock on pasture, range and paddock (F_{PRP}) (IPCC, 2006). The collection of activity data for F_{SN}, F_{ON}, F_{CR}, F_{PRP} and F_{SOM} is described above under *Direct emissions (nitrous oxide) (CRF 3.D.1)*.

New Zealand has reported all emissions from leaching under the *Agricultural soils* category. As discussed under *Manure management*, New Zealand livestock are predominantly grazed outdoors (table 5.3.2) and leaching from anaerobic ponds handling dairy and swine effluent is unlikely to be significant. New Zealand uses a Tier 1 methodology with the country-specific default parameters which is in line with the IPCC (2006) guidelines to calculate indirect N_2O emissions from nitrogen leaching:

$$N_2O_L\ emissions = \frac{44}{28}(N_2O_L - N)$$
$$= \frac{44}{28} \cdot (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \cdot Frac_{LEACH-H} \cdot EF_5$$

Where: N_2O_L–N is the annual amount of N_2O-N from runoff and leaching from agricultural soils (kg N_2O-N/year),

F_{SN}, F_{ON}, F_{PRP}, F_{CR}, and F_{SOM} are defined above (kg N/year),

$Frac_{LEACH-H}$ is the fraction of N added to, or mineralised from, agricultural soils where leaching and runoff occur that is lost through leaching and runoff (table 5.5.3), and,

EF_5 is the emission IPCC 2006 default emission factor for N_2O emissions from leaching and runoff.

New Zealand uses a country-specific value for the fraction of nitrogen applied to agricultural land that is lost through leaching and runoff[30]. Scientific research and a literature review in New Zealand have shown lower rates of nitrogen leaching than are suggested in the 1996 and 2006 IPCC guidelines. 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 for different farm systems, IPCC-based estimates 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, nitrate leaching is determined by rainfall, soil type, and the amount of nitrogen entering the farm system, for example in nitrogen-based fertilisers and dung and urine applied as dairy farm effluent and directly excreted by grazing animals. The latter is calculated from the difference between nitrogen intake by grazing animals and nitrogen retained in animal products – milk, meat, velvet etc. This is 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 dairy and drystock (sheep and non-dairy cattle) farming systems (Thomas et al, 2005). 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) and is used for all years as it best reflects New Zealand's national agricultural circumstances.

In 2013, N_2O emissions from leaching and runoff made up 1.3 per cent (496.1 kt CO_2-e) of agricultural emissions, an increase of 27.0 per cent from the 1990 value of 390.8 kt CO_2-e.

Incorporation of nitrous oxide mitigation technologies into the Agriculture Inventory

Urease inhibitor (UI)

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

Urease inhibitor mitigation is included into New Zealand's Agriculture Inventory by adjusting the value of the existing country-specific N_2O parameter: $Frac_{GASF}$. In particular, Saggar et al (2013) considered the mitigating effect of a widely used UI,

[30] For reporting under the 1996 IPCC guidelines this parameter was defined as $Frac_{LEACH}$; under the 2006 IPCC guidelines, it is defined as $Frac_{LEACH-(H)}$.

nBTPT sold as 'Agrotain', as it is the most widely used product. Based on field and laboratory studies conducted in New Zealand and worldwide, Saggar et al (2013) showed that the presently recommended country-specific value of $Frac_{GASF}$ = 0.1 (Sherlock et al, 2008) can be reduced to 0.055 where urea coated with urease inhibitors is applied at a rate of 0.025% w/w, which is equivalent to a scaling factor for $Frac_{GASF}$ of 0.55.

Indirect nitrous oxide emissions from atmospheric deposition from all synthetic fertiliser, urea and other, with and without urease inhibitors applied to the urea component are calculated below:

$$N_2O_{ATD-FSN}\ emissions = \frac{44}{28}(N_2O_{ATD-FSN} - N) = \frac{44}{28}\sum_{S}[F_{SN} \cdot Frac_{GASF}] \cdot EF_4$$

Where: $N_2O_{ATD\text{-}FSN}$–N is the annual amount of N_2O-N produced by atmospheric deposition of volatilised N from all synthetic fertiliser applied to agricultural soils (kg N_2O-N/year),

S is urea fertiliser (untreated), urea fertiliser (treated) or non-urea N fertiliser F_{SN} F_{SN} is the total annual amount of synthetic fertiliser nitrogen applied (kg N/year) per fertiliser type, S,

$Frac_{GASF}$ is the fraction of N from synthetic fertiliser that volatilises as NH_3 and NO_x, 0.0045 for treated urea fertiliser and 0.1 for untreated urea and other N fertiliser, and,

EF_4 is the emission factor for N_2O emissions from atmospheric deposition of N on soils and water, 0.01.

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

Activity data on urease inhibitor usage are provided by Ballance AgriNutrients New Zealand from sales records for 2001 to 2013. Data are provided as tonnes of nitrogen contained in urea treated with urease inhibitors. Urea fertiliser coated with urease inhibitor was first used commercially in 2001 in New Zealand.

The N_2O emissions reported in the *Agricultural soils* category (direct soil emissions, synthetic nitrogen fertilisers) take into account the use of urease inhibitors. Estimates of mitigation from nitrous oxide emissions from volatilisation for the calendar years 2001 to 2013 are shown in table 5.5.6.

Table 5.5.6 Mitigation of Atmospheric Deposition Emissions for New Zealand's Urease Inhibitor

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Percentage of urea fertiliser applied including inhibitor (urea treated: total urea)	5.6	3.8	4.6	8.1	1.6	8.4	5.0	5.2	9.4	6.9	5.3	7.0	9.2
Mitigation (kt CO_2-e)	10.9	9.6	13.0	24.0	4.8	23.1	14.9	14.9	23.1	20.1	17.2	22.5	29.9

Nitrification inhibitor dicyandiamide (DCD)[31]

A methodology to incorporate the N_2O mitigation technology, the nitrification inhibitor dicyandiamide (DCD) into the Agriculture sector of the Inventory has been developed. A detailed description of the methodology can be found in Clough et al (2008). The N_2O emissions reported in the *Agricultural soils* category take into account the use of nitrification inhibitors on dairy farms using the methodology described in Clough et al (2008).

Dicyandiamide has been well researched and the research to date has shown that it reduces N_2O emissions and nitrate leaching in pastoral grassland systems grazed by ruminant animals. There have been over 28 peer-reviewed and published New Zealand studies on its use and effects.

The method to incorporate inhibitor mitigation of N_2O emissions into New Zealand's Agriculture Inventory is by an amendment to the existing IPCC methodology. Activity data on livestock numbers is drawn from Statistics New Zealand's Agricultural Production survey. This survey has recently included questions on the area that DCD was applied on grazed pastures.

The inhibitor is applied to pastures based on research that has identified good management practice to maximise N_2O emission reductions. This is at a rate of 10 kilograms per hectare, applied twice per year in autumn and early spring within seven days of the application of animal excreta. 'Good practice' application methods of DCD can be by slurry or DCD-coated granule.

Changes to the emission factors $EF_{3PR\&P}$ and parameter $Frac_{LEACH}$ were established through research (table 5.5.4). These emission factors and parameters were modified based on comprehensive field-based research that showed significant reductions in direct and indirect N_2O emissions and nitrate leaching where the DCD was applied. The peer-reviewed literature on inhibitor use in grazed pasture systems was reviewed and it was determined that, on a national basis, reductions in $EF_{3PR\&P}$ and $Frac_{LEACH}$ of, 67 per cent and 53 per cent could be made respectively (Clough et al, 2008). There has been some research into the effect of the inhibitor on $EF_{3(PR\&P\ DUNG)}$, however, these data are limited and further work needs to be carried out 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 the inhibitor to calculate DCD weighting factors.

$$DCD\ weighting\ factor = \left(1 - \frac{\%\ reduction\ in\ EF_x}{100} \cdot \frac{DCD\ area\ treated}{Total\ area\ of\ dairy}\right)$$

The appropriate weighting factor is then used as an additional multiplier in the current methodology for calculating indirect and direct emissions of N_2O from grazed pastures. The calculations use a modified $EF_{3(PR\&P)}$ of 0.0099 and $Frac_{LEACH}$ of 0.0696 for dairy grazing area in the months that the inhibitor is applied (May to September). The modified emission factors (table 5.5.7) are based on information from the Agricultural Production census that 2.9 per cent of the effective dairying area in New Zealand received inhibitor in 2012.

Mitigation estimates for calendar years 2007 to 2012 are shown in table 5.5.7. Application of this inhibitor was found to have no effect on ammonia volatilisation during May to September when it is applied. This is supported by the results of field studies (Clough et al, 2008; Sherlock et al, 2008).

[31] After 2012, there was a voluntary suspension of DCD sales in New Zealand, so no mitigation estimates are reported for 2013.

Table 5.5.7 Emission factors, parameters and mitigation for New Zealand's DCD inhibitor calculations

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

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

All other emission factors and parameters relating to animal excreta and fertiliser use ($Frac_{GASM}$, $Frac_{GASF}$, EF_4 and EF_5) remain unchanged when inhibitor is used as an N_2O mitigation technology.

5.5.3 Uncertainties and time-series consistency

To ensure consistency in the calculations involving animal manure, a single livestock population characterisation and feed-intake estimate is produced by the Tier 2 model for the major livestock categories, and is used in different parts of the calculations for the Inventory 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 grazing manure subcategory.

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 5.5.8). The distribution of the emission factors is skewed, reflecting pastoral soil drainage classes whereby 74 per cent of soils are classified as well-drained soils, 17 per cent are imperfectly drained soils and 9 per cent are classified as poorly drained soils. For the 2012 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the 2002 Monte Carlo simulation as a percentage of the mean value (ie in 2002, the uncertainty in annual emissions was +74 per cent and –42 per cent).

Table 5.5.8 New Zealand's uncertainties in nitrous oxide emissions from agricultural soils for 1990, 2002 and 2012 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2012)

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

The overall Inventory uncertainty analysis shown in annex 7 demonstrates that the uncertainty in annual emissions from agricultural soils is a major contributor to uncertainty in the total estimate and to the uncertainty in the trend from 1990. The uncertainty between years was assumed to be correlated. Therefore, the uncertainty is mostly in the emission factors and the uncertainty in the trend is much lower than the uncertainty for an annual estimate.

The Monte Carlo numerical assessment is also used to determine the effects of variability in the nine most influential parameters on uncertainty of the calculated N_2O emissions in 1990 and 2002. These parameters are shown in table 5.5.9, together with their percentage contributions to the uncertainty. There was no recalculation of the influence of parameters for the 2012 data. The Monte Carlo analysis confirmed that uncertainty in parameter

$EF_{3(PR\&P)}$ has the most influence on total uncertainty, accounting for 91 per cent of the uncertainty in total N_2O emissions in 1990. This broad uncertainty reflects natural variance in EF_3 due to weather, climate and soil type (by drainage classification); however there have been no trials or uncertainty analysis on the effects of weather.

Table 5.5.9 Proportion contribution of the nine most influential parameters on the uncertainty of New Zealand's total nitrous oxide emissions for 1990 and 2002

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

Source: Kelliher et al, (2003, Table 16).

5.5.4 Source-specific QA/QC and verification

In preparation for the 2015 Inventory submission, the data for the direct soil, manure from grazing livestock, and indirect emissions categories underwent Tier 1 and Tier 2 quality checks.

In 2008 and 2011, the Ministry for Primary Industries commissioned a report investigating N_2O emission factors and activity data for crops (Thomas et al, 2008; Thomas et al, 2011). Statistics New Zealand's Agricultural Production survey activity data for wheat and maize was verified with the Foundation for Arable Research production database between 1995 and 2007. Data for wheat and maize between the two data sources was very similar.

Fertiliser sales data (year-end May 2013) received from the Fertiliser Association of New Zealand were verified with data collected from the Agricultural Production survey for year-end June 2011. The Agricultural Production survey data for fertiliser use in New Zealand was 91,000 tonnes lower (approximately 25 per cent). The Fertiliser Association of New Zealand data are 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 is more likely to be accurate than a survey of some 35,000 individual farmers. There are a large number of differently named nitrogen fertilisers and the Agricultural Production survey respondents often have difficulty filling in the fertiliser question in the annual questionnaire. Some farmers use contract fertiliser spreading companies (including aerial spreading), and may not have an accurate estimate of the tonnes of fertiliser applied. The Agricultural production census and survey data verified the long-term trend of the increasing use of synthetic fertiliser derived from urea.

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 5.5.10 compares the New Zealand-specific values for EF_1, and EF_3 with the 2006 IPCC default value and emission factors used by Australia. For EF_1 the New Zealand value is the same as the IPCC default value. For EF_3 the value for cattle, poultry and pigs is lower, the New Zealand value for cattle being based on country-specific research (Luo et al, 2009).

Table 5.5.10 Comparison of IPCC default emission factors and country-specific implied emission factors (IEFs) for EF_1 and $EF_{3PR\&P}$

	EF_1 (kg N_2O-N/kg N)	EF_3 (kg N_2O-N/kg N excreted)
IPCC (2006) developed temperate climate/Oceania default value	0.01	0.02 (cattle, poultry and pigs) 0.01 (sheep and other animals)
Australian-specific IEF 2011 value	0.0058	0.004
New Zealand-specific 2012 value	0.01	0.01

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

Table 5.5.11 compares the New Zealand-specific values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH\text{-}H}$ with the 2006 IPCC default and fractions used by Australia. New Zealand has taken a country-specific value for $Frac_{GASF}$ of 0.1, and it is the same as the IPCC default and that of Australia. Research showed that the 0.1 value was appropriate to New Zealand conditions (Sherlock et al, 2008).

However, research showed that the default value of 0.2 for $Frac_{GASM}$ was too high and, therefore, New Zealand has adopted a lesser value of 0.1. The reduction is due to the proportion of the different sources that make up this value. In New Zealand, 97 per cent of animal excreta is deposited onto pasture and only 3 per cent is managed. Whereas the 1996 IPCC default value was calculated taking into account a much higher percentage of manure management and storage. Manure management and storage results in a much higher proportion of nitrogen being volatilised and, hence, the higher $Frac_{GASM}$ for the default value compared with the country-specific New Zealand value. The value of 0.1 adopted for the emission factor $Frac_{GASM}$ after an extensive review of scientific literature (Sherlock et al, 2008) was also confirmed by subsequent field experiments (Laubach et al, 2012).

New Zealand also has a much lower value of $Frac_{LEACH\text{-}H}$. Research showed that New Zealand applies a much lower rate of nitrogen fertiliser than what was assumed when developing the IPCC default value (Thomas et al, 2003; 2005). 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 5.5.11 Comparison of IPCC default emission factors and country-specific implied emission factors (IEFs) for $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH\ (H)}$

	$Frac_{GASF}$ (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)	$Frac_{LEACH\text{-}(H)}$ (kg N/kg fertiliser or manure N)
IPCC (2006) developed temperate climate/Oceania default value	0.1	0.2	0.3
Australian-specific IEF 2011 value	0.1	0.0	0.3
New Zealand-specific 2012 value	0.1	0.1	0.07

Source: UNFCCC (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/ items/7383.php Downloaded 14 January 2015).

A study was commissioned to investigate the possibility of developing a country-specific emission factor for EF_5 (components EF_{5r}, EF_{5g} and EF_{5e}) including a review of international and New Zealand literature. An examination of EF_{5r} in this report supports the use of the 2006 IPCC default value for EF_5 of 0.0075 as suitable for New Zealand.

However, the authors concluded that there is presently not enough evidence to recommend a country-specific value (Clough and Kelliher, 2014).

5.5.5 Source-specific recalculations

All activity data were updated with the latest available data: Statistics New Zealand table builder and Infoshare database (2013) and Livestock Improvement Corporation statistics (2013). Updated data on crops were provided by Plant and Food Research Ltd.

Enhancements, described in sections 5.2.5 and 5.3.5, to New Zealand's Tier 2 Inventory model have resulted in recalculations of nitrogen inputs from excreta by dairy cattle, non-dairy cattle, sheep and deer.

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

5.5.6 Source-specific planned improvements

New Zealand scientists are continuing to research N_2O emission factors for New Zealand's pastoral soils. New Zealand is also continuing research to refine the methodology used to estimate N_2O emission reductions using nitrification inhibitors.

Tier 2 Inventory model

Enhancements to the New Zealand Tier 2 Inventory model that will improve usability and speed of calculations are currently in progress. These enhancements will also permit the use of regional inhibitor data as activity data allows, as well as the use of regional emission factors as they are developed. The use of regional activity data and emission factors will improve the accuracy of emissions estimations.

N_2O emissions on hill country (EF_3) implementation

New Zealand has completed research and published papers on the effects of medium hill slope on nitrous oxide emissions, which confirmed that emissions of N_2O from excreta applied to sloping hill pastoral land are significantly less than those from excreta deposited on flat pastoral land. In New Zealand, sheep, non-dairy (beef) cattle and deer are generally grazed on hill country with sloping pastures. Dairy cattle are grazed on flat to low sloping pasture. A project was completed to determine a sufficiently robust method to use spatial data to determine the distribution of sheep, non-dairy cattle and deer excreta by hill slope (Giltrap and Saggar, 2014) and this recalculation is expected to be included in the 2016 submission.

Additionally, new research and a field-based methodology has commenced to determine nitrous oxide emissions from dung and urine from New Zealand non-dairy cattle, sheep (and deer, if possible) on steeply sloping (more than 25 degrees) pastoral land under

New Zealand environmental conditions. The trials will be conducted over the next three-to-four years.

N_2O emissions on steep hill country (EF_3) field trials

Field trials are being conducted on N_2O emissions from nitrogen fertiliser and effluent applied to soils on steeply sloping land, and combinations on these nitrogen treatments to derive acceptable emissions factors and methodologies specific for New Zealand conditions.

N_2O emissions (EF_1 and EF_3) field trials

Two projects aim to improve New Zealand's understanding of regional nitrous oxide emissions from animal excreta manually spread or deposited by livestock on pastoral land (emission factors, EF_1 and EF_3) for cattle and sheep (and deer, if possible) for different soil types. The trials will be conducted over the next three-to-four years.

N_2O uncertainty analysis

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

2006 IPCC guidelines

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

5.6 Prescribed burning of savanna (CRF 3.E)

5.6.1 Description

Prescribed burning of savanna is reported under the LULUCF sector from the 2015 submission onwards.

5.7 Field burning of agricultural residues (CRF 3.F)

5.7.1 Description

Burning of agricultural residues produced 33.8 kt CO_2-e in 2013. This was an increase of 6.4 kt CO_2-e (23.3 per cent) above the level of 27.4 kt CO_2-e in 1990. Burning of agricultural residues was not identified as a key category in 2015.

New Zealand reports emissions from burning barley, wheat and oats residue in this category. Maize, legume 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. 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 (Thomas et al, 2011).

5.7.2 Methodological issues

The emissions from burning agricultural residues are estimated using country-specific methodology and emission factors (Thomas et al, 2011). The methodology is aligned with the 1996 IPCC methodology but utilises country-specific parameters. 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, where:

$$N_2O_{BURN} = \frac{44}{28} AG_{BURN} \cdot Frac_{OXIDISED} \cdot Frac_{N-BIOMASS} \cdot EF_1$$

Where: AG_{BURN} is the biomass burned,

$Frac_{OXIDISED}$ is the fraction of burnt biomass that is oxidised, and,

$Frac_{N\text{-}BIOMASS}$ is the N fraction in the biomass burned.

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, the fraction oxidised and the carbon and nitrogen fractions of the residue. The country-specific values for these parameters are those from the OVERSEER® nutrient budget model for New Zealand (Wheeler et al, 2003) and are the same as those used for estimates of emissions from crop residues (section 5.5.2). 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 then calculated using the carbon and nitrogen released and an emissions ratio. Further detail is provided in Thomas et al (2011).

Statistics New Zealand did not collect statistics on crop residue burning prior to 2005. Therefore, there was no annual data series for crop residue previously and other methods for obtaining these data were used. The recommended proportion of crop area burned for 1990 to 2004 was determined by a farmer survey and is 70 per cent of wheat, 50 per cent of barley and 50 per cent of oat crops (Thomas et al, 2011). These values are in alignment with Statistics New Zealand data for 2005–2007 (2005 being the first year Statistics New Zealand gathered these data) and are, therefore, 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 (ie, $Frac_{REMOVE}$ is assumed to be zero; Thomas et al, 2011). This is consistent with the reporting in section 5.5.2. 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.

From 2005, data on the total area of crop residues burned in New Zealand were 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.

All parameters used in the calculation of emissions from agricultural residue burning for all years are detailed in table 5.7.1 and emission ratios in table 5.7.2.

Table 5.7.1 Values used to calculate New Zealand emissions from burning of agricultural residues

	Barley	Wheat	Oats
Fraction of residue actually burnt	0.7	0.7	0.7
Fraction oxidised	0.9	0.9	0.9
Fraction of nitrogen in biomass	0.005	0.005	0.005
Fraction of carbon in biomass	0.4567	0.4853	0.4567
Dry-matter fraction	0.86	0.86	0.86
Harvest index	0.46	0.41	0.30
Wheat residue remaining in field	1	1	1

Source: Thomas et al, 2011.

Table 5.7.2 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

5.7.3 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 is taken from farmer surveys in the Canterbury area, where 80 per cent of cereal production occurs, and, between 2005 and 2009, an average of 86 per cent of residue burning occurred. Estimates of crop burning for 2010 are 49 per cent and have ranged from a high in 2006 of 61 per cent to a low in 2009 of 40 per cent, reflecting variations in annual weather patterns.

The country-specific values for these parameters are those from the OVERSEER® nutrient budget model for New Zealand (Wheeler et al, 2003) and are the same as those used for estimates of emissions from crop residues. This provides consistency between the two emissions estimates for crop residue and crop burning.

IPCC good practice guidance suggests that an estimate of 10 per cent of residue burned may be appropriate for developed countries but also notes that the IPCC default values: "are very speculative and should be used with caution. The actual percentage burned varies substantially by country and crop type. This is an area where locally developed, country-specific data are highly desirable" (IPCC, 2000).

5.7.4 Source-specific QA/QC and verification

Plant and Food Research reviewed the implementation of the methodology to estimate emissions of N_2O from Crop residues, Nitrogen-fixing crops, and Field burning of agricultural residues, and this analysis is detailed in Thomas et al, (2008) and Thomas et al (2011).

5.7.5 Source-specific recalculations

There were no recalculations for this source in 2013.

5.7.6 Source-specific planned improvements

No improvements are currently planned.

5.8 Liming (CRF 3.G)

5.8.1 Description

In New Zealand, lime and dolomite fertilisers are mainly applied to acidic grassland and cropland soils to reduce soil acidity and to maintain or increase production of pasture and crops. Prior to the 2015 submission, emissions from lime and dolomite fertilisers were reported under the LULUCF chapter.

Emissions from the application of lime produced 540.1 kt CO_2 in 2013. This was an increase of 6.4 kt CO_2-e (50.0 per cent) above the level of 360.1 kt CO_2 in 1990. *Liming* was identified as a key category for the Agriculture sector in 2015 (level and trend).

5.8.2 Methodological issues

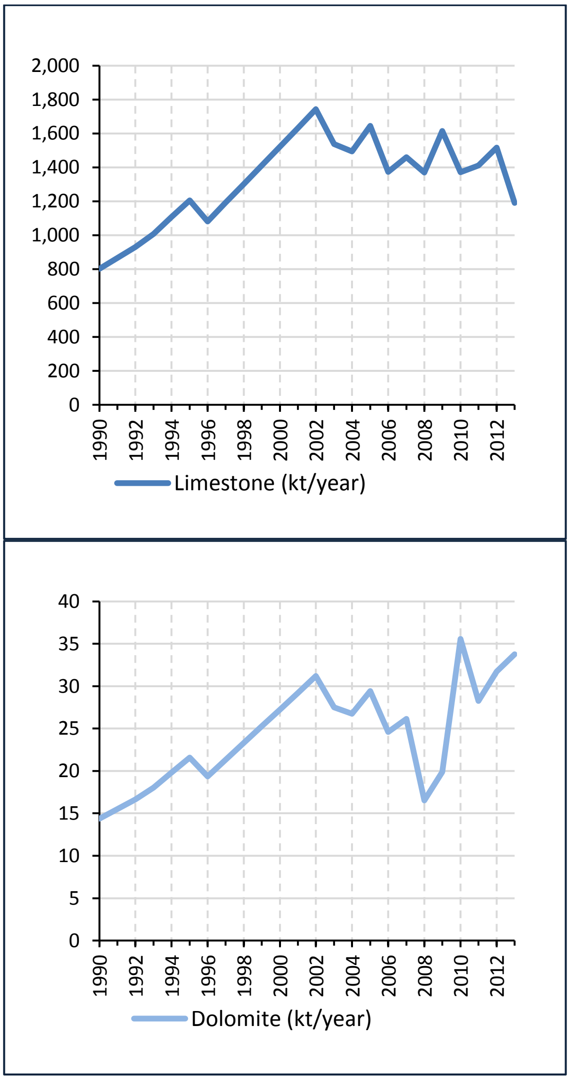
Information on agricultural lime (limestone and dolomite) application is collected by Statistics New Zealand, as a part of its five-yearly Agricultural Production census and inter-annual survey. Analysis of the data indicates that, each year around 94 per cent of agricultural lime used in New Zealand is applied to grassland, with the remaining 6 per cent applied to cropland (N Searles, pers comm, 2014).

Emissions associated with liming are estimated using a Tier 1 method (equation 11.12; IPCC, 2006), using the default emission factors for carbon conversion of 0.12 and 0.13 for limestone and dolomite respectively.

5.8.3 Activity data

Limestone application is more common than dolomite application in New Zealand because limestone occurs widely in New Zealand but dolomite is only available from a smaller, localised area (figure 5.8.1). Activity data from the Statistics New Zealand Agricultural Production census and survey show that limestone and dolomite use increased during the 1990s. Limestone use declined since 2002, whereas dolomite use has increased in recent years. The quantity of lime applied each year varies depending on a number of factors, including farm profitability.

Figure 5.8.1 Limestone and dolomite use on agricultural land in New Zealand since 1990



5.8.4 Uncertainties and time-series consistency

Using the IPCC (2006) Tier 1 methodology, the default emission factors are used which assume conservatively that all carbon in the lime is emitted as CO_2 to the atmosphere. The default emission factors are assumed certain, given this assumption.

The Agricultural Production census and survey data have gaps in the time-series: no data are available for 1991 or between 1997 and 2001. In the absence of other supporting data, linear interpolation has been used to estimate the data for these years.

5.8.5 Source-specific QA/QC and verification

In the preparation of this Inventory, the data for liming underwent Tier 1 quality checks. Statistics New Zealand, the agency which collects the activity data for liming, also carries out a series of quality-assurance and quality-control procedures as part of the data collection carried out each year.

5.8.6 Source-specific recalculations

Emissions from liming in 2012 have been updated as a result of the activity data from the Agricultural Production survey being finalised in June 2013.

5.8.7 Source-specific planned improvements

New Zealand will continue to update activity on liming as the data become available from Statistics New Zealand. No other future improvements are currently planned.

5.9 Urea application (CRF 3.H)

5.9.1 Description

Urea fertiliser accounts for the majority of synthetic nitrogen fertiliser used in New Zealand and is mainly applied to dairy pasture land to boost pasture growth during autumn and spring months.

Carbon dioxide emissions from the application of urea produced 490.0 kt CO_2 in 2013. This was an increase of approximately eleven-fold above the level of 39.2 kt CO_2 in 1990.

5.9.2 Methodological issues

Emissions associated with the application of urea are estimated using a Tier 1 methodology (equation 11.13; IPCC, 2006), using the default emission factors for carbon conversion of 0.20.

Urease inhibitors are effective in slowing down the activity of the urease enzyme that hydrolyses urea to ammonium (as reported in section 5.5.2), but these inhibitors do not reduce the release of carbon dioxide (Saggar, pers comm, 2014).

5.9.3 Activity data

Data on nitrogen fertiliser use is provided by the Fertiliser Association of New Zealand from sales records for 1990 to 2013. Data on the percentage of synthetic fertiliser derived from urea is sourced from the International Fertilizer Industry Association (IFA) online database and is used to calculate the amount of applied urea fertiliser. During this time there has been a twelve-fold increase in elemental nitrogen applied to agricultural land from urea fertiliser, from 24,586 tonnes in 1990 to 307,373 tonnes in 2013. However, the total amount of synthetic fertiliser has increased only six-fold during this time (see reporting on *Agricultural soils* category) as the proportion of urea fertiliser applied has increased since 1990 to over 80 per cent of all synthetic fertiliser (figure 5.5.1).

5.9.4 Uncertainties and time-series consistency

Under the IPCC (2006) Tier 1 methodology, the default emission factors are used, which assume conservatively that all carbon in the urea is emitted as CO_2 into the atmosphere. The default emission factors are assumed certain, given this assumption.

Sales data for synthetic fertiliser N have been supplied for all years by the Fertiliser Association of New Zealand but the uncertainties in the data are not known.

5.9.5 Source-specific QA/QC and verification

In the preparation of this Inventory, the data for urea fertiliser underwent Tier 1 quality checks. The Fertiliser Association of New Zealand, the organisation that collects the sales activity data for synthetic fertiliser, also carries out a series of quality-assurance and quality-control procedures as a part of the data collection carried out each year.

5.9.6 Source-specific recalculations

The 2015 submission is the first year that CO_2 emissions from urea have been reported under the requirement from the IPCC (2006) guidelines, and no recalculations have been performed.

5.9.7 Source-specific planned improvements

New Zealand will continue to update activity on urea as the data become available from the Fertiliser Association of New Zealand and the International Fertilizer Industry Association. A review of synthetic fertiliser data availability and uncertainty in New Zealand is planned in future.

5.10 Other carbon-containing fertilisers (CRF 3.I)

5.10.1 Description

The IPCC (2006) guidelines do not provide guidance for reporting on other carbon-containing fertilisers. Other carbon-containing synthetic fertilisers besides limestone, dolomite and urea (sections 5.8 and 5.9) are not applied to agricultural land in New Zealand (van der Weerden and de Klein, pers. comm., 2015).

Manure application to agricultural land will slowly mineralise, producing a small amount of CO_2 as a by-product, but these losses are unlikely to be significant for New Zealand (van der Weerden and de Klein, pers. comm., 2015). This category is therefore reported as not estimated (NE).

Chapter 5: References

Some references may be downloaded directly from the following webpage: http://mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/agriculture-greenhouse-gas-inventory-reports/

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Chapter 6: Land Use, Land-Use Change and Forestry (LULUCF)

6.1 Sector overview

Emissions summary

2013

In 2013, net emissions by the Land Use, Land-Use Change and Forestry (LULUCF) sector were –26,761.1 kilotonnes of carbon dioxide equivalents (kt CO_2-e). This comprises net removals of –26,962.5 kt carbon dioxide (CO_2), emissions of 71.8 kt CO_2-e of methane (CH_4) and 129.6 kt CO_2-e of nitrous oxide (N_2O). The greatest contribution to removals was from the *Land converted to forest land* subcategory. The largest source of emissions was from the *Land converted to grassland* subcategory.

1990–2013

Net emissions in 2013 have increased by 1,893.3 kt CO_2-e (6.6 per cent) from the 1990 level of –28,654.4 kt CO_2-e (table 6.1.1 and figure 6.1.1). This is largely due to increased harvesting of plantation forests as a larger proportion of the estate reaches harvest age. Increased emissions in the *Grassland* land-use category are primarily due to the conversion of plantation forests to grassland that has occurred since 2003. The biomass emissions from land-use change are reported in the 'land converted to' category from the year of the event; changes in the mineral soil carbon stock are estimated as occurring over a 20-year period.

Table 6.1.1 New Zealand's greenhouse gas emissions for the LULUCF sector by land-use category in 1990 and 2013

	Emissions (kt CO_2-e)		Difference	% Change
Land-use category	**1990**	**2013**	**1990–2013**	**1990–2013**
Forest land	–30,226.1	–33,705.1	–3,479.0	11.5
Cropland	479.1	443.6	–35.5	–7.4
Grassland	1,104.3	6,469.5	5,365.2	485.8
Wetlands	–21.8	4.7	26.6	–121.7
Settlements	2.3	–4.6	–6.9	–300.4
Other land	7.7	30. 8	23.1	298.5
Total LULUCF	**–28,654.4**	**–26,761.1**	**1,893.3**	**–6.6**

Note: Net removals are expressed as a negative value in the table to help the reader in clarifying that the value is a removal and not an emission. Emissions for the harvested wood products pool are included under forest land. Columns may not total due to rounding.

Emissions in the LULUCF sector are primarily caused by harvesting production forests, deforestation and the decomposition of organic material following these activities. However, removals are primarily because of the sequestration of carbon dioxide from plant growth and increases in the size of the harvested wood products pool. 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).

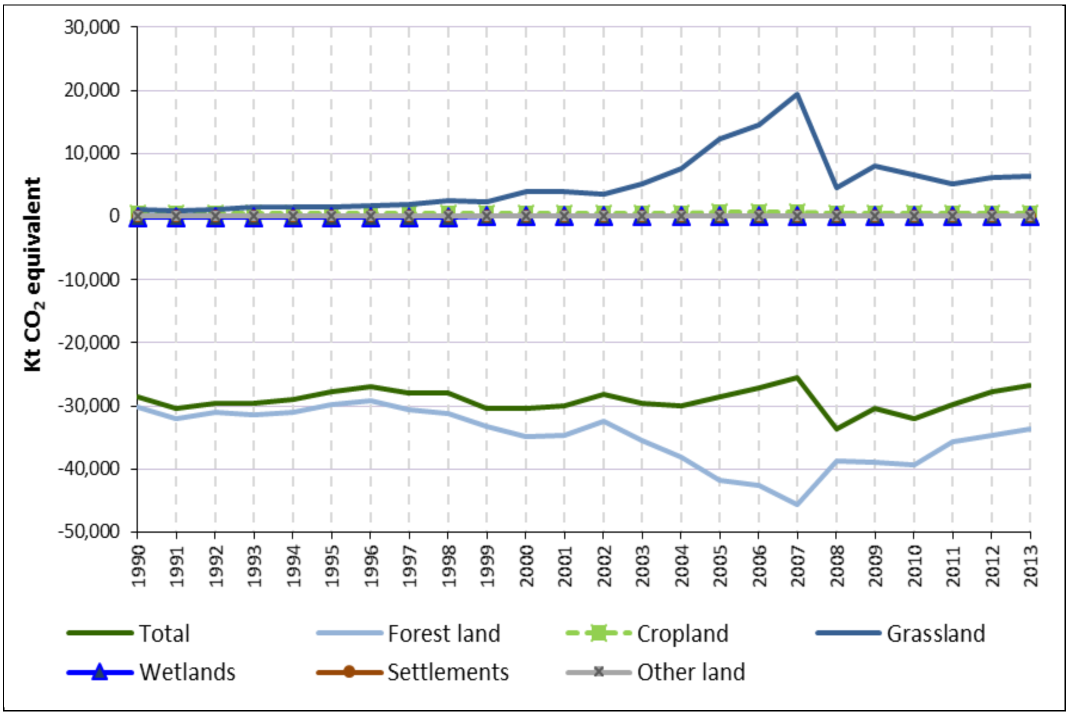
2012–2013

Between 2012 and 2013, net emissions from the LULUCF sector increased by 1,087.7 kt CO_2-e (3.9 per cent). The main contributor to the change occurred within the *Forest land* category as a greater proportion of forest reached harvest age in 2013 compared with 2012 due to the age structure of New Zealand's production forests. Emissions have also increased for *Land converted to grassland* due to the area of *Forest land* being converted to *Grassland* being larger in 2013 than in 2012.

New Zealand has adopted the six broad categories of land use as described in the *IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use* (IPCC, 2006a), hereafter referred to as GPG-AFOLU.

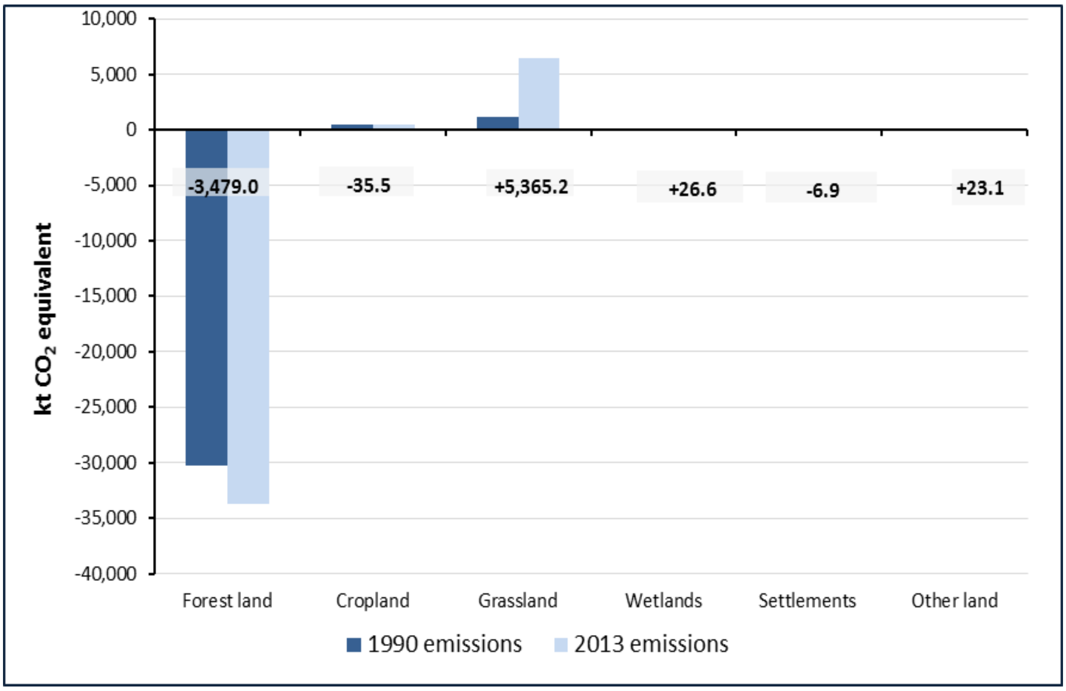
The land-use categories *Forest land remaining forest land*, *Land converted to forest land*, *Grassland remaining grassland*, *Harvested wood products*, *Land converted to grassland* and *Cropland remaining cropland* are key categories for New Zealand in 2013.

Figure 6.1.1 New Zealand's annual emissions from the LULUCF sector from 1990 to 2013



Note: Emissions for the harvested wood products pool are reported under forest land.

Figure 6.1.2 Change in New Zealand's emissions from the LULUCF sector from 1990 to 2013



Note: Emissions for the harvested wood products pool are reported under forest land.

Recalculations since 2014 submission

Since the 2014 submission, there have been major recalculations in LULUCF sector emissions. There have been changes to both the global warming potentials used in calculating LULUCF sector emissions, as well as changes in the sources reported for the LULUCF sector. These changes mean comparisons with the values submitted in 2014 are not meaningful. The largest real changes to LULUCF sector estimates have been in the estimate of carbon stock change for natural forests, and the inclusion for the first time of the harvested wood products pool. Further details on these recalculations are provided in section 6.4.2, section 6.10 and chapter 10.

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

New Zealand has a land area of approximately 270,000 square kilometres with extensive coastlines (11,500 kilometres). New Zealand has a temperate climate, which is highly influenced by the surrounding ocean. Sixty per cent of the land is hilly or mountainous, with many lakes and fast-flowing rivers and streams.

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

Before human settlement, natural forests were New Zealand's predominant land cover, estimated at 85 per cent of total land area (McGlone, 2009). Today, natural forest covers around 29 per cent of the total land area of New Zealand (see table 6.1.2). Nearly all lowland areas have been cleared of indigenous vegetation for agriculture, horticulture, plantation forestry and urban development. Much of the remaining indigenous vegetation, however, is now legally protected, whether in private ownership or within the conservation estate.

Forestry and agriculture are core to the New Zealand economy and are the main determinants of its LULUCF emissions profile. Intensive forest management combined with a temperate climate, fertile soils and high rainfall mean New Zealand has one of the highest rates of exotic forest growth among Annex 1 countries.

New Zealand's exotic forest plantation estate is intensively managed for production forestry, with rapid growing genotypes selected and enhanced for optimum growth. In 2013, plantation forests covered approximately 2.1 million hectares – around 7.8 per cent of New Zealand's total land area. This also includes areas not managed for timber supply; for instance, areas planted for erosion control.

Table 6.1.2 Land use in New Zealand in 2013

Land-use category	Subcategory	Area (hectares)	Proportion of total area (%)
Forest land	Natural forest	7,834,943	29.1
	Pre-1990 planted forest	1,437,525	5.3
	Post-1989 forest	659,332	2.4
	Subtotal	*9,931,801*	*36.9*
Cropland	Annual	371,791	1.4
	Perennial	104,534	0.4
	Subtotal	*476,325*	*1.8*
Grassland	High producing	5,808,111	21.6
	Low producing	7,544,632	28.0
	With woody biomass	1,363,634	5.1
	Subtotal	*14,716,377*	*54.7*
Wetlands		680,922	2.5
Settlements		224,733	0.8
Other land		895,010	3.3
Total		**26,925,168**	**100.0**

Note: Areas as at 31 December 2013. Columns may not total due to rounding.

6.1.2 Methodological issues for the LULUCF sector

New Zealand uses a combination of Tier 1 and Tier 2 methodologies for estimating and reporting emissions for the LULUCF sector (tables 6.1.3 and 6.1.4). A Tier 1 approach has been used to estimate carbon stock change in the four biomass pools for all land-use categories except for *Forest land*, perennial cropland and grassland with woody biomass, which use Tier 2 approaches.

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

Different methods are used to obtain emission factors when estimating emissions and removals for post-1989 natural forest and post-1989 forest planted for timber production. This ensures the different growth characteristics are reflected in the estimates. These divisions are combined into a single subcategory of post-1989 forest when reporting emissions in the common reporting format (CRF) tables.

To distinguish differences in the methodologies used for post-1989 and pre-1990 forests, the prefix pre-1990 is used within the national inventory report (NIR) to describe areas where forest existed at 1990.

Grassland with woody biomass consists of grassland areas where the cover of woody species is less than 30 per cent and/or does not meet, nor have the potential to meet, the New Zealand forest definition. Grassland with woody biomass is therefore a diverse category. To account for these differences, grassland with woody biomass is split into 'permanent' and 'transitional' subcategories for modelling of land-use change. Separate emission factors for each type of grassland with woody biomass are derived from the Land Use and Carbon Analysis System (LUCAS) plot network (Wakelin and

Beets, 2013). Within the CRF tables, grassland with woody biomass is reported at the aggregate level.

Emission factors

The emission factors required to estimate carbon stock changes using the Tier 1 and Tier 2 equations are provided in tables 6.1.3 and 6.1.4. Table 6.1.3 contains biomass carbon stocks in each land-use subcategory prior to conversion and table 6.1.4 contains the annual growth in biomass carbon stock after land-use change.

Table 6.1.3 New Zealand's biomass carbon stock emission factors in land use before conversion

Land-use category	Land-use subcategory	2015 submission emission factors (t C ha^{-1})	Carbon pools	Reference
Forest land	Pre-1990 natural forest: shrub	84.88*	All biomass pools	LUCAS plot-based estimate
	Pre-1990 natural forest: tall forest	253.14*	All biomass pools	LUCAS plot-based estimate
	Pre-1990 planted forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot-based estimate
	Post-1989 natural forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot-based estimate
	Post-1989 planted forest	Based on an age-based carbon yield table	All biomass pools	LUCAS plot-based estimate
Cropland	Annual	5	Above- and below-ground biomass	Table 5.9, IPCC, 2006a
	Perennial	18.76	Above-ground biomass	Davis and Wakelin, 2010
Grassland	High producing	6.75	Above- and below-ground biomass	Table 6.4, IPCC, 2006a
	Low producing	3.05	Above- and below-ground biomass	Table 6.4, IPCC, 2006a
	With woody biomass – transitional	11.99	All biomass pools	LUCAS plot-based estimate
	With woody biomass – permanent	59.96	All biomass pools	LUCAS plot-based estimate
Wetlands		NE	NA	Section 3.5.2.2 and annex 3A, IPCC, 2003
Settlements		NE	NA	Section 3.6.2, IPCC, 2003
Other land		NE	NA	Section 3.7.2.1, IPCC, 2003

Note: NA = not applicable; NE = not estimated. * For conversions from natural forest, the indicated carbon stock is emitted instantaneously depending on the vegetation type present (tall forest or shrub) immediately before conversion. 'All biomass pools' includes above- and below-ground biomass, litter and dead organic matter. See below in section 6.3 and under Methodological issues in each category-specific section for further details on how emissions are estimated.

Table 6.1.4 New Zealand's emission factors for annual growth in biomass carbon stock in land after conversion

Land-use category	Land-use subcategory	2015 submission emission factor (t C ha^{-1})	Carbon stock maturity cycle	Carbon pools	Reference
Forest land	Pre-1990 natural forest	Based on net annual growth increment	NA	All biomass pools	LUCAS plot-based estimate
	Pre-1990 planted forest	Based on an age-based carbon yield table	NA	All biomass pools	LUCAS plot-based estimate
	Post-1989 natural forest	Based on an age-based carbon yield table	NA	All biomass pools	LUCAS plot-based estimate
	Post-1989 planted forest	Based on an age-based carbon yield table	NA	All biomass pools	LUCAS plot-based estimate
Cropland	Annual	5	1	Above- and below-ground biomass	Table 5.9, IPCC, 2006a
	Perennial	0.67	28	Above-ground biomass	Davis and Wakelin, 2010
Grassland	High producing	6.75	1	Above- and below-ground biomass	Table 6.4, IPCC, 2006a
	Low producing	3.05	1	Above- and below-ground biomass	Table 6.4, IPCC, 2006a
	With woody biomass – transitional	0.43	28	All biomass pools	LUCAS plot-based estimate
	With woody biomass – permanent	NO	NA	NA	NA
Wetlands		NE	NA	NA	Assume steady state (IPCC, 2006a)
Settlements		NE	NA	NA	Assume steady state (IPCC, 2006a)
Other land		NE	NA	NA	Assume steady state (IPCC, 2006a)

Note: NA = not applicable; NE = not estimated; NO = not occurring. 'All biomass pools' includes above- and below-ground biomass, litter and dead organic matter.

New Zealand is estimating carbon stock change for each of the five Kyoto Protocol carbon pools (to meet Kyoto Protocol reporting requirements) and aggregating the results to the three pools used for reporting under the United Nations Framework Convention on Climate Change (Climate Change Convention). Table 6.1.5 summarises the methods being used to estimate carbon by pool for each land use.

Table 6.1.5 Relationships between land-use category, carbon pool, and method of calculation used by New Zealand

Climate Change Convention reporting pool		Living biomass		Dead organic matter		Soils	
						Soil organic matter	
Kyoto Protocol reporting pool		Above-ground biomass	Below-ground biomass	Dead wood	Litter	Mineral soils	Organic soils
Land-use category	Pre-1990 natural forest	Allometric equations	Per cent of above-ground biomass	Allometric equations	Lab analysis	Tier 2, country-specific data and model	Not applicable
	Pre-1990 natural forest [D]	Emission factor based on the vegetation type present (tall forest or shrub) before deforestation occurring since 1 January 1990					
	Pre-1990 planted forest	Age-based carbon yield table by biomass pool derived from the LUCAS plot network and the Forest Carbon Predictor model				Tier 2, country-specific data and model	IPCC Tier 1 default parameters
	Post-1989 natural forest [AR and D]	Allometric model	Per cent of above-ground biomass	Allometric model	Allometric model	Tier 2, country-specific data and model	IPCC Tier 1 default parameters
	Post-1989 planted forest [AR and D]	Age-based carbon yield table by biomass pool derived from the LUCAS plot network and the Forest Carbon Predictor model				Tier 2, country-specific data and model	IPCC Tier 1 default parameters
	Cropland – annual	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters (NE)			Tier 2, country-specific data and model	IPCC Tier 1 default parameters
	Cropland – perennial	Country-specific emission factor	IPCC Tier 1 default parameters (NE)			Tier 2, country-specific data and model	IPCC Tier 1 default parameters
	Grassland (high and low producing)	IPCC Tier 1 default parameters		IPCC Tier 1 default parameters (NE)		Tier 2, country-specific data and model	IPCC Tier 1 default parameters
	Grassland with woody biomass – transitional and permanent	Country-specific emission factor				Tier 2, country-specific data and model	IPCC Tier 1 default parameters
	Wetlands	IPCC Tier 1 default parameters (NE)				Tier 2, country-specific data and model	Not estimated
	Settlements	IPCC Tier 1 default parameter (NE)				Tier 2, country-specific data and model	Not estimated
	Other land	IPCC Tier 1 default parameter (NE)				Tier 2, country-specific data and model	Not estimated

Note: AR = afforestation/reforestation; D = deforestation; NE = not estimated. See the methodology sections for an explanation of soil carbon calculations (section 6.3) and forest models, C_Change and Forest Carbon Predictor (section 6.4.2).

Calculation of national emission estimates

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

- land use and land-use change area data from 1962 to 1989, which provide land in a transition state as at 1990 for each land-use subcategory
- annual land use and land-use change area data from 1990 to 2013 (see section 6.2)
- biomass carbon stocks per hectare prior to land-use conversion, and annual growth in biomass carbon stocks per hectare following conversion (tables 6.1.3 and 6.1.4)
- age-based biomass carbon yield tables for pre-1990 planted forests and post-1989 forests (see section 6.4.2)
- growth increment for pre-1990 natural forest (see section 6.4.2)
- emission factors and country-level activity data on Biomass burning (section 6.11.4)
- Intergovernmental Panel on Climate Change (IPCC) default conversion factors for converting carbon to carbon dioxide.
- The formula used to calculate emissions from biomass changes on land-use conversion is:

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

The formula used to calculate emissions from mineral soil changes on land-use conversion is:

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

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

Biomass change = (–3.05 × 100) + (0.67 × 100) = –238 t C *(1)*

Mineral soil change = (((105.98– 88.44) / 20) × 100) = –87.7 t C *(2)*

Total carbon stock change = –325.7 t C

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

Total emissions = 1.194 kt CO_2

Note: New Zealand follows the Tier 1 guidance in GPG-AFOLU for calculating emissions for organic soils (IPCC 2006a).

These calculations have been performed to produce estimates of annual carbon stock and carbon stock changes since 1990 to inform the Climate Change Convention and Kyoto Protocol reporting.

New Zealand Land Use and Carbon Analysis System

New Zealand's LULUCF estimates are calculated using a programme of data collection and modelling called the Land Use and Carbon Analysis System. The LUCAS Data Management System stores, manages and retrieves data for international greenhouse gas reporting for the LULUCF sector. The Data Management System comprises: the Geospatial System, a data warehousing 'Gateway', and the Calculation and Reporting Application. These systems are used for managing the land-use spatial databases and the plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting. Details on these databases and applications are provided in annex 3.2.2.

6.1.3 Uncertainties in LULUCF

Table 6.1.6 shows the four land-use subcategories within the LULUCF sector that make the greatest contribution to uncertainty in the net carbon emissions for the sector. These are given in descending order.

Table 6.1.6 Land-use subcategories making the greatest contribution to uncertainty in the LULUCF sector

Land-use subcategory	Absolute emissions by subcategory (kt CO_2)	Uncertainty introduced into emissions for LULUCF (%)
Pre-1990 planted forest remaining pre-1990 planted forest	4,472.1	33.6
Harvested wood products	10,295.6	27.0
Pre-1990 natural forest remaining pre-1990 natural forest	6,107.8	9.4
Low producing grassland converted to post-1989 forest	9,704.9	5.0

Pre-1990 planted forest remaining pre-1990 planted forest contributes the largest uncertainty into the LULUCF sector. The age structure of the pre-1990 planted forest estate results in high removals from growth and high emissions from harvesting, leaving a relatively small net change. The uncertainties are calculated on emissions and removals relative to net change. This results in high uncertainty introduced into emissions for LULUCF despite relatively low uncertainty in carbon stocks (12.4 per cent).

Harvested wood products provides the second greatest contribution to uncertainty in the LULUCF sector. This is driven by large removals in the subcategory and high uncertainty associated with the end-use and discard rates of New Zealand wood.

A Monte Carlo simulation approach was used to assess the main sources of uncertainty on carbon stock and carbon stock change in pre-1990 natural forest. The regenerating component of pre-1990 natural forest was found to be a statistically significant sink of carbon, sequestering 1.39 ± 0.55 tonnes C $ha^{-1}yr^{-1}$ (Holdaway et al, 2014b). The variation between individual plot estimates of carbon change results in an uncertainty of 39.6 per cent for biomass change in the category. Coupled with high removals, as the area of pre-1990 natural forest is large, this results in the third largest contributor to uncertainty in the LULUCF sector.

Low producing grassland converted to post-1989 forest contributes the forth-greatest level of uncertainty due to high removals from forest growth despite the low biomass uncertainty for this land-use conversion (8.6 per cent).

The uncertainties were recalculated and independently reviewed in the 2014 submission.

Further details on the emission factor and activity data uncertainties for specific land uses and non-carbon emissions are given within the relevant sections of this chapter. Further detailed analysis of LULUCF uncertainties is presented in annex 3.2.1.

6.1.4 Recalculations in LULUCF

For the 2015 submission, New Zealand has recalculated its emission estimates for the LULUCF sector from 1990 to 2012 to incorporate new activity data, New Zealand-specific emission factors, improved methodology for the entire time series and to meet the new requirement for reporting for the harvested wood products pool.

The recalculations have resulted in improvements to the accuracy and completeness of the LULUCF estimates. An estimate of the impact of new activity data and emission factors on the 1990 and 2012 figures has been made by excluding emissions from sources for which reporting has changed, namely the harvested wood products pool, and emissions from liming (this is now reported under Agriculture). Both sets of values have also been estimated using the global warming potentials from the Contribution of Working Group I to the Fourth Assessment Report of the IPCC (IPCC, 2007).

These estimates show emissions in 1990 have increased by approximately 23.8 per cent, and emissions in 2012 have decreased by approximately 2.2 per cent (table 6.1.7).

Table 6.1.7 Recalculations to New Zealand's total net LULUCF emissions for 1990 and 2012

	Reported net emissions		Change in estimate	
Year	2014 submission (kt CO_2-e)	2015 submission (kt CO_2-e)	(kt CO_2-e)	(%)
1990	–37,615.0	–28,654.4	+8,960.5	–23.8
2012	–27,253.9	–27,848.8	–594.9	+2.2

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions reported in the 2014 submission are the result of (in decreasing order of magnitude):

- revised estimates of carbon stock change in pre-1990 natural forest based on the first complete set of re-measurement data for these forests. Carbon stock change estimates in this report are based on results of the latest analysis, presented in Holdaway et al (2014b). This has accounted for an increase in emissions of around 10,000 kt CO_2-e annually for every year of the inventory
- a change to the pre-1990 planted forest age-class distribution to more accurately reflect the latest available activity data on the forest class. Previously, an older age-class distribution was grown forward using harvesting data, but this method resulted in a constructed pre-1990 planted forest age-class that departed from the latest available data (Wakelin and Paul, 2012; Paul et al, 2014)
- the post-1989 and pre-1990 planted forest yield tables being updated for the 2015 submission. The updates include reclassification of a small number of plots due to mapping improvements, amendments to align with a revised estimate of net stocked area in both forest classes and the inclusion of a sub-set of previously unused plots in post-1989 planted forest
- continued improvements to the 1990, 2008 and 2012 land-use maps. Mapping data provided from the New Zealand Emissions Trading Scheme (NZ ETS) was integrated into the three maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest

- incorporating new data collected from post-1989 planted forests into the mineral soil organic carbon estimates, this changes not only the estimates for post-1989 planted forests but for other land uses also.

The impact of these recalculations on net CO_2-e emissions in each land-use category is provided in table 6.1.8. Emissions for the harvested wood products pool are included at the end of the table so a comparison of the relative size of reporting changes can be made.

Table 6.1.8 Recalculations to New Zealand's net LULUCF emissions for 1990 and 2012

Land-use category	Net emissions (kt CO_2-e) 2014 submission: 1990 estimate	2015 submission: 1990 estimate	2014 submission: 2011 estimate	2015 submission: 2011 estimate	Change in 1990 estimate (%)	Change in 2012 estimate (%)
Forest land	–39,135.7	–28,256.8	–33,147.4	–25,644.7	–27.8	–22.6
Cropland	479.6	479.1	465.6	455.4	–0.1	–2.2
Grassland	810.4	1,104.3	5,368.7	6,247.4	+36.3	+16.4
Wetlands	218.2	–21.8	44.4	7.2	–110.0	–83.8
Settlements	6.3	2.3	–3.0	0.3	–63.7	–110.8
Other land	6.2	7.7	17.8	38.6	+24.1	+117.3
Total	**–37,615.0**	**–28,654.4**	**–27,253.9**	**–27,848.8**	**–23.8**	**2.2**
Harvested wood products	NA	–1,969.2	NA	–8,952.9	NA	NA

Note: NA = not applicable. 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. The 2014 submission figures have been updated with the revised global warming potentials from the global warming potentials from the Contribution of Working Group I to the Fourth Assessment Report of the IPCC (IPCC, 2007) so vary slightly from those published in the 2014 submission. These values also exclude emissions from liming at both dates.

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

6.1.5 LULUCF planned improvements

Category-specific planned improvements are reported separately under each of the relevant sections of this chapter. The major themes are:

- continued method development to implement the 2006 IPCC guidelines (GPG-AFOLU, IPCC, 2006a)
- improvements to mapping as further data becomes available
- harvest modelling improvements
- research is currently under way to assess the end-use and life-span of exported raw materials to improve New Zealand's harvested wood products estimate.

6.2 Representation of land areas

The total land area of New Zealand is 26,925.2 kilohectares. This includes all significant New Zealand land masses; the two main islands, the North Island and South Island, as well as Stewart Island, Great Barrier Island, Little Barrier Island, the Chatham Islands, the sub-Antarctic islands and other, small outlying islands.

New Zealand has used Reporting Method 2 and Approach 3 to map land-use changes between 1 January 1990 and 31 December 2013 (IPCC, 2006a, chapter 3.3.1). The total land-use areas as at 1 January 1990, 1 January 2008 and 31 December 2012 are based on wall-to-wall mapping of satellite and aircraft remotely sensed imagery taken in, or close to the start of, 1990, 2008 and 2012 respectively, as described in section 6.2.2. The mapping of forest areas includes improvements made up to August 2014 using aerial photography and data from the NZ ETS. Deforestation occurring between 2008 and 2012 has been mapped by year using ancillary satellite imagery and oblique aerial photography. All other land-use changes occurring between 1990 and 2013 have been interpolated from other sources. This is described in further detail in section 6.2.3.

6.2.1 Land-use category definitions

The New Zealand land-use categories and subcategories are shown in table 6.2.1. The land-use subcategories are consistent with those used for the 2013 submission.

Table 6.2.1 New Zealand's land-use categories and subcategories

IPCC land-use category	New Zealand land-use subcategory
Forest land	Pre-1990 natural forest
	Pre-1990 planted forest
	Post-1989 forest(1)
Cropland	Annual cropland
	Perennial cropland
Grassland	High producing grassland
	Low producing grassland
	Grassland with woody biomass
Wetlands	Open water
	Vegetated wetland
Settlements	Settlements
Other land	Other land

Note: (1) Mapped as a single land-use subcategory but stratified into 'post-1989 natural forest' and 'post-1989 planted forest' for calculating carbon based on the plot network.

The land-use subcategories were chosen for their conformation with the dominant land-use types in New Zealand, while still enabling reporting under the land-use categories specified in the GPG-AFOLU (IPCC, 2006a).

The national thresholds used by New Zealand to define *Forest land* for both Climate Change Convention and Kyoto Protocol reporting are:

- a minimum area of 1 hectare
- a crown cover of at least 30 per cent
- a minimum height of 5 metres at maturity in situ (Ministry for the Environment, 2006).

The definitions of New Zealand's land-use subcategories, as they have been mapped, are provided in table 6.2.2, and further details are included in *Land Use and Carbon Analysis System: Satellite imagery interpretation guide for land-use classes* (2nd edition) (Ministry for the Environment, 2012).

Table 6.2.2 New Zealand's mapping definitions for land-use subcategories

Land-use subcategory	Definition
Pre-1990 natural forest	Areas that, on 1 January 1990, were and presently include: • tall indigenous forest • self-sown exotic trees, such as wilding pines and grey willows, established before 1 January 1990 • broadleaved hardwood shrubland, mānuka–kānuka (*Leptospermum scoparium*–*Kunzea ericoides*) shrubland and other woody shrubland (≥ 30 per cent cover, with potential to reach ≥ 5 metres at maturity *in situ* under current land management within 30–40 years) • areas of bare ground of any size that were previously forested but, due to natural disturbances (eg, erosion, storms, fire), have temporarily lost vegetation cover • areas that were planted forest at 1990 but are subsequently managed to regenerate with natural species that will meet the forest definition • roads and tracks less than 30 metres in width and other temporarily unstocked areas associated with a forest land use.
Pre-1990 planted forest	Areas that, on 1 January 1990, were and presently include: • radiata pine (*Pinus radiata*), Douglas fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.) or other planted species (with potential to reach ≥ 5 metre height at maturity *in situ*) established before 1 January 1990 or replanted on land that was forest land as at 31 December 1989 • exotic forest species that were planted after 31 December 1989 on land that was natural forest • riparian or erosion control plantings that meet the forest definition and that were planted before 1 January 1990 • harvested areas within pre-1990 planted forest (assumes these will be replanted, unless deforestation is later detected) • roads, tracks, skid sites, and other temporarily unstocked areas less than 30 metres in width associated with a forest land use • areas of bare ground of any size that were previously forested at 31 December 1989 but, due to natural disturbances (eg, erosion, storms, fire), have lost vegetation cover.
Post-1989 forest	Includes post-1989 planted forest, which consists of: • exotic forest (with the potential to reach ≥ 5 metre height at maturity *in situ*) planted or established on land that was non-forest land as at 31 December 1989 (eg, radiata pine, Douglas fir, eucalypts or other planted species) • riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989 • harvested areas within post-1989 forest land (assuming these will be replanted, unless deforestation is later detected). Includes post-1989 natural forest, which consists of: • forests arising from natural regeneration of indigenous tree species as a result of management change after 31 December 1989 • self-sown exotic trees, such as wilding conifers or grey willows, established after 31 December 1989. Includes areas within post-1989 natural forest or post-1989 planted forest that are: • roads, tracks, skid sites, and other temporarily unstocked areas associated with a forest land use • areas of bare ground of any size that were previously forested (established after 31 December 1989) but, due to natural disturbances (eg, erosion, storms, fire), have lost vegetation cover.
Annual cropland	Includes: • all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland.
Perennial cropland	Includes: • all orchards and vineyards • linear shelterbelts associated with perennial cropland.
High producing grassland	Includes: • grassland with high-quality pasture species • linear shelterbelts that are < 1 hectare in area or < 30 metres in mean width

Land-use subcategory	Definition
	(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.
Low producing grassland	Includes: • low-fertility grassland and tussock grasslands (eg, *Chionochloa* and *Festuca* spp.) • mostly hill country • montane herbfields either at an altitude higher than above-timberline vegetation or where the herbfields are not mixed up with woody vegetation • linear shelterbelts that are < 1 hectare in area or < 30 metres in mean width (larger shelterbelts are mapped separately as grassland – with woody biomass) • other areas of limited vegetation cover and significant bare soil, including erosion and coastal herbaceous sand-dune vegetation.
Grassland with woody biomass	Includes: • grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (eg, māhoe – *Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), mānuka–kānuka (*Leptospermum scoparium–Kunzea ericoides*) shrubland, coastal and other woody shrubland (< 5 metres tall and any per cent cover) where, under current management or environmental conditions (climate and/or soil), it is expected that the forest criteria will not be met over a 30–40 year period • above-timberline shrubland vegetation intermixed with montane herbfields (does not have the potential to reach > 5 metres in height *in situ*) • grassland with tall tree species (< 30 per cent cover), such as golf courses in rural areas (except where the Land Cover Database (LCDB) has classified these as settlements) • grassland with riparian or erosion control plantings (< 30 per cent cover) • linear shelterbelts that are > 1 hectare in area and < 30 metres in mean width • areas of bare ground of any size that previously contained grassland with woody biomass but, due to natural disturbances (eg, erosion, fire), have lost vegetation cover.
Open water	Includes: • lakes, rivers, dams and reservoirs • estuarine–tidal areas including mangroves.
Vegetated wetland	Includes: • 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	Includes: • built-up areas and impervious surfaces • grassland within 'settlements' including recreational areas, urban parklands and open spaces that do not meet the forest definition • major roading infrastructure • airports and runways • dam infrastructure • urban subdivisions under construction.
Other land	Includes: • montane rock and/or scree • river gravels, rocky outcrops, sand dunes and beaches, coastal cliffs, mines (including spoil), quarries • permanent ice and/or snow and glaciers • any other remaining land that does not fall into any of the other land-use categories.

Further refinements are planned to improve New Zealand's estimates of land-use change, as stated in section 6.2.7. Land areas reported as 'converted' and 'remaining' within each land-use category are the best current estimates and will be improved should additional activity data become available.

6.2.2 Land-use mapping methodology

Areas of land use and land-use change between 1990 and 2013 are based on three wall-to-wall land-use maps derived from satellite imagery at nominal mapping dates of 1 January 1990, 1 January 2008 and 31 December 2012. Area information from these maps is interpolated and extrapolated to obtain a complete time series of land-use change occurring between 1990 and 2013 (section 6.2.3).

Satellite image acquisition and pre-processing

Each of the national land-use maps is based on a collection of either Landsat or SPOT satellite imagery acquired over the summer periods (October to March) as described in table 6.2.3. This type of satellite imagery is only acquired over New Zealand during the summer months because a high sun angle is required to reduce shadowing and increase the dynamic range of the signal received from the ground.

Table 6.2.3 Satellite imagery used for land-use mapping in 1990, 2008 and 2012

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

All the imagery was orthorectified and atmospherically corrected, then standardised for spectral reflectance using the Ecosat algorithms documented in Dymond et al (2001), Shepherd and Dymond (2003), as well as Dymond and Shepherd (2004). This standardisation process removes the effect of terrain slope from the imagery and effectively 'flattens' the imagery so that individual land cover types are a more consistent colour across the whole image. By minimising the effects of terrain, a more accurate and consistent classification of land use is possible. This is particularly important in New Zealand due to the extensive areas of steep terrain.

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

1990 and 2008 land-use maps

Mapping approach

The 1990 and 2008 land-use maps were created using a common mapping approach based on difference detection from an intermediate reference land cover layer that was derived from Landsat 7 ETM+ imagery acquired in 2000–2001. A semi-automated approach was used to classify woody land cover[32] in the 1990 and 2008 image mosaics. These layers were then differenced from the 2001 reference layer to create a 1990–2001 potential woody change layer and a 2001–2008 potential woody change layer.

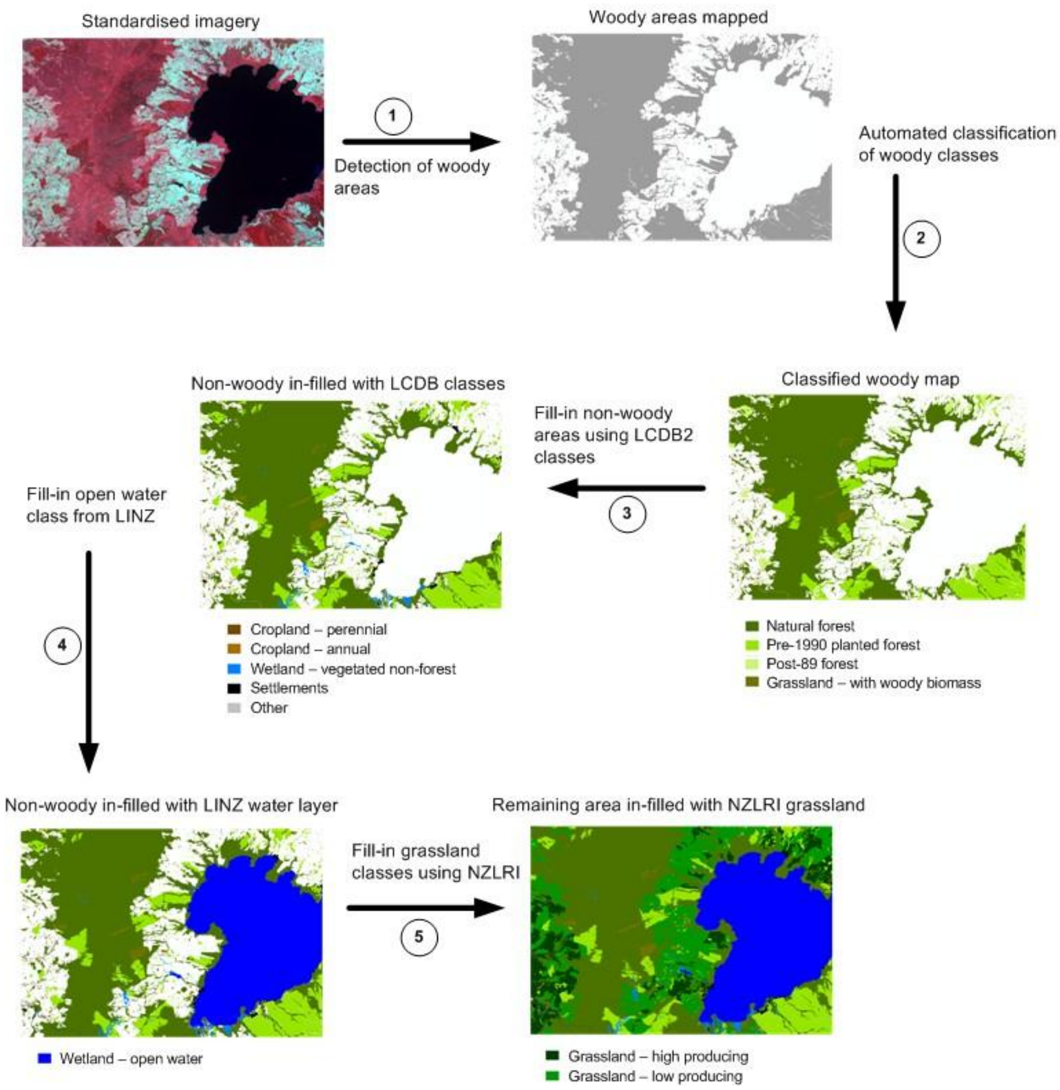
[32] Land cover consistent with pre-1990 natural forest, pre-1990 planted forest, post-1989 forest and grassland with woody biomass land-use subcategories.

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

To determine the spatial location of the other land-use categories and subcategories as at 1990 and 2008, information from two Land Cover Databases, LCDB1 (1996) and LCDB2 (2001) (Thompson et al, 2004), hydrological data from Land Information New Zealand (a government agency) and the New Zealand Land Resource Inventory (NZLRI) (Eyles, 1977) was used (Shepherd and Newsome, 2009b).

The NZLRI database defined the area of high and low producing grassland. Areas tagged as 'improved pasture' in the NZLRI vegetation records were classified as high producing grassland in the land-use maps. All other areas were classified as low producing grassland. Figure 6.2.1 illustrates this mapping process.

Figure 6.2.1 New Zealand's land-use mapping process

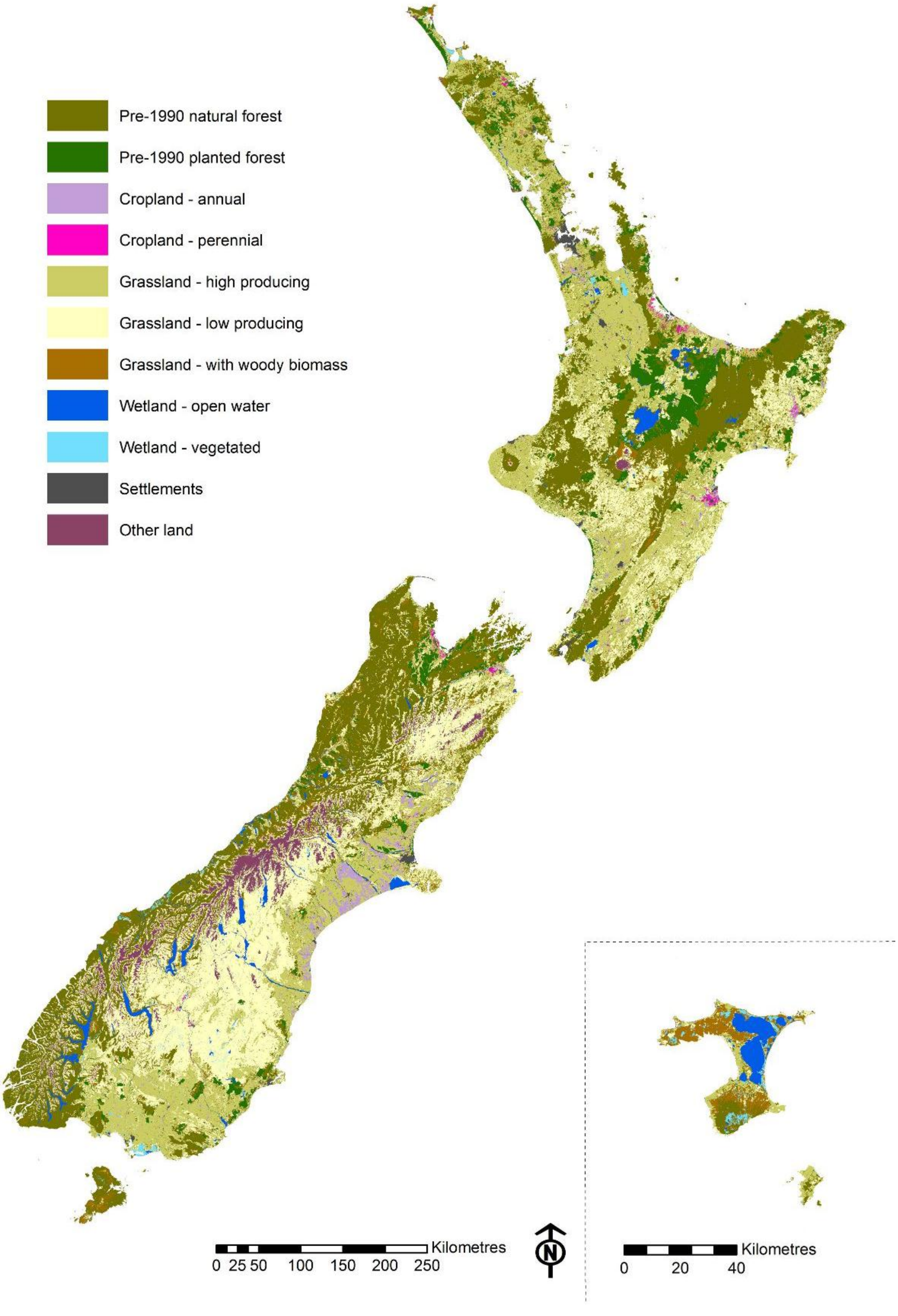


Note: LINZ = Land Information New Zealand.

