Ministry for the Environment
Manatū Mō Te Taiao

New Zealand's Greenhouse Gas Inventory 1990–2006

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

New Zealand Government

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Executive Summary

The annual inventory of emissions and removals of greenhouse gases (the inventory) forms part of New Zealand's obligations under the United Nations Framework Convention on Climate Change (the Climate Change Convention) and the Kyoto Protocol. The inventory is also an important element of the Ministry for the Environment's state of the environment reporting.

The inventory reports the emissions and removals of greenhouse gases not controlled by the Montreal Protocol. The gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The indirect greenhouse gases carbon monoxide (CO), oxides of nitrogen (NO_X), sulphur dioxide (SO_2) and non-methane volatile organic compounds (NMVOCs) are also reported in the inventory. Under the Climate Change Convention, only emissions and removals of the direct greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) are reported in the national greenhouse gas total. The gases are reported under six sectors: energy, industrial processes, solvent and other product use, agriculture, LULUCF (land use, land-use change and forestry) and waste.

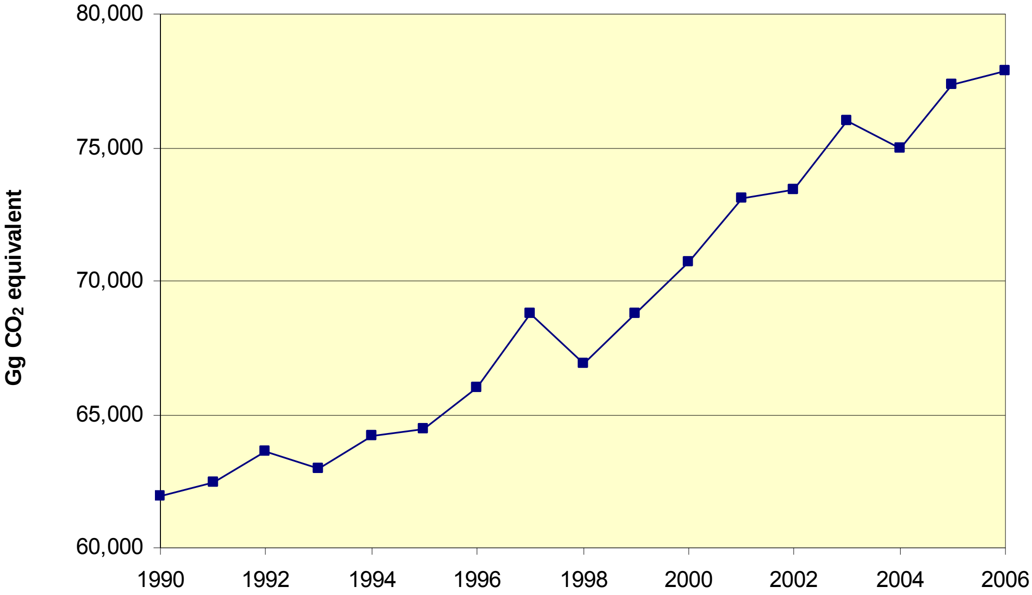
Only human-induced emissions and removals of greenhouse gases are reported in the inventory. This submission in 2008 includes a complete time-series of emissions and removals from 1990 through to 2006 (the current inventory year). Each inventory report is 15 months in arrears allowing time for data to be collected and analysed.

Primarily, the inventory fulfils reporting obligations under the Climate Change Convention. As New Zealand enters the first commitment period of the Kyoto Protocol, supplementary information, for example transactions of Kyoto units from the New Zealand registry, will be included in the national inventory report. There is no requirement to include additional Kyoto Protocol information in the 2008 inventory submission.

National trends in New Zealand's emissions and removals

In 1990, New Zealand's total greenhouse gas emissions were equal to 61,947.9 Gg CO_2 equivalent (CO_2-e). In 2006, total greenhouse gas emissions were 77,868.1 Gg CO_2-e equating to a 15,920.2 Gg CO_2-e (25.7 per cent) rise since 1990 (Figure 1.1). Net removals of CO_2 through forest sinks increased from 20,507.7 Gg CO_2 in 1990 to 22,749.3 Gg CO_2 in 2006.

Figure 1.1 New Zealand's total greenhouse gas emissions from 1990 to 2006 (all figures are Gg CO_2-e)



The predominant greenhouse gases emitted by New Zealand have changed since 1990. Whereas CH_4 and CO_2 contributed equally to New Zealand's emissions in 1990, CO_2 is now the major greenhouse gas in New Zealand's emissions profile (Table 1.1). Growing emissions of CO_2 reflect the increased growth in emissions from the energy sector compared to the agriculture sector.

Table 1.1 Emissions of greenhouse gases in 1990 and 2006

Greenhouse gas emissions	Gg CO_2-equivalent 1990	Gg CO_2-equivalent 2006	Change from 1990 (Gg CO_2-equivalent)	Change from 1990 (%)
CO_2 (excluding LULUCF)	25,382.2	36,388.0	11,005.7	43.3
CH_4 (excluding LULUCF)	25,485.6	27,499.3	2,013.7	7.9
N_2O (excluding LULUCF)	10,426.0	13,283.7	2,857.7	27.4
HFCs	0.0	593.0	593.0	–
PFCs	641.7	90.9	–550.8	–85.8
SF_6	12.3	13.2	0.9	7.4
Total	**61,947.9**	**77,868.1**	**15,920.2**	**25.7**

Source and sink category emission estimates and trends

New Zealand's emissions profile is unusual amongst developed nations because 48.4 per cent of total emissions in 2006 were produced by the agriculture sector (Figure 1.2). By comparison, emissions from agriculture are typically 12 per cent of total greenhouse gas emissions across developed nations or Parties listed in Annex I of the Climate Change Convention. New Zealand's agricultural emissions are predominantly CH_4 emissions from ruminant farm animals and N_2O emissions from animal excreta and nitrogenous fertiliser use. The current level of emissions from the agriculture sector is 5,168.8 Gg CO_2-e (15.9 per cent) above the 1990 level of 32,498.9 Gg CO_2-e (Table 1.2).

The energy sector is the other large component of New Zealand's emissions profile comprising 34,069.3 Gg CO_2-e (43.8 per cent) of total emissions in 2006. Emissions from the energy sector are now 10,570.2 Gg CO_2-e (45.0 per cent) above the 1990 level of 23,499.1 Gg CO_2-e (Table 1.2). The growth in energy emissions since 1990 is primarily from "road transport" (an increase of 5,127.3 Gg CO_2-e or 66.9 per cent) and "public electricity and heat production" (an increase of 4,807.3 Gg CO_2-e or 137.6 per cent). Emissions from thermal electricity generation vary from year to year depending on the water resources available for hydro generation. In dry years there is a greater reliance on thermal electricity generation.

Emissions from the industrial processes and waste sectors are a small component of New Zealand's emissions profile, comprising 5.4 per cent and 2.4 per cent respectively of all greenhouse gas emissions in 2006. Emissions from the waste sector have decreased 647.8 Gg CO_2-e (25.9 per cent) since 1990 because of improvements in solid waste disposal. Emissions from industrial processes have increased 830.4 Gg CO_2-e (24.4 per cent) since 1990. Emissions from the solvent and other product use sector are negligible in New Zealand.

The land use, land-use change and forestry (LULUCF) sector represents a major carbon sink for New Zealand removing 22,749.3 Gg CO_2-e or 29.2 per cent of all of New Zealand's greenhouse gas emissions in 2006. Net removals in 2006 were 2,241.6 Gg CO_2-e (10.9 per cent) above net removals in 1990. Variations in planting rates and the impact of harvest regimes affect the size of this carbon sink from year to year. The LULUCF sector of the inventory is not the same as forest sinks or afforestation under the Kyoto Protocol. The inventory reports emissions and removals from all forests (planted and natural) for all years, whereas the Kyoto Protocol limits forest sinks to forests planted after the 31st of December, 1989.

Figure 1.2 Change in New Zealand's sectoral emissions from 1990 to 2006 (all figures Gg CO_2-e and exclude LULUCF)

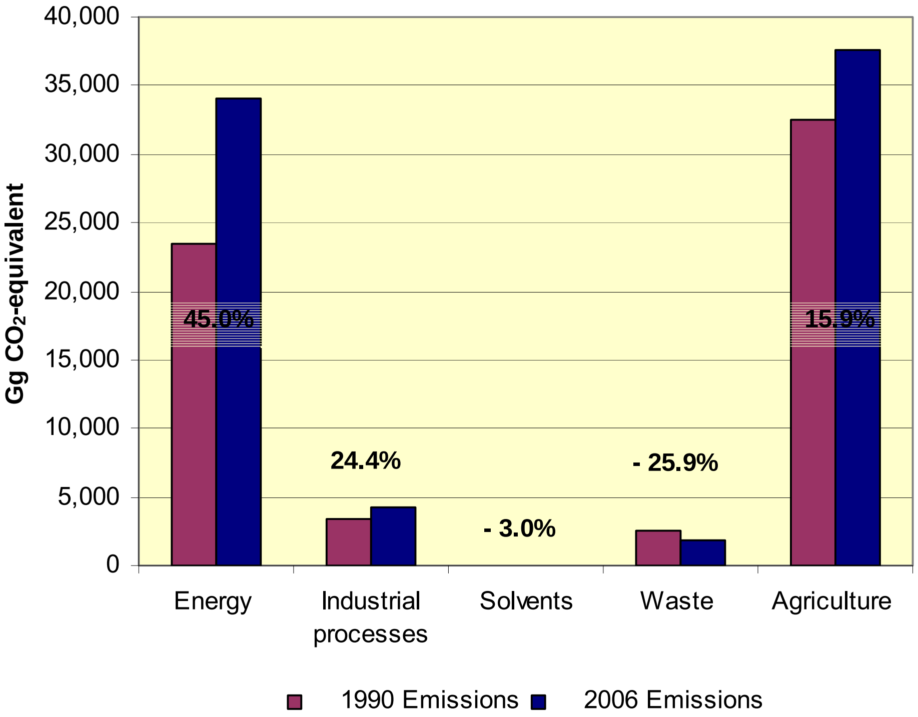


Table 1.2 Sectoral emissions of greenhouse gases in 1990 and 2006

Sector	Gg CO_2-equivalent 1990	Gg CO_2-equivalent 2006	Change from 1990 (Gg CO_2-equivalent)	Change from 1990 (%)
Energy	23,499.1	34,069.3	10,570.2	45.0
Industrial processes	3,402.7	4,233.1	830.4	24.4
Solvent and other product	41.5	40.3	–1.2	–3.0
Agriculture	32,498.9	37,667.6	5,168.8	15.9
Waste	2,505.7	1,857.8	–647.8	–25.9
Total (excluding LULUCF)	61,947.9	77,868.1	15,920.2	25.7
Land-use change and forestry (including CH_4 & N_2O)	–20,507.7	–22,749.3	–2,241.6	10.9
Net Total (including LULUCF)	**41,440.2**	**55,118.8**	**13,678.7**	**33.0**

Contents

Tables

Figures

Chapter 1: Introduction

1.1 Background

Greenhouse gases in the Earth's atmosphere trap warmth from the sun and make life as we know it possible. However, since the industrial revolution (about 1750) there has been a global increase in the atmospheric concentration of greenhouse gases such as carbon dioxide, methane and nitrous oxide (IPCC, 2007). This increase is attributed to human activities, particularly the burning of fossil fuels and land-use change.

In 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded that most of the increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations (IPCC, 2007). The IPCC has predicted that continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century.

1.1.1 The United Nations Framework Convention on Climate Change

At a global level, 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 (the Climate Change Convention)** at the Earth Summit in Rio de Janeiro in May 1992.

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

The main objective of the Climate Change Convention is to achieve "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (caused by humans) interference with the climate system. Such a level should be achieved within a time-frame 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 are required to address climate change. A part of the obligation is to monitor greenhouse gas trends. The annual inventory of greenhouse gas emissions and removals fulfils this obligation. Countries are also obligated to protect and enhance carbon sinks (for example, forests) and implement measures that assist in national and or regional climate change adaption and mitigation. In addition, developed countries commit to providing financial assistance to developing countries.

Developed countries who ratified the Climate Change Convention agreed to non-binding targets to reduce greenhouse gas emissions to 1990 levels by 2000.

Only a few countries made appreciable progress towards achieving their targets. The international community recognised that the Climate Change Convention alone was not enough to ensure greenhouse gas levels would be stabilised at safe levels. More urgent action was needed. In response, Parties launched a new round of talks for stronger and more detailed commitments for developed countries. After two and a half years of negotiations, **the Kyoto Protocol** was adopted in Kyoto, Japan, on 11 December 1997. New Zealand ratified the Kyoto Protocol on 19 December 2002. The Protocol came into force on 16 February 2005.

1.1.2 The Kyoto Protocol

The Kyoto Protocol shares the Climate Change Convention's objective, principles and institutions. The Protocol also considerably strengthens the Climate Change Convention. Article 3 of the Kyoto Protocol states that the Annex I Parties ratifying the Protocol shall individually or jointly ensure that their aggregate anthropogenic greenhouse gas emissions do not exceed their "assigned amount". The goal is to reduce the aggregate emissions of the six greenhouse gases from Annex I countries by at least 5 per cent below 1990 levels in the first commitment period (2008 to 2012). 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 "assigned amount" is the maximum amount of greenhouse gas emissions (measured as tonnes of CO_2 equivalent) that a Party may emit over the commitment period. For the first commitment period, New Zealand's assigned amount is the gross greenhouse gas emissions in 1990 multiplied by 5. The assigned amount does not include emissions and removals from the land use, land-use change and forestry sector (LULUCF) in 1990 unless this sector was a source of emissions.

New Zealand's assigned amount is recorded as 309,564,733 metric tonnes CO_2-e. The assigned amount is based on the 1990 inventory submitted as part of the Initial Report under the Kyoto Protocol (Ministry for the Environment, 2006) and reviewed by an international review team in February 2007 (UNFCCC, 2007). The assigned amount does not change during the first commitment period of the Kyoto Protocol. In contrast, emissions and removals for all years of the inventory are subject to change due to continuous improvement. Consequently, the level of emissions in 1990 reported in 2008 inventory submission is different (0.1 per cent) from the 1990 level used in the assigned amount calculation.

To meet their commitments, Annex I Parties must put in place domestic policies and measures to reduce emissions. Reducing global greenhouse gas concentrations in the atmosphere can be achieved by reducing the quantity of greenhouse gases emitted or removing CO_2 presently in the atmosphere by increasing and maintaining carbon sinks (for example, managing forests). Carbon sinks that meet Kyoto Protocol requirements create removal units. The removal units are added to a Party's assigned amount.

The Kyoto Protocol also defined three "flexibility mechanisms" to lower the overall costs of achieving its commitments. These are Clean Development Mechanisms (CDM), Joint Implementation (JI) and emissions trading. These mechanisms enable Parties to access cost-effective opportunities to reduce emissions or to remove carbon from the atmosphere through action in other countries. While the cost of limiting emissions varies considerably from region to region, the benefit for the atmosphere is the same, wherever the action is taken. More information on these mechanisms can be obtained from the website of the Climate Change Convention (www.unfccc.int).

Under Article 7.1 of the Kyoto Protocol, New Zealand is required to include additional information within the submission of the annual greenhouse gas inventory. This becomes mandatory for the 1990 – 2008 inventory submitted in 2010, as this includes the first year of the first commitment period. However, in order to fully participate in Kyoto mechanisms (outlined above), a Party must submit a complete greenhouse gas inventory required under the Climate Change Convention in 2007 and continue to do so until reporting is completed for all years of the commitment period.

The additional information required includes:

- Significant changes to a Party's national system / registry.
- Holdings and transactions of transferred / acquired units under Kyoto mechanisms.
- Information relating to the implementation of Article 3.14 on the minimisation of adverse impacts.

In the 2008 inventory submission, New Zealand has reported supplementary information under the Kyoto Protocol in Annex 8. Information on transactions of transferred and/or acquired units under Kyoto mechanisms during the 2008 calendar year will be included in the 2009 inventory submission.

1.1.3 A national greenhouse gas inventory

The development and publication of an annual inventory of all human-induced emissions and removals of greenhouse gases not controlled by the Montreal Protocol is part of New Zealand's obligations under the Climate Change Convention (Articles 4 and 12) and the Kyoto Protocol (Article 7). The inventory is the primary tool for measuring New Zealand's progress against these obligations.

The content and format of the inventory is prescribed by the IPCC (IPCC, 1996; 2000; 2003) and relevant decisions of the Conference of the Parties (COP) to the Climate Change Convention, the most recent being FCCC/SBSTA/2006/9 (UNFCCC, 2006). A complete inventory submission requires two components: the National Inventory Report (NIR) and emissions and removal data in the Common Reporting Format (CRF). Inventories are subject to an annual three-stage international review process administered by the Climate Change Convention secretariat. All review reports are available online (www.unfccc.int).

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

New Zealand greenhouse gas emissions profile

In 1990, New Zealand's total greenhouse gas emissions were equal to 61,947.9 Gg CO_2 equivalent (CO_2-e). In 2006, total greenhouse gas emissions were 77,868.1 Gg CO_2-e equating to a 15,920.2 Gg (25.7 per cent) rise since 1990. Net removals of CO_2 through forest sinks increased 10.9 per cent from 20,507.69 Gg CO_2 in 1990 to 22,749.26 Gg CO_2 in 2006.

Agricultural emissions contributed 48.4 per cent of New Zealand's total emissions in 2006. The large proportion of agricultural greenhouse gas emissions creates a unique greenhouse gas emission profile for New Zealand. In a typical developed country the majority of emissions come from electricity production, transport and industrial processes.

In 2006, New Zealand's emissions from the energy sector accounted for 43.8 per cent of the total emissions. The energy sector experienced the highest rate of growth of any sector, increasing 45 per cent from 1990 to 2006. This growth is due to increasing demands for energy from transport, electricity generation, manufacturing industries and construction.

Renewable energy sources dominate New Zealand's electricity generation. Hydro generation, geothermal, woody biomass, wind, solar, biogas and landfill gas contribute 66 per cent of New Zealand's annual generation (Ministry of Economic Development, 2007b). The proportion of renewable energy used to produce electricity varies year to year depending on the availability of water for generating hydro electricity (refer to section 3.2.1).

The predominant greenhouse gases emitted by New Zealand have changed since 1990. Whereas CH_4 and CO_2 contributed equally to New Zealand's emissions in 1990, CO_2 is now the major greenhouse gas in New Zealand's emissions profile (Table 1.1). Growing emissions of CO_2 reflects the increased growth in emissions from the energy sector compared to the agriculture sector.

1.2 Institutional arrangements

The Climate Change Response Act 2002 (CCRA) enables New Zealand to meet its international obligations under the Climate Change Convention and the Kyoto Protocol. The CCRA names the person "who is for the time being the chief executive of the Ministry for the Environment" as New Zealand's inventory agency. The section "Part 2 Institutional Arrangements Sub part 3 – Inventory Agency of the CCRA" (2002) specifies the primary functions of the inventory agency, including:

- "to estimate annually New Zealand's human-induced emissions by sources and removals by sinks of greenhouse gases" (32.1(a))
- "to prepare New Zealand's annual inventory report under Article 7.1 of the Protocol and New Zealand's national communication (or periodic report) under Article 7.2 of the Protocol and Article 12 of the Climate Change Convention" (32.1(b)(i) and (ii)).

The CCRA also specifies the responsibilities of the inventory agency in carrying out its functions, including record keeping and publication of the inventory. Part 3 of the CCRA provides for the authorisation of inspectors to collect information needed to estimate emissions or removals of greenhouse gases.

The Ministry for the Environment (MfE) is responsible for overall development, compilation and submission of the annual inventory to the Climate Change Convention secretariat. The Ministry also calculates estimates of emissions for the agriculture and waste sectors and emissions and removals from the LULUCF sector.

The Ministry of Economic Development (MED) collects and compiles all emissions from the energy sector and CO_2 emissions from the industrial processes sector. Emissions of the non-CO_2 gases from the industrial processes sector are obtained through industry survey by consultants, contracted to the Ministry for the Environment.

The Ministry of Agriculture and Forestry (MAF) provides many of the statistics for the agriculture sector and removals data from planted forests in the LULUCF sector. The inventory estimates are underpinned by the research and modelling of researchers at New Zealand's crown research institutes and universities.

New Zealand's national statistical agency, Statistics New Zealand, provides many of the official statistics for the agriculture sector through regular agricultural census and surveys. Statistics New Zealand also provides statistics on fuel consumption through the "Deliveries of Petroleum Fuels by Industry Survey" and the "New Zealand Coal Sales Survey". Population census data from Statistics New Zealand is used in the waste and solvent and other product use sectors.

1.3 Inventory preparation processes

Each inventory report is 15 months in arrears of the calendar year, allowing time for data to be collected and analysed. Sector-based data analysis, data entry into the Climate Change Convention "CRF Reporter" database and quality checking occurs over the period October to December. The NIR is updated over this 3 month time period. Once the sector-based emissions estimates are updated the National Inventory Compiler at the MfE calculates the inventory uncertainty, undertakes the key category assessment and further quality checking and finalises the NIR. The inventory is reviewed within the MfE, MED and MAF before being approved and submitted to the Climate Change Convention secretariat. The inventory and all required data for the submission to the Climate Change Convention secretariat are stored on the Ministry's central computer network in a controlled file system. The inventory is available from the websites of the MfE and the Climate Change Convention.

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

1.4 Methodologies and data sources used

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

Energy: Greenhouse gas emissions from the energy sector are calculated using the IPCC Tier 1 approach. Activity data is compiled from industry-supplied information via the MED and Statistics New Zealand (refer to Chapter 3 and Annex 2). Country specific emission factors are used for CO_2 emission calculations. Applicable IPCC default factors are used for non-CO_2 emissions where New Zealand emission factors are not available.

Industrial processes and solvent and other product use: Activity data and carbon dioxide emissions are supplied directly to the MED by industry sources. The IPCC Tier 2 approach is used and emission factors are country-specific. Activity data for the non-CO_2 gases are collated via an industry survey. Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach and SF_6 emissions from large users are assessed via the Tier 3a approach (IPCC, 2000).

Agriculture: 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. The methodology uses animal productivity data to estimate dry matter intake and methane production. The same dry matter intake data is used to calculate N_2O emissions from animal excreta. A Tier 1 approach is used to calculate CH_4 and N_2O emissions for livestock species present in insignificant numbers.

Land use, land-use change and forestry: The LULUCF inventory is completed using a mix of IPCC Tier 2 and Tier 1 approaches. A Tier 2 approach is used for the "planted forest" subcategory of forest land. Changes in planted forest stocks are assessed from national forest survey data and computer modelling of the planted forest estate. A Tier 1 approach is used for the categories cropland, grassland, wetland, settlements and other land. Changes in land area for these categories are based on modified national land cover databases reclassified to the IPCC LULUCF categories. At present, this is the best data available for reporting the LULUCF sector within New Zealand. Results from the Land Use and Carbon Analysis System (LUCAS), as described in Annex 3.2, will improve the reporting for the LULUCF sector and be consistent with reporting under the Kyoto Protocol.

Waste: Emissions from the waste sector are estimated using waste survey data combined with population data from Statistics New Zealand. Calculation of emissions from solid-waste disposal uses an IPCC Tier 2 method with country-specific emission factors. Methane and N_2O emissions from domestic and industrial wastewater handling are calculated using a refinement of the IPCC methodology (IPCC, 1996). There is no incineration of municipal waste in New Zealand. The only incineration is for small specific waste streams including medical, quarantine and hazardous wastes. Emissions of CO_2, CH_4 and N_2O from waste incineration have been calculated for the first time in the 2008 inventory submission using a Tier 1 methodology (IPCC, 2006).

1.5 Key categories

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

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

In accordance with *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 full 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 2006 year are summarised in Table 1.5.1. The major contributions to the level analysis including LULUCF (Table 1.5.2) are CO_2 from "forest land remaining forest land" (23.9 per cent) and CH_4 from enteric fermentation in domestic livestock (22.3 per cent).

The largest contribution to the trend analysis, including LULUCF, (Table 1.5.3) is from CH_4 emissions from enteric fermentation in domestic livestock (16 per cent), CO_2 emissions from road transportation (15.2 per cent), and CO_2 emissions from stationary combustion of solid fuels (13.5 per cent).

There were two modifications to the IPCC suggested key categories to reflect New Zealand's national circumstances. The category for fugitive emissions from geothermal operations was separated from the "fugitive emissions from fuels-oil and natural gas" category. Carbon dioxide emissions from the "ammonia production" category are considered to be a qualitative key category because of the large increase in nitrogenous fertiliser use observed in the agriculture sector. More information on the calculation of the level and trend analysis is included in Annex 1.

Table 1.5.1 Summary of key categories for 2006 (including and excluding LULUCF activities)

Quantitative method used: Tier 1		
IPCC Source Categories	**Gas**	**Criteria for Identification**
Energy Sector		
CO_2 emissions from stationary combustion - solid	CO_2	level, trend
CO_2 emissions from stationary combustion - liquid	CO_2	level, trend
CO_2 emissions from stationary combustion - gas	CO_2	level, trend
Mobile combustion - road vehicles	CO_2	level, trend
Mobile combustion - aviation	CO_2	level
Fugitive emissions from oil and gas operations	CO_2	level, trend
Fugitive emissions from geothermal operations	CO_2	trend
Industrial processes sector		
Emissions from cement production	CO_2	level
Emissions from the iron and steel industry	CO_2	level
Emissions from aluminium production	CO_2	level
PFCs from aluminium production	PFCs	trend
Ammonia production	CO_2	qualitative
Emissions from substitutes for ozone depleting substances	HFCs	level, trend
Agricultural Sector		
Emissions from enteric fermentation in domestic livestock	CH_4	level, trend
Emissions from manure management	CH_4	level
Direct emissions from agricultural soils	N_2O	level, trend
Emissions from agricultural soils - animal production	N_2O	level, trend
Indirect emissions from nitrogen used in agriculture	N_2O	level
LULUCF Sector		
Forest land remaining forest land	CO_2	level, trend
Cropland remaining cropland	CO_2	level
Conversion to forest land	CO_2	level, trend
Other-emissions from liming	CO_2	level, trend
Conversion to grassland	CO_2	level, trend
Waste sector		
Emissions from solid waste disposal sites	CH_4	level, trend

Table 1.5.2 (a&b) Key category analysis for 2006 – Tier 1 level assessment including LULUCF (a) and excluding LULUCF (b)

(a) Tier 1 Category Level Assessment - including LULUCF

IPCC Categories	Gas	2006	Level	Cumulative
Forest land remaining forest land	CO_2	25859.65	23.9	23.9
Emissions from enteric fermentation in domestic livestock	CH_4	24110.67	22.3	46.2
Mobile combustion - road vehicles	CO_2	12606.68	11.7	57.8
Emissions from stationary combustion - gas	CO_2	7938.09	7.3	65.2
Emissions from agricultural soils - animal production	N_2O	7609.13	7.0	72.2
Emissions from stationary combustion - solid	CO_2	6754.95	6.2	78.5
Indirect emissions from nitrogen used in agriculture	N_2O	3387.22	3.1	81.6
Emissions from stationary combustion - liquid	CO_2	3008.08	2.8	84.4
Conversion to forest land	CO_2	2127.72	2.0	86.3
Direct emissions from agricultural soils	N_2O	1736.81	1.6	87.9
Emissions from the iron and steel industry	CO_2	1622.36	1.5	89.4
Emissions from solid waste disposal sites	CH_4	1475.39	1.4	90.8
Mobile combustion - aviation	CO_2	1114.18	1.0	91.8
Emissions from manure management	CH_4	743.13	0.7	92.5
Cropland remaining cropland	CO_2	679.95	0.6	93.1
Other-emissions from liming	CO2	676.11	0.6	93.8
Conversion to grassland	CO_2	661.04	0.6	94.4
Fugitive emissions from oil and gas operations	CO_2	657.47	0.6	95.0

(b) Tier 1 Category Level Assessment - excluding LULUCF

IPCC Categories	Gas	2006	Level	Cumulative
Emissions from enteric fermentation in domestic livestock	CH_4	24110.67	31.0	31.0
Mobile combustion - road vehicles	CO_2	12606.68	16.2	47.2
Emissions from stationary combustion - gas	CO_2	7938.09	10.2	57.3
Emissions from agricultural soils - animal production	N_2O	7609.13	9.8	67.1
Emissions from stationary combustion - solid	CO_2	6754.95	8.7	75.8
Indirect emissions from nitrogen used in agriculture	N_2O	3387.22	4.3	80.1
Emissions from stationary combustion - liquid	CO_2	3008.08	3.9	84.0
Direct emissions from agricultural soils	N_2O	1736.81	2.2	86.2
Emissions from the iron and steel industry	CO_2	1622.36	2.1	88.3
Emissions from solid waste disposal sites	CH_4	1475.39	1.9	90.2
Mobile combustion - aviation	CO_2	1114.18	1.4	91.6
Emissions from manure management	CH_4	743.13	1.0	92.6
Fugitive emissions from oil and gas operations	CO_2	657.47	0.8	93.4
Emissions from substitutes for ozone depleting substances	HFCs & PFCs	601.35	0.8	94.2
Emissions from cement production	CO_2	560.66	0.7	94.9
Emissions from aluminium production	CO_2	552.76	0.7	95.6

Table 1.5.3 Key category analysis for 2006 – Tier 1 trend assessment including LULUCF (a) and excluding LULUCF (b)

(a) Tier 1 Category Trend Assessment - including LULUCF

IPCC Categories	Gas	Base year estimate Gg	2006 estimate Gg	Trend assessment	Contribution to trend	Cumulative total
Emissions from enteric fermentation in domestic livestock	CH_4	21810.44	24110.67	0.034	16.0	16.0
Mobile combustion - road vehicles	CO_2	7534.97	12606.68	0.032	15.2	31.2
Emissions from Stationary combustion - solid	CO_2	3148.78	6754.95	0.029	13.5	44.7
Conversion to forest land	CO_2	141.28	2127.72	0.020	9.4	54.2
Emissions from Stationary combustion - gas	CO_2	7691.14	7938.09	0.018	8.4	62.6
Emissions from solid waste disposal sites	CH_4	2121.53	1475.39	0.012	5.8	68.3
Direct emissions from agricultural soils	N_2O	487.19	1736.81	0.011	5.4	73.8
Forest land remaining forest land	CO_2	21397.92	25859.65	0.011	5.0	78.8
Emissions from agricultural soils - animal production	N_2O	6850.46	7609.13	0.010	4.9	83.7
PFC's from aluminium production	PFC	641.68	82.49	0.007	3.5	87.2
Emissions from substitutes for Ooone depleting substances	HFCs & PFCs	0.00	601.35	0.006	2.9	90.1
Fugitive emissions from oil and gas operations	CO_2	263.48	657.47	0.003	1.6	91.7
Conversion to grassland	CO_2	704.22	661.04	0.002	1.1	92.7
Other (including liming)	CO2	373.83	676.11	0.002	1.0	93.7
Emissions from stationary combustion - liquid	CO_2	2546.55	3008.08	0.002	0.9	94.7
Fugitive emissions from geothermal operations	CO_2	357.34	305.68	0.001	0.7	95.4

(b) Tier 1 Category Trend Assessment - excluding LULUCF

IPCC Categories	Gas	Base year estimate Gg	2006 estimate Gg	Trend assessment	Contribution to trend	Cumulative total
Emissions from enteric fermentation in domestic livestock	CH_4	21810.44	24110.67	0.0338	19.3	19.3
Mobile combustion - road vehicles	CO_2	7534.97	12606.68	0.0320	18.3	37.7
Emissions from stationary combustion - solid	CO_2	3148.78	6754.95	0.0286	16.4	54.0
Emissions from stationary combustion - gas	CO_2	7691.14	7938.09	0.0177	10.1	64.1
Emissions from solid waste disposal sites	CH_4	2121.53	1475.39	0.0122	7.0	71.1
Direct emissions from agricultural soils	N_2O	487.19	1736.81	0.0115	6.6	77.7
Emissions from agricultural soils - animal production	N_2O	6850.46	7609.13	0.0102	5.9	83.5
PFC's from aluminium production	PFC	641.68	82.49	0.0074	4.2	87.8
Emissions from substitutes for ozone depleting substances	HFCs & PFCs	0.00	601.35	0.0061	3.5	91.3
Fugitive emissions from oil and gas operations	CO_2	263.48	657.47	0.0033	1.9	93.2
Emissions from stationary combustion - liquid	CO_2	2546.55	3008.08	0.0020	1.1	94.3
Fugitive emissions from geothermal operations	CO_2	357.34	305.68	0.0015	0.8	95.1

1.6 Quality assurance and quality control

Quality assurance (QA) and quality control (QC) are an integral part of preparing New Zealand's inventory. The MfE developed a QA/QC plan in 2004 as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006) to formalise, document and archive the procedures. The plan is annually updated in conjunction with New Zealand's inventory improvement plan. As a result of recommendations from the initial review report (UNFCCC, 2007) New Zealand has increased quality control and assurance activities for the 2008 inventory submission. Details are discussed in sections 1.6.1 and 1.6.2 below.

1.6.1 Quality control

For the 2008 inventory submission, the MfE used Tier 1 QC checksheets. The Tier 1 checks are based on the procedures suggested in the good practice guidance (IPCC, 2000) for all key categories.