An interpretation guide for automated and visual interpretation of satellite imagery was prepared and used to ensure a consistent basis for all mapping processes (Ministry for the Environment, 2012). Independent quality control was performed for all mapping. This involved an independent agency looking at randomly selected points across New Zealand and using the same data as the original operator to decide within what land-use category the point fell. The two operators were in agreement at least 95 per cent of the time. This is described in more detail in GNS Science (2009).

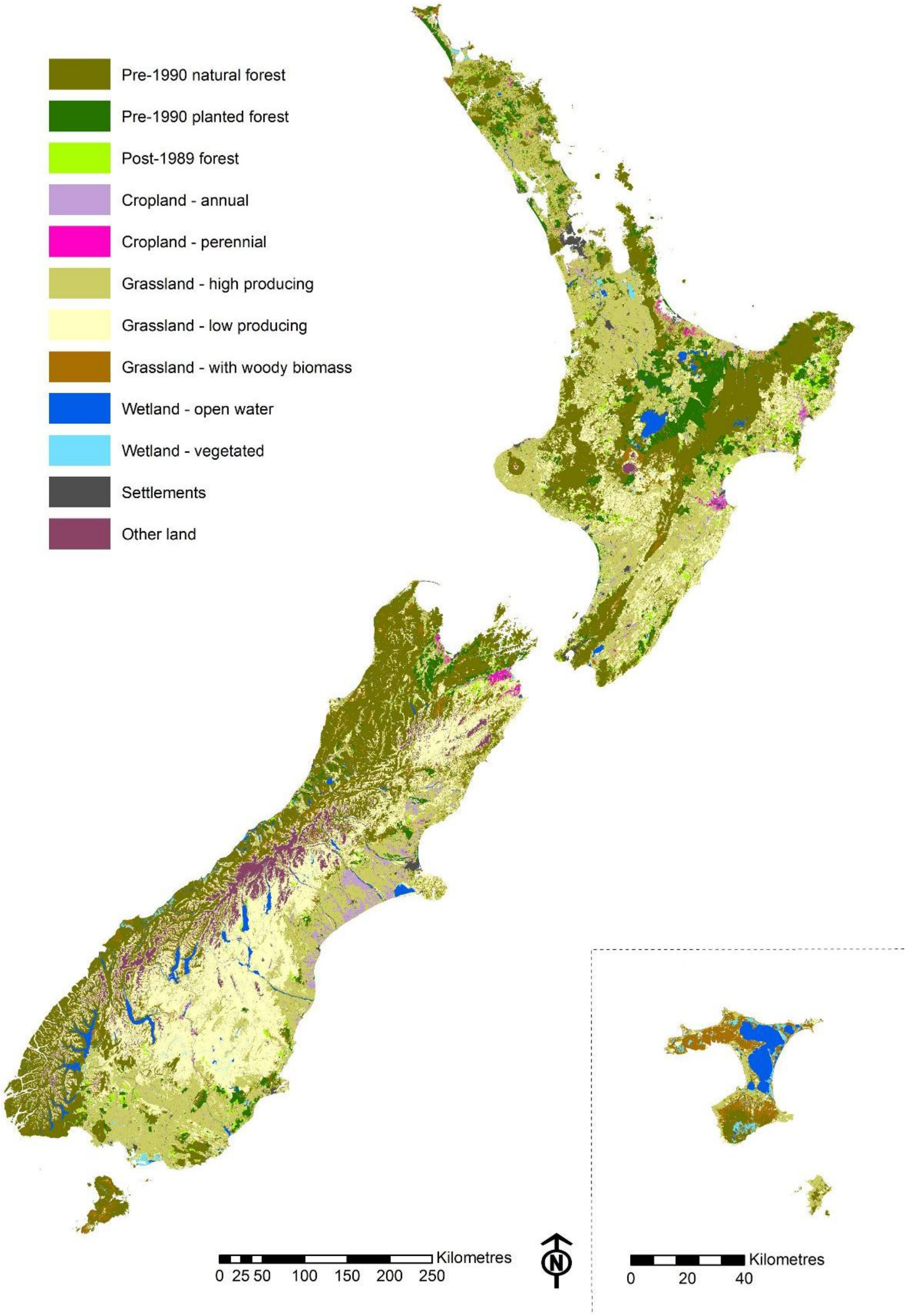
Figures 6.2.2 and 6.2.3 show the land-use map of New Zealand as at 1 January 1990 and 1 January 2008 respectively.

Figure 6.2.2 Land-use map of New Zealand as at 1 January 1990



Note: The inset map is of the Chatham Islands, which lie approximately 660 kilometres south-east of the south-eastern corner of the North Island.

Figure 6.2.3 Land-use map of New Zealand as at 1 January 2008



Note: The inset map is of the Chatham Islands, which lie approximately 660 kilometres south-east of the south-eastern corner of the North Island.

Decision process for mapping post-1989 forests

The use of remotely sensed imagery 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) Landsat 4 and 5 imagery captured around 1990. This situation is compounded by the lack of ancillary data at 1990 to support land-use classification decisions. However, since 2009, the NZ ETS has provided valuable spatial information that has been used to confirm 1990 forest land-use classifications.

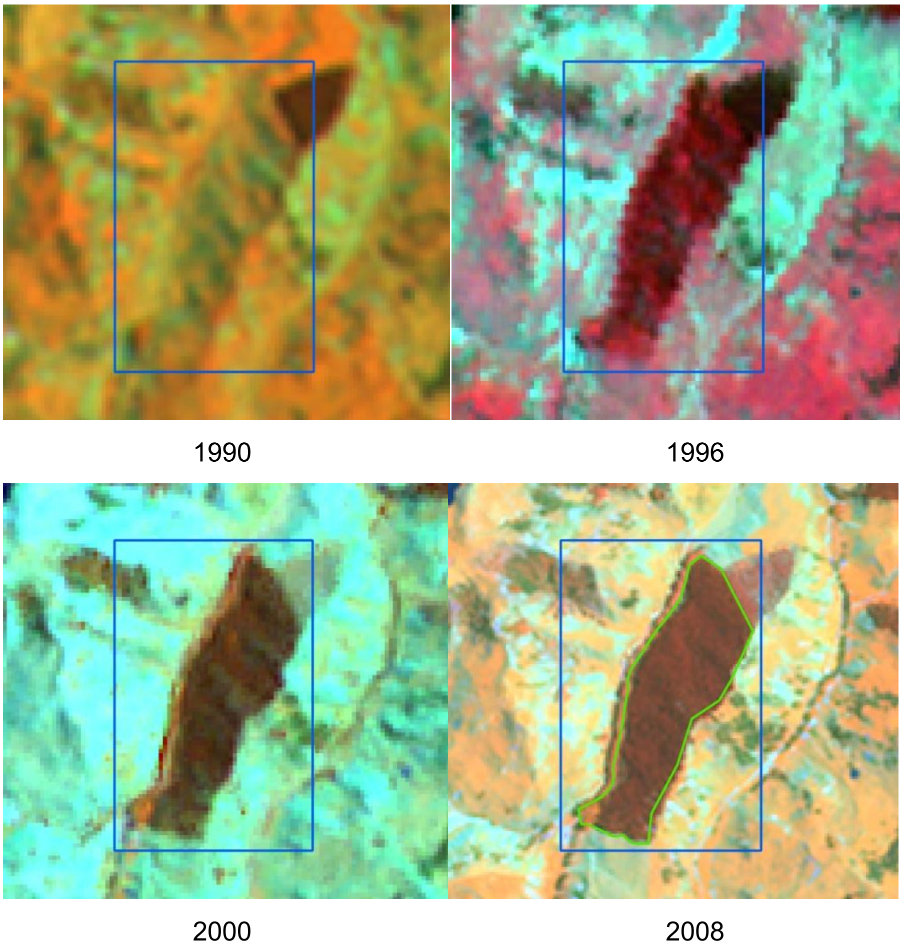
Owners of post-1989 forest are able to lodge their forests with the NZ ETS to obtain credit for increases in carbon stock since 1 January 2008. Mapping received by the Ministry for Primary Industries for these applications is used to improve LUCAS land-use maps.

Mapping from the NZ ETS has also provided a significant source of planting date information, which helps determine the correct classification of planted forest. The Forestry Allocation Plan, which forms part of the NZ ETS, partially compensates private owners of pre-1990 planted forest for the loss in land value arising from the introduction of penalties for deforesting pre-1990 forest land. Forest owners must apply for this compensation, providing detailed mapping and evidence of their forest planting date. This mapping data is used regularly to improve the classification accuracy of the LUCAS land-use maps.

To aid the decision-making process, nationwide cloud-free 1996 SPOT and 2001 Landsat 7 satellite image mosaics are also used to determine the age of forests that have been planted within two to three years of 1990. Figure 6.2.4 illustrates how mapping operators use the spectral signature in later imagery and ancillary information, to determine the status of an area of planted forest established around 1990.

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 and post-1989 forest classification.

Figure 6.2.4 Identification of post-1989 forest in New Zealand



Images:	1990 Landsat 4 (top left) 1996 SPOT 2 (top right) 2000 Landsat 7 ETM+ (bottom left) 2008 SPOT 5 (bottom right)
Location:	2,017,800, 5,730,677 (NZTM)
1990 land use:	Low producing grassland
2008 land use:	Post-1989 forest
Explanation:	In the Landsat 1990 imagery acquired on 2 December 1990, there is little evidence of the forest within the blue box that is clearly apparent in later imagery. The strength of the spectral response in the SPOT 1996 imagery suggests that the forest must have been planted near to 1990. Final confirmation of the planting date is provided via the NZ ETS application (delineated in green in the 2008 imagery), which states that the forest was planted in 1990 and, therefore, is classed as a post-1989 forest.

2012 land-use mapping

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

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

Mapping approach: non-forest areas

Potential change in areas mapped as non-forest subcategories at 2008 were manually checked in the satellite imagery to determine whether a land-use change had occurred between 2008 and 2012. Operators used the 2008 and 2012 SPOT imagery along with other imagery data sets as listed in table 6.2.4 to establish whether land-use change had occurred.

Table 6.2.4 Ancillary imagery data sets used in land-use mapping

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

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

Mapping approach: forest areas

Areas of possible change within the forest extent were considered to be potential destocking.[33] The areas of potential destocking were first checked in aerial photography to determine whether replanting had occurred. Cases of replanting were then removed from the destocking layer.

All remaining areas were field checked, with oblique aerial photography taken over each site to determine the current land use. It is not possible to determine whether deforestation has occurred using currently available satellite imagery alone; however, efficient flight planning made oblique over-flight of all areas of destocking a realistic and cost-effective alternative.

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

- harvested: The area shows evidence of ongoing forestry land use such as replanting, preparation for planting or a context consistent with replanting, such as being surrounded by plantation forestry
- deforested: The area shows evidence of land-use change such as the removal of stumps, pasture establishment, fencing and stock, or the area has been destocked and lying fallow for four or more years[34]
- awaiting: The area has been destocked for less than four years and there is no evidence of land-use change. That is, the area is lying fallow or, in the case of natural forest areas, the vegetation has been sprayed but not cleared[35]

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33 ‘Destocking’ is defined here as forest loss for any reason including harvesting, deforestation or some type of non-anthropogenic change, such as wind damage or erosion.

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

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

Deforested areas were then attributed with further information, such as the year in which the deforestation occurred. This was determined by examining the ancillary imagery data sets listed in table 6.2.4, as well as a national time series of Landsat 7 satellite imagery acquired between 2007 and 2012. Figure 6.2.5 shows the process of confirming deforestation and establishing the year in which it occurred. Further information on the mapping of forest change can be found in Indufor Asia-Pacific (2013).

The final step in the 2012 land-use mapping process was to add the confirmed areas of deforestation into the 2012 map. Figure 6.2.6 shows the land-use map of New Zealand as at 31 December 2012.

[35] Often regenerating shrubland areas are sprayed but land-use conversion is not completed by clearing the area. In these instances, the vegetation regenerates and recovers, therefore land-use change has not occurred.

Figure 6.2.5 New Zealand's identification of deforestation

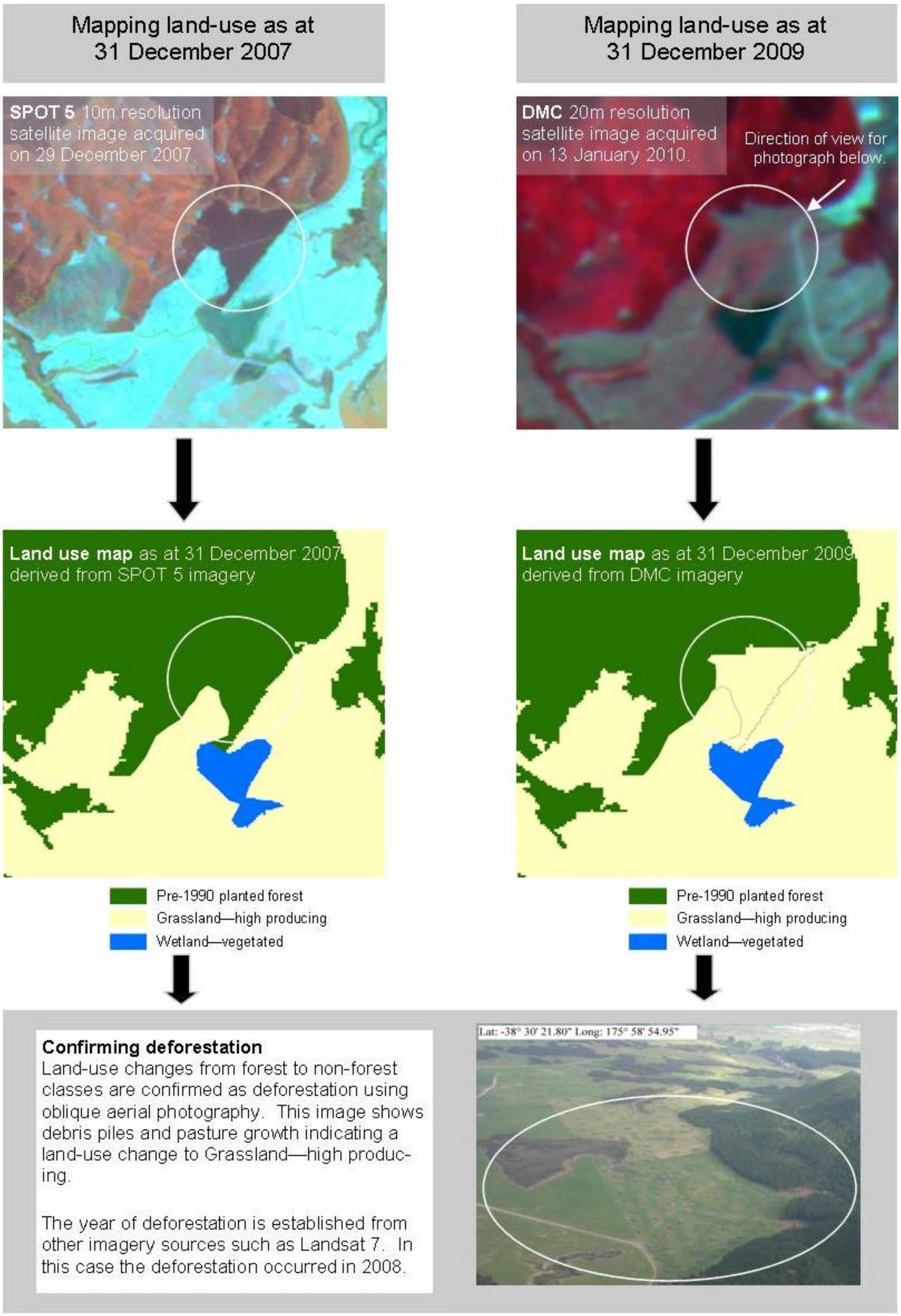
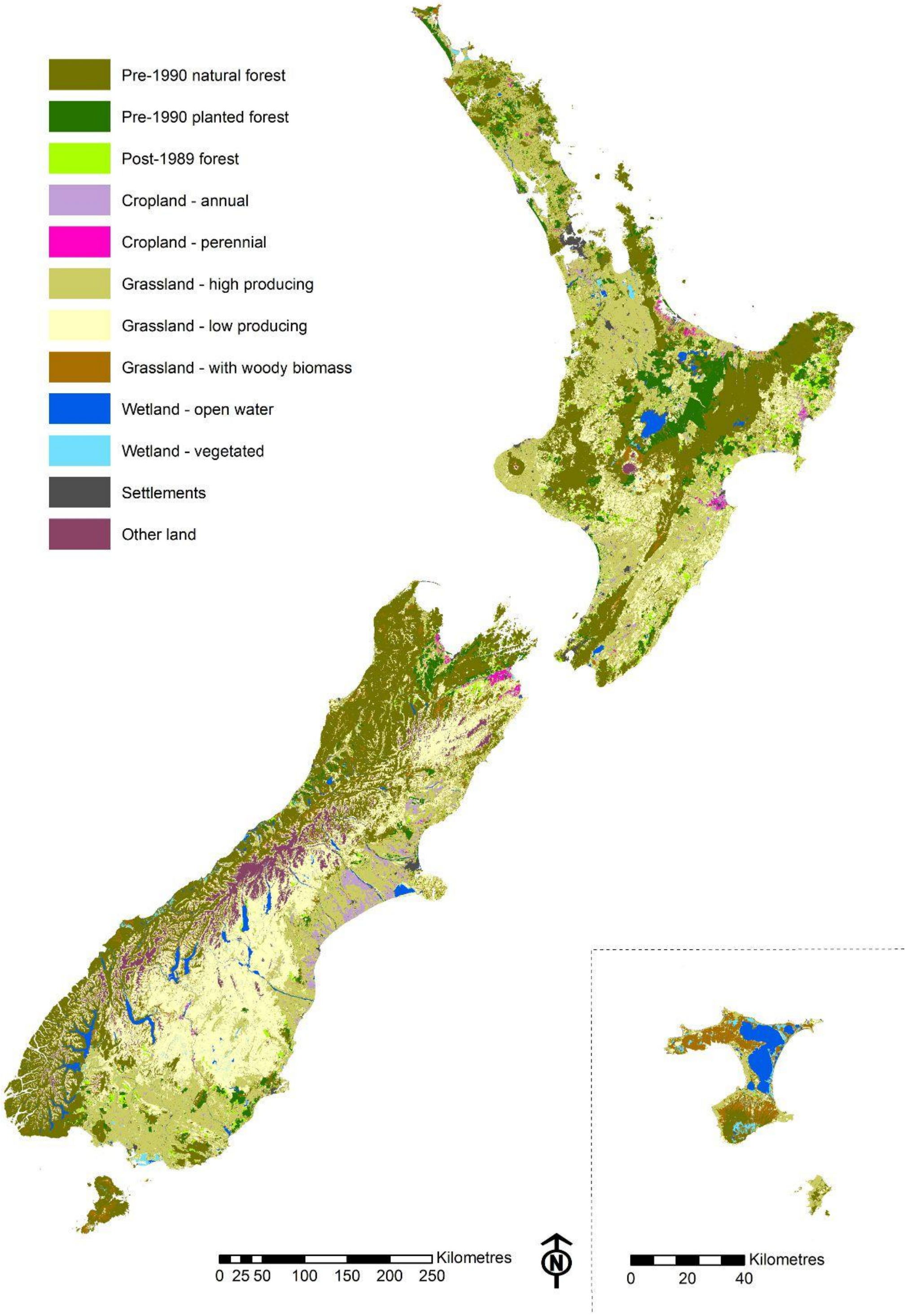


Figure 6.2.6 Land-use map of New Zealand as at 31 December 2012



Note: The inset map is of the Chatham Islands, which lie approximately 660 kilometres south-east of the south-eastern corner of the North Island.

6.2.3 Land-use change

Land-use change prior to 1990

The estimation of land-use change prior to 1990 was introduced in the 2011 submission and further details on the methodology used are available in that report.

A variety of data sources were used to determine land areas prior to 1990. Data sources suitable for determining land use at a national level typically comprise either maps or scaled images depicting land use or proxies for land use (eg, a 'map of forest areas'), or tabulated land-use area data collected for an administrative area (eg, county, district or region) or production sector (eg, the area of orchard crops).

The same land-use data and methodology used to determine land use prior to 1990 in the 2011 submission have been used for the 2014 submission. This methodology was peer reviewed by Landcare Research Ltd (Hunter and McNeill, 2010), which provided independent subject-matter expertise. The land-use change matrix from 1962 to 1989 is presented in table 6.2.5.

Land-use change from 1990 to 2012

Annual land-use changes from 1990 to 2012 are interpolated from the 1990, 2008 and 2012 land-use maps. Two separate interpolations are calculated. The first covers the period between 1990 and 2007 and the second covers the period between 2008 and 2012. Most of the land-use changes are interpolated linearly between mapping dates; however, some of the land-use changes make use of surrogate data sets to better reflect land-use change trends within these periods. This approach follows methodology outlined in section 3.3.1 of the GPG-AFOLU (IPCC, 2006a).

The surrogate data sets used between 1 January 1990 and 31 December 2007 are as follows:

- deforestation trends between 1990 and 1 January 2008 for pre-1990 planted forest and post-1989 forest are based on the 2008 Deforestation Survey (Manley, 2009) and unpublished work by Scion (the New Zealand Forest Research Institute). The work by Scion is referred to in Wakelin (2008)
- afforestation trends for post-1989 planted forest are based on estimates from the National Exotic Forest Description (Ministry for Primary Industries, 2013a)
- afforestation trends for post-1989 natural forest are based on plot analysis as described in Beets et al (2013).

Surrogate data sets used between 1 January 2008 and 31 December 2012 are as follows:

- total afforestation for 2008 to 2012 is estimated from the National Exotic Forest Description (Ministry for Primary Industries, 2013a). This data set is used to provide a surrogate for afforestation occurring between 2008 and 2012. The National Exotic Forest Description data set is used to provide the total afforestation up to 2012 in preference to the total 2012 mapped afforestation because not all new planting will have been detected in satellite imagery. Further details on the use of the National Exotic Forest Description data for estimating total afforestation can be found in section 6.4.1
- deforestation occurring between 2008 and 2012 has been mapped by year for most of the country. Some extrapolation was required to complete the estimate of deforestation in 2012. This was necessary to account for the portion of New Zealand that was imaged for mapping in the summer of 2011/12 as opposed to the summer of 2012/13. The average deforestation occurring in these regions for 2008 to 2011 was used to provide the 2012 estimate. This proved to be the most robust method for completing the estimate of 2012 deforestation and was tested by comparing the deforestation totals for regions where 2012 data was available with estimates based on the same extrapolation methodology.

Table 6.2.6 shows a land-use change matrix for the years 1990 to 2013 based on these inputs.

Prominent land-use changes between 1 January 1990 and 31 December 2013 include:

- forest establishment of 182,189 hectares (classified as post-1989 forest) that has occurred mostly on land that was previously grassland, primarily low producing grassland. Approximately 22,857 hectares of this post-1989 forest has subsequently been deforested
- deforestation of 168,024 hectares. This includes the 22,857 hectares of post-1989 forest mentioned above. This deforestation has occurred mainly in planted forests since 2004. Between 1990 and 2004, there was little deforestation of planted forests in New Zealand due to market conditions.

Table 6.2.7 shows a land-use change matrix for the period 31 December 2012 to 31 December 2013.

Land-use change from 2012 to 2013

No new mapping has been completed in 2013, therefore, most land-use changes for 2013 have been linearly extrapolated based on changes mapped between 2008 and 2012. The only exceptions to this are afforestation and deforestation where the following surrogate data sets have been used to estimate land-use change in 2013:

- deforestation of pre-1990 planted forest and post-1989 forest have been estimated based on the 2013 Deforestation Survey (Manley, 2014)
- deforestation of pre-1990 natural forest has been estimated as occurring at the same annual rate as during the period of 2008 to 2012. There are no trends in the mapped pre-1990 natural forest deforestation during the 2008 to 2012 period or obvious policy or market drivers to suggest a better approach to estimating the 2013 deforestation than simple averaging
- afforestation of post-1989 planted forest is based on estimates from the National Exotic Forest Description (Ministry for Primary Industries, 2013a).

Table 6.2.5 New Zealand's land-use change matrix from 1962 to 1989

1989 \ 1962		Forest land			Cropland		Grassland			Wetlands		Settlements	Other land	Net area 31 Dec 1989 (kha)
		Pre-1990 natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Open water	Vegetated	Settlements	Other land	
Forest land	Pre-1990 natural	7,850.3							46.8					7,897.1
	Pre-1990 planted	273.3	448.4					357.1	441.6					1,520.3
	Post-1989													–
Cropland	Annual				325.5		21.3	8.2						354.9
	Perennial				0.9	59.2	5.1	4.1						69.2
Grassland	High producing	77.0			21.1	19.1	4,869.1	484.1	392.8		50.8			5,914.1
	Low producing	413.2						7,440.4	36.8					7,890.4
	With woody biomass	55.1						409.0	1,033.5					1,497.6
Wetlands	Open water	14.4								517.5				531.9
	Vegetated										146.0			146.0
Settlements	Settlements	5.2			7.4	0.1	6.7	3.5	0.3			182.7		206.0
Other land	Other land												897.5	897.5
Net area as at 31 Dec 1962 (kha)		8,688.4	448.4	–	354.9	78.4	4,902.1	8,706.5	1,951.8	517.5	196.9	182.7	897.5	26,925.2
Net change 1962–1989		–791.3	1,072.0	0.0	0.0	–9.2	1,011.9	–816.1	–454.2	14.4	–50.8	23.3	0.0	0.0
Net change 1962–1989 (%)		–9.1	239.1	NA	NA	–11.7	20.6	–9.4	–23.3	2.8	–25.8	12.7	NA	NA

Note: Units in 000's hectares; NA = not applicable. Shaded cells indicate land remaining in each category. Land-use area values are as at 1 January for 1962 and 31 December for 1989. Columns and rows may not total due to rounding.

Table 6.2.6 New Zealand's land-use change matrix from 1990 to 2013

2013 \ 1990		Forest land			Cropland		Grassland			Wetlands		Settlements	Other land	Net area 31 Dec 2013 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Open water	Vegetated	Settlements	Other land	
Forest land	Natural	7,834.6	0.4											7,834.9
	Pre-1990 planted	19.0	1,418.3				0.1	0.1	0.0					1,437.5
	Post-1989				0.3		111.4	387.5	155.9		0.3	0.0	4.1	659.6
Cropland	Annual	0.0	0.4		345.0	2.6	22.9	0.7	0.1			0.0	0.1	371.7
	Perennial	0.1	0.3		6.7	60.8	33.0	3.2	0.4	0.0	0.0	0.0	0.1	104.5
Grassland	High producing	8.6	51.1		1.9	4.7	5,715.5	2.9	23.2	0.0	0.1	0.0	0.2	5,808.1
	Low producing	26.8	42.2		0.0	0.1	0.1	7,427.4	47.2	0.0	0.3		0.6	7,544.6
	With woody biomass	7.1	6.5		0.1	0.1	14.5	64.3	1,269.5	0.2	0.1	0.0	1.3	1,363.6
Wetlands	Open water	0.0	0.0		0.4	0.0	2.0	1.4	0.1	531.7	0.1	0.0	0.0	535.8
	Vegetated	0.0	0.0			0.0	0.0	0.0	0.1	0.0	114.9			145.1
Settlements	Settlements	0.3	0.5		0.5	0.8	13.7	1.9	0.7	0.0	0.0	206.0	0.1	224.6
Other land	Other land	0.7	0.7		0.0	0.0	0.9	0.9	0.5	0.0	0.2	0.0	891.1	895.0
Area as at 1 Jan 1990 (kha)		7,897.1	1,520.3	NA	354.9	69.2	5,914.1	7,890.4	1,497.6	531.9	146.0	206.0	897.5	26,925.2
Net change 1 Jan 1990–31 Dec 2013		–62.2	–82.8	659.6	16.8	35.3	–106.0	–345.8	–134.0	3.9	–1.0	18.6	–2.5	–
Net change 1990–2013 (%)		–0.8	–5.4	NA	4.7	51.0	–1.8	–4.4	–8.9	0.7	–0.7	9.1	–0.3	NA

Note: Units in 000's hectares; NA = not applicable. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 hectares; however, areas are mapped to 1 hectare resolution. Blank cells indicate no land-use change greater than 100 hectares during the period. Land-use change areas do not include deforestation of post-1989 forest since 1990 (22,857 hectares), as this land became forest after 1990. Land-use change values refer to change over the course of the period irrespective of intervening land-use changes. Land-use area values are as at the point in time indicated (31 December for 2013 and 1 January for 1990). Columns and rows may not total due to rounding.

Table 6.2.7 New Zealand's land-use change matrix from 2012 to 2013

2012 / 2013		Forest land			Cropland		Grassland			Wetlands		Settlements	Other land	Net area 31 Dec 2013 (kha)
		Natural	Pre-1990 planted	Post-1989	Annual	Perennial	High producing	Low producing	With woody biomass	Open water	Vegetated	Settlements	Other land	
Forest land	Natural	7,834.9												7,834.9
	Pre-1990 planted	0.1	1,437.3				0.0	0.0	0.0					1,437.5
	Post-1989			641.2	0.0	0.0	2.7	10.8	4.5		0.0		0.1	659.3
Cropland	Annual		0.0		371.3	0.4	0.1	0.0	0.0					371.8
	Perennial				0.2	103.4	0.8	0.1	0.0					104.5
Grassland	High producing	0.0	0.8	0.2	0.0	0.4	5,805.2	0.2	1.3	0.0	0.0		0.0	5,808.1
	Low producing	2.4	10.9	1.8		0.0	0.0	7,524.7	4.8	0.0	0.0		0.0	7,544.6
	With woody biomass	0.1	0.1	0.0	0.0	0.0	0.3	1.9	1,361.1	0.0			0.0	1,363.6
Wetlands	Open water	0.0		0.0	0.1	0.0	0.4	0.0	0.0	535.2	0.0		0.0	535.8
	Vegetated	0.0						0.0	0.0	0.0	145.1	0.0		145.1
Settlements	Settlements		0.0		0.0	0.0	0.2	0.1	0.0			224.4	0.0	224.7
Other land	Other land	0.0				0.0	0.1	0.1	0.1	0.0	0.0		894.7	895.0
Net area as at 31 Dec 2012 (kha)		7,836.5	1,443.0	656.3	371.8	104.3	5,808.9	7,537.7	1,366.6	535.5	145.1	224.6	894.9	26,925.2
Net change 31 Dec 2012 – 31 Dec 2013		-1.5	-5.5	3.1	0.0	0.2	-0.8	7.0	-3.0	0.3	0.0	0.1	0.1	0.0
Net change 2012–2013 (%)		0.0	–0.4	0.5	0.0	0.2	0.0	0.1	–0.2	0.1	0.0	0.1	0.0	NA

Note: Units in 000's hectares; NA = not applicable. Shaded cells indicate land remaining in each category. The minimum area shown for land-use change is 100 hectares; however, areas are mapped to 1 hectare resolution. Blank cells indicate no land-use change during the period greater than 100 hectares. Land-use change values refer to change over the course of the period. Land-use area values are as at the point in time indicated (31 December for 2012 and 2013.) Columns and rows may not total due to rounding.

6.2.4 Methodological change

The 2012 land-use map was developed using a similar methodology to the earlier 1990 and 2008 land-use maps. The process for detecting change in satellite imagery between 2008 and 2012 used an enhanced multi-date segmentation approach described in Shepherd et al (2013).

Previous submissions included a range of approaches to annual deforestation mapping. For 2008 and 2009 deforestation reporting, wall-to-wall mapping was completed using DMC 22-metre resolution satellite imagery. For 2010, only a partial mapping of deforestation across New Zealand was completed using 10-metre resolution SPOT satellite imagery, with the remaining area of unmapped deforestation estimated based on trends from earlier years. No deforestation mapping was undertaken for 2011, given that the two-year national image acquisition programme for the 2012 land-use map commenced in October 2011.

Following completion of the 2012 land-use map using 10-metre resolution SPOT satellite imagery, deforestation mapping for 2008 to 2011 was updated. The method used to map deforestation between 2008 and 2012 built on techniques developed for earlier deforestation mapping projects. The improved resolution of the SPOT satellite imagery, when compared with the last national coverage of DMC 22-metre resolution data, allowed more deforestation to be identified in 2008 and 2009. It has also completed the coverage of 2010 deforestation mapping, which had only partial coverage of New Zealand, and provided mapping for 2011 and 2012.

The introduction of a third mapping date has added complexity to the interpolation process that is used to derive annual land-use change estimates. Previous submissions were based on interpolations between the activity data derived from the 1990 and 2008 mapping, and an extrapolation for the reporting years after 2007. Now that activity data from the 2012 land-use map is available, a second interpolation process is used to derive annual land-use change estimates for the years 2008 to 2012.

The addition of activity data for the 2013 year has seen a return to the extrapolation approach used between 2008 and 2011 to infer annual activity data beyond the last available mapping date.

A new element added to the annual mapping process this year is the review of four-year-old areas of awaiting land. These are forested areas that were destocked more than four years ago and where the future land use was uncertain, that is, they may be replanted and therefore remain in a forestry land use or they may undergo land-use change and therefore be reclassified into another land use. New Zealand has elected a period of four years in which to make a final determination of future land use of these areas. Therefore, areas destocked in 2009 were reviewed for this inventory and those that were not replanted, or regenerating, were reclassified into a non-forest land use. A new national SPOT-6 satellite image mosaic, with a ground resolution of 1.5 metres, captured in the summers of 2012/13 and 2013/14 was used for this activity, along with recent aerial photography, where available. More information on awaiting land can be found in section 11.4.3.

6.2.5 Uncertainties and time-series consistency

In 2014, an accuracy assessment was completed for the 2012 land-use map. A stratified random sample of 2000 points was made, and the land-use classification was independently assessed at each point location. SPOT-6 natural colour 1.5 metre resolution imagery was used as the reference data source. This imagery met the criteria for a reference data source, having better resolution than the SPOT-5 10 metre resolution imagery used to create the 2012 land-use map and being acquired over a similar time period.[36]

The overall map accuracy was found to be 95.2 per cent (Poyry Management Consulting (NZ) Ltd, 2014). The user and producer accuracies for the three forest classes were all over 94 per cent. For both pre-1990 natural and planted forests, the total mapped area fell within the 95 per cent confidence interval of the total class area as determined by the accuracy assessment. In the case of post-1989 forest, the mapped area was 2.9 per cent lower than the accuracy assessment area, placing it just outside the 95 per cent confidence interval of 2.04 per cent.

Non-forest land uses generally had user and producer accuracies over 90 per cent. Exceptions to this were *Wetlands* and grassland with woody biomass, with producer accuracies of 85 per cent and 56 per cent respectively. In the case of the *Wetlands* class, there was a small amount of confusion between vegetated wetland and grassland with woody biomass, with the wetland class being slightly under-mapped. These two classes are sometimes difficult to distinguish in imagery where the extent of flooding varies seasonally. The grassland with woody biomass class appears to be more substantially under-mapped, with accuracy assessment operators identifying areas of *Grassland* that should have been mapped as grassland with woody biomass. This is also a difficult judgement call, because the boundary between areas of *Grassland* and grassland with woody biomass can be hard to define.

6.2.6 Quality assurance/quality control (QA/QC) and verification

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, consistent with GPG-AFOLU (IPCC, 2006a) and New Zealand’s inventory quality-control and quality-assurance plan. Data quality and data assurance plans are established for each type of data used to determine carbon stock and stock changes, as well as for the mapping of the areal extent and spatial location of land-use changes.

The 1990, 2008 and 2012 land-use mapping data have been checked to determine the level of consistency in satellite image classification with the requirements set out in *Land Use and Carbon Analysis System: Satellite imagery interpretation guide for land-use classes* (Ministry for the Environment, 2012).

The quality-control checks performed on the 1990 and 2008 land-use maps included checking approximately 28,000 randomly selected points in the 1990 and 2008 woody classes. These were evaluated by independent assessors. In this exercise, independent assessors agreed with the original classification 91 per cent of the time. Where there was disagreement, the points were recorded in a register and this was used to plan improvements to the 1990 and 2008 land-use maps. These improvements have now been completed.

Two distinct quality-control checks were performed on the 2012 land-use map. The first of these checked every polygon where land-use change had occurred from a non-forest land use between 2008 and 2012. The acceptance criterion for this check was that the land-use classification had to be correct at both mapping dates at least 90 per cent of the time, that is, the land use at the start of the land-use change event and at the end of the land-use change event had to both be correct. The second quality-control check was to check the accuracy of destock detection in areas that were in a forest land-use at 2008. Sampling for this check was designed to test that at least 90 per cent of the destocking

[36] The SPOT-6 natural colour 1.5 metre resolution imagery was acquired in the summers of 2012/13 and 2013/14 making it generally one year later than the SPOT-5 multi-spectral 10 metre resolution imagery used to create the 2012 land-use map.

had been detected at the 95 per cent confidence level. Checks were completed on each of the 16 regions of New Zealand individually and all regions passed. A total of 14,443 points were checked during this process.

These quality-control checks do not determine errors of omission and/or commission that would provide an accuracy assessment and definitive level of uncertainty.[37] An accuracy assessment is planned for mid-2014.

Each mapping improvement activity carried out on the 1990 and 2008 maps has been subjected to quality-assurance checks to ensure accuracy and consistency. Quality-assurance strategies have been tailored to each improvement activity, usually including a combination of random sampling of updated areas and analysis of the changes in land-use areas.

As part of the 2012 land-use mapping process, data from the NZ ETS was reconciled with the 1990, 2008 and 2012 land-use maps. The NZ ETS data contains pre-1990 and post-1989 forest boundaries as submitted by forest owners and verified by the Ministry for Primary Industries. The NZ ETS forest areas were checked against the land-use maps. Where mapping differences were identified, these areas were assessed against satellite imagery and the LUCAS forest land-use definitions to determine whether the 1990, 2008 and/or 2012 land-use map should be changed. After integration, quality-assurance checks were performed to ensure that updates to the 1990 and 2008 land-use maps were accurate and completed.

Quality assurance of the 2008–2012 deforestation mapping activity was a multi-stage process. The contractor undertook initial quality assurance by cross-checking operator interpretation of oblique aerial photography acquired from light aircraft (figure 6.2.5). All areas of mapped deforestation were then visually checked by LUCAS analysts to verify both the deforestation decision and the original mapped land use.

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

6.2.7 Planned improvements

The NZ ETS provides an ongoing source of mapping information on forest extent and age along with limited information on deforestation activity. This will be used as part of a continuous improvement programme to update the 1990, 2008 and 2012 land-use maps.

In order to build a stronger evidence base for the mapping of areas of post-1989 regenerating natural forest, a set of reference maps will be compiled including information such as conservation and protection status, participation in forestry planting schemes, ownership and land-use potential (eg, areas of steep erodible land designated for erosion control planting by regional councils). These evidence maps will be used to review areas currently mapped as post-1989 regenerating forest. Where evidence is insufficient to support a regenerating forest classification, the area will be reclassified as grassland with woody biomass.

6.3 Soils

In this submission, New Zealand uses a Tier 2 method to estimate soil carbon changes in mineral soils and follows the Tier 1 approach for organic soils.

37 An error of commission is where a particular class has been mapped incorrectly, for example, as a result of similarities in spectral signatures; an error of omission is where mapping has failed to detect a particular land use, for example, a planted forest block visible in imagery.

6.3.1 Mineral soils

New Zealand's Tier 2 method for mineral soils involves estimating steady state soil organic carbon (SOC) stocks for each land use based on New Zealand soil data (described in more detail below). Changes in soil carbon stocks associated with land-use change are calculated according to the IPCC default method (IPCC, 2006a) using the equation:

$$\Delta C = [(SOC_0 - SOC_{(0\text{-}T)})/20] \times A \qquad (3)$$

Where:

ΔC = change in carbon stocks (tonnes (t))

SOC_0 = Stable SOC stock in the inventory year (tonnes C ha^{-1})

$SOC_{(0\text{-}T)}$ = Stable SOC stock T years prior to the inventory year (tonnes C ha^{-1})

A = land area of parcels with these SOC terms (hectare)

20 = default SOC stock transition period (year)

The SOC stock for each land use is characterised with country-specific data via the Soil Carbon Monitoring System (Soil CMS) model (McNeill et al, 2013, McNeill and Barringer, 2014**)**. The correct operation of the Soil CMS model involves fitting the model to the soil carbon data set and then using the coefficients for the different land-use classes for each land-use transition (equation 3). The interpretation of the different land-use effects is informed by multi-comparison significance.

Characterising SOC stocks: New Zealand's Soil Carbon Monitoring System

Unbiased estimates of SOC stocks associated with each land use in New Zealand are calculated by using country-specific data in the Soil CMS model. The operation of the Soil CMS model to produce SOC pool estimates involves applying a linear statistical model to key factors of land use, climate and soil class, which together regulate net SOC storage. The model also includes an additional environmental factor consisting of the product of slope and rainfall (hereafter, slope × rainfall) – a term used as a proxy for erosivity, the potential for surface soil erosion to occur (Giltrap et al, 2001).

The key concept in the operation of the Soil CMS model is the premise that land use affects SOC on decadal time scales (Baisden et al, 2006b). Therefore, estimates must be reported grouped by specified land-use classes. The model allows for an explanatory effect by land-use class, so that estimates grouped by land use are unbiased where a specific land-use class has an effect significantly different from the pooled soil carbon value from all land-use classes. In addition, where some land-use classes have such an effect, incorporating land use as an explanatory variable reduces the overall residual standard error in soil carbon (McNeill and Barringer, 2014).

Soil C linear parametric model

The generalised least squares (GLS) model used for the Soil CMS is a minimum variance unbiased estimator (Draper and Smith, 1998) so the soil C values, and the soil C changes as a result of a land-use transition, are unbiased. This approach is consistent with the physically based soil C model outlined in the literature (Baisden et al, 2006b; Kirschbaum et al, 2009; Scott et al, 2002; Tate et al, 2005).

The GLS regression model for soil C in the 0–30-centimetre layer uses explanatory variables of the soil–climate factor, the land-use class and slope × rainfall. This model is represented as an equation for the soil carbon $C_{i,j}^{0-30cm}$ in land-use class i and soil–climate class j as:

$$C_{i,j}^{0-30cm} = M + L_i + S_j + b.SR + \varepsilon \qquad (4)$$

In equation (4), $C_{i,j}^{0-30cm}$ is the mean soil carbon in the 0–30-centimetre layer for the combination of the reference level of land use (low producing grassland), M is the reference level for soil–climate (moist temperate – high activity clay) and level ground. L_i is the effect of the i-th land use, specifying the difference in soil carbon relative to the reference land use (low producing grassland), in tonnes per hectare (t/ha). S_j is the effect of the j-th soil–climate class relative to the reference level, and b is the additional soil carbon for each unit of erosivity (slope × rainfall), or SR (millidegree $\times\ 10^{-1}$). The model uncertainty is encapsulated in ε.

The quantities M, L_i, S_j, as well as the slope × rainfall coefficient b, are obtained by fitting a statistical model to the Soil CMS calibration data set; all other quantities are obtained from other data sets or from separate analyses (McNeill and Barringer, 2014). For example, the mean value of the slope × rainfall must be obtained from national statistics of rainfall and a terrain slope map, which has been calculated from geographic information system (GIS) layers (Giltrap et al, 2001).

More elaborate alternatives to the model have been considered but were not found to be significantly better than the simple model given in equation 4 above (McNeill and Barringer, 2014).

Soil data sets

Soil data for the Soil CMS inventory model comes from five sources.

Historic Soils: The Historic Soils data set is derived primarily from the National Soils Database (NSD), with a small number of samples from various supplementary data sets; data were collected between 1935 and 2005. The NSD represents soil profile data for over 1,500 soil pits scattered throughout New Zealand. These data contain the soil description following either the *Soil Survey Method* (Taylor and Pohlen, 1962) or *Soil Description Handbook* (Milne et al, 1995), as well as physical and chemical analyses from either the Landcare Research Environmental Chemistry Laboratory or the Department of Scientific and Industrial Research (DSIR) Soil Bureau Laboratory. This data set was collated as the first stocktake of available soil data for national greenhouse gas reporting and, as such, underwent substantial quality-assurance and quality-control checks (Baisden et al, 2006b; Scott et al, 2002; Tate et al, 2005).

Natural Forest Soils: These data were gathered between 2001 and 2007 as part of the Natural Forest Survey, with soil subsampled on a regular 8-kilometre grid across the country (Garrett, 2009). The Natural Forest Soils were important in the development of the Soil CMS model as they provide spatial balancing in areas of New Zealand not adequately covered by the historic soils data set.

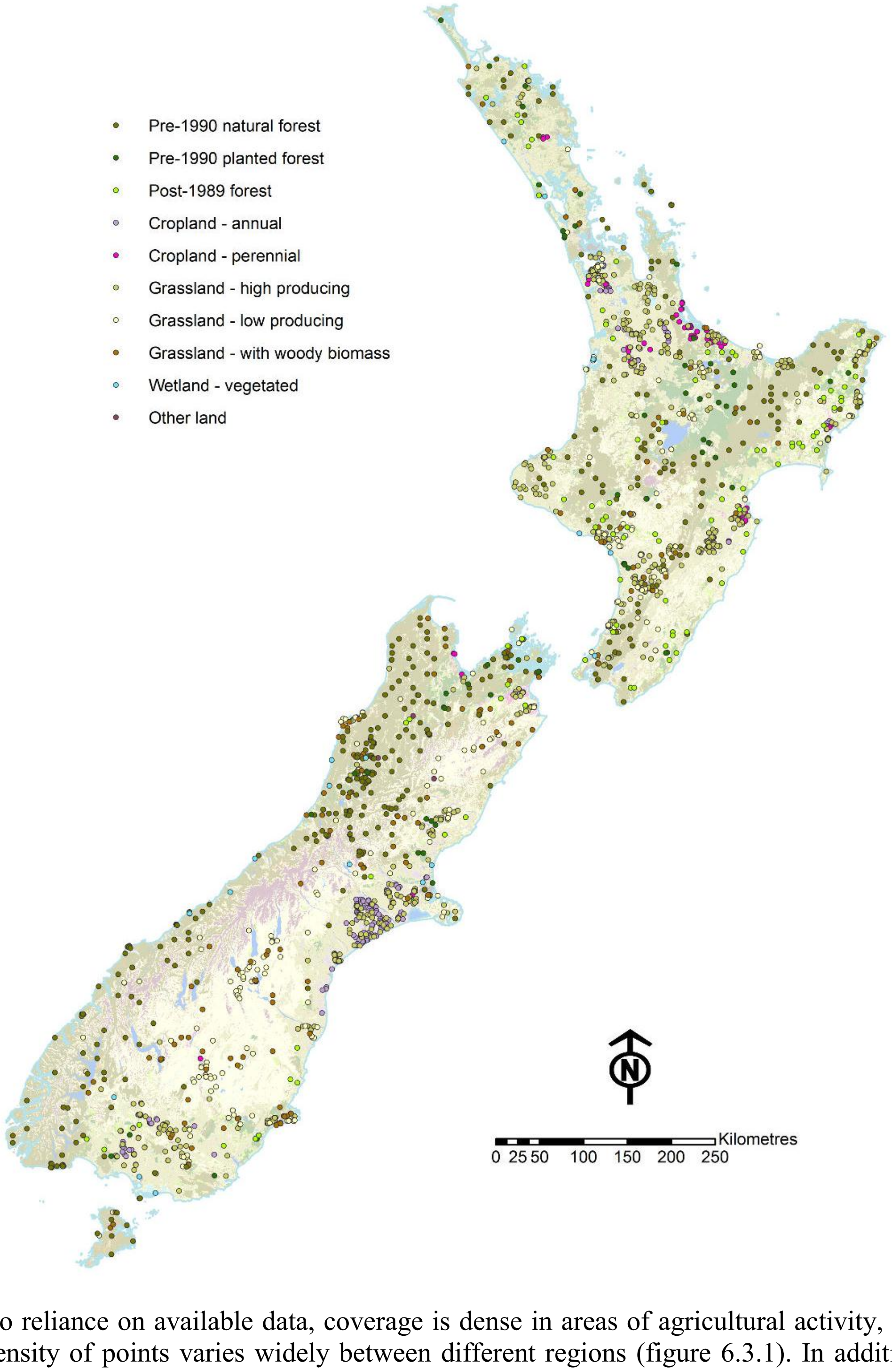
Cropland data set: The third source of data originated as a set of intensively spatially sampled high producing grassland, annual cropland and perennial cropland records collected for other purposes, referred to as the Cropland data set (Lawrence-Smith et al, 2010).

Wetland: The fourth source of data comprises *Wetland* soil data from a recent research effort to combine field data with analysis of the spatial distribution of current wetlands in New Zealand (Ausseil et al, 2013). This resulted in the addition of 21 *Wetland* mineral soil samples to the Soil CMS data set (McNeill et al, 2014).

Post-1989 forest data: This data set was added to the analysis in 2014. It contains data collected specifically for United Nations Framework Convention on Climate Change (UNFCCC) reporting from 90 post-1989 forest sites across New Zealand (Interpine Forestry Limited, 2014; Basher et al, 2014).

Together, the five combined data sets cover most of New Zealand (figure 6.3.1), including Stewart Island, although coverage does not extend to the Chatham Islands and other offshore islands.

Figure 6.3.1 Soil samples in Soil CMS model calibration data set



Due to reliance on available data, coverage is dense in areas of agricultural activity, and the density of points varies widely between different regions (figure 6.3.1). In addition, types of land use vary geographically: some are widespread (eg, high producing grassland), whereas others are spatially constrained (eg, *Cropland*), so that the number of soil samples needed varies according to land-use category (McNeill et al, 2013).

There is a wide variation in the number of records associated with the different land-use classes and soil orders, with the largest land use (high producing grassland) having

767 samples and the smallest (*Other land*) only three samples. Thus, it would be reasonable to expect that there will also be considerable variability in the uncertainty of the estimated land-use effect for each of the different land-use classes, assuming all other things are equal.

Two of the 12 land-use categories were not used in the model due to lack of soil carbon data: open water (assumed 0, by definition) and *Settlements* (assumed to be the same as the low producing grassland as no data was available for this land-use category).

Ancillary data

S-map: S-map is a contemporary digital soil spatial information system for New Zealand (Lilburne et al, 2012), which provides the best-available knowledge of the classification of the soil order consistent with the *New Zealand Soil Classification* (Hewitt, 1998). S-map coverage is not available for all the land area, as its focus is on regions of intensive agricultural use.

Fundamental Soils Layer: Where S-map was unavailable, data from the Fundamental Soils Layer (FSL) was used instead. FSL provides GIS information on the classification of soil order and other soil or landscape attributes over New Zealand. It is generated from the NZLRI and NSD. FSL provides GIS information on the expert-assessed classification of soil order and other soil or landscape attributes over New Zealand.

Topographic information: Topographic slope information was estimated from a digital elevation model generated from Land Information New Zealand 1:50,000 scale topographic data layers, including 20-metre contours, spot heights, lake shorelines and coastline.

Land-use effects: Characterising soil carbon stocks

The 2014 version of the Soil CMS model used in this report builds on previous model versions (McNeill and Barringer, 2014). The ‘land-use effect’ (LUE) denotes the influence of land use on soil carbon stocks and corresponds to the model coefficients calculated for each land-use category. The land-use effect for a transition from low producing grassland to one of the other land-use classes can be obtained by using the coefficients of the soil C model (table 6.3.1). SOC stocks for each land use are derived from the land-use effect coefficient in relation to the intercept (the reference of low producing grassland on high activity soils in a moist temperate climate (table 6.3.1). These values are used in equation (3) (as SOC_0 and $SOC_{(0\text{-}T)}$) to calculate soil carbon changes due to land-use change.

Table 6.3.1 Land-use effect coefficients with standard errors, *t*-values, and corresponding *p*-value significance estimates, extracted from full model results

Subcategory	Value	Standard error	*t*-value	*p*-value
Intercept: Low producing grassland	105.98	3.96	26.79	0.000
High producing grassland	–0.64	3.13	–0.21	0.837
Grassland with woody biomass	–7.75	3.68	–2.11	0.0350
Perennial cropland	–17.54	6.37	–2.76	0.0059
Annual cropland	–16.21	4.45	–3.64	0.0003
Vegetated wetland	30.08	8.53	3.52	0.0004
Pre-1990 planted forest	–13.54	5.78	–2.34	0.0193
Post-1989 planted forest	–14.06	4.86	2.90	0.0038
Pre-1990 natural forest	–13.73	3.70	–3.71	0.0002
Other land	–47.61	21.05	–2.26	0.0238

Source: McNeill and Barringer, 2014.

Note: The model intercept (estimate for low producing grassland) is used for settlements and open water due to lack of data.

Table 6.3.2 Soil organic carbon stocks, with 95 per cent confidence intervals, calculated from Soil CMS model (v. 2014)

Subcategory	Steady state carbon SOC stock (t)	95% confidence intervals (CI)	
		2.5% CI SOC stock (t)	97.5% CI SOC stock (t)
Pre-1990 natural forest	92.25	84.99	99.51
Pre-1990 planted forest	92.44	81.12	103.77
Post-1989 forest	91.92	82.40	101.44
Grassland with woody biomass	98.23	91.02	105.43
High producing grassland	105.34	99.21	111.47
Low producing grassland	105.98	98.23	113.73
Perennial cropland	88.44	75.96	100.92
Annual cropland	89.77	81.04	98.49
Open water	105.98	98.23	113.73
Vegetated wetland	136.06	119.33	152.78
Settlements	105.98	98.23	113.73
Other land	58.37	17.12	99.62

The residual standard error (RSE) for the model is 41.3 t/ha, and the corrected Akaike information criterion value (AICc) is 21,044.2. The spatial autocorrelation scale distance is 18.1 kilometres, with a nugget of 0.47. A correction for spatial correlation is necessary as the samples are located close to one another rather than evenly spread throughout New Zealand (as land use is not even throughout New Zealand). These are values consistent with earlier analyses (McNeill, 2010, 2012). The use of the AICc as a model selection and comparison mechanism is widely supported in the literature in general, and soil modelling specifically (Burnham and Anderson, 2002; Elsgaard et al, 2012; Ogle et al, 2007).

Measures of statistical validity: Assessing significant differences among SOC stocks

As noted in the model results, two of the land-use effect coefficients are not significant (table 6.3.1). The land-use effect of high producing grassland has not been detected as significantly different from the reference low producing grassland. The land-use effect for the other land category is also not significant.

The uncertainty of the land-use effect (the change in soil C, assuming the transition is stable) between two land-use classes in isolation is conceptually straightforward: two estimates of land-use effect are more likely to be significantly separated if their point estimates are farther apart after taking account of the covariance between the two land-use effects. The standard error $\sigma_{i,j}$ of the LUE change for a transition between two land-use classes with effects L_i and L_j is then estimated from:

$$\boldsymbol{\sigma_{i,j} = \sqrt{Var\,(L_i) + Var\,(L_j) - 2.Cov\,(L, L_j)}} \quad (5)$$

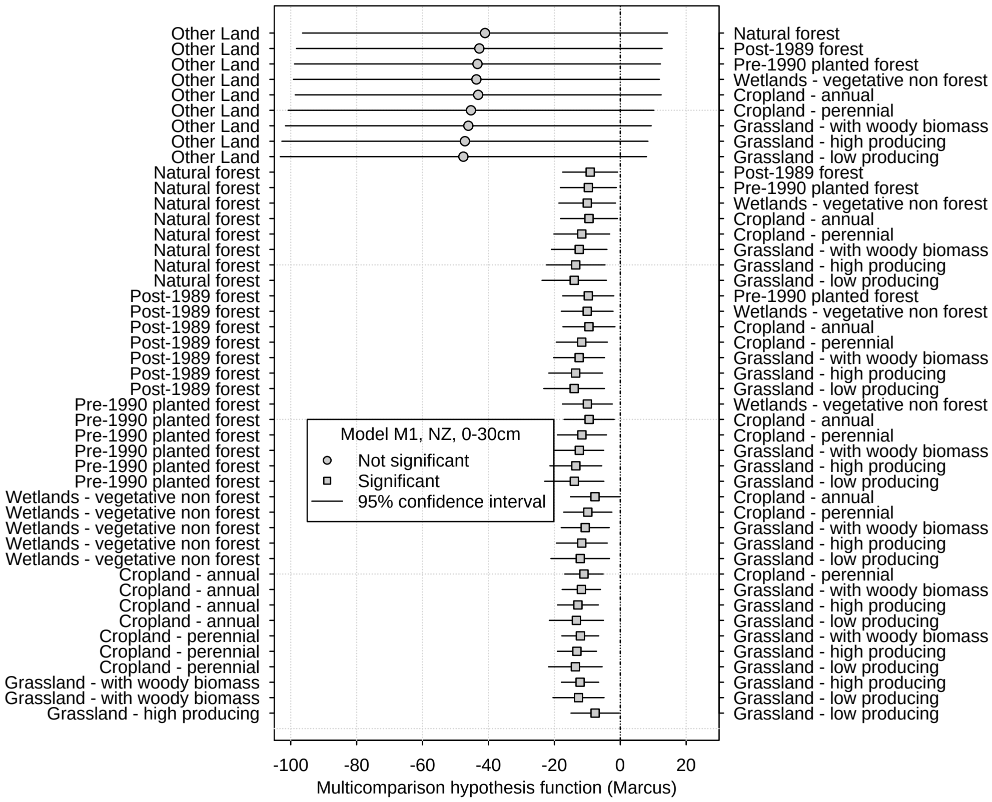
where $Var(L_i)$ is the variance of land-use effect i, and $Cov(L_i, L_j)$ is the covariance between land-use effects L_i and L_j (McNeill et al, 2013, 2014; McNeill and Barringer, 2014).

Although equation (5) provides a mathematically straightforward way to estimate the significance of a single transition from one land-use class to another (a comparison-wise significance), it is often desirable to be able to determine whether a number of land-use classes are likely to be significantly different or essentially the same as an ensemble. As more comparisons are made between many different land-use types, it becomes more likely that at least one of the land-use effect changes will be different as a result of random chance alone, resulting in an increase in the Type 1 error. Thus, the significance of all possible land-use transitions must be calculated as a family of simultaneous comparisons (multiple comparison significance), rather than one at a time (McNeill and Barringer, 2014).

To control the Type 1 error rate in multiple comparison significance testing for the soil C change model, all possible combinations of the land-use classes were tested for equality (a two-sided test) simultaneously. For the Soil CMS model (v. 2014) (McNeill and Barringer, 2014), a closed testing procedure test described by Marcus et al (1976) was used, which is a general method for performing a number of hypothesis tests simultaneously implemented in the multi-comparison package in R (Bretz et al, 2010).

The closed testing procedure described by Marcus et al (1976) yielded point estimates and confidence intervals of a test statistic for each distinct combination of land-use transitions, and the critical test is whether the confidence intervals brace zero. All land-use transition pairs were significant, except those involving other land (figure 6.3.2).

Figure 6.3.2 Result of applying Marcus' multi-comparison test to the adopted model



Source: McNeill and Barringer, 2014.

Note: The marker is the estimated value for the specified transition to indicate significance, and the error bars represent the 95 per cent confidence interval of the test statistic. Land-use transitions with point estimates and confidence intervals marked with a grey square are considered highly significant differences within the set of all possible land-use transitions.

These land-use transition pairs contribute relatively little to land-use induced carbon change calculations. All land-use transitions involving other land make up approximately 0.04 per cent of all land-use change detected between 1990 and 2013.

It is important to note that this interpretation of significance does not alter the method of calculation of the soil C change as a result of land-use transition. In particular, it would not be correct to substitute a value of zero for the effect of a land-use transition where the transition itself is not significant in the multi-comparison sense, because, if such a substitution were to be carried out, the calculation of the soil C would no longer be unbiased. Avoiding the bias in this manner also reduces the residual uncertainty of the soil C estimates. For this reason, the effect of all land-use transitions ought to be included in calculations of soil C change (McNeill et al, 2014; McNeill and Barringer, 2014).

6.3.2 Organic soils

Organic soils occupy a small proportion of New Zealand's total land area (0.9 per cent), and the area of organic soils subject to land-use change is approximately 0.01 per cent of New Zealand's total land area. New Zealand uses a Tier 1 method to estimate soil carbon stock change in organic soils.

The definition of organic soils is derived from the *New Zealand Soil Classification* (Hewitt, 1998), which defines organic soils as those soils with at least 18 per cent organic carbon in horizons at least 30 centimetres thick and within 60 centimetres of the soil surface. New Zealand-specific climate and soil data is used to estimate the areas of organic soil found in each climate zone. Climate data is based on the temperature data layer of the Land Environments New Zealand (LENZ) classification (Leathwick et al, 2002). Soil-type data is based on the FSL associated with the NZLRI (Newsome et al, 2000) and converted to the IPCC classification (Daly and Wilde, 1997). These data layers have been analysed in a GIS system to determine the areas of organic soils in warm and cold climatic zones. These areas are compared with the land use to determine the area of organic soils in each land-use category.

The LULUCF organic soils definition is the same as that used for reporting under the Agriculture sector (Dresser et al, 2011).

New Zealand has used IPCC default emission factors for organic soils under *Forest land*, *Grassland* and *Cropland* (IPCC, 2003) to estimate organic soil emissions (table 6.3.3). IPCC guidance for organic soils under forest is limited to estimates associated with the drainage of organic soils in managed forests. In New Zealand, natural forests are not drained and therefore the default emission factor is not applicable. It is assumed that all planted forests on organic soils are drained prior to forest establishment. The warm temperate and cold temperate defaults for *Grassland* and *Cropland* are applied in proportion to the area of land in New Zealand where the mean annual temperature is above or below 10°C, respectively. There are no default emission factors for organic soils under *Settlements*, *Wetlands* or *Other land*; therefore, emissions from organic soils under these land uses are not estimated.

Table 6.3.3 New Zealand emission factors for organic soils

Land use	Climatic temperature regime	IPCC Tier 1 default emission factor applied and ranges (t C $ha^{-1}yr^{-1}$)	Reference
Pre-1990 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 and post-1989 planted forest	Temperate	0.68 (range 0.41–1.91)	IPCC (2003), section 3.2.1.3, table 3.2.3
Cropland	Cold temperate Warm temperate	1.0 ± 90% 10.0 ± 90%	IPCC (2003), section 3.3.1.2, table 3.3.5
Grassland	Cold temperate Warm temperate	0.25 ± 90% 2.5 ± 90%	IPCC (2003), section 3.4.1.2, table 3.4.6
Wetlands	NA	NE	IPCC guidance applies only to peat extraction, which is not a significant activity in New Zealand. IPCC (2003), section 3.5.2.1
Settlements	NA	NE	No IPCC guidance is available. IPCC (2003), chapter 3.6
Other land	NA	NE	No IPCC guidance is available. IPCC (2003), chapter 3.7

Note: NA = not applicable; NE = not estimated.

6.3.3 Uncertainties and time-series consistency

Mineral soils

For the most part, uncertainties associated with the model coefficients (table 6.3.2) are substantially reduced from the Tier 1 default value of 95 per cent. Those land-use categories with higher uncertainties are those with few data points, such as other land, or are dominant land uses in the country and thus occur across a wide range of environmental factors, such as high producing grassland.

Uncertainties also arise from lack of soil carbon data for some soil, climate and land-use combinations (Scott et al, 2002), and from variations in site selection, sample collection and laboratory analysis with data from different sources and time periods (Baisden et al, 2006b). Other uncertainties in the Soil CMS include: the assumption that soil carbon reaches steady state in all land uses and the 20-year linear transition period to reach it; lack of soil carbon data and soil carbon changes estimates below 0.3 metres; potential carbon losses from mass-movement erosion; and a possible interaction between land use and the soil–climate classification (Tate et al, 2004, 2005).

Organic soils

New Zealand uses the IPCC Tier 1 default value for uncertainty of organic soils under *Forest land*, *Grassland* and *Cropland* as given in IPCC 2003 (tables 3.3.5 and 3.4.6). This value is 90 per cent.

Further detail on uncertainty for each land-use category is discussed in the appropriate category sections.

The same method is used for all years of reporting to ensure time-series consistency.

6.3.4 Source-specific QA/QC and verification

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, to be consistent with GPG-AFOLU (IPCC, 2006a) and New Zealand's inventory quality-control and quality-assurance plan.

- Details of the quality-management system for data collection, laboratory analyses and database management of the NSD are given in Wilde (2003).
- Recent data collection, analyses and management methods are subject to the soils quality-control and quality-assurance plan.
- The consolidated soils data set used within the Soil CMS has been subject to further quality-assurance procedures (Fraser et al, 2009).

The Soil CMS model has been subject to various forms of testing, validation and recalibration. Testing of the Soil CMS was completed to evaluate its ability to predict soil carbon stocks at regional and local scales. The results from the Soil CMS have been compared against independent, stratified soil sampling for South Island low producing grassland (Scott et al, 2002) and for an area of the South Island containing a range of land-cover and soil-climate categories (Tate et al, 2003a, 2003b). A regional-scale validation exercise has also been performed using the largest climate–soil–land-use combination cell (moist temperate – volcanic × high producing grassland), within dependent random sampling of 12 profiles taken on a fixed grid over a large area (2,000 square kilometres). Mean values derived from the random sampling were well within the 95 per cent confidence limits of the database values (Tate et al, 2005; Wilde et al, 2004). A second study validated the Soil CMS model for a different cell, dry temperate – high-activity clay – low producing grassland, finding no significant differences among field data, calibration data and model estimates (Hedley et al, 2012). Overall, tests have indicated that the Soil CMS estimates soil carbon stocks reasonably well at a range of scales (Tate et al, 2005).

The system has also been validated for its ability to predict soil carbon changes between land uses at steady state for New Zealand's main land-use change, *Grassland* converted to planted forest. This was done by comparing the Soil CMS results with estimates based on paired sites (Baisden et al, 2006a; Tate et al, 2003a). This validation approach compares two nearby sites that have reasonably uniform morphological properties and were previously under a single land use, for which one site has changed to a different land use and sufficient time has elapsed for it to reach steady state values for soil carbon

(Baisden et al, 2006a, 2006b). This removes the influence that differing soil types, climatic conditions and previous land-use regimes may have on soil carbon. Therefore, any resulting changes in soil carbon can be attributed to the most recent change in land use. In one study, results indicated that, once a weighting for forest species type was applied to the paired-site data set (to remove potential bias because *Pinus radiata* was under-represented in the analysis), the predictions of mean soil carbon from the Soil CMS model and paired sites were in agreement within 95 per cent confidence intervals (Baisden et al, 2006a, 2006b). In a more recent study comparing low producing grassland and pre-1990 planted forests (Hewitt et al, 2012), the measured decrease in SOC under pre-1990 planted forest (–17.4 tonnes ha^{-1}) matched that determined by the Soil CMS model (McNeill et al, 2013). This supported the Soil CMS model estimate (both in magnitude and direction) that forests planted pre-1990 have significantly lower soil carbon stocks than the low producing grassland and that the sampling depth of 0.3 metres was adequate for the estimation of soil carbon stock change.

6.3.5 Source-specific planned improvements

New Zealand continues to pursue increasing the accuracy and reducing the uncertainty of the soil carbon stock estimates produced by the Soil CMS model. Improvement activities include data collection for under-represented land-use categories (eg, post-1989 planted forests during the 2013/14 field season), further recalibration and development of the Soil CMS model, and investigation of other modelling options.

6.4 Forest land (CRF 4A)

6.4.1 Description

In *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006), national forest definition parameters were specified as required by UNFCCC Decision 16/CMP.1. The New Zealand parameters are a minimum area of 1 hectare, a height of 5 metres and a minimum crown cover of 30 per cent. Where the height and canopy cover parameters are not met at the time of mapping, the land has been classified as *Forest land* if the land-management practice(s) and local site conditions (including climate) are such that the forest parameters will be met over a 30- to 40-year timeframe.

New Zealand also uses a minimum forest width of 30 metres from canopy edge to canopy edge. This removes linear shelterbelts from the *Forest land* category as they are not on land managed as forest. The width and height of linear shelterbelts can vary, because they are trimmed and topped from time to time. Further, they form part of non-forest land uses, namely *Cropland* and *Grassland* (as shelter to crops and/or animals).

New Zealand has adopted the definition of managed *Forest land* as provided in the GPG-AFOLU (IPCC 2006a, page 1.5): "Managed land is land where human interventions and practices have been applied to perform production, ecological or social functions". Accordingly, all of New Zealand's forests, both those planted for timber production and natural forests managed for conservation values, are considered managed forests. However, emissions from harvested wood products are now addressed independently (see section 6.10).

Forest land is the most significant contributor to carbon stock changes in the LULUCF sector. In 2013, forests covered 36.9 per cent (just under 10 million hectares) of New Zealand's total land area. In 2013, *Forest land* contributed –23,409.5 kt CO_2-e of net emissions. This does not include emissions for the harvested wood products pool as these are reported separately within CRF Reporter. The harvested wood products pool and calculation of emissions for this are discussed in section 6.10.

Net emissions from *Forest land* have increased by 4,847.3 kt CO_2-e (17.2 per cent) on the 1990 level of –28,256.8 kt CO_2-e (table 6.4.1).

In 2013, *Forest land remaining forest land* and *Land converted to forest land* were key categories (trend and level assessment).

Table 6.4.1 New Zealand's land-use change for the forest land category, and associated CO_2-equivalent emissions, in 1990 and 2013

Land-use category	Net area in 1990 (ha)	Net area in 2013 (ha)	Change from 1990 (%)	Net emissions (kt CO2-e) 1990	Net emissions (kt CO2-e) 2013	Change from 1990 (%)
Forest land remaining forest land	8,572,275	9,139,776	+6.6	–9,521.3	–2,110.5	–77.8
Land converted to forest land	857,972	792,025	–7.7	–18,735.6	–21,299.0	+13.7
Total	**9,430,246**	**9,931,801**	**+5.3**	**–28,256.8**	**–23,409.5**	**–17.2**

Note: 1990 and 2013 areas are as at 31 December. Net area values include land in a state of conversion (due to land-use change prior to 1990) and afforestation since 1990. Net emission estimates are for the whole year indicated. Columns may not total due to rounding.

For Climate Change Convention and Kyoto Protocol reporting for *Forest land*, New Zealand uses three *Forest land* subcategories: pre-1990 natural forest (predominantly native forest), pre-1990 planted forest (predominantly *Pinus radiata*) and post-1989 forest (natural and planted forests established after 31 December 1989). The definitions used for mapping these land-use subcategories are given in table 6.2.2.

Table 6.4.2 shows land-use change by forest subcategory since 1990 and the associated CO_2 emissions from carbon stock change only (excludes non-carbon emissions).

Table 6.4.2 New Zealand's land-use change for the forest land subcategories, and associated CO_2 emissions from carbon stock change, in 1990 to 2013

Land-use category	Net area in 1990 (ha)	Net area in 2013 (ha)	Change from 1990 (%)	Net emissions (kt CO_2 only) 1990	Net emissions (kt CO_2 only) 2013	Change from 1990 (%)
Pre-1990 natural forest	7,894,225	7,834,943	–0.8	–6,360.2	-6,150.4	-3.3
Pre-1990 planted forest	1,521,344	1,437,525	–5.5	–22,219.9	–276.9	–98.8
Post-1989 forest	14,678	659,332	+4,391.9	97.7	–17,146.6	–17,653.0
Total	**9,430,246**	**9,931,801**	**+5.3**	**–28,482.4**	**-23,573.9**	**-17.2**

Note: 1990 and 2013 areas are as at 31 December. Net area values include land in a state of conversion to forest (due to land-use change prior to 1990) and afforestation since 1990. Net emission estimates are for the whole year indicated. Columns may not total due to rounding. Emissions associated with the conversion of forest to other land uses are reported in the land-use category the land is converted to.

Table 6.4.3 shows New Zealand's carbon stock change by carbon pool within the *Forest land* category from 1990 to 2013. From 1990 to 2013, the total carbon stock stored in *Forest land* had increased by 194,373.4 kt C, equivalent to emissions of –712,702.4 kt CO_2 since 1990.