The initial review report (UNFCCC, 2007) recommended New Zealand intensify the time and resources directed at implementing the QA/QC plan with the aim of reducing the number of minor errors and inconsistencies. New Zealand responded to the recommendation by changing the inventory compilation schedule to allow more time for quality checking.

For the 2008 inventory submission, all sector level data was entered into the CRF Reporter by January 2008. The earlier deadline allowed two months for further quality checking at the sector level (between data spreadsheets and the CRF tables) and checking consistency between the CRF tables and the NIR. Corrections were made to any errors that were found. As a consequence of the earlier deadline, reporting in the agriculture and LULUCF sectors has changed from 3 year averages to single year values.

KPMG were contracted for 3 months to complete quality checks on key categories for the 2006 inventory year and to develop data quality objectives to further advance the implementation of New Zealand's QA/QC plan. KPMG checked the calculations and assumptions used in the key spreadsheets and models were consistently applied, that the data from the spreadsheets and models were accurately transferred to the CRF Reporter and data from the CRF tables was accurately represented in the draft NIR. KPMG did not identify any significant errors within the source data spreadsheets or between the spreadsheets and the CRF Reporter and the draft NIR.

Data in the Climate Change Convention secretariat's CRF Reporter database were checked visually for anomalies, errors and omissions. The MfE used the QC checking procedures included in the CRF Reporter database to ensure the data submitted to the Climate Change Convention secretariat were complete.

1.6.2 Quality assurance

New Zealand is in the process of updating its quality control and assurance system to ensure quality is built in at all stages of the inventory compilation process. KMPG developed a risk register to highlight potential risks in the inventory data compilation process. The Ministry for the Environment will use the risk register to aid prioritising further improvements to the inventory.

Quality assurance reviews of individual sectors and categories are included in the national inventory plan and commissioned by the MfE. A list of previous quality assurance reviews, their major conclusions and follow up are included in the excel workbooks available for download with this report from the Ministry for the Environment's website.

Most of the activity data in the energy and agriculture sectors are compiled using data collected via surveys. These surveys are conducted and administered by Statistics New Zealand who conducts their own rigorous quality assurance and quality control procedures on the data.

1.6.3 The Climate Change Convention annual inventory review

New Zealand's greenhouse gas inventory was reviewed in 2001 and 2002 as part of a pilot study of the technical review process (UNFCCC, 2001a; 2001b; 2001c; 2003), where the inventory was subject to detailed in-country, centralised and desk review procedures. The inventories submitted for the years 2001 and 2003 were reviewed during a centralised review process. The 2004 inventory was reviewed as part of the Kyoto Protocol initial review. This was an in-country review held from 19 to 24 February 2007. In all instances, the reviews were conducted by a review team comprising of experts nominated by Parties to the Climate Change

Convention. Review reports are available from the Climate Change Convention website (www.unfccc.int).

New Zealand has consistently met the reporting requirements under the Climate Change Convention and the Kyoto Protocol. The submission of the inventory to the Climate Change Convention secretariat is consistently within the allocated six weeks of April 15th as required under decision 15/CMP.1 The national system for the greenhouse gas inventory, the national registry, and the 1990 (base year) greenhouse gas inventory was reviewed by an expert review team in February 2007. The expert review report (UNFCCC, 2007) concluded that:

- "New Zealand's greenhouse gas inventory is consistent with the Revised 1996 IPCC Guidelines and the IPCC good practice guidance, and adheres to the reporting guidelines under Article 7 of the Kyoto Protocol"
- "New Zealand's national system is prepared in accordance with the guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol and reported in accordance with the guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol"
- "New Zealand's national registry is fully compliant with the registry requirements as defined by decisions 13/CMP.1 and 5/CMP.1".

These significant developments allowed New Zealand to be one of the first four Parties to be eligible to participate in the Kyoto Protocol mechanisms. New Zealand's registry was operational on January 1, 2008.

1.7 Inventory uncertainty

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 in the future and guide decisions on methodological choice (IPCC, 2000). Inventories prepared following IPCC good practice guidance (IPCC, 2000 and 2003) will typically contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable estimates such as N_2O fluxes from soils and waterways.

New Zealand has included a Tier 1 uncertainty analysis as required by the Climate Change Convention inventory guidelines (UNFCCC, 2006) and good practice guidance (IPCC, 2000 and 2003). Uncertainties in the categories are combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. LULUCF categories have been included using the absolute value of any removals of CO_2 (Table A7.1). Table A7.2 calculates the uncertainty in emissions only (ie, excluding LULUCF removals).

The calculated uncertainty for New Zealand's total inventory (emissions and removals for a given year) in 2006 is ± 16.6 per cent. The uncertainty in the overall trend from 1990 to 2006 is lower at ± 4.6 per cent. The uncertainty in total emissions (excluding removals) is ± 20.6 per cent with ± 5.4 per cent uncertainty in the trend of emissions.

The high uncertainty in a given year is dominated by emissions of CH_4 from enteric fermentation (refer to section 6.2) and N_2O emissions from agricultural soils (refer to section 6.5). These categories comprise 11.9 per cent and 8.7 per cent respectively of New Zealand's total emissions and removals uncertainty. The uncertainty in these categories reflects the inherent variability when estimating emissions from natural systems, eg, the uncertainty in cattle dry-matter intake and CH_4 emissions per unit of dry matter. With the agricultural sector comprising approximately half of New Zealand's emissions, high uncertainty in a given year is inevitable. Removals of CO_2 from forest land are also a major contribution to the uncertainty for 2006 at 6.6 per cent of New Zealand's total emissions and removals. In comparison, the uncertainty in CO_2 emissions from burning of fossil fuels is only 1.5 per cent of the total.

Uncertainty in the trend is dominated by CO_2 emissions from the energy sector, at 2.7 per cent of the trend. This is because the uncertainty in energy activity data is greater than the uncertainty in energy emission factors and the energy sector is the second largest contributor to total emissions. The other major contributors to trend uncertainty are removals of CO_2 by forest land with 2.3 per cent and N_2O from agricultural soils with 1.1 per cent.

In most instances, the uncertainty values are determined by either expert judgement from sectoral or industry experts, by analysis of emission factors or activity data, or by referring to uncertainty ranges quoted in the IPCC documentation. A Monte Carlo simulation was used to determine uncertainty for CH_4 from enteric fermentation and N_2O from agricultural soils in the 2001/2002 inventory. As there have been no significant changes to the emission factors and or activity data, the 95 per cent confidence intervals developed from the Monte Carlo simulation were extended to the 2006 inventory.

1.8 Inventory completeness

The New Zealand inventory for the period 1990-2006 is complete. In accordance with good practice guidance (IPCC, 2000), New Zealand has focused its resources for inventory development on the key categories. Some categories considered to have negligible emissions are reported as "not estimated". Where this has occurred explanations have been provided in the NIR and in the CRF tables.

The LULUCF data are the best estimate possible given the presently available data. The Land Use and Carbon Analysis System (LUCAS) is being developed to improve the accuracy of these data. Estimates using this system will be included when available. Development of the LUCAS will also reduce uncertainty by using country-specific emission and removal factors and use spatial data mapped specifically for the Climate Change Convention and Kyoto Protocol reporting. Details of the LUCAS development are included in Annex 3.2.

1.9 General notes

Units

Standard metric prefixes used in this inventory are:

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

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

1 gigagram (Gg) = 1,000 tonnes = 1 kilotonne (kt)

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

Gases

CO_2	carbon dioxide
CH_4	methane
N_2O	nitrous oxide
PFCs	perfluorocarbons
HFCs	hydrofluorocarbons
SF_6	sulphur hexafluoride
CO	carbon monoxide
NMVOC	non-methane volatile organic compounds
NO_x	oxides of nitrogen
SO_2	sulphur dioxide

Global warming potentials

The global warming potential is an index, representing the combined effect of the differing times greenhouse gases remain in the atmosphere and their relative effectiveness in absorbing thermal infrared radiation (IPCC, 2007).

The Climate Change Convention reporting requirements (UNFCCC, 2006) specify that the 100-year global warming potentials contained in the IPCC Second Assessment Report (IPCC, 1995) are used in national inventories. The indirect effects of a number of gases (CO, NO_x, SO_2 and NMVOCs) cannot currently be quantified and consequently these gases do not have global warming potentials. In accordance with the Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases that do not have GWPs are reported in the inventory but are not included in the inventory emissions total.

Common Global Warming Potentials (100 year time period)

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

CO_2 = 1

CH_4 = 21

N_2O = 310

CF_4 = 6,500

C_2F_6 = 9,200

SF_6 = 23,900

HFC–32 = 650

HFC–125 = 2,800

HFC–134a = 1,300

HFC–143a = 3,800

HFC–227ea = 2,900

Conversion factors

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

Notation keys

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

NO	**Not occurring**: when the activity or process does not occur in New Zealand.
NA	**Not applicable**: when the activity occurs in New Zealand but the nature of the process does not result in emissions or removals.
NE	**Not estimated**: where it is known that the activity occurs in New Zealand but there is no data or methodology available to derive an estimate of emissions. This can also apply to negligible emissions.
IE	**Included elsewhere**: where emissions or removals are estimated but included elsewhere in the inventory. Table 9 of the Common Reporting Format details the source category where these emissions or removals are reported.
C	**Confidential**: where reporting of emissions or removals at a disaggregated level could lead to the disclosure of confidential information.

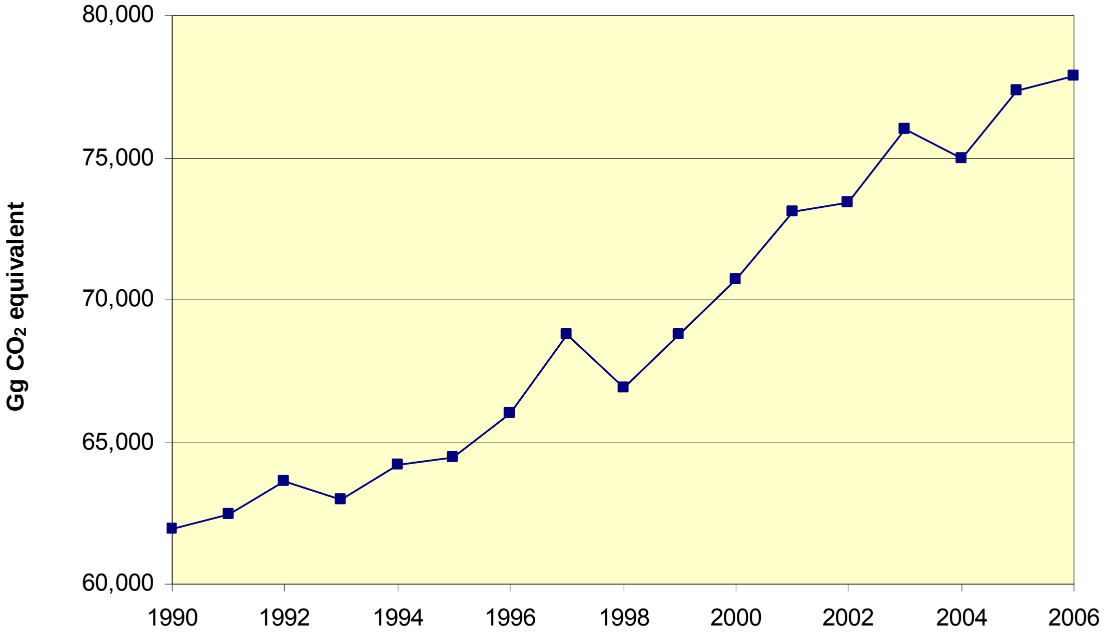
Chapter 2: Trends in greenhouse gas emissions

2.1 Emission trends for aggregated greenhouse gas emissions

In 1990, New Zealand's total greenhouse gas emissions were equivalent to 61,947.9 Gg carbon dioxide equivalent (CO_2-e). In 2006, total greenhouse gas emissions had increased by 15,920.2 Gg CO_2-e (25.7 per cent) to 77,868.1 Gg CO_2-e (Figure 2.1.1). Between 1990 and 2006, the average annual growth in overall emissions was 1.5 per cent per year.

New Zealand's total emissions trend is different to many other countries. Instead of a predictable increase or decline in emissions, the trend for New Zealand consists of year to year fluctuations (Figure 2.1.1). These fluctuations are largely due to the change in proportion of non-renewable energy used in electricity and heat production affecting CO_2 emissions (Figure 3.2.2). This is further explained in section 3.2.1.1.

Figure 2.1.1 New Zealand's total greenhouse gas emissions from 1990 to 2006 (all figures are Gg CO_2-e)



2.2 Emission trends by gas

Inventory reporting under the Climate Change Convention covers six direct greenhouse gases, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). Figure 2.2.1 shows the change in each direct greenhouse gas between 1990 and 2006. Trends in CO_2, CH_4 and N_2O emissions over the period 1990–2006 are shown in Figure 2.2.2. In accordance with the Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases are included in inventory reporting but not in the national emission total. These indirect gases include carbon monoxide (CO), sulphur dioxide (SO_2), oxides of nitrogen (NO_X), and non-methane volatile organic compounds (NMVOCs).

Removals of carbon dioxide from the atmosphere are reported in the LULUCF sector.

- Carbon dioxide contributed the largest share of all 2006 emissions at 36,388.0 Gg CO_2-e (46.7 per cent). Carbon dioxide emissions increased by 11,005.8 Gg CO_2-e (43.3 per cent) from the 1990 level of 25,382.2 Gg CO_2-e.
- Methane contributed 27,499.3 Gg CO_2-e (35.3 per cent) of total emissions in 2006. Methane emissions have grown by 2,013.7 Gg CO_2-e (7.9 per cent) from the 1990 level of 25,485.6 Gg CO_2-e.
- Nitrous oxide contributed 13,283.7 Gg CO_2-e (17.1 per cent) of emissions in 2006. Emissions have increased by 2,857.7 Gg CO_2-e (27.4 per cent) from the 1990 level of 10,426.0 Gg CO_2-e.
- Perfluorocarbons, SF_6 and HFCs contributed the remaining 697.1 Gg CO_2-e (0.9 per cent) of emissions in 2006.
- Emissions of PFCs have decreased by 550.8 Gg CO_2-e (85.8 per cent) from the 641.7 Gg CO_2-e in 1990, to 90.9 Gg CO_2-e in 2006.
- Emissions of SF_6 have grown by 0.9 Gg CO_2-e (7.4 per cent), from the 1990 level of 12.3 Gg CO_2-e to the 2006 level of 13.2 Gg CO_2-e.
- In 1990, no HFCs were used in New Zealand. In 2006, 592.9 Gg CO_2-e of HFC emissions were produced.

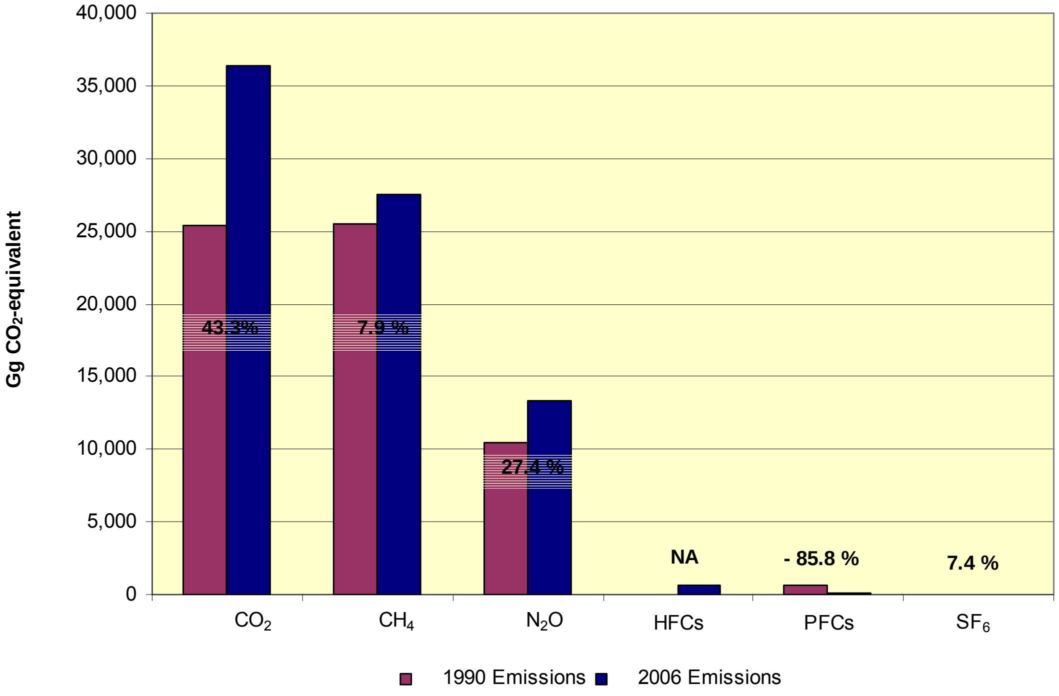
The growth in CO_2 represents the increased emissions from the energy sector particularly in road transport and energy generation. The growth in N_2O is from increased emissions from animal excreta and the increased use of nitrogenous fertilisers in the agriculture sector. The amount of nitrogenous fertilisers used in New Zealand has increased six-fold since 1990.

Although the contribution of the other gases (HFCs, PFCs and SF_6) in the inventory is around 1 per cent of the total emissions, these gases have also undergone large relative changes between 1990 and 2006. Emissions of PFCs have decreased due to improvements in the aluminium smelting process. HFC emissions have increased because of the use of HFCs as a substitute for chlorofluorocarbons (CFCs) phased out under the Montreal Protocol. No emissions of HFCs occurred in 1990 therefore no percentage has been shown in Figure 2.2.1 and Table 2.2.1.

Table 2.2.1 Emissions of greenhouse gases in 1990 and 2006

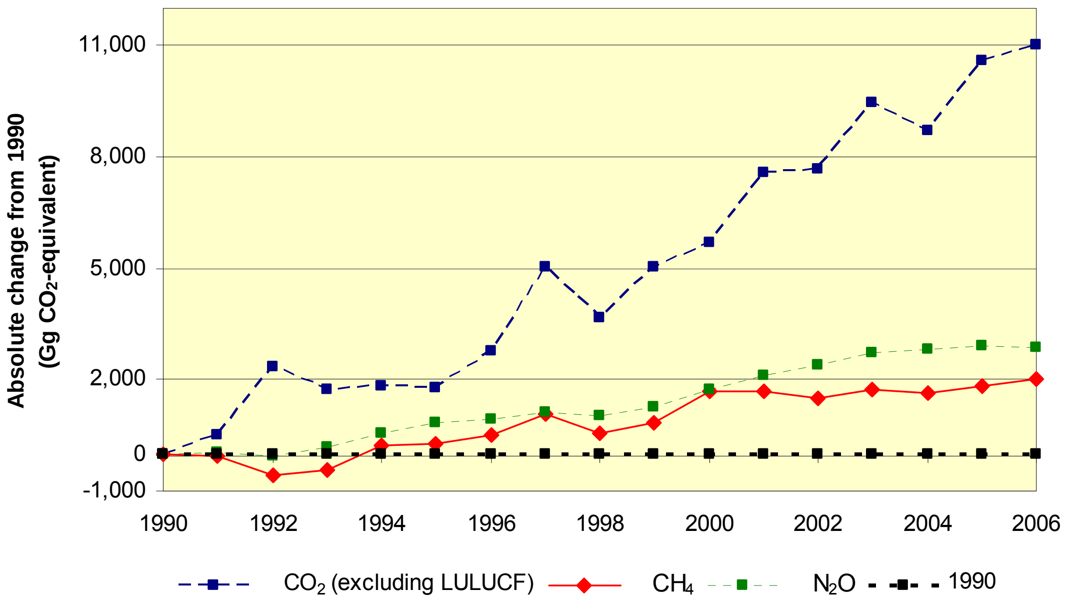
	Gg CO_2-equivalent		Change from 1990 (Gg CO_2 - equivalent)	Change from 1990 (%)
Greenhouse gas emissions	**1990**	**2006**		
CO_2 (excluding LULUCF)	25,382.2	36,388.0	11,005.7	43.3
CH_4 (excluding LULUCF)	25,485.6	27,499.3	2,013.7	7.9
N_2O (excluding LULUCF)	10,426.0	13,283.7	2,857.7	27.4
HFCs	0.0	593.0	593.0	NA
PFCs	641.7	90.9	–550.8	–85.8
SF6	12.3	13.2	0.9	7.4
Total	**61,947.9**	**77,868.1**	**15,920.2**	**25.7**

Figure 2.2.1 Change in New Zealand's emissions by gas from 1990 to 2006 (all figures Gg CO_2-e and exclude LULUCF)



Note: The per cent change for hydrofluorocarbons is not applicable (NA) as there was no production of hydrofluorocarbons in 1990.

Figure 2.2.2 Change in New Zealand's emissions of CO_2, CH_4, and N_2O from 1990 to 2006 (all figures are Gg CO_2-e)



2.3 Emission trends by source

- The agriculture sector is the largest source of emissions, contributing 37,667.6 Gg CO_2-e (48.4 per cent) of total emissions in 2006 (Figure 2.3.1 and Table 2.3.1). Consequently, New Zealand has a unique emissions profile. In other developed countries, agricultural emissions typically are around 12 per cent of national emissions. In 2006, agricultural emissions have increased 5,168.8 Gg CO_2-e (15.9 per cent) from the 1990 level of 32,498.9 Gg CO_2-e. The agriculture sector contributed 12,801.9 Gg CO_2-e (96.3 per cent) of New Zealand's total nitrous oxide emissions and 24,865.7Gg CO_2-e (90.3 per cent) of total methane emissions in 2006.
- The energy sector was the source of 34,069.3 Gg CO_2-e (43.8 per cent) of all emissions in 2006. In 2006, energy emissions have increased 10,570.2 Gg CO_2-e (45.0 per cent) from the 1990 level of 23,499.1 Gg CO_2-e. This growth in emissions is primarily from electricity generation and heat production and transport.
- The industrial processes sector accounts for 4,233.1 Gg CO_2-e (5.4 per cent) of total emissions in 2006. Emissions from the industrial processes sector have increased 830.4 Gg CO_2-e (24.4 per cent) from the 1990 level of 3,402.7 Gg CO_2-e. The increase is mainly growth in emissions from metal production and consumption of hydrofluorocarbons.
- The solvents and other products sector is a minor contributor to New Zealand's total direct greenhouse gas emissions, being responsible for 40.3 Gg CO_2-e (0.05 per cent) of total emissions.
- The waste sector accounts for 1,857.8 Gg CO_2-e (2.4 per cent) of total emissions in 2006. Emissions from the waste sector have decreased 647.8 Gg CO_2-e (25.9 per cent) from a 1990 level of 2,505.7 Gg CO_2-e. This decrease is due to initiatives to improve solid waste management practices in New Zealand.

- Under the LULUCF sector, removals are estimated to be 22,749.3 Gg CO_2-e (29.2 per cent) of national emissions in 2006. LULUCF removals have increased 2,241.6 Gg CO_2-e (10.9 per cent) from the 1990 level of 20,507.7 Gg CO_2-e. LULUCF removals fluctuate with the planting and harvesting of New Zealand's planted forest.

Table 2.3.1 Sectoral emissions of greenhouse gases in 1990 and 2006

Sector	Gg CO_2-equivalent 1990	Gg CO_2-equivalent 2006	Change from 1990 (Gg CO_2-equivalent)	Change from 1990 (%)
Energy	23,499.1	34,069.3	10,570.2	45.0
Industrial processes	3,402.7	4,233.1	830.4	24.4
Solvent and other product	41.5	40.3	–1.2	–3.0
Agriculture	32,498.9	37,667.6	5,168.8	15.9
Waste	2,505.7	1,857.8	–647.8	–25.9
Total (excluding LULUCF)	**61,947.9**	**77,868.1**	**15,920.2**	**25.7**
Land-use change and forestry (including CH_4 & N_2O)	–20,507.7	-22,749.3	–2,241.6	10.9
Net Total (including LULUCF)	**41,440.2**	**55,118.8**	**13,678.7**	**33.0**

Figure 2.3.1 Change in New Zealand's sectoral greenhouse gas emissions from 1990 to 2006 (all figures Gg CO_2-e and exclude LULUCF)

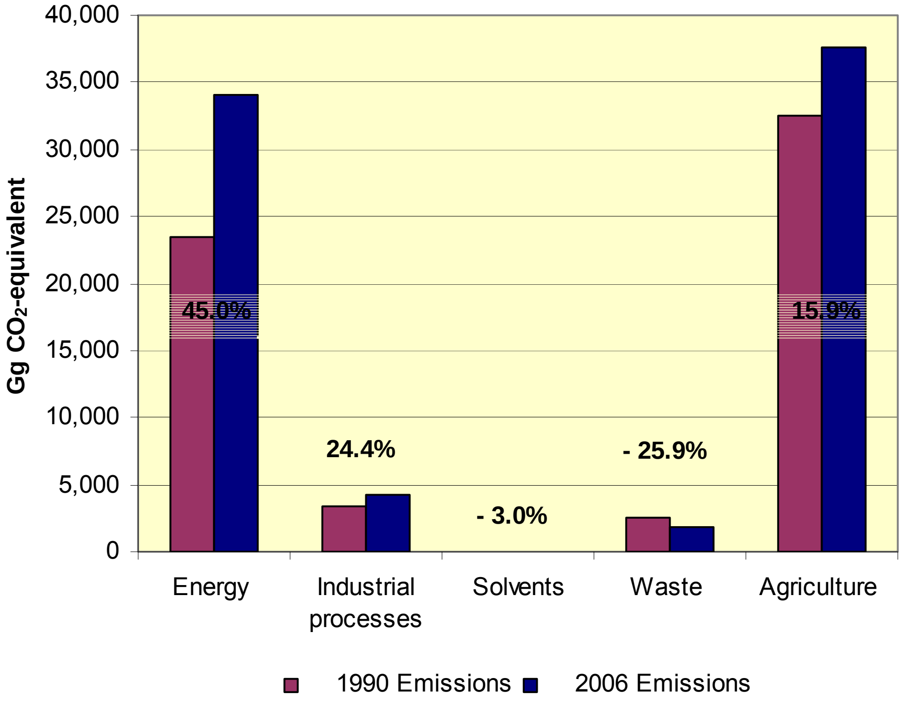
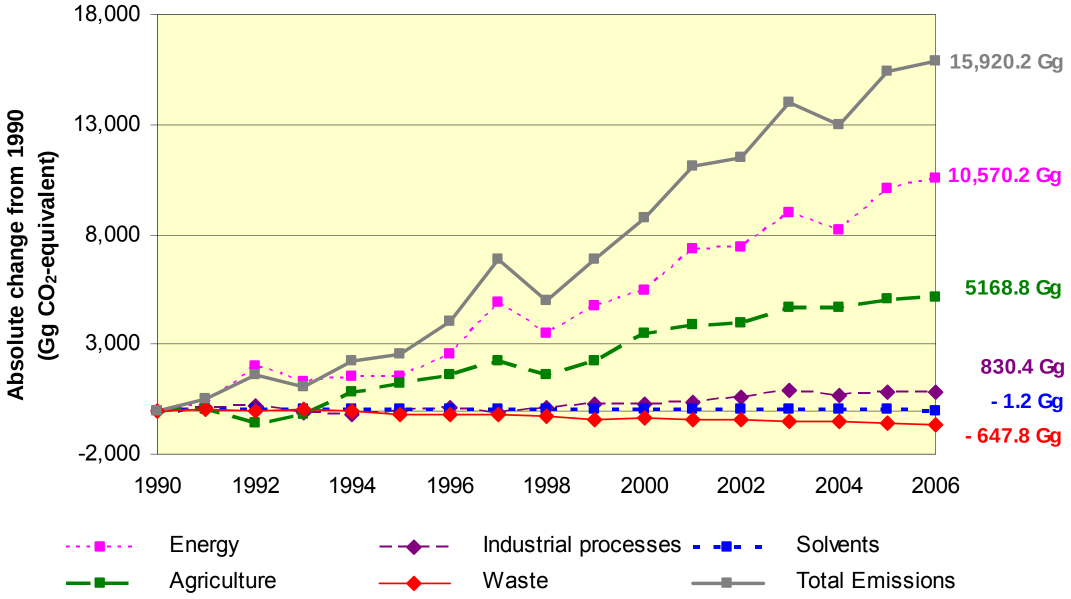


Figure 2.3.2 Change in sectoral greenhouse gas emissions from 1990 to 2006 (all figures are Gg CO_2-e and exclude LULUCF)



2.4 Emission trends for indirect greenhouse gases and SO_2

The indirect greenhouse gases SO_2, CO, NO_x and NMVOC are also reported in the inventory. Emissions of these gases in 1990 and 2006 are shown in Table 2.4.1. There have been increases in the emissions of all gases. Indirect greenhouse gases are not included in New Zealand's total greenhouse gas emissions.

Table 2.4.1 Emissions of indirect greenhouse gases and SO_2 in 1990 and 2006

Gas	Gg of gas(es) 1990	Gg of gas(es) 2006	Change from 1990 (Gg)	Change from 1990 (%)
NO_x	107.3	167.5	60.2	56.1
CO	526.1	650.8	124.7	23.7
NMVOC	133.7	168.5	34.8	26.0
SO_2	54.3	81.3	27	49.7
Total	**821.4**	**1,068.1**	**246.7**	**30.0**

Emissions of CO and NO_x are largely from the energy sector. The energy sector produced 87.6 per cent of total CO emissions in 2006. The largest single source of CO emissions was "road transportation". Similarly, the energy sector was the largest source of NO_x emissions (98 per cent), with "road transportation" dominating. Other large sources of NO_x emissions are from "manufacturing industries and construction" and "energy industries".

The energy sector was also the largest producer of NMVOCs and SO_2, producing 71.2 per cent of NMVOC emissions in 2006. Emissions from "road transportation" comprised 63.1 per cent of total NMVOC emissions. Other major sources of NMVOC are in the solvent and other product use sector (20.3 per cent) and the industrial processes sector (8.5 per cent).

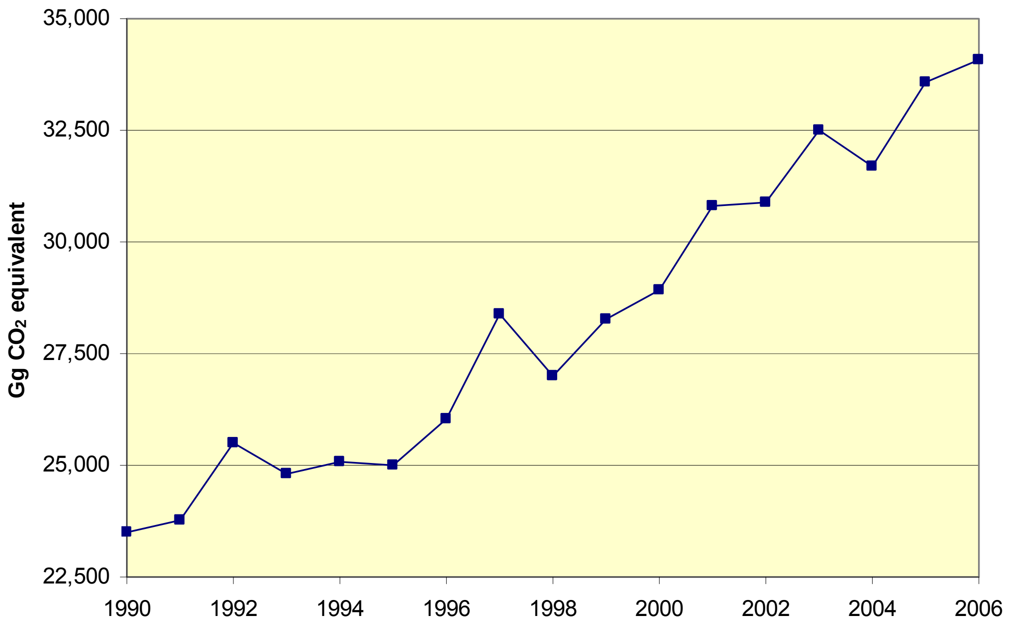
Emissions of SO_2 from the energy sector comprised 86.2 per cent of total SO_2 emissions. The "energy industries" category contributed 28.8 per cent, "manufacturing industries and construction" 25.8 per cent and "transport" 15.2 per cent of total SO_2 emissions. The other source of SO_2 was from the industrial processes sector.

Chapter 3: Energy

3.1 Sector overview

The energy sector produced 34,069.3 Gg carbon dioxide equivalent (CO_2-e) in 2006, representing 43.8 per cent of New Zealand's total greenhouse gas emissions. Emissions from the energy sector are now 45.0 per cent above the 1990 value of 23,499.1 Gg CO_2-e (Figure 3.1.1). The sources contributing most to the increase since 1990 are emissions from "public electricity and heat production", an increase of 4,807.3 Gg CO_2-e (137.6 per cent), and "road transportation", an increase of 5,127.3 Gg CO_2-e (66.9 per cent). Emissions from the "manufacture of solid fuels and other energy industries" subcategory have decreased by 1,426.1 Gg CO_2-e (-80.3 per cent) from 1990; this is primarily due to the cessation of synthetic petrol production in 1997.