Table 6.4.3 **New Zealand's net carbon stock change by carbon pool for the forest land category from 1990 to 2013**

Forest land subcategory	Net carbon stock change 1990–2013 (kt C): Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2013 (kt CO_2)
Pre-1990 natural forest	38,929.3	2,077.0	–145.4	40,860.9	–149,823.3
Pre-1990 planted forest	78,564.1	15,122.7	–4,101.9	89,584.8	–328,477.8
Post-1989 forest	59,214.4	11,128.3	–6,415.0	63,927.6	–234,401.4
Total	**176,707.7**	**28,328.0**	**–10,662.3**	**194,373.4**	**–712,702.4**

Note: Emissions associated with the conversion of forest are reported in the land-use category the land is converted to. Columns may not total due to rounding.

Pre-1990 natural forest

Pre-1990 natural forest is the term used to distinguish New Zealand's native and unplanted (self-sown or naturally regenerated) forests that existed prior to 1990 from pre-1990 planted and post-1989 forests. The category includes both mature forest and areas of regenerating vegetation that have the potential to return to forest under the management regime that existed in 1990. Pre-1990 natural forest ecosystems comprise a range of indigenous and some naturalised exotic species. In New Zealand, two principal types of natural forest exist: beech forests (mainly *Nothofagus* species) and podocarp–broadleaf forests. In addition, a wide range of seral plant communities fit into the natural forest category where they have the potential to succeed to forest *in situ*. At present, New Zealand has just under 7.9 million hectares (29.3 per cent of land area) of pre-1990 natural forest (including these successional communities).

Pre-1990 planted forest

New Zealand has a substantial estate of planted forests created specifically for timber-supply purposes. In 2013, pre-1990 planted forests covered an estimated 1.44 million hectares of New Zealand (5.3 per cent of the total land area). New Zealand's planted forests are intensively managed and there is well-established data on the estate's extent and characteristics. Having a renewable timber resource has allowed New Zealand to protect and sustainably manage its pre-1990 natural forests. *Pinus radiata* is the dominant species, making up about 90 per cent of the planted forest area. These forests are usually composed of stands of trees of a single age class, and all forests are subject to relatively standard silvicultural management regimes.

Post-1989 forest

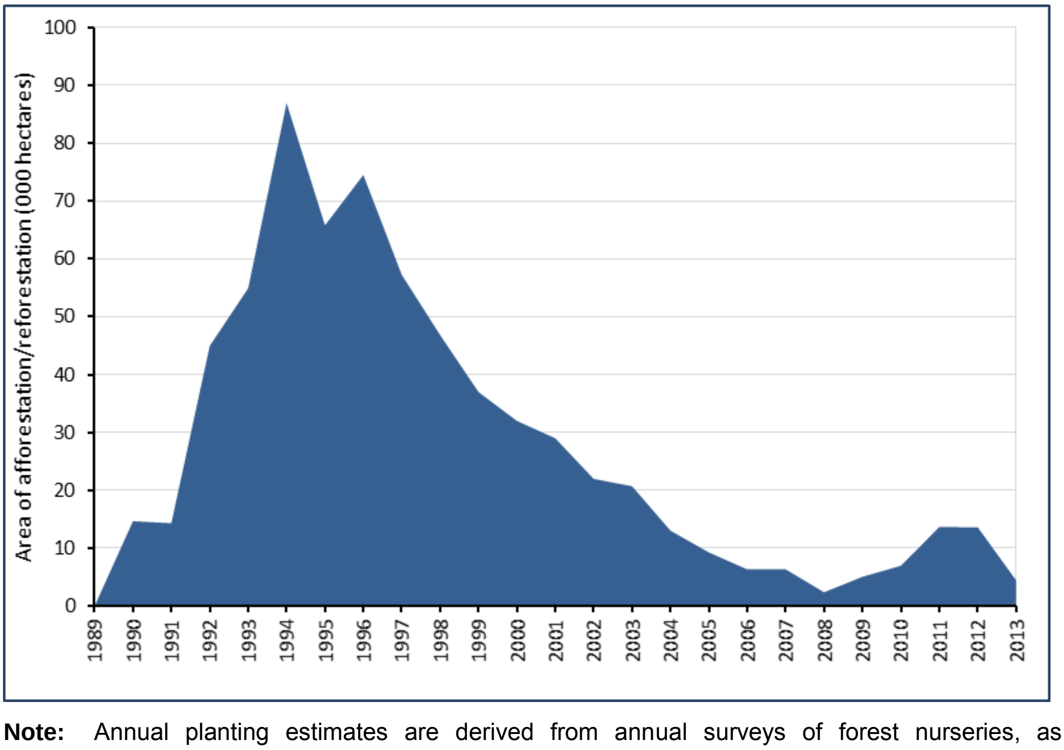
Between 1 January 1990 and 31 December 2013, the net area of forest established as a result of reforestation activities was 659,332 hectares (taking into account deforestation of post-1989 forests). It is estimated that 93 per cent of this forest subcategory is planted forest, with the remaining area comprising natural forest. *Pinus radiata* comprises 89 per cent of the planted tree species in this forest subcategory, with Douglas fir (*Pseudotsuga menziesii*) and *Eucalyptus* species making up most of the remainder (Ministry for Primary Industries, 2013a).

The new forest planting rate (afforestation) between 1990 and 2013 was, on average, 28,425 hectares per year (figure 6.4.1). New planting rates were high from 1992 to 1998 (averaging 61,618 hectares per year). This followed a change in the taxation regime, an unprecedented price spike for forest products with subsequent favourable publicity, a government focus on forestry as an instrument for regional development and the conclusion of the state forest assets sale. The removal of agricultural subsidies and the generally poor performance of the New Zealand and international share markets also encouraged investors to seek alternatives (Rhodes and Novis, 2002).

Since 1998, the rate of new planting declined, reaching an estimated low of 2,383 hectares in 2008. In 2013, it is provisionally estimated that 4,462 hectares of new plantation forest were established. This compares with around 13,600 hectares of new planting in 2011 and 2012. The increase in planting between 2008 and 2012 is largely attributable to the NZ ETS (Ministry for Primary Industries, 2011), Afforestation Grants Scheme (Ministry of Agriculture and Forestry, 2009) and Permanent Forest Sink Initiative (Ministry of Agriculture and Forestry, 2008), which have been introduced by the New Zealand Government to encourage new planting and regeneration of natural ecosystems.

There are differences in the area defined and reported as planted forest for Convention on Climate Change reporting and the area captured by the *National Exotic Forest Description* (Ministry for Primary Industries, 2013a) from which the new planting statistics are sourced. Convention on Climate Change reporting uses a gross stocked area standard, which includes forest tracks, skid sites and unstocked areas. The *National Exotic Forest Description* reports to a net stocked area standard. To account for these area differences, the net productive forest area has been identified and modelled separately. An unstocked area component is added to the new planting statistic between 2008 and 2013 to maintain consistency with the mapped area used prior to 2008. This ensures the planted forest areas used for Convention on Climate Change reporting are consistent with those reported by the Ministry for Primary Industries and time-series consistency is maintained for Convention on Climate Change reporting. The individual emission factors for the productive and unstocked areas are derived from appropriate plots in the national plot network, as described below in section 6.4.2.

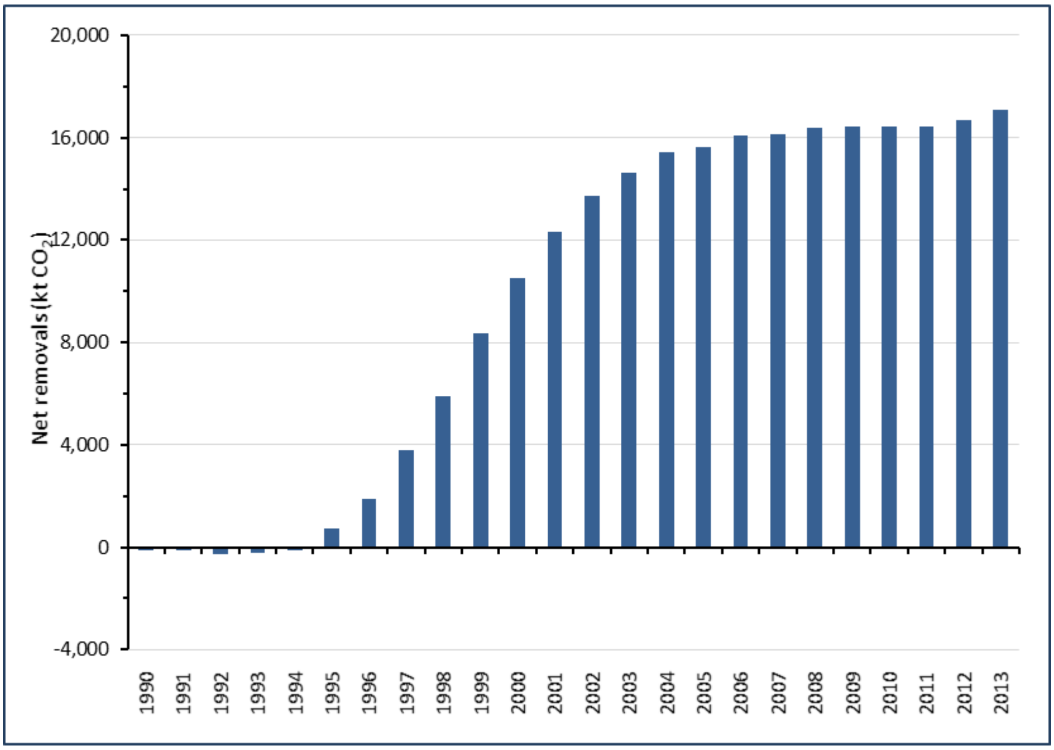
Figure 6.4.1 Annual areas of afforestation/reforestation in New Zealand from 1990 to 2013



Note: Annual planting estimates are derived from annual surveys of forest nurseries, as published in the *National Exotic Forest Description* (Ministry for Primary Industries, 2013a) and have been scaled using a ratio derived from the LUCAS mapping of post-1989 forest area.

Post-1989 forests did not become a net sink until 1995 (figure 6.4.2). This is due to the emissions from loss of biomass carbon stocks associated with the previous land use and the change (loss) of soil carbon with a land-use change to forestry, outweighing removals by forest growth.

Figure 6.4.2 New Zealand's net carbon dioxide removals by post-1989 forests from 1990 to 2013



Deforestation

In 2013, an estimated 8,453 hectares of *Forest land* were converted to other land uses, primarily *Grassland*. Table 6.4.4 shows the areas of *Forest land* subject to deforestation in 2013 and since 1990. The land uses that *Forest land* has been converted to following deforestation are shown in tables 6.2.6 and 6.2.7.

Table 6.4.4 New Zealand's forest land subject to deforestation, 1990 and 2013

		Deforestation since 1990		Deforestation in 2013	
Forest land subcategory	Area of forest in 1990 (hectares)	Area (hectares)	Proportion of 1990 area (%)	Area (hectares)	Proportion of 1990 area (%)
Pre-1990 natural forest	7,897,109	43,531	0.55	1,453	0.02
Pre-1990 planted forest	1,520,335	101,635	6.69	5,588	0.37
Post-1989 forest	0	22,857	NA	1,412	NA
Total	**9,417,445**	**168,024**	**1.78**	**8,453**	**0.09**

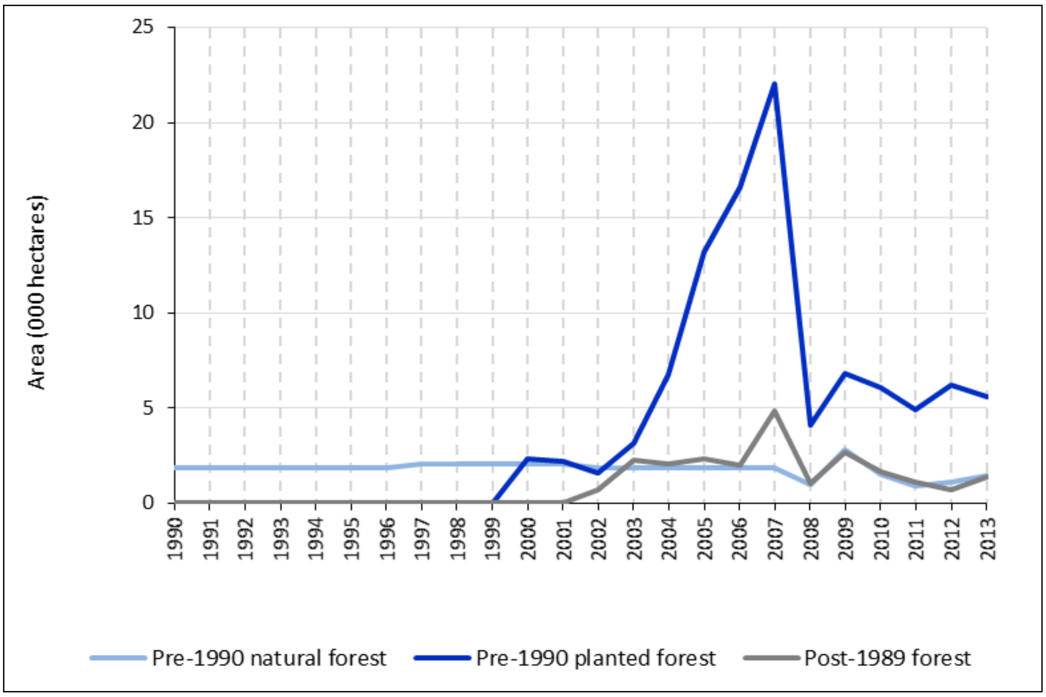
Note: NA = not applicable. 2013 areas are as at 31 December 2013; 1990 areas are as at 1 January 1990 and, therefore, differ from 1990 area values in the CRF tables, which are as at 31 December 1990. Columns may not total due to rounding.

The conversion of *Forest land* to *Grassland* is due in part to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared with forestry.

Figure 6.4.3 illustrates the increase in planted forest deforestation that occurred leading up to 2008 and the decrease after the introduction of the NZ ETS in 2008.

During the first Kyoto Protocol commitment period (2008–2012), it was expected that the level of deforestation would continue to be less than that seen prior to the introduction of the NZ ETS in 2008 (Manley, 2009). However, since the introduction of the NZ ETS, the carbon price has been in steady decline and has not impeded deforestation as much as predicted. The low carbon price has reduced the liability on forest owners for deforestation. Consequently, more deforestation has occurred since 2008 than previously expected.

Figure 6.4.3 New Zealand's area of deforestation since 1990, by forest subcategory



As there is no data on the deforestation profile for pre-1990 natural forests between 1990 and 2007, the total area of deforestation detected over this period is allocated evenly across the years. The rate of pre-1990 natural forest deforestation has been confirmed from 2008 to 2012 through satellite image mapping of deforestation (see figure 6.2.5).

A number of factors suggest that the rate of pre-1990 natural forest deforestation is unlikely to have been constant between 1990 and 2007. The area available for harvesting (and potentially deforestation) was higher before 1993 when the Forests Act 1949 was amended to bring an end to unsustainable harvesting and deforestation of natural forest. Further restrictions to the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand in 2002. Both of these developments are likely to have reduced pre-1990 natural forest deforestation since 2002. There has been a slight decrease in the annual rate since 2007, though rates in recent years are more variable. Due to the above-mentioned restrictions on logging and deforestation of natural forest in New Zealand, a very small portion of the total area of pre-1990 forest can be destocked, making it unlikely that rates of pre-1990 deforestation will increase in the future.

New Zealand assumes instant emissions of all biomass carbon at the time of deforestation, based on the following:

- the majority of deforestation since 2000 has resulted from land conversion to *Grassland*, leading to the rapid removal of all biomass as the land is prepared for farming
- it is not practical to estimate the emission of residues following the deforestation activity, given the rapid conversion from one land use to another and multiple methods of removing residues. Further estimating residue biomass and decay rates for multiple deposal methods is difficult and costly.

However, estimates of biomass burning emissions associated with deforestation are provided in the Inventory (see section 6.11.5).

Soil carbon changes associated with deforestation are modelled over a 20-year period using a linear decay profile (section 6.3).

These deforestation emissions are reported in the relevant 'land converted to' category, as are all emissions from land-use change. See sections 6.2.2 and 11.1.3 for further information on deforestation.

Harvesting

The estimated area of pre-1990 planted forest harvested each year between 1990 and 2009 is based on the harvested area reported in the *National Exotic Forest Description* (Ministry for Primary Industries, 2013a). Roundwood statistics (Ministry for Primary Industries, 2013b) are used where an increase in reported harvest volume is not consistent with harvest area reported in the *National Exotic Forest Description* (as in 2010 and 2011) and where published area data is not yet available (as in 2013). In these situations, a combination of roundwood statistics, and the ratio of roundwood volume-to-area harvested over the five-year period 2008–2012, is used to estimate the area harvested in 2010, 2011 and 2013 from the volume of roundwood removals reported.

There are differences in the area defined and reported as planted forest for Convention on Climate Change reporting and the area captured by the *National Exotic Forest Description* from which the harvesting statistics are sourced. Convention on Climate Change reporting uses a gross stocked area standard, which includes forest tracks, skid sites and unstocked areas. The *National Exotic Forest Description* generally uses a net stocked area standard. To account for these area differences, the net planted forest area for Convention on Climate Change reporting has been identified and modelled separately. This ensures the harvesting data used for Convention on Climate Change reporting are consistent with those reported by the Ministry for Primary Industries.

The total area harvested is then split by forest type.

- Pre-1990 planted forest harvesting: This was estimated as the difference between total harvesting (based on statistics from the Ministry for Primary Industries, as outlined above) and the amount of post-1989 forest harvesting estimated.
- Post-1989 forest: There is no published information available for the area of post-1989 forest harvesting in New Zealand. Post-1989 forest harvesting is estimated from the harvested area mapped between 2008 and 2012. There is no mapped estimate for 2013 post-1989 forest harvesting, therefore, the average harvest between 2008 and 2012 is used.

In 2013, it is estimated that 0.08 per cent of New Zealand's total forest timber production was from the harvesting of natural forests (Ministry for Primary Industries, 2013b).

No timber is legally harvested from New Zealand's publicly owned natural forests (an area approximately 5.5 million hectares in size). Most other harvesting of natural forests is required by law to be undertaken on a sustainable basis.

Any harvesting that occurs in natural forests is captured within the natural forest carbon stock and stock change estimates.

6.4.2 Methodological issues

Forest land remaining forest land

Only pre-1990 natural forest and pre-1990 planted forest are described in this section because land in the post-1989 forest subcategory is included in the *Land converted to forest land* category. Land areas converted to post-1989 forest had been in that land use for a maximum of 23 years in 2013 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 (this is the average age at which the majority of planted radiata pine forests are harvested (Ministry for Primary Industries, 2013a). Where there has been land-use change between natural forest and planted forest, the associated carbon changes are reported under *Forest land remaining forest land*.

New Zealand has established a sampling framework for forest inventory purposes based on an 8-kilometre national grid system. The grid has a randomly selected origin and provides an unbiased framework for establishing plots for field and/or Light Detection and Ranging (LiDAR) measurements. The network is subdivided into a 4-kilometre grid for measurement of post-1989 forest. Figure 6.4.4 shows the distribution of the pre-1990 natural and planted forest carbon monitoring plots throughout New Zealand.

Table 6.4.5 Summary of methods used to calculate New Zealand's natural forest biomass carbon stock from plot data

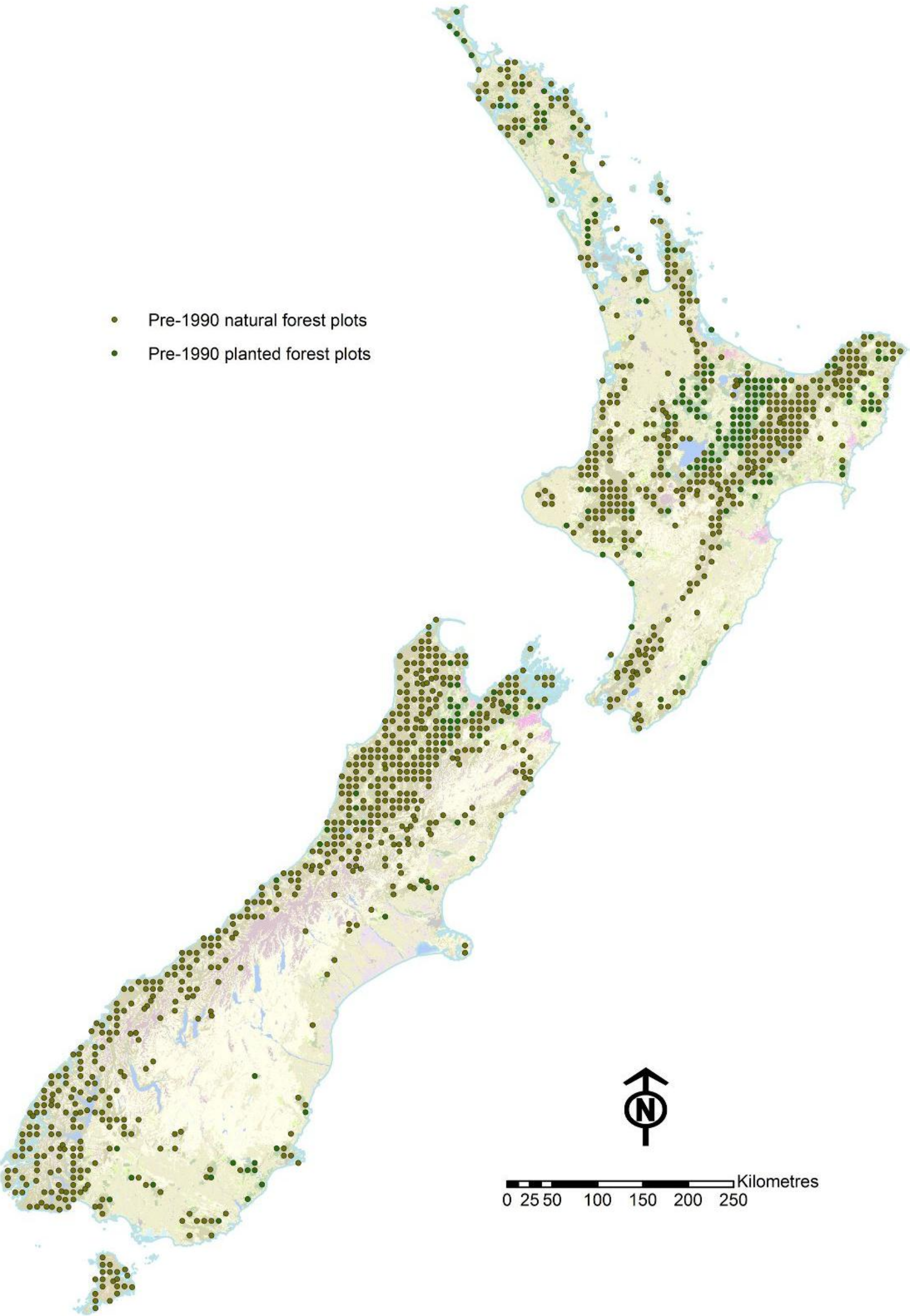
Pool		Method	Source
Living biomass	Above-ground biomass	Plot measurements; allometric equations	Holdaway et al, 2014b
	Below-ground biomass	Estimated at 20 per cent of total living biomass	Coomes et al, 2002
Dead organic matter	Dead wood	Plot measurements; Allometric equations	Holdaway et al, 2014b
	Litter	Plot samples; Laboratory analysis of samples collected at plots	Holdaway et al, 2014b; Garrett, 2009

Living biomass

Living biomass is separated into two carbon pools.

- Above-ground biomass: The carbon content of individual trees and shrubs is calculated using species-specific allometric relationships between diameter, height and wood density (for trees), a non-specific conversion factor with diameter and height (for tree ferns) or volume and biomass (for shrubs) (Beets et al, 2012b). Shrub volumes are converted to carbon stocks using species and/or site-specific conversion factors, determined from the destructive harvesting of reference samples.
- Below-ground biomass: This is derived from above-ground biomass and is assumed to be 25 per cent of above-ground biomass (or 20 per cent of total biomass). This value is based on a review of studies that report root to total biomass ratios of 9 to 33 per cent (Coomes et al, 2002).

Figure 6.4.4 Location of New Zealand's pre-1990 forest carbon monitoring plots



Pre-1990 natural forest

Plot network

A national monitoring programme designed to enable unbiased estimates of carbon stock and change for New Zealand's natural forests was developed between 1998 and 2001 (Goulding et al, 2001). One thousand, two hundred and fifty-six permanent sample plots of 0.04 hectares were installed systematically on the 8-kilometre grid across New Zealand's natural forests (see figure 6.4.4) and these were first measured over five years between 2002 and 2007.

The plots were sampled using a method designed specifically for the purpose of calculating carbon stocks (Payton et al, 2004b).

Re-measurement of the plot network provides repeat measures data suitable for calculating carbon stock change in natural forest. The first re-measurement of the plot network has recently been completed, with plots re-measured over five years between 2009 and 2014, following methodology revised for this purpose (Ministry for the Environment, 2013). The measurement programme is planned to continue at a reduced frequency on a 10-year cycle. The full set of plots will be measured across a period of 10 years starting 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 6.4.5 summarises the method used to calculate the carbon stock in each biomass pool from the information collected at each plot.

Dead organic matter

Dead organic matter is separated into two carbon pools.

- Dead wood: The carbon content of dead standing trees is determined in the same way as live trees but excludes branch and foliage biomass calculations. The carbon content of the fallen wood and stumps is derived from the volume of the piece of wood, its species (if able to be identified) and what stage of decay it is at. Dead wood comprises woody debris with a diameter greater than 10 centimetres.
- Litter: The carbon content of the fine debris is calculated by laboratory analysis of sampled material. Litter comprises fine woody debris (dead wood from 2.5 to 10 centimetres in diameter), the litter (all material less than 2.5 centimetres in diameter) and the fermented humic horizons. Samples were taken at approximately one-third of the natural forest plots.

Carbon stock

Biomass in the above pools is summed to calculate the total carbon stock for these pools. Based on the most recent analysis, carbon stock in the tall forest component of pre-1990 natural forest is 257.74 ± 11.33 tonnes C ha^{-1} and carbon stock in the regenerating component of pre-1990 natural forest is 88.80 ± 16.23 tonnes C ha^{-1} (Holdaway et al, 2014b).

Carbon stock change

Carbon stock change in natural forest is calculated as the difference in carbon stock at time two minus time one. This is calculated for each plot, and the mean change across all plots is used as the national average. With the recent completion of the first re-measurement of the plot network, New Zealand now has a full inventory of pre-1990 natural forest at two points in time. The average measurement date of the first point is 2004 and average measurement date of the second point is 2011.

Analysis of the full set of re-measurement data is now complete. Results of this analysis found that between 2002–2007 and 2009–2014 the regenerating forest component of New Zealand's pre-1990 natural forest was a net sink of carbon, sequestering 1.39 (95% CI 0.84 to 1.94) tonnes C ha^{-1} yr^{-1}. Due to the dominance of tall forest types, the combined overall net change across all pre-1990 natural forest was indistinguishable from zero (+0.34 (95% CI −0.09 to 0.77) tonnes C ha^{-1} yr^{-1}). Carbon stock change in regenerating forest was driven primarily by an increase in live above-ground biomass of 1.06 (95% CI 0.65 to 1.47) tonnes C ha^{-1} yr^{-1} (Holdaway et al, 2014b).

Interim results were reported in the last submission. While the trend remains the same, the revised estimates have scaled back the magnitude of the carbon stock change reported. This is described further in section 6.4.5.

Soil organic carbon

Mineral soil organic carbon stocks in pre-1990 natural forest land remaining pre-1990 natural forest land are estimated using a Tier 2 method. The steady state mineral soil carbon stock in natural forest is estimated to be 92.25 tonnes C ha^{-1} (table 6.3.2).

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with the drainage of organic soils in managed forests (IPCC, 2003, section 3.2.1.3). In New Zealand, natural forests are not drained and, therefore, oxidation processes associated with drainage are not occurring. It is therefore assumed that there are no carbon emissions from organic soils in pre-1990 natural forest land remaining pre-1990 natural forest land.

Non-CO_2 emissions for pre-1990 natural forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other land

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use, and, therefore, all *Direct N_2O emissions from nitrogen fertilisation of forest land and other land* are reported in the Agriculture sector under the subcategory, *Direct soil emissions*.

Pre-1990 planted forest

All planted forest land established prior to 1990, whether established for wood production or ecosystem services, is included in the pre-1990 planted forest subcategory. This subcategory also includes areas that were natural forest in 1990 but have since been planted with exotic forest. The emissions associated with this area are calculated as the removal of biomass associated with pre-1990 natural forest and the subsequent growth of pre-1990 planted forest. The pre-1990 planted forest yield table best represents the growth on ex-natural forest land because it remains in the *Forest land* category. It has been demonstrated in the development of the post-1989 forest yield table that forests planted on to *Grassland* are more productive than those planted on to *Forest land* (Paul et al, 2013).

Pre-1990 planted forest inventory

New Zealand's pre-1990 planted forest was sampled in 2010. The analysis of the data collected has provided a plot-based estimate of carbon stock and mean carbon density within this forest subcategory (Beets et al, 2012a). The pre-1990 planted forest inventory is closely linked, in terms of design and methodology, with the post-1989 planted forest inventory described later in this section.

For the pre-1990 planted forest inventory, 192 circular 0.06 hectare plots (see figure 6.4.4) were established on a systematic 8-kilometre grid consistent with that used for all forest subcategories. These plots were ground measured using procedures 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 at breast height of live and dead trees; a sample of tree total heights for each tree species; pruned heights; and the timing of pruning and thinning activities. Ground plot centres were located using a 12-channel differential global positioning system (GPS) for accurate LiDAR co-location and relocation for future measurements (Beets et al, 2012a).

Airborne scanning LiDAR data was collected from 893 plots, including those that were ground measured. The LiDAR-only plots are located on a 1 kilometre (north–south) by 8 kilometre (east–west) grid within the mapped area of pre-1990 planted forest (Beets et al, 2012a). LiDAR data from pre-1990 planted forests are not included in this submission but it is expected to be incorporated at a later date to improve the precision of the estimates.

Living biomass and dead organic matter

The crop tree plot data collected from the planted forest inventories was modelled using a forest carbon modelling system developed for the two most common plantation tree species in New Zealand (the Forest Carbon Predictor, version 4.1 (Beets and Kimberley, 2011)). To enable predictions of carbon stocks and changes in New Zealand's planted forests, this system integrates:

- the 300 Index growth model (Kimberley and Dean, 2006) for *Pinus radiata*
- the 500 Index growth model for Douglas-fir (Knowles, 2005)
- a wood density model (Beets et al, 2007)
- a stand tending model (Beets and Kimberley, 2011)
- the C_Change carbon allocation model (Beets et al, 1999).

The individual components of the Forest Carbon Predictor are explained below and illustrated in figure 6.4.5.

The 300 Index and 500 Index growth models produce a productivity index for forest plots derived from stand parameters. These stand parameters include: stand age, mean top height, basal area, stocking and stand silvicultural history. Plot latitude and altitude are also required to run the models. The growth models use these parameters to predict stem volume under bark over a full rotation (planting to harvest). A specific productivity index is produced for each plot, which is then used to estimate the total live and dead stem volume by annual increment. The growth models account for past and future silviculture treatments using plot data, information on past silvicultural treatments and assumptions of future management events based on plot observations and standard regimes (Beets and Kimberley, 2011).

The wood density model within the Forest Carbon Predictor uses site mean annual temperature, soil nitrogen fertility, ring age and stocking to determine the mean density of stem wood growth sheaths produced annually in *Pinus radiata*. Wood density is an important variable in the estimation of carbon. Of the parameters entered into the wood density model, temperature and stand age have the greatest influence on wood density, followed by site fertility and stocking. The combined result of these individual effects can be large, as shown in table 6.4.6 (Beets et al, 2007).

Table 6.4.6 Influence of individual site and management factors on predicted wood density for New Zealand planted forest

Factor affecting wood density	Range in predicted density ($kg\ m^{-3}$)	(% difference)
Temperature: 8°C versus 16°C	359–439	22
Age: 10-year-old versus 30-year-old	380–446	17
C/N ratio: 12 versus 25	384–418	9
Stocking: 200 versus 500 stems ha^{-1}	395–411	4

The stand tending model: New Zealand's plantation forests are intensively managed and, therefore, pruning and thinning provide the majority of the inputs to the dead wood and litter pools. The Forest Carbon Predictor requires silvicultural history inputs to predict changes between biomass pools over time. The information required includes initial stocking, the timing of management events, stocking following each thinning operation and the pruned height and number of stems pruned for each pruning lift. Information on silvicultural events prior to the plot measurement date is normally gathered from forest owners but sometimes this data is incomplete. A history module has been incorporated into the Forest Carbon Predictor that makes use of existing data to identify potential gaps in the stand history. Within the history module, assumptions are made to complete the stand history based on field observations, standard management regimes and known silviculture to date (Beets and Kimberley, 2011). The history module enables reasonable estimates of stand history and, therefore, biomass transfers between pools resulting from past silvicultural events.

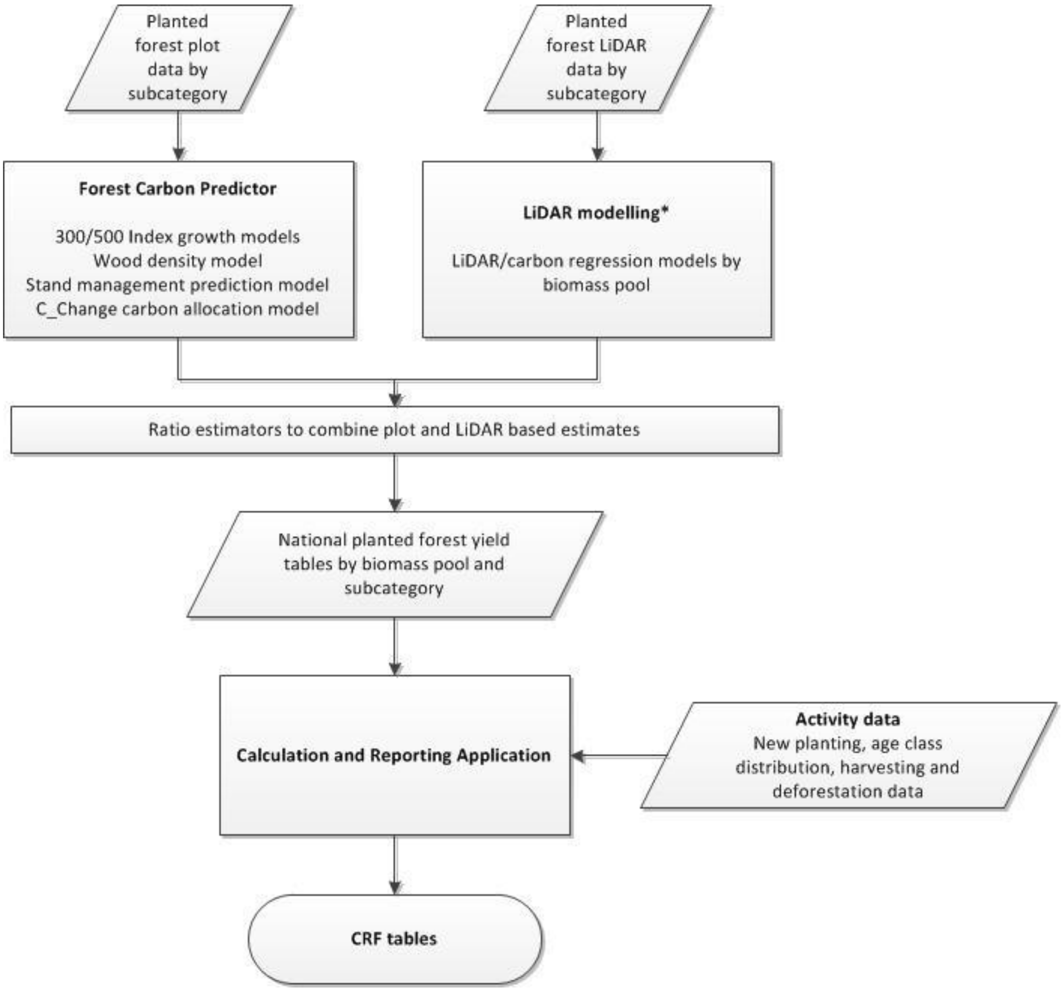
The C_Change carbon allocation model is integrated into the Forest Carbon Predictor and is designed to apportion carbon to needles, branches, stems, roots and reproductive parts via growth partitioning functions. Dead wood and litter pools are estimated by accounting for losses to the live pools from natural mortality, disease effects on needle retention, branch and crown mortality and silvicultural management activities, for example, pruning and thinning. Component-specific and temperature-dependent decay functions are used to estimate losses of carbon to the atmosphere (Beets et al, 1999). The Forest Carbon Predictor also takes into account biomass removals during production thinning.

The individual plot yield curves generated by the Forest Carbon Predictor are combined into estimates of above-ground live biomass, below-ground live biomass, dead wood and litter in an area-weighted and age-based carbon yield table for the productive area of each planted forest subcategory. Plots that are located outside the productive area within the mapped forest boundary are used to provide emission factors for unstocked areas in the post-1989 and pre-1990 planted forest categories (Paul et al, 2014).

Below-ground biomass is derived from the above-ground biomass estimates. For plantation crop trees, the above- to below-ground biomass ratio is 5:1 (Beets et al, 1999). The ratio for non-crop trees and shrubs is 4:1 (Coomes et al, 2002).

The carbon content of the dead wood pool within rotation is estimated using the Forest Carbon Predictor model as described above. Immediately following harvesting, 30 per cent of the above-ground biomass pool is transferred to the dead wood pool; the other 70 per cent is instantaneously emitted. All material in the dead wood and litter pools is decayed using an empirically derived, temperature-dependent decay profile as described in Garrett et al (2010).

Figure 6.4.5 New Zealand's planted forest inventory modelling process



Note: *LiDAR used only in post-1989 planted forests for this submission.

For shrubs and non-crop tree species measured within the planted forest plot network, the carbon content is estimated using species-specific allometric equations. These equations estimate carbon content from diameter and height measurements, and wood density by species (Beets et al, 2012a).

The carbon stock in pre-1990 planted forest as at 31 December 2012, estimated directly from the national plot network, is 154.95 ± 15.72 tonnes C ha^{-1} (at the 95 per cent confidence interval).

Soil organic carbon

Soil carbon stocks in pre-1990 planted forest land remaining pre-1990 planted forest are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils (section 6.3). The steady state mineral soil carbon stock in pre-1990 planted forest is estimated to be 92.44 tonnes C ha^{-1} (table 6.3.2).

The IPCC default emission factor for organic soils under planted forest is 0.68 tonnes C ha^{-1} per annum (table 6.3.3). Soil carbon change with harvesting is not explicitly estimated, as the long-term soil carbon stock for this land use includes any emissions associated with harvesting.

Non-CO_2 emissions for pre-1990 planted forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other land

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use and, therefore, all *Direct N_2O emissions from nitrogen fertilisation of forest land and other land* are reported in the Agriculture sector under the subcategory, *Direct soils emissions*.

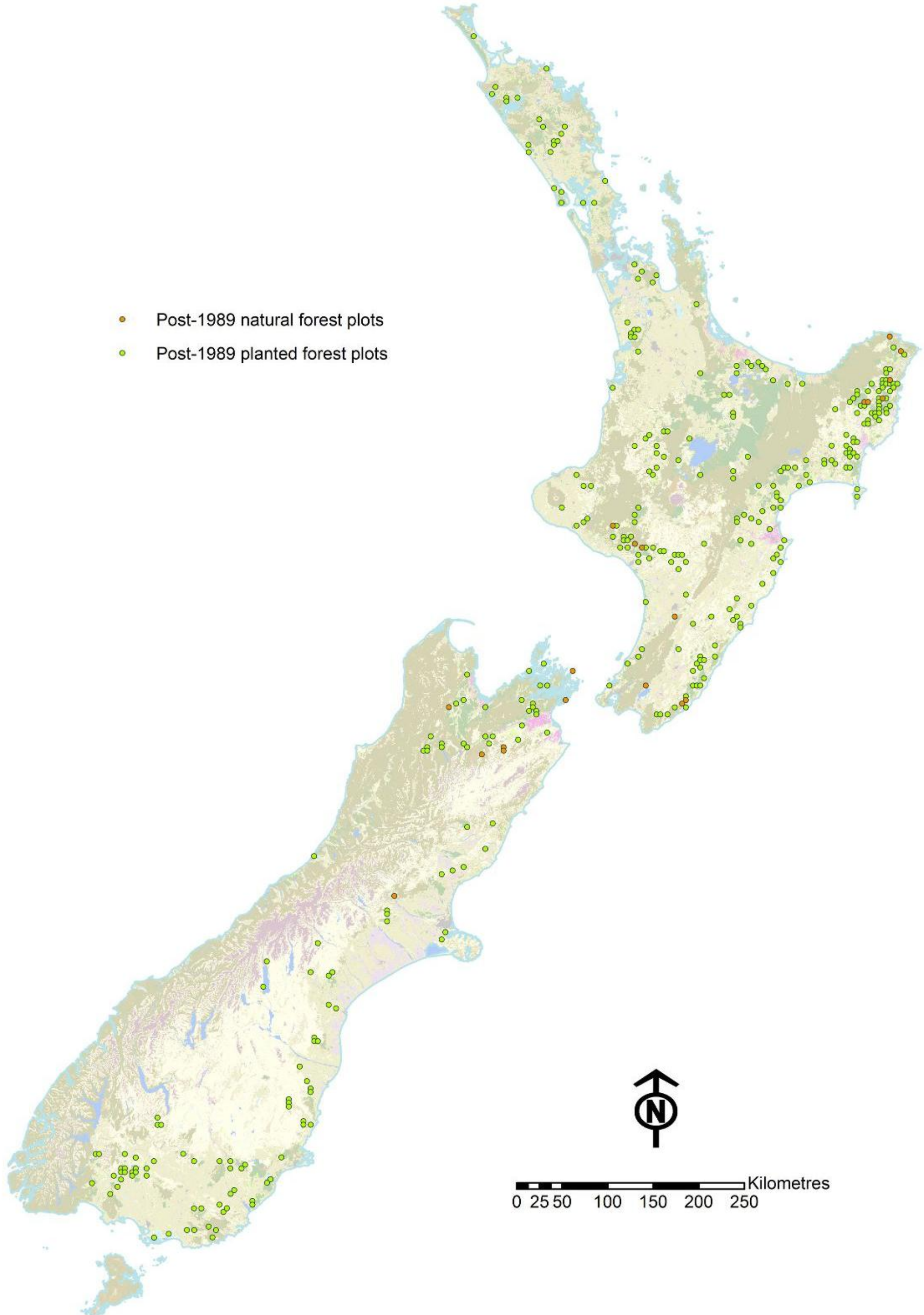
Land converted to forest land

All *Land converted to forest land* since 1 January 1990, either by planting or as a result of human-induced changes in land-management practice (eg, removing grazing stock and actively facilitating the regeneration of tree species), is included in the post-1989 forest subcategory. The post-1989 forest subcategory is split into two divisions for calculating emissions and removals: post-1989 natural forest and post-1989 planted forest. Reporting is at the aggregate level of post-1989 forest in the inventory.

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 establishment preparation. Between 1990 and 2013, approximately 59 per cent of the non-forest land converted to post-1989 forest has been from low producing grassland, with another 24 per cent converted from grassland with woody biomass. The grassland with woody biomass land-use subcategory provides the largest source of emissions associated with land-use change to forest because of the amount of biomass present prior to land-use conversion.

New Zealand's post-1989 forests have been sampled on a systematic 4-kilometre grid-based plot network consistent with that used for all forest subcategories, as shown in figure 6.4.6. Sampling includes both post-1989 planted forests and post-1989 natural forest and the method is described below.

Figure 6.4.6 Location of New Zealand's post-1989 forest plots



Post-1989 planted forests

All *Forest land* planted since 1 January 1990, whether established for wood production or soil control purposes, is included in the post-1989 *f*orest subcategory.

Living biomass and dead organic matter

A plot-based forest inventory system has been developed for carbon estimation in New Zealand's post-1989 planted forest (see Beets et al, 2011). The majority of post-1989 forests in New Zealand are privately owned and access could not be guaranteed at the beginning of the inventory. Initially, a double-sampling approach involving LiDAR was employed to reduce the possibility of sampling bias arising from unmeasured plots

(Stephens et al, 2012). In practice, access to privately owned forests was generally unrestricted so LiDAR was then used to improve the precision of the carbon stock estimates using a ratio estimator procedure.

In the post-1989 planted forest inventory, circular 0.06 hectares of permanent sample plots have been established within forests on a systematic 4-kilometre grid coincident with that used for the pre-1990 natural forest and pre-1990 planted forest inventories (Moore and Goulding, 2005). Permanent sample plots were selected over temporary sample plots because change over time is more easily analysed when there are multiple measurements of the same plot set (Beets et al, 2011).

The initial post-1989 planted forest inventory was carried out during the winters of 2007 and 2008 at 246 sites consisting of up to four sample plots in a cluster arrangement. Plots were sampled using methodology as described in Payton et al (2008). A second inventory was carried out during the winters of 2011 and 2012 where the centre plot of the earlier established cluster plots were re-measured and additional plots were established. In total, 342 plots were ground measured from the mapped area of post-1989 planted forest in the second inventory. Importantly, the additional plots in the later inventory addressed a bias in the earlier estimates caused by incomplete sampling of the forest area. This was due to the initial field inventory beginning prior to the completion of the 2008 land-use map.

The ground measurements in the post-1989 planted forest inventory include: stem diameters of live and dead trees at breast height; a sample of tree total heights for each tree species; pruned heights, measurement of dead wood and soil fertility samples for predicting wood density (Beets et al, 2011). Silvicultural information, including tree age, stocking (stems per hectare) and timing of pruning and thinning activities, was gathered from forest owners and estimated by field teams on site. Ground plot centres were located using a 12-channel differential GPS for sub-meter LiDAR co-location and for relocation in future inventories (Beets et al, 2011).

LiDAR data was captured for 25 plots in addition to those that were ground measured in the mapped post-1989 planted forest area (Paul et al, 2014). LiDAR data was acquired at a minimum of three points (or returns) per square metre. Aerial photography, at 200-millimetre resolution, was captured at the same time to aid in data analysis and for plot centre location during ground sampling.

Stock change in the productive area of post-1989 planted forests is estimated using a subcategory-specific national yield table approach similar to that described above under ‘Living biomass and dead organic matter’ within pre-1990 planted forest. Plots that are located outside the productive area within the mapped forest boundary are used to provide emission factors for unstocked areas of post-1989 planted forests (Paul et al, 2014).

Specific to post-1989 planted forest are plot measurements at two points in time and the use of LiDAR data in the 2013 estimates. To utilise both plot measurements, a single yield table per plot was developed using:

- the earlier measurement for ages below the first measurement age
- the later measurement for ages above the later measurement age
- an interpolated estimate for the ages between the earlier and later measurements.

For plots that were measured once, a ratio estimator derived from the plots that were twice measured was applied to the earlier ages in the yield tables. A LiDAR-based yield table was developed using a regression model developed for predicting 2008–2012 carbon sequestration from LiDAR metrics. A ratio estimator derived from LiDAR sequestration and the plots that were twice measured was developed and applied to the LiDAR-based yield table. Individual yield tables were combined as weighted means in a national yield table for the productive area of post-1989 planted forest (Paul et al, 2014).

New Zealand plantation forests are actively managed, with thinning and pruning activities undertaken early in the rotation. The majority of these activities are completed before trees reach the age of 13 years. Thus, there is a gradual increase in the dead wood and litter pools from these management practices leading up to this age. This is followed by a decline in these pools after age 13 when pruning and thinning cease and decay exceeds inputs. Due to the age-class structure of post-1989 forest in New Zealand, this can be seen as a rapid increase in the dead wood and litter pools over consecutive years.

The carbon stock estimate for the productive area of post-1989 planted forest is 135.4 ± 6.6 tonnes C ha^{-1} (at the 95 per cent confidence interval) as at 31 December 2012 (Paul et al, 2013). This carbon stock estimate, while high, is consistent with the international comparisons provided in table 3A.1.4 (IPCC, 2003) and reflects that the composition of this forest subcategory is made up of fast-growing and actively managed production forestry.

Post-1989 natural forests

Post-1989 natural forest is forest land established since 1 January 1990 resulting from direct human-induced changes in land-management practice. For example, the removal of grazing stock that has actively facilitated the regeneration of tree species, the land use has changed from *Grassland* to *Forest land*. This area covers an estimated 41,074 hectares. The resulting forest is composed of a mix of native and introduced species, especially in early successional stages. As this forest matures, it generally becomes increasingly dominated by native species and, in most cases, will become native forest. Forest carbon stocks and stock change in post-1989 natural forest are reported for the first time in 2012.

Estimates of carbon stock and stock change in post-1989 natural forest are calculated based on measurements taken in a field inventory. The inventory samples post-1989 natural forest using permanent sample plots on a systematic 4-kilometre grid (consistent with the post-1989 planted forest inventory). Twenty plots in post-1989 natural forest were established and measured for the first time in 2012. The plot network design is described in Beets et al (2012a), and detailed methods for plot measurement are given in the data collection manual (Ministry for the Environment, 2013).

Living biomass and dead organic matter

At permanent sample plots within post-1989 natural forest, measurements are taken of standing and fallen, live and dead plants. Destructive biomass samples taken outside of the plots are used to create plot-specific allometric equations, which are applied to these measurements to calculate above-ground live biomass.

Biomass of standing dead wood (woody debris with a diameter greater than 10 centimetres) and litter (woody debris with a diameter of less than 10 centimetres) is calculated as for living biomass but is then adjusted for decay using decay functions. Biomass of fallen dead wood is calculated from plot measurements of volume in combination with species-specific wood densities and then also adjusted for decay in the same way.

Biomass sampling on post-1989 natural forest plots includes the determination of plant age, which enables the backcasting of biomass through time. Backcast estimates of biomass are used to calculate carbon stock change. The method used to do this was developed and validated using plots for which multiple measurements in time had been obtained and for which carbon stock change was able to be measured directly (Beets et al, 2012b). Full methods for the calculation of carbon stock and stock change in post-1989 natural forest are described in Beets et al (2013).

The carbon stock estimate for post-1989 natural forest is 26.92 ± 7.05 tonnes C ha^{-1} (at the 95 per cent confidence interval) as at 31 December 2012 (Beets et al, 2013). The average rate of carbon sequestration in post-1989 natural forest over the first commitment period is 2.2 tonnes C ha^{-1} yr^{-1} (Beets et al, 2013). This rate is similar to previously reported rates of carbon sequestration in regenerating shrubland in New Zealand (Carswell et al, 2012; Trotter et al, 2005).

Soil organic carbon

Soil carbon stocks in land converted to post-1989 forest are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils, as described in section 6.3. The steady state mineral soil carbon stock in post-1989 forest is estimated to be 91.92 tonnes C ha^{-1} (table 6.3.2).

In the absence of country- and land-use specific data on the rate of change, the IPCC default method of a linear change over a 20-year period is used to estimate the change in SOC stocks between the original land use and planted forest land for any given period. For example, the soil carbon change associated with a land-use change from low producing grassland (soil carbon stock 105.98 tonnes C ha^{-1}) to post-1989 planted forest (soil carbon stock 91.92 tonnes C ha^{-1}) would be a loss of 14.06 tonnes C ha^{-1} over the 20-year period.

The IPCC default emission factor for organic soils under planted forest is 0.68 tonnes C ha^{-1} per annum (table 6.3.3). This is also applied to organic soils on land converted to post-1989 forest.

Quality assurance and quality control

Quality-assurance and quality-control activities were conducted throughout the post-1989 planted forest data capture and processing steps. These activities were associated with the following: inventory design (Brack, 2009; Moore and Goulding, 2005); acquisition of raw LiDAR data and LiDAR processing; checking eligibility of plots; independent audits of field plot measurements; data processing and modelling; regression analysis and double-sampling procedures (Woollens, 2009); and investigating LiDAR and ground plot co-location (Brack and Broadley, 2010). These activities, along with those undertaken within the post-1989 natural forest, are described in more detail in section 6.4.4.

Non-CO_2 emissions for post-1989 forest

Direct N_2O emissions from nitrogen fertilisation of forest land and other land

New Zealand activity data on nitrogen fertilisation is not currently disaggregated by land use and, therefore, all *Direct N_2O emissions from nitrogen fertilisation of forest land and other land* are reported in the Agriculture sector under the subcategory, *Direct soils emissions*.

6.4.3 Uncertainties and time-series consistency

Emissions from *Forest land* are 3.1 per cent of New Zealand's net emissions uncertainty in 2013 (annex 2). *Forest land* introduces 2.6 per cent uncertainty into the trend in the national total from 1990 to 2013.

Pre-1990 natural forest

The uncertainty in mapping pre-1990 natural forest is 5 per cent (table 6.4.7). Further details are given in section 6.2.5.

Uncertainty in biomass carbon stock and stock change in New Zealand's pre-1990 natural forest is calculated using a published methodology designed specifically for this purpose (Holdaway et al, 2014c). The pre-1990 natural forest plot network provides biomass carbon stock estimates that are within 95 per cent confidence intervals of 4.4 per cent of the mean (257.74 ± 11.33 tonnes C ha^{-1}) for tall natural forest and 18.27 per cent of the mean (88.80 ± 16.23 tonnes C ha^{-1}) in regenerating natural forest (Holdaway et al, 2014b). Estimates of carbon stock change in the regenerating component are within 95 per cent confidence intervals of 39 per cent of the mean (+1.39 ± 0.55 tonnes C ha^{-1}) (Holdaway et al, 2014b).

Table 6.4.7 Uncertainty in New Zealand's 2013 estimates from pre-1990 natural forest (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	5.0
Emission factors	
Uncertainty in biomass carbon stocks	6.7
Uncertainty in biomass carbon change	39.6
Uncertainty in soil carbon stocks	7.9
Uncertainty introduced into net emissions for LULUCF	**9.4**

Note: NO = not occurring. A Monte Carlo simulation approach is used to assess uncertainty in carbon stock and carbon stock change in pre-1990 natural forest. The regenerating component of pre-1990 natural forest was found to be a statistically significant sink of carbon, sequestering 1.39 ± 0.55 tonnes C $ha^{-1}yr^{-1}$ (Holdaway et al, 2014b). However, the variation between individual plot estimates of change and the relatively low sequestration in pre-1990 natural forest results in an uncertainty of 39.6 per cent for change in the category. Land area includes land in transition in 2013. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equations 3.1 and 3.2 from the IPCC *General Guidance and Reporting* (IPCC, 2006b).

Pre-1990 planted forest

A national plot-based inventory system in conjunction with a suite of models is used to estimate carbon stock and change within New Zealand's planted forest (see Beets et al, 2012a). The models are collectively called the Forest Carbon Predictor version 4.1 (Beets and Kimberley, 2011) and are described in further detail in section 6.4.2 under 'Living biomass and dead organic matter' for pre-1990 planted forest. Extensive work has been carried out to reduce the uncertainty in the estimates, including the use of a specifically designed plot network and research-based improvements to the models.

A paper has been published on the validation of the Forest Carbon Predictor model (Beets et al, 2011b) used to produce carbon yield tables for the LULUCF sector. For the plots in this study, they found that estimates of total carbon stock per plot made using the Forest Carbon Predictor were within 5 per cent of measured values. When just above-ground biomass per plot was considered, accuracy was within approximately 1 per cent. Carbon stock change was estimated within 5 per cent accuracy when linked with plot data at the start and end of each five-year period, linking closely with the scheduled duration between the national plot-based inventories (Moore and Goulding, 2005).

New Zealand's pre-1990 planted forests were sampled in 2010 and the analysis of the data collected has provided an unbiased plot-based estimate of carbon stock and change within this forest subcategory. This has reduced the uncertainty of the biomass estimates and growth from the previous estimate based on the *National Exotic Forest Description* (Ministry for Primary Industries, 2013a). The uncertainty of the pre-1990 planted forest biomass estimate at the 95 per cent confidence interval is 12.4 per cent (table 6.4.8).

The uncertainty in the estimates of pre-1990 planted forest for the 2014 submission is provided in table 6.4.8.

Table 6.4.8 Uncertainty in New Zealand's 2013 estimates from pre-1990 planted forest (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	5.0
Emission factors	
Uncertainty in biomass carbon stocks	12.4
Uncertainty in soil carbon stocks	12.3
Uncertainty introduced into net emissions for LULUCF	**33.6**

Note: The biomass uncertainties are low for pre-1990 planted forest (12.4 per cent). However, the total uncertainty for the subcategory is calculated on the net change. The age structure of the estate in 2013 results in high removals from growth and high emissions from harvesting, leaving a relatively small net change. Therefore, uncertainty is high in this subcategory. Land area includes land in transition in 2013. Lime application to pre-1990 planted forest does not occur (NO) in New Zealand. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equations 3.1 and 3.2 from the IPCC *General Guidance and Reporting* (IPCC, 2006b).

Post-1989 forest

Biomass

As described in section 6.4.2, post-1989 forest is split into post-1989 natural and post-1989 planted forest. The modelling process for post-1989 planted forest is similar to pre-1990 planted forest, and the uncertainty in the modelling process is outlined above. Additionally, the Forest Carbon Predictor validation is described in Beets et al (2011b) and New Zealand's inventory approach is described in Beets et al (2011a).

New Zealand's post-1989 planted forests were first sampled in 2007 and 2008, and were re-measured in 2011 and 2012. The inventory provides a plot-based estimate of carbon stock within this forest subcategory. LiDAR and ground-based measurements have been employed to reduce the possibility of sampling bias arising from unmeasured plots due to access restrictions. The uncertainty of the post-1989 planted forest biomass estimate at the 95 per cent confidence interval is 8.6 per cent (table 6.4.9).

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. When the national forest map had been completed, additional plots were measured in 2012 and 2013. The inclusion of these plots in the analysis provided an unbiased and representative sample of post-1989 planted and natural forests.

The inventory of post-1989 natural forest provides estimates of carbon stock that are within 26.2 per cent of the mean at the 95 per cent confidence level as at 2013.

Table 6.4.9 Uncertainty in New Zealand's 2013 estimates from post-1989 forest (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	8.0
Emission factors	
Uncertainty in biomass carbon stocks	8.6
Uncertainty in soil carbon stocks	10.4
Uncertainty introduced into net emissions for LULUCF	**5.6**

Note: Land area includes land in transition in 2013. The biomass carbon stocks value is the weighted value for post-1989 natural and post-1989 planted forests. Lime application to post-1989 forest does not occur (NO) in New Zealand. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equations 3.1 and 3.2 from IPCC *General Guidance and Reporting* (IPCC, 2006b).

6.4.4 Category-specific QA/QC and verification

Carbon dioxide emissions from both *Forest land remaining forest land* and *Land converted to forest land* are key categories (for both level and trend assessments). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality-assurance and quality-control checks as well as Tier 2, category-specific quality-assurance and quality-control checks. Details of these checks are provided below.

Pre-1990 natural forest

Quality control and assurance are undertaken at the data collection, data entry and data analysis stages for natural forest.

During the initial measurement of the natural forest plot network (2002–2007), 5 per cent of plots measured in the first field season were subject to audit (Beets and Payton, 2003). In all field seasons, data collection followed quality-assurance and quality-control processes as described in Payton et al (2004a, 2004b). This included on-site quality-control checks of field data and review by senior ecologists. Data was collected in the field and recorded by hand on paper field sheets. The electronic 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.

During the re-measurement of the plot network from 2009–2014, 10 per cent of plots measured were subject to independent audit. This involved a partial re-measure of randomly selected plots, and the assessment of measurements against data quality standards as described in Ministry for the Environment (2013). Data entry of all data was subject to quality assurance by the Ministry for the Environment for 10 per cent of plots. The data is also subject to further checking for measurement and data entry errors prior to analysis (Holdaway et al, 2014a).

Pre-1990 planted forest and post-1989 planted forest

During the ground-measurement season, 10 per cent of plots were randomly audited without the prior knowledge of the inventory teams. Plots were fully re-measured with feedback supplied no later than one month after measurement to ensure prompt identification of data collection errors and procedural issues. Differences between the inventory and audit measurements were objectively and quantitatively scored. Measurements that exceeded predefined tolerances incurred incremental demerit points. Demerit severity depended on the size of error and the type of measurement. Special attention was given to the most influential measurements; for example, tree diameter, tree height and the number of trees in a plot. Plots that failed quality control had to be re-measured (Beets et al, 2011a, 2012a). Following each inventory season, the data collection manual (Herries et al, 2011) is revised to clarify procedures and highlight potential sources of error.

The inventory data was pre-processed using Scion's Permanent Sample Plot (PSP) system. The PSP system has been programmed to check for erroneous values over a wide range of attributes. The system automatically identifies fields that do meet predetermined validation rules so these can be repaired manually before plot data are modelled by the Forest Carbon Predictor. The PSP data validation system and the Forest Carbon Predictor model were independently reviewed by Woollens (2009). The Forest Carbon Predictor has been recently validated in Beets et al (2011b).

Quality-assurance and quality-control procedures for LiDAR data collected during the planted forest inventories involved the checking of data as it was acquired following the methodology outlined in Stephens et al (2008). To ensure that the data was supplied within the predetermined specifications, the following activities were carried out: LiDAR sensor calibration and bore-sight alignment, checking of LiDAR point positional accuracy and point densities, correct point cloud classification and accuracy of digital terrain mapping. For example, the post-1989 forest inventory LiDAR acquisition included four individual sensor calibrations; six LiDAR point positional accuracy tests; and a summary of returns describing LiDAR specifications, which were provided for all data deliveries. Sites that failed to meet the required specifications were re-flown. These analyses were carried out using the LiDAR analysis software FUSION (McGaughey, 2010) and the Esri Arc Map GIS application. LiDAR metrics or parameters describing the forest from the canopy to the ground were extracted using FUSION. The process of extracting LiDAR metrics and the extracted metrics were audited by an organisation independent of the data capture and analysis (Stephens et al, 2008).

The carbon stock estimate for the productive area of post-1989 planted forest has also been verified by comparing it with table 3A.1.6 (IPCC, 2003). The New Zealand estimate is 135.4 ± 6.6 tonnes C ha^{-1} (at the 95 per cent confidence interval) as at 31 December 2012 (Paul et al, 2013). This carbon stock estimate (135.4 ± 6.6 tonnes C ha^{-1}), while high, is consistent with the international comparisons provided in table 3A.1.6 (IPCC, 2003) and reflects that this forest subcategory is made up of fast-growing and actively managed production forestry.

Post-1989 natural forest

As for pre-1990 natural forest, quality control and assurance were undertaken at the data collection, entry and analysis stages for post-1989 natural forest.

During field data collection, 10 per cent of plots were subject to an independent field audit. The audit involved randomly selected sites being re-measured by an audit field team, and the assessment of differences between inventory and audit measurements against set data quality standards as set out in Ministry for the Environment (2012). Audit results are described in Beets and Holt (2013). Further checks for data entry and measurement were also undertaken prior to the data analysis stage, as described in Beets et al (2013).

6.4.5 Category-specific recalculations

In this submission, New Zealand has recalculated its emission estimates for the whole LULUCF sector from 1990, including the *Forest land* category. These recalculations have involved improved country-specific methods, activity data and emission factors. The impact of the recalculations on net CO_2-e emission estimates for the *Forest land* category is provided in table 6.4.10. The differences shown are a result of recalculations for all carbon pools used in Climate Change Convention and Kyoto Protocol reporting for the whole time series for the LULUCF sector.

Table 6.4.10 Recalculations of New Zealand's estimates for the forest land category in 1990 and 2012

Net emissions (kt CO_2-e)	2014 submission	2015 submission	Change from the 2014 submission	% change
1990	–39,135.7	–28,256.8	10,878.9	–27.8
2012	–33,147.4	–25,644.7	7,502.7	–22.6
Area (hectares)				
1990	9,441,618	9,430,246	–11,371	–0.1
2012	9,952,380	9,935,792	–16,588	–0.2

Note: Areas are as at the end of the year indicated. The 2014 submission figures have been updated with the revised global warming potentials from the Contribution of Working Group I to the Fourth Assessment Report of the IPCC (IPCC, 2007) so vary slightly from those published in the 2014 submission. These values also exclude emissions from liming at both dates.

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

Methods

There has been a change to the pre-1990 planted forest age-class distribution to more accurately reflect the latest available activity data on the forest class. Previously, an older age-class distribution was grown forward, with annual harvesting data, but this was found to depart from the latest available data over time.

Activity data

Deforestation

The area estimates of deforestation within *Forest land* subcategories have been updated from the previous submission. These areas and the associated emissions are reported in the 'land converted to' category.

Emission factors

Pre-1990 natural forest carbon stock and stock change

Carbon stock and stock change estimates for pre-1990 natural forest have been updated in this submission. The first re-measurement of the pre-1990 natural forest plot network was completed in 2014. Data analyses have subsequently been revised to include the full data set for the first time. In addition, improvements in analysis methodology applied have also impacted the estimates in relation to last year's submission. Details of this analysis are provided in Holdaway et al (2014b).

Post-1989 and pre-1990 planted forest carbon stock change

The post-1989 and pre-1990 planted forest yield tables have been updated for the 2015 submission. The updates include reclassification of a small number of plots due to mapping improvements, amendments to align with a revised estimate of net stocked area in both forest classes and the inclusion of a sub-set of previously unused plots in post-1989 planted forest.

6.4.6 Category-specific planned improvements

New Zealand will continue to measure the natural forest plot network on a 10-year cycle, and analyse the data collected as this becomes available.

Mapping of forest areas will be iteratively improved by comparison with other spatial forest data sets administered by the Ministry for Primary Industries. These include post-1989 forest areas lodged with the NZ ETS, pre-1990 planted forest areas lodged with the Forestry Allocation Scheme and new post-1989 forests planted through the Afforestation Grants Scheme and the Permanent Forest Sink Initiative.

6.5 Cropland (CRF 4B)

6.5.1 Description

Cropland in New Zealand is separated into two subcategories: annual and perennial. In 2013, there were 371,791 hectares of annual cropland in New Zealand (table 6.5.3; 1.4 per cent of total land area) and 104,534 hectares of perennial cropland (table 6.5.3; 0.4 per cent of total land area).

Annual crops include cereals, grains, oil seeds, vegetables, root crops and forages. Perennial crops include orchards, vineyards and their associated shelterbelts except where these shelterbelts meet the criteria for *Forest land*.

The amount of carbon stored in, emitted by or removed from permanent cropland depends on crop type, management practices, soil and climate variables. Annual crops are harvested each year, with no long-term storage of carbon in biomass. However, the amount of carbon stored in woody vegetation in orchards can be significant, with the amount depending on the species, density, growth rates, and harvesting and pruning practices.

In 2013, the net emissions from *Cropland* were 443.6 kt CO_2-e, comprising 431.7 kt CO_2 from carbon stock change and 0.04 kt N_2O (11.9 kt CO_2-e) from the nitrogen mineralisation on *Land converted to cropland*. Net emissions from *Cropland* have decreased by 35.5 kt CO_2-e (7.4 per cent) from the 1990 level when net emissions were 479.1 kt CO_2-e (table 6.5.1).

Table 6.5.1 New Zealand's land-use change by cropland category, and associated CO_2-e emissions, from 1990 to 2013

Cropland land-use category	Net area in 1990 (ha)	Net area in 2013 (ha)	Change from 1990 (%)	Net emissions (kt CO_2-e) 1990	Net emissions (kt CO_2-e) 2013	Change from 1990 (%)
Cropland remaining cropland	386,553	409,881	+6.0	356.3	339.5	–4.7
Land in conversion to cropland	40,341	66,444	+64.7	122.8	104.1	–15.2
Total	**426,894**	**476,325**	**+11.6**	**479.1**	**443.6**	**–7.4**

Note: 1990 and 2013 areas are as at 31 December. Land in conversion to cropland includes land that was converted prior to 1990. Net emission values are for the whole year indicated. Values include CO_2-e emissions from N_2O from cultivation of land.

The *Cropland remaining cropland* category is responsible for the majority of *Cropland* emissions. This category comprised 86.1 per cent of all *Cropland* area in 2013.

From 1990 to 2013, the total carbon stock stored in *Cropland* decreased by 3,306.9 kt C, equivalent to emissions of 12,125.5 kt CO_2 from *Cropland* since 1990 (table 6.5.2). The majority of the emissions due to carbon stock change are in the soil organic carbon pool (3,321.4 kt C or 12,178.5 kt CO_2).

Table 6.5.2 New Zealand's carbon stock change by carbon pool for the cropland category from 1990 to 2013

Cropland subcategory	Net carbon stock change 1990–2013 (kt C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2013 (kt CO_2)
Annual cropland	–147.8	–6.9	–2,235.5	–2,390.2	8,764.1
Perennial cropland	174.6	–5.5	–1,085.9	–916.7	3,361.4
Total	**26.9**	**–12.4**	**–3,321.4**	**–3,306.9**	**12,125.5**

Note: This table includes CO_2 emissions from carbon stock change only (emissions from N_2O disturbance are not included in this table). The reported dead organic matter losses result from the loss of dead organic matter of woody land-use classes on conversion to cropland. Columns may not total due to rounding.

Table 6.5.3 shows land-use change by *Cropland* subcategory since 1990, and the associated CO_2 emissions from carbon stock change.

Table 6.5.3 New Zealand's land-use change by cropland subcategories, and associated CO_2 emissions from carbon stock change, from 1990 to 2013

Cropland land-use subcategory	Net area in 1990 (ha)	Net area in 2013 (ha)	Change from 1990 (%)	Net emissions (kt CO_2 only) 1990	2013	Change from 1990 (%)
Annual cropland	355,796	371,791	+4.5	342.2	341.9	–0.1
Perennial cropland	71,099	104,534	+47.0	129.6	89.7	–30.7
Total	**426,894**	**476,325**	**+11.6**	**471.8**	**431.7**	**–8.5**

Note: 1990 and 2013 areas are as at 31 December. This table includes CO_2 emissions from carbon stock change only. Columns may not total due to rounding.

A summary of land-use change within the *Cropland* category, by subcategory and land conversion status, is provided in table 6.5.4. This shows that land-use change within the *Cropland* category has been dominated by conversions to perennial cropland, both from within the *Cropland* category and from other land-use categories. This conversion has predominantly been for the establishment of vineyards (Davis and Wakelin, 2010).

Table 6.5.4 New Zealand's land-use change for the cropland category from 1990 to 2013

Cropland category	Subcategory	Net area in 1990 (ha)	Net area in 2013 (ha)	Change from 1990 (%)
Cropland remaining cropland	Annual remaining annual	326,063	341,051	4.6
	Perennial remaining perennial	59,216	59,564	0.6
	Annual to perennial	1,194	6,736	464.1
	Perennial to annual	80	2,530	3,059.9
	Subtotal	*386,553*	*409,881*	*6.0*
Land in conversion to cropland	Annual cropland	29,653	28,209.6	–4.9
	Perennial cropland	10,688	38,234	+257.7
	Subtotal	*40,341*	*66,444*	*+64.7*
Total		**426,894**	**476,325**	**+11.6**

Note: This table shows the change between 31 December 1990 and 31 December 2013. Columns may not total due to rounding.

6.5.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter pools have been calculated using IPCC Tier 1 emission factors for annual cropland, Tier 2 emission factors for perennial cropland (Davis and Wakelin, 2010) and activity data as described in section 6.2. Emissions and removals by the soil organic carbon pool are estimated using a Tier 2 method for mineral soils and IPCC Tier 1 defaults for organic soils (section 6.3).

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for *Cropland* is provided in table 6.5.5.

Table 6.5.5 Summary of New Zealand's carbon stock change emission factors for cropland

Cropland land-use subcategory	Carbon pool	Steady state carbon stock (t C ha–1)	Annual carbon stock change (t C ha–1)	Years to reach steady state	Source
Annual	Biomass				
	Living biomass	5.0	NA	1	IPCC default EF
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral	89.77	*	20	Soil CMS model (v.2013) LUE coefficient
	Organic	NE	–1.0 / –10.0		IPCC tier 1 default parameters
Perennial	Biomass				
	Living biomass	18.76	0.67	28	NZ-specific EF
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral	88.44	[*]	20	Soil CMS model (v.2013) LUE coefficient
	Organic	NE	–1.0 / 10.0		IPCC tier 1 default parameters

Note: EF = emission factor; LUE = land-use effect; NA = not applicable; NE = not estimated. * Annual carbon stock change in mineral soils on land undergoing land-use change will depend on the land-use category the land has been converted to or from; see section 6.3.

The New Zealand-specific emission factor for the living biomass pool for perennial cropland is lower than the default value for temperate ecozones provided in GPG-AFOLU (IPCC, 2006a). The IPCC default value is based on a single study of an agroforestry system where crops are grown in rotation with trees, whereas the New Zealand-specific emission factor takes into account that New Zealand's main perennial crops are not grown in rotation with trees (ie, are not part of an agroforestry system). New Zealand's main perennial crops are also vine fruit (ie, kiwifruit and grapes) so have a lower carbon content per area in living biomass at maturity than the cropland types included in the IPCC default value.

Cropland remaining cropland

For *Cropland remaining cropland*, the Tier 1 assumption is that for annual cropland there is no change in biomass carbon stocks after the first year (GPG-AFOLU, section 5.2.1, IPCC, 2006a). 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. Where there has been land-use change between the *Cropland* subcategories, carbon stock changes are reported under *Cropland remaining cropland*. Between 1990 and 2013, there were 9,266 hectares converted from one *Cropland* subcategory to another.