Figure 3.1.1 Energy sector emissions from 1990 to 2006 (all figures are Gg CO_2-e)



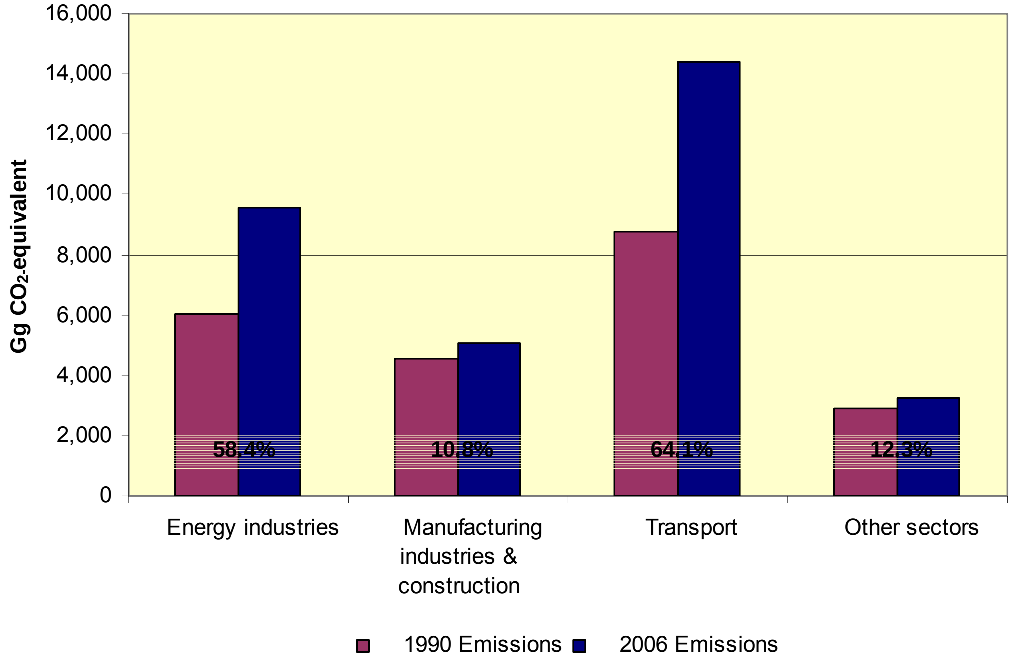
3.2 Fuel combustion (CRF 1A)

Description

The "fuel combustion" category reports all emissions from fuel combustion activities. This includes "energy industries", "manufacturing industries and construction", "transport" and "other sectors" (commercial, residential and agriculture/forestry/fisheries) (Figure 3.2.1). These subcategories use common activity data sources and emission factors. The common reporting tables require energy emissions to be reported by sub category. Splitting energy activity data across sub categories is not as accurate as splitting activity data by fuel type because of difficulties in allocating liquid fuel use.

Examples of the calculations used to estimate emissions for 2006 are included in the excel workbooks available for download with this report from the Ministry for the Environment's website. Information about methodologies, emission factors, uncertainty and quality control and assurance relevant to each of the subcategories are discussed below.

Figure 3.2.1 Change in emissions from the energy sector from 1990 to 2006: fuel combustion (all figures are Gg CO_2-e)



Methodological issues

Energy activity data is compiled using the Ministry of Economic Development's energy database along with relevant country specific emission factors. Greenhouse gas emissions are calculated by multiplying the emission factor of specific fuels by the activity data. There are only a few occasions where emission factors are not able to be reported due to confidentiality reasons and instances where natural gas is used as a feedstock.

The "fuel combustion" category is separated into stationary combustion and mobile combustion. Carbon dioxide emissions from the stationary combustion of gas, solid fuels, and liquid fuels are identified as key categories. New Zealand has data on fuel combustion detailed by fuel type and sub category but not for every individual energy facility therefore the methodologies used to calculate emissions for the energy sector are based on the IPCC Tier 1 approach.

Activity data – liquid fuels

Statistics New Zealand conducts the "Delivery of Petroleum Fuels by Industry Survey". The survey is run as a quarterly census. The purpose of the census 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 Statistics New Zealand with the volume of petroleum fuels delivered to resellers and industry groups.

Activity data – solid fuels

The "New Zealand Coal Sales Survey" conducted by Statistics New Zealand is an ongoing quarterly survey which began on 1 March 1981. The purpose of this survey is to measure the amount of coal which is sold and available to users. The target population is all coal mines and major resellers of coal in New Zealand. Completion of the survey has been approved by the Minister of Statistics. Returning the completed and signed questionnaire is a requirement under the Statistics Act 1975.

The three ranks of coal measured are bituminous, sub-bituminous and lignite coal. From 1988 onwards the coal sales questionnaire separated coal sales into seven end-use sectors; however these do not match the IPCC sectors. The sectoral shares of coal use that can be used for the inventory are based on CRL Energy Limited's survey of sectoral coal use for 1990 and 1995. Data is interpolated between 1990 and 1995 and extrapolated for all years beyond 1995. The exceptions are for the coal used for "iron and steel", "public electricity and heat production" and the "residential household" sector where the Ministry of Economic Development use data from the New Zealand Coal Sales Survey. Sectoral shares are calculated by:

- Summing the four calendar year quarters of coal sales data from the New Zealand Coal Sales Survey.
- Subtracting coal exports, coal used by the "residential" sector, coal used for "iron and steel production" and coal used for "public electricity and heat production"; then, dividing CRL's annual coal tonnage for each sector by the total (excluding exports, steel, electricity and residential coal use) to give sectoral shares of coal use for 1990 and 1995.
- Interpolating sectoral shares between 1990 and 1995 and extrapolating from 1995 to 2006.

Activity data – gaseous fuels

The amount of gas extracted, vented and flared at each gas field in New Zealand is provided to the MED by the individual gas field operators. Activity data on processed gas from the Kapuni gas field and gas transmission and distribution throughout New Zealand is provided to the MED by the gas transportation and processing company Vector. Large users of gas, including electricity generation companies, provide their activity data directly to the MED. Gas activity data from small industrial, commercial and residential users is obtained by the MED through a quarterly gas survey sent to gas retailers and wholesalers.

Activity data – biomass

Activity data for the use of biomass comes directly from the companies involved with combusting wood residues to provide process heat in the wood processing industry (such as kiln drying) and electricity production from cogeneration plants.

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. Explanation of the characteristics of liquid, solid and gaseous fuels and biomass used in New Zealand are described under each of the fuel sections below.

A review of New Zealand's energy emission factors (Hale and Twomey Ltd, 2003) identified a number of non-CO_2 emission factors where the supporting information was assessed to be insufficient to retain the country-specific emission factors used in previous inventories. Where a country-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 revised IPCC 1996 guidelines (IPCC, 1996) are converted from net calorific value to gross calorific value.

The emission factors recommended by the Hale and Twomey review and agreed by a New Zealand review panel were first used in the 2004 inventory submission, and have been used in all subsequent inventory submissions. The exception is the use of IPCC default emission factors for CH_4 emissions in "road transport" which have been used since the 2007 inventory submission.

Emission factors – liquid fuels

The CO_2 emission factors for oil products are from the New Zealand Refining Company (NZRC) data, import data from industry and from Baines (1993). There is a direct relationship between each fuel's carbon content and the corresponding CO_2 emissions during combustion. However, the carbon composition of oil products is not closely monitored and there will be variation over time, depending on the crude oil used in production.

Before the 2004 inventory submission, the CO_2 emission factors used in inventories for the "transport" category were sourced from the *New Zealand Energy Information Handbook* (Baines, 1993). As a result of the Hale and Twomey review the CO_2 emission factors were replaced with individual liquid fuels emission factors derived from the New Zealand Refining Company data on carbon content and calorific values. The emission factors will be updated if the fuel specifications of liquid fuels change.

Emission factors – solid fuels

New Zealand's emissions from coal burning are calculated using the emission factor for sub-bituminous coal of 91.2 kt CO_2/PJ (Baines, 1993). Using the sub-bituminous value for all ranks of coal is a reasonable assumption for New Zealand as the bulk of the high-quality bituminous coal is exported and all coal used in public electricity generation is of sub-bituminous rank (Ministry of Economic Development, 2006).

Emission factors – gaseous fuels

New Zealand uses the gas production from the Maui and Kapuni gas fields reported in the New Zealand Energy Data File (Ministry of Economic Development, 2007b) to support the calculation of a weighted average annual CO_2 emission factor for natural gas. The average emission factor is applied to a number of categories in the energy sector, for example in the "manufacturing industries and construction category".

New Zealand has a gas field (Kapuni) with particularly high CO_2 content which has historically been valued by the petrochemicals industry as a feedstock. However, most of the gas from this field is now treated and the excess CO_2 removed. Separate emissions factors are used for Kapuni treated and un-treated gas due to the difference in carbon content (refer to Annex 2).

Emission factors – biomass

The emission factors for wood consumption are calculated from the IPCC default emission factors (IPCC, 1996) assuming the net calorific value is five per cent less than the gross calorific value. In accordance with good practice (IPCC, 2000) CO_2 emissions from wood used for energy production are reported as a memo item and not included in the greenhouse gas emissions total.

Uncertainties and time-series consistency

Uncertainty in greenhouse gas emissions from fuel combustion varies depending on the gas (Table 3.2.1). The uncertainty of CO_2 emissions is relatively low at ± 5 per cent and is primarily due to uncertainty in activity data rather than emission factors. This is because of the direct relationship between fuels' carbon content and the corresponding CO_2 emissions during combustion. The low level of uncertainty in CO_2 emissions is important as CO_2 emissions comprise 96.8 per cent of emissions in the energy sector. Details of how uncertainty in CO_2 emissions is assessed are provided under each fuel type in Annex 2.

In comparison, emissions of the non-CO_2 gases are much less certain as emissions vary with combustion conditions. Many of the non-CO_2 emission factors used by New Zealand are the IPCC default values. The revised 1996 IPCC guidelines (IPCC, 1996) often do not quantify the uncertainty in the default emission factors. The uncertainties proposed in Table 3.2.1 are best estimates derived for New Zealand conditions (Ministry of Economic Development, 2006).

Table 3.2.1 General uncertainty ranges for emission estimates from fuel combustion (Ministry of Economic Development, 2006)

Gas	Uncertainty
CO_2	± 5%
CH_4	± 50%
N_2O	± 50%
NO_x	± 33%
CO	± 50%
NMVOC	± 50%

3.2.1 Fuel combustion: Energy industries (CRF 1A1)

Description

This category comprises emissions from fossil fuels burnt in stationary combustion. It includes combustion for “public electricity and heat production”, “petroleum refining”, the “manufacture of solid fuels” and “other energy industries”.

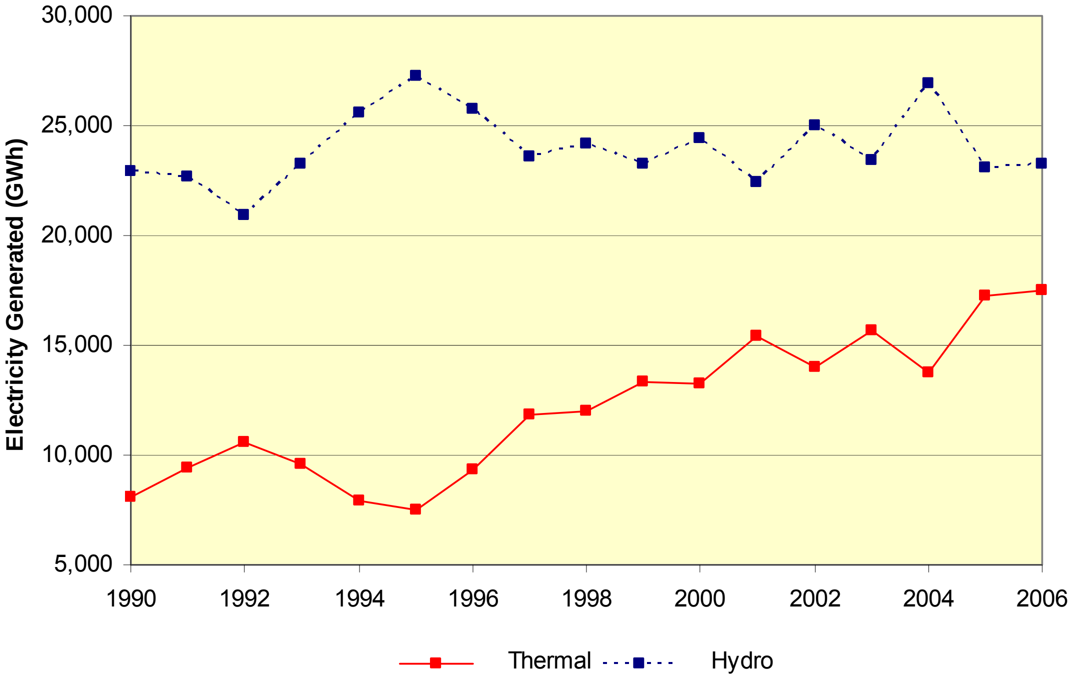
In 2006, emissions in the “energy industries” category totalled 9570.7 Gg CO_2-e (28.1 per cent) of the energy sector. Emissions from energy industries have increased 3,527.7 Gg CO_2-e (58.4 per cent) since the 1990 level of 6,043.0 Gg CO_2-e. Public electricity and heat production accounted for 8,300.5 Gg CO_2-e (86.7 per cent) of the emissions from energy industries in 2006. This is an increase of 4,807.3 Gg CO_2-e (137.6 per cent) from the 1990 level of 3,493.2 Gg CO_2-e.

New Zealand’s electricity generation is dominated by hydro-electric generation. For the 2006 calendar year, hydro generation provided 55 per cent of New Zealand’s electricity generation. A further 11 per cent came from other renewable sources (such as geothermal, wind and biomass) and waste heat sources. The remaining 34 per cent was provided by fossil fuel thermal generation plants using coal and gas (Ministry of Economic Development, 2007b).

Greenhouse gas emissions from “public electricity and heat production” show large year-to-year fluctuations because use of thermal power generation stations complements the hydro-electric generation available. Generation in a ‘normal’ hydro year requires lower gas and coal use, while a ‘dry’ hydro year requires higher gas and coal use. This is a different trend from the steady increase in emissions from coal and gas observed in electricity generation in many other countries.

Figure 3.2.2, which shows net electricity production by fuel type from 1990 to 2006, clearly illustrates that on an annual basis when the level of hydro-electric generation decreases, the level of thermal electricity generation from fossil fuels (gas, coal and oil) increases.

Figure 3.2.2 Hydro-electric and thermal generation from 1990 to 2006



Methodological issues

Public electricity and heat production

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

A small percentage of New Zealand's electricity is supplied by co-generation (also known as combined heat and power). Most of the major co-generation plants are attached to large industrial facilities that consume most of the electricity and heat generated. According to the definition of public electricity and heat production in the revised 1996 IPCC guidelines (IPCC, 1996) there is only one co-generation plant in New Zealand producing electricity as its primary purpose. The emissions from this plant are included under electricity and heat production whereas emissions from other co-generation plants are included under the "manufacturing industries and construction (other)" subcategory.

Petroleum refining

The New Zealand Refining Company Limited provides the MED with CO_2 emissions associated with activities from the "petroleum refining" category. As no data is available concerning non-CO_2 emissions from the refinery, IPCC default emission factors for industrial boilers are used (IPCC, 1996).

Manufacturing of solid fuels and other energy industries

New Zealand reports emissions from natural gas in oil and gas extraction and natural gas in synthetic petrol production.

Activity data for oil and gas extraction is provided by each individual gas field operator. Activity data for synthetic petrol production was provided by Methanex New Zealand Limited while the plant was in operation. Production of synthetic petrol stopped in New Zealand in 1997.

The low implied emission factors (IEFs) for “manufacturing of solid fuels and other energy industries” subcategory for gaseous fuels between 1990 and 1996 was caused by the sequestration of carbon in the process of producing synthetic petrol.

Uncertainties and time-series consistency

Uncertainties in emissions estimates for this category are relevant to the entire fuel combustion sector (refer to Table 3.2.1 and Annex 2).

Source-specific QA/QC and verification

In preparation of this inventory, the “energy industries” category underwent Tier 1 quality checks.

Source-specific recalculations

In previous inventory submissions, constant calorific values were used to convert tonnes (t) of fuel to peta joules (PJ) of fuel. For the 2008 inventory submission year-specific calorific values have been introduced to improve the accuracy of the activity data between 1990 and 2006.

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

Description

This category comprises emissions from fuels burnt in manufacturing industries and construction, including iron and steel, other non-ferrous metals, chemicals, pulp, paper and print, food processing, beverages and tobacco, and other uses.

In 2006, emissions from “manufacturing industries and construction” accounted for 5,078.4 Gg CO_2-e (14.9 per cent) emissions from the energy sector. Emissions are 494.8 Gg CO_2-e (10.8 per cent) above the 1990 level of 4,583.6 Gg CO_2-e. Emissions from this category declined significantly between 2003 and 2004, mainly as a result of a decrease in the production of methanol.

Methodological issues

Activity data for coal used in iron and steel production is reported to the Ministry of Economic Development by Blue Scope Steel Limited. A considerable amount of coal is used in the production of iron, however virtually all the coal is used in a direct reduction process to remove oxygen from ironsand and not as a fuel. All emissions from the use of coal are therefore included in the industrial processes sector. A small amount of gas is used in the production of iron and steel to provide energy for the process. This data also comes directly from Blue Scope Steel Limited.

Methanol production is the largest source of emissions in the "chemical" subcategory. The activity data for methanol production is supplied directly by Methanex New Zealand Limited. Carbon dioxide emissions are calculated by comparing the amount of carbon in the gas purchased by the plants with the amount stored in methanol as shown in Box 3.1.

Box 3.1 Calculation of CO_2 emissions from methanol production (Ministry of Economic Development, 2006)

Assumptions

- Synthetic petrol is 85.8% carbon by weight.
- Methanol is 37.5% carbon by weight.
- CO_2 emissions factor for Maui gas is 52.0 kt/PJ (2006) (refer Annex 2).
- CO_2 emissions factor for Kapuni gas is 84.1kt/PJ.
- CO_2 emissions factor for mixed feed gas is 62.4 kt/PJ.

The resulting calculations are:

- Weight of carbon in gas to Methanex = [(PJ Maui)*52.0 + (PJ Kapuni)*84.1 + (PJ mixed feed)*62.4] *12/44 kilotonnes.
- Weight of carbon in synthetic petrol = [amount of petrol produced * 0.858] kilotonnes.
- Weight of carbon in methanol = [amount of methanol produced * 0.375] kilotonnes.
- Weight of carbon sequestered in the products = [weight of carbon in petrol + weight of carbon in methanol] kilotonnes.
- Total emissions of CO_2 = [(weight of carbon in gas to Methanex)–(weight of carbon sequestered)] * 44/12 kilotonnes.

The activity data for the "other" sub category (including construction, food and beverage and dairy processing) is from the "Delivery of Petroleum Fuels by Industry Survey", the "New Zealand Coal Sales Survey" and energy supply and demand balance tables in the Energy Data File (Ministry of Economic Development, 2007b).

Uncertainties and time-series consistency

Uncertainties in emission estimates are those relevant to the entire energy sector (refer table 3.2.1 and Annex 2).

Source-specific QA/QC and verification

In preparation of this inventory, the data for CO_2 emissions from stationary combustion underwent Tier 1 quality checks.

Source-specific recalculations

In previous inventory submissions, constant calorific values were used to convert tonnes (t) of fuel to peta joules (PJ) of fuel. For the 2008 inventory submission year-specific calorific values have been introduced to improve the accuracy of the activity data between 1990 and 2006.

3.2.3 Fuel combustion: transport (CRF 1A3)

Description

This category includes emissions from fuels combusted during transportation such as civil aviation, road, rail and domestic marine transport. Emissions from international marine and aviation bunkers are reported but not included in the total emissions.

In 2006, transport was responsible for 14,406.4 Gg CO_2-e (42.3 per cent) of emissions from the energy sector. Emissions have increased 5,628.2 Gg CO_2-e (64.1 per cent) from the 8,778.2 Gg CO_2-e emitted in 1990. The transport emissions profile in 2006 is dominated by emissions from the "road transportation" subcategory. Road transport accounted for 12,795.7 Gg CO_2-e (88.8 per cent) of total transport emissions. This is an increase of 5,127.3 Gg CO_2-e (66.9 per cent) from the 1990 level of 7,668.4 Gg CO_2-e. Carbon dioxide emissions from the "road transportation" subcategory were identified as having a major influence on the trend in New Zealand's greenhouse gas emissions (Table 1.5.3).

Methodological issues

Emissions from transport are compiled from the Ministry for Economic Development's energy database. It is good practice to use a Tier 1 approach (total fuel consumed multiplied by an emission factor) for calculating CO_2 emissions as this provides the most reliable estimate of emissions using country-specific and IPCC default emission factors (IPCC, 2000).

Activity data on the consumption of fuel by the transport sector are extracted from the "Delivery of Petroleum Fuels by Industry Survey" conducted by Statistics New Zealand. Liquefied petroleum gas (LPG) and compressed natural gas (CNG) consumption figures are reported in the Energy Data File (Ministry of Economic Development, 2007b).

Road transport

The Tier 1 approach has been used to calculate CO_2 from road transport which is consistent with good practice (IPCC, 2000). Although good practice encourages the use of a Tier 2 approach for calculating emissions of CH_4 and N_2O, calculating emissions from these gases is more complicated because emission factors depend on vehicle technology, fuel and operating characteristics. New Zealand does not currently have all of the data to accurately estimate non-CO_2 emissions from transport using a Tier 2 methodology. Therefore estimates of CH_4 and N_2O emissions from "road transportation" are calculated using a Tier 1 approach. Emission factors of CO_2 and non-CO_2 gases for the various fuel types used in "road transportation" can be found in Annex 2.

Navigation (domestic marine transport)

Emissions from "navigation" in New Zealand are estimated using a Tier 1 approach with country-specific emission factors for estimating CO_2 emissions and IPCC default emission factors for CH_4 and N_2O. Prior to the 2004 inventory submission, New Zealand specific emission factors were used for CH_4 and N_2O emissions from fuel oil in domestic transport. The 2003 review of emission factors (Hale and Twomey Ltd, 2003) recommended reverting to the IPCC default emission factors.

Civil aviation

The New Zealand methodology for estimating emissions from "civil aviation" is a Tier 1 approach that does not use landing and take-off (LTO) cycles. There is no gain in inventory quality by moving from a Tier 1 to a Tier 2 approach using LTO cycles (IPCC, 2000). The distinction between domestic and international flights is based on refuelling at the domestic and international terminals of New Zealand airports. There is no basis for splitting the domestic and international components of fuel use for international flights with a domestic leg. This is because information on fuel use for "civil aviation" and "navigation" is available from the oil companies rather than from the individual airlines or shipping companies.

Uncertainties and time-series consistency

Uncertainties in emission estimates from the "transport" category are relevant to the entire fuel combustion sector (refer Table 3.2.1 and Annex 2).

Source-specific QA/QC and verification

In preparation of this inventory, data for carbon dioxide emissions from the "transport" category underwent Tier 1 quality checks.

Source-specific recalculations

In previous inventory submissions, constant calorific values were used to convert tonnes (t) of fuel to peta joules (PJ) of fuel. For the 2008 inventory submission year-specific calorific values have been introduced to improve the accuracy of the activity data between 1990 and 2006.

3.2.4 Fuel combustion: other sectors (CRF 1A4)

Description

This sector comprises emissions from fuels combusted in the "commercial/institutional", "residential" and "agriculture, forestry and fisheries" sub-categories.

In 2006, fuel combustion of the "other sectors" category accounted for 3,245.6 Gg CO_2-e (9.5 per cent) of the emissions from the energy sector. This is an increase of 355.3 Gg CO_2-e (12.3 per cent) above the 1990 value of 2,890.2 Gg CO_2-e. The emissions contribution in 2006 is divided between the "commercial and institutional" subcategory and the "agriculture, forestry and fisheries" subcategory with the "residential" subcategory.

Commercial and institutional emissions were 1,321.6 Gg CO_2-e (40.7 per cent) of the other sectors category in 2006. This is an increase of 155.7 (13.4 per cent) since the 1990 level of 1,165.8 Gg CO_2-e.

Agricultural, forestry and fisheries emissions were 1,283.9 Gg CO_2-e (39.6 per cent) of the other sectors category in 2006. This is an increase of 163.0 Gg CO_2-e (14.5 per cent) since the 1990 level of 1,120.9 Gg CO_2-e.

Residential emissions were 640.1 Gg CO_2-e (19.7 per cent) of the other sectors category in 2006. This is an increase of 36.6 Gg CO_2-e (6.1 per cent) from the 1990 level of 603.5 Gg CO_2-e.

Methodological issues

Accurately partitioning energy use between categories is difficult. This means that some categories eg, "agriculture, forestry and fisheries" subcategory may be underestimated. However, the fuel use and associated emissions have been included in other subcategories such as industry and transport and are therefore included in New Zealand's total emissions.

More accurate activity data for residential biomass has been included from 2000. Activity data prior to this date is based on a 1996 study which estimated average wood consumption per household at 4.3GJ. A subsequent study which involved monitoring of residential wood use provided a more accurate estimate of 13.7 GJ per household. Activity data for residential biomass has been revised back to 2000 based on this more accurate estimate and is consistent with the Energy Data File (Ministry of Economic Development, 2007b).

Uncertainties and time-series consistency

Uncertainties in emission estimates for data from other sectors is relevant to the entire energy sector (refer Table 3.2.1 and Annex 2).

Source-specific QA/QC and verification

There were no specific Tier 1 quality checks undertaken for this category as it is not a key category. It was checked in the previous submission as part of a selection of non-key categories chosen for quality checking.

Source-specific recalculations

In previous inventory submissions, constant calorific values were used to convert tonnes (t) of fuel to peta joules (PJ) of fuel. For the 2008 inventory submission year-specific calorific values have been introduced to improve the accuracy of the activity data between 1990 and 2006.

Revisions to residential biomass activity data is outlined in section 3.2.4.2 above.

Source-specific planned improvements

New Zealand will reassess the methodology and assumptions used to calculate emissions from residential biomass consumption.

3.3 Fugitive emissions from fuels (CRF 1B)

Fugitive emissions arise from the production, processing, transmission, storage and use of fossil fuels, and from non-productive combustion. This category is comprised of two sub-categories, solid fuels and oil and natural gas.

In 2006, fugitive emissions from fuels accounted for 1,768.3 (5.2 per cent) of energy emissions from the energy sector. This is an increase of 564.1 (46.8 per cent) from the 1990 level of 1,204.2 Gg CO_2-e.

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

Description

In 2006, fugitive emissions from the “solid fuels” sub-category produced 450.2 Gg CO_2-e (25.5 per cent) of emissions from the fugitive emissions category. This is an increase of 178.1 Gg CO_2-e (65.4 per cent) from the 272.1 Gg CO_2-e reported in 1990.

New Zealand’s fugitive emissions from the “solid fuels” category are a product of coal mining operations. Methane is created during coal formation. The amount of CH_4 released during coal mining is dependant on the coal rank and the depth of the coal seam. In 2006, 82 per cent of the CH_4 from coal mining (including post-mining emissions) came from underground mining.

There is no flaring of CH_4 at coal mines and CH_4 is rarely captured for industrial uses. Methane is also emitted during post-mining activities such as coal processing, transportation and use.

Methodological issues

The underground mining subcategory dominates fugitive emissions from coal mining. New Zealand focuses its efforts on accurately estimating emissions from this subcategory in accordance with good practice. A New Zealand-specific emission factor for underground mining of sub-bituminous coal is used to calculate CH_4 emissions (Beamish and Vance, 1992). Emission factors for the other subcategories, for example, surface mining, are sourced from the revised 1996 IPCC guidelines (IPCC, 1996) as shown in Table 3.3.1.

Table 3.3.1 Methane release factors for New Zealand coal

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

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

Uncertainties and time-series consistency

Uncertainties in fugitive emissions are relevant to the entire energy sector (refer Table 3.2.1 and Annex 2).

Source-specific QA/QC and verification

There were no specific Tier 1 quality checks undertaken for this category as it is not a key category. It was checked in the previous submission as part of a selection of non-key categories chosen for quality checking.

Source-specific recalculations

There were no recalculations for the “fugitive emissions from fuels: solid fuels” subcategory.

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

Description

In 2006, fugitive emissions from the “oil and natural gas” sub-category totalled 1,318.1 Gg CO_2-e (74.5 per cent) of emissions from the fugitive emissions category. This is an increase of 386.0 Gg CO_2-e (41.4 per cent) from 932.0 Gg CO_2-e in 1990.

The main source of emissions from the production and processing of natural gas is the Kapuni gas treatment plant. The plant removes CO_2 from a portion of the Kapuni gas (a high CO_2 gas when untreated) before it enters the distribution network. Although emissions from the source are not technically due to flaring, they are included under this category because of data confidentiality concerns. The large increase in CO_2 emissions for this source between 2003 and

2004 (from 388 to 620 Gg CO_2-e) and 2004 to 2005 (620 to 661 Gg CO_2-e) is related to a drop in methanol production. Carbon previously sequestered during this process is now being released as fugitive emissions from venting at the Kapuni gas treatment plant.

Carbon dioxide is also produced when natural gas is flared at the wellheads of other fields. The combustion efficiency of flaring is 95–99 per cent (Ministry of Economic Development, 2007a), leaving some fugitive emissions as a result of incomplete combustion.

Fugitive emissions also occur in transmission and distribution of the natural gas although they are relatively minor in comparison with those from venting and flaring.

This sector also includes emissions from geothermal operations. Some of the energy from geothermal fields is transformed into electricity and the emissions are reported under the "fugitive emissions from fuels" category. Emissions from geothermal electricity generation are reported in the fugitive emissions category because they are not the result of fuel combustion, unlike the emissions reported under the "energy industries" category. Sites with naturally occurring emissions where there is no use of geothermal steam for energy production are excluded from the inventory.

Methodological issues

Venting and flaring from oil and gas production

Data on the amount of CO_2 released through flaring is either supplied directly by the gas field operators or calculated from the supplied energy data using emission factors from Baines (1993). Vector Limited supplies estimates of CO_2 released during the processing of the natural gas.

Gas transmission and distribution

Gas leakage occurs almost exclusively from low-pressure "distribution" pipelines rather than from high-pressure "transmission" pipelines. Estimates of annual leakage in 2006 from transmission pipelines, provided by Vector Limited, are approximately 20 tonnes of CO_2 and 150 tonnes of CH_4 (Ministry of Economic Development, 2007a). In consultation with the Gas Association of New Zealand, the Ministry of Economic Development estimates that 3.5 per cent of the gas entering the distribution system is unaccounted for and that half of this (1.75 per cent) is lost through leakage. The other half is unaccounted for due to metering errors and theft. The split between fugitive CO_2 and CH_4 emissions is based on gas composition data.

Oil transport, refining and storage

Fugitive emissions from the "oil-transport" and "oil-refining/storage" subcategories are calculated using an IPCC Tier 1 approach. For "oil-transport", the fuel activity data are the total New Zealand production of crude oil reported in the Energy Data File (Ministry of Economic Development, 2007b), and the CH_4 emission factor is the mid-point of the IPCC default value range (0.745 t CH_4/PJ). Emissions from "oil-refining/storage" are based on oil intake at New Zealand's single oil refinery. The CH_4 emission factor for refining is the same as that for transportation. The emission factor for storage is 0.14 t CH_4/PJ (a New Zealand-specific emission factor). The combined emissions factor for "oil-refining/storage" is 0.885 t CH_4/PJ, derived by adding the emissions factors for refining and storage together.

Geothermal

Estimates of CO_2 and CH_4 for the "geothermal" subcategory are obtained directly from the geothermal field operators. Analyses of the gases emitted from the geothermal fields occur on a routine basis (at least once a year) and are carried out by a single independent laboratory.

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

Uncertainties and time-series consistency

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

Source-specific QA/QC and verification

No specific QA/QC activities are performed for this category.

Source-specific recalculations

There were also minor recalculations of CO_2, and CH_4 emissions in the "fugitive emissions from fuels: oil and natural gas" category due to increased precision in data entry into the CRF Reporter.

3.4 Other information

3.4.1 Comparison of sectoral approach with reference approach

The reference approach calculation identifies the apparent consumption of fuels in New Zealand from production, import and export data. This information is included as a check for combustion related emissions (IPCC, 2000). The check is performed for all years from 1990 to 2006.