Living biomass

To estimate carbon change in living biomass for annual cropland converted to perennial cropland, New Zealand is using Tier 1 defaults for biomass carbon stocks at harvest. The value being used for annual cropland is 5 tonnes C ha^{-1} (see table 6.5.5). This is the carbon stock in living biomass after one year as given in GPG-AFOLU, table 5.9 (IPCC, 2006a). The Tier 1 method for estimating carbon change assumes carbon stocks in biomass immediately after conversion are zero; that is, the land is cleared of all vegetation before planting crops (5 tonnes C ha^{-1} is removed).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 tonnes C $ha^{-1}yr^{-1}$. This value is based on the New Zealand-specific value of 18.76 tonnes C ha^{-1} (Davis and Wakelin, 2010), sequestered over 28 years, which is the maturity period New Zealand uses for its lands to reach steady state.

The activity data available does not provide information on areas of perennial cropland temporarily destocked; therefore, no losses in carbon stock due to temporary destocking can be calculated.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation NE (not estimated) is used in the CRF 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, 2006a).

Soil organic carbon

Soil carbon stocks in *Cropland remaining cropland* are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils, as described in section 6.3. The steady state mineral soil carbon stock for annual cropland is estimated to be 89.77 tonnes C ha^{-1}; for perennial cropland, it is estimated to be 88.44 tonnes C ha^{-1} (table 6.3.2).

Mineral soil carbon change for annual cropland converted to perennial cropland is estimated using the IPCC default method of applying a linear rate of change over 20 years (equation (3) in section 6.3).

The IPCC default emission factors for organic soils under cropland are 1.0 and 10.0 tonnes C ha^{-1} per annum for cold temperate and warm temperate regimes, respectively (table 6.3.3).

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 6.1.3 and 6.1.4.

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 2.5 of GPG-AFOLU (IPCC, 2006a).

To estimate growth after conversion to annual cropland, New Zealand uses the IPCC default biomass accumulation rate of 5 tonnes C ha^{-1} for the first year following conversion (GPG-AFOLU, table 5.9, IPCC, 2006a). 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, 2006a, section 5.2.1).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 tonnes C $ha^{-1}yr^{-1}$. This value is based on the New Zealand-specific value of 18.76 tonnes C ha^{-1} (Davis and Wakelin, 2010), sequestered over 28 years, which is the maturity period New Zealand uses for its lands to reach steady state.

Dead organic matter

New Zealand reports only losses in dead organic matter associated with the previous land use for this category. The losses are calculated based on the carbon in dead organic matter at the site prior to conversion to *Cropland*. It is assumed that, immediately after conversion, dead organic matter is zero (all carbon in dead organic matter prior to conversion is lost). There is insufficient information to estimate gain in carbon stock in dead organic matter pools after land is converted to *Cropland* (IPCC, 2006a). Consequently, where there are no dead organic matter losses associated with the previous land use, the notation key NE (not estimated) is used in the CRF tables.

Soil organic carbon

Soil carbon stocks in land converted to annual and perennial cropland are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils, as described in section 6.3. In the absence of country- and land-use specific data on the rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original and new land uses.

The IPCC default emission factors for organic soils under *Cropland* are also applied to *Land converted to cropland.*

Non-CO_2 emissions

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

Nitrous oxide emissions from disturbance associated with land-use conversion to *Cropland* are described in section 6.11.3.

6.5.3 Uncertainties and time-series consistency

The uncertainty in mapping cropland is ± 8 per cent. Further details are given in section 6.2.5 and Dymond et al (2008).

New Zealand uses IPCC default values for biomass accumulation in annual cropland. For perennial cropland, we use a New Zealand-specific emission factor (Davis and Wakelin, 2010). As the perennial and annual cropland emission factors are based on only a limited number of biomass studies, the uncertainty in these figures is estimated as ± 75 per cent.

For mineral soils, the uncertainty is ± 9.7 per cent for SOC in annual cropland and ± 14.1 per cent for SOC in perennial cropland, as calculated from the Tier 2 method estimates of SOC (see table 6.5.6). For organic soils, New Zealand uses IPCC default values for annual and perennial cropland. The uncertainty associated with the IPCC default values is 95 per cent (based on GPG-AFOLU, table 2.3, IPCC, 2006a).

As shown in table 6.5.6, while uncertainty in activity data is low, the uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand.

Table 6.5.6 Uncertainty in New Zealand's 2013 cropland estimates (including land in transition)

Variable	Uncertainty at a 95% confidence interval	
Land-use subcategory	Annual cropland (%)	Perennial cropland (%)
Activity data		
Uncertainty in land area	8.0	8.0
Emission factors		
Uncertainty in biomass carbon stocks	75.0	75.0
Uncertainty in soil carbon stocks	9.7	14.1
Uncertainty introduced into net emissions for LULUCF	**0.9**	**0.4**

6.5.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for CO_2 emissions from the conversion to *Cropland* category underwent Tier 1 quality checks.

As part of verification of the New Zealand-specific above-ground biomass emission factor for perennial cropland, this factor has been compared with the IPCC default for temperate perennial cropland (table 5.1 of GPG-AFOLU, IPCC, 2006a). The New Zealand value for above-ground biomass of 18.76 tonnes C ha^{-1} is much lower than the default value of 63 tonnes C ha^{-1} provided in GPG-AFOLU (IPCC, 2006a). Further research into the differences between the values has shown the IPCC default value is based on just four studies of agroforestry systems where crops are grown in rotation with trees, and none of these studies are New Zealand specific. While the country-specific emission factor used is based on a New Zealand study, it takes into account that New Zealand's main perennial crops are not grown in rotation with trees (ie, are not part of an agroforestry system) and that a proportion of New Zealand's main perennial crops is vine fruit (ie, kiwifruit and grapes). This means it has lower carbon content per area in living biomass at maturity than the cropland types included in the study on which the IPCC default value is based.

6.5.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the *Cropland* category is shown in table 6.5.7. Recalculations of the entire time series were carried out for this category as a result of updated activity data on the land area of *Cropland* as part of land-use mapping improvements.

Table 6.5.7 Recalculations of New Zealand's net emissions from the cropland category in 1990 and 2012

	Net emissions (kt CO_2-e)		Change from the 2014 submission	
Year	2014 submission	2015 submission	(kt CO_2-e)	(%)
1990	479.6	479.1	–0.5	–0.1
2012	465.6	455.4	–10.2	–2.2

Note: The 2014 submission figures have been updated with the revised global warming potentials from the Contribution of Working Group I to the Fourth Assessment Report of the IPCC (IPCC, 2007) so vary slightly from those published in the 2014 submission. These values also exclude emissions from liming at both dates.

6.5.6 Category-specific planned improvements

No future improvements are planned for this category at this stage.

6.6 Grassland (CRF 4C)

6.6.1 Description

In New Zealand, grassland is used to describe a range of land-cover types. In this submission, three subcategories of *Grassland* are used: high producing, low producing and with woody biomass.

High producing grassland consists of intensively managed pasture land. Low producing grassland consists of low-fertility grasses on hill country, areas of native tussock or areas composed of low, shrubby vegetation, both above and below the timberline. Grassland with woody biomass consists of grassland areas where the cover of woody species is less than 30 per cent and/or does not meet, nor have the potential to meet, the New Zealand forest definition due to either the current management regime (eg, periodically cleared for grazing), characteristics of the vegetation or environmental constraints (eg, alpine shrubland). Grassland with woody biomass is therefore a diverse category. To account for these differences, grassland with woody biomass is split into permanent and transitional subcategories for modelling of land-use change effects on carbon. Separate emission factors for each type of grassland with woody biomass are derived from the LUCAS plot network (Wakelin and Beets, 2013). Within CRF Reporter, reporting on grassland with woody biomass is at the aggregate level.

Land-use research indicates that, under business-as-usual grassland farming operations, areas of woody shrublands (grassland with woody biomass – transitional) within farmland do not become forest over a 30- to 40-year timeframe (Trotter and MacKay, 2005). This is the case as long as the farmer's intention is to manage the land as grassland for grazing animals. When it becomes evident that the farmer has modified land management in a way that encourages sustained growth of woody vegetation, such as by removing stock or planting, then these areas will be mapped as forest. A description of the land-management approaches that result in the sustained growth of woody vegetation is contained in the mapping interpretation guide (Ministry for the Environment, 2012).

In 2013, there were 5,808,111 hectares of high producing grassland (21.6 per cent of total land area), 7,544,632 hectares of low producing grassland (28.0 per cent of total land area) and 1,363,634 hectares of grassland with woody biomass (5.1 per cent of total land area).

The net emissions from *Grassland* were 6,469.5 kt CO_2-e in 2013 (table 6.6.1). These emissions comprise 6,399.8 kt CO_2 emissions from carbon stock change and 0.04 kt N_2O (12.9 kt CO_2-e) and 2.27 kt CH_4 (56.8 kt CO_2-e) emissions from *Biomass burning* and nitrogen mineralisation on *Land converted to grassland*.

The *Grassland remaining grassland* and *Land converted to grassland* categories were identified as key categories for the level and trend assessment in 2013.

Net emissions from *Grassland* have increased by 5,365.2 kt CO_2-e (485.8 per cent) from the 1990 level of 1,104.3 kt CO_2-e (see table 6.1.1). The majority of this change is in the subcategory pre-1990 planted forest converted to low producing grassland and is the effect of deforestation that involves large losses in the living biomass pool.

Table 6.6.1 **New Zealand's land-use change for the grassland category, and associated CO_2-equivalent emissions, from 1990 to 2013**

Grassland land-use category	Area in 1990 (ha)	Area in 2013 (ha)	Change from 1990 (%)	Net emissions ($kt CO_2$-e) 1990	2013	Change from 1990 (%)
Grassland remaining grassland	14,673,261	14,520,636	–1.0	1,063.7	1,595.3	+50.0
Land in conversion to grassland	612,347	195,741	–68.0	40.6	4,874.2	+11,912.1
Total	**15,285,609**	**14,716,377**	**–3.7**	**1,104.3**	**6,469.5**	**+485.8**

Note: 1990 and 2013 areas are as at 31 December. Net emission estimates are for the whole year indicated. Land in conversion to grassland includes land converted up to 28 years prior to 1990. Columns may not total due to rounding.

From 1990 to 2013, the net carbon stock change attributed to *Grassland* was a decrease of 30,389.4 kt C, equivalent to emissions of 111,427.7 kt CO_2 from *Grassland* since 1990 (table 6.6.2). The majority of these emissions are due to the loss of living biomass carbon stock associated with *Forest land* conversion to *Grassland* (deforestation).

Table 6.6.2 **New Zealand's carbon stock change by carbon pool for the grassland category from 1990 to 2013**

Grassland subcategory	Net carbon stock change 1990–2013 (kt C): Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2013 ($kt CO_2$)
Grassland – high producing	–10,725.0	–984.2	–5,598.9	–17,308.1	63,462.9
Grassland – low producing	–10,673.2	–1,136.8	–122.7	–11,932.7	43,753.3
Grassland – with woody biomass	–312.8	–127.1	–708.7	–1,148.6	4,211.5
Total	**–21,711.0**	**–2,248.2**	**–6,430.2**	**–30,389.4**	**111,427.7**

Note: Columns may not total due to rounding.

Non-CO_2 emissions from *Grassland* in 2013 comprised 2.27 kt CH_4 (56.8 kt CO_2-e) and 0.04 kt N_2O (12.9 kt CO_2-e) from *Biomass burning* and nitrogen mineralisation on *Land converted to grassland*.

Grassland remaining grassland

There were 14,520,636 hectares of *Grassland remaining grassland* in 2013, equivalent to 53.9 per cent of New Zealand's total land area. For estimating carbon stock change with land-use change, this category has been split into three subcategories.

Land converted to grassland

Much of New Zealand's *Grassland* is grazed, with agriculture being the main land use. The majority of New Zealand's agriculture is based on extensive pasture systems, with animals grazed outdoors year-round. Increased profitability of dairy farming relative to other land uses has seen a recent trend for conversion of planted forest to pasture (deforestation).

Between 2012 and 2013, 16,906 hectares of land were converted to *Grassland*, while 20,184 hectares of *Grassland* were converted to other land-use categories.

The majority (94.5 per cent) of *Land converted to grassland* since 1990 is land that was previously *Forest land*. The 161,853 hectares of forest land converted to grassland since 1990 comprises an estimated 41,420 hectares of natural forest and 97,999 hectares of pre-1990 planted forest. A further 22,433 hectares of post-1989 forest (land that was not *Forest land* at the start of 1990) has also been converted to *Grassland* since 1990. (For more information on deforestation, see sections 6.2 and 6.4 and chapter 11.) Land-use change of *Forest land* to *Grassland* resulted in net emissions of 4,859.1 kt CO_2 in 2013.

6.6.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter have been calculated using a combination of IPCC Tier 1 emission factors and country-specific factors (table 6.6.3). Emissions and removals from mineral soils are estimated using a Tier 2 method, whereas organic soils are estimated using a Tier 1 method (section 6.3).

Table 6.6.3 Summary of New Zealand's biomass emission factors for grassland

Grassland subcategory	Carbon pool	Steady state carbon stock (t C ha^{-1})	Annual carbon accumulation (t C ha^{-1})	Years to reach steady state	Source
High producing	Biomass	6.75	6.75	1	IPCC default emission factor
	AGB	1.35	1.35	1	
	BGB	5.4	5.4	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
Low producing	Biomass	3.05	3.05	1	IPCC default emission factor
	AGB	0.8	0.8	1	
	BGB	2.25	2.25	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
With woody biomass – transitional	Biomass	11.99	0.44	28	Plot network derived emission factor
	AGB	9.35	0.33	28	
	BGB	3.05	0.11	28	
	Dead organic matter	0.65	0.02	28	
	Dead wood	0.10	0.004	28	
	Litter	0.55	0.02	28	
With woody biomass – permanent	Biomass	59.96	2.03	28	Plot network derived emission factor
	AGB	45.18	1.61	28	
	BGB	11.71	0.42	28	
	Dead organic matter	3.68	0.13	28	
	Dead wood	3.68	0.13	28	
	Litter	0.00	0.00	28	

Note: AGB = above-ground biomass; BGB = below-ground biomass; NA = not applicable; NE = not estimated. Columns may not total due to rounding.

Grassland remaining grassland

For grassland remaining grassland, the Tier 1 assumption is there is no change in carbon stocks (GPG-AFOLU, section 6.2.1.1, IPCC, 2006a). 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 CRF 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 (288,525 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 6.1.4 representing the annual growth in biomass for land converted to another land use. The values given in table 6.1.4 for high producing and low producing grassland are Tier 1 defaults. The values given for grassland with woody biomass are country-specific factors based on the LUCAS national plot network (Wakelin and Beets, 2013).

Dead organic matter

New Zealand does not report estimates of dead organic matter for high producing grassland or low producing grassland because GPG-AFOLU states there is insufficient information to develop default coefficients for estimating the dead organic matter pool (IPCC, 2006a). The notation key NE (not estimated) is used in the CRF tables.

For grassland with woody biomass, an estimate of dead organic matter is derived from the LUCAS national plot network (Wakelin and Beets, 2013), and estimates of changes in dead organic matter stocks with conversion to and from this land use are given in the CRF tables.

Soil carbon

Soil carbon stocks in *Grassland remaining grassland* are estimated using a Tier 2 method for mineral soils (table 6.6.4) and a Tier 1 method for organic soils (section 6.3). The IPCC default emission factors for organic soils under *Grassland* are 0.25 and 2.5 tonnes C ha^{-1} per annum for cold temperate and warm temperate regimes, respectively (IPCC, 2006a).

Table 6.6.4 New Zealand's soil carbon stock values for the grassland subcategories

Land-use	Soil carbon stock density (t C ha^{-1})
High producing grassland	105.34
Low producing grassland	105.98
Grassland with woody biomass	98.23

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 6.1.3. 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 2.9 of GPG-AFOLU (IPCC, 2006a).

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 CRF tables.

Where land is converted to grassland with woody biomass, dead organic matter accumulates to 0.65 tonnes C ha^{-1} over 28 years (the maturity period New Zealand has chosen for land to reach steady state).

Soil organic carbon

Soil carbon stocks in *Land converted to grassland* are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils (section 6.3). In the absence of country- and land-use-specific data on the rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and the new land use.

The IPCC default emission factors for organic soils under *Grassland* are also applied to *Land converted to grassland* (IPCC, 2003).

6.6.3 Uncertainties and time-series consistency

While the uncertainty introduced into the LULUCF net emissions by activity data is low, uncertainty in the IPCC default variables (table 3.4.2, IPCC, 2003) dominates the overall uncertainty in the estimate for *Grassland* provided by New Zealand (table 6.6.5).

The uncertainty in mapping *Grassland* is 8 per cent for high and low producing grassland, and 83 per cent for grassland with woody biomass. Further details are given in section 6.2.5.

New Zealand uses IPCC default values for biomass accumulation in high producing and low producing grassland. The uncertainty in these figures is given as ± 75 per cent. A New Zealand-specific value derived from the LUCAS national plot network is used for biomass accumulation in grassland with woody biomass. Grassland with woody biomass is a diverse category; therefore the IPCC default uncertainty value is used (Wakelin and Beets, 2013).

Of the *Grassland* subcategories, low producing grassland has the greatest uncertainty in soil carbon stocks. Soil carbon stocks for low producing grassland are variable because this land use covers a wide range of environmental factors due to its geographic extent.

Table 6.6.5 Uncertainty in New Zealand's 2013 estimates for the grassland category (including land in transition)

Variable	Uncertainty at a 95% confidence interval		
Land-use subcategory	High producing (%)	Low producing (%)	With woody biomass (%)
Activity data			
Uncertainty in land area	8.0	8.0	83.0
Emission factors			
Uncertainty in biomass carbon stocks	75.0	75.0	75.0
Uncertainty in soil carbon stocks	5.8	7.3	7.3
Uncertainty introduced into net emissions for LULUCF	**3.9**	**2.5**	**0.4**

Note: Uncertainty in biomass carbon stocks for grassland with woody biomass is estimated using the IPCC default uncertainty value because an independent estimate of uncertainty for this subcategory is not available.

6.6.4 Category-specific QA/QC and verification

Carbon dioxide emissions from the *Grassland remaining grassland* and *Land converted to grassland* categories are key categories (level and trend). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

6.6.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the *Grassland* category is shown in table 6.6.6 below.

Table 6.6.6 Recalculations of New Zealand's net emissions from the grassland category in 1990 and 2012

	Net emissions (kt CO_2-e)		Change from the 2014 submission	
Year	2014 submission	2015 submission	(kt CO_2-e)	(%)
1990	+810.4	+1,104.3	293.9	36.3
2012	+5,368.7	+6,247.4	878.7	16.4

Note: The 2014 submission figures have been updated with the revised global warming potentials from the Contribution of Working Group I to the Fourth Assessment Report of the IPCC (IPCC, 2007) so vary slightly from those published in the 2014 submission. These values also exclude emissions from liming at both dates.

These recalculations are due to updated activity data as discussed in section 6.1.4.

6.6.6 Category-specific planned improvements

There are no improvements planned for this category at this time.

6.7 Wetlands (CRF 4D)

6.7.1 Description

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

Section 3.2 of GPG-AFOLU defines *Wetlands* as "areas of peat extraction and land that is covered or saturated by water for all or part of the year (eg, peatlands), and that does not fall into the *Forest Land*, *Cropland*, or *Grassland* categories." (IPCC, 2006a, p 3.6). The definition includes reservoirs as a managed subdivision, and natural rivers and lakes as unmanaged subdivisions. Flooded lands are defined in GPG-AFOLU as (IPCC, 2006a, p 7.19):

> *… water bodies where human activities have caused changes in the amount of surface area covered by water, typically through water level regulation. … Regulated lakes and rivers that do not have substantial changes in water area in comparison with the pre-flooded ecosystems are not considered as Flooded Lands.*

The majority of New Zealand's hydroelectric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river, therefore they are not defined as flooded lands.[38]

New Zealand's wetlands are currently mapped into two subcategories: open water, which includes lakes and rivers; and vegetated wetland, which includes herbaceous vegetation that is periodically flooded, and estuarine and tidal areas. New Zealand has mapped its vegetated wetlands using existing LCDB data (see section 6.2 for more information). Areas of open water have been mapped using hydrological boundaries defined by Land Information New Zealand. The area of flooded land has not been mapped separately from other naturally occurring open water (natural lakes). Examples of flooded lands in New Zealand include irrigation reservoirs and the Clyde Dam hydroelectric dam. No methodologies are provided for flooded land remaining flooded land (GPG-AFOLU), and New Zealand does not report emissions estimates for this subcategory.

In 2013, there were 535,836 hectares of open water and 145,086 hectares of vegetated wetlands. These two subcategories combined make up 2.5 per cent of the total New Zealand land area.

In 2013, there were 4.7 kt CO_2-e emissions from *Wetlands*, compared with emissions of –21.8 kt CO_2-e from *Wetlands* in 1990 (see table 6.7.1). This changing trend, from net remover in 1990 to net emitter in 2013, is due to the shift in land-use change patterns that have been observed since 1990 when compared with the changes that had occurred before 1990.

As at 2013, there were 6,295 hectares in a state of conversion to *Wetlands* (table 6.7.1). These lands have been converted to *Wetlands* during the previous 28 years but have not yet reached steady state and entered the *Wetlands remaining wetlands* category.

Table 6.7.1 New Zealand's land-use change for the wetlands category, and associated CO_2-equivalent emissions, in 1990 and 2013

Wetlands land-use category	Net area (ha)		Change from 1990 (%)	Net emissions (kt CO_2-e)		Change from 1990 (%)
	1990	2013		1990	2013	
Wetlands remaining wetlands	664,046	674,627	+1.6	0.0	0.0	+2,225.3
Land in conversion to wetlands	13,997	6,295	–55.0	–21.8	4.7	–121.6
Total	**678,043**	**680,922**	**+0.42**	**–21.8**	**+4.7**	**–121.7**

Note: 1990 and 2013 area values are as at 31 December. Net emission values are for the whole year indicated. Land in conversion to wetlands consists of land converted to hydro lakes prior to 1990. Columns may not total due to rounding.

From 1990 to 2013, the net carbon stock change for *Wetlands* increased by 30.4 kt C, equivalent to emissions of 111.3 kt CO_2 in total since 1990 (table 6.7.2). These carbon stock losses are from the loss of living biomass carbon stock, associated with *Grassland* conversion to *Wetlands*, in addition to historical (pre-1990) conversion of *Forest land* to hydroelectric dams, which continues to have a lagged effect on soil organic carbon in the inventory period.

[38] An exception occurred in the creation of the Clyde Dam. The Clutha River in the South Island was dammed, creating Lake Dunstan. The area flooded was mostly low producing grassland.

Table 6.7.2 New Zealand's carbon stock change by carbon pool for the wetlands category from 1990 to 2013

Wetlands subcategory	Net carbon stock change 1990–2013 (kt C)				Emissions 1990–2013 (kt CO_2)
	Living biomass	Dead organic matter	Soils	Total	
Wetlands – vegetated	–6.4	–0.9	2.2	–5.1	18.6
Wetlands – open water	–33.1	–1.5	70.0	35.4	–129.9
Total	**–39.5**	**–2.4**	**72.3**	**30.4**	**–111.3**

6.7.2 Methodological issues

Wetlands remaining wetlands

Living biomass and dead organic matter

A basic method for estimating CO_2 emissions in *Wetlands remaining wetlands* is provided in section 7.1 of GPG-AFOLU (IPCC, 2006a). Chapter 7 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. New Zealand reports the notation key NE (not estimated) in the common reporting format table for this category.

Soil carbon

Soil carbon stocks in *Wetlands remaining wetlands* are estimated using a Tier 2 method for mineral soils (section 6.3). The mineral soil steady state carbon stock for vegetated wetlands is estimated to be 136.06 tonnes C ha^{-1}, with an uncertainty of 12.3 per cent. For open water, the soil carbon stock at equilibrium is assumed to be zero.

For mineral soils, as with living biomass and dead organic matter, there are no emissions for *Wetlands* in steady state so the notation key NE (not estimated) is used.

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with peat extraction, which is not a significant activity in New Zealand. It is therefore assumed that there are no carbon emissions from organic soils in *Wetlands remaining wetlands*.

Land converted to wetlands

Between 1990 and 2013, 4,212 hectares of land were converted to *Wetlands*, while 1,281 hectares of *Wetlands* were converted to other land uses (mainly grassland 695 hectares). This resulted in a net increase in total wetland area of 2,931 hectares.

Living biomass and dead organic matter

New Zealand uses a Tier 1 method to calculate emissions from *Land converted to wetlands* (GPG-AFOLU, equation 7.10, IPCC, 2006a). The Tier 1 method assumes carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place. For open-water wetlands, the carbon stocks in living biomass and dead organic matter following conversions are equal to zero. For vegetated wetlands, the carbon stocks in living biomass and dead organic matter are not estimated as there is no guidance in GPG-AFOLU for estimating carbon stock following land-use change to *Wetlands*, and all emissions from land-use change to *Wetlands* from removal of the previous vegetation are instantly emitted. The notation keys NO (not occurring) and NE (not estimated) are reported in the CRF tables.

Soil carbon

Soil carbon stocks in *Land converted to wetlands* are estimated using a Tier 2 method, as described in section 6.3. In the absence of data on the rate of change specific to country and land-use, the IPCC default method of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and *Wetlands* for any given period.

Non-CO_2 emissions

Non-CO_2 emissions from drainage of soils and wetlands

New Zealand has not prepared estimates for this category. 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.

6.7.3 Uncertainties and time-series consistency

The uncertainty in mapping *Wetlands* is 33 per cent (table 6.7.3). Further details are given in section 6.2.5.

The uncertainty for soil carbon stocks in vegetated wetlands is 12.3 per cent. No uncertainty is associated with the assumed value of zero for SOC in open water.

Table 6.7.3 Uncertainty in New Zealand's 2013 estimates for the wetlands category (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	33.0
Emission factors	
Uncertainty in biomass carbon stocks	75.0
Uncertainty in soil carbon stocks	12.3
Uncertainty introduced into net emissions for LULUCF	**0.0**

Note: NO = not occurring. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equation 3.2 from IPCC General Guidance and Reporting (IPCC, 2006b).

6.7.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data and emission factor for carbon change underwent Tier 1 quality checks.

6.7.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for *Wetlands* is shown in table 6.7.4. Recalculations were carried out for this category as a result of new activity data from the improved mapping process, as described in section 6.2.

The carbon stock in soils at equilibrium state has also been recalculated since the last submission. Details of this process are described in section 6.3.

Table 6.7.4 **Recalculations for New Zealand's net emissions from the wetlands category in 1990 and 2012**

Year	Net emissions (kt CO_2-e) 2014 submission	Net emissions (kt CO_2-e) 2015 submission	Change from the 2014 submission (kt CO_2-e)	Change from the 2014 submission (%)
1990	+218.2	–21.8	–240.0	–110.0
2012	+44.4	+7.2	–37.3	–83.8

6.7.6 Category-specific planned improvements

During the coming year, the focus of planned improvements in this category will be to ensure the data inputs and modelling are consistent with the 2006 IPCC guidelines.

6.8 Settlements (CRF 4E)

6.8.1 Description

The *Settlements* land-use category, as described in chapter 3.2 of GPG-AFOLU, includes "all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories" (IPCC, 2006a, p 3.7). *Settlements* include trees grown along streets, in public and private gardens, and in parks associated with urban areas.

In 2013, there were 224,733 hectares of *Settlements* in New Zealand, an increase of 17,793 hectares since 1990. This category comprised 0.8 per cent of New Zealand's total land area in 2013. The largest area of change to *Settlements* between 1990 and 2013 was from high producing grassland, with 13,688 hectares of high producing grassland converted to *Settlements* between 1990 and 2013.

In 2013, the net emissions from *Settlements* were –4.6 kt CO_2-e (see table 6.8.1). These emissions are entirely from the subcategory of *Land converted to settlements*.

Settlements were not a key category in 2013.

Table 6.8.1 **New Zealand's land-use change for the settlements category, and associated CO_2-equivalent emissions, from 1990 to 2013**

Settlements land-use category	Net area (ha) 1990	Net area (ha) 2013	Change from 1990 (%)	Net emissions (kt CO_2-e) 1990	Net emissions (kt CO_2-e) 2013	Change from 1990 (%)
Settlements remaining settlements	183,552	202,800	+10.5	NE	NE	NA
Land converted to settlements	23,388	21,933	–6.2	2.3	–4.6	–300.4
Total	**206,940**	**224,733**	**+8.6**	**2.3**	**–4.6**	**–300.4**

Note: NA = not applicable. 1990 and 2013 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for the settlements remaining settlements land-use category are not estimated (NE) as no Tier 1 default emission factor is provided in GPG-AFOLU for this subcategory; see section 6.8.2 for details. Columns may not total due to rounding.

In 2013, there were 202,800 hectares of *Settlements remaining settlements* (table 6.8.1). Carbon in living biomass and dead organic matter is not estimated for this land-use category. The carbon stock in soil for this land use is assumed to be in steady state.

From 1990 to 2013, the net carbon stock change for *Settlements* decreased by 176.7 kt C, equivalent to emissions of 647.7 kt CO_2 in total since 1990 (table 6.8.2). These carbon stock losses are predominantly due to the loss of living biomass on land conversion to *Settlements*.

Table 6.8.2 New Zealand's carbon stock change by carbon pool for the settlements category from 1990 to 2013

Land-use category	Net carbon stock change 1990–2013 (kt C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2013 (kt CO_2)
Settlements	–261.3	–13.9	98.5	–176.7	647.7

6.8.2 Methodological issues

Settlements remaining settlements

The Tier 1 assumption for *Settlements remaining settlements* assumes there is no change in carbon stocks for any pools, that is the growth and loss terms balance (GPG-AFOLU, IPCC, 2006a, sections 8.2.1, 8.2.2 and 8.2.3). As this is not a key category, New Zealand is not investigating methods to move to a higher tier of reporting for this category.

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-AFOLU, equation 2.16, IPCC, 2006a). 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. Furthermore, carbon stocks in living biomass and dead organic matter following conversion are equal to zero (GPG-AFOLU, section 8.3.1 and 8.3.2, IPCC, 2006a).

Soil carbon

Soil carbon stocks *in Land converted to settlements* are estimated using a Tier 2 method (section 6.3). In the absence of either country- or land-use specific data on the rate of change, the IPCC default of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and settlements for any given period.

6.8.3 Uncertainties and time-series consistency

The uncertainty in mapping *Settlements* is ± 22 per cent (table 6.8.3). Further details are given in section 6.2.5.

New Zealand uses the IPCC default values for biomass accumulation. The uncertainty in these figures is ± 75 per cent.

For soils, the default uncertainty of ± 95 per cent is applied here.

Table 6.8.3 Uncertainty in New Zealand's 2013 estimates for the settlements category (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	22.0
Emission factors	
Uncertainty in biomass carbon stocks	75.0
Uncertainty in soil carbon stocks	95
Uncertainty introduced into net emissions for LULUCF	**0.0**

Note: NO = not occurring. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equation 3.2 from IPCC General Guidance and Reporting (IPCC, 2006b).

6.8.4 Category-specific QA/QC and verification

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

6.8.5 Category-specific recalculations

Recalculations were carried out for this category as a result of new activity data from the improved mapping process, as described in section 6.2.

Table 6.8.4 Recalculations for New Zealand's net emissions from the settlements category in 1990 and 2012

	Net emissions (kt CO_2-e)		Change from the 2014 submission	
Year	2014 submission	2015 submission	(kt CO_2-e)	(%)
1990	+6.3	+2.3	–4.0	–63.7
2012	–3.0	+0.3	+3.3	–110.8

6.8.6 Category-specific planned improvements

There are no planned improvements for this category. Improvements to New Zealand's land-use mapping will result in recalculation of emissions from *Settlements* for the 2016 submission.

6.9 Other land (CRF 4F)

6.9.1 Description

Other land is defined in section 3.2 of GPG-AFOLU 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 2013, the net emissions from *Other land* were 30.8 kt CO_2-e (see table 6.9.1). These emissions occur in the *Land converted to other land* category and are 23.1 kt CO_2-e (298.5 per cent) higher than the 1990 level of 7.7 kt CO_2-e. This is primarily because the area of land estimated as having been converted to *Other land* has been steadily increasing since 1990.

An analysis of change in area shows that of the 6,449 hectares converted from other land to different land-use categories, 4,084 hectares were converted to post-1989 forest and 1,304 hectares were converted to grassland with woody biomass.

Between 1 January 1990 and 31 December 2013, there were 3,920 hectares of *Land converted to other land*; most (2,332 hectares) of this was from the *Grassland* categories (table 6.2.4). This is likely to be mainly due to conversion of *Grassland* to roads, mines and quarries. *Other land* was not a key category in 2013.

Table 6.9.1 New Zealand's land-use change for the land-use category of other land from 1990 to 2013

Land-use category – other land	Net area as at 1990 (ha)	Net area as at 2013 (ha)	Change from 1990 (%)	Net emissions ($kt CO_2$-e)		Change from 1990 (%)
				1990	2013	
Other land remaining other land	897,334	891,099	–0.7	NE	NE	NA
Land in conversion to other land	101	3,910	+3,769.5	7.7	30.8	+298.5
Total	**897,436**	**895,010**	**–0.3**	**7.7**	**30.8**	**+298.5**

Note: 1990 and 2013 area values as at 31 December. Net emission values are for the whole year indicated. Net emissions for other land remaining other land are not applicable (NA) as change in carbon stocks and non-CO_2 emissions are not estimated (NE) for this category; see section 6.9.2 for details. Columns may not total due to rounding.

6.9.2 Methodological issues

Other land remaining other land

The area of *Other land* has been estimated based on LCDB2. The method used is described in more detail in section 6.2.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for other land is provided in table 6.9.2.

Table 6.9.2 Summary of New Zealand emission factors for the land-use category of other land

Other land greenhouse gas source category	Steady state carbon stock ($t\ C\ ha^{-1}$)	Years to reach steady state	Carbon stock change on conversion to other land ($t\ C\ ha^{-1}$)	Reference
Biomass	NE	NA	Instantaneous loss of previous land-use carbon stock	IPCC Tier 1 default assumption (section 9.3.1, GPG-AFOLU, IPCC, 2006a)
Soils (mineral)	58.37	20	Linear change over the conversion period between new and previous stock values	Section 6.3 of this submission
Biomass burning	NE	NA	NE	

Note: NA = not applicable; NE = not estimated.

Living biomass and dead organic matter

All of New Zealand's land area in the *Other land* category is classified as 'managed'. New Zealand considers all land to be managed, as all land is under some form of management plan, regardless of the intensity and/or type of land-management practices. No guidance is provided in GPG-AFOLU for estimating carbon stocks in living biomass or dead organic matter for *Other land* that is managed; therefore the change in carbon stocks and non-CO_2 emissions is not estimated for this category.

Soil carbon

Soil carbon stocks in *Other land remaining other land* are estimated using a Tier 2 method for mineral soils (section 6.3). The steady state mineral soil carbon stock in *Other land* is estimated to be 58.37 tonnes C ha^{-1}. This is based on only three samples so has an associated uncertainty of 70.7 per cent (McNeill and Barringer, 2014).

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-AFOLU, equation 2.16, IPCC, 2006a). This is the same as that used for other areas of land-use conversion (eg, *Land converted to cropland*). The Tier 1 method assumes carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place and that carbon stock in living biomass and dead organic matter following conversion is equal to zero. There is no Tier 1 method for calculating carbon accumulation in living biomass or dead organic matter for *Land converted to other land*.

Soil carbon

Soil carbon stocks in *Land converted to other land* prior to conversion are estimated using a Tier 2 method (section 6.3). The IPCC default method of a linear change over a 20-year period is used to estimate the change in soil carbon stocks between the original land use and other land for any given period.

6.9.3 Uncertainties and time-series consistency

Uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. Uncertainty in other land introduces 0.03 per cent uncertainty into the LULUCF net carbon emissions (table 6.9.3). This is low because the change in *Other land* and the emissions from *Other land* are low.

Table 6.9.3 Uncertainty in New Zealand's 2013 estimates for the land-use category of other land (including land in transition)

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	22.0
Emission factors	
Uncertainty in biomass carbon stocks	75.0
Uncertainty in soil carbon stocks	70.7
Uncertainty introduced into net emissions for LULUCF	**0.03**

Note: NO = not occurring. The activity data and combined emission factor uncertainty are weighted values and have been calculated using equation 3.2 from IPCC General Guidance and Reporting (IPCC, 2006b).

6.9.4 Category-specific QA/QC and verification

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

6.9.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the other land category is shown in table 6.9.4. Recalculations were carried out for this category as a result of new activity data from the improved mapping process, as described in section 6.2, and changes to the data and method used to estimate carbon stock change in soil organic matter as explained in section 6.3.

Table 6.9.4 Recalculations for New Zealand's net emissions from the other land category in 1990 and 2012

	Net emissions (kt CO_2-e)		Change from the 2014 submission	
Year	2014 submission	2015 submission	(kt CO_2-e)	(%)
1990	6.2	7.7	1.5	24.1
2012	17.8	38.6	20.8	117.3

6.9.6 Category-specific planned improvements

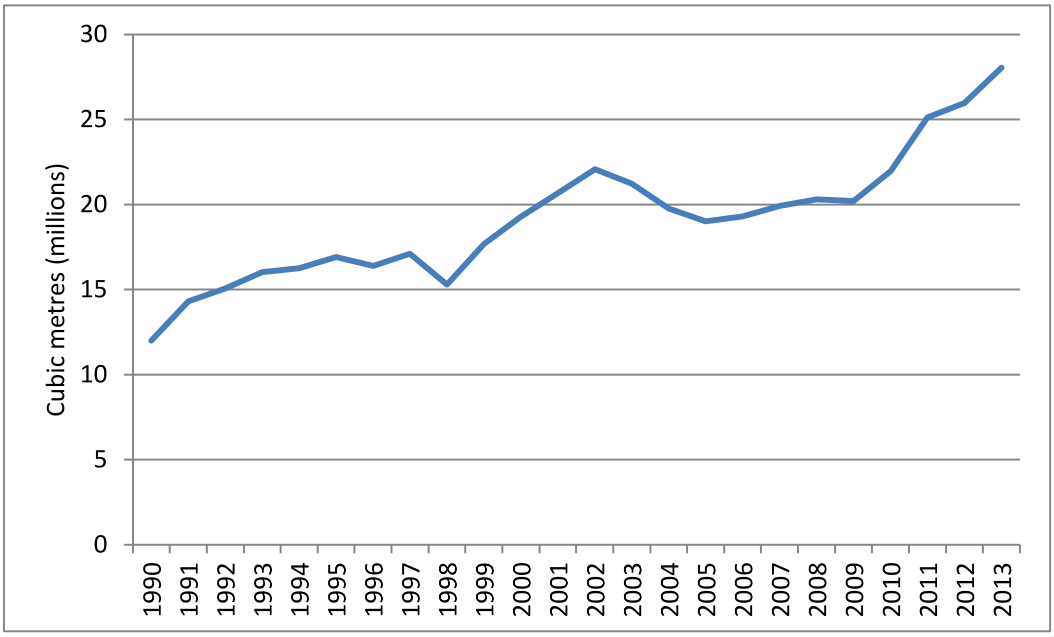
Improvements to New Zealand's land-use mapping will result in recalculation of emissions for other land for the 2016 submission.

6.10 Harvested wood products (CRF 4G)

6.10.1 Description

New Zealand is reporting for the harvested wood products pool for the first time in the 2015 submission. In 2013, the net emissions from harvested wood products were –10,295.6 kt CO_2-e. This is –8,326.4 kt CO_2-e (422.8 per cent) higher than the 1990 level of –1,969.2 kt CO_2-e. This is because the rate of harvest in New Zealand has increased since 1990. This is illustrated in the roundwood production statistics shown in figure 6.10.1.

Figure 6.10.1 Volume of roundwood produced between 1990 and 2013



New Zealand has a large planted forest estate that provides the majority of wood products consumed domestically and exported in either product or raw material form. These forests were planted from the 1920s to supplement and eventually replace the harvesting of natural forests. Forest planting from the 1960s provides a resource specifically established to provide products to the export market. New Zealand currently processes under 50 per cent of its annual harvest. The remaining harvest is exported in raw material form. New Zealand is currently the second largest exporter of softwood logs after the Russian Federation (Wakelin, 2014).

New Zealand's planted forests are dominated by radiata pine, which is used in a wide range of applications including timber-frame construction, packaging, plywood, medium density fibreboard (MDF), posts and poles and mechanical and chemical pulping.

6.10.2 Methodological issues

New Zealand has selected the production approach to report harvested wood products in the Inventory. To do this, New Zealand has adapted the default harvested wood products model and uses a Tier 2 method using some country-specific activity data and parameters. The default model assumes that exported raw materials are converted into products and consumed at the same rate as domestic production. Work is currently under way to validate this assumption via research into the end-use of New Zealand raw materials in export markets.

Activity data

Activity data is from the Food and Agriculture Organization statistical database (FAOSTAT) that is provided to the Food and Agriculture Organization by the Ministry for Primary Industries. Errors within the data sourced from FAOSTAT were corrected, including adding missing data and updating data that was not updated from the previous estimates. The data was corrected using data directly from the Ministry for Primary Industries.

Emission factors

A wood carbon content value of 50 per cent is used in the harvested wood products model to maintain consistency with the planted forest model. Radiata pine contributes over 90 per cent of New Zealand's harvest. Therefore, a country-specific wood density value of 420 kg/m^2 is used to reflect the dominance of this species (Jones, 2005). The default IPCC bark factor for conifers (11 per cent) is used and is appropriate for New Zealand. Wood-based panels, paper products and charcoal all use IPCC defaults as no country-specific value is available.

Table 6.10.1 Country-specific conversion factors for harvested wood products produced in New Zealand

Category	Factor (t C/m^2 or t C/t*)	Source
Sawnwood, other Industrial Roundwood	0.210	Country specific
Wood-based panels	0.294	IPCC default
Paper products	0.450*	IPCC default
Charcoal	0.765*	IPCC default

Note: Country-specific conversion factors are from Wakelin, 2014.* indicates where factors are given in tonnes of carbon per tonne of product.

Half-lives

Half-lives determine the discard rate of products from service in the solid wood and paper product categories. New Zealand uses the default half-lives of 30 years for solid wood and two years for paper. New Zealand wood products have a diverse range of end uses and there has been a limited amount of research into discard rates, making it difficult to estimate country-specific half-lives.

6.10.3 Uncertainties and time-series consistency

Uncertainty in the harvested wood products estimates is introduced by activity data, conversion factors and decay parameters. Harvested wood products provide the second greatest contribution to uncertainty in the LULUCF sector. This is driven by large removals in the subcategory and high uncertainty associated with the end-use and discard rates of New Zealand wood. Uncertainty limits for harvested wood products data and parameters are given in table 6.10.3. Uncertainty in New Zealand's 2013 estimates from emissions associated with harvested wood products are provided in table 6.10.3.

Table 6.10.2 Uncertainty in harvested wood products data and parameters

Parameter	Per cent uncertainty	Origin
Roundwood removals data	20	IPCC default
HWP production, import and export data	15	IPCC default
Product volume to weight factors	10	Country specific
Oven dry product weight to carbon weight	5	Country specific
Discard rate, domestic	50	Country specific
Discard rate, export	90	Country specific

Note: Uncertainty in harvested wood products data and parameters are from Wakelin, 2014.

Table 6.10.3 Uncertainty in New Zealand's 2013 estimates from emissions associated with harvested wood products

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in activity data	15.0
Emission factors	
Domestic production	51.2
Export raw materials	90.7
Total domestic and export uncertainty	67.4
Uncertainty introduced into net emissions for LULUCF	**27.0**

6.10.4 Category-specific QA/QC and verification

New Zealand data from FAOSTAT were checked against data from the Ministry for Primary Industries (the agency responsible for the collection of this data). Missing totals in aggregate categories were filled by summing individual product categories, and incorrect estimates were replaced.

6.10.5 Category-specific recalculations

Harvested wood products estimates for New Zealand are reported for the first time in the Inventory.

6.10.6 Category-specific planned improvements

New Zealand is currently investigating the end-use and discard rates of New Zealand harvested wood products produced from raw materials in export markets, to reduce uncertainty.

6.11 Non-CO_2 emissions (CRF 4(I-V))

6.11.1 Direct N_2O emissions from nitrogen fertilisation of forest land and other land (CRF 4(I))

New Zealand's activity data on nitrogen fertilisation is not currently disaggregated by land use and, therefore, all *Direct N_2O emissions from nitrogen fertilisation of forest land and other land* are reported in the Agriculture sector under the subcategory, *Direct soils emissions* (CRF 4D). The notation key IE (included elsewhere) is reported in the CRF tables for the LULUCF sector.

6.11.2 Non-CO_2 emissions from drainage of soils and wetlands (CRF 4(II))

New Zealand has not prepared estimates for this category. 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 reported in the CRF tables for the LULUCF sector.

6.11.3 Direct N_2O emissions from nitrogen mineralisation/ immobilisation (CRF 4(III))

Description

Nitrous oxide emissions result from the mineralisation of soil organic matter with land-use change. 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-AFOLU, section 11, IPCC, 2006a).

Direct N_2O emissions from nitrogen mineralisation/immobilisation are minor in New Zealand, estimated at 0.04 kt N_2O in 2013 compared with 0.05 kt N_2O in 1990.

Methodological issues

To estimate N_2O emissions from disturbance associated with land-use change, New Zealand uses the method outlined in GPG-AFOLU, equations 11.2 and 11.8 (IPCC, 2006a). The inputs to these equations are:

- loss of carbon in mineral soils
- 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 kilogram N_2O – N/kg N (Kelliher and de Klein, 2006)
- C:N ratio – the IPCC default ratio of carbon to nitrogen in soil organic matter (1:15) is used (IPCC, 2006a).

Where an area of land is converted to a land use with a lower original mineral soil organic carbon stock than the subcategory it is converted from, no N_2O emissions have been estimated as occurring because there is no associated loss of soil organic carbon. For instance, cropland converted to forest land is estimated not to result in net N_2O emissions because this land-use conversion is associated with a net gain in soil organic carbon in New Zealand (refer to table 6.3.1). In these situations, the notation key NO (not occurring) is reported in the CRF tables.

Uncertainties and time-series consistency

New Zealand uses a country-specific value for calculating N_2O emissions from nitrogen in soil. This value has a high level of uncertainty, which is estimated at 40.0 per cent (table 6.11.1).

Table 6.11.1 Uncertainty in New Zealand's 2013 estimates for N_2O emissions from land-use change

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in land area	8.0
Emission factors	
Uncertainty in N_2O calculation	40.0
Uncertainty in carbon calculation	97.0
Uncertainty introduced into net emissions for LULUCF	**0.0**

Source-specific planned improvements

There are no improvements planned for this category at this time.

6.11.4 Biomass burning (CRF 4(V))

Description

Biomass burning may occur as a result of wildfires or controlled burning, and results in emissions of CO_2, CH_4, N_2O, CO and NO_x. The general approach for estimating greenhouse gas emissions from *Biomass burning* is the same regardless of the specific land-use type.

Biomass burning is not a significant source of emissions for New Zealand, as the practice of controlled burning is limited and wildfires are not common due to New Zealand's temperate climate and vegetation.

Emissions of CO_2 are reported as either IE (included elsewhere) (where subsequent regrowth is not captured in the Inventory) or NE (not estimated) (where no data exists) in the CRF tables. The reason for this is explained below under Methodological issues. Non-CO_2 emissions from *Biomass burning* in 2013 were 0.6 kt CH_4 (15.0 kt CO_2-e) and 0.004 kt N_2O (1.2 kt CO_2-e) (table 6.11.2).

Table 6.11.2 Non-CO_2 emissions from biomass burning

Emissions	1990	2013	Change since 1990 (%)
CH_4 emissions (kt CH_4)	0.74	0.6	18.5
N_2O emissions (kt N_2O)	0.01	0.004	18.5

Methodological issues

New Zealand reports on emissions from wildfire in *Forest land* and *Grassland* in the Inventory. Controlled burning associated with the conversion of *Grassland* to *Forest land*, the clearing of vegetation (natural forest) prior to the establishment of exotic planted forest, the burning of post-harvest slash prior to restocking and controlled burning associated with deforestation are also included. For the first time in 2013, estimates are provided for emissions from the controlled burning of grassland with woody biomass and wildfire on deforestation land. The burning of crop stubble is reported under the Agriculture sector (chapter 5).

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 6.2.4.2 and 2.4, GPG-AFOLU, IPCC, 2006a). 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 6.2 and an estimate of area burnt from a survey of forest owners. Wildfire activity data is sourced from the National Rural Fire Authority database, which has data from 1991/92 onwards. In this submission, there have been minor revisions to the activity data for several years in the time series. The main change is the use of estimates from the database for all years in the time series, replacing the previous approach of using averages where no data was available. The April year data from the database is converted to calendar years for use in the Inventory (Wakelin and Clifford, 2013).

There has not been a significant change in wildfire activity since 1990. Wildfires induced by natural disturbances (lightning) are estimated to account for only 0.1 per cent of burning in *Grassland* and *Forest land* in New Zealand (Doherty et al, 2008; Wakelin, 2006). Non-CO_2 emissions from these events are reported in the Inventory because the National Rural Fire Authority does not distinguish between anthropogenic and natural wildfire events in the data. Given the small incidence of natural-disturbance-induced wildfires in New Zealand, this is not regarded as a significant source of error.

Emissions of CO_2 from wildfires in *Forest land remaining forest land* are included in the general stock change calculation. In *Forest land remaining forest land*, burnt stands are either harvested, so emissions are included with the harvesting emissions, or left to grow on at reduced stocking. Carbon dioxide emissions are reported when the stand is harvested or deforested (with no reduction in stock when compared with an unburnt stand). For both natural and planted forests, emissions from areas burnt are captured within the forest plot networks that New Zealand uses to estimate carbon stock change. In these cases, to avoid double counting of CO_2 emissions, the notation key IE (included elsewhere) is used. *Biomass burning* is not a key category for New Zealand.

A single weighted biomass density is used to estimate non-CO_2 emissions from wildfire in the *Forest land remaining forest land* subcategory. Wildfire activity data is attributed to each subcategory by proportion of forest type estimated to be burned over the time series. This is split by 87.5 per cent to planted forest with the remaining to natural forest (Wakelin, 2011). The planted forest activity data is further split into pre-1990 and post-1989 forest by the proportion of area each subcategory makes up of the total planted forest area. In planted forest, it is assumed that the carbon stock affected by wildfire is equivalent to the carbon stock at the average stand age in each subcategory (Wakelin, 2011). The individual forest subcategory estimates that make up the single weighted figure are derived from the national plot network described in section 6.4.

An estimate for wildfire in *Land converted to grassland* is provided for the first time in this submission. The activity data for wildfire in *Grassland* is attributed to the land converted to and land remaining subcategories by the proportion of area each subcategory makes up of the total area.

A survey of controlled burning in planted forest was carried out in 2011 to estimate controlled burning activity on *Forest land* in New Zealand. Estimates were provided for burning associated with the clearing of vegetation (ie, natural forest and grassland with woody biomass) prior to the establishment of exotic planted forest. The survey indicated that 5 per cent of conversions to planted forest involved burning to clear vegetation. This was allocated to pre-1990 planted forest (conversions from natural forest) and post-1989 forest (conversions from grassland with woody biomass) on a pro rata basis (Wakelin, 2012).

Activity data is combined with an emission factor derived from the natural forest national plot network (see table 6.1.3) to estimate non-CO_2 emissions from burning associated with the clearing of vegetation prior to the establishment of exotic planted forest. Below-ground biomass is assumed not to burn. The IPCC default combustion proportion for the burning of non-eucalypt temperate forest in land clearing fires (0.51) is then applied to estimate emissions from this activity (Wakelin, 2012).

The survey also provided data on the burning of post-harvest slash prior to restocking. This activity was found to occur mainly as a training exercise for wildfire control or for the clearing of slash heaps on skid sites. The data indicated that 0.8 per cent of restocked area was burnt each year in recent years. This estimate was combined with two earlier estimates of controlled burning in planted forest (Forest Industry Training and Education Council, 2005; Robertson, 1998) to provide activity data throughout the time series. It is assumed that 1.6 per cent of restocked area was burnt from 1990 to 1997. From 1997, the area burnt declines linearly to 0.8 per cent, which is used from 2005 onwards (Wakelin, 2012).

Activity data is combined with an emission factor derived from the pre-1990 planted forest carbon-yield table to estimate emissions from the burning of post-harvest slash (harvest residue) on *Forest land*. The harvest residue is calculated by subtracting the amount of above-ground biomass that is taken off site as logs (70 per cent) from the total above-ground biomass predicted at the age of 28 years (the average harvest age in New Zealand). Below-ground biomass is assumed not to burn. The IPCC default combustion proportion for the burning of harvest residue in non-eucalypt temperate forest (0.62) is applied to estimate emissions from this activity (Wakelin, 2012).

An estimate is provided for burning of post-harvest residues associated with deforestation in the Inventory. No information is available on the extent of burning associated with deforestation in New Zealand. Therefore, it is assumed that 30 per cent of conversions involve burning to clear residues. The IPCC default combustion proportion for the burning of harvest residue in non-eucalypt temperate forest (0.62) is applied to subcategory-specific emission factors to estimate emissions from this activity. The emission factor excludes the proportion of logs taken off site (70 per cent of above-ground biomass) and is taken from the plot-network-derived yield tables by forest subclass at the average age of harvest in New Zealand.

Carbon dioxide emissions from controlled burning in planted forests in the Inventory are captured at the time of conversion or harvest.

Different emission factors derived from the LUCAS plot network are used for wildfire and controlled burning on grassland with woody biomass in the Inventory. The differences are due to the vegetation that is typically converted to forest, which is generally of a lesser stature when compared with other shrubland (Wakelin and Beets, 2013).

Uncertainties and time-series consistency

Uncertainties arise from relatively coarse activity data for wildfires and controlled burning activities in New Zealand (table 6.11.3). The biomass burning statistics have gaps in the time series where data collection did not occur or survey methodologies changed. Assumptions are made for some activity data, emission factors and burning fractions where insufficient data exists.

Table 6.11.3 Uncertainty in New Zealand's 2013 estimates for CH_4 and N_2O emissions from biomass burning

Variable	Uncertainty at a 95% confidence interval (%)
Activity data	
Uncertainty in activity data	30.0
Emission factors	
Uncertainty in emission factors	41.9
Uncertainty introduced into net emissions for LULUCF	**1.94**

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 data set is verified whenever new data is supplied. The *Biomass burning* parameters (emission factors, burning and emission factors), assumptions and data set are reviewed and updated (Wakelin et al, 2009; Wakelin, 2011, 2012).

Source-specific recalculations

An estimate is provided for burning of post-harvest residues associated with deforestation for the first time in this submission.

The emission factors for *Forest land* and grassland with woody biomass have been updated for the 2014 submission and this has changed the amount of dry matter lost on burning.

Activity data has also been updated between the 2013 and 2014 submissions.

Source-specific planned improvements

There are no improvements planned for this category at this time.

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Chapter 7: Waste

7.1 Sector overview

7.1.1 The waste sector in New Zealand

Waste sector emissions cover greenhouse gas emissions resulting from the disposal or processing of solid waste and wastewater. In New Zealand this includes solid waste disposal to municipal landfills and a variety of other, unmanaged disposal sites such as those on farms and industry, wastewater treatment including industrial wastewater, and a very small amount of incineration of hazardous and specialised waste.

7.1.2 Emissions summary

The Waste sector in New Zealand produces mainly methane (CH_4) emissions (96.4 per cent) followed by nitrous oxide (N_2O) emissions (3.5 per cent) and carbon dioxide (CO_2) emissions (0.04 per cent). There are significant additional emissions of CO_2 from disposal of solid waste, but these are of biogenic origin and are not reported.

2013

In 2013, emissions from the Waste sector contributed 5,054.0 kt carbon dioxide equivalent (CO_2-e) or 6.2 per cent of New Zealand's total greenhouse gas emissions.

The emissions by source category are shown in table 7.1.1 below. The largest source category is solid waste disposal. In New Zealand all solid waste disposal is to land, in various types of landfills and similar disposal sites.

1990–2013

Total Waste sector emissions in 2013 were 45.0 kt CO_2-e below the 1990 baseline emissions of 5,099.0 kt CO_2-e. Emissions increased between 1990 and 2002, peaked in 2005 at 5,443.0 kt CO_2-e, and have decreased since that time.

There has been ongoing growth in population and economic activity, which has resulted in increasing volumes of solid waste and wastewater for the whole of the time series. This drove an increase in total Waste sector emissions from 1990 to 2004.

There have been ongoing improvements in the management of solid waste disposal at municipal landfills, including increased methane recovery and increased recycling and other diversion of waste away from disposal to land, particularly since 2002. As a result the total Waste sector emissions have been trending down from 2005.

2012–2013

Total Waste sector emissions in 2013 were 25.9 kt CO_2-e (0.5 per cent) lower than emissions in 2012. This decrease is the result of ongoing improvements in municipal solid waste management.

Table 7.1.1 New Zealand's greenhouse gas emissions for the Waste sector by source category

Source category	Emissions ($kt\ CO_2$-e) 1990	Emissions ($kt\ CO_2$-e) 2013	Difference ($kt\ CO_2$-e) 1990–2013	Change (percentage) 1990–2013	Share (percentage) 1990	Share (percentage) 2013
Solid waste disposal (5.A)	4,698.6	4,600.3	–98.2	–2.1	92.1	91.0
Biological treatment (5.B)	–	–	–	–	–	–
Incineration (5.C)	1.93	3.10	1.17	60.6	0.04	0.06
Wastewater (5.D)	398.5	450.5	52.0	13.1	7.8	8.9
Total	**5,099.0**	**5,054.0**	**–45.0**	**–0.9**		

Note: Significant biological treatment of solid waste does not occur in New Zealand.

Figure 7.1.1 Changes in New Zealand's emissions from the Waste sector from 1990 to 2013

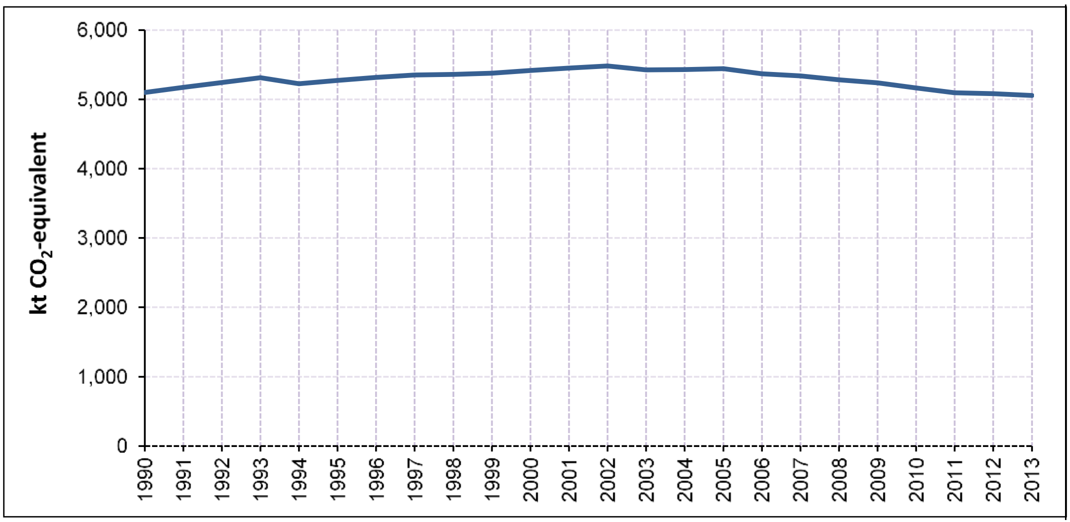
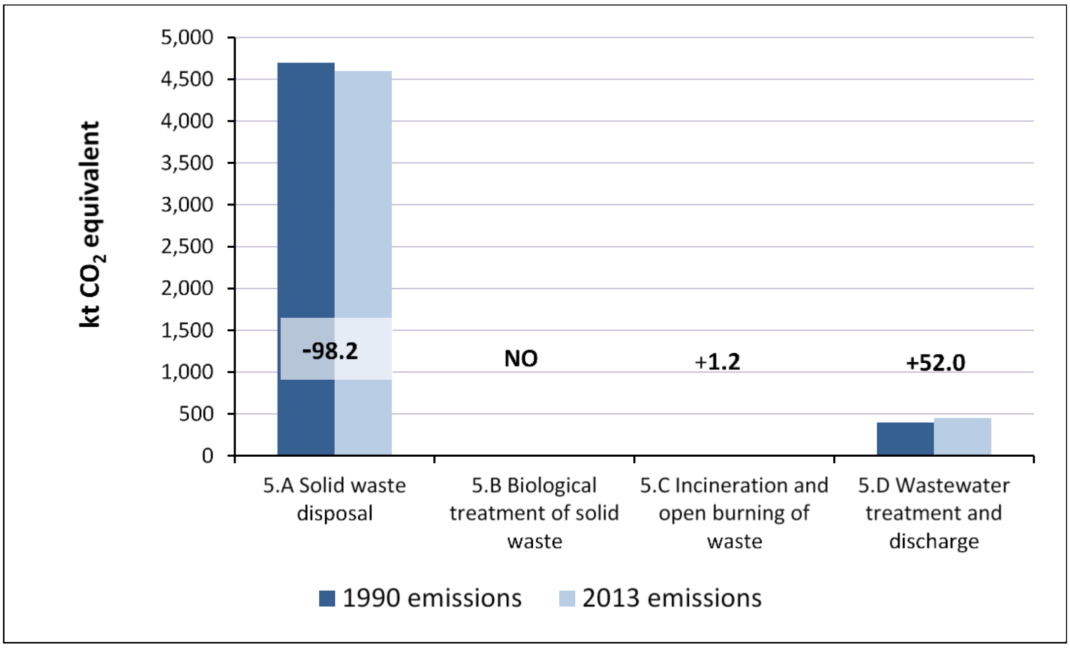


Figure 7.1.2 Change in New Zealand's emissions from the Waste sector from 1990 to 2013 by source category



7.1.3 Key categories for Waste sector emissions

Details of New Zealand's key category analysis are in section 1.5. The key categories in the Waste sector are:

- *Solid waste disposal (CH_4) – level and trend assessment*
- *Water treatment and discharge (CH_4) – level assessment.*

7.1.4 Methodological issues for the Waste sector

Activity data has come from a variety of sources. Municipal solid waste disposal data from mandatory reporting under the Waste Management Act and for the New Zealand Emissions Trading Scheme (NZ ETS) was used for the years (2010 onwards) for which it is available. Activity data for all other sources was based on specific surveys. Interpolation based on GDP or population is used for other years.

New Zealand uses Tier 2 methodologies for *Solid waste disposal*, which is a key category. Tier 1 methods are used for other emissions in the waste sector.

Country-specific emission factors have been used where available, including parameters for municipal waste and for treatment of some types of industrial wastewater.

Methodological issues are discussed under each source category in this chapter.

7.1.5 Uncertainties

The uncertainties for emission estimates are discussed under each category in this chapter. They are in conformity with IPCC Guidelines and for most sources the uncertainty is ±40 per cent, with much greater uncertainty for waste disposal by farmers due to substantial uncertainty in the activity data.

7.1.6 Verification

Where available, data from different sources was used for verification. Municipal landfills report their activity data annually under the requirements of the Waste Minimisation Act, and in addition most of them now report activity data and estimated emissions as part of the NZ ETS. These data sources are used as primary sources or for verification, as appropriate.

7.1.7 Recalculations and improvements

NZ ETS return data has been used as a primary source for disposal to land for the first time in this submission. This has resulted in a minor recalculation of activity data and methane emissions because the gap between the last available survey data (2009) and the first year of NZ ETS data has been filled by interpolation.

The use of revised Global Warming Potentials (GWPs) for this submission has meant that reported emissions are significantly different from the previous submission when expressed in CO_2-e terms. This is mainly because the GWP for methane has changed from 21 to 25.

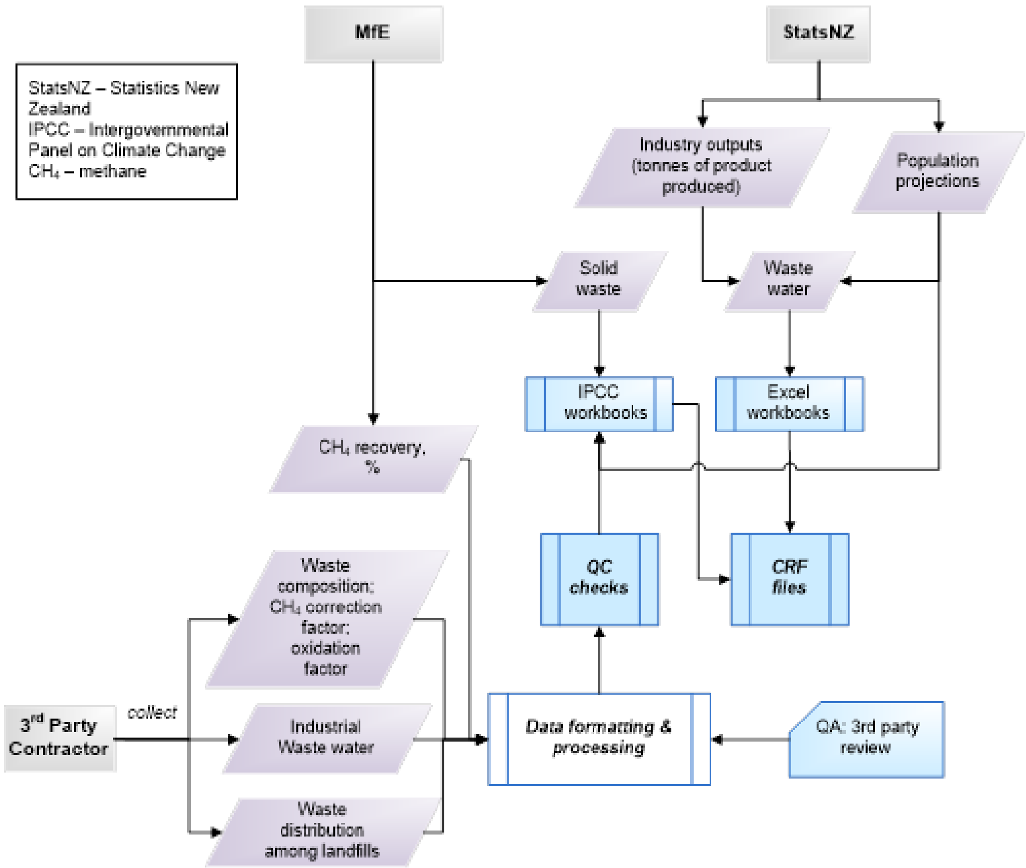
Emissions from on-farm disposal are now reported as unmanaged waste disposal sites and included in CRF table 5.A.2. Previously these sites were reported as uncategorised. This change does not affect the estimated emissions.

Following review of previous submissions the Expert Review Team (ERT) recommended that New Zealand explore improvements to the quality and temporal coverage of municipal solid waste activity data. For this submission, the quality of data has been improved by use of NZ ETS and Waste Minimisation Act reporting.

The ERT also encouraged New Zealand to improve reporting of any possible open burning of waste. This will be explored as and when data becomes available from surveys carried out by local authorities.

7.1.8 Quality assurance/quality control (QA/QC) processes

Figure 7.1.3 Tier 1 quality checks for the Waste sector



7.2 Solid waste disposal (5.A)

7.2.1 Description

In 2013, solid waste disposal contributed 4,600.3 kt CO_2-e (92.1 per cent) of total emissions from the Waste sector. Solid waste disposal emissions in 2013 were 98.2 kt (2.1 per cent) below the 1990 level of 4,698.6 kt CO_2-e. This small decrease is the net result of two trends:

1. Methane emissions from municipal landfills have been decreasing since 2004 due to improved landfill management practices, particularly methane recovery; and
2. The total amount of waste disposed has continued to increase, due mainly to population growth.

In 2013 the amount of methane recovered from solid waste disposal sites was 1,354.25 kt CO_2-e. Methane recovered in 2013 was 1169.6 kt CO_2-e higher than the 1990 level of 184.65 kt CO_2-e and 71.25 kt CO_2-e higher than in 2012.

Methane emissions from solid waste disposal were identified as a key category in the 2013 level assessment and trend assessment.

Solid waste management in New Zealand

Household and industrial solid waste in New Zealand is disposed of almost exclusively to landfills. There are three broad types of landfill sites in New Zealand:

1. Municipal landfills, which accept household waste but may also accept industrial waste or other types of solid waste.
2. Non-municipal landfills or significant landfill sites that do not accept household waste. These include cleanfills (sites disposing of largely inert waste), industrial fills, and sites that dispose of construction and demolition waste.
3. Farm fills. Disposal of household and other on-farm waste to land is prevalent in the farm sector.

Since 1990, there have been a number of initiatives to improve solid waste management practices in New Zealand. These include:

- requirements for all landfills to meet resource consent conditions set under the Resource Management Act 1991
- guidance and direction to local government and the Waste sector through the *New Zealand Waste Strategy* (Ministry for the Environment, 2002a) and its revision in 2010 (Ministry for the Environment, 2010)
- development of the *Solid Waste Analysis Protocol*, which provides a consistent classification system, sampling regimes and survey procedures to estimate the composition of solid waste (Ministry for the Environment, 2002b)
- the Waste Minimisation Act 2008, which imposes a levy of NZ$10 per tonne of municipal solid waste and enables regulations to establish product stewardship requirements and for information reporting.

In addition, most municipal landfills are now mandatory participants in the NZ ETS, with obligations to report and surrender emission units for their methane emissions.

These initiatives have contributed to substantial improvements in waste management since 1990. A large number of small, often poorly located and substandard municipal landfills have been closed, and most communities are now using larger, more modern regional facilities for disposal of their waste. In 2013 there were 49 municipal landfill sites, in comparison to 327 in 1995 and 563 in 1971.

Management of non-municipal landfills and farm fills has also been affected by the Resource Management Act. However, these facilities are not currently required to pay the waste levy, to monitor and report the waste they accept, or to participate in the NZ ETS.

7.2.2 Methodological issues

New Zealand has applied a Tier 2 approach by using the IPCC first order decay model for estimation of methane emissions from solid waste disposal to land.

The different types of landfill sites – municipal landfills, non-municipal landfills and farm fills – are discussed below. These map to the CRF tables as shown in table 7.2.1.

Table 7.2.1 Landfill emissions in CRF

Landfill type	CRF table	Comment
Managed municipal landfills	5.A.1.a (Anaerobic)	Includes all municipal landfill sites that are now accepting waste, and all sites with gas recovery
–	5.A.1.b (Semi-aerobic)	No semi-aerobic landfill sites identified in New Zealand
Non-municipal landfills	5.A.2 (Unmanaged)	Includes industrial landfills
Farm fills	5.A.2 (Unmanaged)	Disposal of waste on farms
Other municipal landfills	5.A.3 (Uncategorised)	Prior to 2010 only

Municipal landfills

In 2013, 23 municipal landfill sites had operational gas recovery systems. This includes 17 operating landfills and six closed sites (no longer accepting waste) which still have gas collection in operation. In addition, one site was closed in 1996 and its gas collection system was shut down in 2006.

For each of these 24 landfill sites, the IPCC first order decay model (IPCC, 2006a) has been applied to develop estimates of methane emissions, with site-specific data on waste placement, composition, and other parameters applied where available. In 2013 these 24 sites accounted for 84 per cent of waste disposed to municipal landfills.

Municipal waste outside of these 24 sites is disposed to smaller landfills that have never had gas recovery. In 1990 there were more than 300 of these sites, and in 2013 there were 25 still in operation. The IPCC first-order decay model has been applied to estimate the total methane emissions from these landfills.

Activity data

Annual total waste placement, to all municipal landfills, has been estimated based on:

- back-casting from a 1982 national survey, using real (inflation-adjusted) GDP, for the years before 1982
- national surveys carried out for the years 1982, 1995, 1998, 2002, and 2006
- linear interpolation for the years between these surveys
- linear interpolation for the years 2007 to 2009
- data collected annually under the requirements of the Waste Management Act 2008 for the years 2010 to 2013.

A regression analysis established that there was a correlation between real GDP and the amount of waste landfilled up to 2002. The transition from national surveys to using Waste Management Act information uses a linear interpolation. Other methods were explored, but this approach gave the most robust estimates (Eunomia and Waste Not, 2014).

Data on the annual waste placement history and intentions for each of the 24 landfills with gas recovery systems (or with plans to install recovery systems by 2012) was obtained from the landfill operators in 2009 (SKM, 2009). The 17 of these sites that were still operating in 2013 have also submitted ETS returns which specify their monitored annual waste placement. The time series has been updated using this information, with linear interpolation as necessary between 2009 and 2012.

For each year in the time series, the total waste placement to all sites without gas recovery systems is estimated as the difference between the national total, estimated as above, and the total of the individual estimates made for the 24 sites with gas recovery.

Waste composition

Many municipal landfills in New Zealand accept locally-produced industrial waste as well as municipal waste. New Zealand has insufficient data to determine how much of the waste disposed to municipal landfills comes from industrial sources. All waste at these sites is therefore entered as municipal waste in the IPCC models. Some industrial waste is included in the composition estimates used.

Waste composition has been estimated from national surveys carried out in 1995 and in 2004 (Ministry for the Environment, 1997; Waste Not Consulting, 2006). In addition, estimates have been made for 2008 and 2012 based on individual landfill surveys (Waste Not Consulting, 2013). The waste surveys have been based on the Solid Waste Analysis Protocol (Ministry for the Environment, 2002b) to ensure a consistent methodology for sampling and analysis.