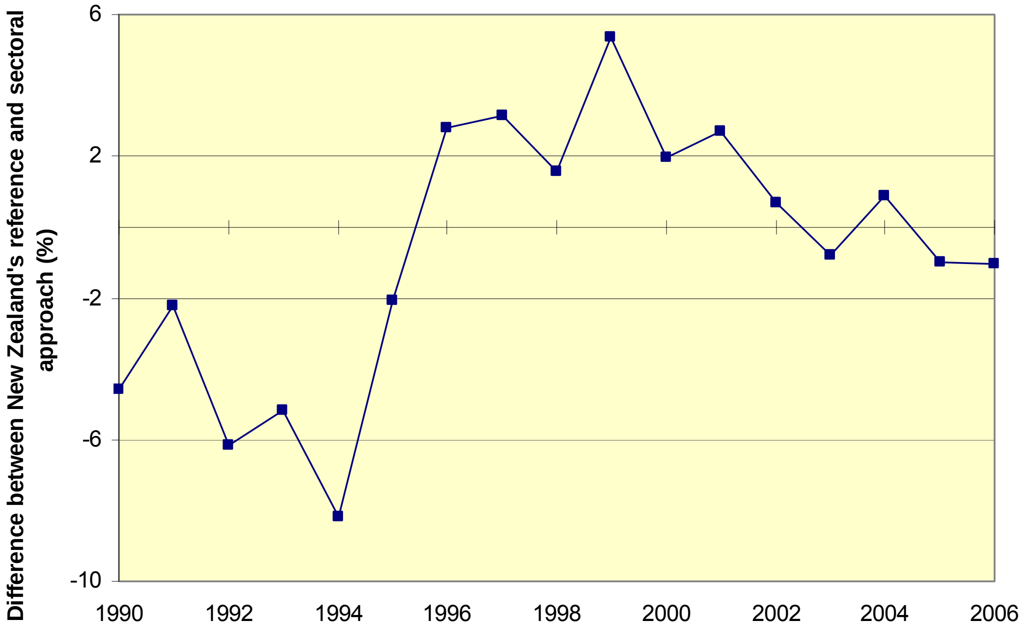
The majority of the CO_2 emission factors for the reference approach are New Zealand specific. The natural gas emission factors used, which change from year to year are estimated based on a production-derived weighted average of emission factors from the Kapuni and Maui gas fields. This approach differs from previous inventories, where the emissions factors were estimated from the sectoral approach analysis by dividing aggregated CO_2 emissions (including carbon later stored) by aggregate energy use.

Comparison of the reference approach and sectoral approach in 2006 shows the sectoral total of CO_2 emissions is 1.06 per cent more than the reference total. This is mainly related to the differences in energy consumption.

The activity data for the reference approach are obtained from "calculated" energy use figures. These are derived as a residual figure from an energy-balance equation comprising production, imports, exports, stock change and international transport on the supply side (from which energy use for transformation activities is subtracted). The activity data used for the sectoral approach are referred to as "observed" energy-use figures. These are based on surveys and questionnaires administered by Statistics New Zealand on behalf of the Ministry of Economic Development or by the Ministry itself. The differences between "calculated" and "observed" figures are reported as statistical differences in the energy-balance tables contained in the Energy Data File (Ministry of Economic Development, 2007b).

The energy-use and calculated emissions for the major fuel categories are not directly comparable between the reference and sectoral approaches. First, the reference approach counts non-energy sector use of fuels such as gas in ammonia production, coal in steel production and bitumen use, whereas the sectoral approach does not. However, the carbon embodied in fuels used for these purposes is included under stored carbon in the reference approach. Another difference is that combustion of refinery gas is included under gaseous fuels consumption in the sectoral approach but is not in the reference approach. This is because refinery gas is a by-product of the refining process derived from crude oil inputs. Consequently, emissions from the combustion of refinery gas are counted against crude oil in the reference approach.

Figure 3.4.1 Percentage difference between the reference and sectoral approach for New Zealand's inventory



3.4.2 International bunker fuels

The data on fuel use by international transportation come from the Energy Data File (Ministry of Economic Development, 2007b). This uses information from oil company survey returns provided to the Ministry for Economic Development. Data on fuel use by domestic transport are sourced from the "Deliveries of Petroleum Fuels by Industry" survey undertaken by Statistics New Zealand.

3.4.3 Feedstock and non-energy use of fuels

The fuels supplied to industrial companies are used both as fuel and as feedstock. Emissions are calculated using the total fuel supplied to each company (this includes fuel used as feedstock) and by estimating the difference between the carbon content of the fuels used and the carbon sequestered in the final output (this is based on industry production and chemical composition of the products). This difference is assumed to be the amount of carbon emitted as CO_2.

3.4.4 CO_2 capture from flue gases and subsequent CO_2 storage

There is no CO_2 capture from flue gases and subsequent CO_2 storage occurring in New Zealand.

3.4.5 Country-specific issues

Energy sector reporting shows very few areas of divergence from the IPCC guidelines and good practice (IPCC 1996; 2000). The differences that exist are listed below:

- A detailed subdivision of the "manufacturing and construction" category as set out in the IPCC guidelines is currently not available due to historical needs and practices of energy statistics collection in New Zealand.
- Some gas usage data from large industrial consumers in New Zealand and some emission factors for gas have been withheld for confidentiality reasons.
- Some of the coal production activity data in the reference approach is used in steel production. The CO_2 emissions from this coal are accounted for under the "industrial processes" sector and have been netted out of the energy reference approach using the "Estimating the carbon stored in products" table.
- Excel workbooks containing the activity data for the sectoral approach are available for download with this report from the Ministry for the Environment's website. The sectoral activity data excludes energy sources containing carbon that is later stored in manufactured products, specifically methanol. Therefore no subsequent subtraction of emissions is needed to account for this carbon sequestration.
- An additional worksheet is included in the excel workbooks to cover fugitive CO_2 and CH_4 emissions from geothermal electricity and heat generation plants.

3.4.6 Ozone precursors and SO_2 from oil refining

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

3.4.7 Energy balance

The *New Zealand Energy Data File* is an annual publication from the Ministry of Economic Development. It covers energy statistics including supply and demand by fuel types, energy balance tables, pricing information and international comparisons. An electronic copy of this report is available online at www.med.govt.nz/energy/info.

A table providing an overview of the 2006 energy supply and demand balance for New Zealand is included in Annex 2 of this report.

Chapter 4: Industrial processes

4.1 Sector overview

New Zealand's industrial processes sector totalled 4,233.1 Gg carbon dioxide equivalent (CO_2-e) in 2006 and represented 5.4 per cent of total greenhouse gas emissions. Emissions from industrial processes are now 830.4 Gg CO_2-e (24.4 per cent) above the 1990 baseline of 3402.7 Gg CO_2-e (Figure 4.1.1). The sector is dominated by emissions from the metal production category (CO_2 and perfluorocarbons (PFCs)) at 53.3 per cent of sectoral emissions.

Figure 4.1.1 Industrial processes sector emissions from 1990 to 2006 (all figures are Gg CO_2-e)

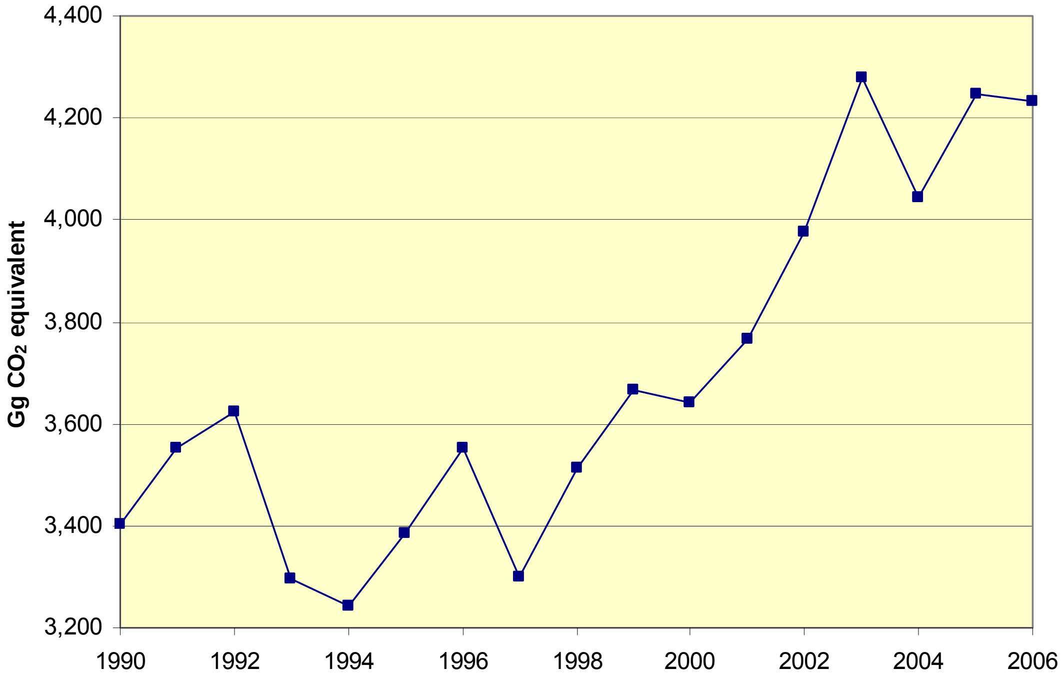
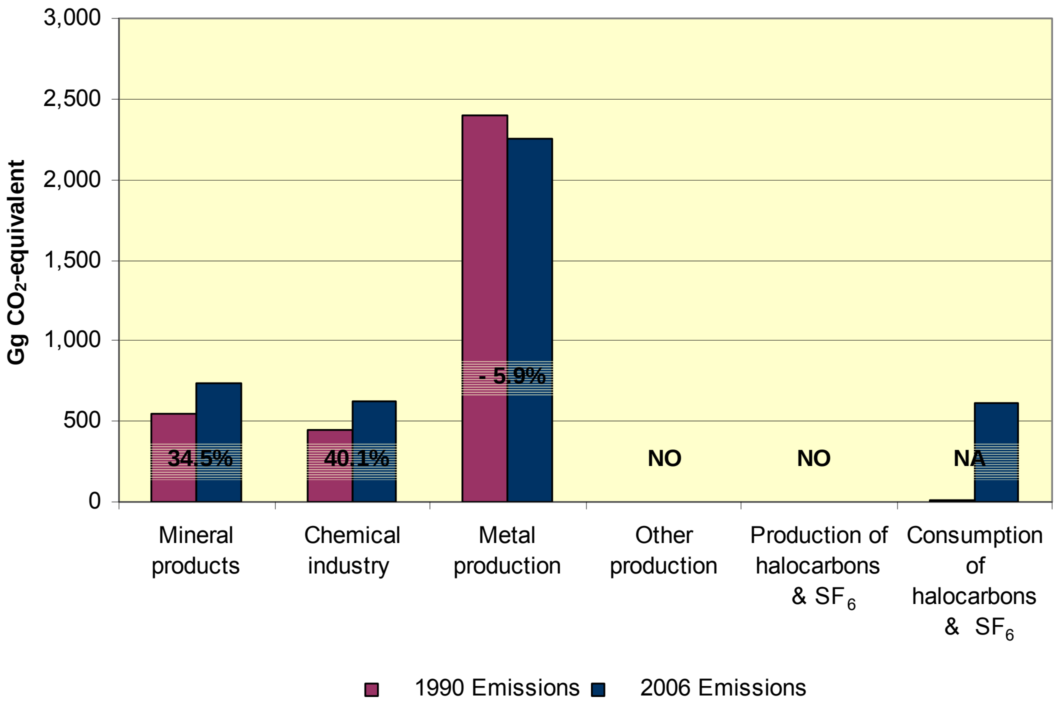


Figure 4.1.2 Change in industrial processes sector emissions from 1990 to 2006 (all figures are Gg CO_2-e)



Note: The per cent change for other production and the production of halocarbons and SF_6 is not occurring within New Zealand. The per cent change for the consumption of halocarbons and SF_6 is not applicable (NA) as there is no known production of HFCs in 1990.

The emissions included in the industrial processes sector are from the chemical transformation of materials from one substance to another. Although fuel is also often combusted in the manufacturing process, emissions arising from combustion are included in the energy sector. CO_2 emissions related to energy production, for example, refining crude oil and the production of synthetic petrol from natural gas, are also considered within the energy sector.

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

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

Within the industrial processes sector, some of the categories employ common data sources and emission factors. For this reason, general information about methodologies and uncertainties are included in this section as an overview.

4.1.1 Methodological issues

Emissions of CO_2 from industrial processes are compiled by the Ministry of Economic Development (MED) from information collected through industry surveys. The results are reported in *New Zealand Energy Greenhouse Gas Emissions 1990–2006* (Ministry of Economic Development, 2007a).

Activity data for the non-CO_2 gases are collated via an industry survey. Currently the only CH_4 emissions from the industrial processes sector are from methanol production. Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach and SF_6 emissions from large users are assessed via the Tier 3a approach (IPCC, 2000).

Activity data and emission factors are included in the excel workbooks available for download with this report from the Ministry for the Environment's website.

4.1.2 Uncertainties

The number of companies in New Zealand producing CO_2 from industrial processes is small and the emissions of CO_2 supplied by the companies are considered to be accurate to ± 5 per cent (Ministry of Economic Development, 2006). The uncertainty surrounding estimates of non-CO_2 emissions is greater than for CO_2 emissions and varies depending on the particular gas and category. Uncertainty of non-CO_2 emissions is discussed under each category.

4.2 Mineral products (CRF 2A)

4.2.1 Description

In 2006, the "mineral products" category accounted for 734.5 Gg CO_2-e (17.4 per cent) of emissions from the industrial processes sector. Emissions in this category have grown by 188.4 Gg CO_2-e (34.5 per cent) from the 1990 level of 546.1 Gg CO_2-e. There are no emissions of CH_4 or N_2O from the mineral products category.

This category includes emissions produced from chemical transformations in the production of cement and lime, soda ash production and use, asphalt roofing, limestone and dolomite use, road paving with asphalt and glass production. Cement production accounts for 560.7 Gg CO_2-e (76.3 per cent) of emissions from the mineral products category. Lime production accounts for 124.8 Gg CO_2-e (17.0 per cent). Only the emissions related to the calcination process for lime and cement production are included in this category. The emissions from the combustion of coal, used to provide heat for the calcination process, are reported in the energy sector.

4.2.2 Methodological issues

Cement production

Currently, there are two cement production companies operating in New Zealand, Holcim New Zealand Ltd and Golden Bay Cement. From 1995 to 1998 inclusive, another smaller cement company was in operation. Estimates of CO_2 emissions from cement production are calculated by the companies using the IPCC Tier 2 methodology (IPCC, 1996 and 2000)). Total process CO_2 emissions from cement production are reported. The clinker data and corresponding implied emission factors are not included in the CRF tables as this information is considered confidential by the companies. The amount of clinker produced by each cement plant is multiplied by a plant-specific emission factor for the clinker. The emission factors used are based on the calcium oxide (CaO) and magnesium oxide (MgO) content of the clinker produced. The inclusion of MgO results in the emission factors being slightly higher than the IPCC default of 0.50 t CO_2/t cement.

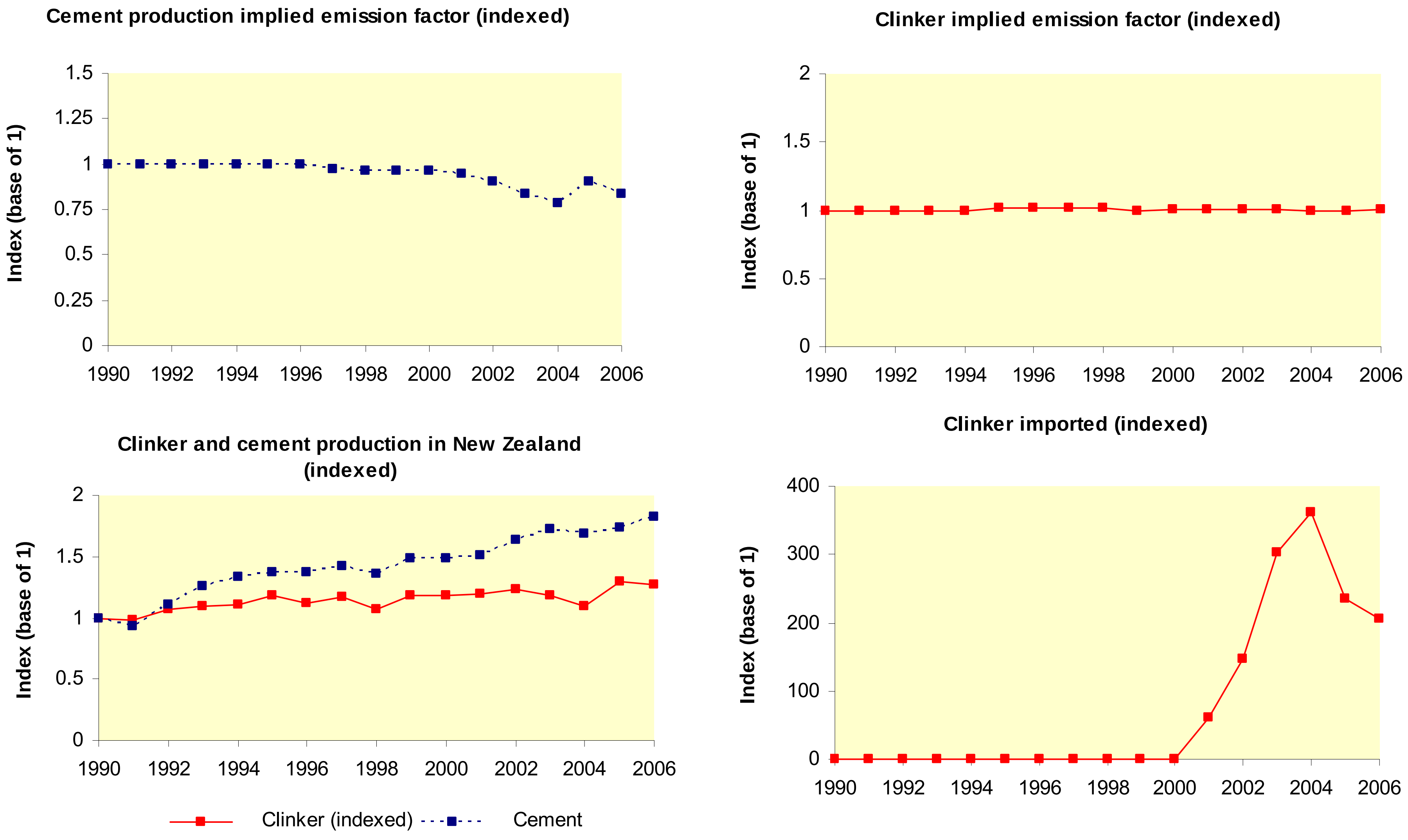
A plant-specific clinker kiln dust correction factor is included in one company's CO_2 emissions calculation. The other company does not include a correction factor as it operates a "dry" process with no calcinated clinker kiln dust lost to the system.

Figure 4.2.1 shows trends in New Zealand clinker production, imported clinker and the implied emission factors for cement and clinker. The information is indexed to respect the confidentiality of the data.

The figure shows clinker production increasing over the time-series 1990–2006 while the implied CO_2 emission factor for cement production has been decreasing. The exception to this trend is from 2004 to 2006 when imports of clinker decreased. The cement companies have been importing increasing amounts of clinker in recent years to meet the high demand for cement in New Zealand. An increase in imported clinker has decreased CO_2 emissions while overall cement production has continued to increase. A change in national standards for cement production in 1995, permitting mineral additions to cement of up to 5 per cent by weight (CCANZ, 1995), has also resulted in less CO_2 emissions per tonne of cement produced.

Sulphur dioxide is emitted in small quantities from the cement making process. The amount of SO_2 is determined by the sulphur content of the limestone. Seventy five to 95 per cent of the SO_2 will be absorbed by the alkaline clinker product (IPCC, 1996). New Zealand uses an emission factor for SO_2 calculated using information from a sulphur mass balance study on one company's dry kiln process. The mass balance study enabled the proportion of sulphur originating in the fuel and the sulphur in the raw clinker material as sodium and potassium salts to be determined. The average emission factor was calculated as 0.64 kg SO_2/t clinker and was weighted to take into account the relative activity of the two cement companies. The SO_2 emission factor has not been updated for the 2006 activity data. The 2008 inventory submission uses the 2005 value of 0.64 kg SO_2/t clinker as this is considered to still accurately reflect the New Zealand situation.

Figure 4.2.1 Indexed cement production data including clinker production, clinker imports and cement and clinker implied emission factor



Cement production implied emission factor (indexed)

Clinker implied emission factor (indexed)

Clinker and cement production in New Zealand (indexed)

Clinker imported (indexed)

Lime production

There are three companies producing burnt lime in New Zealand. Carbon emissions from lime production are supplied to the MED by the lime production companies. Emissions are calculated by multiplying the amount of lime produced by an emission factor. Given the limited data availability before 2002, a single New Zealand-specific emission factor based on the typical levels of impurities in the lime produced in New Zealand was applied for 1990–2002. Since 2002, plant-specific emission factors have been used. There has been little change in the implied emission factor varying from 0.72 t CO_2/t lime to 0.73 t CO_2/t lime from 1990 to 2006.

The SO_2 emissions emitted during lime production vary depending on the processing technology and the input materials. An average emission factor for SO_2 from was calculated as 0.5 kg SO_2/t lime. The emission factor was weighted to take sulphur measurements at the various lime plants into account (CRL Energy Ltd, 2006). The 2005 emission factor is used with the 2006 activity data.

Limestone and dolomite use

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

Small amounts of limestone are used in the production of iron and steel by the company New Zealand Steel. In the iron production process, the coal is blended with limestone to achieve the required primary concentrate specifications. Previously all CO_2 process emissions from iron and steel production, including limestone use, were reported under the iron and steel category in the CRF tables (2.C.1). For the 2008 inventory submission New Zealand has separated emissions arising from limestone, coke and electrodes used in the iron and steel making process from the rest of the process CO_2 emissions and reported these emissions under the limestone and dolomite use category (2A.3). Currently data cannot be broken down any further (ie, only limestone emissions from iron and steel production). Emissions from limestone/coke/electrode use make up 1 to 2 per cent of total process iron and steel emissions.

Soda ash production and use

There is no soda ash production in New Zealand. A survey of the industrial processes sector in 2005 made preliminary estimates of CO_2 emissions resulting from the use of soda ash in glass production (CRL Energy Limited, 2006). The glass manufacturer provided information on the amount of imported soda ash used in 2005. The manufacturer also provided approximate proportions of recycled glass over the last 10 years to enable CO_2 emissions from soda ash to be estimated from 1996 to 2005. This is because the soda ash amount is in fixed proportion to the production of new (rather than recycled) glass. Linear extrapolation was used to estimate activity data from 1990 to 1995. Updated activity data for 2006 was provided by the glass manufacturer through an external consultant. The IPCC default emission factor of 415 kg CO_2 per tonne of soda ash is applied to calculate the CO_2 emissions.

Asphalt roofing

There is one company manufacturing asphalt roofing in New Zealand, Bitumen Supply Ltd. Default IPCC emission factors of 0.05 kg NMVOC/t product and 0.0095 kg CO/t product respectively are used to calculate NMOVC and CO emissions respectively (IPCC, 1996). A survey of indirect greenhouse gases was not undertaken for the 2006 calendar year. In the absence of updated data, activity data for 2005 was used for 2006.

Road paving with asphalt

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

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

The revised 1996 IPCC guidelines (IPCC, 1996) make no reference to cut-back bitumen but do provide default emission factors for the low rates of SO2, NOx, CO and NMVOC emissions that arise from an asphalt plant. The IPCC recommended default road surface emissions factor of 320 kg of NMVOC per tonne of asphalt paved is not considered applicable to New Zealand. There is no possibility of this level of NMVOC emissions because the bitumen content of asphalt in New Zealand is only 6 per cent.

For the 2004 inventory submission, the New Zealand Bitumen Contractors Association provided the methodology shown in Box 4.1 for calculating the total NMVOC emissions from the use of solvents in the roading industry. The industrial processes survey undertaken in 2005 (CRL Energy Limited, 2006) showed that the fraction of weight of bitumen used to produce chip-seal has been changing over recent years as methods of laying bitumen have improved. From 1990 to 2001 the fraction by weight of bitumen used to produce chip-seal was 0.80. From 2002 to 2003 it was 0.65 and from 2004 the fraction was 0.60. The emissions of NMVOCs have been updated to reflect this changing fraction.

Box 4.1 Calculation of NMVOC emissions from road paving asphalt

NMVOC emitted = A x B x C x D

where

A = The amount of bitumen used for road paving

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

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

D = The fraction of solvent emitted (0.75)

Glass production

There is one major glass manufacturer in New Zealand, O-I New Zealand. The IPCC guidelines (IPCC, 1996) state NMVOCs may be emitted from the manufacture of glass and suggest a default emissions factor of 4.5 kg NMVOC/tonne of glass output. It has been assumed that the IPCC default emission factor for NMVOC is based on total glass production which includes recycled glass input. NO_x and CO emissions are assumed to be associated with fuel use and are reported under the energy sector. Estimates of CO_2 from soda ash use were obtained from the industrial processes survey undertaken in 2007 (CRL Energy Limited, 2007). Refer to the soda ash production and use section above.

4.2.3 Uncertainties and time-series consistency

Uncertainties in CO_2 emissions are assessed as ± 5 per cent as discussed in section 4.1.2. Uncertainties in non-CO_2 emissions have been assessed by a contractor from the questionnaires and correspondence with industry sources (CRL Energy Limited, 2006). These are documented in Table 4.2.1.

Table 4.2.1 Uncertainty in non-CO_2 emissions from "mineral products"

Product	Uncertainty in activity data	Uncertainty in emission factors
Cement	0%	± 40%
Lime	± 1%	± 80%
Asphalt roofing	± 30% (±50% for 1990–2000)	± 40%
Road paving with asphalt	± 10%	± 15% (chip-seal fraction and solvent emission fraction) to ± 25% (solvent dilution).
Glass	0%	NMVOC: ± 50% SO2: : ± 10%

4.2.4 Source-specific QA/QC and verification

Carbon dioxide emissions from cement production are a key category (level assessment). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

4.2.5 Source-specific recalculations

Activity data and the CO_2 emissions attributed to cement production has been updated and recalculated for the years 1995-1998. The revision has been due to the inclusion of data from a small cement company operating in New Zealand who produced clinker from 1995-1998. This data had not been included in previous submissions.

Emissions arising from limestone, coke and electrodes used in the iron and steel making process have been reported separately from the rest of the process CO_2 emissions for the first time in the 2008 inventory submission. This has resulted in recalculations for the 1990-2005 time series for both the limestone and dolomite use and iron and steel categories. Data provided by the iron and steel companies cannot be broken down any further (ie, limestone emissions on their own). Emissions from limestone/coke/electrode use make up 1 to 2 per cent of total process iron and steel emissions.

4.3 Chemical industry (CRF 2B)

4.3.1 Description

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

In 2006, emissions from the chemical industry category comprised 626.4 Gg CO_2-e (14.8 per cent) of emissions from the industrial processes sector. Emissions from the chemical industry have increased by 179.4 Gg CO_2-e (40.1 per cent) from the 447.0 Gg CO_2-e estimated in 1990. Carbon dioxide emissions from ammonia production accounted for (60.9 per cent) of emissions in the chemical industry category.

Methane emissions from the chemical industry have decreased 28.7 Gg CO_2-e (62.8 per cent) between 2004 and 2006. The closure of the Motunui methanol production plant in November 2004 caused this decrease in emissions. There is one methanol production plant in operation at Waitara.

4.3.2 Methodological issues

Ammonia/urea

Ammonia is manufactured in New Zealand by the catalytic steam reforming of natural gas. Liquid ammonia and CO_2 are reacted together to produce urea. The total amount of natural gas supplied to the plant is provided to the MED by the company operating the ammonia production plant. In accordance with IPCC guidelines (IPCC, 1996) it is assumed that the carbon in urea is eventually released after it is applied to the land. Emissions of CO_2 are calculated by multiplying the quantities of gas (from different gas fields) by their respective emission factors. Ammonia production in New Zealand uses gas from three different fields. The CO_2 emission factors vary from Kapuni (84.1 kt/PJ), Kaimiro (65.2 kt/PJ) to Maui (52.0 kt/PJ). The proportion of gas from each of these fields used in ammonia production changes on an annual basis. This explains the fluctuation in the CO_2 implied emission factor over the 1990–2006 time-series.

Non-CO_2 emissions are considered by industry experts to arise from fuel combustion rather than from the process of making ammonia and are therefore covered in the energy sector.

Formaldehyde

Formaldehyde is produced at five plants (owned by two different companies) in New Zealand. NMVOC emissions are calculated from company-supplied activity data and a country-specific emission factor of 1.5 kg NMVOC/t of product. Emissions of CO and CH_4 are not reported under this subcategory as these emissions relate to fuel combustion and are reported in the energy sector.

Methanol

Until recently methanol was produced at two plants by Methanex New Zealand. In November 2004 the Motunui plant was closed and methanol is now only produced at the Waitara plant. Carbon dioxide emissions are reported in the energy sector (manufacturing industries and construction) as the emissions relate to fuel combustion. The process to calculate CO_2 emissions is shown in Box 3.1 (chapter 3).

The major non-fuel related emissions from the methanol process are CH_4 and NMVOCs. Emissions are calculated from company-supplied activity data and emission factors. The IPCC default factor for CH_4 (2kg CH_4/t product) is applied and is assessed to be appropriate for New Zealand (CRL Energy Limited, 2006). The NMVOC emissions factor, 5kgNMVOC/t product, was estimated in 2001 from American Petroleum Institute methods for calculating vapour emissions from storage tanks. Emission factors for NOx (0.9 kg NOx/t product) and CO (0.1 kg CO/t product) were measured in 1999 and are considered to still accurately reflect the New Zealand situation.

Fertiliser

The production of sulphuric acid (H2SO4) during the manufacture of superphosphate fertiliser is largely responsible for the indirect emissions of SO_2. In New Zealand there are two companies, Ballance and Ravensdown, involved in the production of superphosphate. Each company owns two production plants. Three plants produce sulphuric acid. One plant imports the sulphuric acid.

Both companies supplied activity data for 2006 to the Ministry for the Environment. Plant specific emission factors used in previous years were applied to the 2006 data. No reference is made to superphosphate production in the IPCC guidelines (IPCC, 1996). For sulphuric acid the IPCC guidelines recommend a default emission factor of 17.5 kg SO_2 (range of 1 to 25) per tonne of sulphuric acid. However, New Zealand industry experts have recommended that this is a factor of two to ten times too high for the New Zealand industry. Consequently, emission estimates are based on industry supplied emission factors and activity levels.

Hydrogen

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

4.3.3 Uncertainties and time-series consistency

Uncertainties in CO_2 emissions are assessed as ± 5 per cent as discussed in section 4.1.2. Uncertainties in non-CO_2 emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy Limited, 2006). These are documented in Table 4.3.1.

Table 4.3.1 Uncertainty in non-CO_2 emissions from the "chemical industry"

Product	Uncertainty in activity data	Uncertainty in emission factors
Ammonia /Urea	± 0%	± 30%
Formaldehyde	± 2%	± 50% (NMVOCs)
Methanol	± 0%	± 50% (NOx and CO)
		± 30% (NMVOCs)
		± 80% (CH_4)
Fertiliser	± 10% sulphuric acid	± 15% sulphuric acid
	± 10% superphosphate	± 25 to ± 60% superphosphate (varies per plant)

4.3.4 Source-specific QA/QC and verification

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

4.3.5 Source-specific recalculations

There was a minor recalculation for ammonia production for 2003 due to rounding. There were no other recalculations for this category.

4.4 Metal production (CRF 2C)

4.4.1 Description

The “metal production” category reports CO_2, emissions from the production of iron and steel, ferroalloys, aluminium and magnesium. The major metal production activities occurring in New Zealand are the production of steel (from ironsand and scrap steel) and aluminium. A small amount of SF_6 was used in a magnesium foundry from 1990-1999. New Zealand has no production of coke, sinter or ferroalloys. Carbon dioxide emissions from “iron and steel production” and “aluminium production” are key categories (level assessment). Perfluorocarbon emissions from “aluminium production” are a key category in the trend analysis.

In 2006, emissions from the “metal production” category were 2,257.6 Gg CO_2-e (53.3 per cent) of emissions from the industrial processes sector. Emissions from this category decreased 5.9 per cent from the 1990 level of 2,400.1 Gg CO_2-e. Carbon dioxide emissions account for 96.3 per cent of emissions in this category with another 3.7 per cent from PFCs. In 2006, the level of CO_2 emissions increased by 419.6 Gg CO_2-e (23.9 per cent) above the 1990 baseline. Perfluorocarbon emissions have decreased from the 641.7 Gg CO_2-e in 1990 to 82.5 Gg CO_2-e in 2006, a decrease of 559.2 Gg CO_2-e (87.1 per cent).

The decrease in PFC emissions is because the Tiwai Point aluminium smelter has made improvements in reduction cell control and reduction cell operating practices.

4.4.2 Methodological issues

Iron and steel

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

The majority of the CO_2 emissions from the iron and steel subcategory are produced through the production of iron from titanomagnetite ironsand. The carbon dioxide emissions arise from the use of coal as a reducing agent and the consumption of other carbon-bearing materials such as electrodes. The carbon content of the ironsand is negligible with iron (in the form of magnetite) the predominant chemical in the sand (Ure, 2000). Sub-bituminous coal and limestone in the multi-hearth furnaces are heated and dried together with the ironsand. This iron mixture is then fed into the reduction kilns, where it is converted to 80 per cent metallic iron. Melters then convert this into molten iron. The iron, at a temperature around 1480°C, is transferred to the Vanadium Recovery Unit, where vanadium-rich slag is recovered for export and further processing into a steel-strengthening additive. The molten pig iron is then converted to steel in a Klockner Oxygen Blown Maxhutte (KOBM) oxygen steel-making furnace. Further refining occurs at the ladle treatment station, where ferroalloys are added to bring the steel composition up to its required specification. The molten steel from the ladle treatment station is then transferred to the continuous caster, where it is cast into slabs.