No usable waste composition data is available for the period before 1995. For the years 1950 to 1994, data from the 1995 survey has been used, with an adjustment to account for the fact that disposable nappies came into use through the 1960s. Linear interpolation was used for years between the survey years, and 2013 is assumed to be the same as 2012.

Table 7.2.3 shows the resulting measured and estimated composition data used for the total waste stream from 1950 to 2013.

Table 7.2.3 Estimated composition of waste to municipal landfills

Year	Food	Garden	Paper	Wood	Textile	Nappies	Inert	Notes
1950–60	17	11	16	7	1	0	48	No nappies
1961–69	17	11	16	7	1	1	47	Interpolation
1970–79	17	11	16	7	1	2	46	Interpolation
1980–94	17	11	16	7	1	3	45	As 1995
1995	17	11	16	7	1	3	45	Survey
1996	17	11	16	8	1	3	45	Interpolation
1997	17	11	16	9	1	3	44	Interpolation
1998	16	10	16	9	2	3	44	Interpolation
1999	16	10	16	10	2	3	43	Interpolation
2000	16	10	16	11	2	3	43	Interpolation
2001	15	10	15	12	3	3	43	Interpolation
2002	15	10	15	12	3	3	42	Interpolation
2003	15	9	15	13	4	3	42	Interpolation
2004	14	9	15	14	4	3	41	Survey
2005	15	9	13	13	4	3	42	Interpolation
2006	16	9	12	13	4	3	43	Interpolation
2007	16	9	10	12	4	3	44	Interpolation
2008	17	9	9	12	4	3	45	Survey
2009	17	9	9	12	4	3	45	Interpolation
2010	17	9	10	12	5	3	44	Interpolation
2011	17	9	10	12	5	3	44	Interpolation
2012	17	8	11	12	6	3	44	Survey
2013	17	8	11	12	6	3	44	As for 2012

The resulting estimates of degradable organic carbon (DOC) content in waste track these changes in composition. The overall average DOC fraction has varied from 0.145 in the 1950s to a peak of 0.1747 in 2004.

Methane correction factor and oxidation factor

There is limited information about management practices at the many small municipal landfill sites that were operated in New Zealand between 1950 and the 1990s. A survey carried out in 1971 indicated that few of the 563 landfills open at that time would be categorised as managed sites. Additional survey information from 1982, 1995, and 2010 provided estimates for the proportion of waste that could be considered to be disposed to managed sites. These are shown in Table 7.2.4.

Table 7.2.4 Proportion of municipal waste disposed to managed landfills

Year	Proportion to managed sites
1950–70	0%
1971	0%
1982	55%
1995	90%
2010–13	100%

The methane correction factor (MCF) used is 1.0 for all managed landfill sites, including the landfills that have gas recovery. An oxidation factor of 10 per cent is also used for waste disposed to these sites.

For all sites other than managed landfills, there was an unknown mix of shallow and deep disposal areas. The larger sites in operation in 1971 were assessed at that time to be roughly half deep (more than 5 metres) and half shallow. The use of cover material was variable. Therefore, the MCF for uncategorised sites (0.6) and an oxidation factor of zero have been used.

Methane generation rates

For the landfills with gas recovery, k-values for waste were estimated based on those used for municipal solid waste in in the United States inventory as at 2007, which are:

Table 7.2.5 Default methane generation rates used for landfills with gas recovery

Annual rainfall at site	k-value
Less than 20 inches	0.020
20 to 40 inches	0.038
More than 40 inches	0.057

In addition, these k-values were increased by 5–25 per cent for sites which do not collect leachate, sites which recirculate leachate, and sites which were assessed to be using poor quality capping materials or practices (SKM 2009).

For sites without gas recovery, the IPCC default k-values for a wet temperate climate have been used. This is the best overall match for New Zealand's climate.

Gas recovery

For each of the landfill sites that have gas recovery, estimates of recovery rates were developed through either the use of metered gas flow data (for those sites that had good quality metering in place in 2009) or from consideration of the landfill capping quality, landfill lining, well placement, active or passive gas control in use, and whether wells were original or retrofitted (SKM, 2009).

Recovery efficiencies vary from 42 per cent to 90 per cent, with an overall average of 68 per cent for the landfill sites that collected gas in 2013. Across all municipal landfills, 40 per cent of the methane generated (from closed as well as operational landfills) is recovered.

Summary of parameters used

Table 7.2.6 gives a summary of the parameter values that have been applied for estimating methane emissions for solid waste disposed to municipal landfills.

Table 7.2.6 Summary of parameters for municipal landfills

Parameter	Values	Source	Reference
Managed landfills with methane recovery:			
k-value	0.038–0.090	Country specific	Tonkin and Taylor, 2014
MCF	1.0	IPCC default	IPCC, 2006a
Oxidation factor	10%	IPCC default	IPCC, 2006a
Recovery efficiency	42–90%	Site specific	SKM, 2009
Managed landfills without methane recovery:			
k-value	0.030–0.185	IPCC default	IPCC, 2006a
MCF	1.0	IPCC default	IPCC, 2006a
Oxidation factor	10%	IPCC default	IPCC, 2006a
Uncategorised landfills:			
k-value	0.030–0.185	IPCC default	IPCC, 2006a
MCF	0.6	IPCC default	IPCC, 2006a
Oxidation factor	0	IPCC default	IPCC, 2006a
All landfill sites:			
Starting year	1950	IPCC default	IPCC, 2006a
Delay time	6 months	IPCC default	IPCC, 2006a
Fraction of DOC that decomposes	0.5	IPCC default	IPCC, 2006a
Fraction of CH_4 in gas	0.5	IPCC default	IPCC, 2006a
DOC (Kt C/Kt waste)	0.145–0.175	Country specific	Ministry for the Environment, 1997

Non-municipal landfills and farm fills

Non-municipal landfills include privately owned industrial landfills, and a large number of landfill sites that are consented for largely inert waste, and do not accept household waste (cleanfills and construction and demolition fills). Only limited information is available on these sites and their management practices, particularly historic information. The IPCC first-order decay model has been applied to estimate total methane emissions from non-municipal landfills.

Farm fills are used to dispose of various types of farming waste such as scrap metal, timber used for fencing, plastic wraps and ties, batteries, and demolition waste. Farmers also use them to dispose of organic and general household waste. The IPCC first-order decay model has been applied to estimate the total methane emissions from on-farm waste disposal to land.

The information used to estimate emissions from farm fills has come from surveys carried out in the Canterbury region in 2012 and 2013 (GHD, 2013; Tonkin and Taylor, 2014). The results from these surveys are extrapolated to the rest of the country. Farming practices are quite similar around the country, so the extrapolation is unlikely to introduce a systematic bias. However the sample size is small in relation to the number of farms in New Zealand.

Activity data

The available information on historic and current disposal rates to non-municipal landfills is derived from direct contact with landfill operators, and from regional councils that regulate these activities under the Resource Management Act. There are substantial gaps, which have been filled by correlating waste quantities with regional GDP (Tonkin and Taylor, 2014).

Waste placement data for farm fills has been estimated using the Canterbury survey results. Waste quantities were determined for the farm types surveyed: dairy, livestock, arable and viticulture. The survey results have been applied nationally, accounting for the different prevalence of these four farm types (Tonkin and Taylor, 2014).

Waste composition

The main waste types disposed to non-municipal landfills are described in survey data as cleanfill, construction and demolition waste, green waste and wood. These were mapped to the IPCC waste types (IPCC, 2006a) and the IPCC default DOC values were applied. Most sites provided data on which types of waste are accepted, but only a few could quantify the amounts. To fill this data gap, the number of individual sites accepting each waste type has been used as a proxy for the amount of that waste type.

Farm waste comprises a mix of household and other wastes with similar composition and diversity to general municipal solid waste. The default DOC value for municipal waste has been used for farm fills.

Other parameters

The majority of non-municipal landfills and farm fills are shallow, with less than five metres depth of waste. These are estimated to account for 90 per cent of the waste disposed with an MCF value of 0.4. The other 10 per cent (approximately) goes to fills that are assumed to be:

- for non-municipal landfills, an unknown mix that would have an average MCF value of 0.6; this gives an overall average for these sites of 0.42
- for farm fills, deeper pits with an average depth greater than five metres, so the MCF value is 0.8 and the average for all farm fills is 0.44.

Default k-values for a wet temperate climate are used. No oxidation is assumed to occur in the cover for these unmanaged sites.

Summary of parameters used

Table 7.2.7 gives a summary of the parameter values that have been applied for estimating methane emissions for solid waste disposed to non-municipal landfills and farm fills.

Table 7.2.7 Summary of parameters for non-municipal and farm fills

Parameter	Values	Source	Reference
Non-municipal landfills:			
k-value	0.030–0.185	IPCC default	IPCC, 2006a
MCF	0.44	Country specific	Tonkin and Taylor, 2014
Oxidation factor	0	IPCC default	IPCC, 2006a
DOC (Kt C/Kt waste)	0.040–0.043	Country specific	Ministry for the Environment, 1997
Farm fills:			
k-value	0.09	IPCC default	IPCC, 2006a
MCF	0.42	Country specific	Tonkin and Taylor, 2014
DOC (kt C/kt waste)	0.28	Country specific	Ministry for the Environment, 1997
All sites:			
Oxidation factor	0	IPCC default	IPCC, 2006a
Starting year	1950	IPCC default	IPCC, 2006a
Delay time	6 months	IPCC default	IPCC, 2006a
Fraction of DOC that decomposes	0.5	IPCC default	IPCC, 2006a
Fraction of CH_4 in gas	0.5	IPCC default	IPCC, 2006a

7.2.3 Uncertainties

For methane emissions from municipal landfills, the uncertainty estimate is ±40 per cent. This is consistent with the estimates provided in the IPCC Guidelines. It is set at this level because some, but not all, of the estimates for methane recovery are based on metered gas flow data.

For non-municipal landfills and farm fills, the uncertainty is ±140 per cent, driven mainly by very high uncertainty in the activity data. Historic information on the amount of waste placed in these sites is very limited, given the nature of the management of such fills.

7.2.4 Verification

In the preparation of this submission, the data for this category underwent Tier 1 quality checks.

7.2.5 Recalculations

All municipal landfills in New Zealand, except for some small and remote landfills which are exempt, are now required to submit annual NZ ETS returns, which report the amount of waste disposed.

As indicated in 7.2.1 above, 17 of these emission returns are from landfill sites for which individual IPCC first-order decay models have been used to estimate methane emissions and recovery for the inventory. The previously available site-specific activity data was for years up to 2009. For this submission, the ETS data has been used for 2013, and consequently the placement estimates for the years 2010–12 have been recalculated by linear interpolation between 2009 and 2013. This responds to an ERT comment which recommended New Zealand explore how to improve the quality and temporal coverage of municipal solid waste data.

Farm fills, which were previously described as ‘other’ in CRF Table 6.A.3, are now reported as unmanaged waste disposal sites and included in Table 5.A.2. This change does not affect the estimated emissions.

7.2.6 Source-specific planned improvements

Landfill operators who are mandatory NZ ETS participants have the option of applying for a Unique Emissions Factor (UEF) to account for either gas recovery or for changing waste composition. The inventory agency will consider using data sourced from approved UEF applications to improve site-specific estimates of gas recovery, waste composition, and other parameters for future submissions. This may also enable the use of site-specific estimates for some landfills that do not have gas recovery.

Regional councils in Canterbury and other parts of the country are likely to carry out additional surveys and other research on farm waste disposal in future. As and when better activity data becomes available, it will be used to improve the estimates of waste disposal on farms.

Emissions of CO, NOx, and NMVOC for landfills have not been estimated for this submission. These emissions are considered likely to be immaterial, but the inventory agency will consider estimating them for future submissions.

7.3 Biological treatment of solid waste (5.B)

New Zealand has no large-scale biological treatment of solid waste. There is likely to be a relatively small amount of composting of solid waste on a household scale. Emissions from this source are likely to be immaterial. However, the inventory agency will consider investigating the scale of this activity and the scope for estimation of emissions in future submissions.

7.4 Incineration and open burning of waste (5.C)

7.4.1 Description

In 2013, waste incineration accounted for 3.096 kt CO_2-e (0.1 per cent) of Waste sector emissions. This was an increase of 1.166 kt CO_2-e from 1990, with no change estimated from 2012.

Incineration and open burning of waste in New Zealand

There is no incineration of municipal waste in New Zealand, for energy production or otherwise. Incineration is used for medical, quarantine, and hazardous wastes and sewage sludge. The practice of incinerating these wastes has declined due to environmental regulation and the use of alternative technologies such as sterilisation.

Waste incineration is regulated under the Resource Management Act 1991. In addition, in 2004 a National Environmental Standard was introduced that required consents for all existing low-temperature incinerators, such as those historically used in schools and sometimes in hospitals.

There is no open burning of waste at municipal or non-municipal landfill facilities in New Zealand. It is possible that farmers may burn some waste when disposing it to land (Tonkin and Taylor, 2014) but there is no available data to confirm whether this occurs or the extent of the practice. For this submission, all farm waste disposal is assumed to be to pits rather than open burning, and the emissions are reported in CRF 5.A.

Waste oil is used in the cement industry for firing a cement kiln. All emissions from this source are reported in the energy sector.

7.4.2 Methodological issues

Estimates of direct emissions from the incineration of waste are made using the default Tier 1 methodology (IPCC, 2006a). The data used was collected and collated in 2007 and the sources used included information previously collected for purposes of air quality regulation, consent data from regional councils, and from site operators (SKM, 2007).

Activity data

Limited information was available from individual site operators on the amount of waste that they burned between 1990 and 2007. For most sites this activity data needed to be assessed, as the only hard information available was the capacity of equipment and the amounts allowed by consent conditions. For years after 2007, in the absence of better information, it has generally been assumed that facilities are continuing in operation at the same rates.

Waste composition and emission factors

Quarantine waste is a significant proportion of the material incinerated in New Zealand. There is no IPCC default category that specifies quarantine waste. The composition is closest to clinical waste, so emission factors for clinical waste have been used.

IPCC default parameters are used as detailed in Table 7.4.1. These are as given in the Guidelines (IPCC, 2006a and 2006b) except:

- where a range is given the mid-point is used
- methane emission factors for hazardous and clinical waste (IPCC, 2006b) have been converted from a TJ basis to a kt basis.

Table 7.4.1 Parameter values applied to estimate emissions from incineration

Parameter	Hazardous waste	Clinical waste	Sewage sludge
Dry-matter content in waste	50%	65%	10%
Fraction of carbon in dry matter	N/A	0.6	0.45
Fraction of fossil carbon in total carbon	0.275	0.4	1.0
Oxidation factor	1.0	1.0	1.0
Methane emission factor (kg/kt)	2.34	1.79	9.7
Nitrous oxide emission factor (kg/kt)	100	60	900
References: IPCC, 2006a and IPCC, 2006b			

7.4.3 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, 2007).

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.

7.4.4 Source-specific QA/QC and verification

There are no recalculated values in this source category. Therefore, quality assurance and quality control efforts for the Waste sector have been focused on the disposal to land and wastewater categories.

7.4.5 Source-specific recalculations

There have been no recalculations for this category.

7.4.7 Source-specific planned improvements

No specific improvements are planned for this category. Over time, surveys by local authorities on disposal of waste in the farm sector are expected to provide a better understanding of any open burning that may occur in New Zealand, particularly in the farm sector. This will respond to comments made by the Expert Review Team (ERT) on previous submissions.

7.5 Wastewater treatment and discharge (CRF 5D)

7.5.1 Description

In 2013, *Wastewater treatment and discharge* contributed 450.5 kt CO_2-e (8.9 per cent) of emissions from the Waste sector. This was an increase of 71.2 kt CO_2-e (18.8 per cent) from the 1990 level of 398.5 kt CO_2-e and is due to increases in emissions from both the industrial and domestic sectors. This increase is due to increases in the total wastewater handled over this time period. A small amount of meat processing wastewater is added to agricultural soils, and N_2O emissions from this source are reported in the Agriculture sector.

Methane emissions from *Wastewater treatment and discharge* were identified as a key category in the 2013 level assessment.

Domestic and commercial wastewater

Domestic and commercial wastewater contributed 254.5 kt CO_2-e (56.5 per cent) of the 2013 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 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 196.1 kt CO_2-e (43.5 per cent) of the 2013 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.

7.5.2 Methodological issues

Methane emissions from domestic wastewater treatment

Method

Methane emissions from *Domestic wastewater treatment* have been calculated using the Tier 1 IPCC method (IPCC, 2006a).

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, 2007).

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, 2007). In 2013, the total connected population was estimated to be 4.1 million. This is a minor difference between the estimated official 2013 population of 4.4 million. The relative difference is similar to other years and is considered unlikely to be significant within the accuracy of the calculations (Tonkin and Taylor, 2014. The connected population includes an estimated 434,569 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, 2015).

Methane correction factors for handling systems

Methane correction factors (MCFs) 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, 2006a). This value has been determined as a typical value for wastewater treatment methods adopted in New Zealand (Beca, 2007). This value has been increased by 25 per cent for most treatment plants to allow for commercial and industrial activity within a municipal area. Ten treatment plants have been identified to accept much larger amounts of industrial and/or commercial activity. The correction factor for BOD for these plants range from 77 per cent to 1,490 per cent (Beca, 2007).

Default parameters applied

New Zealand uses the 2006 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, 2007). Plants using methane for energy generation are included in the Energy's sector estimates.

Summary of parameters used

Table 7.5.1 provides a summary of the parameter values applied for estimating methane emissions from domestic wastewater treatment.

Table 7.5.1 Parameter values applied by New Zealand for estimating methane emissions for domestic wastewater treatment

Parameter	Value	Source	Reference
Methane correction 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, 2007
Correction factor for BOD	Range of 1.25–14.9	New Zealand specific	Beca, 2007
Maximum methane-producing capacity (kgCH_4/kgBOD)	0.6	IPCC default	IPCC, 2006a

Methane emissions from industrial wastewater treatment

The following industries were identified as having organic-rich wastewaters that are treated anaerobically (in order of significance): meat processing, pulp and paper, and dairy processing. Emissions from wine production and wool scouring wastewater have also been included to ensure all industries known to have wastewater treatment facilities are accounted for.

Meat processing industry

Method

The IPCC Tier 1 method is used to calculate methane emissions from the wastewater treatment by the meat processing industry (IPCC, 2006a).

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, 2015), venison (obtained from Deer Industry New Zealand, pers comm, 2015) and poultry (obtained from Poultry Industry Association of New Zealand, pers comm, 2015).

The total organic wastewater from meat rendering was determined in 2006 (Beca, 2007). Using the 2006 figure, a ratio of wastewater from rendering to kills has been determined and has been applied to all years.

The emissions for each of the activities (processing and rendering) are calculated separately and then combined to determine the emission for the meat industry as a whole. These separate calculations allow for the application of different MCF values.

Degradable organic component

SCS Wetherill Environmental, 2002, determined there was a range of 50 to 123 kilograms of chemical oxygen demand per tonne of product for the different producers within the meat industry.

Methane correction factor

The meat processing methane correction factor for all of the different producers is 0.55, as reported by SCS Wetherill Environmental, 2002.

Default parameters applied

New Zealand uses the 2006 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 7.5.2 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the meat industry.

Table 7.5.2 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 correction factor	0.55	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.

Pulp and paper industry

Method

The IPCC Tier 1 method is used to calculate methane emissions from the wastewater treatment by the pulp and paper industry (IPCC, 2006).

Activity data

Estimated pulp and paper wastewater output is based on paper, paperboard and pulp production. This information is obtained from the Ministry for Primary Industries (Ministry for Primary Industries, 2015).

Degradable organic component

The degradable organic component was derived from the chemical oxygen demand (COD)/t product, which is determined from industry data (Beca, 2007).

Methane conversion factor

The methane correction factor of 0.02 was determined by SCS Wetherill Environmental, 2002. This same conversion factor was also determined from 2006 data (Beca, 2007).

Default parameters applied

New Zealand uses the 2006 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 7.5.3 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the pulp and paper industry.

Table 7.5.3 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, 2007
Methane correction factor	0.02	New Zealand specific	SCS Wetherill Environmental, 2002, Beca, 2007
Maximum methane-producing capacity (kgCH_4/kgDC)	0.25	IPCC default	IPCC, 2006a

Note: COD = chemical oxygen demand.

Dairy industry

The dairy industry predominantly uses aerobic treatment. There is only one factory that uses anaerobic treatment. The emissions from the wastewater treatment process are recovered and the majority of the captured biogas (consisting of 55 per cent methane) is used to operate the boilers. The emissions generated from the operation of the boilers are accounted for in the Energy sector. The remainder is flared. Consequently, there are no emissions from this industry (Beca, 2013).

Wine industry

Method

A Tier 2 approach is used to estimate emissions from the wine industry. Information on the waste water treatment practices of the industry were obtained from a survey (Beca, 2013). IPCC default values are used where New Zealand-specific information was not available.

Activity data

Emissions from wastewater for the wine industry are based on the outputs obtained from the national organisation for New Zealand's grape and wine sector. For the purposes of this assessment, an average industry wastewater discharge metric of 2.7 m^3 of water per tonne of grapes processed is assumed. This value is derived from national data. It is noted that this value is significantly less than IPCC default values (Beca, 2013).

Methane conversion factor

The methane correction factor of the wine industry is 0.1 (Beca, 2013).

Degradable organic component

Beca, 2013, determined there were 4.6 kilograms of chemical oxygen demand per cubic metre wastewater.

Default parameters applied

New Zealand uses the 2006 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 7.5.4 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the wine industry.

Table 7.5.4 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the wool scouring industry

Parameter	Value	Source	Reference
Methane correction factor	0.1	New Zealand specific	Beca, 2013
Degradable organic component (kg COD/m^3)	4.6	New Zealand specific	Beca, 2013
Maximum methane-producing capacity (kgCH_4/kgCOD)	0.25	IPCC default	IPCC, 2006a

Note: COD = chemical oxygen demand.

Wool scouring industry

Method

The IPCC Tier 1 method is used to calculate methane emissions from the wastewater treatment by the wool scouring industry (IPCC, 2006a).

Activity data

Emissions from wastewater for the wool scouring industry are based on the outputs obtained and parameters estimated by SCS Wetherill Environmental, 2002, for estimates up to 2000. From 2001, the SCS estimates have been pro-rated against the industry's output data and applied to the output data for subsequent years – up to 2012, when the wool scouring industry started using aerobic treatment of wastewater and emissions were no longer produced.

Methane conversion factor

The methane correction factor of the wool scouring industry is 0.29 (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 2006 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 7.5.5 provides a summary of the parameter values applied for estimating methane emissions from wastewater treatment by the meat industry.

Table 7.5.5 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the wool scouring industry

Parameter	Value	Source	Reference
Methane correction 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, 2006a

Note: COD = chemical oxygen demand.

Nitrous oxide emissions from domestic wastewater

Direct emissions of nitrous oxide from domestic wastewater plants are typically minor and only occur in advanced centralised treatment plants. The IPCC Guidelines (IPCC, 2006a) advise that the estimation of direct nitrous oxide emissions is only necessary where advanced centralised treatment plants account for a major proportion of wastewater treatment. This is not the case in New Zealand. However, indirect emissions of nitrous oxide may occur after disposal of effluent into waterways, lakes, or the ocean. Therefore, New Zealand reports indirect emissions of nitrous oxide from domestic wastewater.

Method

To estimate nitrous oxide emissions from domestic wastewater treatment, New Zealand uses the IPCC Tier 1 method, which calculates nitrogen production based on average per capita protein intake (IPCC, 2006a).

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 2013.

Default parameters used

Default values for the fraction of nitrogen in protein (0.16 kg N/kg protein), the factor for non-consumed protein discharged to wastewater (1.4), the factor for industrial and commercial co-discharged protein into the sewer system (1.25), nitrogen removed with sludge (0 kg), emission factor (0.005 kg N_2O-N/kg N), and the emissions from wastewater treatment plants (0 kg N_2O-N/kg N) are used (IPCC, 2006).

Recovery

There is no recovery of emissions reported for this source.

Summary of parameters used

Table 7.5.6 provides a summary of the parameter values applied for estimating nitrous oxide emissions from domestic and commercial wastewater sludge treatment.

Table 7.5.6 Parameter values applied by New Zealand for estimating nitrous oxide emissions from domestic and commercial wastewater treatment

Parameter	Value	Source	Reference
Per capita protein consumption (kg/person/year)	36.135	New Zealand specific	Beca, 2007
Fraction of nitrogen in protein	0.16	IPCC default	IPCC, 2006a
Fraction of non-consumed 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 wastewater treatment

IPCC Guidelines indicate that, compared with domestic wastewater, the nitrous oxide emissions from industrial wastewater are believed to be insignificant (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 7.5.7 provides a summary of the parameter values applied for estimating nitrous oxide emissions from wastewater sludge treatment by the meat industry.

Table 7.5.7 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

7.5.3 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, 2007)). 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 stems from uncertainties in the:

- factors used to calculate emissions from the different wastewater treatment processes
- quantities of wastewater handled by the different wastewater treatment plants
- 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, 2007). This stems from uncertainties in the:

- factors used to calculate the degradable organic content in the wastewater
- wastewater treatment methods.

Nitrous oxide emissions from domestic 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, $EF_{EFFLUENT}$, has an uncertainty of –90 per cent to +98 per cent (IPCC, 2006).

7.5.4 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.

7.5.5 Source-specific recalculations

Emissions from domestic and industrial wastewater treatment

In previous submissions, emissions for wastewater and sludge removed from wastewater have been calculated separately. However, IPCC 2006 guidelines have removed this distinction (IPCC, 2006a). Sludge removed and associated emissions are reported in solid waste disposal and waste incineration source categories.

7.5.6 Source-specific planned improvements

No specific improvements have been confirmed for this category.

Chapter 7: References

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Chapter 8: Other

New Zealand does not report any emissions under the United Nations Framework Convention on Climate Change category, ‘Other’.

Chapter 9: Indirect carbon dioxide and nitrous oxide emissions

New Zealand elected not to report indirect carbon dioxide and nitrous oxide emissions in its 2015 Inventory submission.

Chapter 10: Recalculations and improvements

This chapter summarises the recalculations and improvements made to the Inventory following the 2014 submission. Further details on the recalculations for each sector are provided in chapters 3 to 7 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 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 2006) and good practice guidance (IPCC, 2003)
- activity data and emission factors that become available for sources that were previously reported as NE (not estimated) because of insufficient data
- a shift from AR2 to AR4 Global Warming Potentials (GWPs) as recommended by IPCC Assessment Report 4 (IPCC, 2007).

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

10.1 Implications and justifications

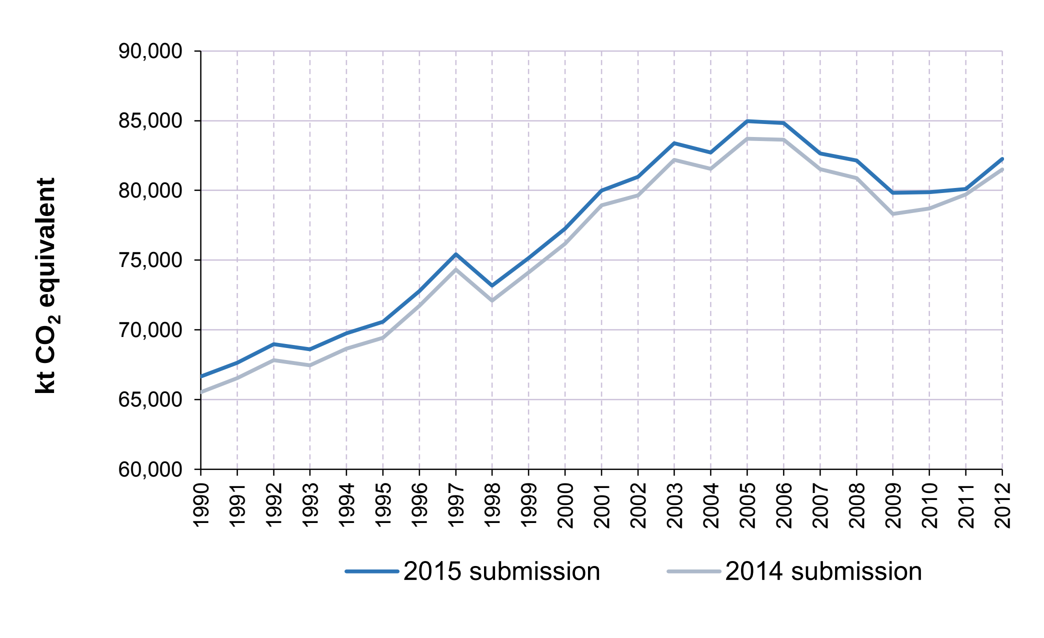
The effect of recalculations on New Zealand's total (gross) emissions in the 2015 Inventory submission is shown in Figure 10.1.1. There was a 0.5 per cent (311.6 kt carbon dioxide equivalent (CO_2-e)) increase in total (gross) emissions for the base year, 1990, and a 0.9 per cent (772.7 kt CO_2-e) decrease in total emissions for the 2012 year. The greatest contribution to this change in emission estimates came from the Agriculture sector, due to shifting to the AR4 GWPs.

The effect of recalculations when including the land use, land-use change and forestry (LULUCF) sector was an increase of 38.1 per cent (8906.0 kt CO_2-e) in net emissions for the base year, 1990, and a 0.9 per cent (490.1 kt CO_2-e) decrease in net emissions in 2012. The changes in net emissions estimates reflect an additional impact of improvements made in the LULUCF sector (see section 10.1.4) and improvements to gross emissions.

In the 2014 Inventory submission (1990–2012), total (gross) emissions for 2012 were 24.3 per cent above 1990 levels. As a result of the recalculations in the 2015 Inventory submission, total emissions for 2012 were 23.4 per cent above 1990.

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 2012



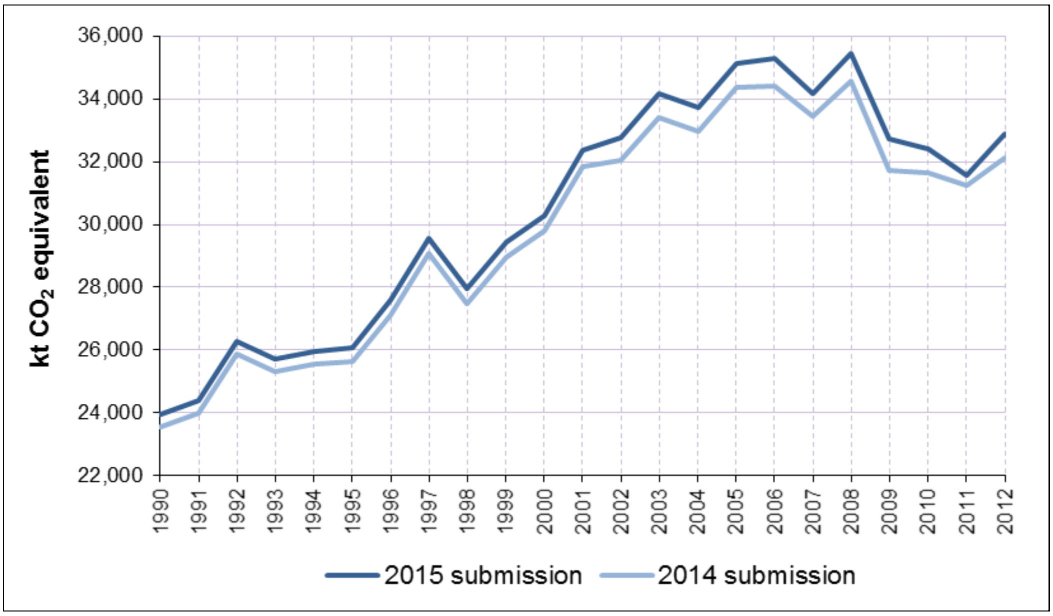
Note: Both time series are calculated using AR4 GWPs.

10.1.1 Energy

The overall change from all recalculations in the current Inventory submission made in the Energy sector have resulted in a 1.8 per cent (434.2 kt CO_2-e) increase in energy emissions in 1990 and a 1.8 per cent (573.6 kt CO_2-e) increase in energy emissions in 2012 (figure 10.1.2). The most significant contribution to this recalculation was the change from using oxidation factors for the fraction of carbon oxidised as specified in the 1996 guidelines, to not applying such factors as specified in 2006 guidelines. The other significant contribution to the recalculation resulted from the change in GWPs from AR2 to AR4 values. Figure 10.1.3 shows the effect of shifting from AR2 to AR4 GWPs for the 1990–2013 emission estimates from the 2015 Inventory submission, while figure 10.1.4 portrays the change due to a different approach to oxidation factors for 2015 Inventory submissions from 2014 submission. The combined effects of both of these changes (GWPs and oxidation factors) have also been evaluated and are shown in figure 10.1.5.

Explanations and justifications for recalculations of New Zealand's energy emission estimates in the 2015 submission are summarised in table 10.1.1.

Figure 10.1.2 Effect of recalculations on New Zealand's Energy sector from 1990 to 2012



Note: Both time series are using AR4 GWPs.

Figure 10.1.3 Effect of change in GWPs on New Zealand's Energy sector from 1990 to 2013

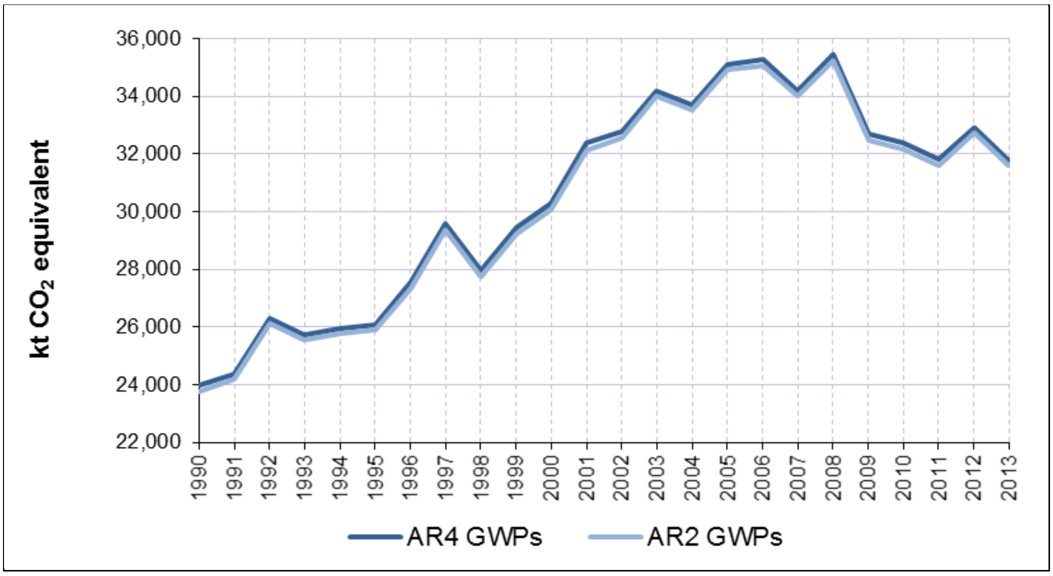
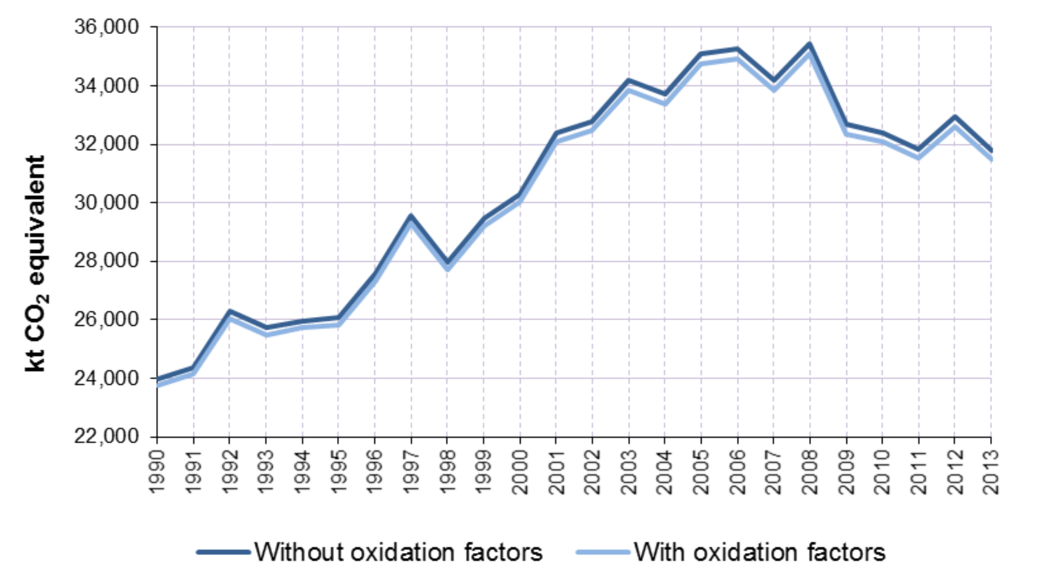


Figure 10.1.4 Effect of change to oxidation factors on New Zealand's Energy sector from 1990 to 2013



Note: This figure compares the emission estimates from the 2015 submission using different approaches to the use of oxidation factors.

Figure 10.1.5 Effect of change in GWPs and oxidation factors on New Zealand's Energy sector from 1990 to 2013

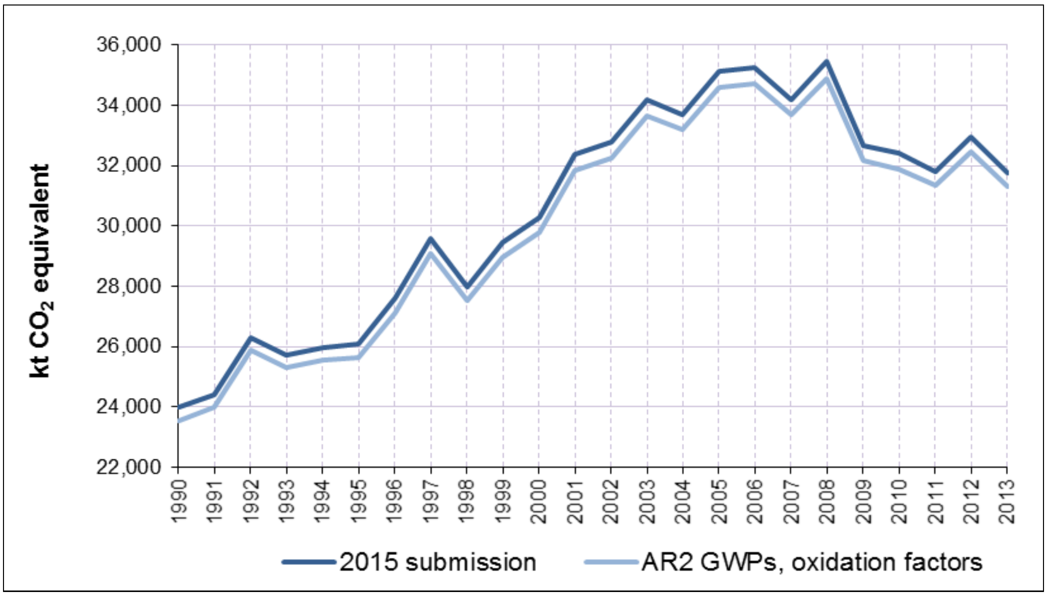


Table 10.1.1 Explanations and justification for recalculations in the Energy sector

Explanation of recalculation	Good practice principle that was improved	Additional information
Change in GWPs for CH_4 and N_2O	Comparability	AR4 values are now used in place of AR2
Change in oxidation factors for solid, liquid and gaseous fuels	Comparability	Oxidation factor of 1.0 is now used for all fuels
Some national energy statistics used as activity data have been revised by the data provider	Accuracy	Revised data released in conjunction with Energy in New Zealand (MBIE, 2014)

10.1.2 Industrial Processes and Product Use

Improvements and recalculations made in the Industrial Processes and Product Use (IPPU) sector have resulted in a 0.8 per cent (27.6 kt CO_2-e) decrease in IPPU emissions in 1990 and a 6.7 per cent (355.3 kt CO_2-e) decrease in IPPU emissions in 2012. The overall effect of recalculations on the IPPU sector from 1990 to 2012 is presented in figure 10.1.6. These changes are the combined effect of the reclassification of urea emissions, changes to GWPs, and improvements.

The recalculation that had the largest impact between the 2014 and 2015 Inventory submission was caused by use of urea as fertiliser for ammonia production in the chemical industry category (2.B) moving to the Agriculture sector. This change was made to comply with the 2006 IPCC Guidelines (see section 4.3.5 for further information). Other improvements are summarised in table 10.1.2 below.

Figure 10.1.6 Effect of recalculations on the Industrial Processes and Product Use sector from 1990 to 2012

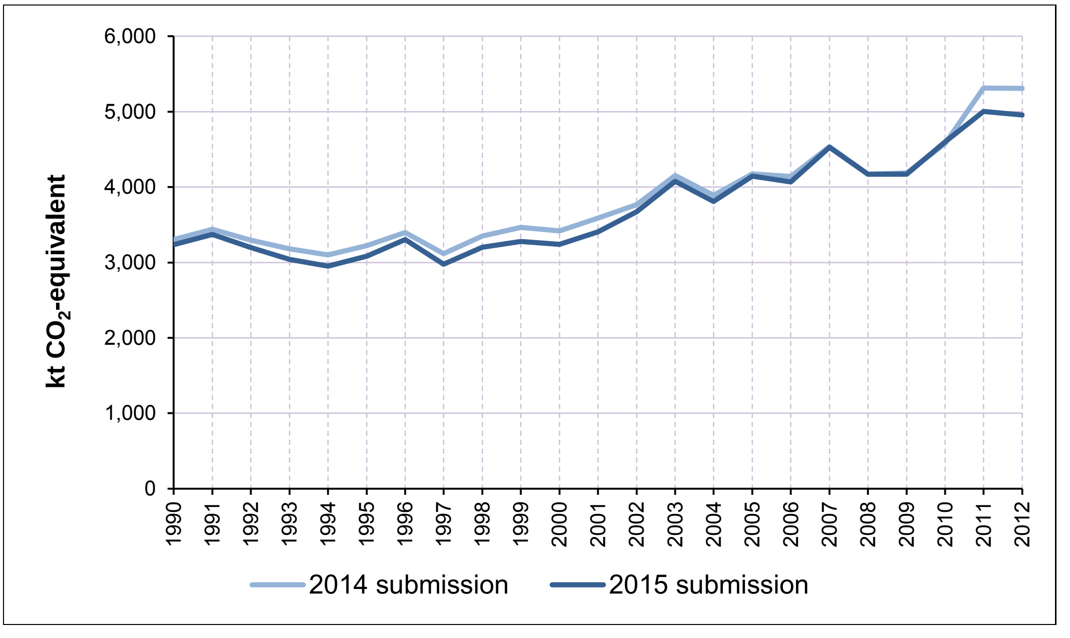


Table 10.1.2 Explanations and justifications for recalculations of New Zealand's previous Industrial Processes and Product Use estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
CO_2 emissions from the use of urea, made from ammonia, as a fertiliser are now reported in the Agriculture sector. Previously they were included in the *Chemical industry* category. See section 4.3.5 for further detail.	Accuracy and transparency	
Reassessment of 2011 and 2012 emissions of HFCs used in stationary air conditioning, due to stockpiling of HFCs by suppliers on introduction of the NZ ETS.	Accuracy and Transparency	Correction identified and resolved through quality-assurance and quality-control processes.
Re-assessment of the amount of alternative refrigerants installed and used in 2012.	Accuracy	Improved information from industry.
Small changes to SF6 nameplate capacity of electrical equipment. See section 4.8.5 for further detail.	Accuracy	Correction identified and resolved through quality assurance and quality-control processes.

10.1.3 Agriculture

Improvements made to the Agriculture sector have resulted in a 0.5 per cent (164.2 kt CO_2-e) decrease in agricultural emissions in 1990, and a 0.1 per cent (12.4 kt CO_2-e) decrease in agricultural emissions in 2012 (figure 10.1.7). This does not include the effect of updated IPCC 2006 Guidelines (see below).

The conversion of non-CO_2 emissions to CO_2-e using the AR4 GWPs resulted in a 12.7 per cent (3,879.6 kt CO_2-e) increase in 1990, and a 12.4 per cent (4,327.4 kt CO_2-e) increase in 2013 emissions. Figure 10.1.7 shows a comparison of emission estimates for 1990 to 2012 between the 2014 and 2015 Inventory submissions.

All recalculations, including the changes in reporting introduced by the migration to the 2006 IPCC guidelines, made within the Agriculture sector are summarised in tables 10.1.3 and 10.1.4 below.

Figure 10.1.7 Effect of recalculations on New Zealand's Agriculture sector from 1990 to 2012

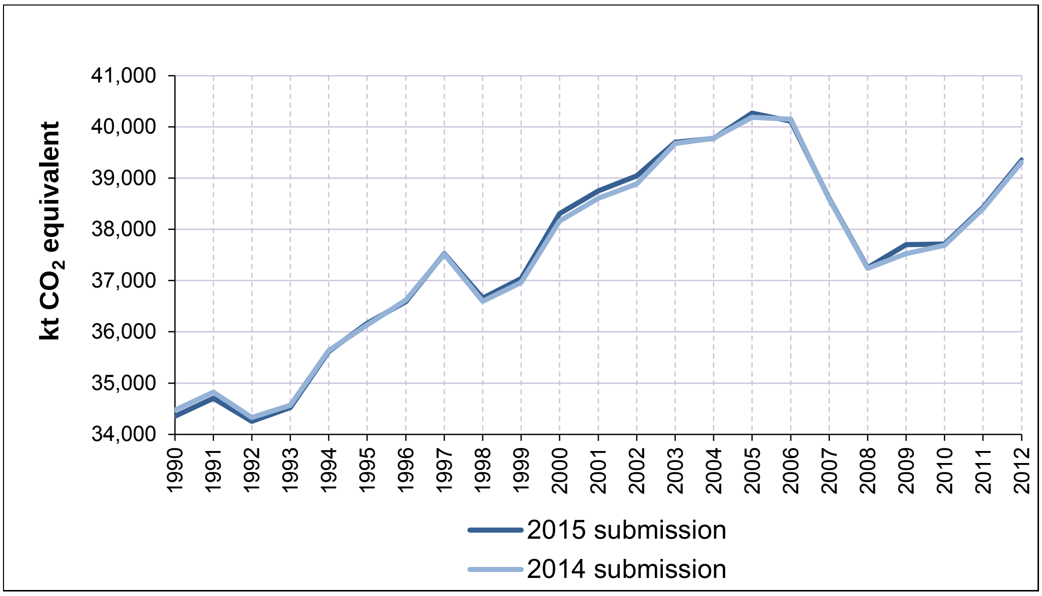


Figure 10.1.8 Effect of recalculations on New Zealand's Agriculture sector from 1990 to 2012 using AR2 GWPs

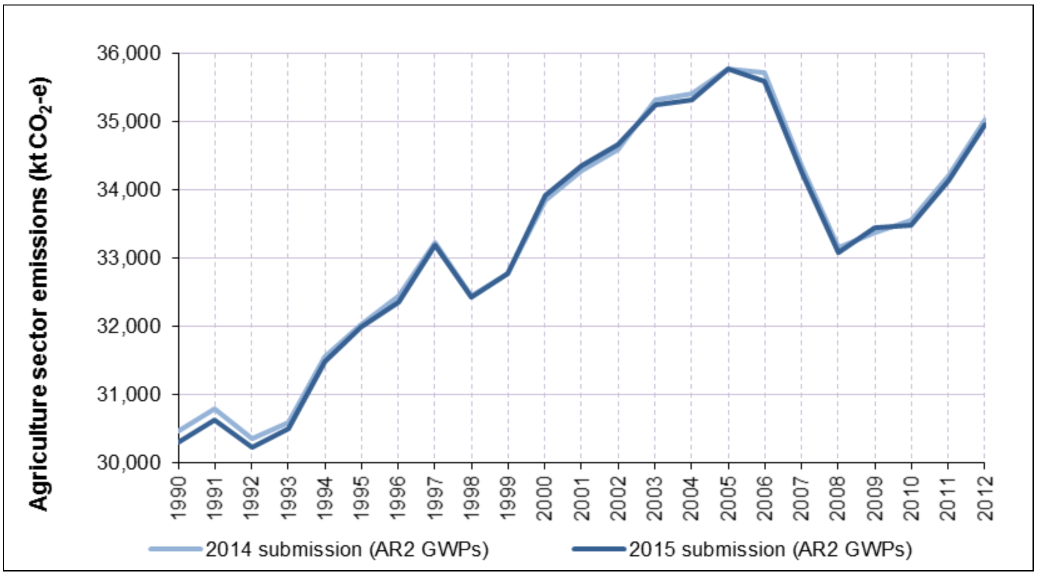


Table 10.1.3 Explanations and justifications for recalculations of New Zealand's previous agriculture estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Corrections identified in the Tier 2 model through recoding the Inventory programme and population models into Visual Basic. The recoding has made the model more transparent and accessible for quality assurance and quality control.	Transparency, consistency and accuracy	Correction identified and resolved through quality-assurance and quality-control processes.
The methodology for calculating methane emissions from anaerobic lagoons has been improved and updated in line with the 2006 IPCC guidelines	Transparency, accuracy, comparability and consistency	Requirement for improvement identified through discussion with scientific experts
The country-specific emission factor for urea fertiliser has been updated	Accuracy	Improved data are available
The parameters for calculating nitrogen retention in cattle milk and deer velvet have been reduced.	Accuracy	Improved data are available
Savanna burning is now reported under the LULUCF sector	Completeness	Reporting moved with agreement from LULUCF compilers

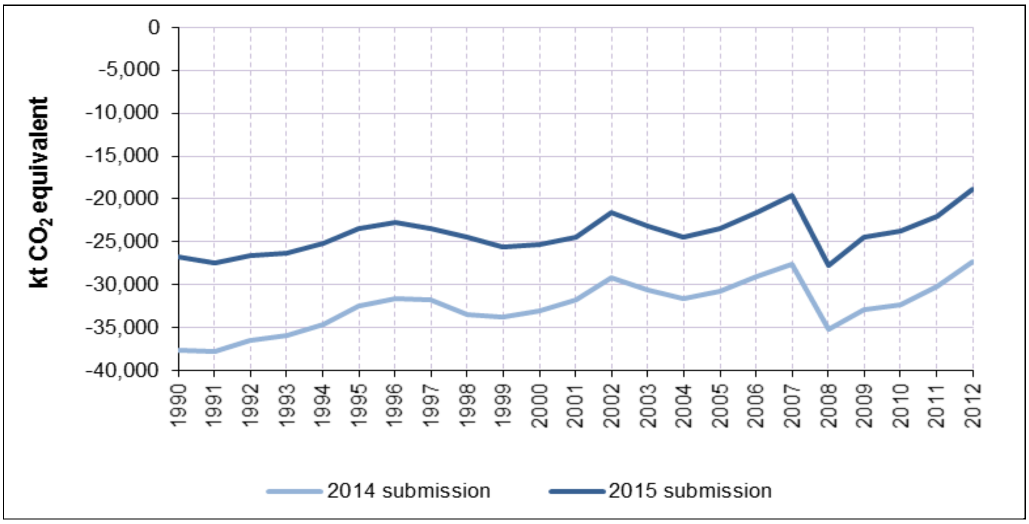
Table 10.1.4 Explanations and justifications for recalculations of New Zealand's previous agriculture estimates, arising from the migration to reporting to the 2006 IPCC guidelines

Explanation of recalculation	Good practice principle that was improved	Additional justification
Units have been changed from Gg to kt	Transparency, consistency and comparability	IPCC, 2006, requirement
The emission factors for horse, mules and asses, and poultry (other) and the emission factor for manure management of goats have been changed to 2006 IPCC default values	Accuracy, consistency, comparability	
Emission from camelids (alpaca and llama) are now reported under the 'Camels' category (there are no Middle-Eastern camels in New Zealand)	Consistency, comparability, completeness	
N_2O emissions from manure management are reported by livestock category	Transparency, consistency, comparability, completeness	
Indirect N_2O emissions are now calculated for manure management and agricultural soils categories	Consistency, comparability, completeness	
Reporting on emissions from pasture renewal activities is included under the calculation of N_2O emissions from crop residues	Consistency, comparability, completeness	
The proportion of synthetic fertiliser that is applied as urea has been calculated. Reporting on CO_2 emissions from urea fertiliser are included	Consistency, comparability, completeness	
Reporting on CO_2 emissions from liming activities are included	Consistency, comparability, completeness	
The IPCC 1996 and 2000 guidelines erroneously recommended that FracGAS be deducted before applying the Direct N_2O emission factor. This has been rectified.	Accuracy, consistency	
Reporting on mineralisation associated with loss of soil organic matter for cropland remaining cropland is included	Consistency, comparability, completeness	
The global warming potentials (GWPs) have been updated to values recommended in the IPCC Fourth Assessment Report (AR4) (CH4 GWP = 25; N_2O GWP = 298)	Transparency, consistency, comparability	In line with UNFCCC decision 24/CP. 19 (Annex III).

10.1.4 Land use, land-use change and forestry

Improvements made to the LULUCF sector have resulted in a 29.1 per cent (10,929.8 kt CO_2-e) increase in net LULUCF emissions in 1990 and a 30.7 per cent (8,358.0 kt CO_2-e) increase in net LULUCF emissions in 2012 (figure 10.1.9).[39]

Figure 10.1.9 Effect of recalculations on net removals from New Zealand's LULUCF sector from 1990 to 2012



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. These values exclude emissions from harvested wood products, liming and have been recalculated to use AR4 global warming potentials.

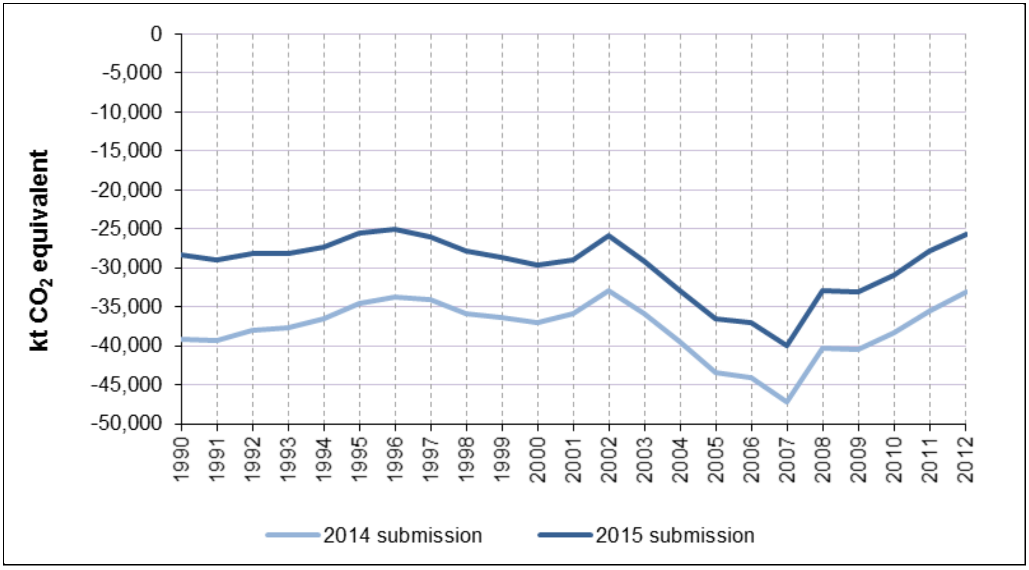
Significant improvements to the 2015 Inventory submission include:

- the revision of carbon stock change estimates for pre-1990 natural forests based on the final analysis of the re-measurement of these forests
- a change to the pre-1990 planted forest age class distribution to more accurately reflect the latest available activity data on the forest age classes
- updated post-1989 and pre-1990 planted forest yield tables. The updates include reclassification of a small number of plots due to mapping improvements, amendments to align with a revised estimate of net stocked area in both forest classes, and the inclusion of a sub-set of previously unused plots in post-1989 planted forest
- continued improvements to the 1990, 2008 and 2012 land-use maps. Mapping data provided from the New Zealand Emissions Trading Scheme (NZ ETS) was integrated into the three maps. This has improved the accuracy and consistency of the mapping of pre-1990 planted forest and post-1989 forest
- incorporating new data collected from post-1989 planted forest into the mineral soil organic carbon estimates.

Further details on these changes are in chapter 6. The effect of recalculations on emissions and removals in the *Forest land* and *Grassland* categories are shown in figures 10.1.6 and 10.1.7. The explanations and justifications for the major recalculations to New Zealand's LULUCF estimates in the 2014 Inventory submission are summarised in table 10.1.5.

[39] These values vary from those published in last year's Inventory as they have been updated to use AR4 global warming potentials. Both sets of numbers also exclude emissions from harvested wood products and liming so they are comparable.

Figure 10.1.10 Effect of recalculations on net removals from New Zealand's forest land category from 1990 to 2012



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 10.1.11 Effect of recalculations on net emissions from New Zealand's grassland category from 1990 to 2012

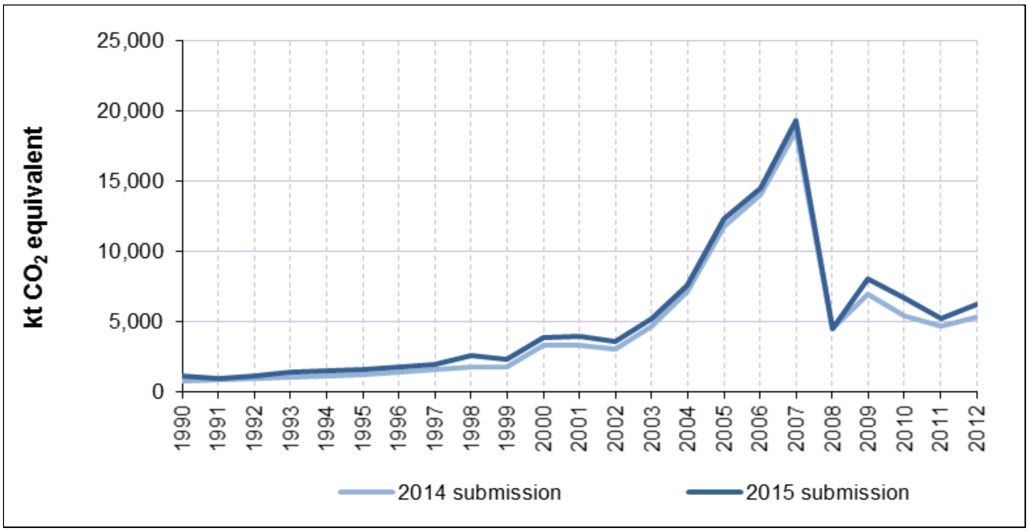


Table 10.1.5 Explanations and justifications for recalculations of New Zealand's previous LULUCF estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
The emission factor for pre-1990 natural forest has been revised following completion of re-measurement of the natural forest plot network. The emission factors now use the most recent measurement data and improved analysis methodology.	Accuracy	Key category improvement (forest land remaining forest land).
There has been a change to the pre-1990 planted forest age-class distribution. This now more accurately reflects the latest available activity data on pre-1990 planted forests. Previously an older age-class distribution was grown forward using harvesting statistics, but this was found to depart from the latest available data over time.	Accuracy and consistency	Key category improvement (forest land remaining forest land).
Post-1989 and pre-1990 planted forest yield tables have been updated for the 2015 submission. The updates include reclassification of a small number of plots due to mapping improvements, amendments to align plot estimates with a revised estimate of net stocked area in both planted forest classes, and the inclusion in the analysis of a subset of previously unused plots in post-1989 planted forest.	Accuracy	Key category improvement (land converted to forest land and forest land remaining forest land).
Improvements to the accuracy of the 1990, 2008 and 2012 land-use maps based on information from the New Zealand Emissions Trading Scheme, field visits and notified errors. This has resulted in improvements being incorporated for the entire time series to maintain consistency in reporting.	Accuracy and consistency	Key category improvement (land converted to forest land; land converted to grassland).
The modelling of the net planted forest area, for alignment with the new planting and harvesting activity data, has been updated for this submission.	Accuracy and consistency	Key category improvement (forest land remaining forest land and land converted to forest land).
Incorporating new data from post-1989 planted forest into the mineral soil organic carbon estimates.	Accuracy	Addresses ERT recommendation. Key category improvement (land converted to forest land).

10.1.7 Article 3.3 activities under the Kyoto Protocol

New Zealand's greenhouse gas estimates for activities under Article 3.3 of the Kyoto Protocol have been recalculated since the 2013 Inventory submission (tables 10.1.6, 10.1.7 and 10.1.8). The recalculations incorporate changes to meet new guidance as set out in the KP Supplement, include improved activity data, emission factors, and to move to the AR4 global warming potentials (see chapter 11, and table 10.2.1).

Table 10.1.6 Explanations and justifications for recalculations of New Zealand's previous Kyoto Protocol estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Improvements to the accuracy of the 1990, 2008 and 2012 land-use maps based on information from the New Zealand Emissions Trading Scheme, field visits and notified errors. This has resulted in improvements being incorporated for the entire time series to maintain consistency in reporting.	Accuracy and consistency	Key category improvement (afforestation/reforestation and deforestation).
Post-1989 and pre-1990 planted forest yield tables (emission factors) have been updated for the 2015 submission. The updates include reclassification of a small number of plots due to mapping improvements.	Accuracy	Key category improvement (afforestation/reforestation and deforestation).
The emission factor for pre-1990 natural forest has been revised following completion of re-measurement of the natural forest plot network. The emission factors now use the most recent measurement data and improved analysis methodology.	Accuracy	Key category improvement (deforestation).
The modelling of the net planted forest area, for alignment with the new planting activity data, has been updated for this submission.	Accuracy and consistency	Key category improvement (afforestation/reforestation and deforestation).
The area of deforestation during the commitment period has been updated. All area destocked during 2009 was confirmed as either replanted or deforested, as more than four years have passed since the land was cleared (see section 11.4).	Accuracy	Key category improvement (deforestation).
Incorporating new data from post-1989 planted forest into the mineral soil organic carbon estimates.	Accuracy	Key category improvement (afforestation/reforestation and deforestation).

Table 10.1.7 Impact of the recalculations of New Zealand's CO_2 removals under Article 3.3 of the Kyoto Protocol in 2012

Activities under Article 3.3 of the Kyoto Protocol	2012 net emissions ($kt\ CO_2$) 2014 submission	2015 submission	Change from 2014 submission (%)
Afforestation/reforestation	–18,970.2	–16,722.1	11.9
Forest land not harvested since the beginning of the commitment period	–19,151.1	–17,117.0	10.6
Forest land harvested since the beginning of the commitment period	180.8	394.9	118.4
Deforestation since the beginning of the commitment period	3,969.9	4,642.6	16.9
Total	**–15,000.3**	**–12,079.5**	**19.5**

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. These values include only CO_2 emissions and exclude emissions from liming and harvested wood products, as reporting of these has changed between the 2014 and 2015 submissions.

Table 10.1.8 Recalculations to New Zealand's 2012 activity data under Article 3.3 of the Kyoto Protocol

Activities under Article 3.3 of the Kyoto Protocol	Area as at 2012 (ha) 2014 submission	2015 submission	Change from 2014 submission (%)
Afforestation/reforestation	654,354	643,329	–1.7
Forest land not harvested since the beginning of the commitment period	653,686	654,576	0.1
Forest land harvested since the beginning of the commitment period	6,351	8,833	39.1
Deforestation	151,544	159,571	5.3
Activities occurring in 2012	**Area change in 2012 (ha)**		**Change from 2014 submission (%)**
New planting	12,539	13,637	8.8
Deforestation			
Pre-1990 natural forest	811	1,079	33.0
Pre-1990 planted forest	5,384	6,186	14.9
Post-1989 forest	567	683	20.5

10.1.6 Waste

Improvements and recalculations made in the Waste sector have resulted in a 54.2 per cent (1792.5 kt CO_2-e) increase in waste emissions in 1990, and a 41.3 per cent (1484.2 kt CO_2-e) increase in waste emissions in 2012 (figure 10.1.12). The increase was almost entirely due to the use of a GWP of 25 in calculation of methane emissions. The other recalculation made results from improved activity data from NZ ETS reporting, as shown in table 10.1.9.

Figure 10.1.12 Effect of recalculations on the Waste sector from 1990 to 2012

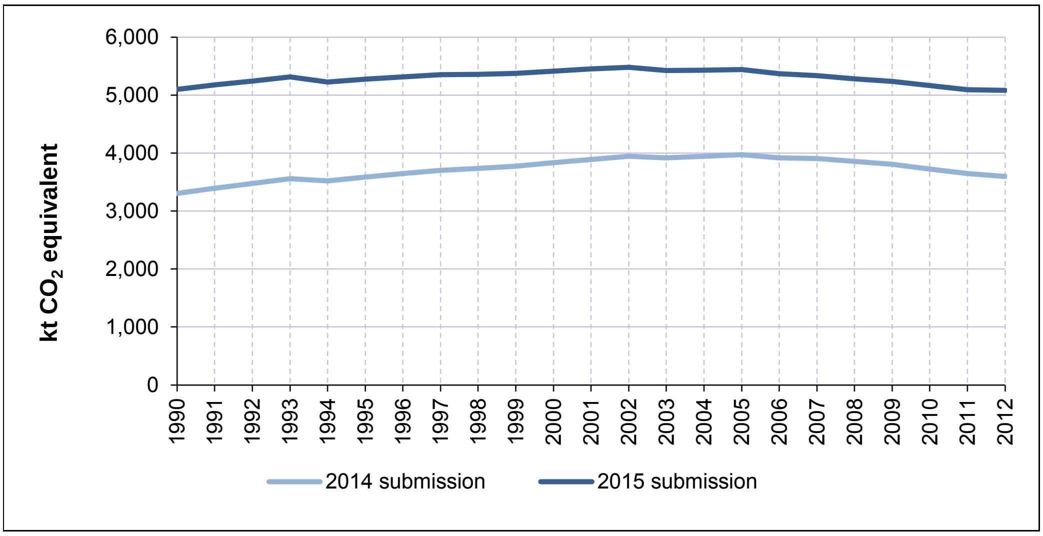


Table 10.1.9 Explanations and justifications for recalculations of New Zealand's previous waste estimates

Explanation of recalculation	Good practice principle that was improved	Additional justification
Improvements of NZ ETS activity data for individual landfills in 2013, with interpolation to recalculate activity at these sites in 2010-12.	Accuracy	NZ ETS data collection will facilitate verification and improved emission estimates over time.

10.2 Recalculations in response to the review process and planned improvements

10.2.1 Response to the review process

The recommendations from the review of the 2013 Inventory submission (UNFCCC, 2013) and New Zealand's responses are included below in table 10.2.1. The Expert Review Team (ERT) report for the 2014 Inventory submission was not published in time to be taken into account for this submission.

Table 10.2.1 New Zealand's response to expert review team recommendations from the individual review of New Zealand's 2013 Inventory submission

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
Energy	Para 38. Review the carbon dioxide (CO_2) emission factor (EF) for solid fuels and report the findings.	**Work in progress**. This will be implemented in future submissions. Note that the EF for solid fuels is well within the IPCC range and is only 2 per cent below the IPCC medium.
Energy – Comparison of the reference approach with the sectoral approach	Para 40. Disaggregate liquefied petroleum gas from natural gas liquids.	**Work in progress**. New Zealand will provide further information in the future Inventory submissions.
Energy	Para 46. Improve the transparency of the information on the CO_2 and CH_4 EFs used for geothermal energy and on the consistency of the time series, and reassess the country-specific unique emission factor when more data becomes available.	**Work in progress**. New Zealand will report the information when more data becomes available in the future Inventory submissions.
Energy – Stationary combustion: solid and gaseous fuels – CO_2	Para 49. Include additional information on how the CO_2 EFs used for solid fuels were calculated and the applicability of total solid fuels used in New Zealand across the entire time series.	**Work in progress**. New Zealand will report the information when more data becomes available in the future Inventory submissions.
Energy – Sector Overview	Para 23. Include more background information on each recalculation with a view to enhancing the transparency of the GHG Inventory.	**Completed**. Recalculation explanations have been entered into the 2014 CRF tables where applicable.
Energy – Comparison of reference and sectoral approach	Para 26. Apply greater rigour in its investigation of underlying reasons for the differences over the time series, especially for the later years when it is greater than 2.0 per cent.	**Completed**. New Zealand has undertaken a systematic and rigorous investigation into differences between the reference and sectoral approaches. Explanations of differences have been reported in the 2014 Inventory submission. Sources of differences have been identified for a more accurate and useful comparison with the reference approach.
Energy – International bunker fuels	Para 29. Addresses the inconsistency between CRF table 1.A (b) and table 1.C	**Completed**. This is addressed in section 3.2.2 of the 2014 Inventory submission, and also in section 3.3.8 of the 2014 Inventory submission.
Energy – feedstock and non-energy use of fuels	Para 31. Clarity where emissions from methanol production are reported.	**Completed**. This has been addressed and the reporting of emissions from methanol production now follows IPCC guidelines.
Energy – Stationary combustion: solid fuel – CO_2	Para 32. Investigate the appropriateness of the 2007 EF for use in the earlier years of the Inventory time series, and report thereon.	**Completed**. The emissions factors for solid fuels have been revised for the time series 1990–2007. Values are now calculated by interpolation between 1990 and 2008.
Energy – Oil and natural gas – CO_2,	Para 34. Report estimates of emissions from venting and flaring	**Completed**. New Zealand has included this information in the 2014 Inventory

Sector	Expert review team recommendation (including report paragraph number)	New Zealand response
CH_4	separately. Para 34. Report estimates of emissions from oil exploration and production and natural gas exploration and production/processing.	submission.
	Para 35. Include background information on the methodologies used to calculate emissions from natural gas distribution, transmission and storage.	**Completed**. New Zealand has included this information in the 2014 Inventory submission.
Energy – Navigation: liquid fuels – CO_2, CH_4, N_2O	Para 37. Clarify the text in the NIR regarding the collection of data for marine diesel use in domestic navigation.	**Completed**. This has been clarified in section 3.3.8 of the 2014 Inventory submission.
Energy – Oil and Natural Gas – N_2O	Para 38. New Zealand includes information on the revised estimates in its next annual submission.	**Completed**. This is reported in section 3.2.7 of the Inventory submission. Emissions of N_2O as a result of flaring have been included and are now aligned with the 1996 IPCC Guidelines methodologies.
LULUCF	Para 65. For reporting the area of organic soil: Add an explanation and comment on the use of the notation key "NO".	**Completed.** Instead of adding an explanation on the use of the "NO" notation key the land-use area threshold used for changes less than 100 hectares was removed for the 2014 submission.
LULUCF	Para 66. Provide more detailed information for the SOCREF estimation.	**Completed.** Additional information on New Zealand's Tier 2 soils model was provided in section 7.3 of the 2014 submission.
LULUCF	Para 67. For reporting of natural forest under forest land remaining forest land: Include emission estimates for each carbon pool for each year of the Inventory, as well as detailed documentation in the NIR on the research undertaken and interpretation of the results, and the effect of these estimates on the time series.	**Completed.** Interim results of analyses from the re-measurement of natural forest plots were used for the 2014 submission. The 2015 submission uses the final results of analyses from a full re-measurement of natural forest plots in New Zealand.
LULUCF	Para 68. Correct the notation key to "NA" for the dead organic matter pool on the basis that "the IPCC Tier 1 approach assumes that there is no change in dead organic matter carbon stocks in grassland remaining grassland".	**Not implemented.** This was not implemented as guidance prepared in November 2013, Annex 1 of Decision 24/CP.19, indicates that the notation key NE should be used in this case instead (refer to para 37(b) and footnote 6 of Annex 1 of this decision).
LULUCF	Para 69. Improve the transparency of its reporting on controlled burning of grassland and woody biomass within the agriculture sector by including cross-references in the NIR where appropriate.	**Completed.** Additional cross-referencing to the agriculture chapter was added for the 2014 submission.
KP-LULUCF	Para 76. Provide more transparent information on how the Party will avoid the potential underestimation of emissions from CO_2, CH_4, N_2O deforestation at the end of the first commitment period.	**Completed.** Sections 7.2.2 and 11.4 of the 2014 submission contained additional information on avoidance of potential underestimation of emissions in the first commitment period.
KP-LULUCF	Para 77: Include estimates of non-CO_2 emissions from controlled burning and wildfires on land subject to deforestation activities.	**Completed**. New Zealand provided estimates for controlled burning and wildfires on land subject to deforestation in the 2014 submission (section 11.3.1 and section 7.10.5).

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Chapter 11: KP-LULUCF

11.1 General information

Emissions summary

For reporting under the Kyoto Protocol, New Zealand has categorised its forests into three subcategories: pre-1990 natural forest, pre-1990 planted forest and post-1989 forest. These subcategories are also used for greenhouse gas inventory reporting on the Land-Use, Land-Use Change and Forestry (LULUCF) sector under the United Nations Framework Convention on Climate Change (Climate Change Convention) (see chapter 6).

For post-1989 forests, emissions and removals from carbon losses and gains due to afforestation,[40] reforestation and deforestation are reported under Article 3.3, along with emissions from deforestation of pre-1990 natural and pre-1990 planted forests. For all *Forest land* that existed on 31 December 1989, which has been categorised as either pre-1990 natural forest or pre-1990 planted forest, all emissions and removals not associated with deforestation are reported under Article 3.4 – forest management.

2013

In 2013, net emissions from afforestation, reforestation and deforestation activities were –12,165.2 kilotonnes of carbon dioxide equivalent (kt CO_2-e) (table 11.1.1). This value is the total of all emissions and removals from activities under Article 3.3 of the Kyoto Protocol and includes: removals from the growth of post-1989 forest and emissions from the conversion of land to post-1989 forest; emissions from harvesting of forests planted on non-forest land after 31 December 1989; emissions and removals from harvested wood products from afforestation land; emissions from deforestation of all *Forest land* subcategories; and emissions from *Biomass burning*, and mineralisation of soil nitrogen associated with afforestation, reforestation or deforestation since 1990.

In 2013, net emissions from forest management were –9,029.9 kt CO_2-e (table 11.1.1). This includes removals from growth of pre-1990 natural and pre-1990 planted forests, emissions from harvesting of these forests, emissions and removals from harvested wood products, and emissions from *Biomass burning*.

[40] Including emissions from harvesting of post-1989 forest.

Table 11.1.1 New Zealand's emissions under Article 3.3 and 3.4 of the Kyoto Protocol, in 2013

Activity	Gross area (ha) 1990–2013	Net area (ha) 2013	Emissions in 2013 (kt CO2-e)
Afforestation/reforestation	682,189	659,332	–17,057.37
Deforestation	168,024	8,453	4,892.17
Forest management		9,272,279	–9,029.93
Net emissions			**–21,195.12**
Excluded emissions from natural disturbances		0	0
Forest management reference level			11,150
Accounting quantity			**–12,165.2**

Note: Removals are expressed as a negative value as per section 2.2.3 of the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006a). Afforestation/reforestation refers to new forest established since 31 December 1989. The gross afforestation/reforestation area includes 22,857 hectares of land in transition to post-1989 forest that has subsequently been deforested. The 2013 areas are as at 31 December 2013. The accounting quantity is calculated by applying the accounting rules from Decision 2/CMP.7 to net emissions. Columns may not total due to rounding.

From 2013, there are new rules for accounting under the Kyoto Protocol. These include the ability to exclude from accounting emissions and removals due to natural disturbance, on land identified as carbon equivalent forests, and reference level accounting for forest management. While New Zealand has not taken its emissions reduction target to 2020 under the Kyoto Protocol, New Zealand must still meet reporting obligations under the protocol. Further detail on the new accounting rules from Decision 2/CMP.7 are provided under the heading New reporting requirements for the second commitment period of the Kyoto Protocol later in this section.

1990–2013

Between 1990 and 2013, 682,189 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities – an average of 28,425 hectares per year (figure 6.4.1 and table 11.1.1). During 2013, an estimated 4,462 hectares of new forest were planted, a decrease from 13,637 hectares in 2012.

Deforestation of all subcategories of *Forest land* (post-1989, pre-1990 planted and pre-1990 natural forest) during 2013 was estimated at 8,453 hectares. Since 1990, the area of deforestation of all subcategories of forest is estimated as 168,024 hectares.

Between 1990 and 2013, the area under forest management decreased by 145,166 hectares, or (1.54 per cent) due to deforestation, at which time the land is transferred from Article 3.4 – forest management reporting to Article 3.3 – Reporting under the Kyoto Protocol (*KP Supplement*, IPCC, 2014a, section 2.7.2).

Conversion to *Forest land* (afforestation and reforestation), conversion to *Grassland* (deforestation), and *Forest land remaining forest land* (forest management) are all key categories for New Zealand (table 1.5.4).

A breakdown of New Zealand's emissions under the Kyoto Protocol by greenhouse gas source category is provided in table 11.1.2.

Table 11.1.2 New Zealand's emissions in 2013 under the second commitment period of the Kyoto Protocol by greenhouse gas source category

Greenhouse gas source category	Source form	Emissions in 2013 (kt) Source emission	CO_2-equivalent
CO_2 emissions from afforestation/reforestation	CO_2	–17,161.9	–17,161.9
CO_2 emissions from deforestation	CO_2	4,857.7	4,857.7
CO_2 emissions from forest management activities	CO_2	–9,043.1	–9,043.1
Mineralisation of soil nitrogen associated with land-use change	N_2O	0.3	102.3
Biomass burning	CH_4	1.8	46.1
Biomass burning	N_2O	0.01	3.8
Net emissions			**–21,195.1**

Note: CO_2 = carbon dioxide; N_2O = nitrous oxide; C = carbon; CH_4 = methane. Columns may not total due to rounding.

Data on the use of nitrogen fertiliser in New Zealand is not segregated by land use. Therefore, emissions from all fertiliser use are reported under the Agriculture sector to avoid double counting (IPCC, 2014a, section 2.4.4.2). Emissions associated with indirect nitrous oxide (N_2O) emissions from managed soils are also reported under the Agriculture sector. New Zealand reports IE (included elsewhere) in the relevant common reporting format (CRF) tables.

Methodologies for estimating non-CO_2 emissions associated with drainage, rewetting and other soils are not within the guidance currently adopted by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP), and the Conference of the Parties. Where no adopted methodology for calculating these emissions exist, New Zealand reports NE (not estimated).

New reporting requirements for the second commitment period

New Zealand's second commitment period target

New Zealand remains a party to the Kyoto Protocol and has taken a quantified economy-wide emissions reduction target under the Climate Change Convention for the period 2013 to 2020. New Zealand will be applying the Kyoto Protocol framework of rules in reporting against this target.

Harvested wood products

New Zealand is reporting emissions for the harvested wood products pool for the first time in this report. Changes in the harvested wood products pool are reported for afforestation and reforestation, and for forest management using estimates derived from a modified harvested wood products IPCC Convention reporting model. Harvested wood products originating from deforestation events are reported on the basis of instant oxidation. Harvested wood products reported under afforestation and reforestation include emissions since 1990. Harvested wood products reported under forest management only include emissions since 1 January 2013 as New Zealand's forest management reference level (FMRL) is based on a business-as-usual projection. This follows the guidance provided in the *KP Supplement* (IPCC, 2014a) and is consistent with the guidance on projection based business-as-usual FMRLs.

Natural disturbance

New Zealand intends to apply the provisions to exclude emissions due to natural disturbances from accounting for afforestation and reforestation under Article 3.3, and forest management under Article 3.4, of the Kyoto Protocol from 1 January 2013 in accordance with Decision 2/CMP.7.[41] Information on how New Zealand has calculated the background level for natural disturbance is included in section 11.3.1.

Forest management

New Zealand is now required to report forest management activities under Article 3.4 of the Kyoto Protocol. New Zealand has applied the broad approach to interpreting the definition of forest management in identifying the area subject to forest management activities. This includes the area classified as pre-1990 natural forest and pre-1990 planted forest (excluding any area deforested since 1990, as this is reported under Article 3.3 – deforestation). Accounting for emissions from forest management activities under Article 3.4 of the Kyoto Protocol will be against a business-as-usual projected reference level. This means that New Zealand takes responsibility for emissions from land under forest management where these emissions are greater than the reference level. New Zealand's forest management reference level for the second commitment period is 11,150 kt CO_2-e.[42] This reference level will require technical corrections in order to be consistent with the requirements of Decision 2/CMP.7, annex 1, paragraph 14, see section 11.5.1.

Carbon equivalent forests

New Zealand intends to apply the carbon equivalent forest provision where land meets the requirements of this provision.[43] No carbon equivalent forest conversions were carried out in New Zealand during 2013.

11.1.1 Definitions of forest and any other criteria

New Zealand is using the same *Forest land* definition for the period to 2020 as that used for the first commitment period and as defined in *New Zealand's Initial Report under the Kyoto Protocol* (Ministry for the Environment, 2006). This definition is consistent with that used for the LULUCF sector under the Climate Change Convention reporting (chapter 6). Table 11.1.3 provides the defining parameters for *Forest land.*

Table 11.1.3 Parameters defining forest in New Zealand

Forest parameter	Kyoto Protocol range	New Zealand selected value
Minimum land area (ha)	0.05–1	**1**
Minimum crown cover (%)	10–30	**30**
Minimum height (m)	**2–5**	**5**

Note: The range values represent the minimum forest definition values as defined under the Kyoto Protocol, Decision 16/CMP.1.

New Zealand also uses a minimum forest width of 30 metres, which removes linear shelterbelts from the forest land category. Linear shelterbelts can vary in width and height, because they are trimmed and topped from time to time. Further, they form part of non-forest land uses, namely *Cropland* and *Grassland* as shelter to crops and/or animals.

The definition used for reporting to the Food and Agriculture Organization is currently different from that used for Climate Change Convention and Kyoto Protocol reporting. 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

[41] Decision 2/CMP.7, annex I, para 33 and 34.

[42] This value is subject to technical corrections as in Decision 2/CMP.7, annex I, para 14.

[43] Decision 2/CMP.7, annex I, paras 37–39, and Decision 2/CMP.8, annex II, para 5(g).

and Forestry, 2002). The two estates are indigenous and planted production forest. The former estate is included within the pre-1990 natural forest as reported in this submission; however, it excludes areas of regenerating vegetation that do not meet the forest definition but have the potential to under current management. The latter largely equates to pre-1990 planted forest and post-1989 planted forest. New Zealand is working to align reporting to the Food and Agriculture Organization with Climate Change Convention and Kyoto Protocol reporting in the 2015 Global Forest Resources Assessment and Montreal Process Criteria and Indicators reports.

11.1.2 Activities under Article 3.4

New Zealand is reporting on net emissions for forest management for the first time in this report. For this reporting, it uses the same definition of forest as outlined above (section 11.1.1). New Zealand has not elected to report on any of the voluntary activities under Article 3.4 of the Kyoto Protocol for the second commitment period. This is consistent with New Zealand's reporting for the first commitment period.

11.1.3 Implementation and application of activities under Article 3.3 and Article 3.4

New Zealand reports afforestation and reforestation, deforestation and forest management under Articles 3.3 and 3.4 respectively. In 2013, this covered 10,098,223 hectares or 37.5 per cent of New Zealand's total land area.

Once a forest area has been identified as deforested it remains in this category. Therefore, all subsequent stock changes, emissions and removals on this land are reported under deforestation.

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 and reforestation or forest management land, and that the emissions and removals associated with the new land use are reported under deforestation. The process for identification of deforested land is outlined in section 11.4.

Afforestation and reforestation

Between 1990 and 2013, it is estimated that 682,189 hectares of new forest (post-1989 forest) were established as a result of afforestation and reforestation activities (table 11.1.4). The net area of post-1989 forest as at the end of 2013 was 659,332 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. Removals from this land in 2013 were –17,040.8 kt CO_2-e compared with –16,606.1 kt CO_2-e in 2012. Of the total area afforested or reforested between 1990 and 2013, an estimated 22,857 hectares were deforested between 1990 and 2013 (table 11.1.4). The emissions for this area are reported under deforestation.

While new planting rates were high from 1992 to 1998 (averaging 61,618 hectares per year), the rate of new planting declined from 1998 and reached a low of 2,383 hectares in 2008 (table 11.1.4). The planting rate has slowly recovered over the past three years, with around 13,600 hectares planted in 2011 and 2012, and a provisional estimate of 4,462 hectares for 2013. The activity data used to estimate new planting in planted forests between 2008 and 2013 is obtained from a national survey of forest owners (Ministry for Primary Industries, 2013). The survey respondents report areas as net stocked area rather than gross stocked area, as reported in the Inventory. To account for the difference between the two sources of data (mapping and survey), the net planted forest area has been identified and modelled separately. An unstocked area component is added to the new planting statistic between 2008 and 2013 to maintain consistency with the mapped area used prior to

2008. This ensures the net new planting data used in the Inventory is consistent with that reported by the Ministry for Primary Industries.

New Zealand's post-1989 forests are described in further detail in section 6.4.

Table 11.1.4 New Zealand's estimated annual area of afforestation/reforestation from 1990 to 2013

	Annual area of post-1989 forest (ha)			
Year	New forest planting+	Harvesting	Deforestation	Net cumulative area
1990	14,678	0	0	14,678
1991	14,328	0	0	29,006
1992	44,972	0	0	73,978
1993	54,940	0	0	128,918
1994	86,953	0	0	215,871
1995	65,815	0	0	281,686
1996	74,534	0	0	356,220
1997	57,263	0	0	413,483
1998	46,852	0	0	460,335
1999	36,988	0	0	497,323
2000	32,006	0	0	529,329
2001	29,004	0	0	558,333
2002	21,989	0	716	579,606
2003	20,719	0	2,257	598,067
2004	13,020	0	2,074	609,014
2005	9,267	200	2,359	615,921
2006	6,339	600	2,022	620,238
2007	6,343	600	4,854	621,728
2008	2,383	801	1,068	623,043
2009	5,063	1,017	2,644	625,462
2010	6,966	1,721	1,639	630,789
2011	13,669	2,188	1,130	643,329
2012	13,637	1,706	683	656,282
2013P	4,462	1,487	1,412	659,332
Total	**682,189**	**10,320**	**22,857**	**659,332**

Note: P = provisional figure; + = gross area. Columns may not total due to rounding.

Since 1993, the New Zealand Government has introduced legislation and government initiatives to encourage forest establishment and discourage deforestation of planted forests. These include the:

- Climate Change Response Act 2002 (amended 8 December 2009)
- Erosion Control Funding Programme (Ministry for Primary Industries, 2014)
- Permanent Forest Sink Initiative (Ministry of Agriculture and Forestry, 2008b)
- Hill Country Erosion Programme (Ministry of Agriculture and Forestry, 2008a)
- Afforestation Grant Scheme (Ministry of Agriculture and Forestry, 2009b).

The New Zealand Emissions Trading Scheme (NZ ETS) has been introduced under the Climate Change Response Act 2002. Forest land was introduced into the scheme on 1 January 2008. Under the scheme, owners of post-1989 forest land may voluntarily participate in the NZ ETS and receive emission units (NZUs) for any increase in carbon stocks in their forests from 1 January 2008.

The Erosion Control Funding Programme, formerly the East Coast Forestry Project, is a grant scheme that was established in 1993. Its aim is to afforest erosion-prone land in the Gisborne district and has approved funding to 2020. To date, around 33,000 hectares of forest have been established under the scheme with another 5,000 hectares approved for establishment over the next few years (Ministry for Primary Industries, 2014).

The Permanent Forest Sink Initiative promotes the establishment of permanent forests on non-forest land since 1990. Just over 10,000 hectares were registered under this scheme between June 2008 and June 2014.

The Hill Country Erosion Programme, like the East Coast Forestry Project, is focused on the retiring and afforestation of erosion-prone, hill-country farmland in the North Island. It has recently undergone a review and continues with an expanded target area throughout erosion-prone land in the North Island (Ministry of Agriculture and Forestry, 2011).

The Afforestation Grant Scheme was established in 2008 to promote carbon sequestration and sustainable land use. Funding ended in 2013 and no new application rounds are planned at present (Ministry of Agriculture and Forestry, 2011).

New Zealand now reports on harvested wood products from afforestation and reforestation land. This is described further in section 11.3.1.

From 2013, New Zealand may apply the provision for the treatment of natural disturbance emissions to its afforestation and reforestation accounting and has indicated its intention to do so (section 11.1). Due to the nature of afforestation and reforestation accounting and reporting methods, the background level is already captured implicitly within the reported estimates. New Zealand will therefore account for the difference between additional disturbance emissions and the background level, which is set at zero with a zero margin.

While some wildfire was detected on afforestation and reforestation land in 2013 this was not at a high enough level for New Zealand to trigger the natural disturbance provision.

Deforestation

In 2013, deforestation emissions were 4,892.2 kt CO_2-e, compared with 4,642.6 kt CO_2-e in 2012. These emissions result from the carbon stock loss caused by deforestation activity in the year that it occurred, and lagged emissions from previous deforestation events (ie, soil carbon stock change), emissions from biomass burning of deforested land and removals from biomass change of the new land use.

The estimated area of deforestation reported for 2013 was 8,453 hectares, 6.4 per cent higher than the 7,948 hectares reported for 2012, and the higher deforestation emissions reported in 2013 reflect this. The area of deforestation for the first commitment period has been updated from last year's submission following revision of deforestation mapping for the period. This mapping identified and confirmed areas of deforestation occurring between 1 January 2008 and 31 December 2012 using satellite imagery and field observations captured in oblique aerial photography. Further information on this process can be found in sections 6.2.2 and 6.2.3.

Table 11.1.5 shows the areas of *Forest land* subject to deforestation by forest subcategory.

Table 11.1.5 **Area of New Zealand subject to deforestation**

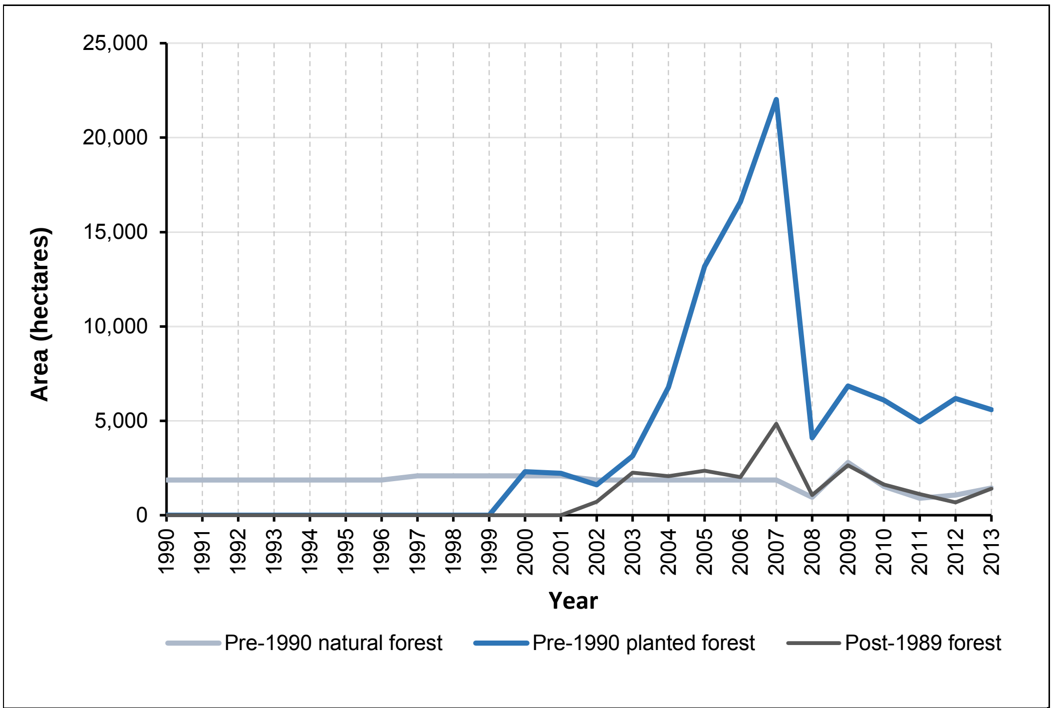
Year	Annual area of deforestation (ha) Pre-1990 natural forest	Pre-1990 planted forest	Post-1989 forests
2008	953	4,103	1,068
2009	2,805	6,847	2,644
2010	1,533	6,102	1,639
2011	896	4,945	1,130
2012	1,079	6,186	683
2013	1,453	5,588	1,412

Note: Areas as at 31 December.

Figure 11.1.1 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 11.1.1 New Zealand's annual areas of deforestation from 1990 to 2013



There are no emissions from deforestation of pre-1990 planted forest or post-1989 forest estimated before 2000. This activity was not significant, and insufficient data exists to reliably report the small areas of deforestation that may have occurred.

Since the introduction of the NZ ETS in 2008, owners of pre-1990 planted forest are now able to deforest a maximum of 2 hectares in any five-year period without having to surrender emission units. Above this level of deforestation, they are required to surrender units equal to the reported emissions, with some exemptions for smaller forest owners and tree weeds within the conservation estate (Ministry of Agriculture and Forestry, 2009a). This led to a significant reduction in the rate of deforestation of pre-1990 planted forest from 2008. Post-1989 forest owners who are registered in the scheme also have legal obligations to surrender units if the carbon stocks in their registered forest area fall below a previously reported level (for example, due to deforestation, harvesting or fire). It should be noted that the area of pre-1990 planted forest deforestation in 2013 was only 0.5 per cent of the total pre-1990 planted forest area. Following a drop in the price of carbon units in 2011, deforestation increased.

The area of deforestation of pre-1990 natural forests prior to 2008 has been estimated by linear interpolation from the average land-use change mapped between 1 January 1990 and 1 January 2008. However, a number of factors suggest that the rate of pre-1990 natural forest deforestation is unlikely to have been relativity constant over the 18-year period between 1990 and 2007, but instead mostly occurred prior to 2002. The area available for harvesting (and potentially deforestation) was higher before 1993 when amendments were made to the Forests Act 1949. Further restrictions on the logging of natural forests were also introduced in 2002, resulting in the cessation of logging of publicly owned forests on the West Coast of New Zealand from that time on. Both of these developments are likely to have reduced pre-1990 natural forest deforestation since 2002.

The rate of pre-1990 natural forest deforestation occurring during the commitment period is, on average, lower than that reported pre-2008. This observed reduction in the rate of deforestation confirms that the rate of deforestation pre-2008 was likely to already be in decline (see figure 6.2.5 for details of the mapping process). Deforestation for 2013 is estimated as described in section 6.2.3. This is because New Zealand does not carry out annual land-use change mapping.

Deforestation in New Zealand is described in more detail in sections 6.2, 11.3.1 and 11.4.2.

Forest management

From 2013, New Zealand is required to report on emissions and removals from forest management. This is accounted for against a business-as-usual reference level, based on projections (the FMRL) as inscribed in the appendix to the annex to Decision 2/CMP.7. This value for New Zealand is 11.150 million tonnes (Mt) CO_2-e per year. In 2013, emissions on this land were –5,073.70 kt CO_2-e. There were also emissions of –3,225.5 kt CO_2-e in the harvested wood products pool from forest management land. The total area remaining in forest management at the end of 2013 was 9,272,279 hectares; this is a decrease of 145,166 hectares (or 1.54 per cent) since 1990.

The emissions for forest management in 2013 were significantly lower than the FMRL. The FMRL is the annual average over the eight years from 2013–2020 inclusive. Over this period, New Zealand expects emissions from forest management to increase as harvesting of pre-1990 planted forest increases. The FMRL does not include removals from natural forests. A technical correction for this is required, and work on this is currently under way for the next annual submission.

New Zealand's FMRL is described further in section 11.5.1.

The source of the emission data for land under forest management is described in more detail within chapter 6, sections 6.2 and 6.4.

Carbon equivalent forests

While New Zealand intends to utilise the carbon equivalent forest provision in Decision 2/CMP.7 (paragraph 37), no area that meets the requirements as outlined in the decision was identified in 2013.

Natural disturbance

New Zealand has indicated its intention to apply the natural disturbance provision to forest management land. As part of electing this provision, New Zealand is required to calculate a background level of natural disturbance for forest management land. This is described in section 11.3.1.

11.2 Land-related information

11.2.1 Spatial assessment unit

New Zealand is mapping land use to 1 hectare.

11.2.2 Methodology for land transition matrix

The land transition matrix is based on data derived from the 1990, 2008 and 2012 land-use maps, an estimate of total afforestation for the period 2008 to 2013 from the *National Exotic Forest Description* (Ministry for Primary Industries, 2013) and an estimate for 2013 deforestation based on the *Deforestation Survey 2013* (Manley, 2014).

Because of the land class and forest management definitions used by New Zealand, the land transition matrix can be derived directly from the land-use change matrix. The relationship between mapped land-use changes and activities reported under Articles 3.3 and 3.4 are shown in table 11.2.1

Table 11.2.1 Relationship between mapped land-use changes and activities reported under Articles 3.3 and 3.4

Initial \ Final	Pre-1990 natural forest	*Pre-1990 planted forest*	Post-1989 forest	Grassland	Cropland	Wetland	Settlements	Other land
Pre-1990 natural forest	FM	FM	–	D	D	D	D	D
Pre-1990 planted forest	FM	FM	–	D	D	D	D	D
Post-1989 forest	–	–	A	D	D	D	D	D
Grassland	*	*	A					
Cropland	*	*	A					
Wetland	*	*	A					
Settlements	*	*	A					
Other land	*	*	A					

Note: A = afforestation; D = deforestation; FM = forest management; '–' denotes land-use changes that are not possible given the land-use definitions; '*' denotes land-use changes that are valid only if the land was forested at 1990, in which case the land-use transition is accounted for under deforestation; that is, pre-1990 planted forest, converted to grassland since 1990 that is later converted back to pre-1990 planted forest would be reported under deforestation.

Mapping of land-use change is described in sections 6.2.2 and 6.2.3. Further information on the estimation of the total area of afforestation occurring between 2008 and 2013 can be found in section 6.4.1.

Essential to accurate determination of the area to be reported as afforestation in the land transition matrix is accurate classification of the pre-1990 planted forest and post-1989 forest subcategories. Satellite imagery at various dates near to 1990 and mapping from the NZ ETS have been used to ensure that these forests are classed correctly. An illustration of this process is shown in figure 6.2.4.

Transitions to deforestation are based on deforestation mapping, as described in section 6.2.2. All areas of deforestation are confirmed using oblique aerial photography. For deforestation occurring between 2008 and 2012, annual Landsat satellite imagery is used to estimate the year of the conversion.

11.2.3 Identifying geographical locations

New Zealand has used Reporting Method 2 for preparing estimates of emissions and removals from afforestation and reforestation and deforestation, and Approaches 3 to map land-use change. Wall-to-wall mapping is completed every four-to-five years, with national statistics and ancillary mapping data used in the intervening years to estimate afforestation and reforestation and deforestation.

The geographic units New Zealand reports 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.

11.2.4 Planned improvements

Calculation of the areas of annual land-use change occurring between 1990 and 2007 are based on interpolation of land-use changes mapped between the nominal mapping dates of 1 January 1990 and 1 January 2008 (see section 6.2.3). Because of the length of time between these mapping dates, it is possible that an area of land could be in a forest land use at 1990, then deforested and converted to an alternative land use for a number of years, before being reforested prior to 2008. In this instance, the deforestation event would not be identified and the area would be reported under forest management rather than deforested land. This would lead to an under-estimation of removals on deforested land.

Information from the NZ ETS will be used to identify forest areas that were deforested at some time between 1990 and 2008 to allow these areas to be reported under the deforested land activity in next year's submission.

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 6.

Carbon stock change

Emissions and removals from afforestation and reforestation, deforestation and forest management are determined using plot-network-based estimates for each subcategory of forest (pre-1990 natural forest, pre-1990 planted forest and post-1989 forest). Carbon analyses are performed to estimate the carbon per hectare per pool and are described in section 6.4.2.

Pre-1990 natural forest deforestation has been further sub-classified according to species composition, to identify the proportion of deforestation that was tall forest as opposed to younger or immature natural forest (regenerating shrubland that has the potential to meet the forest definition) areas (table 11.3.1). This has been estimated using the Land Cover Database 4 (LCDB4), 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 LCDB4 layer, refer to: www.nlrc.org.nz/resources/datasets/lcdb3.

Table 11.3.1 New Zealand's areas of pre-1990 natural forest deforestation estimated by sub-classification from 2008 to 2013

Pre-1990 natural forest sub-classification	Area of natural forest deforestation (ha)						
	2008	2009	2010	2011	2012	2013	Total
Regenerating shrubland	738	1,863	917	422	732	930	5,603
Tall forest	215	942	615	474	347	524	3,116
Total	**953**	**2,805**	**1,533**	**896**	**1,079**	**1,453**	**8,719**

Note: Columns may not total due to rounding.

The carbon densities for pre-1990 natural forest and post-1989 planted forest have been updated following scheduled re-measurement and/or re-modelling of these forests as described in section 6.4.2.

Following deforestation, carbon on the new land use then accumulates at rates given in table 6.1.4.

Harvested wood products (CRF 4(KP-I)C)

New Zealand has a large planted forest estate that provides the majority of wood products consumed domestically and exported in either product or raw material form. A description of the forest estate and New Zealand wood use is provided in section 6.10.

New Zealand has developed a Tier 3 method to report harvested wood products under the Kyoto Protocol. New Zealand uses the default Tier 2 methodology, as described in the guidance (*KP Supplement*, IPCC, 2014a), and uses some country-specific activity data and parameters where available. IPCC default half-lives and some conversion factors are used. Country-specific conversion factors are used for sawnwood and veneer sheets.

Harvested wood products production, import and export data from 1990 to 2013 were sourced from the Food and Agriculture Organization Statistics database (FAOSTAT). These data are provided to the Food and Agriculture Organization by the Ministry for Primary Industries. The basic data are the same as that used for Convention reporting except the time-series begins in 1990 for afforestation and reforestation and 2013 for forest management. Also, the solid wood Convention category is disaggregated into sawnwood and panels for Kyoto Protocol reporting. Errors within the data were corrected, missing data were added and data that were not updated from the previous estimates were corrected. The data were corrected using data directly from the Ministry for Primary Industries.

In 2013, a large proportion (over 50 per cent) of New Zealand's harvest was exported as raw materials in the form of logs or wood chips. The FAOSTAT database provides data on the export quantity of raw materials but no information currently exists on the conversion of these materials to products and their expected half-lives. Therefore, exported raw materials are currently excluded from New Zealand's Kyoto Protocol harvested wood products pool estimates and they are treated as an instantaneous emission. Work is currently under way to assess the end-use of New Zealand raw materials in export markets.

Harvest of afforestation and reforestation land is estimated from 1990 onwards. These lands provide a small contribution to harvested wood products because the majority of post-1989 planted forests are yet to reach harvest age. Harvested wood products originating from these lands are estimated by prorating the proportion of afforestation and reforestation harvest emissions to total harvest emissions (excluding deforestation).

Harvest on forest management land, specifically pre-1990 planted forest, is estimated from 2013 onwards, and these lands currently provide over 90 per cent of New Zealand's annual harvest. Harvested wood products originating from these lands are estimated by prorating the proportion of forest management harvest emissions to total harvest emissions (excluding deforestation). Accounting of harvested wood products on these lands is against New Zealand's projected FMRL and, therefore, emissions prior to 2013 are excluded.

Harvested wood products originating from deforestation are instantly emitted under the Kyoto Protocol; however, the production statistics do not identify removals from these lands. The share of harvest volume originating from deforestation is estimated by comparing emissions from deforestation to emissions from harvesting. This provides a proportion to apply to the production statistics to separate harvested wood products originating from deforestation.

Non-forest harvest is treated as an instant emission. Harvest from these lands is assumed to be used for fuel wood. Therefore, the harvested wood products contribution from non-forest lands is assumed to be zero.

Non-CO_2 emissions

Direct N_2O emissions from nitrogen fertilisation (CRF 4(KP-II)1)

New Zealand's activity data on nitrogen fertilisation is not currently disaggregated by land use, 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 KP-LULUCF sector.

CH_4 and N_2O emissions from drained and rewetted organic soils (CRF 4(KP-II)2)

The methodology for estimating these emissions is contained within the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (IPCC, 2014b). This supplement was not adopted by the CMP and, as such, its use is voluntary unless a country has elected Wetland Drainage and Rewetting.[44] Given this, New Zealand reports NE (not estimated) in the CRF table for *CH4 and N_2O emissions from drained and rewetted organic soils*.

Nitrous oxide emissions from nitrogen mineralisation and immobilisation associated with land-use conversions and management in mineral soils (CRF 4(KP-II)3)

Nitrous oxide emissions, resulting from nitrogen mineralisation and immobilisation associated with land conversion, are reported for afforestation and reforestation, deforestation and forest management. These are calculated following the guidance in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006a). Total emissions for these three activities are 0.04 kt N_2O.

[44] Decision 6/CMP.9, paragraph 10.

Biomass burning (CRF 4(KP-II)4)

Afforestation and reforestation

Non-CO_2 emissions from wildfires in land converted to forest land are reported under afforestation and reforestation. The activity data does not distinguish between forest land subcategories (post-1989 forest/afforestation or pre-1990 planted forest/forest management); therefore, non-CO_2 emissions resulting from wildfire are attributed to afforestation and reforestation by the proportion of area that these forests make 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, 2014a). New Zealand reports IE (included elsewhere) in this table, instead.

A survey of controlled burning activities in planted forests was carried out in 2011. The survey indicated that, on average, 5 per cent of conversions to planted forest between 1990 and 2011 involved burning to clear vegetation. This area is allocated to pre-1990 planted forest (conversions from natural forest) and post-1989 forest (conversions from grassland with woody biomass) on a pro rata basis (Wakelin, 2012).

Expert opinion suggests that controlled burning of post-harvest residues prior to replanting on post-1989 forest land does not occur due to the nature of harvest in short-rotation forest grown for pulp (where most biomass is removed from the site).

Deforestation

An estimate is provided for controlled burning of post-harvest slash associated with deforestation. No information is available on the extent of burning associated with deforestation in New Zealand. Therefore, it is assumed that 30 per cent of conversions involve burning. This percentage is chosen as a conservative proportion of one of the four main methods for disposing of residues in New Zealand. The other methods for residue disposal are chipping and removal, mulching into the soil and leaving to decay (Goulding, 2007). To estimate emissions from the burning of harvest residue, the IPCC default combustion proportion for non-eucalypt temperate forest (0.62) is applied to an emission factor derived from the national plot network. The emission factor excludes the proportion of logs taken offsite (70 per cent of above-ground biomass) and is taken from the plot-network-derived yield tables by forest subclass at the average age of harvest in New Zealand.

Estimates are provided for wildfire on deforested land (forest land converted to grassland) in the Inventory. The activity data does not identify deforested land; therefore, non-CO_2 emissions resulting from wildfire are attributed to deforested land by the proportion of area that deforested land makes up of the total *Grassland* area. The methodology follows that described in section 6.11.4. Around 1 per cent of wildfire emissions in *Grassland* are estimated to have occurred on deforested land between 2008 and 2013.

Forest management

Non-CO_2 emissions from wildfires in pre-1990 forest land are reported under forest management. A plot-network-derived biomass density is used to estimate non-CO_2 emissions from wildfire in forest management lands. Aggregated wildfire activity data is attributed to each subcategory by proportion of forest type estimated to be burned over the time series. This is split by 87.5 per cent to planted forest with the remaining to natural forest (Wakelin, 2011). The planted forest activity data is further split into pre-1990 and post-1989 forest (see Afforestation and reforestation above). 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).

A survey of controlled burning in planted forest was carried out in 2011. Estimates were provided for burning associated with the clearing of vegetation (ie, natural forest and grassland with woody biomass) prior to the establishment of exotic planted forest (see Afforestation and reforestation above).

The survey also provided data on the burning of post-harvest slash prior to restocking. This activity was found to occur mainly as a training exercise for wildfire control or for the clearing of slash heaps on skid sites. The data indicated that 0.8 per cent of restocked area was burnt each year in recent years. This estimate was combined with two earlier estimates of controlled burning in planted forest (Forest Industry Training and Education Council, 2005; Robertson, 1998) to provide activity data throughout the time series. It is assumed that 1.6 per cent of restocked area was burnt from 1990 to 1997 (Wakelin, 2012). From 1997, the area burnt declines linearly to 0.8 per cent, which is used from 2005 onwards (Wakelin, 2012).

A more detailed description of biomass burning on forest land is provided in section 6.11.4.

Natural disturbance

The minimum annual historical emissions method was used to estimate the background level of emissions due to natural disturbances on afforestation and reforestation and forest management land.

Types of natural disturbances New Zealand intends to exclude from the accounting are:

- wildfires
- invertebrate and vertebrate pests and diseases
- extreme weather events
- geological disturbances.

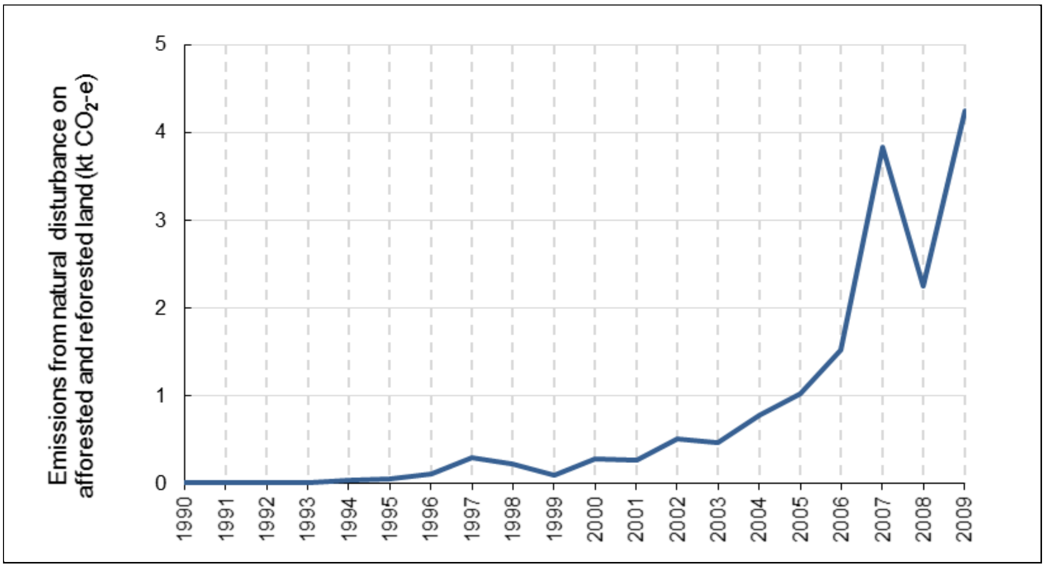
In all cases except fire, New Zealand assumes a zero baseline between 1990 and 2009.

While other natural disturbance events occurred throughout the calibration period, assumptions were made for the purposes of calculating the background level. For planted forests reported under afforestation and reforestation and forest management, salvage logging is considered to take place in all disturbed forests. In the case of natural forests, the ground plot measurement programme captures emissions from natural disturbances implicitly, and the emissions from natural disturbance events apart from wildfires cannot be separated from other disturbance events. The stock change estimates reported for natural forests include background levels of small scale natural disturbance events. Only direct oxidation of biomass in wildfires is considered for the purposes of calculating a background level of natural disturbance for both afforestation and reforestation and forest management lands, regardless of forest type.

Background level

New Zealand has chosen the minimum historic level approach for calculating its background level for natural disturbances for both afforestation and reforestation and forest management. Data from wildfire emissions reported under the Climate Change Convention for the period 1990–2009, as reported in section 6.11.4, were used to obtain the minimum historic level of natural disturbances for afforestation and reforestation and forest management. Figure 11.3.1 shows the emissions from natural disturbance during the calibration period for afforestation and reforestation land. For afforestation and reforestation, the minimum historic level was calculated on a per hectare basis in order to eliminate the confounding issue of increasing emissions because of area increases. The minimum was found to be 0.0000784 kt CO_2-e per hectare. This number is multiplied by the net stocked area of afforestation and reforestation land to give a background level of 0.0422 kt CO_2-e for 2013. In both cases, the margin is zero. The value for forest management was calculated as 21.85 kt CO_2-e (figure 11.3.2).

Figure 11.3.1 Emissions from natural disturbance during the calibration period for afforestation and reforestation land



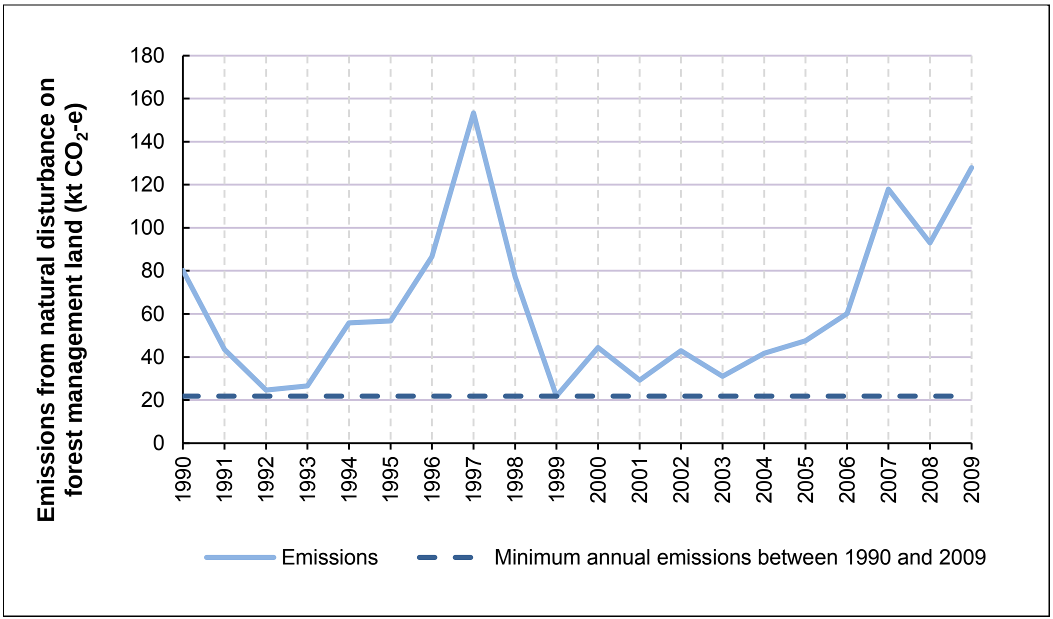
Avoiding the expectation of net credits or net debits for the application of the natural disturbance provision: afforestation and reforestation

The background level has been set at the minimum annual emissions value per hectare of the historical time series because:

- a trend is observed in natural disturbance emissions during the calibration period for afforestation and reforestation. Emissions from natural disturbances have been increasing throughout the calibration period as the age of these forests and, therefore, biomass increases through time. It is expected that this trend will continue during the second commitment period. The calibration period was used to obtain an annual emissions per hectare value and the minimum then used to calculate the background level for the 2013 year base on the area of afforestation and reforestation lands in 2013
- the background level of emissions for afforestation and reforestation in 2013 is calculated by applying the minimum annual emissions value per hectare during the calibration period to the area of afforestation and reforestation land in 2013
- as gross:net account applies to afforestation and reforestation activities, emissions from natural disturbances occurring during any year of the commitment period, which fall below the background level, are not excluded from the accounting. Emissions from natural disturbances that are greater than the background level in any year of the commitment period are able to be excluded from the accounting
- as the background level has been set at the minimum historical level, there is an expectation that emissions will exceed the background level every year during the commitment period. If emissions from natural disturbances are greater than the background level, they can be excluded from the accounting and there is no expectation of net debits arising. If emissions are less than the background level in any year of the commitment period, all emissions from natural disturbance will still be accounted for. There is no expectation of net debits in this scenario. Under

gross:net accounting for afforestation and reforestation activities, it would not be possible to expect net credits when applying this approach to the exclusion of emissions from natural disturbances from accounting.

Figure 11.3.2 Emissions from natural disturbance during the calibration period on forest management land



Avoiding the expectation of net credits or net debits for the application of the natural disturbance provision: forest management

The background level has been set at the minimum annual emissions value of the historical time series because:

- there is no observed trend in natural disturbance emissions during the calibration period for forest management and none can be expected during the second commitment period
- the background level of emissions for forest management, to be included in the FMRL via a technical correction, is equal to the minimum annual emissions value during the calibration period
- any emissions from natural disturbances during the commitment period that fall below the background level are not excluded from the accounting. During the commitment period, emissions from natural disturbances that are above the background level are, subject to New Zealand’s discretion, able to be excluded from the accounting
- as accounting for forest management is against the FMRL, the background level is included within the FMRL, and any emissions greater than the background level can be excluded from the accounting. When applying this approach, there is no expectation of net debits. In setting the background level to the minimum across the calibration period, emissions are expected to exceed this level every year. Therefore, there is no expectation that emissions will be less than the background level and, therefore, there is no expectation of net credits.

Justification when omitting any carbon pool or greenhouse gas emissions from activities under Article 3.3 and Article 3.4

New Zealand has accounted for all carbon pools for mandatory reporting activities under Article 3.3 and 3.4. New Zealand has not elected any of the voluntary activities under Article 3.4.

Direct N_2O emissions from the application of nitrogen fertiliser to land subject to afforestation and reforestation, and indirect N_2O emissions from managed soils are reported as IE (included elsewhere), as these emissions are reported in the Agriculture sector.

Factoring out information

New Zealand does not factor out from reporting either 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.

The dynamic effects of age structure resulting from activities prior to 1 January 1990 are factored out of accounting by the forest management reference level.

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 meet new guidance as set out in the *KP Supplement*, incorporate improved activity data, emission factors and to move to the global warming potentials from the Contribution of Working Group I to the Fourth Assessment Report of the IPCC (IPCC, 2007).

Activity data

The activity data used to estimate new planting and harvesting in planted forests is obtained from a national survey of forest owners (Ministry for Primary Industries, 2013). The survey respondents report areas as net stocked area rather than gross stocked area as reported in the Inventory. To account for these area differences, the net planted forest area has been identified and modelled separately in the Inventory. This ensures the new planting and harvesting data used in the Inventory is consistent with that reported by the Ministry for Primary Industries. The net stocked area and gross stocked area analysis has been updated for the 2013 submission.

Table 11.3.2 shows that, since the last submission, there has been an increase in the total area of afforestation. This is largely due to improvements made to the 2008 land-use map based on new planting information from the NZ ETS and other forestry schemes such as the Afforestation Grants Scheme.

Deforestation areas for 2012 have also increased due to the confirmation of some areas as deforested that were previously identified as destocked but 'awaiting a land-use determination'. The area of 2012 deforestation has also increased due to the identification of new areas of deforestation, adjacent to mapped deforestation, which were previously obscured by cloud in satellite imagery.

Table 11.3.2 Recalculations to New Zealand's 2012 activity data under Article 3.3 of the Kyoto Protocol

Activities under Article 3.3 of the Kyoto Protocol	Area as at 2012 (ha)		Change from 2014 submission (%)
	2014 submission	2015 submission	
Afforestation/reforestation	654,354	643,329	–1.7
Forest land not harvested since the beginning of the commitment period	653,686	654,576	0.1
Forest land harvested since the beginning of the commitment period	6,351	8,833	39.1
Deforestation	151,544	159,571	5.3
Activities occurring in 2012	**Area change in 2012 (ha)**		**Change from 2014 submission (%)**
New planting	12,539	13,637	8.8
Deforestation			
Pre-1990 natural forest	811	1,079	33.0
Pre-1990 planted forest	5,384	6,186	14.9
Post-1989 forest	567	683	20.5

Emission factors

Post-1989 and pre-1990 planted forest yield tables have been updated for the 2013 submission. The updates include reclassification of a small number of plots due to mapping improvements, amendments to align with a revised estimate of net stocked area in both forest classes, and the inclusion of a sub-set of previously unused plots in post-1989 planted forest. More information is provided in section 6.4.

The emission factor for pre-1990 natural forest has been revised following the acquisition of the most recent measurement data and improved analysis methodology. This is described in more detail in section 6.4.

Uncertainty and time-series consistency

The uncertainty in net emissions from afforestation and reforestation is 6.3 per cent. This is based on the uncertainty in emissions from post-1989 forest and a small contribution from harvested wood products (tables 11.3.3 and 11.3.4). The uncertainty in emissions from deforestation is determined by the type of *Forest land* (table 11.3.3). The combined uncertainty introduced into emissions from deforestation is 2.4 per cent (table 11.3.4).

The combined uncertainty in forest management is 9.5 per cent at a 95 per cent confidence interval. This is the combined uncertainty of pre-1990 natural and pre-1990 planted forest, and includes uncertainty associated with harvested wood products.

Further detail on the uncertainty in emissions for pre-1990 natural forest, pre-1990 planted forest, post-1989 forest and harvested wood products is provided in sections 6.4.3 and 6.10.3.

Table 11.3.3 **Uncertainty in New Zealand's estimates for afforestation/ reforestation, deforestation and forest management in 2013**

	Uncertainty (%) at a 95% confidence interval					
	Afforestation/ reforestation	Deforestation			Forest management	
	Post-1989 forest	Pre-1990 natural forest	Pre-1990 planted forest	Post-1989 forest	Pre-1990 natural forest	Pre-1990 planted forest
Activity data						
Uncertainty in land area	8.0	5.0	5.0	5.0	5.0	5.0
Emission factors						
Uncertainty in biomass carbon stocks	8.6	6.7	12.4	8.6	6.7	12.4
Uncertainty in soil carbon stocks	10.4	7.9	12.3	10.4	7.9	12.3
Uncertainty in harvested wood products	51.3	–	–	–	–	51.3
Uncertainty introduced into emissions for Kyoto Protocol	**6.3**	**0.3**	**2.4**	**0.2**	**10.7**	**41.0**

Note: All land that has been afforested or reforested since 1 January 1990 is defined as post-1989 forest. Land deforested since 1 January 1990 may be pre-1990 natural forest, pre-1990 planted forest or post-1989 forest.

Total uncertainty in New Zealand's estimates of emissions for Article 3.3. and 3.4 of the Kyoto Protocol is 42.9 per cent at a 95 per cent confidence interval.

Table 11.3.4 **Total uncertainty in New Zealand's estimates for afforestation/reforestation, deforestation and forest management in 2013**

Variable	Uncertainty (%) at a 95% confidence interval
Afforestation/reforestation uncertainty introduced into emissions for Kyoto Protocol	6.3
Deforestation uncertainty introduced into emissions for Kyoto Protocol	2.4
Forest management uncertainty introduced into emissions for Kyoto Protocol	9.5
Total uncertainty for Kyoto Protocol	**42.9**

Other methodological issues

Quality control and quality assurance procedures have been adopted for all data collection and data analyses, to be consistent with the IPCC guidelines *General Guidance and Reporting* (IPCC, 2006b) and New Zealand's inventory quality control and quality assurance plan. Data-quality and data-assurance plans were established for each type of data used to determine carbon stock and stock changes, as well as the areal extent and spatial location of land-use changes. All data was subject to an independent and documented quality-assurance process. Data validation rules and reports were established to ensure that all data is fit for purpose, is of consistent and known quality, and that data quality continues to be improved over time. The data used to derive the country-specific yield tables and average carbon values have also undergone quality assurance as described in section 6.4.4.

Year of the onset of an activity

Paragraph 18 of the annex to Decision 16/CMP.1 (Land Use, Land-Use Change and Forestry) requires Parties to account for emissions and removals from Article 3.3 activities beginning with the onset of the activity or the beginning of the commitment period, whichever is later. In practical terms, paragraph 18 means there is a need to differentiate activities that occurred between 1 January 1990 and 31 December 2007 from those after this period.

During 2013, an estimated 4,462 hectares of post-1989 forest were established and 8,453 hectares of forest (pre-1990 natural forest, pre-1990 planted forest and post-1989 forest) were deforested.

The afforestation area is estimated from the *National Exotic Forest Description* survey, which includes information from the Afforestation Grants Scheme and the East Coast Forestry Project (Ministry for Primary Industries, 2013). This information ensures that the activity is attributed to the correct year of onset.

The annual area of deforestation reported between 2008–2012 is based on deforestation mapping completed in 2013 and supported by earlier deforestation mapping activities. Deforestation was confirmed using oblique aerial photography, and the year of onset (destocking year) was determined using annual Landsat imagery. Therefore, the year of onset of the activity was clearly defined. As no further deforestation mapping was carried out in 2013, deforestation for that year has been estimated as described in section 6.2.3.

It can take up to four years following the loss of forest cover to determine that deforestation has occurred. This is because sometimes the landowner does not replant trees immediately but leaves the land fallow for a period of time. (The process for monitoring this unclassified deforestation is described in 11.4.3). When deforestation is finally confirmed, the deforestation is attributed to the year when forest cover was removed, regardless of whether that forest loss occurred in a previous commitment period.

11.4 Article 3.3

11.4.1 Demonstration that activities apply

The Climate Change Convention reporting guidelines require that countries provide information demonstrating that activities under Article 3.3 began on or after 31 December 1989 and before 31 December 2012. Furthermore, countries must demonstrate that these activities are directly human-induced.

All land in New Zealand is under some form of management and management plan. Land is managed for a variety of reasons, including agriculture and/or forestry production, conservation, biodiversity, fire risk management (eg, fire breaks) and scenic and cultural values. Most land-use changes occur in agriculture and forestry landscapes. All land-use changes, including deforestation, are therefore a result of human decisions to change the vegetation cover and/or change the way land is managed.

New Zealand has used satellite imagery collected around the start of 1990, 2008 and 2012 to detect changes in land use between these periods.

To estimate land-use change between 2008 and 2012, Land Use and Carbon Analysis System (LUCAS) mapping was augmented with data from the Afforestation Grants Scheme (Ministry of Agriculture and Forestry, 2009c), the NZ ETS (Ministry of Agriculture and Forestry, 2009a) and the *National Exotic Forest Description* (Ministry for Primary Industries, 2013). This was used to estimate the total area of afforestation and reforestation occurring during commitment period one because new planting is often not visible in satellite imagery for up to three years after planting. Deforestation occurring between 2008 and 2012 was mapped and estimated from satellite imagery (see section 6.2.2).

11.4.2 Distinction between harvesting and deforestation

The Climate Change Convention 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 definition of deforestation from Decision 16/CMP.1 as “the direct human-induced conversion of forested land to non-forested land”. Deforestation is different from harvesting, in that harvesting is part of usual forest management practice and involves the removal of biomass from a site followed by reforestation (replanting or natural regeneration, ie, no change in land use).

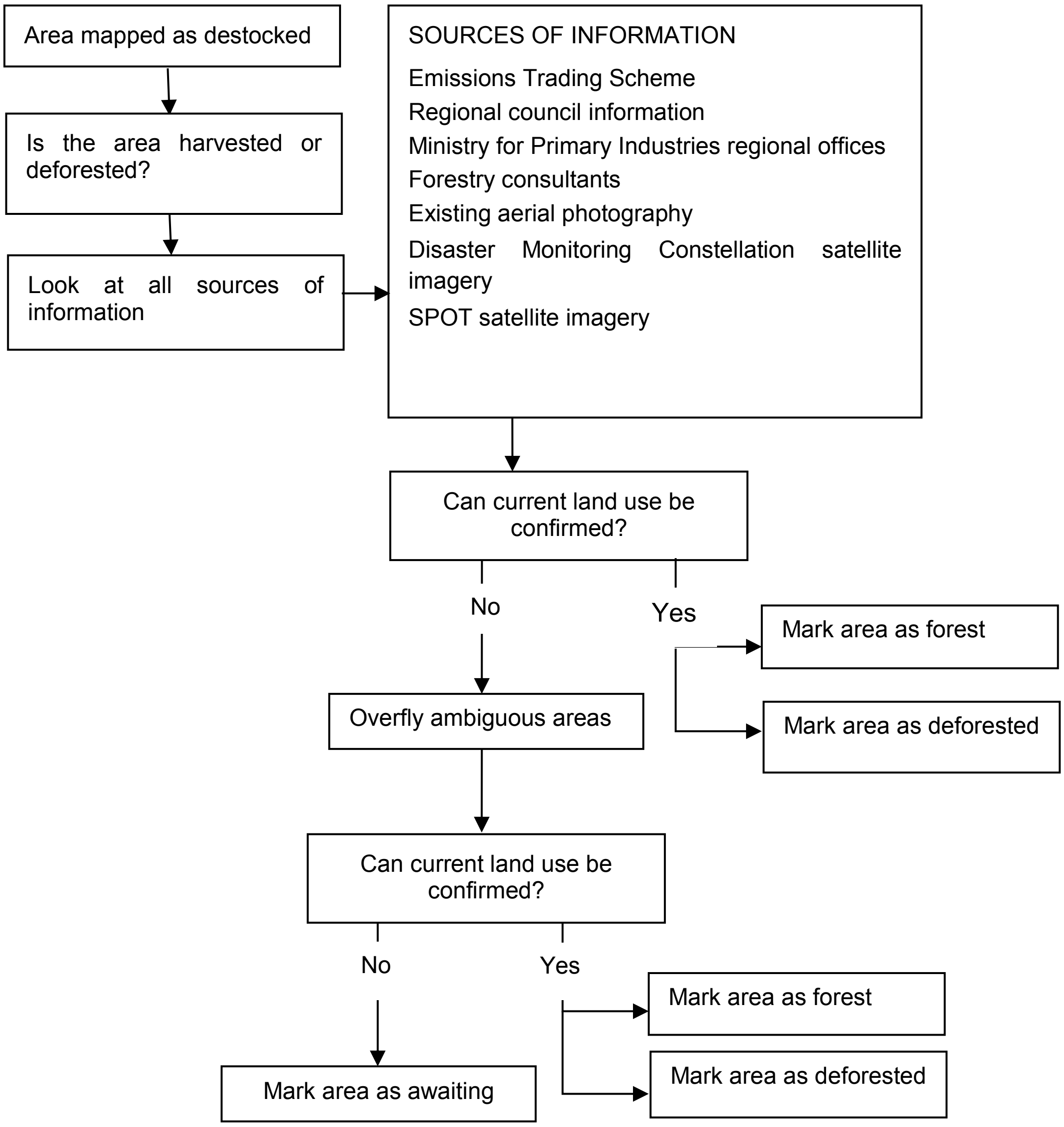
In New Zealand, temporarily unstocked or cleared areas of forest (eg, harvested areas and areas subject to disturbances) remain designated as forest land unless there is a confirmed change in land use or if, after four years, no reforestation (replanting or regeneration) has occurred. This follows the process for determining whether land is subject to direct human-induced deforestation set out in section 2.6.2.1 of the *KP Supplement* (IPCC, 2014a). 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 have been carried out to determine if land-use change has occurred, including the analysis of satellite imagery and oblique aerial photography. The use of oblique aerial photography is described in section 6.2.

Evidence from the NZ ETS is also used to confirm deforestation. Under the NZ ETS, owners of pre-1990 planted forest and owners of post-1989 forest who are participants in the scheme are required to notify the Government of any deforestation activity (Ministry of Agriculture and Forestry, 2009a). There is a data-sharing agreement that allows for the Ministry for Primary Industries, the agency that administers the forestry aspects of the NZ ETS, to provide the Ministry for the Environment with regular updates of the area of confirmed deforestation.

A summary of the decision-making process for determining whether deforestation has occurred, including all sources of information, is shown in figure 11.4.1. Once a land-use change is mapped and confirmed, the deforestation emissions will be reported in the year of forest clearance.

Figure 11.4.1 Verification of deforestation in New Zealand



11.4.3 Unclassified deforestation

The Climate Change Convention reporting guidelines require that countries provide information on the size and geographical location of forest areas that have lost forest cover but that are not yet classified as deforested.

To identify these areas, the deforestation mapping methodology was modified in 2010 to allow destocked land to be mapped into three main classes: harvested, deforested and awaiting. The awaiting areas are those areas where there is no clear evidence to support harvesting (replanting activity, forestry context) or deforestation (confirmed land-use change, such as pasture establishment, fences and stock). The areas are therefore awaiting a land-use determination.

Wall-to-wall mapping of harvested, deforested and awaiting areas was completed for 2008 to 2012. Because of New Zealand's four-year rule, there is now no awaiting land that was destocked in 2008 or 2009. Any areas destocked in these years that show no evidence of replanting have been classed as deforested.

Areas destocked after 2009, which have been classed as awaiting land, are still considered to be forested land until either evidence of land-use change is identified or four years have passed since destocking (whichever comes first). This is consistent with section 4.2.6.2.1 of GPG-LULUCF (IPCC, 2003, p 4.58) which states that:

> *In the absence of land-use change or infrastructure development, and until the time for regeneration has elapsed, these units of land remain classified as forest. Note that this is consistent with the approach suggested for afforestation and reforestation, i.e., units of land that have not been confirmed as afforested/reforested remain classified as non-forest land.*

Estimates of the total areas of awaiting land for 2010 to 2012 are shown in table 11.4.1.

Table 11.4.1 Estimate of land destocked in New Zealand between 2010 and 2012 awaiting a land-use determination

Pre-1990 natural forest (ha)	Pre-1990 planted forest (ha)	Post-1989 forest (ha)	Total (ha)
3,539	14,516	2,372	20,428

No estimate of awaiting land for 2013 has been made because land-use mapping has not been undertaken for this calendar year yet. The deforestation area reported for 2013 is based on survey estimates as described in section 6.2.3.

11.5 Article 3.4

11.5.1 Forest management

Forest management

From 2013, New Zealand is required to report on emissions and removals on forest management land. These are accounted for against a business-as-usual projection of the FMRL, as inscribed in the appendix to the annex to Decision 2/CMP.7. This value is 11.150 Mt CO_2-e averaged over the eight years of the second commitment period.

In 2013, New Zealand's net emissions for forest management were –9,029.9 kt CO_2-e.

Forest management reference level

New Zealand's FMRL, as inscribed in the appendix to the annex to Decision 2/CMP.7, is 11.15 Mt CO_2-e. In the conclusions of the technical assessment report of the FMRL (UNFCCC Secretariat, 2011, pp 9–10), the expert review team:

> *Noted that New Zealand has indicated that a technical correction for the "flexible land use rule" components of the FMRL would be made if these rules are not agreed as part of the LULUCF modalities being negotiated for a second commitment period of the Kyoto Protocol.*
>
> *Noted New Zealand's FMRL does not disaggregate gains and losses for biomass, unlike in its GHG [greenhouse gas] inventory submissions. It notes New Zealand's explanation that the FOLPI [Forestry Oriented Linear Programming Interpreter] model is not able to provide this data. The ERT [Expert Review Team] considers that this is a weakness in the FMRL and encourages New Zealand to make efforts to disaggregate gains and losses.*
>
> *Recommends that New Zealand provides further information on how forest owners will be able to move from historic/current harvesting practice to the longer rotation length projected in the FOLPI model.*
>
> *Encourages New Zealand to compare the results provided in its submission with a rerun of the FOLPI model in which the harvesting of overmature forests (over 32 years of age) is constrained, and to modify its reference level accordingly if necessary.*

> *Recommends that, in case New Zealand will provide estimates for natural forests in future GHG inventory submissions, it proposes a technical adjustment of the FMRL.*
>
> *Notes that New Zealand has indicated that a technical correction for the HWP [harvested wood products] components of the FMRL would be made if these rules are agreed as part of the LULUCF modalities being negotiated for a second commitment period of the Kyoto Protocol.*

New Zealand has not been able to implement these recommendations in time for submission of this report but intends to technically correct the FMRL in the future to align the FMRL with the data used for reporting against it. This will involve corrections to:

- correct for the uptake of carbon equivalent forests (called 'flexible land-use rule' in the above conclusions)
- include removals of natural forest
- incorporate the new reporting requirements for harvested wood products
- provide more disaggregated data for the projection
- other method changes as necessary that fit within the guidance provided in the annex to Decision 2/CMP.7.

11.5.2 Voluntary activities under Article 3.4

New Zealand has not elected to report on any voluntary activities under Article 3.4 of the Kyoto Protocol.

11.6 Other information

11.6.1 Key category analysis for Article 3.3 and 3.4 activities (CRF NIR-3)

Land converted to forest land (afforestation and reforestation), *Land converted to grassland* (deforestation), and *Forest land remaining forest land* (forest management) are all key categories.

11.7 Information relating to Article 6

New Zealand is not involved in any LULUCF activities under Article 6 of the Kyoto Protocol.

Chapter 11: References

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Chapter 12: Information on accounting of the Kyoto Protocol units

12.1 Background information

Assigned amount and commitment period reserve

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

The commitment period reserve of 278,608,260 metric tonnes CO_2-e is 90 per cent of the assigned amount, fixed after the initial review in 2007.

Holdings and transactions of Kyoto Protocol units

Please refer to the standard reporting format tables below (table 12.2.2). These tables are also provided in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (www.mfe.govt.nz/publications/climate).

General note

Abbreviations used in this chapter include:

AAUs	Assigned amount units
ERUs	Emission reduction units
RMUs	Removal units
CERs	Certified emission reduction units
tCERS	Temporary certified emission reduction units
lCERs	Long-term certified emission reduction units
NZEUR	New Zealand Emission Unit Register
NO	Not occurring
PPSR	Previous Period Surplus Reserve

(for *table 2b Annual external transactions* in tables 12.2.2, 12.2.3 and 12.2.4 in the column 'Transfers and acquisitions')

AU	Australia
CH	Switzerland
EU	European Economic Community
GB	United Kingdom of Great Britain and Northern Ireland
JP	Japan
NL	Netherlands

12.2 Summary of the standard electronic format tables for reporting Kyoto Protocol units

At the beginning of the calendar year 2014, New Zealand's national registry held 305,777,516 first commitment period (CP1) assigned amount units, 79,861,097 CP1 emissions reduction units, 10,864,195 CP1 certified emission reduction units and 9,050,000 CP1 removal units (table 1 in table 12.2.2). No second commitment period (CP2) units were held by New Zealand during the 2013 and 2014 years (tables 1 to 6 in tables 12.2.3 and 12.2.4)

At the end of 2014, there were 305,777,516 assigned amount units, 100,858,523 emission reduction units, 18,122,229 certified emission reduction units and 9,050,000 removal units held in the New Zealand registry (table 4 in table 12.2.2).

New Zealand's national registry did not hold any temporary certified emission reduction units or long-term certified emissions reduction units during 2014 (table 4 in table 12.2.2).

The transactions made to New Zealand's national registry during 2014 (tables 2 (a), (b), (c) in table 12.2.2) are summarised below.

- No assigned amount units were added to New Zealand's national registry; 8,358 assigned amount units were subtracted from the registry via voluntary cancellation. There were no conversions to ERUs or external subtractions. No CP2 assigned amount units were held by New Zealand during the 2014 year.
- There were 23,447,465 emission reduction units added to New Zealand's national registry and 2,450,039 were subtracted. No units were added due to New Zealand-verified projects under Article 6 of the Kyoto Protocol. The largest external addition of emission reduction units was 14,510,127 units from Switzerland. Four registries were the recipients of external subtractions of emission reduction units, with the largest being 2,200,002 to Switzerland. There were no internal subtractions. No CP2 emission reduction units were held by New Zealand during the 2014 year.
- There were 13,984,503 certified emission reduction units added to New Zealand's national registry and 6,740,687 were subtracted. The greatest addition was 6,146,249 certified emission reduction units from the European Economic Community. There were four external subtractions of certified emission reduction units, with the largest being 6,087,469 to the European Economic Community. There were 14,218 units subtracted internally through voluntary cancellation. No CP2 certified emission reduction units were held by New Zealand during the 2014 year.
- No removal units were added to New Zealand's national registry. No removal units were subtracted from the New Zealand registry. No CP2 removal units were held by New Zealand during the 2014 year.
- There were no transactions of temporary certified emission reduction units or long-term certified emissions reduction units. No CP2 temporary certified emission reduction units or long-term certified emissions reduction units were held by New Zealand during the 2014 year.

During 2014, no Kyoto Protocol units were expired, replaced or cancelled.

Table 12.2.1 New Zealand's submission of the standard electronic format

Annual submission item	New Zealand's national registry response
15/CMP.1, annex I.E, paragraph 11: Standard electronic format (SEF)	The SEF reports for 2014 first commitment period units, and the 2013 and 2014 SEF reports for second commitment period units, have been submitted to the United Nations Framework Convention on Climate Change Secretariat electronically and are included in this section (2014 CP1 SEF – table 12.2.2; 2013 CP2 SEF table 12.2.3; 2014 CP2 SEF table 12.2.4).

Table 12.2.2 Copies of the 2014 first commitment period standard report format tables (ie, tables 1–6) from New Zealand's national registry

Party	NZ
Submission Year	2015
Reported Year	2014
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	302,802,271	45,535,954	8,012,771	7,601,797	NO	NO
Entity holding accounts	2,948,595	34,325,143	1,037,229	3,238,427	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Other cancellation accounts	26,650	NO	NO	23,971	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	305,777,516	79,861,097	9,050,000	10,864,195	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	1

Table 2a. Annual internal transactions												
	Additions						Subtractions					
Transaction type	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Art6 issuance and conversion												
Party verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Art3.3 and 3.4 issuance or cancellation												
3.3 Afforestation 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		
Art 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							8,358	NO	NO	14,218	NO	NO
Subtotal		NO	NO				8,358	NO	NO	14,218	NO	NO

Transaction type	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	1

Table 2b. Annual external transactions												
	Additions						Subtractions					
Transfers and acquisitions	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
AU	NO	NO	NO	30,000	NO	NO	NO	100,000	NO	354,203	NO	NO
CH	NO	14,510,127	NO	1,211,912	NO	NO	NO	2,200,002	NO	250,817	NO	NO
EU	NO	2,165,402	NO	6,146,249	NO	NO	NO	37	NO	6,087,428	NO	NO
GB	NO	6,117,509	NO	2,556,740	NO	NO	NO	NO	NO	34,021	NO	NO
JP	NO	244,485	NO	4,039,602	NO	NO	NO	150,000	NO	NO	NO	NO
NL	NO	409,942	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Subtotal	NO	23,447,465	NO	13,984,503	NO	NO	NO	2,450,039	NO	6,726,469	NO	NO

Additional Information												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Independently verified ERU								NO				

Table 2c. Total annual transactions												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Total (Sum of table 2(a) and 2(b))	NO	23,447,465	NO	13,984,503	NO	NO	8,358	2,450,039	NO	6,740,687	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	1

Table 3. Expiry, cancellation and replacement

	Expiry, cancellation and requirement to replace		Replacement					
Transaction or event 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	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
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	302,803,330	77,390,474	8,671,868	9,656,714	NO	NO
Entity holding accounts	2,939,178	23,468,049	378,132	8,427,326	NO	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Other cancellation accounts	35,008	NO	NO	38,189	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	305,777,516	100,858,523	9,050,000	18,122,229	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	1

Table 5 a. Summary information on additions and subtractions	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Starting Values												
Issuance pursuant to Article 3.7 and 3.8	309,564,733											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Subtotal	309,564,733	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	120,000	NO	25,108	NO	NO	120,000	NO	NO	15,800	NO	NO
Year 2 (2009)	1,000	496,567	NO	401,000	NO	NO	1,068,018	568,469	NO	401,000	NO	NO
Year 3 (2010)	1	419,880	NO	621,002	NO	NO	1,120,979	447,650	NO	100,090	NO	NO
Year 4 (2011)	18,530	1,731,931	3,900,000	4,396,232	NO	NO	1,037,988	1,221,913	NO	1,991,598	NO	NO
Year 5 (2012)	1	16,760,023	5,150,000	13,638,382	NO	NO	213,621	1,136,835	NO	7,893,637	NO	NO
Year 6 (2013)	NO	86,407,353	NO	6,506,641	NO	NO	272,793	22,699,790	NO	4,346,016	NO	NO
Year 7 (2014)	NO	23,447,465	NO	13,984,503	NO	NO	8,358	2,450,039	NO	6,740,687	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Subtotal	19,532	129,383,219	9,050,000	39,572,868	NO	NO	3,841,757	28,524,696	NO	21,488,828	NO	NO
Total	309,584,265	129,383,219	9,050,000	39,572,868	NO	NO	3,841,757	28,524,696	NO	21,488,828	NO	NO

Table 5 b. Summary information on replacement	Expiry, cancellation and requirement to replace		Replacement					
	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						
Year	Retirement					
	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	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	1

Table 6 a. Memo item: corrective transactions relating to additions and subtractions											
Additions						Subtractions					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 b. Memo item: corrective transactions relating to replacement							
Expiry, cancellation and requirement to replace		Replacement					
tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 c. Memo item: corrective transactions relating to retirement					
Retirement					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 12.2.3 Copies of the 2013 second commitment period standard report format tables (ie, tables 1–6) from New Zealand's national registry

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

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	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	NO	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						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	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

Table 2a. Annual internal transactions

Transaction type	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Art6 issuance and conversion												
Party verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Art3.3 and 3.4 issuance or cancellation												
3.3 Afforestation 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		
3.4 Wetland drainage and rewetting			NO				NO	NO	NO	NO		
Art 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
Cancellation for reversal of storage												NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Cancellation for non submission of certification report												NO
Other cancelation												
Voluntary cancellation							NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation							NO					
Subtotal		NO	NO				NO	NO	NO	NO	NO	NO

Transaction type	Retirement					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO
Retirement from PPSR	NO					
Total	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

Table 2b. Annual external transactions												
	Additions						Subtractions					
Total transfers and acquisitions	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Subtotal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 2 (c). Annual transactions between PPSR accounts												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Subtotal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 2 (d). Share of proceeds transactions under decision 1/CMP.8, paragraph 21 - Adaptation Fund												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
First international transfers of AAUs	NO						NO					
Issuance of ERU from Party-verified projects		NO						NO				
Issuance of independently verified ERUs		NO						NO				

Table 2 (e). Total annual transactions												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Total (Sum of sub-totals in table 2a and table 2b)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

Table 3. Expiry, cancellation and replacement

Transaction or event type	Requirement to replace or cancel			Replacement						Cancellation					
Transaction or event type	**tCERs**	**lCERs**	**CERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Temporary CERs															
Expired in retirement and replacement accounts	NO			NO	NO	NO	NO	NO							
Expired in holding accounts	NO													NO	
Long-term CERs															
Expired in retirement and replacement accounts		NO		NO	NO	NO	NO								
Expired in holding accounts		NO													NO
Subject to reversal of Storage		NO		NO	NO	NO	NO		NO						NO
Subject to non submission of certification Report		NO		NO	NO	NO	NO		NO						NO
Carbon Capture and Storage CERs															
Subject to net reversal of storage			NO							NO	NO	NO	NO		
Subject to non submission of certification report			NO							NO	NO	NO	NO		
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

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	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	NO	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						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	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

Table 5 a. Summary information on additions and subtractions

	Additions						Subtractions					
	AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Assigned amount units issued	NO											
Article 3 Paragraph 7 ter cancellations							NO					
Cancellation following increase in ambition							NO					
Cancellation of remaining units after carry over							NO	NO	NO	NO	NO	NO
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over		NO		NO				NO		NO		
Carry-over to PPSR	NO						NO					
Total	NO	NO		NO			NO	NO	NO	NO	NO	NO

Table 5 (b). Summary information on annual transactions

	Additions						Subtractions					
	AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

Table 5 (c). Summary information on annual transactions between PPSR accounts

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO						NO					
Year 2 (2014)	NO						NO					
Year 3 (2015)	NO						NO					
Year 4 (2016)	NO						NO					
Year 5 (2017)	NO						NO					
Year 6 (2018)	NO						NO					
Year 7 (2019)	NO						NO					
Year 8 (2020)	NO						NO					
2021	NO						NO					
2022	NO						NO					
2023	NO						NO					
Total	NO						NO					

Table 5 (d). Summary information on expiry, cancellation and replacement

	Requirement to replace or cancel			Replacement						Cancellation					
	tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

Table 5 (e). Summary information on retirement						
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO
2021	NO	NO	NO	NO	NO	NO
2022	NO	NO	NO	NO	NO	NO
2023	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2013
Commitment Period	2

Table 6 a. Memo item: corrective transactions relating to additions and subtractions

Additions						Subtractions					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 b. Memo item: corrective transactions relating to replacement

Expiry, cancellation and requirement to replace		Replacement					
tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 c. Memo item: corrective transactions relating to retirement

Retirement					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 12.2.4 Copies of the 2014 second commitment period standard report format tables (ie, tables 1–6) from New Zealand's national registry

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

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	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	NO	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						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	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 2a. Annual internal transactions												
Transaction type	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Art6 issuance and conversion												
Party verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Art3.3 and 3.4 issuance or cancellation												
3.3 Afforestation 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		
3.4 Wetland drainage and rewetting			NO				NO	NO	NO	NO		
Art 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
Cancellation for reversal of storage												NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Cancellation for non submission of certification report												NO
Other cancelation												
Voluntary cancellation							NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation							NO					
Subtotal		NO	NO				NO	NO	NO	NO	NO	NO

Transaction type	Retirement					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO
Retirement from PPSR	NO					
Total	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 2b. Annual external transactions												
	Additions						Subtractions					
Total transfers and acquisitions	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Subtotal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 2 (c). Annual transactions between PPSR accounts												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Subtotal	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 2 (d). Share of proceeds transactions under decision 1/CMP.8, paragraph 21 - Adaptation Fund												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
First international transfers of AAUs	NO						NO					
Issuance of ERU from Party-verified projects		NO						NO				
Issuance of independently verified ERUs		NO						NO				

Table 2 (e). Total annual transactions												
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Total (Sum of sub-totals in table 2a and table 2b)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 3. Expiry, cancellation and replacement

Transaction or event type	Requirement to replace or cancel			Replacement						Cancellation					
Transaction or event type	**tCERs**	**lCERs**	**CERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Temporary CERs															
Expired in retirement and replacement accounts	NO			NO	NO	NO	NO	NO							
Expired in holding accounts	NO													NO	
Long-term CERs															
Expired in retirement and replacement accounts		NO		NO	NO	NO	NO								
Expired in holding accounts		NO													NO
Subject to reversal of Storage		NO		NO	NO	NO	NO		NO						NO
Subject to non submission of certification Report		NO		NO	NO	NO	NO		NO						NO
Carbon Capture and Storage CERs															
Subject to net reversal of storage			NO							NO	NO	NO	NO		
Subject to non submission of certification report			NO							NO	NO	NO	NO		
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

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	NO	NO	NO	NO	NO	NO
Entity holding accounts	NO	NO	NO	NO	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	NO	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						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	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 5 a. Summary information on additions and subtractions

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Assigned amount units issued	NO											
Article 3 Paragraph 7 ter cancellations							NO					
Cancellation following increase in ambition							NO					
Cancellation of remaining units after carry over							NO	NO	NO	NO	NO	NO
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over		NO		NO				NO		NO		
Carry-over to PPSR	NO						NO					
Total	NO	NO		NO			NO	NO	NO	NO	NO	NO

Table 5 (b). Summary information on annual transactions

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 5 (c). Summary information on annual transactions between PPSR accounts

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO						NO					
Year 2 (2014)	NO						NO					
Year 3 (2015)	NO						NO					
Year 4 (2016)	NO						NO					
Year 5 (2017)	NO						NO					
Year 6 (2018)	NO						NO					
Year 7 (2019)	NO						NO					
Year 8 (2020)	NO						NO					
2021	NO						NO					
2022	NO						NO					
2023	NO						NO					
Total	NO						NO					

Table 5 (d). Summary information on expiry, cancellation and replacement

	Requirement to replace or cancel			Replacement						Cancellation					
	tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 5 (e). Summary information on retirement						
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO
2021	NO	NO	NO	NO	NO	NO
2022	NO	NO	NO	NO	NO	NO
2023	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO

Party	NZ
Submission Year	2015
Reported Year	2014
Commitment Period	2

Table 6 a. Memo item: corrective transactions relating to additions and subtractions

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 b. Memo item: corrective transactions relating to replacement

	Expiry, cancellation and requirement to replace		Replacement					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6 c. Memo item: corrective transactions relating to retirement

	Retirement					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

12.3 Discrepancies and notifications

New Zealand has not received any notification of discrepancies, failures or invalid units as shown in table 12.3.1.