A Tier 2 approach is used for calculating CO_2 emissions from the iron and steel plant operated by New Zealand Steel. Emissions from pig iron and steel production are not estimated separately as all of the pig iron is transformed into steel. The carbon content in the ironsand is negligible (Ure, 2000) and therefore not accounted for. A plant specific emission factor is applied to the sub-bituminous coal used as a reducing agent. The emission factor is calculated based on the specific characteristics of the coal used. Care has been taken not to double-count coal use for iron and steel-making. New Zealand energy statistics for coal are disaggregated into coal used in steel making and coal used in other industries and sectors. The coal used in the iron-making process acts both as a reductant and an energy source.

The amount of coal used as an energy source is small compared to the amount used as a reducing agent. Data does not exist to accurately split the amount of coal used in energy and industrial processes. All coal used for iron and steel production is reported under the industrial processes sector.

Pacific Steel melts approximately 250 kt of recycled steel annually in an electric arc furnace. The process CO_2 emissions from the electric arc furnace arise from charge additions of carbon with the scrap metal and the oxidation of carbon electrodes. No meaningful CO_2 emissions data are available from the company before the year 2000. Emissions are calculated by multiplying steel production by an emission factor based on the average implied emission factor for the plant for the years 2000–2004 (approximately 0.1 t CO_2/t steel). The implied emission factor has been calculated using a mass balance approach. This calculation is based on the principle of the net difference between the amount of carbon contained in the raw materials and the amount of carbon sequestered in the finished product. From the mass balance approach analysis the emission factor for the years 2000–2004 lies within the range of 0.088 – 0.104 tCO_2/t steel, with an average of 0.097 t CO_2/t steel.

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

Aluminium

Aluminium production activity data and associated CO_2 and PFC emissions are supplied by Rio Tinto Aluminium, New Zealand's sole aluminium smelter operator. The technology type used by the smelter is Centre Worked Prebaked (CWPB). Carbon anode oxidisation is responsible for almost 90 per cent of the CO_2 emissions from aluminium production.

The aluminium smelter calculates the process CO_2 emissions using the Aluminium Sector Addendum to the WBCSD/WRI Greenhouse Gas Protocol released in October 2006 by the IPCC and International Aluminium Institute (IAI). The IPCC/IAI methodology breaks the prebake anode process into three stages (baked anode consumption, pitch volatiles consumption and packing coke consumption). This methodology more accurately reflects the use of carbon in the process.

The emissions from combustion of various fuels used in the aluminium production process, such as heavy fuel oil, LPG, petrol and diesel, are included in the energy sector.

Emission estimates of PFCs (CF_4 and C_2F_6) from the production of aluminium are also supplied by the aluminium smelter. The PFC emissions from aluminium smelting are calculated using the IPCC/IAI Tier 2 methodology summarised below:

PFC (t CO_2-e) = Hot metal production × slope factor × anode effect duration (min/cell-day) × global warming potential

The smelter captures every anode effect, both count and duration, through its process control software. All monitoring data are logged and stored electronically to give 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 specific to the CWPB technology and are sourced from the Aluminium Sector Addendum to the WBCSD/WRI Greenhouse Gas Protocol.

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.

For estimates of indirect greenhouse gases, the IPCC default emission factor is used for NO_x emissions. Plant-specific emission factors are used for CO and SO_2. An industry supplied value of 110 kg CO per tonne (IPCC range 135–400 kg CO per tonne) is based on measurements and comparison with Australian CO emission factors. Sulphur dioxide emissions are calculated from the input sulphur levels and direct monitoring.

Other metal production

Small amounts of sulphur hexafluoride (approximately 3 Gg CO_2-e per year) were used as a cover gas in a magnesium foundry to prevent oxidation of molten magnesium from 1990–1999. The company has since changed to zinc technology so SF_6 is no longer used and emitted.

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

4.4.3 Uncertainties and time-series consistency

Uncertainty in CO_2 emissions is assessed as ± 5 per cent as discussed in section 4.1.2. Uncertainties in non-CO_2 emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy Limited, 2006). These are documented in Table 4.4.1.

Table 4.4.1 Uncertainty in non-CO_2 emissions from "metal production"

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

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

4.4.4 Source-specific QA/QC and verification

Carbon dioxide emissions from "iron and steel production" and "aluminium production" are key categories. Perfluorocarbon emissions from aluminium production are a key category (trend assessment). In the preparation of this inventory, the data for these sub-categories underwent Tier 1 quality checks.

4.4.5 Source-specific recalculations

As explained under the mineral products section, New Zealand has been able to separate emissions arising from limestone, coke and electrodes used in the iron and steel making process from the rest of the process CO_2 emissions for the first time in the 2008 inventory submission. This has resulted in recalculations for the 1990-2005 time series for both the mineral products (limestone and dolomite use) and metal production (iron and steel production) categories.

Activity data and resulting CO_2 and PFC emissions from aluminium production was updated for the 1990 – 2006 time series. Rio Tinto Aluminium provided a new time series of data to reflect CO_2 and PFC emissions calculated using the methodologies outlined in the Aluminium Sector Addendum to the WBCSD/WRI Greenhouse Gas Protocol. The addendum was released in October 2006 by the IPCC and International Aluminium Institute (IAI).

4.5 Other production (CRF 2D)

4.5.1 Description

The "other production" category includes emissions from the production of pulp and paper, and food and drink. In 2006, emissions from this category totalled 7.4 Gg NMVOC. This was an increase of 1.4 Gg NMVOCs since the 1990 level of 6.0 Gg CO_2-e.

4.5.2 Methodological issues

Pulp and paper

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

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

Pulp production in New Zealand is evenly split between mechanical pulp production and chemical production. Estimates of emissions from the chemical pulping process are calculated from production figures obtained from the MAF. Emission estimates from all chemical pulping processes have been calculated from the industry-supplied emission factors for the Kraft process. In the absence of better information, the NMVOC emission factor applied to the chemical pulping processes is also applied to the thermomechanical pulp processes (CRL Energy Limited, 2006). Emissions of CO and NO_x from these processes are related to fuel combustion and not reported under industrial processes.

Food and drink

NMVOCs are produced during the fermentation of cereals and fruits in the manufacture of alcoholic beverages. They are also produced during all processes in the food chain which follow after the slaughtering of animals or harvesting of crops. Estimates of indirect greenhouse gas emissions fro the period 1990 – 2005 have been calculated using New Zealand production figures from Statistics New Zealand and relevant industry groups with default IPCC emission factors (IPCC, 1996). No New Zealand-specific emission factors could be identified. The 2006 NMVOC estimates from food and drink have been estimated using linear extrapolation due to no industry survey. In 2006, NMVOC emissions were estimated to be 6.5 Gg an increase of 1.3 Gg since 1990.

4.5.3 Uncertainties and time-series consistency

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

Table 4.5.1 Uncertainty in non-CO_2 emissions from "other production"

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

4.5.4 Source-specific QA/QC and verification

"Other production" is not a key category and no specific QA/QC activities were performed. Where possible, activity data are cross-referenced between companies and industry associations to verify the data.

4.5.5 Source-specific recalculations

There are no source-specific recalculations performed for this category in the 2008 inventory submission.

4.6 Production of halocarbons and SF_6 (CRF 2E)

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

4.7 Consumption of halocarbons and SF_6 (CRF 2F)

4.7.1 Description

Emissions from hydrofluorocarbons (HFCs) totalled 593.0 Gg CO_2-e in 2006. There was no known use of HFCs in 1990. The first consumption of HFCs in New Zealand was reported in 1992. The large increase in HFC emissions is due to the replacement of ozone-depleting CFCs and HCFCs with HFCs. HFC emissions are identified as a key category (level and trend).

SF_6 emissions have increased from 9.5 Gg CO_2-e in 1990 to 13.2 Gg CO_2-e in 2006, an increase of 3.8 Gg CO_2-e (40.0 per cent). The majority of SF_6 emissions are from use in electrical equipment.

HFCs and PFCs are used in a wide range of equipment and products from refrigeration systems to aerosols. No HFCs or PFCs are manufactured within New Zealand. Perfluorocarbons are produced from the aluminium smelting process (as discussed in section 4.4.2). The use of synthetic gases, especially HFCs has increased since the mid 1990s when CFCs and HCFCs began to be phased out under the Montreal Protocol. In New Zealand, the Ozone Layer Protection Act (1996) sets out a programme for phasing out the use of ozone-depleting substances by 2015. According to the 1996 IPCC guidelines, emissions of HFCs and PFCs are separated into seven major source categories:

- aerosols
- solvents
- foam
- mobile air conditioning (MAC)
- stationary refrigeration and air conditioning
- fire protection
- "other".

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

4.7.2 Methodological issues

HFCs/PFCs

Bulk import data of HFCs and PFCs is based on an annual survey of importers and distributors of these chemicals. Activity data was collected to identify the end users of the imported bulk chemicals. This data was used to estimate the proportion of bulk chemical used in each sub-source category. The total quantity of HFCs imported each year was estimated from data supplied by Statistics New Zealand. Non-bulk imports of HFCs and bulk imports of PFCs and SF_6 are more difficult to determine as import tariff codes are not specific enough to identify these chemicals. For example, HFC134a, the most commonly used HFC, is imported in a wide range of aerosol products. Information on the consumption of aerosol products was obtained from the Aerosol Association of Australia/New Zealand and from New Zealand manufacturers of aerosol products.

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

Potential emissions for HFCs and PFCs are included for completeness as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006). Potential emissions for HFCs and PFCs have been calculated using the IPCCC Tier 1b approach. Very little data is available on bulk imports of individual HFC and PFC gases. Potential emissions have been estimated using the fraction of actual individual HFC and PFC emissions and applying this fraction to the total of all bulk HFCs and PFCs imported into New Zealand.

Table 4.7.1 Halocarbon and SF_6 calculation methods and emission factors

HFC source	**Calculation method**	**Emission factor**
Aerosols	IPCC GPG 2000 Equation 3.35	IPCC default factor of 50% of the initial charge per year
Foam	IPCC GPC 2000 Table 3.17	IPCC default factor of 10% initial charge in first year and 4.5% annual loss of initial charge over an assumed 20-year lifetime
Mobile air conditioning	IPCC GPG 2000 Equation 3.44	Top down approach First fill: 0.5%
Stationary refrigeration/ air conditioning	IPCC GPG 2000 Equation 3.40	N/A
Fire protection	IPCC GPG 2000 Equation 3.51	Top-down approach using emission rate of 0.015
SF_6 source	**Calculation method**	**Emission factor**
Electrical equipment	IPCC GPG 2000 Equation 3.17	Tier 3 approach based on overall consumption and disposal. Company-specific emission factors measured annually and averaging ~1% for the main utility (representing 75-85% of total holdings) This was supplemented by data from other utilities and an equipment manufacturer using the IPCC default emission factor of 2% (Tier 2b approach)
Other applications	IPCC GPG 2000 Equation 3.22	No emission factor required as 100% is emitted within two years

Aerosols

Activity data on aerosol usage are provided by Arandee Ltd, the only New Zealand aerosol manufacturer using HFCs, and the Aerosol Association of Australia/New Zealand. Arandee Ltd also provided activity data on annual HFC use, domestic and export sales and product loading emission rates. Data on the total number of doses contained in metered dose inhalers used from 1999 to 2006 are provided by Pharmac, the New Zealand drug purchasing agency. The weighted average quantity of propellant per dose was calculated from information supplied by industry. There were no HFCs used in aerosols before 1996 and HFC–134a was not used in metered dose inhalers before 1995.

Equation 3.35 (IPCC, 2000) is used to calculate HFC emissions from aerosol use in New Zealand. HFC emissions from metered dose inhalers in 2006 were 48.0 Gg CO_2-e and emissions from other aerosols in 2006 were 22.2 Gg CO_2-e.

Solvents

A survey of distributors of solvent products and solvent recycling firms did not identify any use of HFCs or PFCs as solvents (CRL Energy Limited, 2007).

Foam

The 2007 halocarbon survey (CRL Energy Limited, 2007) found two companies who use HFCs for foam blowing and another company had used HFC in recent years but not in 2006 (CRL Energy Limited, 2007). The use of HFCs in foam blowing started in 2000. From 2000 to 2003 the HFC used was HFC–134a. From 2004, a mixture of HFC–245fa/365mfc has been imported for use. A global warming potential for this mixture has not been agreed to by the IPCC and UNFCCC. On recommendation by the in-country review team in 2007 (UNFCCC, 2007) New Zealand has reallocated these emissions to the section called “information on additional greenhouse gases” in the CRF tables.

Stationary refrigeration/air conditioning

New Zealand uses a top-down Tier 2 approach and country-specific data to obtain HFC emissions from stationary refrigeration and air conditioning (IPCC equation 3.40; IPCC, 2000):

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

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

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

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

It is estimated that there are about 2.2 refrigerators and freezers per household in New Zealand. This calculation included schools, factories, offices and hotels (Roke, 2006). Imported appliances account for around half of new sales each year with the remainder manufactured locally. New Zealand also exports a significant number of factory charged refrigerators and freezers.

Commercial refrigeration includes central rack systems used in supermarkets, chillers used for commercial building air conditioning and process cooling applications, rooftop air conditioners and 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 that have been used to build models of refrigerant consumption and banks for the domestic and commercial refrigeration categories, dairy farms, industrial and commercial cool stores, transport refrigeration and stationary air conditioning can be found in the report on HFC and PFC emissions in New Zealand (CRL Energy Limited, 2007).

HFC and PFC emissions from stationary refrigeration and air conditioning were 337.9 Gg CO_2-e in 2006.

Mobile air conditioning

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

This section does not consider refrigerated transport, which is included in the stationary refrigeration/air conditioning sub-category.

New Zealand uses the Tier 2 top-down approach (IPCC equation 3.44, IPCC, 2000):

Annual emissions of HFC–134a = First fill emissions + Operation emissions
+ Disposal emissions – Intentional destruction

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

Detailed information on the assumptions that have been used in the calculation of emissions from mobile air conditioning can be found in the report on HFC and PFC emissions in New Zealand (CRL Energy Limited, 2007).

HFC emissions from mobile air conditioning were 192.2 Gg CO_2-e in 2006.

Fire protection

HFCs and PFCs are used as substitutes to halons in portable and fixed fire protection equipment. Halons have traditionally been used in areas that contain high-value equipment and where risks to personal safety are high. These include computer rooms, data centres and on aircraft.

HFC-based foams have only been used in fire protection systems in New Zealand since 1994. Within the New Zealand fire protection industry, the two main supply companies were identified as using relatively small amounts of HFC–227ea. The systems installed have very low leak rates with most emissions occurring during routine servicing and accidental discharges.

A simplified version of the top-down approach (IPCC, 2000) is used for estimating emissions from this sub-category. For each year, an emission rate of 1.5 per cent, based on industry information, is applied to the total amount of HFC installed to get annual HFC-227ea emissions.

HFC emissions from fire protection were 1.3 Gg CO_2-e in 2006.

SF_6

Actual and potential emissions of SF_6 result primarily from the use of SF_6 in electrical switchgear. SF_6 questionnaires were sent to the two importers of SF_6 and New Zealand's main users of SF_6, the electricity transmission, generation and distribution companies (CRL Energy Limited, 2007). Actual emissions were calculated using the IPCC Tier 3a approach for the utility responsible for 75-85 per cent of the total SF_6 held in electrical switchgear equipment. This data was supplemented by data from other utilities and an equipment manufacturer and servicing contractor. The additional data enabled a Tier 2b approach to be taken for the rest of the industry (CRL Energy Limited, 2007). Potential emissions of SF_6 are calculated using total annual imports of SF_6 into New Zealand. Potential SF_6 emissions are usually 2 to 3 times greater than actual emissions in a given year. However in 2005, potential emissions were less than actual emissions because there was less SF_6 imported compared with previous years. Import data for 2006 shows potential SF_6 emissions are again greater than actual emissions.

Sulphur hexafluoride emissions from electrical equipment were 13.0 Gg CO_2-e in 2006.

There are small amounts of SF_6 released during tracer gas studies, medical uses and magnesium casting (as discussed in section 4.4.2).

4.7.3 Uncertainties and time-series consistency

The uncertainty in estimates of actual emissions from the use of HFCs and PFCs varies with each application and is described in Table 4.7.2. For many sources there is no statistical measure of uncertainty but a quantitative assessment is provided from expert opinion.

Table 4.7.2 Uncertainties in "consumption of halocarbons and SF_6" (CRL Energy Limited, 2007)

HFC source	Uncertainty estimates
Aerosols	Combined uncertainty ± 56%
Metered Dose Inhalers	Combined uncertainty ± 10%
Solvents	Not occurring
Foam	Combined uncertainty ± 70%
Stationary refrigeration/air conditioning	Combined uncertainty ± 39%
Mobile air conditioning	Combined uncertainty ± 37%
Fire protection	Combined uncertainty ± 32%
SF_6 source	**Uncertainty estimates**
Electrical equipment	Combined uncertainty ± 21%
Other applications	± 50%

4.7.4 Source-specific QA/QC and verification

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

4.7.5 Source-specific recalculations

As a result of an improved survey of the HFC and PFC importers and distributors in 2007 (CRL Energy Limited, 2007) estimates of gas stocks and emissions over the time series have been revised. The main changes have occurred within the stationary refrigeration and mobile air conditioning sub-sectors.

A more detailed model of the household and commercial refrigeration and air conditioning sub-sectors was developed in 2007 (CRL Energy Limited, 2007). Revised assumptions in the equipment charge for the commercial refrigeration sub-sector have resulted in higher amounts of HFCs being used to charge equipment and hence lower emissions compared with the 2007 inventory submission.

The previous methodology used for calculating total charge of new equipment in the stationary refrigeration and air-conditioning sub-sector (IPCC, 1996) was inconsistent when addressing equipment for export. The methodology was amended to exclude HFCs exported in NZ manufactured equipment. This change resulted in HFC emissions being reduced by 25–30 tonnes per year between 2001 and 2006 compared with the 2007 inventory submission.

An improved understanding of the annual scrap rate of vehicles using mobile air-conditioning has resulted in HFC emissions increasing in the mobile air-conditioning subcategory compared to the 2007 inventory submission. An increase in emissions associated with mobile air-conditioning servicing was previously included under the stationary refrigeration subcategory. The reallocation of these emissions in the 2008 inventory submission has increased emissions in the mobile air-conditioning subcategory while decreasing the emissions in the stationary refrigeration subcategory.

4.8 Other (CRF 2G)

4.8.1 Description

Panel products

Activity data are obtained from industry and supplemented with statistics from the MAF. The NMVOC emission factors for particleboard and medium density fibreboard are derived from two major manufacturers. An assumption was made that the industry-supplied NMVOC emission factors are applicable to all particleboard and fibreboard production in New Zealand. There is no information in the IPCC guidelines (1996) for this category.

NMVOC estimates for panel products in 2006 were 1.5 Gg. This is an increase of 0.7 Gg since 1990.

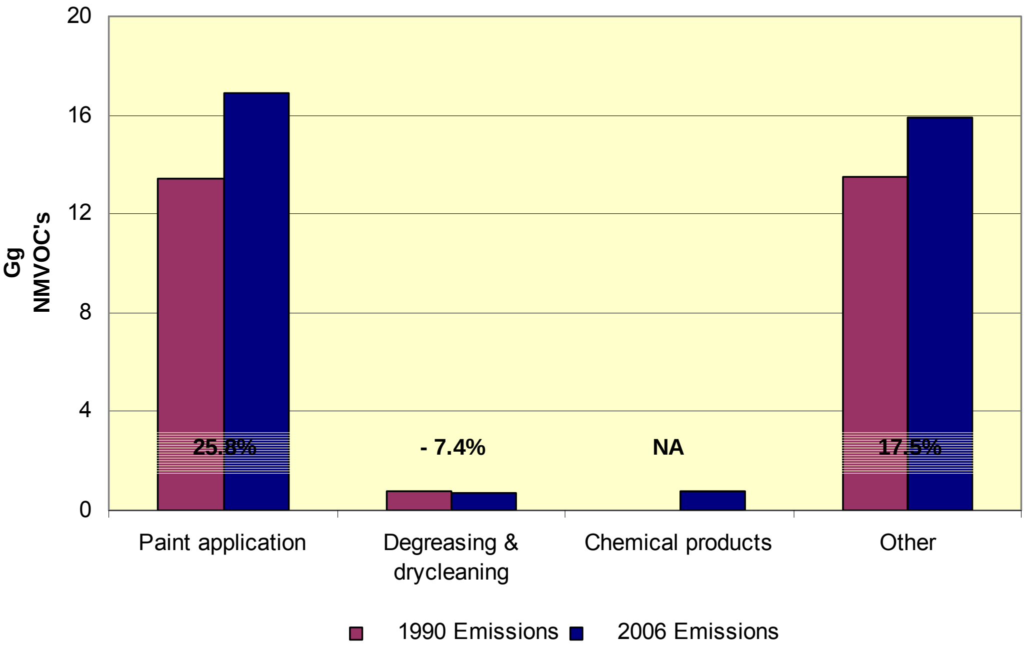
Chapter 5: Solvent and other product use

5.1 Sector overview (CRF 3)

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

In 2006, emissions from the "solvent and other product use" sector comprised 40.3 Gg of NMVOC. This is a decrease of 1.2 Gg (3.0 per cent) from 41.5 Gg in 1990. The categories dominating the sector are NMVOC emissions from "paint application" and "other domestic and commercial use" (Figure 5.1.1).

Figure 5.1.1 Change in emissions of NMVOC from the solvent and other product use sector from 1990 to 2006 (all figures Gg NMVOC)



Note: The per cent change for chemical products is not applicable (NA) as there is no activity data available for 1990.

In 2006, N_2O emissions from anaesthesia use totalled 0.13 Gg N_2O or 40.3 Gg CO_2-e. There has been no change from 1990 when emissions from anaesthesia totalled 0.13 Gg N_2O.

5.1.1 Description

Ethanol and methanol are the only solvents produced in New Zealand and the majority of both products are exported. All other solvents are imported, including some ethanol and methanol (for quality and price reasons).

5.1.2 Methodological issues

Detailed methodologies for emissions from solvents and other product use are not provided in the revised 1996 IPCC guidelines (IPCC, 1996). Two basic approaches for estimating emissions: consumption and production-based estimates are documented. The IPCC guidelines note that for many applications of solvents, the end uses are too small-scale, diverse and dispersed to be tracked directly. Therefore, emission estimates are generally based on total consumption and an assumption that once these products are sold to end users, they are applied and emissions produced relatively rapidly. For most surface coating and general solvent use, this approach is recommended. The New Zealand inventory estimates solvent emissions with a consumption-based approach. Activity data is obtained by an industry survey (CRL Energy Limited, 2006). Details of emission estimates for solvent and other product use are included in the excel workbooks available for download with this report from the Ministry for the Environment's website.

Emission factors are developed based on the likely final release of NMVOC to the atmosphere per unit of product consumed. The emission factors are applied to sales data for the specific solvent or paint products. The subcategories of solvents and other products specified in the common reporting format are detailed below.

Paint application

Consumption and emissions from paints and thinners are based on information from Nelson (1992) and the Auckland Regional Council (1997). Additional activity data for 1993 to 1996 was provided by the New Zealand Paint Manufacturers Association.

Degreasing and dry-cleaning

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

Chemical products (manufacturing and processing)

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

Losses of ethanol (and other minor components such as methanol, acetaldehyde and ethyl acetate) are monitored in the three ethanol plants in New Zealand. Using these values, an emission factor for NMVOC of 6 g/litre has been calculated. Ethanol used for alcoholic beverage production has been reported under food and drink production in the industrial processes sector.

Other – printing ink use

There is one major printing ink company in New Zealand with approximately 50 per cent of the solvent ink market share. The company provided a breakdown on the type of ink used. Approximately 50 per cent of inks used are oil inks (paste inks) which contain high boiling temperature oils. These are evaporated off during “heat setting” but the volatiles are generally treated in a solvent burner that minimises emissions. The remaining 50 per cent of inks are liquid of which 60 per cent are solvent inks (the remaining 40 per cent are water based).

Other – aerosols

Approximately 25 million aerosol units are sold in New Zealand each year. The average propellant charge is 84 grams and 95 per cent are hydrocarbon-based, total NMVOC emissions in 2006 were 2.0 Gg. This is based on the assumptions that the units are fully discharged within two years of purchase.

Other – domestic and commercial use

This category includes NMVOC emissions from domestic and commercial solvent use in the following areas: household products, toiletries, rubbing compounds, windshield washing fluids, adhesives, polishes and waxes, space deodorants, and laundry detergents and treatments. Emissions for this category are based on a per capita emission factor. The emission factor used is 2.54 kg NMVOC/capita/yr (United States EPA, 1985). It is assumed that the emissions rate per capita derived by the United States Environmental Protection Agency is applicable to the average product use in New Zealand (CRL Energy Limited, 2006). Population data is from the Statistics New Zealand website.

N_2O for anaesthesia

Activity data for 2006 were obtained from the sole importer of bulk N_2O into New Zealand. The importer supplies its competitor with its requirements so the figure represents full coverage of N_2O use in New Zealand. Most of the N_2O is used for anaesthesia and the production of Entonox (a half-and-half mixture of nitrous oxide and oxygen for pain relief). There is a very small amount used in motor sports and in scientific analysis.

5.1.3 Uncertainties and time-series consistency

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

Table 5.1.1 Uncertainties in “solvent and other product use” (CRL Energy Limited, 2006)

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

5.1.5 Source-specific recalculations

The 2007 industrial processes survey (CRL Energy Limited, 2007) revealed some inconsistencies in the activity data for nitrous oxide use in New Zealand for the period 2002–2005. Using the latest activity data for the period was updated by linear interpolation.

5.1.6 Source-specific planned improvements

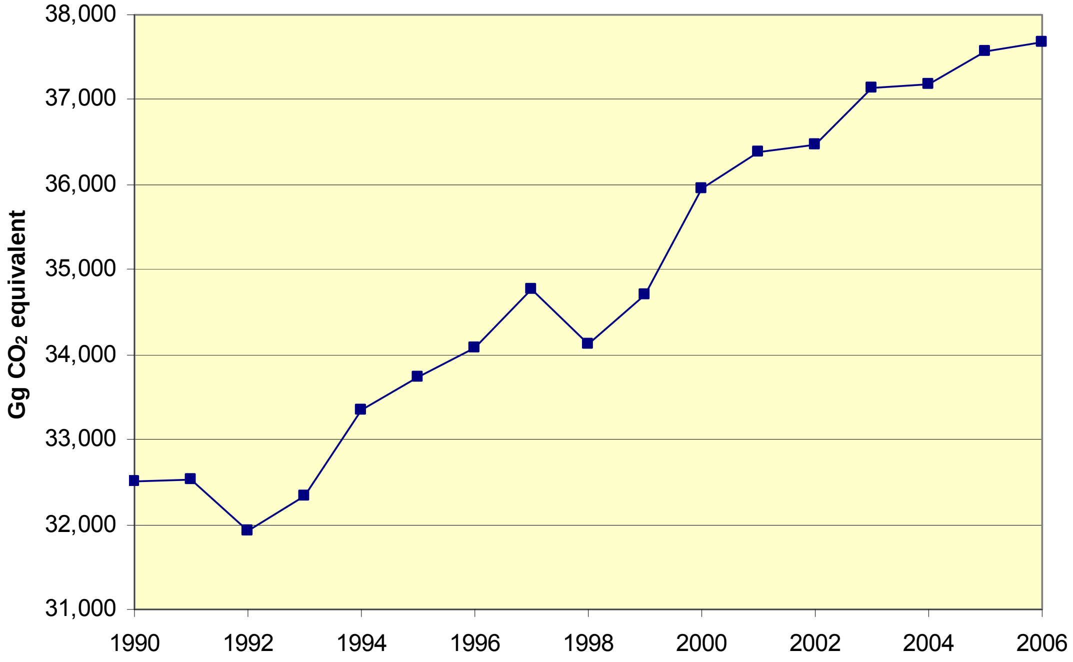
There are no planned improvements for this sector. There are large uncertainties, however the emission levels from the solvents and other products sector are negligible compared with other sectors. In accordance with good practice, New Zealand will continue to focus its inventory development on key source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

Chapter 6: Agriculture

6.1 Sector overview

The agriculture sector contributed 37,667.6 Gg carbon dioxide equivalent (Gg CO_2-e) (48.4 per cent) of total emissions in 2006. Emissions in this sector are now 5,168.8 Gg CO_2-e (15.9 per cent) higher than the 1990 level of 32,498.9 Gg CO_2-e (Figure 6.1.1). The increase is primarily attributable to a 2,300.2 Gg CO_2-e (10.5 per cent) increase in methane (CH_4) emissions from "enteric fermentation" and a 2,693.3 Gg CO_2-e (26.8 per cent) increase in nitrous oxide (N_2O) emissions from the "agricultural soils" category.

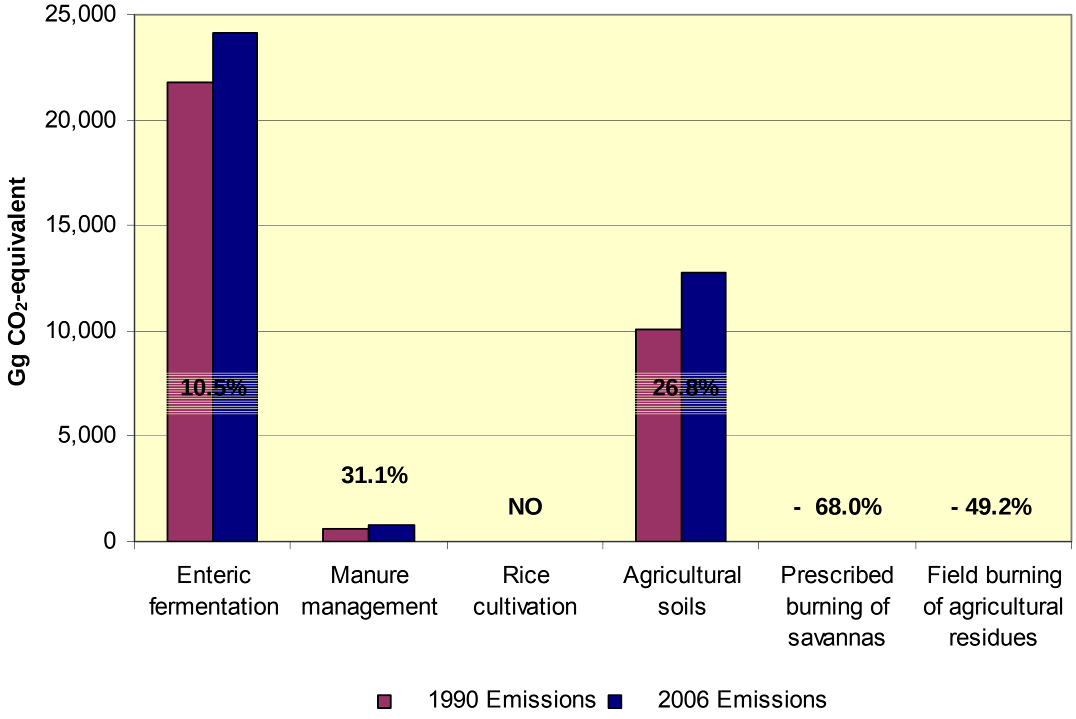
Figure 6.1.1 Agricultural sector emissions from 1990 to 2006 (all figures are Gg CO_2-e)



In 2006, emissions of CH_4 from "enteric fermentation" produce 64.0 per cent of CO_2-e emissions in the sector and 31 per cent of New Zealand's total emissions. Nitrous oxide emissions from "agricultural soils" are the other major component of the sector comprising 33.8 of agricultural CO_2-e emissions.

Agriculture is a major component of the New Zealand economy and agricultural products comprise over 50 per cent of total merchandise exports. This is because of the favourable temperate climate, the abundance of agricultural land and the unique farming practices used in New Zealand. These practices include the extensive use of year-round grazing systems and a reliance on nitrogen fixation by legumes rather than nitrogen fertiliser.

Figure 6.1.2 Change in emissions from the agricultural sector from 1990 to 2006 (all figures Gg CO_2-e)



Note: The per cent change for rice cultivation is not occurring (NO) within New Zealand.

Since 1984, there have been changes in the proportions of the main livestock species farmed. There has been an increase in dairy and deer production because of high world demand and favourable prices. This has been counterbalanced by land coming out of sheep production and decreasing sheep numbers. Beef numbers have remained relatively static. There have also been productivity increases across all major animal species and classes. The land area used for horticulture has not changed significantly since 1990 although the types of produce grown have changed. There is now less grain grown, but more vegetables, fruit, and grapes (for wine production) than in 1990.

There has been a gradual increase in the implied emission factors for dairy cattle and beef cattle from 1990 to 2006. This is to be expected because the methodology uses animal performance data that reflects the increased levels of productivity achieved by New Zealand farmers since 1990. Increases in animal liveweight and productivity (milk yield and liveweight gain per animal) require increased feed intake by the animal to meet higher energy demands. Increased feed intake results in increased CH_4 emissions per animal.

6.1.1 Methodological issues for the Agriculture Sector

New Zealand uses a June year for all animal statistics as this reflects the natural biological cycle for animals in the southern hemisphere. The models developed to estimate emissions work on a monthly timeframe beginning in July of one year and ending in June of the next year. To obtain emissions for single calendar years (January to December) emissions from the last six months of a July to June year are combined with the first six months' emissions of the next July to June year.

To ensure consistency, a single livestock population characterisation and feed intake estimate is used when estimating CH_4 emissions from “enteric fermentation”, CH_4 and N_2O emissions from “manure management” and N_2O emissions from “animal wastes deposited directly onto pasture”.

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

6.2 Enteric fermentation (CRF 4A)

6.2.1 Description

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

Methane emissions from “enteric fermentation” have been identified as the largest key category for New Zealand in the level assessment, excluding LULUCF. In accordance with IPCC good practice guidance (IPCC, 2000), the methodology for estimating CH_4 emissions from “enteric fermentation” in domestic livestock was revised to a Tier 2 modelling approach for the 2003 inventory submission. All subsequent inventories have used this Tier 2 approach.

In 2006, enteric fermentation was the largest single category of New Zealand’s inventory contributing 24,110.7 Gg CO_2-e. This represents 31.0 per cent of New Zealand’s total CO_2-e emissions and 64.0 per cent of agricultural emissions. Cattle contributed 14,023.9 Gg CO_2-e (58.2 per cent) of emissions from “enteric fermentation” and sheep contributed 9,287.0 Gg CO_2-e (38.5 per cent) of emissions. Emissions from “enteric fermentation” in 2006 are 2,300.2 Gg CO_2-e (10.5 per cent) above the 1990 level of 21,810.4 Gg CO_2-e. Since 1990 there have been changes in the source of emissions within the “enteric fermentation” category. The largest increase has been in emissions from dairy cattle. In 2006, dairy cattle were responsible for 8,615.6 Gg CO_2-e, an increase of 3,604.3 Gg CO_2-e (71.9 per cent) from the 1990 level of 5,011.4 Gg CO_2-e. This increase has been partially offset by decreases in emissions from sheep and minor livestock populations such as goats, horses and swine. In 2006, emissions from sheep were 9,287.0 Gg CO_2-e, a decrease of 1,993.0 Gg CO_2-e (17.7 per cent) from the 1990 level of 11,280.0 Gg CO_2-e.

6.2.2 Methodological issues

Emissions from cattle, sheep and deer

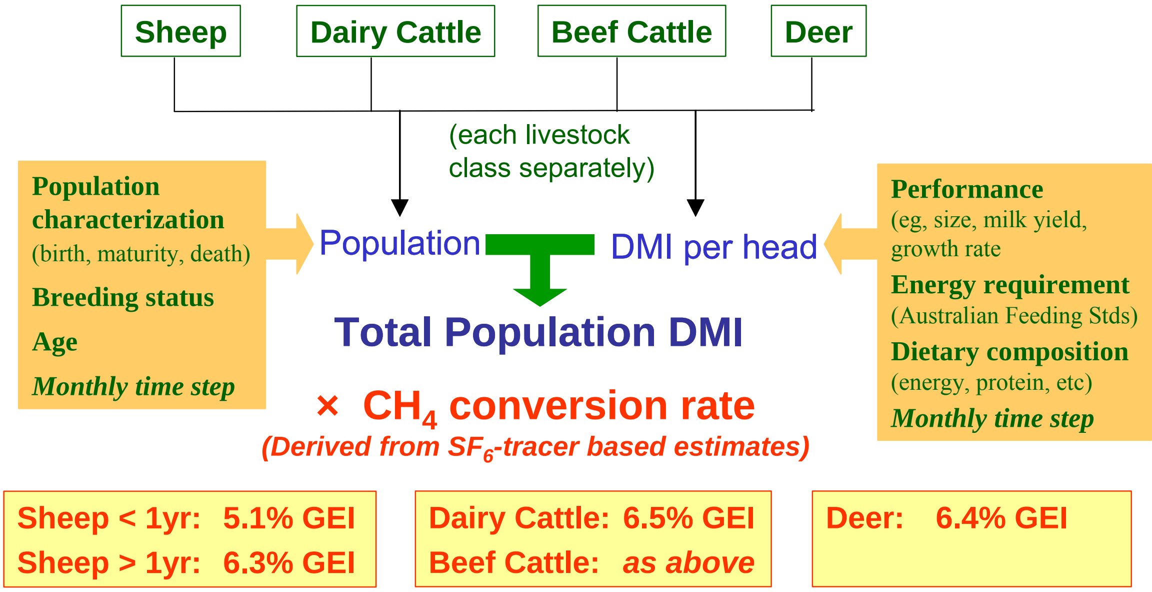
New Zealand’s Tier 2 methodology (Clark et al, 2003) uses a detailed livestock population characterisation and livestock productivity data to calculate feed intake for the four largest categories in the New Zealand ruminant population (dairy cattle, beef cattle, sheep and deer). The amount of CH_4 emitted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

Livestock population data

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

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

Figure 6.2.1 Schematic diagram of New Zealand's enteric fermentation calculation methodology



Livestock productivity data

For each livestock category, the best available data are used to compile the inventory. These data are from Statistics New Zealand and industry statistics. To ensure consistency, the same data sources are used each year. This ensures that the data provide a time-series that reflects changing farming practices, even if there is uncertainty surrounding the absolute values.

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

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

***Dairy cattle*:** Data on milk production are provided by Livestock Improvement Corporation Limited (2006). These data include the amount of milk processed through New Zealand dairy factories plus an allowance for town-milk supply. Annual milk yields per animal are obtained by dividing the total milk produced by the total number of milking dairy cows and heifers. Milk composition data are taken from the Livestock Improvement Corporation national statistics. For all years, lactation length was assumed to be 280 days.

Average liveweight data for dairy cows are obtained by taking into account the proportion of each breed in the national herd and its age structure based on data from the Livestock Improvement Corporation. Dairy cow liveweights are only available from the Livestock Improvement Corporation from 1996 onwards. For earlier years in the time-series, liveweights are estimated using the trend in liveweights from 1996 to 2006 together with data on the breed composition of the national herd. Growing dairy replacements at birth are assumed to be 9 per cent of the weight of the average cow and 90 per cent of the weight of the average adult cow at calving. Growth between birth and calving (at two years of age) is divided into two periods: birth to weaning, and weaning to calving. Higher growth rates apply 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 breeding bulls. An assumption was made that their average weight was 500 kg and that they were growing at 0.5 kg per day. This was based on expert opinion from industry data. For example, dairy bulls range from small Jerseys through to larger-framed European beef breeds. The assumed weight of 500 kg and growth rate of 0.5 kg/day provide an average weight (at the mid-point of the year) of 592 kg. This is almost 25 per cent higher than the average weight of a breeding dairy cow but it is realistic given that some of the bulls will be of a heavier breed/strain (eg, Friesian and some beef breeds). Because these categories of animal make only small contributions to total emissions, eg, breeding dairy bulls contribute 0.089 per cent of emissions from the dairy sector, total emissions are not highly sensitive to the assumed values.

***Beef cattle*:** The principal source of information for estimating productivity for beef cattle was livestock slaughter statistics provided by the Ministry of Agriculture and Forestry. All growing beef animals are assumed to be slaughtered at two years of age and the average weight at slaughter for the three subcategories (heifers, steers and bulls) was estimated from the carcass weight at slaughter. Liveweights at birth are assumed to be 9 per cent of an adult cow weight for heifers and 10 per cent of the adult cow weight for steers and bulls. Growth rates of all growing animals are divided into two periods: birth to weaning, and weaning to slaughter, as higher growth rates apply 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 Ministry of Agriculture and Forestry slaughter statistics do not separate carcass weights of adult dairy cows and adult beef cows. Thus a number of assumptions[1] are made in order to estimate the liveweights of beef breeding cows. A total milk yield of 800 litres per breeding beef cow was assumed.

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[1] Number of beef breeding cows assumed to be 25 per cent of the total beef breeding cow herd; other adult cows slaughtered are assumed to be dairy cows. The carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing-out percentage of 40 per cent. The total weight of dairy cattle slaughtered was calculated (carcass weight x 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 are then obtained assuming a killing-out percentage of 50 per cent.

Sheep: Livestock slaughter statistics from the Ministry of Agriculture and Forestry are used to estimate the liveweight of adult sheep and lambs, assuming killing-out percentages of 43 per cent for ewes and 45 per cent for lambs. Lamb birth liveweights are assumed to be nine per cent of the adult ewe weight with all lambs assumed to be born on 1 September. Growing breeding and non-breeding ewe hoggets are assumed to reach full adult size at the time of mating when aged 20 months. Adult wethers are assumed to be the same weight as adult breeding females. No within-year pattern of liveweight change was assumed for either adult wethers or adult ewes. All ewes rearing a lamb are assumed to have a total milk yield of 100 litres. Breeding rams are assumed to weigh 40 per cent more than adult ewes. Wool growth (greasy fleece growth) was assumed to be 5 kg/annum in mature sheep (ewes, rams and wethers) and 2.5 kg/annum in growing sheep and lambs.

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

Dry matter intake calculation

Dry matter intake (DMI) for the classes (dairy cattle, beef cattle, sheep and deer) and sub-classes of animals (breeding and growing) was estimated by calculating the energy required to meet the levels of animal performance and dividing this by the energy concentration of the diet consumed. For dairy cattle, beef cattle and sheep, energy requirements are calculated using algorithms developed in Australia (CSIRO, 1990). These algorithms are chosen as they specifically include methods to estimate the energy requirements of grazing animals. The method estimates a maintenance requirement (a function of liveweight and the amount of energy expended on the grazing process) and a production energy requirement – influenced by the level of productivity (eg, milk yield and liveweight gain), physiological state (eg, pregnant or lactating) and the stage of maturity of the animal. All calculations are performed on a monthly basis.

For deer, an approach similar to that used for cattle was adopted using algorithms derived from New Zealand studies on red deer. The algorithms take into account animal liveweight and production requirements based on the rate of liveweight gain, sex, milk yield and physiological state.

Monthly energy concentrations

A single set of monthly energy concentrations of the diets consumed by beef cattle, dairy cattle, sheep and deer was used for all years in the time-series. This is because 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 farm surveys on commercial cattle and sheep farms.

Methane emissions per unit of feed intake

There are a number of published algorithms and models[2] of ruminant digestion for estimating CH_4 emissions per unit of feed intake. The data requirements of the digestion models make them difficult to use in generalised national inventories and none of the methods have high predictive power when compared against experimental data. Additionally, the relationships in

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

the models have been derived from animals fed indoors on diets unlike those consumed by New Zealand's grazing ruminants.

Since 1996, New Zealand scientists have been measuring CH_4 emissions from grazing cattle and sheep using the SF_6 tracer technique (Lassey et al, 1997; Ulyatt et al, 1999). New Zealand now has one of the largest data sets in the world of CH_4 emissions determined using the SF_6 technique on grazing ruminants. To obtain New Zealand-specific values, published and unpublished data on CH_4 emissions from New Zealand were collated and average values for CH_4 emissions from different categories of livestock were obtained. Sufficient data were available to obtain values for adult dairy cattle, sheep more than one year old and growing sheep (less than one year old). These data are presented in Table 6.2.1 together with IPCC (2000) default values for per cent gross energy used to produce CH_4. The New Zealand values fall within the IPCC range and are adopted for use in this inventory calculation. Table 6.2.2 shows a time-series of CH_4 implied emission factors for dairy cattle, beef cattle, sheep and deer.

Not all classes of animals are covered in the New Zealand data set and assumptions had to be made for these additional classes. The adult dairy cattle value was assumed to apply to all dairy and beef cattle irrespective of age and the adult ewe value was applied to all sheep greater than one year old. An average of the adult cow and adult ewe value (21.25g CH_4/kg DMI) was assumed to apply to all deer. In very young animals receiving a milk diet, no CH_4 was assumed to arise from the milk proportion of the diet.

Table 6.2.1 Methane emissions from New Zealand measurements and IPCC defaults

	Adult dairy cattle	Adult sheep	Adult sheep < 1 year
New Zealand data (g CH_4/kg DMI)	21.6	20.9	16.8
New Zealand data (%GE)	6.5	6.3	5.1
IPCC (2000) defaults (%GE)	6 ± 0.5	6 ± 0.5	5 ± 0.5

Table 6.2.2 Time-series of implied emission factors for enteric fermentation (EF) (kg methane per animal per annum)

Year	Dairy cattle	Beef cattle	Sheep	Deer
1990	69.4	50.7	9.3	18.8
1991	71.6	51.8	9.4	19.3
1992	72.0	52.4	9.4	20.2
1993	73.9	53.5	9.5	20.4
1994	71.8	54.4	9.6	19.7
1995	71.6	53.1	9.5	20.6
1996	74.1	54.5	9.8	20.9
1997	74.7	55.1	10.2	21.0
1998	73.2	55.1	10.2	21.2
1999	75.9	54.2	10.2	21.3
2000	77.2	56.5	10.7	21.8
2001	77.6	56.9	10.7	21.7
2002	76.8	56.4	10.7	21.6
2003	79.8	55.9	10.7	21.6
2004	78.2	56.8	11.0	21.7
2005	79.3	57.7	11.1	22.2
2006	79.4	58.0	11.0	22.2

Emissions from other farmed species

A Tier 1 approach is adopted for minor species such as goats, horses and swine using either IPCC default emission factors (horses and swine) or New Zealand derived values (goats). These minor species comprised 0.3 per cent of total enteric CH_4 emissions in 2006. Adopting a Tier 1 as opposed to a Tier 2 approach for these species has little effect on total estimated enteric methane emissions.

Livestock population data

The populations of goats, horses and pigs are reported using the animal census (or survey) data from Statistics New Zealand.

Livestock emissions data

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

Goats**:** Enteric CH_4 from goats is not a key category. There are no published data on which to attempt a detailed categorisation of the performance characteristics as has been done for the major livestock categories. New Zealand uses a country-specific value of 9 kg CH_4/head/yr. This was calculated by assuming a default CH_4 emission value from goats for all years which is equal to the per head value of the average sheep in 1990 (ie, total sheep emissions/total sheep population). The goat value was not indexed to sheep over time because there are no data to support the kind of productivity increases that have been seen in sheep.

6.2.3 Uncertainties and time-series consistency

Livestock numbers

Many of the calculations in this sector require livestock numbers. Both census and survey data are used. Surveys occur each year between each census. Detailed information from Statistics New Zealand on the census and survey methods is included in Annex 3.1.1.

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). For the 2006 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value, ie, in 2001, the uncertainty in annual emissions was ± 53 per cent.

Table 6.2.3 Uncertainty in the annual estimate of enteric fermentation emissions for 1990, 2001 and 2006 estimated using Monte Carlo simulation (1990, 2001) and the 95 per cent confidence interval (2006)

Year	Enteric CH_4 emissions (Gg/annum)	95% CI min	95% CI max
1990	1,038.6	488.1	1,589.1
2001	1,123.0	527.8	1,718.2
2006	1,148.1	539.6	1,756.6

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

Uncertainty in the annual estimate is dominated by variance in the measurements used to determine the “CH_4 per unit of intake” factor. For the measurements made of this factor, the standard deviation divided by the mean is equal to 0.26. This uncertainty is predominantly due to natural variation from one animal to the next. Uncertainties in the estimation of energy requirements, herbage quality and population data are much smaller (0.005–0.05), so these variables play a much smaller role.

6.2.4 Source-specific QA/QC and verification

Methane from enteric fermentation was identified as a key category (level and trend assessment). In preparation for this inventory, the data for this category underwent Tier 1 quality checks.

Methane emission rates measured for 20 dairy cows scaled up to a herd have been corroborated using micrometeorological techniques. Laubach and Kelliher (2004) used the integrated horizontal flux technique and the flux gradient technique to measure CH_4 flux above a dairy herd. Both techniques are comparable, within estimated errors, to scaled-up animal emissions. The emissions from the cows measured by integrated horizontal flux and averaged over three campaigns are 329 (± 153) g CH_4/day/cow compared to 365 (± 61) g CH_4/day/cow for the scaled-up measurements reported by Waghorn et al, (2002; 2003). Methane emissions from lactating dairy cows have also been measured using the New Zealand SF_6 tracer method and open-circuit respiration chamber techniques (Grainger et al, 2007). Total CH_4 emissions were similar, 322 and 331 g CH_4/day, when measured using chambers or the SF_6 tracer technique respectively.

6.2.5 Source-specific recalculations

For the 2008 inventory submission all agricultural activity data is reported using single year values rather than 3-year average values. This change was introduced in the agriculture and LULUCF sectors to allow data to be compiled in a timely manner and to allow more time for overall inventory quality checking. The resulting annual values show greater variation than the 3-year average values over the 1990-2006 time series.

6.2.6 Source-specific planned improvements

A national inter-institutional ruminant CH_4 expert group was formed to identify the key strategic directions for research into the CH_4 inventory and mitigation, and to develop a collaborative approach to improve the certainty of CH_4 emissions. This expert group is funded through the Ministry of Agriculture and Forestry. The Pastoral Greenhouse Gas Research Consortium has been established to carry out research, primarily into mitigation technologies and management practices but also improving on-farm inventories. The consortium is funded by both the public and private sectors. The implementation of the Tier 2 approach for CH_4 emissions from enteric fermentation and manure management is a consequence of the research identified and conducted by the expert group.

6.3 Manure management (CRF 4B)

6.3.1 Description

Emissions from the "manure management" category comprised 808.1 Gg CO_2-e (2.1 per cent) of emissions from the agriculture sector in 2006. Emissions from manure management have increased by 191.5 Gg CO_2-e (31.1 per cent) from the 1990 level of 616.6 Gg CO_2-e.

Livestock manure is composed principally of organic material. When the manure decomposes in the absence of oxygen, methanogenic bacteria produce CH_4. The emissions of CH_4 are related to the amount of manure produced and the amount that decomposes anaerobically. Methane from "manure management" has been identified as a key category (level assessment).

This category also includes emissions of N_2O related to manure handling before the manure is added to the soil. The amount of N_2O released depends on the system of waste management and the duration of storage. With New Zealand's extensive use of all-year-round grazing systems, this category is relatively small at 65.0 Gg CO_2-e in 2006. In comparison, agricultural soil emissions of N_2O totalled 12,733.2 Gg CO_2-e.

In New Zealand, only dairy cows have a fraction (5 per cent) of the excreta stored in anaerobic lagoon waste systems. The remaining 95 per cent of excreta from dairy cattle is deposited directly on pasture. These fractions relate to the proportion of time dairy cattle spend on pasture compared to the time they spend in the milking shed. All other ruminant species (sheep, beef cattle, deer and goats) graze outdoors all year round and deposit all of their faecal material directly onto pastures. This distribution is consistent with the revised 1996 IPCC guidelines (IPCC, 1996) for the Oceania region. New Zealand scientists and Ministry of Agriculture and Forestry officials considered the defaults were applicable to New Zealand farming practices. Table 6.3.1 shows the distribution of livestock in animal waste management systems in New Zealand.

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

	Percentage of animals in each animal waste management system			
Livestock	**Anaerobic Lagoon**	**Pasture, range and paddock**	**Solid Storage and drylot**	**Other**
Non-dairy cattle	_	100	_	_
Dairy cattle	5	95	_	_
Poultry	_	_	3	97
Sheep	_	100	_	_
Swine	55	_	17	28
Goats	_	100	_	_
Deer	_	100	_	_
Horses	_	100	_	_

6.3.2 Methodological issues

Methane from manure management

Methane emissions from ruminant animal wastes in New Zealand have used the IPCC Tier 2 approach since the 2006 inventory submission. The methodology adopted is based on the methods recommended by Saggar et al, (2003) in a review commissioned by the Ministry of Agriculture and Forestry.

The approach relies on (1) an estimation of the total quantity of faecal material produced; (2) the partitioning of this faecal material between that deposited directly onto pastures and that stored in anaerobic lagoons; and (3) the development of specific New Zealand emission factors for the quantity of methane produced per unit of faecal dry matter deposited directly onto pastures and that stored in anaerobic lagoons. Table 6.3.2 summarises the key variables in the calculation of methane from manure management.

Table 6.3.2 Derivation of methane emissions from manure management

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

New Zealand-specific emissions factors are not available for CH_4 emissions from manure management for swine, horses and poultry. These are minor livestock categories in New Zealand and emissions estimates for these species use IPCC default emission factors.

Dairy cattle

Faecal material deposited directly onto pastures: The quantity of faecal dry matter produced is obtained by multiplying the quantity of feed eaten by the dry matter digestibility of the feed, minus the feed retained in product. These feed intake and dry matter digestibility estimates are those used in the enteric methane and nitrous oxide inventories. Consistent with the nitrous oxide inventory, 95 per cent of faecal material arising from dairy cows is assumed to be deposited directly onto pastures (Ledgard and Brier, 2004). The quantity of methane produced per unit of faecal dry matter is 0.98 g CH_4/kg. This value is obtained from New Zealand studies on dairy cows (Saggar et al, 2003; Sherlock et al, 2003).

Faecal material stored in anaerobic lagoons: Five per cent of faecal (dung and urine) material arising from dairy cows is assumed to be stored in anaerobic lagoons. The method adopted here is to assume that all faeces deposited in lagoons are diluted with 90 litres of water per kilogram of dung dry matter (Heatley, 2001). This gives a total volume of effluent stored. Annual CH_4 emissions are estimated using the data of McGrath and Mason (2002). McGrath and Mason (2002) calculated specific emissions values of 0.33–6.21 kg CH_4/m^2/year from anaerobic lagoons in New Zealand. The mean value of 3.27 CH_4/m^2/year of this range is assumed in the New Zealand Tier 2 calculations.

Beef cattle

The quantity of faecal dry matter produced is obtained by multiplying the quantity of feed eaten by the dry matter digestibility of the feed, minus the feed retained in product. These feed intake and dry matter digestibility estimates are those used in the enteric methane and nitrous oxide inventories. Beef cattle are not housed in New Zealand and all faecal material is deposited directly onto pastures. No specific studies have been conducted in New Zealand on CH_4 emissions from beef cattle faeces and values obtained from dairy cattle studies (0.98 g CH_4/kg) are used (Saggar et al, 2003; Sherlock et al, 2003).

Sheep

The quantity of faecal dry matter produced is obtained by multiplying the quantity of feed eaten by the dry matter digestibility of the feed, minus the feed retained in product. These feed intake and dry matter digestibility estimates are those used in the enteric methane and nitrous oxide inventories. Sheep are not housed in New Zealand and all faecal material is deposited directly onto pastures. The quantity of methane produced per unit of faecal dry matter is 0.69g CH_4/kg. This value is obtained from New Zealand studies on sheep (Carran et al, 2003).

Deer

The quantity of faecal dry matter produced is obtained by multiplying the quantity of feed eaten by the dry matter digestibility of the feed, minus the feed retained in product. These feed intake and dry matter digestibility estimates are those used in the enteric methane and nitrous oxide inventories. Deer are not housed in New Zealand and all faecal material is deposited directly onto pastures. There are no New Zealand studies on methane emissions from deer manure and values obtained from sheep and cattle are used. The quantity of methane produced per unit of faecal dry matter is assumed to be 0.92 g CH_4/kg. This value is the average value obtained from all New Zealand studies on sheep (Carran et al, 2003) and dairy cattle (Saggar et al, 2003; Sherlock et al, 2003).

Nitrous oxide from manure management

This subcategory reports nitrous oxide emissions from the anaerobic lagoon, solid storage and drylot, and other animal waste management systems. Emissions from the “pasture, range and paddock” animal waste management system are reported in the “agricultural soils” category.

The calculations for the quantity of nitrogen in each animal waste management system are based on the nitrogen excreted (N_{ex}) per head per year multiplied by the livestock population, the allocation of animals to animal waste management systems (Table 6.3.1) and a nitrous oxide emission factor for each animal waste management system (Annex 3.1).

The N_{ex} values are calculated from the nitrogen intake less the nitrogen in animal products. Nitrogen intake is determined from feed intake and the nitrogen content of the feed. Feed intake and animal productivity values are the same as used in the Tier 2 model for determining methane emissions (Clark et al, 2003). The nitrogen content of feed is estimated from a review of over 6,000 pasture samples of dairy and sheep and beef systems (Ledgard et al, 2003).

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

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

Table 6.3.3 N_{ex} values for main livestock classes over time

	Sheep N (kg/head/yr)	Non-dairy Cattle N (kg/head/yr)	Dairy Cattle N (kg/head/yr)	Deer N (kg/head/yr)
1990	12.61	65.39	103.87	24.88
1991	12.83	66.93	107.02	25.64
1992	12.80	67.67	107.49	26.83
1993	12.93	69.25	109.80	27.06
1994	12.97	70.34	106.85	26.20
1995	12.84	68.79	106.50	27.42
1996	13.34	70.70	109.81	27.76
1997	13.85	71.51	110.46	27.84
1998	13.95	71.41	108.50	28.06
1999	14.00	70.17	111.96	28.24
2000	14.63	73.17	113.41	28.91
2001	14.69	73.67	113.95	28.85
2002	14.68	72.88	113.12	28.74
2003	14.68	72.18	117.40	28.67
2004	15.09	73.36	115.27	28.88
2005	15.21	74.59	116.72	29.47
2006	15.12	74.98	116.59	29.48

6.3.3 Uncertainties and time-series consistency

Emission factors from manure and manure management systems, the livestock population, nitrogen excretion rates and the usage of the various manure management systems are the main factors causing uncertainty in N_2O emissions from manure management (IPCC, 2000).

New Zealand uses the IPCC default values for EF_3 (direct emissions from waste) for all AWMS except for $EF_{3(PR\&P)}$ (manure deposited on pasture, range and paddock). The IPCC default values have uncertainties of –50 per cent to +100 per cent (IPCC, 2000). The value of $EF_{3(PR\&P)}$, which is a country-specific factor, is 0.01 kg N_2O–N/kg N (further details in section 6.5.2).

The overall inventory uncertainty analysis shown in Annex 7 (Table A.7.1) demonstrates that the effect of uncertainty in annual emissions from manure management is relatively minor compared to the effect of CH_4 emissions from enteric fermentation and N_2O from agricultural soils.

6.3.4 Source-specific QA/QC and verification

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

6.3.5 Source-specific recalculations

For the 2008 inventory submission all agricultural activity data is reported using single year values rather than 3-year averaged values. This change was introduced in the agriculture and LULUCF sectors to allow data to be compiled in a timely manner and to allow more time for overall inventory quality checking.

6.3.6 Source-specific planned improvements

The National Institute of Water and Atmospheric Research have recently completed continuous measurement of anaerobic lagoons emissions over a full year. New Zealand will assess whether this research can be used to update the manure management estimates in the future.

6.4 Rice cultivation (CRF 4C)

6.4.1 Description

There is no rice cultivation in New Zealand. The “NO” notation is reported in the CRF.

6.5 Agricultural soils (CRF 4D)

6.5.1 Description

In 2006, the “agricultural soils” category produces the majority of N_2O emissions in New Zealand comprising 12,733.2 Gg CO_2-e. Emissions are 2,693.3 Gg CO_2-e (26.8 per cent) above the 1990 level of 10,039.8 Gg CO_2-e. The category comprises three subcategories. Each of these subcategories has been identified as a key category.

- Direct N_2O emissions from agricultural soils as a result of adding nitrogen in the form of synthetic fertilisers, animal waste, biological fixation in crops, inputs from crop residues and sewage sludge. Direct soil emissions from animal production contributed 1,736.8 Gg CO_2-e (13.6 per cent) of agricultural soil emissions. This is an increase of 1,249.6 Gg CO_2-e (256.5 per cent) from the 1990 level of 487.2 Gg CO_2-e.
- Indirect N_2O from nitrogen lost from the field as NO_3, NH_3 or NO_x . Indirect N_2O from nitrogen used in agriculture contributed 3,387.2 Gg CO_2-e (26.6 per cent) of soil agricultural emissions. This is an increase of 685.1 Gg CO_2-e (25.4 per cent) from the 1990 level 2,702.2 Gg CO_2-e.
- Direct N_2O emissions from animal production (the pasture, range and paddock animal waste management system). Emissions from animal production contributed 7,609.1 Gg CO_2-e (59.8 per cent) of agricultural soil emissions. This is an increase of 758.7 Gg CO_2-e (11.1 per cent) from the 1990 level of 6,850.5 Gg CO_2-e.

Carbon dioxide emissions from limed soils are reported in the LULUCF sector.

6.5.2 Methodological issues

Nitrous oxide emissions are determined using the revised 1996 IPCC guidelines (IPCC, 1996). Emission factors and the fraction of nitrogen deposited on the soils are used to calculate N_2O emissions. The two main inputs of nitrogen to the soil are excreta deposited during animal grazing and the application of nitrogen fertilisers.

Three New Zealand-specific factors/parameters are used in the inventory: EF_1, $EF_{3(PR\&P)}$ and $Frac_{LEACH}$. EF_1 (direct emissions from nitrogen input to soil) was reviewed during 2006 and the recommendation by Kelliher and de Klein (2006) to use a country-specific factor of 1 per cent was adopted for agriculture inventory calculations in the 2006 inventory submission. The $EF_{3(PR\&P)}$ emission factor of 1 per cent and $Frac_{LEACH}$ (0.07) were extensively reviewed and first included in the 2001 inventory submission.

The emission factors and other parameters used in this category are documented in Annex 3.1. The calculations are included in the excel workbooks available for download with this report from the Ministry for the Environment's website.

Animal production (N_2O)

Direct soil emissions from animal production refers to the N_2O produced from the pasture, range and paddock animal waste management system. This system is the predominant regime for animal waste in New Zealand as 95 per cent of dairy cattle excreta and 100 per cent of sheep, deer and non-dairy cattle excreta are allocated to it (Table 6.3.1).

The emissions calculation is based on the livestock population multiplied by nitrogen excretion (N_{ex}) values and the percentage of the population on the pasture, range and paddock animal waste management system. The N_{ex} and allocation to AWMS are discussed in section 6.3. The N_{ex} values have been calculated based on the same animal intake and animal productivity values used for calculating CH_4 emissions for the different animal classes and species. This ensures that the same base values are used for both CH_4 and N_2O emission calculations.

New Zealand uses a country-specific emission factor for $EF_{3(PR\&P)}$ of 0.01 (Carran et al, 1995; Muller et al, 1995; de Klein et al, 2003; Kelliher et al, 2003). Considerable research effort has gone into establishing a country-specific value for $EF_{3(PR\&P)}$. Field studies have been performed as part of a collaborative research effort called NzOnet. The parameter $EF_{3(PR\&P)}$ has been measured by NzOnet researchers in the Waikato (Hamilton), Canterbury (Lincoln) and Otago (Invermay) regions for pastoral soils of different drainage classes (de Klein et al, 2003). These regional data are comparable because the same measurement methods were used at the three locations. The percentage of applied nitrogen (as urine or dung) emitted as N_2O, and environmental variables, were measured in four separate trials that began in autumn 2000, summer 2002, spring 2002 and winter 2003. Measurements were carried out for up to 250 days or until urine-treated pasture measurements dropped back to background emission levels.

Kelliher et al (2003, 2005), assessed all available $EF_{3(PR\&P)}$ data and its distribution to pastoral soil drainage class, to determine an appropriate national annual mean value. The complete $EF_{3(PR\&P)}$ data set of NzOnet was synthesised using the national assessment of pastoral soils drainage classes. These studies recognise that:

- Environmental (climate) data are not used to estimate N_2O emissions using the IPCC (1996) methodology.
- 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.

In New Zealand, earlier analysis showed the distribution of drainage classes for pasture land is highly skewed with 74 per cent well-drained, 17 per cent imperfectly drained and 9 per cent poorly drained (Sherlock et al, 2001).

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

Indirect N_2O from nitrogen used in agriculture

Nitrous oxide is emitted indirectly from nitrogen lost from agricultural soils through leaching and run-off. This nitrogen enters water systems and eventually the sea, with quantities of N_2O being emitted along the way. The amount of nitrogen that leaches is a fraction ($Frac_{LEACH}$) of that deposited or spread on land.

Research studies and a literature review in New Zealand have shown lower rates of nitrogen leaching than are suggested in the revised 1996 IPCC guidelines (IPCC, 1996). A New Zealand parameter for $Frac_{LEACH}$ of 0.15 was used in inventory submissions reported before 2003. However, using a $Frac_{LEACH}$ of 0.15, IPCC-based estimates for different farm systems were found on average to be 50 per cent higher than those estimated using the OVERSEER® nutrient budgeting model (Wheeler et al, 2003). The model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems. In pastoral systems, nitrogen leaching is determined by the amount of nitrogen in fertiliser, dairy farm effluent and that excreted in urine and dung by grazing animals. The latter is calculated from the difference between nitrogen intake by grazing animals and nitrogen output in animal products, based on user inputs of stocking rate or production and an internal database with information on the nitrogen content of pasture and animal products.

The IPCC estimates were closer for farms using high rates of nitrogen fertiliser, indicating that the IPCC-based estimates for nitrogen leaching associated with animal excreta were too high. When the IPCC methodology 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 (Thomas et al, 2005). The 0.07 value was adopted and is used for all years as it best reflects New Zealand's national circumstances.