Table 12.3.1 Discrepancies and notifications from New Zealand's national registry

Annual submission item	New Zealand's national registry response
15/CMP.1 annex I.E, paragraph 12: List of discrepant transactions	No discrepant transactions occurred in 2013 or 2014. For completeness, the RREG-2 reports for 2013 and 2014 (for both CP1 and CP2 units) are included with 'Nil' discrepant transactions during the reporting period.
15/CMP.1 annex I.E, paragraph 13 & 14: List of CDM notifications	No Clean Development Mechanism (CDM) notifications occurred in 2013 or 2014. For completeness, the RREG-2 reports for 2013 and 2014 (for both CP1 and CP2 units) are included with 'Nil' CDM notifications for reversal of storage or non-certification received during the reporting period.
15/CMP.1 annex I.E, paragraph 1 15: List of non-replacements	No non-replacements occurred in 2013 or 2014. For completeness, the RREG-4 reports for 2013 and 2014 (for both CP1 and CP2 units) are 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 2014. For completeness, RREG-5 reports for 2013 and 2014 (for both CP1 and CP2 units) are included with 'Nil' invalid units notification received during the reporting period.
15/CMP.1 annex I.E, paragraph 1 17: Actions and changes to address discrepancies	**No actions were taken or changes made to address discrepancies for the period under review.**

12.4 Publicly accessible information

New Zealand's national registry list of publicly accessible information is available at www.eur.govt.nz, 'Search the Register' tab. A list of publicly accessible information is provided in table 12.4.1.

Table 12.4.1 List of the publicly accessible information in New Zealand's national registry

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz/ search-the-register) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
44. Each national registry shall make non-confidential information publicly available and provide a publicly accessible user interface through the Internet that allows interested persons to query and view it.			
45. The information referred to in paragraph 44 above shall include up-to-date information for each account number in that registry on the following:			
(a) Account name: the holder of the account.	Yes (refer Search the Register: Accounts).	Up to date (real-time).	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz/ search-the-register) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(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 and has been withheld for security reasons.	n/a	Section 27(1)(a) of the Climate Change Response Act 2002 does not require this information to be made publicly available. Only the holding account number for each account in the registry is publicly available under this section.
(e) Representative name and contact information: the full name, mailing address, telephone number, facsimile number and email address of the representative of the account holder.	Partial – publication of the personal email addresses, telephone numbers of the representatives has been withheld for security reasons. (Refer Search the Register: Accounts: Click on Account Number hyperlink to access Account Information Report: Representative Details.)	Up to date (real-time).	Section 13 of the Climate Change Response Act 2002 permits the Registrar to withhold access to the email address and phone and fax numbers of account holder's representatives on the grounds of security or integrity of the registry.
46. The information referred to in paragraph 44 shall include the following Article 6 project information, for each project identifier against which the Party has issued ERUs:			
(a) Project name: a unique name for the project.	Yes (refer Search the Register: Joint Implementation (JI) Projects).	Up to date (real-time).	n/a
(b) Project location: the Party and town or region in which the project is located.	Yes (Refer Search the Register: Joint Implementation (JI) Projects).	Up to date (real-time).	n/a
(c) Years of ERU issuance: the years when ERUs have been issued as a result of the Article 6 project.	Yes (This information can be accessed either by clicking on the project ID under the Unit Issuance tab or through the Ministers' Directions menu item. This lists directions relating to the transfer of emission reduction units to individual Joint Implementation (JI) Projects. The NZEUR Unit Holding and Transaction Summary Report shows in aggregate the total ERUs converted from AAUs by year.)	JI projects annually by 31 January for the previous calendar year. Ministers' directions – up to date (real-time).	n/a
(d) Reports: downloadable electronic versions of all publicly available	Partial – this information is published on the Ministry for the Environment's website for	This information becomes publicly available once New	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz/ search-the-register) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
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.	Joint Implementation Projects at www.mfe.govt.nz/issues/climate/policies-initiatives/joint-implementation/notice.html and is not replicated on the New Zealand's national registry website (www.eur.govt.nz). The following information for each JI project is published on the Ministry for the Environment website: • project description • non-host party project approval • annual reports • verification reports. Project proposals are not included as they contain financial information that is considered to be commercially sensitive and confidential.	Zealand gives its approval to the JI project. The information is then updated when necessary and annual reports are added annually.	
47. The information referred to in paragraph 44 shall include the following holding and transaction information relevant to the national registry, by serial number, for each calendar year (defined according to Greenwich Mean Time):			
(a) The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year.	Partial – aggregate unit holdings of ERUs, CERs, AAUs and RMUs for the previous calendar year are disclosed by 31 January of each year (refer Search the Register: NZEUR Holding & Transaction Summary). Total quantity of unit holdings in each account within the most recent calendar year is considered to be confidential information, therefore, the total quantity of unit holdings in each account provided are only those completed more than one year in the past. (refer Search the Register: NZEUR Kyoto Unit Holdings by Account: Use Search Criteria to find information pertaining to more than one year in the past).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year. 1 January for the beginning of the previous calendar year.	Section 27(2) of the Climate Change Response Act 2002 only requires total holdings of AAUs, ERUs, CERs, ICERs, tCERs and RMUs to be publicly available by 31 January of each year for the previous calendar year). Section 27(3) of the Climate Change Response Act 2002 only requires holdings of Kyoto units by each holding account for the beginning of the previous calendar year to be made publicly available.
(b) The total quantity of AAUs issued on the basis of the assigned amount pursuant to Article 3, paragraphs 7 and 8.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz/ search-the-register) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
(c) The total quantity of ERUs issued on the basis of Article 6 projects.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary – Units Converted to).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	n/a
(d) The total quantity of ERUs, CERs, AAUs and RMUs acquired from other registries and the identity of the transferring accounts and registries.	Partial – the total quantity of ERUs, CERs, AAUs and RMUs acquired from other registries, and the identity of the registries is publicly available by 31 January for the previous calendar year (refer Search the Register: NZEUR Incoming Transactions for the Year). The identity of the individual transferring accounts is not available as it is considered to be confidential information.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	n/a Section 27(j) of the Climate Change Response Act 2002 requires that only the following be made publicly available: • total quantity of units transferred; and • total quantity and type of unit transferred; and • the identity of the transferring overseas registries including the total quantity of units transferred from each overseas registry and each type of unit transferred from each overseas registry.
(e) The total quantity of RMUs issued on the basis of each activity under Article 3, paragraphs 3 and 4.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary). NOTE: Reported as "0" as this event did not occur in the specified period.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	n/a
(f) The total quantity of ERUs, CERs, AAUs and RMUs transferred to other registries and the identity of the acquiring accounts and registries.	Partial – the total quantity of ERUs, CERs, AAUs and RMUs transferred to other registries, and the identity of the registries is publicly available by 31 January for the previous calendar year. The identity of the individual acquiring accounts is not available as it is considered to be confidential information.	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year.	n/a Section 27(k) of the Climate Change Response Act 2002 requires that only the following be publicly available: • total quantity of units transferred; and • total quantity and type of unit transferred; and • the identity of the acquiring overseas registries including the total quantity of units transferred to each overseas registry and each type of unit transferred to each overseas registry.
(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	Yes (refer Search the Register:	Annually by 31 January	n/a

Type of information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48	Publicly available on New Zealand's national registry website (refer www.eur.govt.nz/ search-the-register) (yes/no/partial)	Timing of information to be made available under New Zealand's Climate Change Response Act 2002	Relevant reference to New Zealand's Climate Change Response Act 2002 where information is not publicly available in accordance with paragraphs 44 to 48
ERUs, 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.	NZEUR Holding & Transaction Summary). NOTE: Reported as '0' as this event did not occur in the specified period.	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.	
(i) The total quantity of other ERUs, CERs, AAUs and RMUs cancelled.	Yes (refer Search the Register: NZEUR Holding & Transaction Summary).	Annually by 31 January for the previous calendar year. The Registry makes this information available on 1 January of each year, if the event occurred during the reporting period.	n/a
(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 are only those completed more than one year in the past. (refer Search the Register: NZEUR Kyoto Unit Holdings by Account: Use Search Criteria to find information pertaining to more than one year in the past.)	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.
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 for the first commitment period, 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* (Ministry for the Environment, 2006).

The commitment period reserve level as at 31 December 2014 is:

Commitment period reserve limit:	*278,608,260*
Units held:	*433,808,268*
Commitment period reserve level:	*433,808,268*
Commitment period reserve level = (% of assigned amount):	*140.13%%*

Commitment Period Reserve level comprises of the following units:	
AAUs	*305,777,516*
ERUs (converted from AAUs)	*100,858,523*
CERs	*18,122,229*
RMUs	*9,050,000*
Total units	***433,808,268***

New Zealand's commitment period reserve level is also available at: www.eur.govt.nz, and is updated on a daily basis.

Chapter 12: References

Ministry for the Environment. 2006. *New Zealand's Initial Report under the* Kyoto *Protocol. Wellington: Ministry for the Environment*. Retrieved from www.mfe.govt.nz/publications/climate/new-zealands-initial-report-under-the-kyoto-protocol/index.html (14 July 2011).

Chapter 13: Information on changes to the National Inventory System

13.1 Governance

New Zealand uses a hybrid approach to the Inventory programme management. Management and coordination of the Inventory programme as well as compilation, publication and submission of the Inventory are carried out by the Ministry for the Environment in a centralised manner. Sector-specific work, which includes obtaining and processing activity data, estimating emissions, preparing sectoral common reporting format (CRF) tables and writing sectoral Inventory chapters, is carried out by the designated agencies across New Zealand's Natural Resource Sector. The Reporting Governance Group (RGG) includes representatives from all government agencies involved in the production of major climate change reports, including the Inventory, projections and modelling. The RGG is responsible for approving all changes, improvements and major recalculations in the Inventory.

In 2014, the Terms of Reference for the RGG were reviewed to reflect improved clarity for modelling and projections, updated membership and to specify engagement with wider climate change governance across government agencies.

New Zealand's interagency Inventory team follows New Zealand's National Inventory System Guidelines (NIS Guidelines) for compiling New Zealand's Greenhouse Gas Inventory. This document is updated on a yearly basis. The document is peer-reviewed by third parties, and all major changes in the document are approved by the RGG. The document was updated in 2014 to include updated maps for the sectoral quality control processes and procedures, a revised Inventory delivery plan and changes in its CRF section to accommodate the changes due to the introduction of the web-based UNFCCC reporting software.

No changes have been made in the legal or institutional arrangements in the National Inventory System since the last (2014) Inventory submission.

Although there were no major changes in the structure of the National Inventory System, operational improvements designed to facilitate better quality of New Zealand's Inventory reports have occurred during the year. The following sections present an update on further steps in improving quality assurance, automatisation in New Zealand's Inventory system and processes, and in developing Inventory expertise.

13.2 Quality assurance

New Zealand continued to strengthen a process-based approach to the quality assurance and quality control (QA/QC) system for the Inventory governance, production and delivery during 2014, as outlined below:

- Renewing bilateral Inventory collaboration with Australia's National Inventory Report (NIR) team, followed by bilateral meetings with the NIR teams of Germany and Austria for discussions and mutual reviews of key Inventory sections and National Inventory Systems in light of moving to the IPCC 2006 guidelines.
- Revising New Zealand's QC procedures for each individual sector and mapping QC processes and procedures at the sectoral level. The revised process maps were included in the NIS Guidelines.

- Moving to more flexible and robust automated methods of control, especially where large quantities of data are to be moved between different source documents. For example, a more flexible and easy-to-use MS Excel tool for automated key category analysis (KCA) replaced a previously used tool. This new tool allows selecting the level of category for inclusion in the analysis from all categories and was used in conjunction with the KCA function in the CRF Reporter to verify New Zealand's key category lists.
- Further improvements were made in the visual basic application (VBA) model to assist with the processing of significant portions of Agriculture sector data.
- Identifying gaps in New Zealand's QC processes, discussing ways to improve them with the Sector Leads and incorporating the new QC steps in check sheets for the 2015 Inventory submission.
- Emphasising the importance of the QC procedures and training new Inventory team members in the application of correct procedures.

All sector leads are encouraged to schedule QA audits of their systems at least every five years. The Agriculture sector commenced a major QA review of its calculation models with an external party in 2012 (additional details can be found in chapter 5, sections 5.1.4 and 5.1.5). In 2013–14, the Waste sector undertook a comprehensive QA review of the greenhouse gas estimates from non-municipal landfills. Regular meetings to discuss progress with QA/QC processes and relevant issues with each sector lead have been put in place. A new quality control manager for the Inventory has been appointed.

13.3 Data archiving, security and recovery

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

New Zealand's archiving system reflects this organisational approach. Specifically:

- Submitted data files for CRF, CRF tables, back-up database files from the CRF Reporter, sectoral chapters, compiled NIR, sign-off confirmations, supplementary materials that are included into the Inventory submission pack, communication between New Zealand's Inventory team and the Expert Review Teams, NIS, process maps, NIR project planning and documentation, and similar documents are stored in MfE's secure file management system and backed up in several different devices.
- Sectoral data, including communication with contractors, activity data, emission factors, preliminary calculations and specific software applications containing sectoral data models are kept in secure file systems at each sectoral agency. For example, the Ministry for Primary Industries holds the information regarding the Agriculture sector, the Ministry of Business, Innovation and Employment (formerly the Ministry for Economic Development) holds the materials specific to the Energy sector and a portion of the materials relating to CO_2 emissions from the IPPU sector. The Environmental Protection Authority is responsible for the storage of information relating to New Zealand's ETS reports and communications.
- MfE holds the information for LULUCF, Waste, IPPU (non-CO_2 emissions) sectors because the Sector Leads for these sectors work at MfE.
- Each of the agencies has security procedures in place in case of natural disasters, fire, flood or other accidents, which are kept at a high standard. For example, despite several earthquakes of 6.5–6.9 magnitude that happened during the 2013–14 period

in Wellington (where all agencies involved in the Inventory production are located), all of the information regarding the Inventory support remained undamaged, and the processes of the Inventory 2014 production and responses to the ERT questions proceeded without interruption.

13.4 Development of expertise

New Zealand has continued to develop the expertise of the main Inventory contributors. For this submission, additional government experts were trained as the Sector Leads for the Energy, Waste and Agriculture sectors. Eight government officials passed their Inventory reviewer exams under the Climate Change Convention, four government officials participated in their first expert review of Annex I inventories (Energy, IPPU, LULUCF and Waste) and one government official has completed generalist exams.

In 2014–15, New Zealand nominated two government officials for Inventory reviewer training in the LULUCF and Agriculture sectors. New Zealand's goal is that the Inventory Sector Leads and peer reviewers are certified Inventory experts for their sectors, and the officials responsible for cross-sectoral inventory compilation and review are certified generalists. This is to ensure better understanding of the Inventory principles, processes and quality criteria, more efficient participation in the Inventory review process and that the high quality of New Zealand's Inventory is maintained.

Chapter 14: Information on changes to the national registry

This chapter contains information required for reporting changes to New Zealand's national registry. The changes made to New Zealand's national registry since the 2014 submission are included in table 14.1.

No recommendations were made in the most recent review by the Expert Review Team (table 14.2).

A list of reference documents included in the submitted zip file 'Chapter 14 2014' is provided in table 14.3.

Table 14.1 Changes made to New Zealand's national registry

Section subheading	New Zealand's response
15/CMP.1 Annex II.E, paragraph 32.(a): Change in the name or contact for the national registry	In 2014, the contact details for the national registry have been changed. Changes were made to the Alternative Contact. Refer to table 14.4 below for details. The Registry System Administrator (RSA) advised the International Transaction Log (ITL) of these changes via email with confirmation received. The changes have taken effect from 15 August 2014.
15/CMP.1 Annex II.E, paragraph 32.(b): Change in cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
1/CMP.1 Annex II.E, paragraph 32.(c): Change to the database or the capacity of the national registry	No changes to the database or capacity of the national registry occurred during the reported period.
15/CMP.1 Annex II.E, paragraph 32.(d): Change in the conformance to technical standards	No changes to the conformance of technical standards occurred during the reported period.
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	Changes to security during the reported period. Standard, business-as-usual updates to optimise security were introduced. The changes were: • changes to password length for agency users, to bring the New Zealand Emission Unit Register in line with New Zealand Government standards. This change did not affect user authentication for end users • protection against Cross Site Request Forgery Attack (August Security Release 2014) • protection against browser history theft (August Security Release 2014) • removal of unused code (August Security Release 2014) • Input Sanitisation in the User Registration Flow where additional validation could improve security (August Security Release 2014). As changes introduced were minor and business as usual, no changes to the security plan were deemed necessary.
15/CMP.1 Annex II.E, paragraph 32.(g): Change in the list of publicly available information	No changes to the list of publicly available information occurred during the reporting period.
15/CMP.1 Annex II.E, paragraph 32.(h): Change to the internet address	No change of the registry internet address occurred during the reporting period. The internet address is www.eur.govt.nz.
15/CMP.1 Annex II.E, paragraph 32.(i) – Change to the data integrity	No change of data integrity measures occurred during the reporting period.

Section subheading	New Zealand's response
measures	
15/CMP.1 Annex II.E paragraph 32.(j) – Change of the test results	Changes to test results occurred as a result of the security updates reported above (15/CMP.1 Annex II.E, paragraph 32.(f)).

Table 14.2 Previous recommendations for New Zealand from the Expert Review Team

Previous annual review recommendations	New Zealand addressed the recommendation as follows
There were no recommendations made in 2014.	**N/A**

Table 14.3 Reference documents list – all zipped under 'Chapter 14 2014.zip'

ID	Document Name	Document description
1	Document 14.3.1	Email to International Transaction Log (ITL) advising of removal of alternative Registry System Administrator (RSA) contact
2	Document 14.3.2	Additional information relating to changes in security

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	Guy Windley Team Leader, Registry Operations, ETS Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 474 5514 Fax: +64 4 978 3661 Email: guy.windley@epa.govt.nz
Alternative Contact	Justin Bloomfield Systems Analyst, Information Technology Team Environmental Protection Authority Private Bag 63002, Wellington 6140, New Zealand Phone: +64 4 474 5435 Fax: +64 4 978 3661 Email: justin.bloomfield@epa.govt.nz
Release Manager	N/A

Chapter 15: Information on minimisation of adverse impacts

This chapter provides information on New Zealand's implementation of policies and measures that minimise adverse social, environmental and economic impacts on non-Annex I Parties, as required under Article 3.14 of the Kyoto Protocol.

Most of this information is the same or very similar to that provided in the 2013 Inventory submission. However, some revised information is provided for the following:

- information on New Zealand's efforts to promote fossil fuel subsidy reform (see section 15.2)
- further information on energy projects in the Pacific Islands (see section 15.6)
- further information on New Zealand's involvement in activities to provide assistance to non-Annex I Parties that are dependent on the export and consumption of fossil fuels in diversifying their economies (see section 15.7).

15.1 Overview

New Zealand's Cabinet and legislative processes to establish and implement climate change response measures include consultation with the Ministry of Foreign Affairs and Trade and members of the public. Policy advice is coordinated between ministries and involves analysis of all relevant parameters. The Ministry of Foreign Affairs and Trade provides advice to the Government on international aspects of proposed policies. Through this process decision-makers in New Zealand can, and frequently do, consider the social and economic impacts of New Zealand's policies on other countries, whether informed by bilateral engagement or other forms of analysis. During the public consultation phase, concerns and issues about the proposed measure can be raised by any person or organisation. There is no pre-prescribed process for analysis of impacts across all policies. This allows for flexibility in policy making, and enables the most relevant advice to be put before decision-makers.

Through the New Zealand Government's regular trade, economic and political consultations with other governments, including some non-Annex I Parties, there are opportunities for those who may be concerned about the possible or actual adverse impacts of New Zealand policies to raise concerns and have them resolved within the bilateral relationship. To date, there have been no specific concerns raised about any negative impacts of New Zealand's climate change response policies.

The New Zealand Government, through the New Zealand Aid Programme (www.aid.govt.nz), has regular Official Development Assistance programming talks with partner country governments, where partners have the opportunity to raise concerns about any impacts and to ask for or prioritise assistance to deal with those impacts. From these discussions, New Zealand works closely with the partner country to prepare a country strategic framework for development. These engagement frameworks are relatively long term (five or 10 years) and convey New Zealand's development assistance strategy in each country in which it provides aid. They are aligned to the priorities and needs of the partner country, while also reflecting New Zealand's priorities and policies.

The New Zealand Aid Programme also works with partner countries to strengthen governance and improve their ability to respond to changing circumstances. On many of the issues related to the implementation of Article 3.14, New Zealand gives priority to working with countries in the Pacific region.

The 2014 year was designated as the first International Year of Small Island Developing States by the United Nations General Assembly and marked a renewed focus by the United Nations on the particular challenges these countries face. Small Island Developing States are increasing their uptake of renewable energy, which is a critical element of their long-term sustainable development efforts. New Zealand supported Samoa to host the third International Conference on Small Island Developing States in September 2014, co-hosted the Renewable Energy Forum with the Government of Samoa and the International Renewable Energy Agency, and organised the partnership dialogue on Sustainable Economic Development together with Barbados.

15.2 Market imperfections, fiscal incentives, tax and duty exemptions and subsidies

Annex I Parties are required to report any progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities.

New Zealand does not have any inefficient market imperfections, fiscal incentives, tax and duty exemptions or subsidies in greenhouse-gas-emitting sectors of this nature.

New Zealand maintains a liberalised and open trading environment, consistent with the principles of free trade and investment, ensuring that both developed and developing countries can maximise opportunities in New Zealand's market regardless of the response measures undertaken.

New Zealand has been working in a number of international fora to promote the global reform of inefficient fossil fuel subsidies. For example, New Zealand is helping to build capacity for the reform of inefficient fossil fuel subsidies within Asia-Pacific Economic Cooperation (APEC) member economies. In November 2013, New Zealand along with other Friends of the Fossil Fuel Subsidy Reform and the International Institute for Sustainable Development Global Subsidies Initiative jointly organised an event entitled 'Reaping Emissions Reductions from Fossil Fuel Subsidy Reform' on the side-lines of the Warsaw Climate Change Conference (COP19). The event focused on the opportunities that fossil fuel subsidy reform holds for reducing carbon dioxide emissions and, in particular, the role of the United Nations Framework Convention on Climate Change in supporting that process. More recently, New Zealand jointly hosted a fossil fuel subsidy reform roundtable with the United States and World Bank in the margins of the 2014 World Bank–International Monetary Fund Spring Meetings. The event was an opportunity for interested G20 and non-G20 economies to learn more about the peer review processes currently under way under the G20 and APEC settings, hear first-hand accounts from countries about their experiences with reform, and understand the tools and initiatives available to support reform.

New Zealand was one of the first economies to present a submission under APEC's fossil fuel subsidy reform voluntary reporting mechanism in 2012 (along with the United States, Canada and Thailand). All policy measures that directly or indirectly support fossil fuels were reported. In line with New Zealand's commitment to transparency and information sharing, New Zealand was also the first APEC economy to volunteer for fossil fuel subsidy reform peer review under guidelines finalised by the APEC Energy Working Group in December 2013. Technical preparations are now under way for New Zealand's peer review, with the review panel in-country visit scheduled for March 2015. The associated report is expected to be completed by mid-2015. Consistent with New Zealand's approach under APEC's fossil fuel subsidy reform voluntary reporting mechanism, New Zealand intends to put forward for peer review all policy measures that directly or indirectly support fossil fuels.

New Zealand is a member of the 'Friends of Fossil Fuel Subsidy Reform', an informal group of non-G20 countries that encourages and supports the G20 countries to meet their commitments to reform inefficient fossil fuel subsidies. The group's support for reform is based on the essential notion that it is incoherent to continue to underwrite the costs of emissions from fossil fuels at the same time as making concerted efforts to mitigate those emissions through actions elsewhere.

15.3 Removal of subsidies

Annex I Parties are required to report information concerning the removal of subsidies associated with the use of environmentally unsound and unsafe technologies. New Zealand does not have any subsidies of this nature.

15.4 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 participated actively in activities of this nature as yet.

15.5 Carbon capture and storage technology development

Annex I Parties are required to report on cooperation in the development, diffusion and transfer of less-greenhouse-gas-emitting advanced fossil fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouragement of their wider use; and on facilitating the participation of non-Annex I Parties.

New Zealand is a member of the United States-led Carbon Sequestration Leadership Forum (www.cslforum.org) and the International Energy Agency Greenhouse Gas Research and Development Programme (www.ieaghg.org).

15.6 Improvements in fossil fuel efficiencies

Annex I Parties are required to report how they have strengthened the capacity of non-Annex I Parties identified in Article 4.8 and 4.9 of the Climate Change Convention, by improving the efficiency in upstream and downstream activities related to fossil fuels and by taking into consideration the need to improve the environmental efficiency of these activities.

The New Zealand Aid Programme maintains a focus on energy efficiency, and the transition away from fossil fuel dependency to clean efficient, affordable and reliable energy generation, for sustainable economic development. One example is New Zealand's commitment to a major energy programme in Tonga. Working closely alongside development partners, New Zealand is supporting the practical implementation of Tonga's 10-year Energy Roadmap, to improve Tonga's energy sector efficiency and energy self-reliance. Part of New Zealand's NZ$23.2 million commitment from 2013–18 is focused on improving efficiency and access through upgrading Tonga's power distribution network, as well as the feasibility of using wind as a renewable energy resource.

A further example is New Zealand's support to Tokelau, which was 100 per cent dependent upon diesel for electricity generation until 2013, with heavy economic and environmental costs. A New Zealand-funded project to construct solar-based mini-grids on three atolls now provides more than 90 per cent of Tokelau's electricity needs through solar generation.

Projects to implement renewable energy resources, particularly solar energy for remote island communities are also in progress in Samoa, Kiribati, the Cook Islands and Tuvalu, scheduled to deliver in 2015/16, alongside wider regional technical assistance programmes focused on capacity building, asset management and energy sector reform.

15.7 Assistance to non-Annex I Parties dependent on the export and consumption of fossil fuels for diversifying their economies

Annex I Parties are required to report on assistance provided to non-Annex I Parties that are highly dependent on the export and consumption of fossil fuels in diversifying their economies.

The New Zealand Aid Programme provides support to a number of non-Annex I Parties for purposes of economic diversification and renewable energy generation (refer to section 15.6).

For example, New Zealand is helping to provide new economic opportunities in Timor-Leste through rehabilitating the coffee sector, to increase the quality, quantity and value of coffee products, developing the aquaculture sector and providing capacity and capability building for small business in rural areas, particularly those run by women. In 2009, petroleum income accounted for almost 80 per cent of Timor-Leste's gross national income. A key focus for New Zealand's development assistance in Timor-Leste is to support sustainable economic development through private sector investment.

Introducing clean and affordable energy technologies is a high priority for the Pacific region. On average, 10 per cent of the region's gross domestic product is expended on imported fossil fuel and 80 per cent of electricity generation depends on the combustion of diesel. New Zealand is a member of the International Renewable Energy Agency (IRENA), an intergovernmental organisation that aims to promote the widespread use of all forms of renewable energy. New Zealand is involved with a number of IRENA's work streams in the Pacific and further afield.

New Zealand is also a member of other multilateral institutions that play a role in these areas, for example, the International Energy Agency and APEC.

Following the New Zealand Government and the European Union Pacific Energy Summit in 2013, a year on more than 50 of the 79 projects presented at the summit are in progress by development partners across the Pacific. New Zealand has exceeded its orginal $65 million commitment and is supporting 25 projects in seven Pacific countries, worth over $80 million. For example, New Zealand has commissioned a 2.15MW solar system in Apia, the largest solar farm in the Pacific.

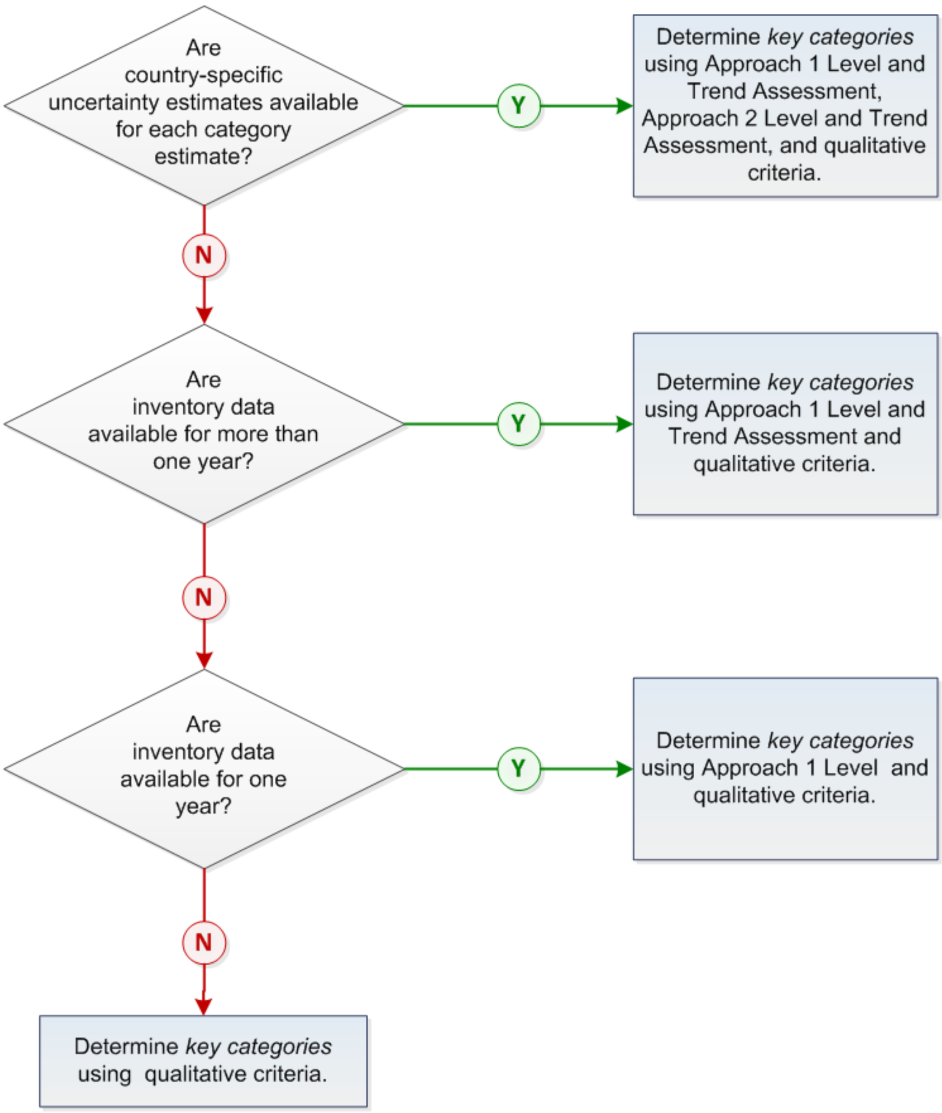
New Zealand is committed to providing long-term assistance to non-Annex I Parties in achieving economic diversification that is independent of fossil fuels and that includes the provision of secure, sustainable energy.

Annex 1: Key categories

A1.1 Methodology used for identifying key categories

The key categories in the Inventory have been assessed using the Approach 1 level and trend methodologies from the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC 2006). 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 4.2 (IPCC, 2006))



For this inventory submission, the Approach 1 level and trend assessments were applied, including the land use, land-use change and forestry (LULUCF) sector and excluding the LULUCF sector (IPCC 2000, 2003). The 'including LULUCF' level and trend assessments are calculated as per equations 5.4.1 and 5.4.2 of *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (GPG-LULUCF, IPCC, 2003). The 'excluding LULUCF' level and trend assessments are calculated as per equations 4.1 and

4.2 of the IPCC 2006 Guidelines (IPCC, 2006). 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 4.1 of the IPCC 2006 Guidelines (IPCC, 2006) by:

- identifying categories at the level of Intergovernmental Panel on Climate Change (IPCC) categories using carbon dioxide (CO_2) equivalent emissions and considering each greenhouse gas from each category separately
- aggregating categories that use the same emission factors
- including LULUCF categories at the level shown in GPG-LULUCF table 5.4.1.

A1.3 Tables 4.2 – 4.3 of the IPCC 2006 Guidelines (General Guidance and Reporting)

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 2013

IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2013					
CRF Code	IPCC categories	Gas	2013 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
4.A.2	Land Converted to Forest Land	CO_2	21,403.5	17.6	17.6
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	13,216.3	10.8	28.4
4.G	Harvested Wood Products	CO_2	10,295.6	8.4	36.9
3.A.2	Enteric Fermentation – Sheep	CH_4	9,223.3	7.6	44.4
1.A.3.b	Transport – Road Transport – Gasoline	CO_2	6,936.0	5.7	50.1
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	5,679.4	4.7	54.8
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	5,576.9	4.6	59.4
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	5,392.4	4.4	63.8
4.C.2	Land Converted to Grassland	CO_2	4,840.4	4.0	67.8
5.A	Solid Waste Disposal	CH_4	4,600.3	3.8	71.5
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	3,409.0	2.8	74.3
4.A.1	Forest Land Remaining Forest Land	CO_2	2,123.7	1.7	76.1
2.C.1	Metal Industry – Iron and Steel Production	CO_2	1,747.5	1.4	77.5
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	1,615.9	1.3	78.8
4.C.1	Grassland Remaining Grassland	CO_2	1,559.4	1.3	80.1
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air Conditioning	HFCs & PFCs	1,518.5	1.2	81.4
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Liquid Fuels	CO_2	1,313.4	1.1	82.4
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	1,295.6	1.1	83.5
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and	CO_2	1,206.3	1.0	84.5

IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2013					
CRF Code	IPCC categories	Gas	2013 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
	Tobacco – Solid Fuels				
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	934.6	0.8	85.3
3.D.B.1	Agricultural Soils – Indirect N_2O Emissions – Atmospheric Deposition	N_2O	913.9	0.8	86.0
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	896.9	0.7	86.7
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	816.6	0.7	87.4
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	778.5	0.6	88.1
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CO_2	597.3	0.5	88.5
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	573.1	0.5	89.0
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Gaseous Fuels	CO_2	573.0	0.5	89.5
2.A.1	Mineral Industry – Cement Production	CO_2	568.6	0.5	89.9
3.A.4	Enteric Fermentation – Other – Deer	CH_4	555.8	0.5	90.4
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	550.4	0.5	90.9
3.G	Liming	CO_2	540.1	0.4	91.3
2.C.3	Metal Industry – Aluminium Production	CO_2	533.8	0.4	91.7
3.D.B.2	Agricultural Soils – Indirect N_2O Emissions – Nitrogen Leaching and Run-off	N_2O	496.1	0.4	92.1
3.H	Urea Application	CO_2	490.0	0.4	92.5
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	411.7	0.3	92.9
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	374.7	0.3	93.2
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Liquid Fuels	CO_2	368.0	0.3	93.5
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	350.7	0.3	93.8
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	343.2	0.3	94.1
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	340.3	0.3	94.3
4.B.1	Cropland Remaining cropland	CO_2	339.5	0.3	94.6
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Gaseous Fuels	CO_2	327.5	0.3	94.9
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	303.8	0.2	95.1
1.A.4.b	Other Sectors – Residential – Gaseous Fuels	CO_2	301.6	0.2	95.4

IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2013					
CRF Code	**IPCC categories**	**Gas**	**2013 estimate (kt CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Solid Fuels	CO_2	293.1	0.2	95.6
5.D	Wastewater Treatment and Discharge	CH_4	272.4	0.2	95.9
2.B.10	Chemical industry – Other – Hydrogen Production	CO_2	252.4	0.2	96.1
3.D.A.4	Agricultural Soils – Direct N_2O Emissions – Crop Residues	N_2O	251.3	0.2	96.3
1.A.4.b	Other Sectors – Residential – Liquid Fuels	CO_2	187.4	0.2	96.4
1.B.2.b.5	Fugitive Emissions from Fuels – Natural Gas – Distribution	CH_4	185.2	0.2	96.6
1.B.1.a.ii	Fugitive Emissions from Fuels – Coal Mining and Handling – Surface Mines	CH_4	179.8	0.1	96.7
1.B.2.c	Fugitive Emissions from Fuels – Oil and Natural Ga s and Other Emissions from Energy Production – Flaring – Combined	CO_2	178.9	0.1	96.9
5.D	Wastewater Treatment and Discharge	N_2O	178.1	0.1	97.0
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Solid Fuels	CO_2	167.8	0.1	97.1
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Liquid Fuels	CO_2	163.6	0.1	97.3
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CH_4	151.7	0.1	97.4
3.D.A.2	Agricultural Soils – Direct N_2O Emissions – Organic N Fertilisers	N_2O	147.8	0.1	97.5
1.A.3.c	Transport – Railways – Liquid Fuels	CO_2	147.2	0.1	97.6
1.A.4.a	Other Sectors – Commercial/Institutional – Solid Fuels	CO_2	134.7	0.1	97.8
2.A.2	Mineral Industry – Lime Production	CO_2	132.5	0.1	97.9
1.B.1.a.i	Fugitive Emissions from Fuels – Coal Mining and Handling – Underground Mines	CH_4	131.5	0.1	98.0
1.A.2.a	Manufacturing Industries and Construction – Iron and Steel – Gaseous Fuels	CO_2	107.8	0.1	98.1
1.A.1.b	Energy Industries – Petroleum Refining – Gaseous Fuels	CO_2	107.5	0.1	98.2
4.A.2	Land Converted to Forest Land	N_2O	101.7	0.1	98.2
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Liquid Fuels	CO_2	98.3	0.1	98.3
1.A.3.b	Transport – Road Transport – Gasoline	N_2O	96.2	0.1	98.4
3.B.2	Manure Management – Sheep	CH_4	94.1	0.1	98.5
4.B.2	Land Converted to Cropland	CO_2	92.2	0.1	98.5
2.F.4	Product Uses as Substitutes for ODS – Aerosols	HFCs & PFCs	91.6	0.1	98.6
1.A.2.g.i	Manufacturing Industries and Construction – Other – Manufacturing of Machinery – Gaseous Fuels	CO_2	88.5	0.1	98.7
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Gaseous Fuels	CO_2	78.9	0.1	98.8

IPCC Tier 1 category level assessment – including LULUCF (net emissions): 2013					
CRF Code	IPCC categories	Gas	2013 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
3.B.5	Agricultural Soils – Indirect N_2O Emissions	N_2O	73.4	0.1	98.8
3.B.1	Manure Management – Cattle – Non-dairy Cattle	CH_4	72.4	0.1	98.9
2.A.4	Mineral Industry – Other Process Uses of Carbonates	CO_2	70.4	0.1	98.9
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Liquid Fuels	CO_2	69.1	0.1	99.0
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Solid Fuels	CO_2	68.2	0.1	99.1

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

IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990					
CRF Code	IPCC Categories	Gas	1990 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
4.A.2	Land Converted to Forest Land	CO_2	18,858.2	19.1	19.1
3.A.2	Enteric Fermentation – Sheep	CH_4	13,956.0	14.1	33.2
4.A.1	Forest Land Remaining Forest Land	CO_2	9,539.4	9.7	42.8
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	5,951.6	6.0	48.9
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	5,737.5	5.8	54.7
1.A.3.b	Transport – Road Transport – Gasoline	CO_2	5,638.5	5.7	60.4
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	5,255.5	5.3	65.7
5.A	Solid Waste Disposal	CH_4	4,698.6	4.8	70.5
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	2,999.6	3.0	73.5
4.G	Harvested Wood Products	CO_2	1,969.2	2.0	75.5
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	1,717.9	1.7	77.2
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	1,423.8	1.4	78.7
2.C.1	Metal Industry – Iron and Steel Production	CO_2	1,306.7	1.3	80.0
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Liquid Fuels	CO_2	1,071.4	1.1	81.1
4.C.1	Grassland Remaining Grassland	CO_2	964.5	1.0	82.0
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Solid Fuels	CO_2	938.6	0.9	83.0
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	892.6	0.9	83.9
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	778.9	0.8	84.7
2.C.3	Metal Industry – Aluminium Production	PFCs	734.6	0.7	85.4
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Solid Fuels	CO_2	731.1	0.7	86.2
3.D.B.1	Agricultural Soils – Indirect N_2O Emissions – Atmospheric Deposition	N_2O	726.8	0.7	86.9

IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990					
CRF Code	IPCC Categories	Gas	1990 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
1.A.2.c	Manufacturing Industries and Construction – Chemicals – Gaseous Fuels	CO_2	531.3	0.5	87.4
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	500.6	0.5	87.9
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	474.8	0.5	88.4
2.C.3	Metal Industry – Aluminium Production	CO_2	449.0	0.5	88.9
2.A.1	Mineral Industry – Cement Production	CO_2	448.7	0.5	89.3
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Gaseous Fuels	CO_2	443.9	0.4	89.8
3.A.4	Enteric Fermentation – Other – Deer	CH_4	415.6	0.4	90.2
3.D.B.2	Agricultural Soils – Indirect N_2O Emissions – Nitrogen Leaching and Run-off	N_2O	390.8	0.4	90.6
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	390.1	0.4	91.0
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	382.9	0.4	91.4
3.G	Liming	CO_2	360.1	0.4	91.7
4.B.1	Cropland Remaining cropland	CO_2	356.3	0.4	92.1
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Gaseous Fuels	CO_2	347.3	0.4	92.5
1.A.4.b	Other Sectors – Residential – Solid Fuels	CO_2	344.9	0.3	92.8
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	331.5	0.3	93.1
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	328.5	0.3	93.5
1.B.1.a.i	Fugitive Emissions from Fuels – Coal Mining and Handling – Underground Mines	CH_4	289.6	0.3	93.8
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Liquid Fuels	CO_2	289.5	0.3	94.1
1.B.2.b.5	Fugitive Emissions from Fuels – Natural Gas – Distribution	CH_4	277.5	0.3	94.3
5.D	Wastewater Treatment and Discharge	CH_4	259.9	0.3	94.6
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	235.2	0.2	94.8
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	232.9	0.2	95.1
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CO_2	228.6	0.2	95.3
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	217.7	0.2	95.5
3.A.4	Enteric Fermentation – Other – Goats	CH_4	196.6	0.2	95.7
1.A.4.b	Other Sectors – Residential – Gaseous Fuels	CO_2	184.9	0.2	95.9
3.D.A.4	Agricultural Soils – Direct N_2O Emissions – Crop Residues	N_2O	175.5	0.2	96.1
1.A.4.b	Other Sectors – Residential – Liquid Fuels	CO_2	167.1	0.2	96.3

IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990					
CRF Code	**IPCC Categories**	**Gas**	**1990 estimate (kt CO_2-e)**	**Level assessment (%)**	**Cumulative total (%)**
2.B.10	Chemical industry – Other – Hydrogen Production	CO_2	152.3	0.2	96.4
1.A.4.a	Other Sectors – Commercial/Institutional – Solid Fuels	CO_2	142.2	0.1	96.6
1.A.3.b	Transport – Road Transport – Gaseous Fuels	CO_2	140.3	0.1	96.7
3.B.2	Manure Management – Sheep	CH_4	139.6	0.1	96.8
5.D	Wastewater Treatment and Discharge	N_2O	138.6	0.1	97.0
4.A.2	Land Converted to Forest Land	N_2O	120.9	0.1	97.1
1.A.2.a	Manufacturing Industries and Construction – Iron and Steel – Gaseous Fuels	CO_2	116.2	0.1	97.2
4.B.2	Land Converted to Cropland	CO_2	115.4	0.1	97.3
1.B.2.c	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Flaring – Combined	CO_2	114.1	0.1	97.4
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Solid Fuels	CO_2	109.5	0.1	97.6
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	109.3	0.1	97.7
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Gaseous Fuels	CO_2	105.8	0.1	97.8
1.A.3.b	Transport – Road Transport – Liquefied Petroleum Gases	CO_2	102.1	0.1	97.9
2.A.2	Mineral Industry – Lime Production	CO_2	82.6	0.1	98.0
3.D.A.2	Agricultural Soils – Direct N_2O Emissions – Organic N Fertilisers	N_2O	78.5	0.1	98.0
1.A.3.c	Transport – Railways – Liquid Fuels	CO_2	78.4	0.1	98.1
1.A.3.b	Transport – Road Transport – Gasoline	N_2O	76.9	0.1	98.2
3.B.1	Manure Management – Cattle – Non-dairy Cattle	CH_4	76.6	0.1	98.3
1.B.1.a.ii	Fugitive Emissions from Fuels – Coal Mining and Handling – Surface Mines	CH_4	74.4	0.1	98.4
4.C.1	Grassland Remaining Grassland	CH_4	68.5	0.1	98.4
1.B.2.c	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Flaring – Combined	CH_4	64.6	0.1	98.5
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Gaseous Fuels	CO_2	64.1	0.1	98.6
1.A.3.b	Transport – Road Transport – Gasoline	CH_4	60.0	0.1	98.6
1.A.2.g.vi	Manufacturing Industries and Construction – Other – Textiles – Gaseous Fuels	CO_2	58.9	0.1	98.7
3.B.3	Manure Management – Swine	CH_4	58.6	0.1	98.7
1.A.4.b	Other Sectors – Residential – Biomass	CH_4	57.5	0.1	98.8
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CH_4	54.8	0.1	98.8
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Liquid Fuels	CO_2	52.0	0.1	98.9
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Liquid Fuels	CO_2	47.9	0.0	98.9

CRF Code	IPCC Categories	Gas	1990 estimate (kt CO_2-e)	Level assessment (%)	Cumulative total (%)
IPCC Tier 1 category level assessment – including LULUCF (net emissions): 1990					
1.A.3.a	Transport – Domestic Aviation – aviation Gasoline	CO_2	47.7	0.0	99.0
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Liquid Fuels	CO_2	45.9	0.0	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 2013

CRF Code	IPCC categories	Gas	1990 estimate (kt CO_2-e)	2013 estimate (kt CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
IPCC Tier 1 category trend assessment – including LULUCF (net emissions)							
4.A.1	Forest Land Remaining Forest Land	CO_2	9,539.4	2123.7	0.1	15.9	15.9
3.A.2	Enteric Fermentation – Sheep	CH_4	13,956.0	9223.3	0.1	13.2	29.1
4.G	Harvested Wood Products	CO_2	1,969.2	10295.6	0.1	13.0	42.1
3.A.1	Enteric Fermentation – Dairy Cattle	CH_4	5,951.6	13216.3	0.0	9.7	51.8
4.C.2	Land Converted to Grassland	CO_2	22.3	4840.4	0.0	7.9	59.7
1.A.3.b	Transport – Road Transport – Diesel Oil	CO_2	1,423.8	5576.9	0.0	6.3	66.0
4.A.2	Land Converted to Forest Land	CO_2	18,858.2	21403.5	0.0	3.0	69.0
1.A.1.c	Energy Industries – Manufacture of Solid Fuels and Other Energy Industries – Gaseous Fuels	CO_2	1,717.9	350.7	0.0	2.9	72.0
3.A.1	Enteric Fermentation – Non-dairy Cattle	CH_4	5,737.5	5392.4	0.0	2.8	74.7
2.F.1	Product Uses as Substitutes for ODS – Refrigeration and Air Conditioning	HFCs & PFCs	0.0	1518.5	0.0	2.5	77.2
5.A	Solid Waste Disposal	CH_4	4,698.6	4600.3	0.0	2.0	79.2
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Solid Fuels	CO_2	474.8	1615.9	0.0	1.7	80.9
2.C.3	Metal Industry – Aluminium Production	PFCs	734.6	48.1	0.0	1.4	82.3
3.D.A.3	Agricultural Soils – Direct N_2O Emissions – Urine and Dung Deposited by Grazing Animals	N_2O	5,255.5	5679.4	0.0	1.3	83.6
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Solid Fuels	CO_2	731.1	167.8	0.0	1.2	84.9
3.D.A.1	Agricultural Soils – Direct N_2O Emissions – Inorganic N Fertilisers	N_2O	217.7	934.6	0.0	1.1	85.9
1.A.2.c	Manufacturing Industries and Construction –	CO_2	531.3	1295.6	0.0	1.1	87.0

CRF Code	IPCC categories	Gas	1990 estimate (kt CO_2-e)	2013 estimate (kt CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
IPCC Tier 1 category trend assessment – including LULUCF (net emissions)							
	Chemicals – Gaseous Fuels						
3.H	Urea Application	CO_2	39.2	490.0	0.0	0.7	87.7
3.B.1	Manure Management – Cattle – Dairy Cattle	CH_4	390.1	896.9	0.0	0.7	88.4
1.A.4.b	Other Sectors – Residential – Solid Fuels	CO_2	344.9	30.6	0.0	0.7	89.1
4.C.1	Grassland Remaining Grassland	CO_2	964.5	1559.4	0.0	0.6	89.7
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CO_2	228.6	597.3	0.0	0.5	90.2
1.A.1.a	Energy Industries – Public Electricity and Heat Production – Gaseous Fuels	CO_2	2,999.6	3409.0	0.0	0.5	90.7
1.A.3.a	Transport – Domestic Aviation – Jet Kerosene	CO_2	892.6	816.6	0.0	0.5	91.2
1.A.4.a	Other Sectors – Commercial/Institutional – Liquid Fuels	CO_2	500.6	340.3	0.0	0.5	91.6
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Solid Fuels	CO_2	35.1	293.1	0.0	0.4	92.0
3.A.4	Enteric Fermentation – Other – Goats	CH_4	196.6	16.7	0.0	0.4	92.4
1.B.1.a.i	Fugitive Emissions from Fuels – Coal Mining and Handling – Underground Mines	CH_4	289.6	131.5	0.0	0.4	92.8
1.B.2.b.3	Fugitive Emissions from Fuels – Natural Gas – Processing	CO_2	109.3	343.2	0.0	0.3	93.1
1.A.1.b	Energy Industries – Petroleum Refining – Liquid Fuels	CO_2	778.9	778.5	0.0	0.3	93.4
1.A.3.b	Transport – Road Transport – Gaseous Fuels	CO_2	140.3	0.0	0.0	0.3	93.7
1.B.2.b.5	Fugitive Emissions from Fuels – Natural Gas – Distribution	CH_4	277.5	185.2	0.0	0.3	94.0
1.A.2.g.iii	Manufacturing Industries and Construction – Other – Mining and quarrying – Liquid Fuels	CO_2	331.5	550.4	0.0	0.2	94.2
2.C.1	Metal Industry – Iron and Steel Production	CO_2	1,306.7	1747.5	0.0	0.2	94.4
1.A.4.a	Other Sectors – Commercial/Institutional – Gaseous Fuels	CO_2	235.2	411.7	0.0	0.2	94.6
1.A.3.b	Transport – Road Transport – Liquefied Petroleum Gases	CO_2	102.1	17.0	0.0	0.2	94.8
1.A.1.b	Energy Industries –	CO_2	0.0	107.5	0.0	0.2	95.0

CRF Code	IPCC categories	Gas	1990 estimate (kt CO_2-e)	2013 estimate (kt CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
IPCC Tier 1 category trend assessment – including LULUCF (net emissions)							
	Petroleum Refining – Gaseous Fuels						
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – at Industrial Plants and Power Stations	CH_4	328.5	303.8	0.0	0.2	95.1
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Solid Fuels	CO_2	382.9	573.1	0.0	0.2	95.3
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Gaseous Fuels	CO_2	347.3	327.5	0.0	0.2	95.5
4.B.1	Cropland Remaining cropland	CO_2	356.3	339.5	0.0	0.2	95.6
1.A.2.g.viii	Manufacturing Industries and Construction – Other – Other non-specified – Liquid Fuels	CO_2	52.0	163.6	0.0	0.2	95.8
3.G	Liming	CO_2	360.1	540.1	0.0	0.2	96.0
2.F.4	Product Uses as Substitutes for ODS – Aerosols	HFCs & PFCs	0.0	91.6	0.0	0.2	96.1
1.B.1.a.ii	Fugitive Emissions from Fuels – Coal Mining and Handling – Surface Mines	CH_4	74.4	179.8	0.0	0.1	96.3
1.A.3.d	Transport – Domestic Navigation – Residual Fuel Oil	CO_2	232.9	374.7	0.0	0.1	96.4
1.B.2.d	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Other – Geothermal	CH_4	54.8	151.7	0.0	0.1	96.5
3.B.2	Manure Management – Sheep	CH_4	139.6	94.1	0.0	0.1	96.7
1.A.4.b	Other Sectors – Residential – Gaseous Fuels	CO_2	184.9	301.6	0.0	0.1	96.8
1.A.2.d	Manufacturing Industries and Construction – Pulp, Paper and Print – Solid Fuels	CO_2	109.5	68.2	0.0	0.1	96.9
2.B.10	Chemical industry – Other – Hydrogen Production	CO_2	152.3	252.4	0.0	0.1	97.0
4.C.1	Grassland Remaining Grassland	CH_4	68.5	25.7	0.0	0.1	97.1
1.B.2.c	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Flaring – Combined	CH_4	64.6	25.4	0.0	0.1	97.2
1.A.4.c	Other Sectors – Agriculture/Forestry/Fishing – Gaseous Fuels	CO_2	105.8	78.9	0.0	0.1	97.3

IPCC Tier 1 category trend assessment – including LULUCF (net emissions)							
CRF Code	IPCC categories	Gas	1990 estimate (kt CO_2-e)	2013 estimate (kt CO_2-e)	Trend assessment	Contribution to trend (%)	Cumulative total (%)
3.D.A.2	Agricultural Soils – Direct N_2O Emissions – Organic N Fertilisers	N_2O	78.5	147.8	0.0	0.1	97.4
1.A.3.b	Transport – Road Transport – Gasoline	CH_4	60.0	23.0	0.0	0.1	97.4
1.A.3.c	Transport – Railways – Liquid Fuels	CO_2	78.4	147.2	0.0	0.1	97.5
1.A.2.g.vi	Manufacturing Industries and Construction – Other – Textiles – Gaseous Fuels	CO_2	58.9	22.5	0.0	0.1	97.6
4.B.2	Land Converted to Cropland	CO_2	115.4	92.2	0.0	0.1	97.7
1.A.2.e	Manufacturing Industries and Construction – Food Processing, Beverages and Tobacco – Solid Fuels	CO_2	938.6	1206.3	0.0	0.1	97.8
5.D	Wastewater Treatment and Discharge	CH_4	259.9	272.4	0.0	0.1	97.9
4.A.2	Land Converted to Forest Land	N_2O	120.9	101.7	0.0	0.1	97.9
1.A.3.b	Transport – Road Transport – Gaseous Fuels	CH_4	37.3	0.0	0.0	0.1	98.0
3.A.4	Enteric Fermentation – Other – Deer	CH_4	415.6	555.8	0.0	0.1	98.1
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Gaseous Fuels	CO_2	64.1	37.3	0.0	0.1	98.1
1.A.2.f	Manufacturing Industries and Construction – Non-metallic Minerals – Liquid Fuels	CO_2	45.9	98.3	0.0	0.1	98.2
1.A.4.a	Other Sectors – Commercial/Institutional – Solid Fuels	CO_2	142.2	134.7	0.0	0.1	98.3
1.B.2.c	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Flaring – Combined	CO_2	114.1	178.9	0.0	0.1	98.3
1.A.2.g.i	Manufacturing Industries and Construction – Other – Manufacturing of Machinery – Gaseous Fuels	CO_2	41.8	88.5	0.0	0.1	98.4
1.A.2.a	Manufacturing Industries and Construction – Iron and Steel – Gaseous Fuels	CO_2	116.2	107.8	0.0	0.1	98.5
3.D.A.4	Agricultural Soils – Direct N_2O Emissions – Crop Residues	N_2O	175.5	251.3	0.0	0.1	98.5
2.A.4	Mineral Industry – Other Process Uses of Carbonates	CO_2	30.5	70.4	0.0	0.1	98.6
1.A.4.b	Other Sectors – Residential – Solid Fuels	CH_4	27.3	2.4	0.0	0.1	98.6
2.A.2	Mineral Industry – Lime	CO_2	82.6	132.5	0.0	0.1	98.7

IPCC Tier 1 category trend assessment – including LULUCF (net emissions)							
CRF Code	**IPCC categories**	**Gas**	**1990 estimate (kt CO_2-e)**	**2013 estimate (kt CO_2-e)**	**Trend assessment**	**Contribution to trend (%)**	**Cumulative total (%)**
	Production						
3.B.3	Manure Management – Swine	CH_4	58.6	44.2	0.0	0.0	98.7
1.A.3.a	Transport – Domestic Aviation – aviation Gasoline	CO_2	47.7	30.8	0.0	0.0	98.8
4.C.2	Land Converted to Grassland	CH_4	2.7	31.1	0.0	0.0	98.8
4.C.1	Grassland Remaining Grassland	N_2O	30.8	10.2	0.0	0.0	98.9
3.B.5	Agricultural Soils – Indirect N_2O Emissions	N_2O	37.5	73.4	0.0	0.0	98.9
1.B.2.c	Fugitive Emissions from Fuels – Oil and Natural Gas and Other Emissions from Energy Production – Venting – Combined	CH_4	1.4	28.5	0.0	0.0	99.0
1.A.2.b	Manufacturing Industries and Construction – Non-ferrous Metals – Gaseous Fuels	CO_2	22.9	54.8	0.0	0.0	99.0
3.A.4	Enteric Fermentation – Other – Horses	CH_4	42.3	25.8	0.0	0.0	99.0

Note: Key categories are those that comprise 95 per cent of the total.

Annex 2: Uncertainty analysis (table 3.2 of the IPCC 2006 Guidelines)

Uncertainty estimates are an essential element of a complete emissions inventory. The purpose of uncertainty information is to help prioritise efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice (IPCC, 2006).

New Zealand has followed Approach 1 for uncertainty analysis, as required by the Climate Change Convention inventory guidelines (UNFCCC, 2006) and IPCC good practice guidance (IPCC, 2006). 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 A2.1.1). Table A2.1.2 calculates the uncertainty only in emissions, that is, excluding LULUCF removals.

A2.1 Approach 1 uncertainty calculation

The uncertainty in activity data and emission and/or removal factors shown in table A2.1.1 and A2.1.2 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 Approach 1, 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 A2.1.1 and A2.1.2, 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, 2006).

The values for individual categories are an estimate of the uncertainty introduced into the trend by the category in question.

Table A2.1.1 The uncertainty calculation (including LULUCF) for New Zealand's Greenhouse Gas Inventory 1990–2013 (IPCC, Approach 1)

IPCC source category	Gas	1990 emissions or absolute value of removals (kt CO_2-e)	2013 emissions or absolute value of removals (kt CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2013 (%)	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	11,793	17,832	2.61	0.5	2.7	0.4	0.0332	0.1791	0.0166	0.6616	0.7	R	M
Energy – solid fuels	CO_2	3,211	4,107	10.89	2.2	11.1	0.4	0.0015	0.0413	0.0033	0.6354	0.6	M	M
Energy – gaseous fuels	CO_2	7,035	7,184	6.95	2.4	7.4	0.4	–0.0149	0.0722	–0.0358	0.7091	0.7	M	M
Energy – fugitive – geothermal	CO_2	229	597	5.00	5.0	7.1	0.0	0.0032	0.0060	0.0159	0.0424	0.0	D	D
Energy – fugitive – venting/flaring	CO_2	229	527	6.95	2.4	7.4	0.0	0.0025	0.0053	0.0059	0.0520	0.1	M	M
Energy – fugitive – oil transport	CO_2	0	0	5.00	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	1	6.95	5.0	8.6	0.0	0.0000	0.0000	0.0000	0.0001	0.0	D	M
IPPU – mineral production	CO_2	561.85	771.52	20.0	7.0	21.2	0.1	0.0008	0.0078	0.0056	0.2192	0.2	D	D
IPPU – chemical industry	CO_2	176.72	276.83	2.0	6.0	6.3	0.0	0.0006	0.0028	0.0036	0.0079	0.0	D	D
IPPU – metal production	CO_2	1,755.71	2,281.32	5.0	7.0	8.6	0.2	0.0012	0.0229	0.0083	0.1621	0.2	D	D
Agriculture – liming	CO_2	360.06	540.07	3.4	50.0	50.1	0.2	0.0010	0.0054	0.0485	0.0261	0.1	D	R
Agriculture – Urea application	CO_2	39.19	490.01	10.0	50.0	51.0	0.2	0.0044	0.0049	0.2219	0.0696	0.2	D	R
LULUCF – forest land	CO_2	28,571.7	23,549.3	6.1	12.3	13.7	2.636902	–0.1166	0.2366	–1.4347	2.0408	2.5	M	R
Cropland	CO2	471.3	431.7	5.23	64.74	65.0	0.2	–0.0015	0.0043	–0.0968	0.0321	0.1	M	R
Grassland	CO2	376.3	6,158.8	6.81	65.94	66.3	3.3	0.0572	0.0619	3.7723	0.5958	3.8	M	M
Wetlands	CO2	21.9	5.0	36.54	1.31	36.6	0.0	–0.0002	0.0000	–0.0003	0.0026	0.0	M	M
Settlements	CO2	1.5	4.4	22.00	186.48	187.8	0.0	0.0000	0.0000	0.0049	0.0014	0.0	M	M
Other Land	CO2	6.7	28.0	22.00	62.17	65.9	0.0	0.0002	0.0003	0.0123	0.0088	0.0	M	M
Harvested wood products	CO2	1,969.2	10,295.6	15.00	67.36	69.0	5.8	0.0790	0.1034	5.3245	2.1940	5.8	M	M
Waste – waste incineration	CO_2	0.4	1.9	50.0	40.0	64.0	0.0	0.0000	0.0000	0.0006	0.0013	0.0	D	D
Energy – liquid fuels	CH_4	68	34	2.61	50.0	50.1	0.0	–0.0005	0.0003	–0.0247	0.0013	0.0	D	M
Energy – solid fuels	CH_4	28	4	10.89	50.0	51.2	0.0	–0.0003	0.0000	–0.0154	0.0006	0.0	D	M
Energy – gaseous fuels	CH_4	43	7	6.95	50.0	50.5	0.0	–0.0005	0.0001	–0.0235	0.0007	0.0	D	M
Energy – biomass	CH_4	68	71	5.00	50.0	50.2	0.0	–0.0001	0.0007	–0.0067	0.0050	0.0	D	D
Energy – fugitive – geothermal	CH_4	55	152	5.00	5.0	7.1	0.0	0.0008	0.0015	0.0042	0.0108	0.0	D	D
Energy – fugitive – venting/flaring	CH_4	66	54	6.95	50.0	50.5	0.0	–0.0003	0.0005	–0.0138	0.0053	0.0	D	M
Energy – fugitive – coal mining & handling	CH_4	364	311	10.89	50.0	51.2	0.1	–0.0014	0.0031	–0.0688	0.0482	0.1	D	M
Energy – fugitive – transmission and	CH_4	280	188	6.95	5.0	8.6	0.0	–0.0016	0.0019	–0.0079	0.0185	0.0	D	M

IPCC source category	Gas	1990 emissions or absolute value of removals (kt CO_2-e)	2013 emissions or absolute value of removals (kt CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2013 (%)	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
distribution														
Energy – fugitive – other leakages	CH_4	337	317	5.00	50.0	50.2	0.1	–0.0010	0.0032	–0.0488	0.0225	0.1	D	D
Energy – fugitive – oil transportation	CH_4	6	7	5.00	50.0	50.2	0.0	0.0000	0.0001	–0.0002	0.0005	0.0	D	D
Agriculture – enteric fermentation	CH_4	26,310.2	28,441.1	0.0	16.0	16.0	3.7	–0.0397	0.2857	–0.6359	0.0000	0.6	M	M
Agriculture – manure management	CH_4	685.5	1,129.6	5.0	30.0	30.4	0.3	0.0029	0.0113	0.0859	0.0802	0.1	M	M
Agriculture – burning of residues	CH_4	22.6	28.0	6.0	20.0	20.9	0.0	0.0000	0.0003	0.0000	0.0024	0.0	D	R
LULUCF	CH_4	275.7	221.0	30.0	41.9	51.5	0.1	–0.0012	0.0022	–0.0499	0.0942	0.1		
Waste – solid waste disposal	CH_4	4,698.6	4,600.3	146.0	40.0	151.4	5.7	–0.0119	0.0462	–0.4768	9.5420	9.6	M	R
Waste – wastewater handling	CH_4	259.9	272.4	40.0	40.0	56.6	0.1	–0.0005	0.0027	–0.0192	0.1548	0.2	D	R
Waste – waste incineration	CH_4	0.0	0.0	50.0	100.0	111.8	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – liquid fuels	N_2O	113	169	2.61	50.0	50.1	0.1	0.0003	0.0017	0.0150	0.0063	0.0	D	M
Energy – solid fuels	N_2O	16	20	10.89	50.0	51.2	0.0	0.0000	0.0002	0.0004	0.0031	0.0	D	M
Energy – gaseous fuels	N_2O	8	8	6.95	50.0	50.5	0.0	0.0000	0.0001	–0.0009	0.0008	0.0	D	M
Energy – biomass	N_2O	44	67	5.00	50.0	50.2	0.0	0.0001	0.0007	0.0064	0.0048	0.0	D	D
IPPU – N_2O from other product use	N_2O	39.9	59.8	15.0	0.0	15.0	0.0	0.0001	0.0006	0.0000	0.0127	0.0	R	
Agriculture – agricultural soils	N_2O	6,874.7	8,453.4	0.0	74.0	74.0	5.1	–0.0001	0.0849	–0.0108	0.0000	0.0	M	M
Agriculture – manure management	N_2O	53.5	89.4	5.0	100.0	100.1	0.1	0.0002	0.0009	0.0236	0.0063	0.0	R	R
Agriculture – burning of residues	N_2O	4.8	5.8	6.0	20.0	20.9	0.0	0.0000	0.0001	0.0000	0.0005	0.0	D	R
LULUCF	N_2O	1,129.4	958.3	30.0	41.9	51.5	0.4	–0.0043	0.0096	–0.1822	0.4085	0.4	R	R
Waste – wastewater handling	N_2O	138.6	178.1	50.0	100.0	111.8	0.2	0.0001	0.0018	0.0075	0.1265	0.1	D	R
Waste – waste incineration	N_2O	1.6	1.2	50.0	100.0	111.8	0.0	0.0000	0.0000	–0.0007	0.0009	0.0	D	D
IPPU	HFCs	0.0	1,615.24		99.5	99.5	1.3	0.0162	0.0162	1.6145	0.0000	1.6	R	R
IPPU – aluminium production	PFCs	734.6	48.13	5.0	30.0	30.4	0.0	–0.0086	0.0005	–0.2582	0.0034	0.3	M	M
IPPU – consumption of perfluorocarbons	PFCs	0	0.00	20.0	5.0	20.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	R	R
IPPU	SF_6	7.3	18.69	25.0	10.0	26.9	0.0	0.0001	0.0002	0.0010	0.0066	0.0	R	R
Total emissions/removals		**99,543.9**	**122,613.9**		**Uncertainty in the year**		**11.2%**	**Uncertainty in the trend**		**12.3%**				

Note: † = Uncertainties for non-forest land in LULUCF are compiled from multiple sub-categories. Therefore, only combined uncertainty reported here. D = default; IE= included elsewhere; M = measurements; NA = not applicable; NE = not estimated; NO = not occurring; R = national referenced information.