New Zealand uses the IPCC default EF_4 emission factor for indirect emissions from volatilisation of nitrogen in the form of ammonia (NH_3) and nitrogen oxides (NO_x).

Direct N_2O emissions from agricultural soils

The N_2O emissions from "direct N_2O emissions from agricultural soils" category arise from synthetic fertiliser use, spreading animal waste as fertiliser, nitrogen fixing in soils by crops and decomposition of crop residues left on fields. All of the nitrogen inputs are summed together and a country-specific emission factor of 0.01 kg N_2O-N/kg N (Kelliher and de Klein, 2006) applied to calculate total direct emissions from non-organic soils.

Nitrogen fertiliser use is provided by the Zealand Fertiliser Manufacturers' Research Association (FertResearch) from sales records for 1990 to 2006. There has been a six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2006 time-series from 51,633 tonnes in 1990 to 329,700 tonnes in 2006. The calculation of N_2O that is emitted indirectly through synthetic fertiliser and animal waste being spread on agricultural soils is shown in the excel workbooks available with this report from the Ministry for the Environment's website. Some of the nitrogen contained in these compounds is emitted into the atmosphere as NH_3 and nitrogen oxides NO_x through volatilisation, which returns to the ground during rainfall and is then re-emitted as N_2O. This is calculated as an indirect emission of N_2O.

The calculation for animal waste includes all manure that is spread on agricultural soils irrespective of which animal waste management system it was initially stored in. This includes all agricultural waste in New Zealand except for emissions from the pasture range and paddock animal waste management system. New Zealand uses a country-specific value for EF1 of 0.01 kg N_2O–N/kg N (Kelliher and de Klein, 2006).

Direct N_2O emissions from organic soils are calculated by multiplying the area of cultivated organic soils by an emission factor. Analysis identified 202,181 hectares of organic soils. Kelliher et al (2002) estimated 5 per cent (ie, 10,109 ha) of organic soils are cultivated on an annual basis. New Zealand uses the IPCC default emissions factor (EF2 equal to 8 kg N_2O–N/kg N) for all years of the time-series.

6.5.3 Uncertainties and time-series consistency

Uncertainties in N_2O emissions from agricultural soils were assessed for the 1990 and 2002 inventory using a Monte Carlo simulation of 5,000 scenarios with the @RISK software (Kelliher et al, 2003) (Table 6.5.1). The emissions distributions are strongly skewed, reflecting pastoral soil drainage whereby 74 per cent of soils are classified as well-drained and 9 per cent are classified as poorly drained. For the 2006 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value, ie, in 2002, the uncertainty in annual emissions was +74 per cent and – 42 per cent.

Table 6.5.1 Uncertainties in N_2O emissions from agricultural soils for 1990, 2002 and 2006 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2006)

Year	N_2O emissions from agricultural soils (Gg/annum)	95% CI min	95% CI max
1990	32.4	18.8	56.4
2002	39.6	23.0	68.9
2006	41.1	23.8	71.5

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 trend from 1990. The uncertainty between years is assumed to be correlated, therefore the uncertainty is mostly in the emission factors and the uncertainty in the trend is much lower than uncertainty for an annual estimate.

The Monte Carlo numerical assessment was also used to determine the effects of variability in the nine most influential parameters on uncertainty of the calculated N_2O emissions in 1990 and 2002. These parameters are shown in Table 6.5.2 together with their percentage contributions to the uncertainty. There was no recalculation of the influence of parameters for the 2006 data. The Monte Carlo analysis confirmed that uncertainty in parameter $EF_{3(PR\&P)}$ has the most influence on total uncertainty, accounting for 91 per cent of the uncertainty in total N_2O emissions in 1990. This broad uncertainty reflects natural variance in EF_3 determined largely by the vagaries of the weather and soil type.

Table 6.5.2 Percentage contribution of the nine most influential parameters on the uncertainty of total N_2O emissions inventories for 1990 and 2002

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

6.5.4 Source-specific QA/QC and verification

Nitrous oxide emissions from “direct soil emissions” and “pasture, range and paddock manure” are key categories (level and trend assessment). Nitrous oxide from “indirect emissions” is a key category (level assessment). In preparation for this inventory, the data for these categories underwent Tier 1 quality checks.

The nitrogen fertiliser data obtained from FertResearch are corroborated by the Ministry of Agriculture and Forestry using nitrogen imports and exports, urea production figures and industrial applications (including resin manufacture for timber processing) data.

6.5.5 Source-specific recalculations

For the 2008 inventory submission all agricultural activity data is reported using single year values rather than 3-year averaged values. This change was introduced in the agriculture and LULUCF sectors to allow data to be compiled in a timely manner and to allow more time for overall inventory quality checking.

6.5.6 Source-specific planned improvements

Research is continuing by New Zealand scientists to better quantify N_2O emission factors for New Zealand’s pastoral soils. This includes development of country specific emission factors for sheep and cattle dung and emission factors for New Zealand hill country pastures.

New Zealand is also exploring methods to incorporate mitigation technology such as the application of dicyandiamide nitrification inhibitor on pasture into future inventory submissions. An extensive body of scientific literature has been published on the unique application methods and circumstances for New Zealand pastoral agriculture. Methodologies for incorporating dicyandiamide mitigation technology into the inventory are being assessed in relation to the requirements of IPCC good practice.

6.6 Prescribed burning of savanna (CRF 4E)

6.6.1 Description

Prescribed burning of savanna is not a key category for New Zealand. The New Zealand inventory includes burning of tussock (*Chionochloa*) grassland in the South Island for pasture renewal and weed control. The amount of burning has been steadily decreasing over the past 50 years as a result of changes in lease tenure and a reduction in grazing pressure. In 2006, total emissions accounted for 1.0 Gg CO_2-e, a 2.2 Gg CO_2-e (68.0 per cent) reduction from the 3.2 Gg CO_2-e reported in 1990.

The revised 1996 IPCC guidelines (IPCC, 1996) state that in agricultural burning, the CO_2 released is not considered to be a net emission as the biomass burned is generally replaced by regrowth over the subsequent year. Therefore the long-term net emissions of CO_2 are considered to be zero. However the by-products of incomplete combustion, CH_4, CO, N_2O and NO_x, are net transfers from the biosphere to the atmosphere.

6.6.2 Methodological issues

New Zealand has adopted a modified version of the IPCC methodology (IPCC, 1996). The same five equations are used to calculate emissions. Instead of using total grassland and a fraction burnt, New Zealand uses statistics of the total amount of tussock grassland that has been granted a consent (a legal right) under New Zealand's Resource Management Act (1991) for burning. Only those areas with a consent are legally allowed to be burned. Expert opinion obtained from land managers in local government is that approximately 20 per cent of the area allowed to be burnt is actually burnt in a given year.

Current practice in New Zealand is to burn in damp spring conditions which reduces the amount of biomass consumed in the fire. The composition and burning ratios used in calculations are from New Zealand-specific research (Payton and Pearce, 2001) and the revised 1996 IPCC guidelines (IPCC, 1996).

6.6.3 Uncertainties and time-series consistency

The same sources of data and emission factors are used for all years. This gives confidence in comparing emissions through the time-series from 1990 and 2006. The major sources of uncertainty are the percentage of consented area actually burnt in that season, extrapolation of biomass data from two study sites for all areas of tussock, and that many of the other parameters (ie, the carbon content of the live and dead components, the fraction of the live and dead material that oxidise and the nitrogen to carbon ratio for the tussocks) are the IPCC default values. Uncertainty in the New Zealand biomass data has been quantified at ± 6 per cent (Payton and Pearce, 2001), however many IPCC parameters vary by ± 50 per cent and some parameters lack uncertainty estimates.

6.6.4 Source-specific QA/QC and verification

There was no source-specific QA/QC for this category.

6.6.5 Source-specific recalculations

For the 2008 inventory submission all agricultural activity data is reported using single year values rather than 3-year averaged values. This change was introduced in the agriculture and LULUCF sectors to allow data to be compiled in a timely manner and to allow more time for overall inventory quality checking.

6.7 Field burning of agricultural residues (CRF 4F)

6.7.1 Description

Burning of agricultural residues produced 14.6 Gg CO_2-e in 2006. Emissions are currently 14.1 Gg CO_2-e lower (-49.2 per cent) than the level of 28.7 Gg CO_2-e in 1990. Burning of agricultural residues is not identified as a key category for New Zealand.

New Zealand reports emissions from burning barley, wheat and oats residue in this category. Maize residue is not burnt in New Zealand.

Burning of crop residues is not considered to be a net source of CO_2 because the CO_2 released into the atmosphere is reabsorbed during the next growing season. However, the burning is a source of emissions of CH_4, CO, N_2O and NO_x (IPCC, 1996). Burning of residues varies between years due to climatic conditions and is a declining source.

6.7.2 Methodological issues

The emissions from burning of agricultural residues are estimated in accordance with the revised 1996 IPCC guidelines (IPCC, 1996). The calculation uses crop production statistics, the ratio of residue to crop product, the dry matter content of the residue, the fraction of residue actually burned, the fraction of carbon oxidised and the carbon fraction of the residue. These figures are multiplied to calculate the carbon released. The emissions of CH_4, CO, N_2O and NO_x are calculated using the carbon released and an emissions ratio. Nitrous oxide and NO_x emissions calculations also use the nitrogen to carbon ratio.

IPCC good practice guidance suggests that an estimate of 10 per cent of residue burnt may be appropriate for developed countries but also notes that the IPCC defaults “are very speculative and should be used with caution. The actual percentage burned varies substantially by country and crop type. This is an area where locally developed, country-specific data are highly desirable” (IPCC, 2000). For the years 1990 to 2003 it is estimated that 50 per cent of stubble was burnt. For the years 2004 to 2006, experts assessed this to have decreased to 30 per cent. These values were developed from opinions of the MAF officials working with the arable production sector. The 2007 agricultural census (results due mid 2008) will provide updated data.

6.7.3 Uncertainties and time-series consistency

No numerical estimates for uncertainty are available for these emissions. The fraction of agricultural residue burned in the field is considered to make the largest contribution to uncertainty in the estimated emissions.

6.7.4 Source-specific QA/QC and verification

There was no source-specific QA/QC for this category.

6.7.5 Source-specific recalculations

For the 2008 inventory submission all agricultural activity data is reported using single year values rather than 3-year averaged values. This change was introduced in the agriculture and LULUCF sectors to allow data to be compiled in a timely manner and to allow more time for overall inventory quality checking.

Chapter 7: Land use, land-use change and forestry (LULUCF)

7.1 Sector overview

In 2006, the LULUCF sector represented the removal of 22,749.3 Gg carbon dioxide equivalent (CO_2-e) (29.2 per cent) of total New Zealand greenhouse gas emissions. Net removals have increased by 2,241.6 Gg CO_2-e (10.9 per cent) since the 1990 level of 20,507.7 Gg CO_2-e (Figure 7.1.1). Figure 7.1.2 shows changes in emissions and removals by land use category from 1990 to 2006.

Carbon dioxide emissions and removals in the LULUCF sector are primarily controlled by uptake from plant photosynthesis and release from respiration, and the decomposition of organic material. Nitrous oxide (N_2O) may be emitted from the ecosystem as a by-product of nitrification and denitrification and the burning of organic matter. Other gases released during biomass burning include methane (CH_4), carbon monoxide (CO), other oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOC). All emissions and removals from the LULUCF sector are excluded from national totals.

Six broad categories of land use are described in *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003), hereafter referred to as GPG-LULUCF. The land use categories are:

- Forest land – all land with woody vegetation consistent with defined national thresholds. It also includes areas of vegetation that currently fall below, but are expected to exceed the defined national thresholds.
- Cropland – arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for forest land.
- Grassland – rangelands and pasture land that are not considered as cropland. It also includes areas of vegetation that fall below but are not expected to exceed, without human intervention, the national threshold defined in the forest land category.
- Wetlands – land that is covered or saturated by water for all or part of the year (eg, peat land) and that does not fall into the forest land, cropland, grassland or settlements categories. Natural rivers and lakes are unmanaged subdivisions of wetlands.
- Settlements – all developed land, including transportation infrastructure and human settlements unless they are already included under other categories.
- Other land – bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories.

Figure 7.1.1 LULUCF sector net removals from 1990 to 2006 (all figures are Gg CO_2-e)

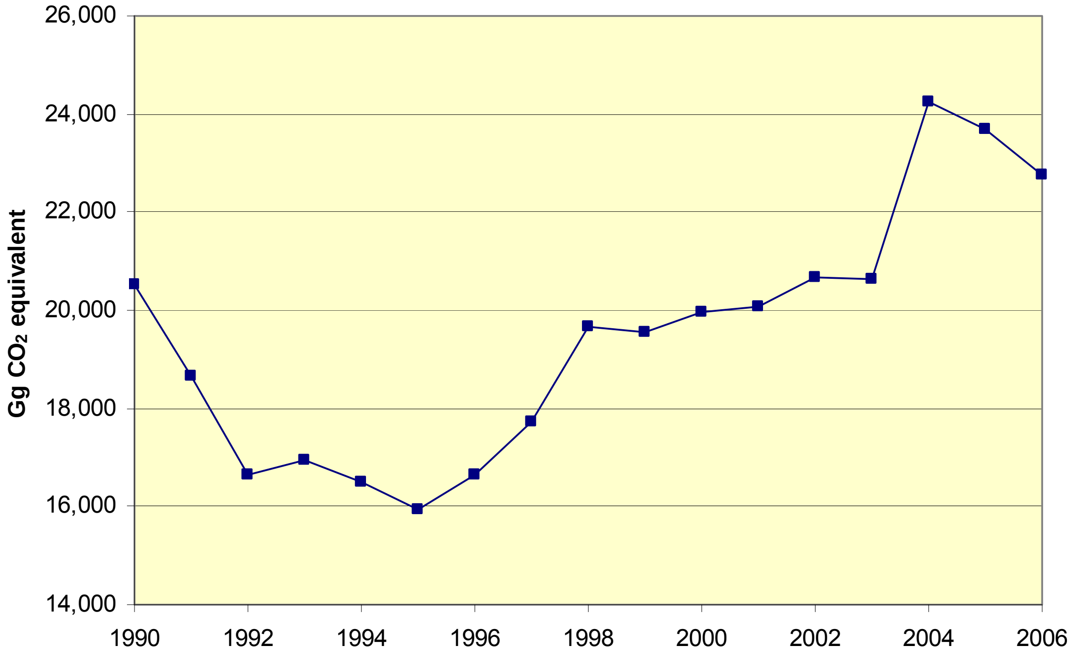
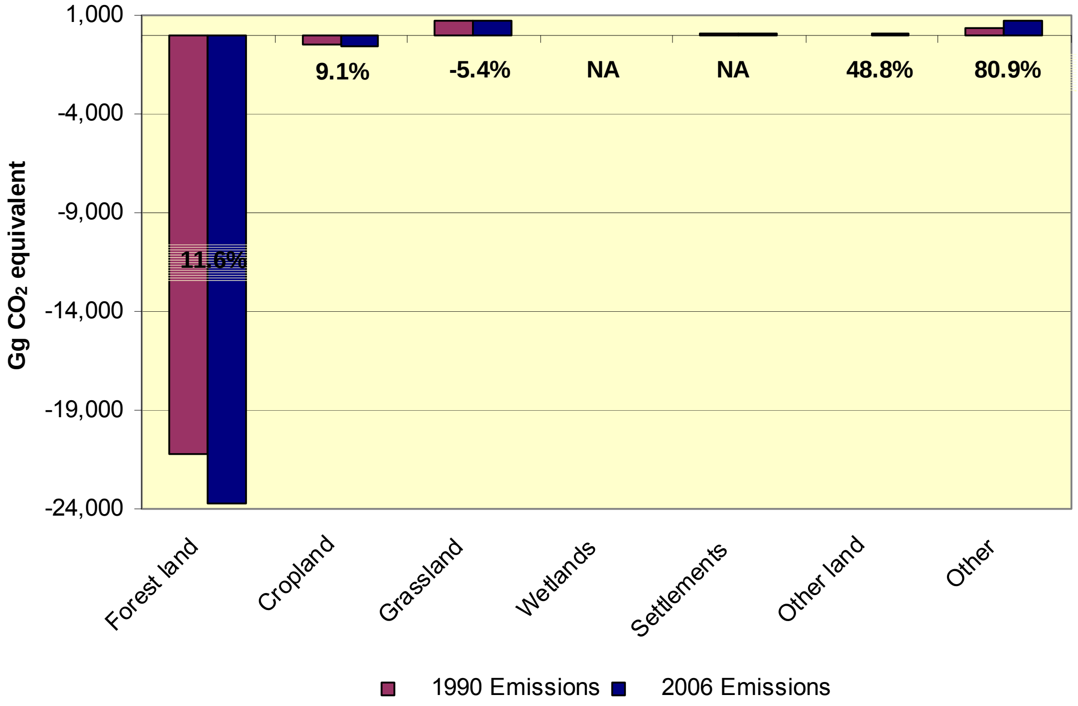


Figure 7.1.2 Change in emissions from the LULUCF sector (net emissions and removals by land use category) from 1990 to 2006 (all figures are Gg CO_2-e)



Note: The per cent change for wetland and settlements is not applicable (NA) as emissions are assumed constant. These two categories are not key categories.

7.1.1 Land use in New Zealand

Before human settlement, natural forests were New Zealand's predominant land cover, estimated at 75 per cent of total land area. Now, around 23 per cent of New Zealand's natural forest cover remains. Figure 7.1.3 shows the IPCC land use categories for New Zealand in 2002. Nearly all lowland areas have been cleared of natural forest for agriculture, horticulture, plantation forestry and urban development.

Deforestation following human settlement is estimated to have resulted in vegetation carbon losses of 3,400,000 Gg C (Scott et al, 2001). Historic land-use practices have had serious impacts on New Zealand's environment, including soil erosion, pollution and increased risk of flooding. Establishment of pastures probably slightly increased mineral soil carbon; however losses of carbon due to erosion are also possible (Tate et al, 2003b). New Zealand soils are naturally acidic with low levels of nitrogen, phosphorus, and sulphur. Consequently, soils used to grow crops and pasture need to be developed and maintained with nitrogen-fixing plants (such as clover), fertilisers and, often, lime to sustain high-yield plant growth.

7.1.2 Methodological issues for New Zealand

Summary of methodological approaches used

New Zealand currently uses a combination of Tier 1 and Tier 2 methodologies for reporting removals and emissions from the LULUCF sector. The Tier 1 approach, based on a simple land-use change matrix is applied for all six land use categories. However, a Tier 2 modelling approach using New Zealand-specific data has been used to estimate removals and emissions in planted forests (excluding soils).

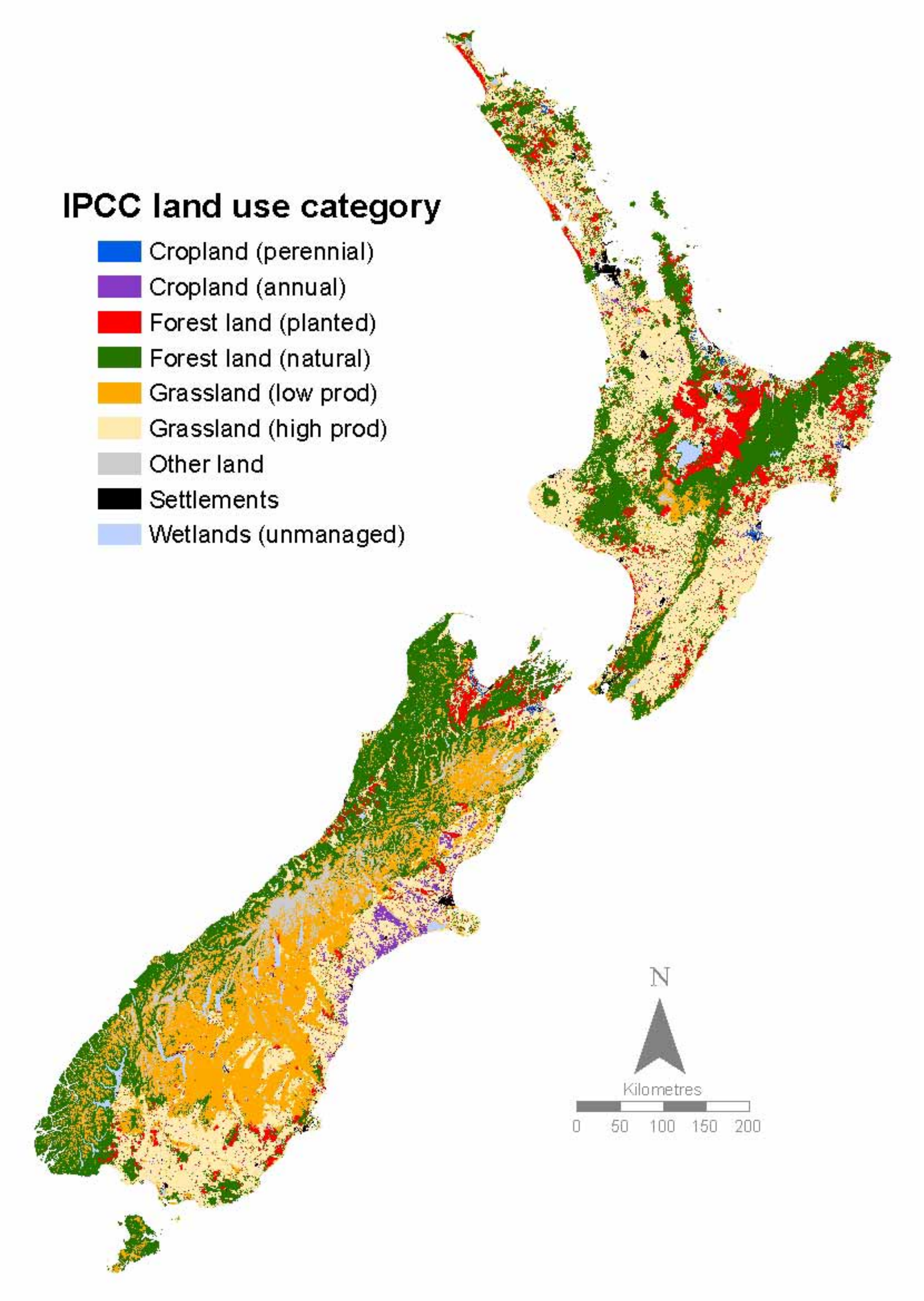
Land use and land use change

The variables used in the Tier 1 equations for all land-use categories (excluding planted forests) include the carbon stocks in each land use prior to conversion and annual growth in stocks. For transparency, these factors are tabulated in Tables 7.1.2 and 7.1.3.

Planted forest

Models are used to derive forest carbon from stem volume yield tables and to calculate historic removals and emissions by time-shifting the latest available data backwards. They also allow forecasting of future forest growth and management, including harvesting. Further detail of the modelling for planted forest is given in section 7.2.

Figure 7.1.3 Land use in New Zealand in 2002: IPCC land use categories (mapped from LCDB2)



Soils

The types of land use and management factors affecting soil carbon stocks are defined in GPG-LULUCF and include: (1) a land-use factor (F_{LU}) that reflects carbon stock changes associated with type of land use; (2) a management factor (F_{MG}) that for permanent cropland represents different types of tillage; and (3) an input factor (F_I) representing different levels of inputs to soil. The values used for the stock change factors for each land use category are shown in Table 7.1.1.

New Zealand is using a country-specific reference soil carbon stock value of 83 t C ha^{-1} for 0–30 cm depth. This value is within the range of the default IPCC values provided in Table 3.2.4 of GPG-LULUCF for warm temperate moist climates (a range of 34–88 t C ha^{-1}). The New Zealand value is calculated from the measured soil carbon in New Zealand grassland soils of 105 t C ha^{-1} (Tate *et al*, 2003a), divided by the stock change factors for high producing grassland, ie, 105 t C ha^{-1} / 1 / 1.14 / 1.11 = 83 t C ha^{-1}. New Zealand has always applied the default inventory time period of 20 years in calculating the Tier 1 estimates.

Liming

Information on the amount of lime applied is currently aggregated nationally and across all land-use categories. Lime applied to forest land or grassland is not reported separately. In addition, limestone and dolomite are not split, with both reported together under “limestone”. Emissions associated with liming are reported in the ‘other’ category within the CRF reporter (see section 7.8).

Biomass burning

Biomass burning takes place either as a controlled burn or as wildfire on forest land or grassland. Reporting is at a national level based on the total areas of grassland or forest land burned. Burning of crop stubble and prescribed burning of savannah are reported in the agriculture sector. Activity data (eg, areas burned) and other variables related to biomass burning (eg, fuel consumption and initial biomass density) are used in the Tier 1 methodology. Due to climate and vegetation types, fire risk has been relatively low historically and biomass burning is not a significant source of greenhouse gases in New Zealand.

It is not necessary to report CO_2 emissions resulting from natural disturbance events if methods are applied that do not capture subsequent re-growth (GPG-LULUCF 3.2.1.4.2). This applies to wildfires in grassland and natural forest in the New Zealand inventory. In the case of wildfire in planted forest land, the CO_2 emission will be captured by the stock change calculation if the fire-damaged area is harvested and replanted, or if the stand is allowed to grow on with a reduced net stocked area. Only in cases where the damaged stand is grown on to maturity without a reduction in its net stocked area will the inventory under-report CO_2 emissions. Given that the total area of wildfires in forests is small this is not regarded as a significant source of error.

Table 7.1.1 Soil stock change factors

Land use	F_{LU} (Land use)	FM_G (Management)	F_I (Input of organic matter)
Planted forest	1	1	1
Natural forest	1	1	1
Annual cropland	0.71	1.0	1.11
Perennial cropland	0.82	1.16	0.91
High-producing grassland	1	1.14	1.11
Low-producing grassland	1	1.14	1
Other land	1	1	1

Soil stock change factors selected from GPG-LULUCF Tables 3.3.4 and 3.4.5

Table 7.1.2 Biomass carbon stocks in land use before conversion

Land use	Value	Pools	Source/Reference
Natural forest	182 t C ha^{-1}	All living biomass	364 tonnes dm ha^{-1} (Hall et al, 1998); carbon fraction of dm (0.5).
Planted forest	223.2 t C ha^{-1}	All living biomass and dead organic matter	1st rotation, 28 years old (Wakelin, 2007).
Annual cropland	0 t C ha^{-1}	All living biomass	Annual crop is harvested. GPG-LULUCF only considers perennial crops (Table 3.4.8).
Perennial cropland	63 t C ha^{-1}	Aboveground biomass only*	GPG-LULUCF Table 3.3.2. Temperate (all moisture regimes).
High-producing grassland	1.35 t C ha^{-1}	Aboveground biomass only*	2.7 tonnes dm ha^{-1} (GPG-LULUCF Table 3.4.2, warm temperate – wet climate); carbon fraction of dm (0.5)
Low-producing grassland	0.8 t C ha^{-1}	Aboveground biomass only*	1.6 tonnes dm ha^{-1} (GPG-LULUCF Table 3.4.2, warm temperate – wet climate); carbon fraction of dm (0.5)
Low-producing grassland with woody vegetation	T2 = 29 t C ha^{-1}	Aboveground biomass only*	Figure used for Tier 2 clearance of grassland woody vegetation (Wakelin 2007).

* Some methods only estimate above-ground biomass. dm = dry matter

Table 7.1.3 Annual growth in biomass for land converted to another land use

Land use	Value	Pools	Source/Reference
Natural forest	T1 = 0 t C ha^{-1}	All living biomass	New Zealand's natural forests are assumed to be approximately in steady-state (Tate et al, 2000)
	T1 = 4.3 t C ha^{-1}		Tier 1 – GPG-LULUCF 3A.1.5 and 3A.1.8 (Gw=3.5 tonnes dm ha^{-1} (an average of the conifer (3.0) and broadleaf (4.0) values), R = 0.24, Cfrac = 0.5)
Planted forest	IE	All living biomass and dead organic matter	Tier 2 – included in C-change modelling (Beets et al, 1999, Wakelin, 2007). Modelled annual growth (net of dead organic matter decay) varies by age from 0.1-12.5 t C ha^{-1}, and averages 8.0 t C ha^{-1} over a 28 year rotation. Net of DOM decay.
Annual cropland	5 t C ha^{-1}	All living biomass	GPG-LULUCF Table 3.3.8 (temperate all moisture regimes)
Perennial cropland	2.1 t C ha^{-1}	Aboveground biomass only*	GPG-LULUCF Table 3.3.8 (temperate all moisture regimes)
High-producing grassland	6.75 t C ha^{-1}	Aboveground biomass only*	13.5 tonnes dm ha^{-1} (GPG-LULUCF Table 3.4.9, warm temperate – wet climate), C_{frac} = 0.5
Low-producing grassland	3.05 t C ha^{-1}	Aboveground biomass only*	6.1 tonnes dm ha^{-1} (GPG-LULUCF Table 3.4.9, warm temperate – dry climate), C_{frac} = 0.5

* Some methods only estimate above-ground biomass. dm = dry matter

Representation of land areas

Land areas are calculated (for the Tier 1 approach) using an analysis of two existing land-cover maps of New Zealand – the Land Cover Databases 1 and 2 (LCDB1 and LCDB2, respectively) (Thompson *et al*, 2004). These databases have been reclassified to reflect the IPCC categories. The land cover databases were mapped in 1997 and 2002. Data for all other years is extrapolated from the changes observed between 1997 and 2002.

The LCDB1 and LCDB2 are an example of the wall-to-wall mapping of Approach 3 as described in GPG-LULUCF. The LCDBs were not specifically developed for use in IPCC reporting, however they are the only national land-cover/land-use spatial databases available that provide recent information and can be reasonably mapped to the LULUCF land categories (Table 7.1.4).

To improve transparency and accuracy of reporting in the LULUCF sector, and to meet the additional reporting requirements of the Kyoto Protocol, the Ministry for the Environment is developing the Land Use and Carbon Analysis System (LUCAS). The LUCAS project is described in detail in Annex 3.2. The land categories to be mapped and monitored through LUCAS are designed specifically for reporting under the UNFCCC and the Kyoto Protocol, and will replace LCDB data in the inventory from the 2010 inventory submission onwards.

New Zealand does not presently have land-use data for 1990. In the 2008 inventory submission the 1990 data has been estimated by linear extrapolation of the 1997 data. Until the 1990 mapping component of the LUCAS project is completed, this method provides the best data available for the inventory.

Table 7.1.4 Mapping of LCDB classification to the IPCC land-use categories

IPCC category	LCDB class
Cropland	
CM (perennial)	Orchard and other perennial crops, vineyard
CM (annual)	Short-rotation cropland
Forest land	
FM (planted)	Afforestation (imaged, post LCDB 1), afforestation (not imaged), deciduous hardwoods, forest harvested, other exotic forest, pine forest – closed canopy, pine forest – open canopy
FM (natural)	Natural forest, broadleaved natural hardwoods, manuka and/or kanuka
Grassland	
GM (low prod)	Alpine grass/herbfield, depleted tussock grassland, fernland, gorse and broom, grey scrub, low producing grassland, major shelterbelts, matagouri, mixed exotic shrubland, sub-alpine shrubland, tall tussock grassland, flaxland, herbaceous freshwater vegetation, herbaceous saline vegetation, mangrove
GM (high prod)	High-producing exotic grassland
Other land	
O	Alpine gravel and rock coastal sand and gravel landslide permanent snow and ice river and lakeshore gravel and rock
Settlements	
S	Built-up area, dump, surface mine, transport infrastructure, urban parkland/open space
Wetlands	
W (unmanaged)	Estuarine open water, lake and pond, river

The LCDB1 and LCDB2 include a shrubland vegetation cover category. Such a category does not exist as a LULUCF category. Some shrubland classes were classified as forest land and others were classified as grassland, based on an assessment of whether the species would usually grow to over 5 metres in height *in situ*. The classification is shown in Table 7.1.4, and will be further refined when the LUCAS project is operational.

Table 7.1.5 shows a simplified land-use change matrix developed from LCDB1 and LCDB2 for the years 1997 and 2002. A land-use change matrix for 2005–2006 was generated by extrapolation. Detail of the conversions between categories and subcategories are included in the sections discussing each land-use category below.

Some prominent land-use changes between 1997 and 2002 include:

- An increase in planted forest area of almost 140,000 ha (or 7%), mostly from conversion of grassland, a decrease of 135,000 ha (2%).
- An increase in the area of settlements by 5,500 ha (2.5 %) mostly from conversion of grassland.
- An increase in the area of cropland by 4,500 ha (7%), mostly perennial cropland.