Table A2.1.2 The uncertainty calculation (excluding LULUCF) for *New Zealand's Greenhouse Gas Inventory 1990–2013* (IPCC, Approach 1)

IPCC source category	Gas	1990 emissions or absolute value of removals (kt CO_2-e)	2013 emissions or absolute value of removals (kt CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2013 (%)	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	11,793	17,832	2.61	0.5	2.7	0.6	0.0526	0.2674	0.0263	0.9877	1.0	R	R
Energy – solid fuels	CO_2	3,211	4,107	10.89	2.2	11.1	0.6	0.0031	0.0616	0.0068	0.9486	0.9	R	R
Energy – gaseous fuels	CO_2	7,035	7,184	6.95	2.4	7.4	0.7	–0.0203	0.1077	–0.0490	1.0586	1.1	R	R
Energy – fugitive – geothermal	CO_2	229	597	5.00	5.0	7.1	0.1	0.0048	0.0090	0.0240	0.0633	0.1	D	D
Energy – fugitive – venting/flaring	CO_2	229	527	6.95	2.4	7.4	0.0	0.0037	0.0079	0.0090	0.0777	0.1	R	R
Energy – fugitive – oil	CO_2	0	0	5.00	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	1	6.95	5.0	8.6	0.0	0.0000	0.0000	–0.0001	0.0002	0.0	R	R
IPPU – mineral production	CO_2	561.85	771.52	20.0	7.0	21.2	0.2	0.0013	0.0116	0.0094	0.3273	0.3	D	D
IPPU – chemical industry	CO_2	176.72	276.83	2.0	6.0	6.3	0.0	0.0009	0.0042	0.0056	0.0117	0.0	D	D
IPPU – metal production	CO_2	1,755.71	2,281.32	5.0	7.0	8.6	0.2	0.0022	0.0342	0.0157	0.2419	0.2	D	D
Agriculture – liming	CO_2	360.06	540.07	3.4	50.0	50.1	0.3	0.0015	0.0081	0.0771	0.0389	0.1	D	R
Agriculture – Urea application	CO_2	39.19	490.01	10.0	50.0	51.0	0.3	0.0066	0.0073	0.3317	0.1039	0.3	D	R
Waste – waste incineration	CO_2	0.4	1.9	50.0	40.0	64.0	0.0	0.0000	0.0000	0.0009	0.0020	0.0	D	D
Energy – liquid fuels	CH_4	68	34	2.61	50.0	50.1	0.0	–0.0007	0.0005	–0.0359	0.0019	0.0	D	D
Energy – solid fuels	CH_4	28	4	10.89	50.0	51.2	0.0	–0.0005	0.0001	–0.0227	0.0010	0.0	D	D
Energy – gaseous fuels	CH_4	43	7	6.95	50.0	50.5	0.0	–0.0007	0.0001	–0.0345	0.0010	0.0	D	D
Energy – biomass	CH_4	68	71	5.00	50.0	50.2	0.0	–0.0002	0.0011	–0.0091	0.0075	0.0	D	D
Energy – fugitive – geothermal	CH_4	55	152	5.00	5.0	7.1	0.0	0.0013	0.0023	0.0064	0.0161	0.0	D	D
Energy – fugitive – venting/flaring	CH_4	66	54	6.95	50.0	50.5	0.0	–0.0004	0.0008	–0.0197	0.0079	0.0	R	R
Energy – fugitive – coal mining and handling	CH_4	364	311	10.89	50.0	51.2	0.2	–0.0020	0.0047	–0.0979	0.0719	0.1	R	R
Energy – fugitive – transmission and distribution	CH_4	280	188	6.95	5.0	8.6	0.0	–0.0023	0.0028	–0.0114	0.0277	0.0	R	R
Energy – fugitive – other leakages	CH_4	337	317	5.00	50.0	50.2	0.2	–0.0014	0.0048	–0.0684	0.0336	0.1	D	D
Energy – fugitive – oil transportation	CH_4	6	7	5.00	50.0	50.2	0.0	0.0000	0.0001	–0.0002	0.0007	0.0	D	D
Agriculture – enteric fermentation	CH_4	26,310.2	28,441.1	0.0	16.0	16.0	5.6	–0.0523	0.4265	–0.8375	0.0000	0.8	M	M
Agriculture – manure management	CH_4	685.5	1,129.6	5.0	30.0	30.4	0.4	0.0045	0.0169	0.1337	0.1198	0.2	M	M
Agriculture – burning of residues	CH_4	22.6	28.0	6.0	20.0	20.9	0.0	0.0000	0.0004	0.0002	0.0036	0.0	D	R

IPCC source category	Gas	1990 emissions or absolute value of removals (kt CO_2-e)	2013 emissions or absolute value of removals (kt CO_2-e)	Activity data uncertainty (%)	Emission or removal factor uncertainty (%)	Combined uncertainty (%)	Combined uncertainty as a per cent of the national total in 2013 (%)	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	4,698.6	4,600.3	146.0	40.0	151.4	8.6	–0.0166	0.0690	–0.6621	14.2449	14.3	M	R
Waste – wastewater handling	CH_4	259.9	272.4	40.0	40.0	56.6	0.2	–0.0006	0.0041	–0.0259	0.2311	0.2	D	R
Waste – waste incineration	CH_4	0.0	0.0	50.0	100.0	111.8	0.0	0.0000	0.0000	0.0000	0.0000	0.0	D	D
Energy – liquid fuels	N_2O	113	169	2.61	50.0	50.1	0.1	0.0005	0.0025	0.0238	0.0094	0.0	D	D
Energy – solid fuels	N_2O	16	20	10.89	50.0	51.2	0.0	0.0000	0.0003	0.0008	0.0046	0.0	D	D
Energy – gaseous fuels	N_2O	8	8	6.95	50.0	50.5	0.0	0.0000	0.0001	–0.0013	0.0012	0.0	D	D
Energy – biomass	N_2O	44	67	5.00	50.0	50.2	0.0	0.0002	0.0010	0.0101	0.0072	0.0	D	D
IPPU – N_2O from other product use	N_2O	39.9	59.8	15.0	0.0	15.0	0.0	0.0009	0.0009	0.0000	0.0190	0.0	R	
Agriculture – agricultural soils	N_2O	6,874.7	8,453.4	0.0	74.0	74.0	7.7	0.0016	0.1268	0.1178	0.0000	0.1	M	M
Agriculture – manure management	N_2O	53.5	89.4	5.0	100.0	100.1	0.1	0.0004	0.0013	0.0367	0.0095	0.0	R	R
Agriculture – burning of residues	N_2O	4.8	5.8	6.0	20.0	20.9	0.0	0.0000	0.0001	0.0000	0.0007	0.0	D	R
Waste – wastewater handling	N_2O	138.6	178.1		94.0	94.0	0.2	0.0001	0.0027	0.0140	0.0000	0.0	D	R
Waste – waste incineration	N_2O	1.6	1.2	50.0	100.0	111.8	0.0	0.0000	0.0000	–0.0010	0.0013	0.0	D	D
IPPU	HFCs	0.0	1,615.24		99.5	99.5	2.0	0.0242	0.0242	2.4103	0.0000	2.4	R	R
IPPU – aluminium production	PFCs	734.6	48.13	5.0	30.0	30.4	0.0	–0.0127	0.0007	–0.3796	0.0051	0.4	M	M
IPPU – consumption of perfluorocarbons	PFCs	0	0.00	20.0	5.0	20.6	0.0	0.0000	0.0000	0.0000	0.0000	0.0	R	R
IPPU	SF_6	7.3	18.69	25.0	10.0	26.9	0.0	0.0001	0.0003	0.0015	0.0099	0.0	R	R
Total emissions		**66,720.2**	**80,961.7**		**Uncertainty in the year**		**13.1%**		**Uncertainty in the trend**			**14.6%**		

Note: D = default; IE = included elsewhere; M = measurements; NA = not applicable; NE = not estimated; NO = not occurring; R = national referenced information.

Annex 3.1: Detailed methodological information for other sectors

A3.1 Agriculture

A3.1.1 Livestock population data

Agricultural Production census and survey

Details of the Agricultural Production census and survey and census are included to provide an understanding of the livestock statistics process and uncertainty values. The information here is provided by Statistics New Zealand, with full details available from the Statistics New Zealand website: www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/info-releases.aspx.

The target population for the 2013 Agricultural Production survey was all businesses that were engaged in agricultural production activity (including livestock, cropping, horticulture and forestry) or owned land that was intended for agricultural activity during the year ended 30 June 2013. The response rate or the estimated proportion of eligible businesses that responded to the 2013 Agricultural Production Survey was 83 percent. These businesses represent 87 per cent of the total estimated value of agricultural operations. 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 recent Agricultural Production surveys are provided in table A3.1.1.1.

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 A3.1.1.1 Imputation levels and sample error for recent Agricultural Production surveys

Statistic	Proportion of total estimate imputed (%)		Relative sampling errors at 95% confidence interval (%)	
Survey year	**2011**	**2013**	**2011**	**2013**
Ewe hoggets put to ram	15	15	7	3
Breeding ewes, two tooth and over	14	14	4	1
Total number of sheep	**14**	**14**	**4**	**1**
Lambs born to ewe hoggets	15	14	8	3
Lambs born to ewes	14	13	4	1
Total number of lambs	**14**	**13**	**4**	**1**
Dairy cows and heifers, in milk or calf	20	21	5	2
Total number of dairy cattle	**20**	**21**	**4**	**2**
Calves born alive to beef heifers/cows	14	22	5	2
Beef cows and heifers (in calf) one to two years	16	14	8	3
Beef cows and heifers (in calf) two years and over	14	14	4	2
Total number of beef cattle	**16**	**15**	**3**	**1**
Calves born alive to dairy heifers/cows	21	12	4	2
Female deer mated	14	12	7	2
Total number of deer	14	12	7	2
Fawns born on farm and alive at four months	14	12	7	2
Breeding sows (1 year and over)	–	7	–	2
Mated gilts	–	8	–	11
Total pigs	**–**	**6**	**–**	**1**
Area of wheat harvested	17	11	8	5
Area of barley harvested	22	15	7	4
Area of maize grain harvested	12	14	15	4

Note: The 2012 year was a census year, so imputation is zero, ie, response rate 100 per cent.

Livestock characterisation in New Zealand's Tier 2 modelling

The delineation of the major livestock categories in New Zealand's Tier 2 livestock nutritional and energy requirements modelling (table A3.1.1.2) are taken from population data collected by Statistical Production census and survey and the Ministry for Primary Industries slaughter statistics.

Table A3.1.1.2 Characterisation of major livestock subcategories (dairy cattle, non-dairy cattle, sheep and deer) in New Zealand's Tier 2 livestock modelling

Livestock category		Subcategory
Dairy cattle	Dairy cattle subcategories	Milking cows and heifers
		Growing females < 1 year
		Growing females 1–2 years
		Breeding bulls
	Dairy data: geographical regions	Northland
		Auckland
		Waikato
		Bay of Plenty
		Gisborne
		Hawke's Bay

Livestock category		Subcategory
		Taranaki
		Manawatu-Wanganui
		Wellington
		Tasman
		Nelson
		Marlborough
		West Coast
		Canterbury
		Otago
		Southland
Non-dairy (beef) cattle subcategories		Breeding growing cows 0–1 year
		Breeding growing cows 1–2 years
		Breeding growing cows 2–3 years
		Breeding mature cows
		Breeding Bulls – mixed age
		Slaughter heifers 0–1 year
		Slaughter heifers 1–2 years
		Slaughter steers 0–1 year
		Slaughter steers 1–2 years
		Slaughter Bulls 0–1 years
		Slaughter Bulls 1–2 years
Sheep subcategories		Dry ewes
		Mature Breeding ewes
		Growing breeding sheep
		Growing non-breeding sheep
		Wethers
		Lambs
		Rams
Deer subcategories		Breeding hinds
		Hinds < 1 year
		Hinds 1–2 years
		Stags < 1 year
		Stags 1–2 years
		Stags 2–3 years
		Mixed age and breeding stags

A3.1.2 Key parameters and emission factors used in the Agriculture sector

Table A3.1.2.1 Proportion of annual milk yield each month for major livestock categories

Month	Dairy cattle	Non-dairy cattle	Sheep	Deer
July	0.00880	0	0	0
August	0.05779	0	0	0
September	0.12132	0.167	0.25	0
October	0.15035	0.167	0.25	0
November	0.14247	0.167	0.25	0.1
December	0.12816	0.167	0.25	0.258333333
January	0.11094	0.167	0	0.258333333
February	0.09004	0.167	0	0.233333333
March	0.08514	0	0	0.15
April	0.06544	0	0	0
May	0.03347	0	0	0
June	0.00607	0	0	0

Source: Dairy Companies Association New Zealand (www.dcanz.com/statistics), Suttie (2012), and Pickering and Wear (2013)

Table A3.1.2.2 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[45]
EF_{HORSES}	Enteric fermentation – horses	IPCC (2006), table 10.10	18
EF_{MULES}	Enteric fermentation – mules and asses	IPCC (2006), table 10.10	10
EF_{SWINE}	Enteric fermentation – swine	Hill (2012) IPCC (2000)	1.06
EF_{ALPACA}	Enteric fermentation – alpaca	IPCC (2006), table 10.10	8
MM_{GOATS}	Manure management – goats	IPCC (2006), table 10.15	0.18
MM_{HORSES}	Manure management – horses	IPCC (2006), table 10.15	2.34
MM_{MULES}	Manure management – mules and asses	IPCC (2006), table 10.15	1.1
MM_{SWINE}	Manure management – swine	Hill (2012) IPCC (2000)	5.94
$MM_{BROILERs}$	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[46]	0.091

45 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 2010-2013 are interpolated and extrapolated based on an assumption that the dairy goat population has remained in a near constant state over time.

46 As was reported in 2010 submission, i.e. the first year that alpacas were included in *New Zealand's Greenhouse Gas Inventory* (Ministry for the Environment, 2010).

Table A3.1.2.3 Emission factors for New Zealand's agriculture nitrous oxide emissions

Emission factor	Emissions	Source	Parameter value
EF_1 (kg N_2O-N/kg N)	Direct emissions from nitrogen input to soil	Kelliher and de Klein (2006)	0.0100
$EF_{1\text{-UREA}}$ (kg N_2O-N/kg N)	Direct emissions from nitrogen input to soil from urea fertiliser	Kelliher et al. 2014	0.0048
EF_2 (kg N_2O-N/ha-yr)	Direct emissions from organic soil mineralisation due to cultivation	IPCC (2006), table 11.1	8.0000
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	0.0200
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)	0.0100
$EF_{3(PRP\ DUNG)}$ (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	0.0050
$EF_{3POULTRY}$ (kg N_2O-N/kg N excreted)	Direct emissions from waste in other animal waste management systems – poultry specific	Fick et al (2011)	0.0010
EF_4 (kg N_2O-N/kg NH_x-N)	Indirect emissions from volatising nitrogen	IPCC (2006), table 11.3	0.0100
EF_5 (kg N_2O-N/kg N leached and run-off)	Indirect emissions from leaching nitrogen	IPCC (2006), table 11.3	0.0075

Table A3.1.2.4 Parameter values for New Zealand's agriculture nitrous oxide emissions

Parameter (fraction)	Fraction of the parameter	Source	Parameter value
FracGASF (kg NH3-N + NOx-N/kg of synthetic fertiliser N applied)	Total synthetic fertiliser emitted as NOx or NH3	IPCC (2006) verified by Sherlock et al (2008)	0.1
FracGASM (kg NH3-N + NOx-N/kg of N excreted by livestock)	Total nitrogen emitted as NOx or NH3	Sherlock et al (2008)	0.1
FracLEACH(-H) (kg N/kg fertiliser or manure N)	Nitrogen input to soils that is lost through leaching and run-off	Thomas et al (2003, 2005)	0.07
FracBURN (kg N/kg crop-N)	Crop residue burned in fields	Thomas et al. (2008, table 14)	Crop specific survey data
FracBURNL (kg N/kg legume-N)	Legume crop residue burned in fields	Thomas et al. (2008) Practice does not occur in New Zealand	0
FracRENEW	Fraction of land undergoing pasture renewal	Thomas et al. (2014)	Year-specific
FracREMOVE	Fraction of N in above-ground residues removed for bedding, feed or construction	Thomas et al. (2014) Practice does not occur in New Zealand	0
FracFUEL (N/kg N excreted)	Livestock nitrogen excretion in excrements burned for fuel	Practice does not occur in New Zealand	0

Table A3.1.2.5 Parameter values for New Zealand's cropping emissions (Thomas et al, 2011)

Crop	HI	dmf	AG_N	Root Shoot ratio R_{BG}	BG_N
Wheat	0.41	0.86	0.005	0.1	0.009
Barley	0.46	0.86	0.005	0.1	0.009
Oats	0.3	0.86	0.005	0.1	0.009
Maize grain	0.5	0.86	0.007	0.1	0.007
Field seed peas	0.5	0.21	0.02	0.1	0.015
Lentils	0.5	0.86	0.02	0.1	0.015
Peas fresh and process	0.45	0.86	0.03	0.1	0.015
Potatoes	0.9	0.22	0.02	0.1	0.01
Onions	0.8	0.11	0.02	0.1	0.01
Sweet corn	0.55	0.24	0.009	0.1	0.007
Squash	0.8	0.2	0.02	0.1	0.01
Herbage seeds	0.11	0.85	0.015	0.1	0.01
Legume seeds	0.09	0.85	0.04	0.1	0.01
Brassica seeds	0.2	0.85	0.01	0.1	0.008

Source: Thomas et al (2011)

A3.2 Supplementary information for the LULUCF sector

A3.2.1 Uncertainty analysis for the LULUCF sector

This section contains the disaggregated uncertainty analysis for the LULUCF sector. This additional information has been provided as a result of the review of New Zealand's 2010 inventory (2012 submission). One of the recommendations of that review was that New Zealand provides "a detailed disaggregated assessment of uncertainty, as well as the aggregated uncertainty associated with the LULUCF sector, consistent with the IPCC good practice guidance for LULUCF". This information is now provided in table A3.2.1.

Table A3.2.1 Uncertainty analysis for the LULUCF sector

IPCC source category	Gas	1990 emissions or absolute value of removals (kt CO_2-e)	2012 emissions or absolute value of removals (kt CO_2-e)	Activity data uncertainty (%)	Emission factor uncertainty (biomass) (%)	Emission factor uncertainty (mineral soil) (%)	Combined uncertainty (%)	Contribution to variance by category in 2012 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in trend in LULUCF emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in LULUCF emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total LULUCF emissions (%)	Emission factor quality indicator	Activity data quality indicator
Pre-1990 natural forest remaining pre-1990 natural forest	CO_2	6,177.7	6,107.8	5.0	39.6	7.9	39.9	9.4	1.5	21.6	0.59	0.1	0.6	M	M
Land converted to pre-1990 natural forest	CO_2	163.8	38.7	5.0	39.6	7.9	38.1	0.1	–0.4	0.1	–0.16	0.0	0.2	M	M
Pre-1990 planted forest remaining pre-1990 planted forest	CO_2	–5,042.2	–4,472.1	5.0	12.4	12.3	195.5	33.6	0.6	–15.8	0.07	0.0	0.1	M	M
Land converted to pre-1990 planted forest	CO_2	2,7370.1	4,728.3	5.0	12.4	12.3	8.7	1.6	–71.6	16.7	–8.86	–5.1	10.2	M	M
Post-1989 forest remaining post-1989 forest	CO_2	0.0	0.0	8.0	8.6	10.4	0.0	0.0	0.0	0.0	0.00	0.0	0.0	M	M
Land converted to post-1989 planted forest	CO_2	–97.8	17,146.5	8.0	8.6	10.4	8.5	5.6	60.9	60.6	5.23	6.9	8.6	M	M
G-WB remaining G-WB	CO_2	–37.8	–25.6	83.0	75.0	7.3	122.4	0.1	0.0	–0.1	0.02	0.0	0.0	M	M
Land converted to G-WB	CO_2	492.8	85.7	83.0	75.0	7.3	110.2	0.4	–1.3	0.3	–0.97	–1.5	1.8	M	M
G-HP remaining G-HP	CO_2	–1,130.0	–1,114.8	8.0	75.0	5.8	90.4	3.9	–0.3	–3.9	–0.20	0.0	0.2	M	M
Land converted to G-HP	CO_2	384.4	150.6	8.0	75.0	5.8	18.0	0.1	–0.7	0.5	–0.54	–0.1	0.5	M	M
G-LP remaining G-LP	CO_2	–232.1	–224.8	8.0	75.0	7.3	90.4	0.8	0.0	–0.8	–0.03	0.0	0.0	M	M
Land converted to G-LP	CO_2	146.5	–5,029.9	8.0	75.0	7.3	12.1	2.3	–18.2	–17.8	–13.69	–2.1	13.8	M	M
Cropland – perennial remaining cropland – perennial	CO_2	–80.7	–75.1	8.0	75.0	14.1	90.4	0.3	0.0	–0.3	0.00	0.0	0.0	M	M
Land converted to cropland – perennial	CO_2	–48.7	–14.7	8.0	75.0	14.1	450.8	0.3	0.1	–0.1	0.08	0.0	0.1	M	M
Cropland –-annual	CO_2	–267.8	–258.8	8.0	75.0	9.7	90.4	0.9	0.0	–0.9	–0.03	0.0	0.0	M	M

IPCC source category	Gas	1990 emissions or absolute value of removals (kt CO_2-e)	2012 emissions or absolute value of removals (kt CO_2-e)	Activity data uncertainty (%)	Emission factor uncertainty (biomass) (%)	Emission factor uncertainty (mineral soil) (%)	Combined uncertainty (%)	Contribution to variance by category in 2012 (%)	Type A sensitivity (%)	Type B sensitivity (%)	Uncertainty in trend in LULUCF emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in LULUCF emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total LULUCF emissions (%)	Emission factor quality indicator	Activity data quality indicator
remaining cropland – annual															
Land converted to cropland – annual	CO_2	–74.1	–83.1	8.0	75.0	9.7	27.6	0.1	–0.1	–0.3	–0.04	0.0	0.0	M	M
Wetlands – open water remaining wetlands – open water	CO_2	0.0	0.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	M	M
Land converted to wetlands – open water	CO_2	22.4	–5.5	33.0	0.0	0.0	83.9	0.0	–0.1	0.0	0.00	0.0	0.0	M	M
Wetlands – vegetative non-forest remaining wetlands – vegetative non-forest	CO_2	0.0	0.0	33.0	75.0	12.3	0.0	0.0	0.0	0.0	0.00	0.0	0.0	M	M
Land converted to wetlands – vegetative non-forest	CO_2	–0.5	0.5	33.0	75.0	12.3	18.1	0.0	0.0	0.0	0.00	0.0	0.0	M	M
Settlements remaining settlements	CO_2	0.0	0.0	22.0	75.0	95.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	M	M
Land converted to settlements	CO_2	–1.5	4.4	22.0	75.0	95.0	80.3	0.0	0.0	0.0	0.02	0.0	0.0	M	M
Other land remaining other land	CO_2	0.0	0.0	22.0	75.0	70.7	0.0	0.0	0.0	0.0	0.00	0.0	0.0	M	M
Land converted to other land	CO_2	–6.7	–28.0	22.0	75.0	70.7	29.4	0.0	–0.1	–0.1	–0.06	0.0	0.1	M	M
Harvested wood products	CO_2	1,969.2	10,295.6	15.0	67.4	–	68.2	27.0	30.0	36.4	20.18	6.4	21.2	M	M
LULUCF CH_4 (CO_2-e)	CH_4	–75.2	–60.3	30.0	41.9	–	51.5	0.4	0.1	–0.8	0.05	0.0	0.1	R	R
LULUCF N_2O (CO_2-e)	N_2O	–308.0	–261.4	30.0	41.9	–	51.5	1.9	0.3	–3.4	0.12	0.1	0.2	R	R

Note: G-HP = high producing grassland; G-LP = low producing grassland; G-WB = grassland with woody biomass; M = measurements.

A3.2.2 LUCAS Data Management System

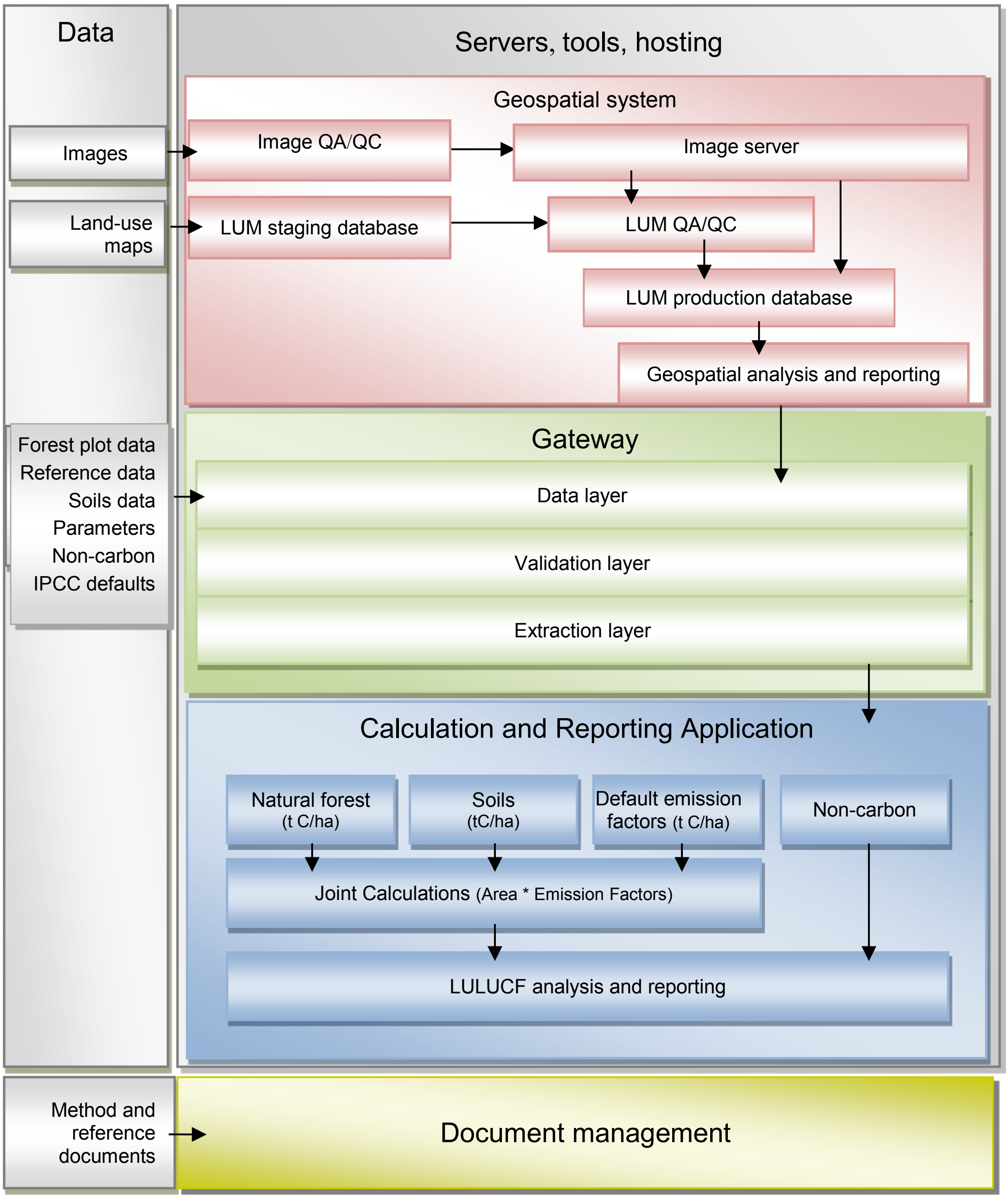
The LUCAS Data Management System stores, manages and archives data for international greenhouse gas reporting for the LULUCF sector. These systems are used for managing the land-use spatial databases, plot and reference data, and for combining the two sets of data to calculate the numbers required for Climate Change Convention and Kyoto Protocol reporting (figure A3.2.1).

The data collected is stored and manipulated within three systems: the Geospatial System, the Gateway, and the Calculation and Reporting Application.

The key objectives of these systems are to:

- provide a transparent system for data storage and carbon calculations
- provide a repository for the versioning and validation of plot measurements and land-use data
- calculate carbon stocks, emissions and removals per hectare for land uses and carbon pools based on the plot and spatial data collected
- calculate biomass burning emissions by land use based on area and emission factors stored in the Gateway
- produce the outputs required for the LULUCF sector reporting under the Climate Change Convention and the Kyoto Protocol
- archive all inputs and outputs used in reporting.

Figure A3.2.1 New Zealand's LUCAS data management system



Note: LUM = land-use map. Joint calculations are described below.

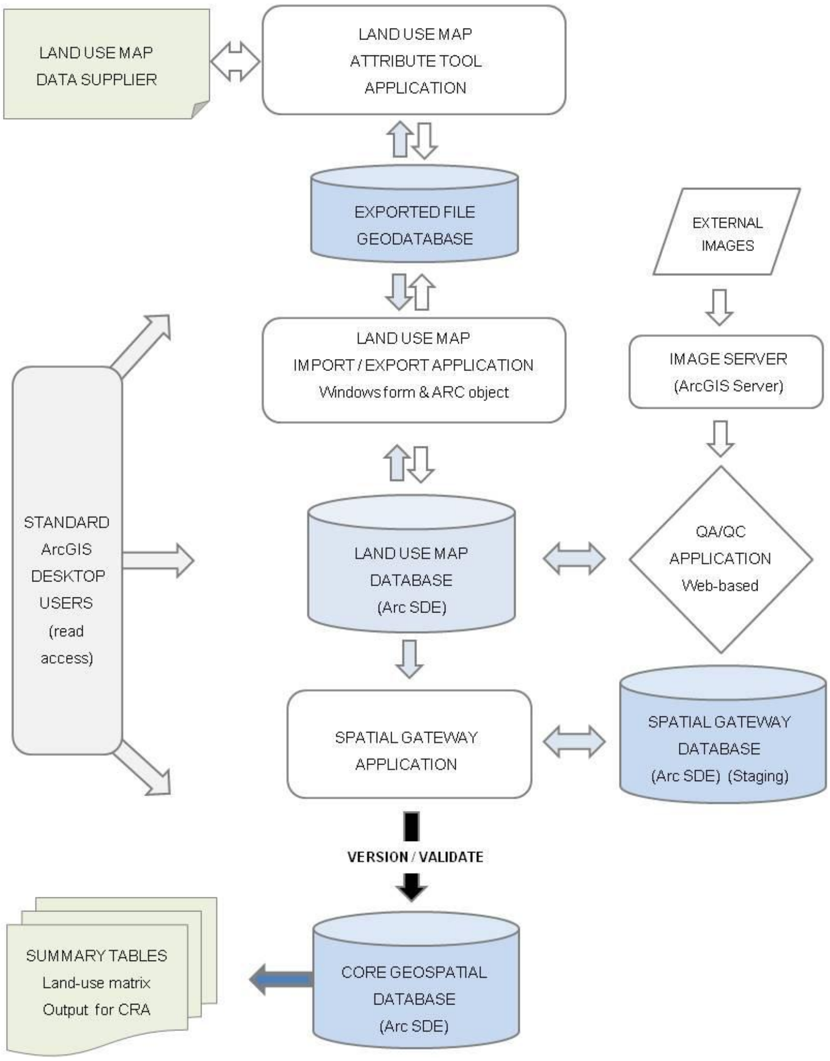
The module 'Joint Calculations' refers to the process New Zealand uses to estimate national average carbon values by carbon pool for each land-use category and subcategory.

The Joint Calculation process is performed within the Calculation and Reporting Application. Within the Joint Calculations interface, the user selects the appropriate area data and emission factors. The results of the calculations are carbon gains, losses and net change for all land-use subcategories whether in a conversion state or land remaining land, by year, by carbon pool, and stratified by North Island or South Island.

Geospatial System

The Geospatial System consists of hardware and specific applications designed to meet LULUCF reporting requirements. The hardware largely comprises servers for spatial database storage, management, versioning and running web-mapping applications. The core components of the Geospatial System are outlined in figure A3.2.2.

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. The five components within the LUM functionality are:

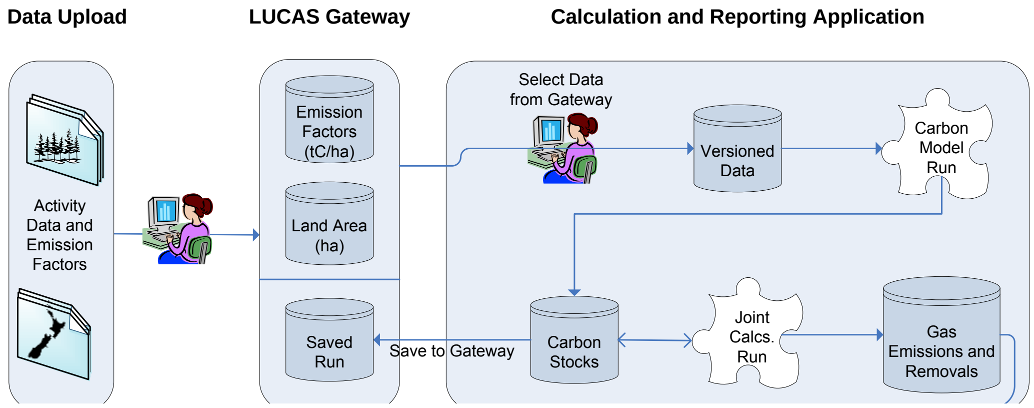
- LUM Import/Export Application – which provides functionality for managing the importing and exporting of land-use mapping information in to and out of the database
- LUM Attribute Tool Application – an extension to the standard ArcGIS Desktop software that facilitates maintenance and updates to the land-use mapping data by external contractors
- LUM Database – a non-versioned GIS database for interim land-use mapping data and related quality assurance and control observation data
- Spatial Gateway Application – which is used to validate and version data from the LUM database prior to loading into the Core Geospatial Database. Spatial gateway rules are stored in the Spatial Gateway Database

- Core Geospatial Database – which stores final versioned geospatial data sets that are used by the Summary Calculation application to generate land-use matrix data. It also stores the summary tables produced.

LUCAS Management Studio

The LUCAS Management Studio (figure A3.2.3) is the package of applications used to store activity data and calculate and report New Zealand's emissions and removals for LULUCF. The LUCAS Gateway is a data warehouse with the purpose of storing, versioning and validating activity data and emission factors. The Calculation and Reporting Application sources all data from the Gateway and calculates and outputs New Zealand's emissions and removals for LULUCF for land remaining land and land converted to another land use, by pool and year.

Figure A3.2.3 LUCAS Management Studio



LUCAS Gateway

The LUCAS Gateway enables the storage of activity data such as: field plot data, land-use area, biomass burning and other data, such as IPCC defaults, needed by the Calculation and Reporting Application.

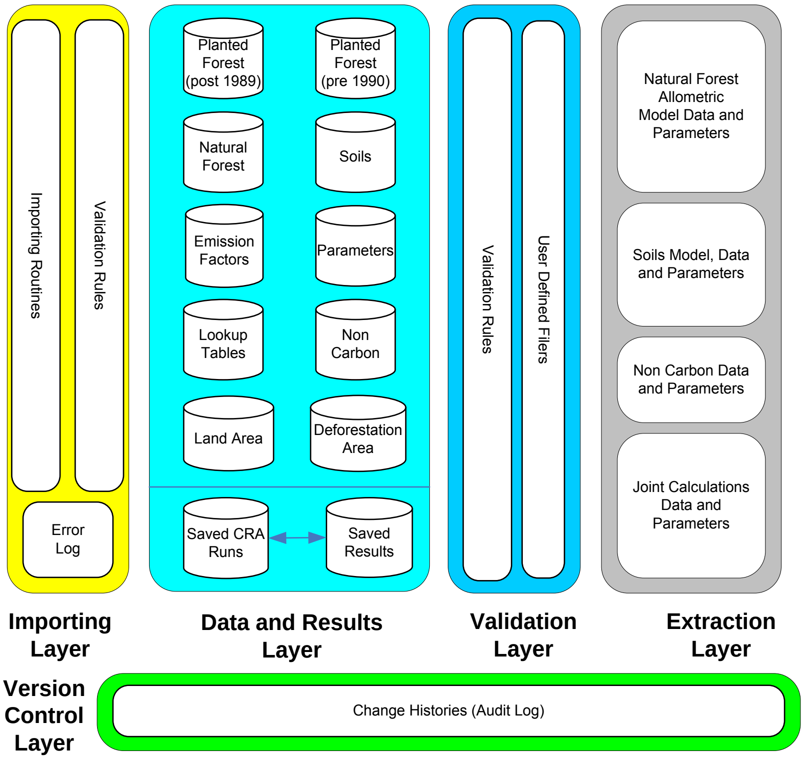
The LUCAS Gateway provides a viewing, querying and editing interface to the source (plot, land-use area, carbon and non-carbon) data. It also stores any published or saved results from running the Calculation and Reporting Application.

All activity data and emission factors are stored within the Gateway database (figure A3.2.4). It contains the following key components.

- A data and results layer contains all activity data (natural, planted forest, soils, default carbon, non-carbon, land-use areas, land-use change and reference tables). The user has the ability to create a 'snapshot' in time (a data set archiving system) of the data held in the Gateway. This enables users of the Calculation and Reporting Application to select from a range of data snapshots and ensures past results can be replicated over time.
- A validation layer allows users to judge the suitability of data for use in the Calculation and Reporting Application calculations, subsequent to passing primary validation. Where records are deemed not acceptable for use within published reports, they are tagged as 'invalid' in the LUCAS Gateway database.
- An audit trail provides a history of any changes to the database tables within the Gateway.

- Versioning at a number of levels ensures any changes to data, schema or the database itself are logged and versioned, while providing the user with the ability to track what changes have been applied and roll back to a previous version if required. The results of saved or published reports within the Calculation and Reporting Application are also stored within the Gateway for repeatability and reference.
- Primary data validation, both during data capture and during import of the data into the Gateway, ensures only data that has passed acceptability criteria is available for a publishable Calculation and Reporting Application run.
- Hosting and application support provides hosting services, system security, backup and restore, daily maintenance and monitoring for the Gateway and Calculation and Reporting Application.

Figure A3.2.4 LUCAS Gateway database



Calculation and Reporting Application

The Calculation and Reporting Application enables users to import carbon and non-carbon data from the Gateway and, by running the various modules, determine emissions and removals by New Zealand's forests, cropland, grassland and other land-use types. This information, combined with land-area data, enables New Zealand to meet its reporting requirements under the Climate Change Convention and Kyoto Protocol.

The Calculation and Reporting Application allows for the inclusion of other data sets, models and calculations without the complete redesign of the applications. All models, data and results are versioned, and the Calculation and Reporting Application allows the user to alter specific key values within a model or calculation (parameters) without the intervention of a programmer or technical support officer. The Calculation and Reporting Application is deployed as a client-based application that sources the required data from the Gateway.

The Calculation and Reporting Application comprises four modules: natural forest, soils, non-carbon, and joint calculations. Any of these modules can be run independently or as a group. The results are provided as 'views' to the user at the completion of the run.

To activate the module, the user selects the module to run within the Calculation and Reporting Application, the version of the data set to be used, the model version and other calculation parameters. The natural forest and soil carbon modules use R statistical language as the base program language, while the non-carbon module and joint calculations module are developed in C Sharp programming language (C#).

Within the joint calculations module, the user has the option of using the carbon results from running the modules or using default carbon estimates (based on published reports) stored within the Gateway. The joint calculations module combines the carbon estimates with the land-use area to calculate carbon stock and change following the methodology set out in section 3.1.4 of the *Good Practice Guidance for Land Use, Land-use Change and Forestry* (IPCC, 2003). The results represent carbon stock and change for every 'from' and 'to' land-use combination outlined by the IPCC since 1990.

On completion of running a module, the results can be saved or published back to the Gateway. This provides a versioned and auditable record of the results used for reporting. If the results are saved or published, other information, such as the time created, the user's identification and the module-particular parameters that were used, is also saved for tracking and audit control.

The Calculation and Reporting Application is maintained and supported by Interpine Forestry Limited, a New Zealand-based company that specialises in forestry inventories and related information technology development. Interpine Forestry Limited also provides support services, such as database and application back-ups and system security (firewalls and virus control), day-to-day issue resolution and enhancement projects to the Gateway or Calculation and Reporting Application, as required.

Any changes to the data or table structure within the Gateway, or to people accessing the Gateway or Calculation and Reporting Application, are tracked via audit logs. For any changes to the data within the Gateway, the person making the change, the date, reason for change and the version are logged and reports are made available to the users for review.

Document management

All reference material, including scientific reports containing information on methodologies or emission factors used in the production of the LULUCF and Kyoto Protocol estimates, is archived on the Ministry for the Environment's document management store SilentOne.

The emission factors and area estimates just for published runs are also archived within Gateway and can be accessed via the Gateway or the Calculation and Reporting Application.

Annex 3: References

Some references may be downloaded directly from the following webpage: www.mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/agriculture-greenhouse-gas-inventory-reports/

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

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Annex 4: 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 A4.1 – A4.4. Where Intergovernmental Panel on Climate Change (IPCC) default emission factors are used, a net-to-gross factor as above is used to account for New Zealand activity data representing gross energy figures:

$$\text{Gross EF} = \text{Net EF} \times \text{Factor.}$$

Table A4.1 Gross carbon dioxide emission factors used for New Zealand's energy sector in 2012

	Emission factor ($t\ CO_2/TJ$)	Emission factor (t C/TJ)	Source
Gas			
Maui	52.26	14.3	1
Kapuni	53.34	14.5	1
McKee	53.35	14.6	3
Kaimiro	54.53	14.9	3
Ngatoro	54.53	14.9	3
TAWN	52.72	14.4	3
Mangahewa	53.31	14.5	3
Turangi	54.96	15.0	3
Pohokura	53.59	14.6	1
Rimu/Kauri	52.04	14.2	3
Maari	53.56	14.6	3
Weighted Average	53.24	14.5	
Kapuni LTS	85.84	23.4	1
Methanol - Mixed Feed – to 94	62.44	17.0	3
Methanol – LTS – to 94	83.97	22.9	3
Liquid fuels			
Crude oil	66.72	18.2	5
Regular petrol	66.51	18.1	4
Petrol – premium	0.00	0.0	4
Diesel (10 parts (sulphur) per million)	0.00	0.0	4
Jet kerosene	69.57	19.0	4
Av gas	69.57	19.0	4
LPG	70.17	19.1	2
Heavy fuel oil	72.50	19.8	4
Light fuel oil	73.46	20.0	4
Power station fuel oil	72.98	19.9	4
Bitumen (asphalt)	73.83	20.1	4
Biomass			
Biogas	100.98	27.5	5
Wood (industrial)	104.15	28.4	5
Bioethanol	64.20	17.5	6
Biodiesel	62.40	17.0	6
Wood (residential)	104.15	28.4	5
Coal			
All sectors excl. electricity (sub-bituminous)	91.99	25.1	7
All sectors (bituminous)	89.13	24.3	7
All sectors (lignite)	93.11	25.4	7

1. Derived by the transmission operator (Vector Ltd) through averaging daily gas composition data.
2. *New Zealand Energy Information Handbook* (Baines, 1993).
3. Specific gas field operator.
4. New Zealand Refinery Company.
5. IPCC guidelines (1996).
6. *New Zealand Energy Information Handbook: Energy data conversion factors and definitions* (Eng, Bywater & Hendtlass, 2008).
7. *Review of Default Emissions Factors in Draft Stationary Energy and Industrial Processes Regulations: Coal* (CRL Energy, 2009).

Table A4.2 Consumption-weighted average emission factors used for New Zealand's sub-bituminous coal-fired electricity generation for 1990 to 2012

	Emission factor ($t CO_2/TJ$)
1990	91.20
1991	91.24
1992	91.29
1993	91.33
1994	91.38
1995	91.42
1996	91.47
1997	91.51
1998	91.56
1999	91.60
2000	91.64
2001	91.69
2002	91.73
2003	91.78
2004	91.82
2005	91.87
2006	91.91
2007	92.43
2008	92.31
2009	92.39
2010	92.20
2011	92.00
2012	92.00
2013	92.00

Table A4.3 Methane emission factors used for New Zealand's energy sector for 1990 to 2013

	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 1–7) oil – aviation
Coal		
Combustion		
Electricity generation	0.67	IPCC Tier 2 (table 1–15) pulverised bituminous combustion – dry bottom, wall fired
Cement	0.95	IPCC Tier 2 (table 1–17) cement, lime coal kilns
Lime	0.95	IPCC Tier 2 (table 1–17) cement, lime coal kilns
Industry	0.67	IPCC Tier 2 (table 1–16) dry bottom, wall fired coal boilers
Commercial	9.50	IPCC Tier 2 (table 1–19) coal boilers
Residential	285.00	IPCC Tier 1 (table 1–7) coal – residential
Biomass		
Wood stoker boilers	14.25	IPCC Tier 2 (table 1–16) wood stoker boilers
Wood – fireplaces	285.00	IPCC Tier 1 (table 1–7) wood – residential
Bioethanol	18.00	IPCC Tier 1 (table 3.2.2) – ethanol, cars, Brazil
Biodiesel	18.00	IPCC Tier 1 (table 3.2.2) – ethanol, cars, Brazil
Biogas	1.08	IPCC Tier 2 (table 1–19) gas boilers

Table A4.4 Nitrous oxide emission factors used for New Zealand's energy sector for 1990 to 2013

	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

A4.1 Emissions from liquid fuels

A4.1.1 Activity data and uncertainties

The *Delivery of Petroleum Fuels by Industry Survey* conducted by the Ministry of Business, Innovation and Employment. As it is a census, there is no sampling error. The only possible sources or error are non-sample error (such as respondent error and processing error). The 2013 statistical difference for liquid fuels in the balance table of the *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2014) was 2.6 per cent. This is used as the activity data uncertainty for liquid fuels in 2013.

A4.1.2 Emission factors and uncertainties

The carbon dioxide emission factors are described in table A4.1. Table A4.5 shows a complete time series of gross calorific values, while table A4.6 shows a complete time series of carbon content of liquid fuels. This information is supplied by the New Zealand Refinery Company and is used in the calculation of annual emission factors for liquid fuels.

A 2009 consultant report (Hale and Twomey, 2009) to the Ministry for the Environment estimates the uncertainty of carbon dioxide emission factors for liquid fuels at ±0.5 per cent. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

Table A4.5 Gross calorific values (MJ/kg) for liquid fuels for 1990 to 2013

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Av gas	Heavy fuel oil	Light fuel oil	Power station fuel oil	Bitumen (asphalt)
1990	47.24	47.22	45.76	46.37	47.30	43.07	44.12	42.71	41.30
1991	47.17	47.17	45.73	46.38	47.30	43.02	44.07	42.70	41.30
1992	47.18	47.14	45.75	46.41	47.30	43.03	44.14	42.72	41.30
1993	47.09	47.14	45.74	46.36	47.30	43.01	44.13	42.75	41.31
1994	47.10	47.11	45.75	46.34	47.30	43.03	44.16	42.70	41.30
1995	47.07	47.14	45.59	46.31	47.30	43.03	44.01	42.69	41.30
1996	46.91	47.14	45.54	46.26	47.30	43.00	43.98	42.68	41.30
1997	46.93	47.17	45.58	46.32	47.30	42.92	43.92	42.56	41.30
1998	46.89	47.12	45.64	46.27	47.30	43.06	44.02	42.79	41.27
1999	46.92	47.13	45.56	46.29	47.30	43.09	43.93	42.79	41.28
2000	46.91	47.12	45.58	46.22	47.30	43.07	43.90	42.74	41.27
2001	46.92	47.15	45.64	46.25	47.30	43.08	43.96	42.76	41.27
2002	46.90	47.16	45.62	46.29	47.30	43.03	43.84	42.79	41.26
2003	46.87	47.11	45.61	46.23	47.30	43.06	43.79	42.77	41.27
2004	46.91	47.10	45.59	46.25	47.30	43.04	43.90	42.79	41.30
2005	46.95	47.10	45.73	46.28	47.30	43.11	43.94	42.78	41.30
2006	46.97	47.09	45.79	46.23	47.30	42.93	43.68	42.65	41.30
2007	46.97	47.10	45.77	46.23	47.30	42.97	43.72	42.66	41.30
2008	46.93	47.06	45.72	46.19	47.30	42.86	43.72	42.56	41.30
2009	46.95	47.03	45.72	46.17	47.30	42.89	43.75	42.56	41.29
2010	46.96	47.03	45.69	46.17	47.30	42.95	43.70	42.62	41.29
2011	46.96	47.04	45.69	46.19	47.30	42.89	43.72	42.61	41.27
2012	46.98	47.03	45.66	46.18	47.30	43.03	43.71	42.72	41.27
2013	46.99	47.05	45.71	46.23	47.30	43.05	43.84	42.72	41.26

Table A4.6 Carbon content (per cent mass) for liquid fuels for 1990 to 2013

	Premium petrol	Regular petrol	Diesel	Jet kerosene	Av gas	Heavy fuel oil	Light fuel oil	Power station fuel oil	Bitumen (asphalt)
1990	84.87	84.92	86.28	85.92	85.00	86.22	86.67	86.03	86.57
1991	85.04	85.04	86.33	85.89	85.00	86.26	86.30	86.04	86.57
1992	85.03	85.13	86.29	85.84	85.00	86.25	86.18	86.03	86.57
1993	85.25	85.13	86.32	85.94	85.00	86.27	86.20	86.00	86.56
1994	85.21	85.19	86.30	85.99	85.00	86.25	86.13	86.04	86.57
1995	85.30	85.13	86.63	86.05	85.00	86.25	86.39	86.05	86.57
1996	85.66	85.13	86.73	86.16	85.00	86.28	86.45	86.05	86.57
1997	85.63	85.04	86.64	86.04	85.00	86.35	86.55	86.16	86.58
1998	85.72	85.17	86.52	86.14	85.00	86.22	86.39	85.97	86.63
1999	85.65	85.15	86.69	86.10	85.00	86.20	86.53	85.96	86.63
2000	85.67	85.16	86.64	86.25	85.00	86.22	86.58	86.01	86.63
2001	85.65	85.09	86.53	86.18	85.00	86.21	86.49	85.98	86.64
2002	85.68	85.06	86.57	86.10	85.00	86.25	86.68	85.96	86.66
2003	85.76	85.19	86.58	86.23	85.00	86.23	86.76	85.98	86.63
2004	85.66	85.22	86.62	86.20	85.00	86.24	86.58	85.97	86.58
2005	85.58	85.22	86.62	86.12	85.00	86.18	86.52	85.97	86.57
2006	85.54	85.25	86.57	86.24	85.00	86.34	86.93	86.08	86.57
2007	85.54	85.23	86.61	86.24	85.00	86.30	86.87	86.07	86.57
2008	85.63	85.32	86.70	86.32	85.00	86.39	86.87	86.16	86.57
2009	85.56	85.38	86.72	86.36	85.00	86.37	86.83	86.16	86.60
2010	85.54	85.40	86.77	86.35	85.00	86.31	86.90	86.11	86.59
2011	85.55	85.37	86.78	86.32	85.00	86.37	86.87	86.12	86.64
2012	85.51	85.38	86.84	86.34	85.00	86.25	86.89	86.02	86.63
2013	85.49	85.35	86.73	86.22	85.00	86.24	86.68	86.02	86.65

A4.2 Emissions from solid fuels

A4.2.1 Activity data and uncertainties

The *New Zealand Quarterly Statistical Return of Coal Production and Sales* conducted by the Ministry of Business, Innovation and Employment has full coverage of the sector, meaning there is no sampling error. The only possible sources or error are non-sample error (such as respondent error and processing error). The 2012 statistical difference for solid fuels in the balance table of *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2013) was 10.9 per cent. This is used as the activity data uncertainty for solid fuels in 2013.

A4.2.2 Emission factors and uncertainties

The estimated uncertainty in carbon dioxide emission factors for solid fuels is ±2.2 per cent. This is based on the difference between the range of updated emission factors for the three different ranks of coal used in New Zealand. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

A4.3 Emissions from gaseous fuels

A4.3.1 Activity data

Through the various surveys and information collected by the Ministry of Business, Innovation and Employment, it has full coverage of the natural gas sector. This means that there is no sampling error in natural gas statistics and the only possible sources or errors are non-sample error (such as respondent error and processing error). The 2012 statistical difference for gaseous fuels in the balance table of *Energy in New Zealand* (Ministry of Business, Innovation and Employment, 2014) was 7.0 per cent. This is used as the activity data uncertainty for gaseous fuels in 2013.

A4.3.2 Emission factors

The estimated uncertainty in carbon dioxide emission factors for gaseous fuels is ±2.4 per cent. This is based on the difference between the range of emission factors for three large gas fields in New Zealand. Together, these gas fields made up over 65 per cent of New Zealand's total gas supply in 2013. The uncertainty for methane and nitrous oxide emission factors is ±50 per cent as almost all emission factors are IPCC defaults.

Table A4.7 Emission factors for European gasoline and diesel vehicles – COPERT IV model (European Environment Agency, 2007)

	N_2O emission factors (mg/km)				CH_4 emission factors (mg/km)			
	Urban		Rural	Highway	Urban		Rural	Highway
	Cold	Hot			Cold	Hot		
Passenger car								
Gasoline								
pre-Euro	10	10	6.5	6.5	201	131	86	41
Euro 1	38	22	17	8	45	26	16	14
Euro 2	24	11	4.5	2.5	94	17	13	11
Euro 3	12	3	2	1.5	83	3	2	4
Euro 4	6	2	0.8	0.7	57	2.87	2.69	5.08
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	3	3	0	0
Euro 4	15	9	4	4	1.1	1.1	0	0
LPG								
pre-ECE	0	0	0	0	80	80	35	25
Euro 1	38	21	13	8	80	80	35	25
Euro 2	23	13	3	2	80	80	35	25
Euro 3 and later	9	5	2	1	80	80	35	25
Light duty vehicles								
Gasoline								
pre-Euro	10	10	6.5	6.5	201	131	86	41
Euro 1	122	52	52	52	45	26	16	14
Euro 2	62	22	22	22	94	17	13	11
Euro 3	36	5	5	5	83	3	2	4
Euro 4	16	2	2	2	57	2	2	0

	N_2O emission factors (mg/km)				CH_4 emission factors (mg/km)			
	Urban		Rural	Highway	Urban		Rural	Highway
	Cold	Hot			Cold	Hot		
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	3	3	0	0
Euro 4	15	9	4	4	1.1	1.1	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

A4.4 Energy balance for year ended December 2013

Table A.4.8 New Zealand energy balance for year ended December 2013 (Ministry of Business, Innovation and Employment, 2014) (available online: http://www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-in-new-zealand)

Converted into PJ using Gross Calorific Values	COAL			OIL							
	Bituminous & Sub-bituminous	Lignite	Total	Crudes/ Feedstocks/ Natural Gas Liquids	LPG	Petrol	Diesel	Fuel Oil	Aviation Fuel/ Kerosene	Others	Total
SUPPLY											
Indigenous Production	114.72	4.44	119.16	75.06	8.72						83.78
+ Imports	11.72	0.00	11.72	243.04	0.09	52.59	29.39	–	3.79	7.17	336.07
- Exports	66.23	–	66.23	66.81	1.41	–	–	9.72	–	–	77.94
- Stock Change	3.23	-0.07	3.16	7.57	-0.12	6.36	-1.53	-0.35	-0.67	-0.41	10.85
- International Transport						0.03	1.66	11.47	37.76	–	50.92
TOTAL PRIMARY ENERGY	**56.97**	**4.51**	**61.48**	**243.73**	**7.52**	**46.19**	**29.26**	**-20.85**	**-33.29**	**7.58**	**280.14**
ENERGY TRANSFORMATION	**-37.11**	**-0.23**	**-37.34**	**-241.79**	**0.01**	**62.67**	**88.10**	**29.14**	**45.10**	**4.57**	**-12.20**
Electricity Generation	-17.56	–	-17.56				-0.03	–			-0.03
Cogeneration	-7.77	-0.23	-8.00								
Oil Production				-241.68		62.96	88.42	27.96	44.97	11.49	-5.87
Other Transformation	-11.55	–	-11.55								
Losses and Own Use	-0.23	–	-0.23	-0.11	0.01	-0.29	-0.28	1.18	0.12	-6.92	-6.29
Non-energy Use										**-12.15**	**-12.15**
CONSUMER ENERGY (calculated)	**19.87**	**4.28**	**24.15**	**1.94**	**7.53**	**108.86**	**117.36**	**8.29**	**11.81**	**–**	**255.79**
DEMAND											
Agriculture, Forestry and Fishing	**3.55**	**0.02**	**3.57**		**0.06**	**1.52**	**15.38**	**1.99**	**–**		**18.95**
Agriculture	3.55	0.02	3.57		0.06	1.38	10.97	–	–		12.42
Forestry and Logging	–	–	–			0.00	2.77	–	–		2.77
Fishing	–	–	–			0.13	1.64	1.99	–		3.76
Industrial	**17.65**	**3.76**	**21.42**		**3.03**	**0.11**	**14.79**	**1.59**	**–**		**19.52**
Mining	–	–	–			0.01	5.02	0.01	–		5.04
Food Processing	9.00	3.74	12.74			–	–	–	–		–
Textiles	0.09	0.00	0.09								
Wood, Pulp, Paper and Printing	0.48	0.01	0.49								
Chemicals	–	–	–								
Non-metallic Minerals	5.54	0.01	5.55								
Basic Metals	0.02	–	0.02			–	–	–	–		–
Mechanical/Electrical Equipment	0.45	0.00	0.45								
Building and Construction	–	0.00	0.00			0.01	3.74	0.02	–		3.76
Unallocated	2.05	–	2.05		3.03	0.10	6.02	1.56	–		10.72
Commercial	**1.10**	**0.36**	**1.46**		**1.22**	**0.22**	**3.72**	**0.02**	**–**		**5.18**
Transport	**–**	**–**	**–**		**0.32**	**104.21**	**81.81**	**4.55**	**11.23**		**202.12**
Residential	**0.19**	**0.14**	**0.33**		**2.90**	**–**	**0.45**	**–**	**–**		**3.35**
CONSUMER ENERGY (observed)	**22.49**	**4.28**	**26.77**	**–**	**7.53**	**106.06**	**116.14**	**8.15**	**11.23**	**–**	**249.12**
Statistical Differences	**-2.63**	**0.00**	**-2.63**	**1.94**	**–**	**2.80**	**1.22**	**0.14**	**0.58**	**–**	**6.68**

	NATURAL GAS	RENEWABLES								ELECTRICITY	WASTE HEAT	TOTAL
	Total	Hydro	Geothermal	Solar	Wind	Liquid Biofuels	Biogas	Wood	Total	Total	Total	TOTAL
	187.17	82.96	174.78	0.39	7.19	0.16	3.38	57.83	326.68		0.85	717.63
												347.79
												144.17
	2.04											16.05
												50.92
	185.13	**82.96**	**174.78**	**0.39**	**7.19**	**0.16**	**3.38**	**57.83**	**326.68**		**0.85**	**854.28**
	-77.54	**-82.96**	**-163.98**		**-7.19**	**-0.16**	**-3.05**	**-4.87**	**-262.19**	**140.31**	**-0.85**	**-249.82**
	-54.13	-82.96	-162.61		-7.19		-2.30		-255.05	146.27		-180.51
	-16.54		-1.37				-0.74	-4.87	-6.98	9.45	-0.85	-22.92
	–					-0.16			-0.16			-6.03
												-11.55
	-6.86									-15.42		-28.81
	-39.67											**-51.82**
	67.92		**10.80**	**0.39**	**–**	**–**	**0.33**	**52.96**	**64.48**	**140.31**	**–**	**552.64**
	1.48		**0.64**						**0.64**	**8.00**		**32.64**
	1.48		0.64						0.64	7.14		25.24
	0.01									0.35		3.13
	–									0.52		4.28
	48.59		**7.51**					**45.56**	**53.07**	**53.67**		**196.26**
	0.02									1.96		7.03
	10.21									7.86		30.81
	0.42									0.35		0.86
	5.05									11.15		16.70
	27.17									2.65		29.82
	0.70									1.25		7.51
	3.03									23.72		26.78
	1.66									0.53		2.65
	0.25									1.03		5.04
	0.06		7.51					45.56	53.07	3.16		69.06
	7.67		**2.37**				**0.28**		**2.65**	**34.19**		**51.15**
	0.03						**–**		**–**	**0.22**		**202.37**
	5.66		**0.29**	**0.36**				**7.40**	**8.05**	**44.30**		**61.70**
	63.44	**–**	**10.80**	**0.36**	**–**		**0.28**	**52.96**	**64.41**	**140.39**	**–**	**544.13**
	4.48		**-0.00**	**0.03**	**–**		**0.05**	**–**	**0.08**	**-0.09**	**–**	**8.52**

A4.5 Fuel flow diagrams for year ended December 2013

Figure A2.1 New Zealand coal energy flow summary for 2013

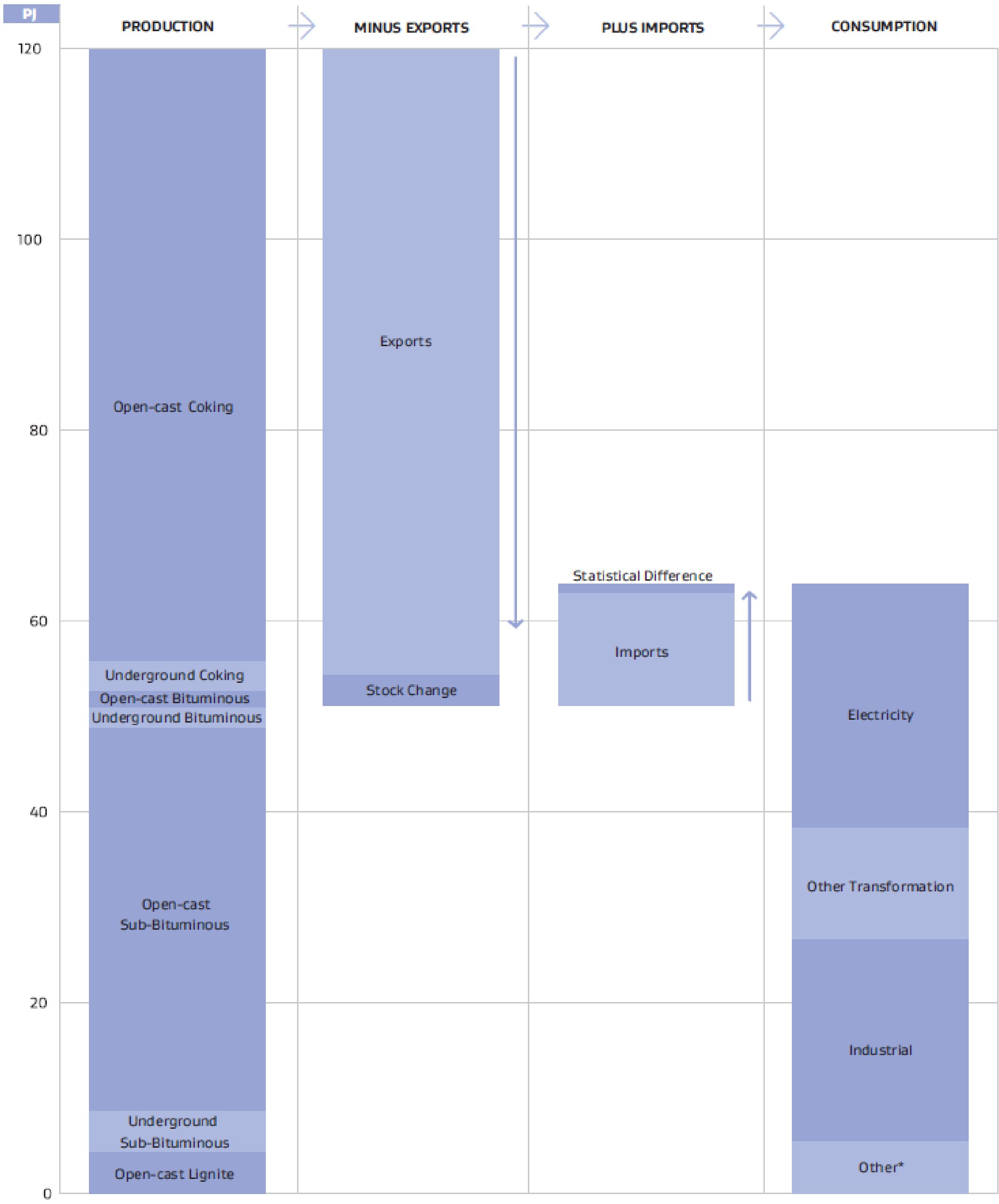
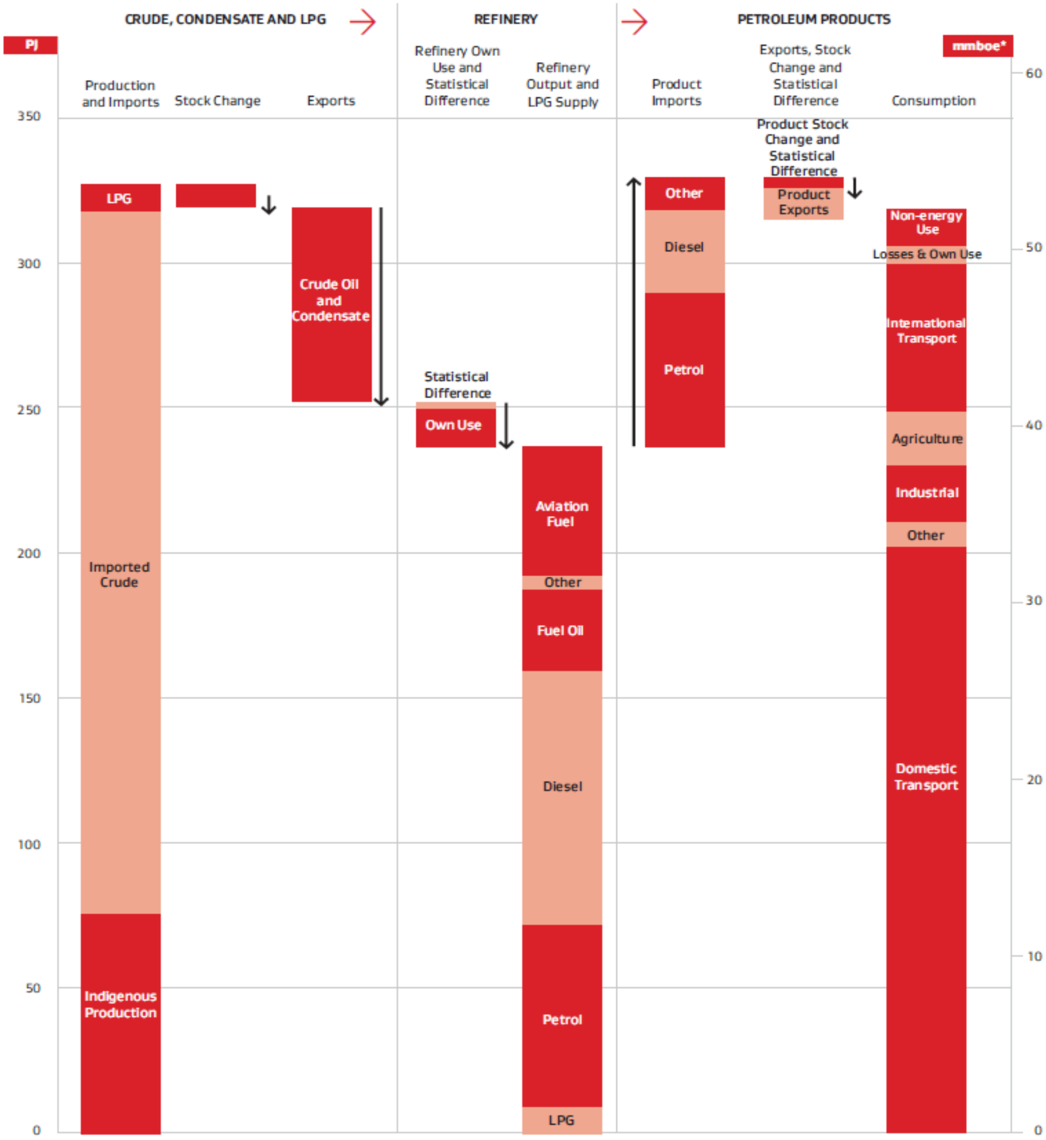
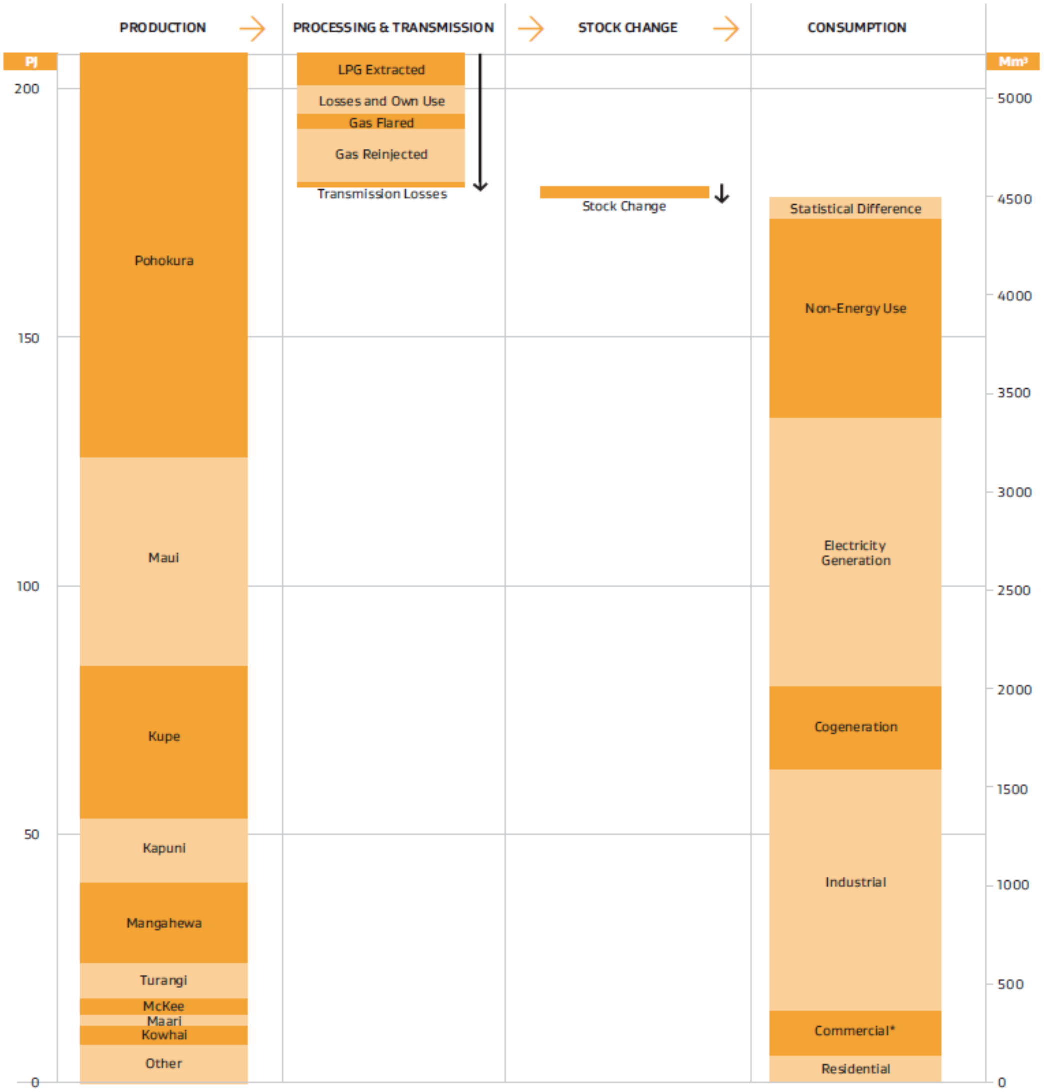


Figure A4.2 New Zealand oil energy flow summary for 2013



*Million barrels of oil equivalent.

Figure A4.3 New Zealand natural gas energy flow summary for 2013



* Includes transport, agriculture, forestry and fishing.

Annex 5: Additional material

This annex includes the time series of activity data for biomass burning within the LULUCF sector (tables 4(V)). This data is provided as there are outstanding issues with the reporting of this data within CRF Reporter.

LULUCF sector: Total biomass burned (kg dm)					
Type of burning	Controlled burning	Controlled burning	Controlled burning	Controlled burning	Wildfire
Land category	Forest land remaining forest land	Land converted to forest	Grassland remaining grassland	Land converted to grassland	Land converted to forest
1990	44,436,546.14	8,424,261.12	35,391.67	13,247,972.84	13,720.93
1991	45,031,307.05	8,189,974.52	41,841.19	13,247,972.84	15,211.45
1992	51,292,513.79	29,282,990.62	31,091.50	13,247,972.84	22,513.18
1993	52,399,908.67	36,223,517.53	30,782.51	13,247,972.84	43,507.36
1994	55,151,366.90	58,566,740.82	21,585.04	13,247,972.84	158,279.76
1995	60,311,719.40	43,830,172.19	13,651.00	13,247,972.84	231,538.44
1996	63,409,847.02	49,864,281.94	18,076.00	13,247,972.84	499,083.50
1997	64,224,653.64	37,828,831.52	16,600.00	13,786,417.28	1,348,724.58
1998	56,104,879.96	30,614,453.48	8,724.00	13,786,417.28	1,028,817.65
1999	56,194,206.14	23,791,008.55	7,434.00	13,786,417.28	433,654.60
2000	55,204,943.17	20,357,064.46	13,606.00	72,198,282.52	1,311,605.81
2001	56,681,323.47	18,246,990.13	10,233.00	70,167,008.91	1,200,507.90
2002	59,207,053.49	13,455,997.94	11,992.00	60,365,854.21	2,351,470.95
2003	51,938,956.23	12,568,449.70	10,691.00	112,177,359.96	2,174,438.70
2004	42,794,436.24	7,421,915.05	10,022.00	202,847,131.16	3,571,998.66
2005	35,526,210.02	5,033,129.54	12,612.64	367,737,920.99	4,737,495.42
2006	31,821,255.06	3,748,895.81	15,297.07	451,250,243.26	7,009,821.10
2007	31,431,694.19	3,361,097.99	23,383.00	613,111,681.39	17,702,663.89
2008	26,123,550.14	2,181,395.85	18,297.00	117,818,361.51	10,407,131.21
2009	26,750,926.47	4,057,432.17	6,806.00	212,263,655.02	19,618,967.73
2010	27,627,543.00	5,984,803.82	10,277.00	176,871,094.23	17,183,590.93
2011	32,427,187.85	10,772,341.57	9,720.00	138,668,502.79	13,762,174.49
2012	31,658,726.43	10,637,507.20	7,060.00	164,183,634.88	13,473,901.18
2013	34,262,321.47	3,950,008.84	6,008.00	154,293,644.46	10,233,957.56