Table 7.1.5 Land-use change matrix between 1997 and 2002

(IPCC land use classes derived from LCDB1 and LCDB2)

1997 2002		**Forest land**		**Cropland**		**Grassland**		**Wetlands**	**Settlements**	**Other Land**	**2002 Total**
		Planted	Natural	Annual	Perennial	High Producing	Low Producing	Unmanaged			
Forest land	Planted	1904.5	10.8	–	–	91.0	39.6	–	–	–	2046.0
	Natural	–	8182.2	–	–	0.3	–	–	–	–	8182.6
Cropland	Annual	–	–	333.6		0.1	–	–	–	–	333.7
	Perennial	0.2	–	1.4	78.0	4.2	–	–	–	–	83.7
Grassland	High Producing	0.1	0.9	–	–	8883.8	0.9	–	–	–	8885.8
	Low Producing	1.2	2.8	–	–	0.1	5475.8	–	–	0.2	5480.2
Wetlands	Unmanaged	–	–	–	–	0.6	–	531.2	–	–	532.0
Settlements		0.5	–	–	–	5.0	–	–	214.8	–	220.5
Other Land		–	0.2	–	–	–	–	–	–	1056.8	1057.1
1997 Total		1906.6	8197.0	335.0	78.0	8985.2	5516.4	531.2	215.0	1057.1	26821.6
Net Change 1997–2002		139.4	–14.4	–1.2	5.7	–99.4	–36.2	0.7	5.5	–	–
% Change		7.3%	–0.2%	–0.4%	7.4%	–1.1%	–0.7%	0.1%	2.5%	0.0%	0.0%

Note: The minimum area shown to represent an actual land-use change is 100ha. Columns and rows may not total due to rounding. Shaded cells indicate land remaining in each category

7.2 Forest land (CRF 5A)

7.2.1 Description

In 2006, forest land contributed 23,710.8 Gg CO_2-e of net removals. This value includes removals from the growth of planted forests, emissions from the conversion of land to planted forest and emissions from harvesting. Net removals from forest land have increased by 2,471.3 (11.6 per cent) since the 1990 level of 21,239.5 Gg CO_2-e.

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 values are a minimum area of 1 hectare, a height of 5 metres and a minimum crown cover of 30 per cent. This definition will be used when forest is mapped by the LUCAS project and reported in future inventories. To complete the 2008 inventory submission, the categories of forest land as mapped in the LCDB1 and LCDB2 were used (an area of 1 hectare and a width of 100 metres).

New Zealand has adopted the definition of managed forest land as provided in the IPCC Guidelines and GPG-LULUCF: "Forest management is the process of planning and implementing practices for stewardship and use of the forest aimed at fulfilling relevant ecological, economic and social functions of the forest". All of New Zealand's forests, both those planted for timber production and natural forests managed for conservation values are considered managed forests.

Forest land is dominant in the LULUCF sector, and is "forest land remaining forest land" is the major key category for the New Zealand inventory. Forests cover almost 40% (around 10,000 ha) of the land area of New Zealand. There has been considerable afforestation since 1990, while deforestation has been small in comparison.

For inventory reporting two sub-categories are used to cover all of New Zealand's forests – natural forest and planted forest. Natural forests are considered to be approximately in steady-state, that is emissions and removals from these forests are assumed to be equal (Tate et al, 2000).

Natural forest

Natural forest is a term used to distinguish New Zealand's native or naturally occurring forests from planted production forests. It consists of native forest ecosystems made up of a range of indigenous and some naturalised exotic species. Two principal types of forest exist: beech forests (mainly *Nothofagus* species) and podocarp/broadleaf forests. In addition shrublands made up predominantly of manuka and kanuka, and retired grasslands have the potential to reach the forest definition in some locations. Currently, New Zealand has an estimated 8.2 million hectares of natural forest (including shrublands).

Government controls on natural forest clearance (deforestation) were first imposed in the late nineteenth century, but continuing demand for timber and agricultural land resulted in further forest clearance. By the 1970s, growing public concern led to stronger government conservation measures. Large-scale forest clearance for agricultural land ceased and New Zealand's domestic timber supply came largely from mature planted forests.

Further government administrative changes in 1987 resulted in reservation of about five million hectares (18 per cent of New Zealand's total land area) of publicly-owned natural forests. Commercial timber harvest from private natural forest was restricted to that sourced under sustainable forest management plans and permitted by a 1993 amendment to the Forests Act 1949. The amendment still exempted West Coast publicly-owned forests and forests on specific Māori-owned lands. Further government controls resulted in the cessation of logging of the West Coast publicly-owned forests in March 2002.

Less than 0.1 per cent of New Zealand's total forest production is now harvested from natural forests. New Zealand's wood needs are now almost exclusively met from planted production forests. No timber is harvested from New Zealand's publicly-owned natural forests. The natural forest harvest reported in the inventory refers to harvest of forests on land returned to Māori under the South Island Landless Natives Act (SILNA) 1906. These forests are currently exempt from provisions that apply to all privately-owned indigenous forests that require a sustainable forest management plan or permit before any harvesting. Approximately 50,000 hectares are covered by the SILNA. There is no specific data to estimate growth in these forests. The LUCAS will provide data for similar forests in similar locations to the SILNA forests.

Timber harvested from privately-owned natural forests and from SILNA forests has continued at a low level since the 1993 controls were imposed. Current proposed legislative changes will continue to exempt the SILNA forests although logging has further reduced in these forests.

Removals of CO_2 in natural forest are calculated by a Tier 1 approach. Preliminary results are that New Zealand's natural forests are approximately in steady-state or a possible small sink of carbon, ie, changes in vegetation carbon stock lie between 0.3 to –2.5 Tg C yr^{-1} (Tate et al, 2000). For this reason removals are set to emissions in the CRF tables. Results from analysis of the Carbon Monitoring System (CMS) data within natural forests as part of the LUCAS project will enable New Zealand to provide improved estimates (refer to Annex 3.2).

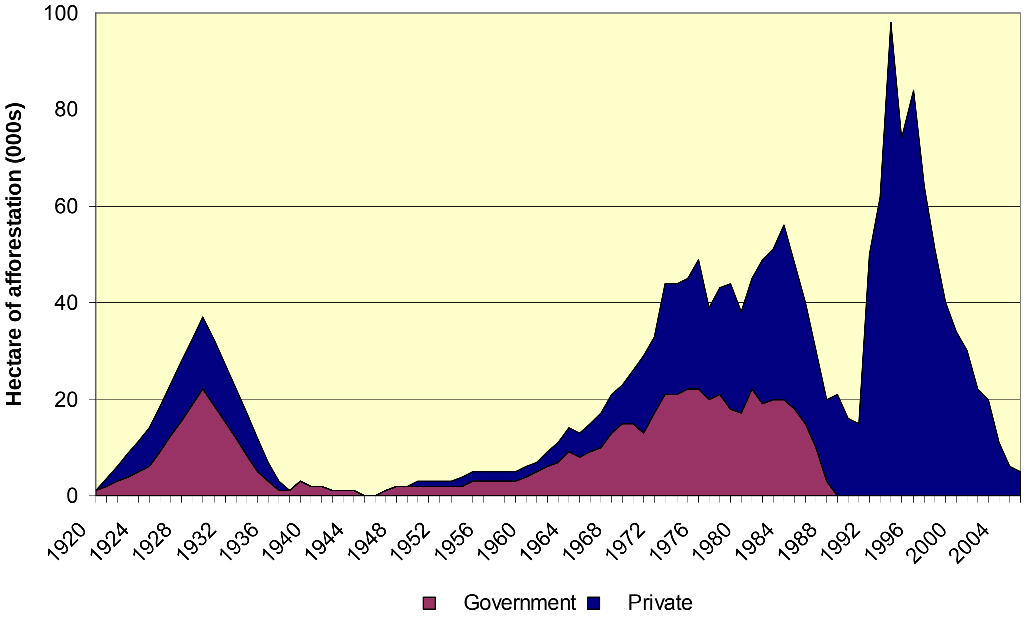
Planted Forest

New Zealand has a substantial estate of planted forests, around 90 per cent *Pinus radiata* (created specifically for timber supply purposes) and has well-established data on the estate's extent and characteristics. These forests are usually composed of stands of trees of a single age class and all forests have relatively standard silviculture regimes applied.

Between 1990 and 2006 it is estimated that 685,000 hectares of new forest has been established as a result of afforestation and reforestation activities. In 2006, plantation forestry covered an estimated 1.8 million hectares of New Zealand (around 7% of the total land area). Having a large planted forest resource enables New Zealand to sustainably manage it's publicly and privately-owned natural forest.

The new planting rate (land reforested or afforested) over the last 30 years has been, on average, 43,000 hectares per year (Figure 7.2.1). From 1992 to 1998, new planting rates were high (averaging 69,000 hectares per year). However, since 1998 the rate of new planting has declined and in 2006 only 5,000 hectares of new forest was established (the lowest rate since 1959). Some of the land not being replanted is being converted into pasture.

Figure 7.2.1 Annual forest planting in New Zealand from 1920 to 2006



7.2.2 Methodological issues

Forest land remaining forest land

Natural forest (Tier 1)

A small amount of harvesting takes place that is exempt from the sustainable management plan requirement. This harvesting is assumed to result in an emission of all above-ground biomass carbon, with no compensating forest growth. This is probably a conservative assumption, as it is possible that some harvesting of these forests is carried out on a sustainable basis. Estimates of harvesting from exempted natural forests are provided by the MAF. Stem wood volumes are converted to oven-dry weight using a factor of 0.5 (IPCC default value from GPG-LULUCF equation 3.2.4) and then expanded to include non-stem wood biomass using a factor of 2.04 (Wakelin, 2007). These country-specific factors are within the ranges given by GPG-LULUCF (2003 (Tables 3A1.9-1 and 3A1.10)).

Results from analysis of the Carbon Monitoring System (CMS) data within natural forests, undertaken as part of the LUCAS project will enable New Zealand to provide improved estimates (refer to Annex 3.2).

Planted forest (Tier 2)

Compared to many forest ecosystems, total biomass and carbon stocks in New Zealand's planted forests are relatively straightforward to estimate. The methodology applied for the inventory is:

- A survey of forest growers – the National Exotic Forest Description (NEFD) – is undertaken annually. This provides estimates of the area of forest by age, species, silvicultural regime and location.

- Stem wood volume yield tables are compiled periodically for combinations of species, silvicultural regime and location.
- The C_change model (Beets et al, 1999) is used to derive forest biomass and carbon from stem volume yield tables.
- The Forestry Oriented Linear Programming Interpreter (FOLPI) (Garcia, 1984; Manley et al, 1991) is used to recalculate historic estimates of CO_2 removals and emissions by time-shifting the latest available data backwards.
- The FOLPI model also time-shifts the estate forwards to forecast future forest growth and forest management, including harvesting.

Planted forest survey data

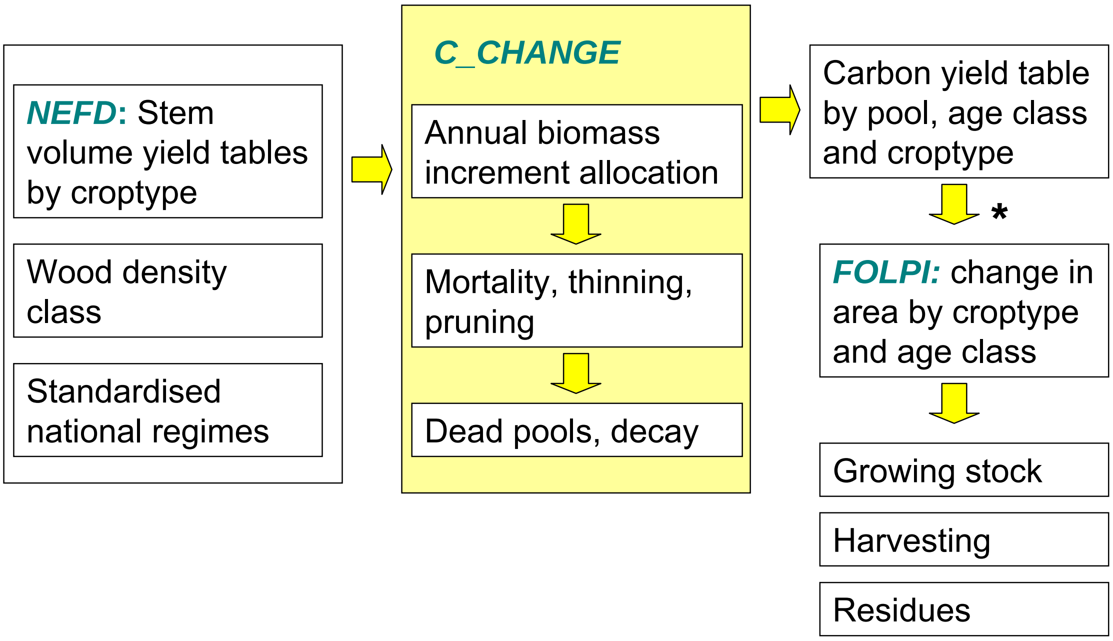
The results of the NEFD survey as at 1 April 2006 are used to calculate removals and emissions provided in the 2008 inventory submission. This latest information brings in new forest-area data along with data on new planting, restocking and harvesting and merchantable stem wood volume by crop-type and age for the 2006 year (Ministry of Agriculture and Forestry, 2006).

A crop-type is an aggregate of forest stands that are similar species, silviculture and location. Each crop-type has a yield table that provides estimated volumes of stem wood per hectare by age. The total forest area after harvest for the year ending March 2006 is based on: (a) the latest area estimates provided by the 2006 NEFD; (b) an estimate of the area to be planted during the year; and (c) an estimate of the area harvested during the year. The area of new land planting is based on the MAF statistics. These estimates are revised and recalculated annually as provisional estimates are replaced by confirmed actual areas.

Modelling

A summary of the modelling steps used in inventory calculations is shown in Figure 7.2.2. The C_change model estimates total dry matter per hectare, by vegetation component and annual age-class from stem wood volume data (Box 7.2).

Figure 7.2.2: Planted forest inventory modelling process



Box 7.2 Process steps in the C_change model (Beets *et al*, 1999)

1. Stem wood volume is converted to an oven-dry biomass weight.
2. The dry weight of non-stem wood components (bark, branches, foliage, cones, stumps, roots, floor litter and understory) is calculated from stem wood volume using allometric equations. These allometric equations take account of age, stocking and site fertility.
3. Total forest biomass is converted to carbon weight. The carbon fraction of dry matter is 0.5 using the IPCC default (GPG-LULUCF p3.25). Note that although the IPCC default for litter is 0.37, preliminary NZ data suggests that the litter pool is higher.

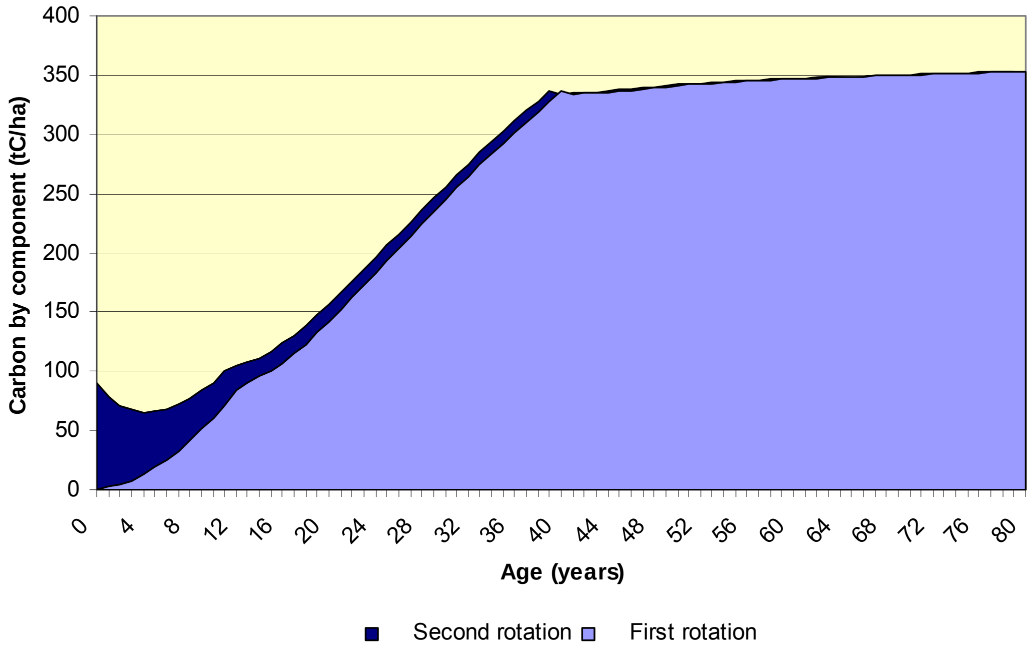
For the 2008 inventory submission, C_change was used to create a corresponding carbon yield table for each wood volume yield table, based on wood density and management assumptions appropriate to the species, regime and region. The allometric equations used were based on data for *Pinus radiata*. Approximately 10 per cent of the estate is made up of other species such as Douglas-fir (*Pseudotsuga menziesii*) (5 per cent), other exotic softwoods (2 per cent), and exotic hardwoods (3 per cent). It is uncertain what impact these other species may have on the accuracy of calculations of total biomass, but current research will enable the impact to be further assessed. To simplify the subsequent modelling, all crop-types were then aggregated to form a single, national area-weighted crop-type and associated area-weighted national yield table.

The second of the two models, FOLPI is a linear programming model used to optimise the management of forest estates over time. It simulates actual rates of planting and harvesting where time-series data exists. Carbon stock estimates are calculated for March years, with calendar year data estimated based on two years of data. The assumption is that the stem wood removed at harvest for both natural and planted forests is oxidised in the year of harvest. The FOLPI model uses the biomass and carbon stocks at one point in time to give total carbon stocks for each modelled year and changes in carbon stocks between those years. Among the outputs of the FOLPI model are the LULUCF inventory results for 1990 to 2006. These results include:

- Stem wood volume harvested from the planted estate, hence CO_2 emitted in that harvest.
- Total stock of estate carbon after harvesting in each year (accounting also for the decay of non-stem wood carbon left after harvesting).

The removal of carbon (net of harvest) is calculated from the total stock values. The gross removal of carbon is then calculated by adding the harvested stem wood carbon back into the net carbon removal figures. This gives the change in carbon stock between last year's harvested forests and this year's unharvested forests. Total carbon yield by stand age and rotation is shown in Figure 7.2.3.

Figure 7.2.3 Total carbon yield by stand age and rotation



Biomass burning

For "forest land remaining forest land" there is no controlled burning in New Zealand. The inventory reports only emissions resulting from wildfire, where the IPCC default temperate forest fuel consumption rate of 45% of total biomass is used (GPG-LULUCF Table 3A.1.12). Wildfire activity data is collected and managed by the New Zealand Fire Service (NZFS) and the National Rural Fire Authority (NRFA). Data used in previous years was provided by the NRFA for 1990–2000, but this data is unofficial and has now been discarded from the inventory. For the 2008 inventory submission, the NZFS data was used from June 2001-June 2007, with the average over this period applied back to 1990. Activity data for wildfire is generally poor quality, but it is estimated that there have not been major changes in wildfire occurrence since 1990 (Challands, 2007).

For wildfire in planted forest, CO_2 emissions will be captured by the stock change calculation if the fire-damaged area is harvested and replanted, or if the stand is allowed to grow on but with a reduced net stocked area. Only in cases where the damaged stand is grown on to maturity without a reduction in its net stocked area will the inventory under-report CO_2 emissions. Given that the total area of wildfires in forests is small this is not regarded as a significant source of error.

Non-CO_2 emissions are largely based on IPCC default values, and have recently been reviewed (Wakelin, 2006). Previously the wildfire combustion efficiency in forests and grassland with aboveground woody biomass was set at 0.9, which is the IPCC default for the proportion of biomass oxidised as a result of *land conversion* burns (see GPG-LULUCF 3.4.2.1.1.2). For the 2008 inventory submission, a more appropriate value of 0.45 for temperate forests has been substituted (GPG-LULUCF Table 3A.1.12).

Land converted to forest land

Data on the amount of land clearance for new forest planting are sourced from the annual NEFD survey. The information includes the proportion of new forest planting that occurs on grassland with woody vegetation that falls below and is not expected to exceed, without human intervention, the threshold used to define forest land for New Zealand under the Kyoto Protocol. Data are available from 1993 to the present and based on these figures it is assumed that the proportion of new forest planting on grassland with woody vegetation was 20 per cent before 1993.

A review of the assumptions regarding the volume of biomass on grassland with woody vegetation (Wakelin 2004) concluded that the estimate previously being used was inappropriately high. For the 2008 inventory submission, a lower value of 29 t C/ha (Wakelin, 2007) is used, as it applies only to land identified as carrying "predominantly scrub" prior to planting. This is around half the estimate previously used, and will be revised when the LUCAS plots have been analysed (refer to Annex 3.2).

Biomass Burning

It is estimated that 25 per cent of the land converted to forest land is cleared using controlled burning, with a country-specific fuel consumption rate of 70% of above-ground biomass (Wakelin, 2007). The remainder and all biomass on unburned sites are assumed to decay over ten years (IPCC default value). Current research aims to quantify emissions from the burning of residues that result from the conversion of planted forests to grassland. Emissions of CO_2 from controlled burns for afforestation are reported as a stock change in the grassland category. Carbon dioxide emissions resulting from natural disturbance events are not reported, as methods are applied that do not capture subsequent re-growth (GPG-LULUCF 3.2.1.4.2).

7.2.3 Uncertainties and time-series consistency

Adopting a Tier 2 modelling approach has allowed the large body of plantation forestry knowledge in New Zealand to be applied to the greenhouse gas inventory. For example, the wood density of *Pinus radiata* in New Zealand has been well studied because of its relationship with important end-product values. It is known that density varies with temperature, soil fertility, genetic stock and age, and equations have been developed to relate routine field measurements (eg, of outer-wood density from core samples) to whole tree density, and to project this over time. The variation in *Pinus radiata* outerwood density at breast height is significant (350 to 600 kg/m^3) with the upper limit occurring on warm, low fertility sites (Beets et al 2001).

In the yield tables that form the national carbon yield table, three broad density regions were recognised, and the effect of age on density is also modelled. As a result, the average density of harvested logs in the model varies with the average clearfell age, and is higher then the average density for the growing stock. The latter is also not constant over time because the age class distribution is variable.

Attempts have been made to quantify the uncertainties in the CO_2 removal estimates for planted forests but it is difficult to quantify the overall error due to the assumptions implicit in the models. Some uncertainties within the C-change (CARBON/ DRYMAT) model are well characterised (Hollinger et al, 1993). These include ± 3 per cent for wood density, ±15 per cent for carbon allocation and ± 5 per cent for carbon content. Combining the uncertainties indicates that the proportional error in the carbon sequestration estimates is likely to be at least ± 16 per cent. The total national planted area is considered to be accurate to within ± 5 per cent (Ministry of Agriculture and Forestry, 2006) and the yield tables are assumed to be accurate to within ± 5 per cent.

A sensitivity analysis was conducted using the above accuracy ranges for total planted area and commercial yield, and a proportional uncertainty error of ± 16 per cent. The C-change

(CARBON/ DRYMAT) model runs indicate that the precision of the carbon stock estimates could be of the order of ± 25 per cent. As part of the LUCAS, research has been commissioned to better quantify uncertainty. No uncertainty estimates are currently available for emissions from harvesting of natural forests.

Removals from forest land are 6.6 per cent of New Zealand's total emissions and removals uncertainty in 2006 (Annex 7). Forest land introduces 2.3 per cent uncertainty into the trend in the national total from 1990 to 2006. This is the second largest impact on the trend following CO_2 emissions from the energy sector.

7.2.4 Source-specific QA/QC and verification

Carbon-dioxide removals from both "forest land remaining forest land" and "land converted to forest land" are key categories (for both level and trend assessments). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

The data presented in the 2008 inventory submission were reviewed by officials from the Ministry for the Environment and the Ministry of Agriculture and Forestry. Calculated estimates were visually assessed for obvious errors in calculations. Land-use change matrices were used to ensure that the allocation of land between categories produced a consistent national total area of land.

One of the primary input data sets used is the National Exotic Forest Description (NEFD). The NEFD is New Zealand's official source of statistics on planted production forests and as such is subject to formalised data checking procedures. Each NEFD report is reviewed by a technical NEFD Committee before publication. Broad comparisons of forest areas reported in the NEFD reports are made with independent sources of information such as the Land Cover Database estimates and the annual results of Statistics New Zealand's Agricultural Production Survey. NEFD yield tables have been subject to review (eg, Jaakko Poyry Consulting, 2003; Manley, 2004) and are in the process of being revised.

The 2006 planted forests removals and emissions have been compared for consistency with the 2005 estimates (Wakelin, 2007), with both level and trend closely aligned.

7.2.5 Source-specific recalculations

The main changes in the data for the 2008 inventory submission were due to:

Use of single year values

Three year averages have been used for most activity data in previous inventories. Single year values are now used in calculations for all activity data. The change was made to allow more time for quality control checking prior to submitting the inventory. This change results in greater inter-annual variation, but does not have a major impact on estimates of emissions and removals.

Revised assumptions for clearance of scrub and biomass burning

For clearance of grassland with aboveground woody biomass, revised emission factors have been applied, while decay of residues has now been spread over 10 years (IPCC default). For biomass burning due to wildfire, revised activity data has been used and country-specific emissions and fuel consumption rates have been applied. These changes improve the accuracy of estimates.

Modelling process and NEFD data

Use of the latest NEFD survey data means that derived historic age class distributions become less robust. Using only the latest data leads to an underestimate of historic removals because of deforestation in recent years. To address this issue the 1990-2004 time series was recalculated from the 2004 planted forest model, while the 2005 and 2006 years were calculated from the 2005 and 2006 planted forest models respectively. Further work is required to assess the appropriate approach to use for future inventories until plot-based LUCAS estimates become available.

7.2.6 Source-specific planned improvements

Development of the LUCAS will enable New Zealand to revise the time-series in the LULUCF sector, and reduce uncertainty by using country-specific emission and removal factors and IPCC category-specific activity data. Details of the research are included in Annex 3.2.

Improvements in NEFD area capture are ongoing. Survey respondents are now being asked to specify whether or not stands are first rotation. This will allow improved analysis of "land converted to forest land" and "forest land remaining forest land". Estimates of dead organic matter stocks resulting from post-harvest residues will also be improved.

Ongoing research is aiming to improve carbon modelling, including partitioning in species other than *Pinus radiata*, plantation understory carbon and biomass decay rates.

7.3 Cropland (CRF 5B)

7.3.1 Description

In 2006, cropland accounted for 546.5 Gg CO_2-e of net removals. Net removals from cropland have increased 45.8 Gg CO_2-e (9.1 per cent) from the 1990 level of 500.7 Gg CO_2-e. Cropland is a key category for New Zealand.

Cropland in New Zealand is separated into two sub-categories, annual and perennial. Cropland comprised than 1.6 per cent (or 417,400 hectares) of New Zealand's total land area in 2002. This included 333,700 hectares in short-rotation/annual cropland and 83,700 hectares in perennial cropland. Annual crops include cereals, grains, oil seeds, vegetables, root crops and forages. Perennial crops include orchards, vineyards and plantations except where these lands meet the criteria for forest land.

The amount of carbon stored in, and emitted or removed from permanent cropland depends on crop type, management practices, and soil and climate variables. Annual crops are harvested each year, with no long-term storage of carbon in biomass. However, perennial woody vegetation in orchards can store significant carbon in long-lived biomass, the amount depending on species type, density, growth rates, and harvesting and pruning practices.

7.3.2 Methodological issues

Emissions and removals have been calculated using IPCC Tier 1 emission and removal factors and activity data from the LCDB analysis described in section 7.1.2.2.

Cropland remaining cropland

Living biomass

The change in biomass is only estimated for perennial woody crops (GPG-LULUCF (section 3.3.1.1.1.)) For annual crops, increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year and there is no net accumulation of biomass carbon stocks.

The biomass accumulation rate (2.1 t C ha^{-1} yr^{-1}) in perennial vegetation and biomass carbon loss (63 t C ha^{-1}) are from GPG-LULUCF Table 3.3.2. New Zealand is using the values for a temperate climate (all moisture regimes). The LCDB analysis cannot provide information on areas of perennial vegetation temporarily destocked; therefore no losses in carbon stock can be calculated.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation “NE” is used in the CRF tables. There is not sufficient information to provide a basic approach with default parameters to estimate carbon stock change in dead organic matter pools in cropland remaining cropland (GPF, LULUCF).

Soil carbon

To provide a Tier 1 estimate, New Zealand uses the IPCC default method for mineral soils (equation 3.3.3 of GPG-LULUCF). Mineral soils comprise 99.93 per cent of New Zealand soils (Tate et al, 2004). This equation compares the soil organic carbon stock in the inventory year, with the soil organic carbon stock in “T” years before the inventory. New Zealand uses the IPCC default value of 20 years for “T”.

Changes in soil carbon stock are caused by changes in the land-use and management factors. The values for $F_{LU,}$ F_{MG} and F_I are from Table 3.3.4 in GPG-LULUCF and are shown for each category in Table 7.1.1. Within the cropland category, the LCDB does not provide sufficient information to determine whether there has been a change in land use and management in the 20 years before the inventory. Therefore for cropland remaining cropland, the values for $F_{LU,}$ F_{MG} and F_I are considered to be constant and there is no net change in carbon stocks in soils. For example, for perennial cropland remaining perennial cropland the calculation is:

(83 x 0.82 x 1.16 x 0.91) – (83 x 0.82 x 1.16 x 0.91)) x Area)/20 = 0.

Land converted to cropland

Living biomass

The Tier 1 method multiplies the annual area of land converted to cropland by the carbon stock change per area for that type of conversion. The calculation includes changes in carbon stocks from one year of cropland growth and is provided in equation 3.3.8 of GPG-LULUCF.

For Tier 1, carbon stocks in biomass immediately after conversion are assumed to be zero, ie, the land is cleared of all vegetation before planting crops. To complete the Tier 1 analysis, New Zealand has selected from default parameter values provided in GPG-LULUCF and country-specific values where possible. These are shown in Tables 7.1.2 and 7.1.3.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation “NE” is used in the CRF tables. There is not sufficient information to provide a basic approach with default parameters to estimate carbon stock change in dead organic matter pools in land converted to cropland (GPG-LULUCF).

Soil carbon

New Zealand has followed the method outlined in GPG-LULUCF. For Tier 1, the initial soil carbon stock is determined from the same reference soil carbon stocks used for all land uses, together with stock change factors (F_{LU}, F_{MG}, F_I) appropriate for the previous land use (refer to section 7.1.2 in this report).

N_2O emissions

N_2O emissions are from mineralisation of soil organic matter resulting from conversion of forest land, grassland, settlements or other land to cropland. New Zealand uses the method outlined in GPG-LULUCF equations 3.3.14 and 3.3.15. The input parameters to these equations are:

- Change in carbon stocks in mineral soils in land converted to cropland: this value is calculated from the land converted to cropland soil carbon calculations.
- EF_1: the emission factor for calculating emissions of N_2O from nitrogen in the soil. The IPCC default value of 0.0125 kg N_2O – N/kg N is used.
- C: N ratio: the IPCC default ratio of carbon to nitrogen in soil organic matter (1:15) is used.

7.3.3 Uncertainties and time-series consistency

Uncertainties can be analysed as uncertainty in activity data and uncertainty in variables such as emission factors, growth rates, and the effect of land management factors. The combined effect of uncertainty in cropland is estimated at ± 75 per cent (95 per cent confidence interval). As shown in Table 7.3.3.1, while uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two years (1997 and 2002) of mapped activity data is used. In addition mapping is not specific to IPCC categories.

Table 7.3.3.1 Uncertainty in emissions and removals from cropland and grassland

Variable	Uncertainty (95% confidence interval)
Uncertainty in land area	
LCDB1 (user accuracy 93.9%)	± 6%
LCDB2 (assumed to be equal to LCDB1)	± 6%
Uncertainty in biomass accumulation rates	± 75% (GPG-LULUCF Tables 3.3.2, 3.4.2)
Carbon accumulation from land use change	± 75%
Carbon stocks in previous land use	± 75%
Estimated uncertainty in land management factors	± 12% (GPG-LULUCF Table 3.3.4)

7.3.4 Category-specific QA/QC and verification

Carbon-dioxide removals from “cropland remaining cropland” are a key category (level assessment). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.3.5 Category-specific recalculations

Recalculations were carried out for this category as emissions or removals from soils were not included in the CRF reporter for the previous submission.

7.3.6 Category-specific planned improvements

The use of historic activity data for cropland is to be investigated. This would allow for improved estimates of land converted to cropland and cropland remaining cropland. A New Zealand specific value for EF_1: the emission factor for calculating emissions of N_2O from nitrogen in the soil has been applied in the agriculture sector. Use of this factor within the LULUCF sector will be investigated for subsequent inventories. Sector-level improvements resulting from the LUCAS are described in Annex 3.2.

7.4 Grassland (CRF 5C)

7.4.1 Description

In 2006, the net emissions from grassland were 694.3 Gg CO_2-e. This is a decrease of 39.8 Gg CO_2-e (5.4 per cent) from the 1990 level of 734.1 Gg CO_2-e. These emissions are from the subcategory “land converted to grassland”.

In New Zealand, grassland covers a range of land-cover types. Reporting covers two sub-categories; low producing and high producing. Low producing grassland consists of either native tussockland or areas composed of shrubby vegetation (often referred to as “scrub” in New Zealand). Scrub contains woody biomass but does not meet the forest definition (section 7.2.1). High producing grassland consists of high intensity pasture land.

In 2002, high producing pasture covered 33 per cent of the country, while low producing grassland made up a further 20 per cent. Much of New Zealand’s grassland is grazed, with pastoral agriculture being the main land use. Most New Zealand agriculture is based on extensive pasture systems with animals grazed outdoors year-round. A shift to more intensive pastoral land use has placed greater pressures on the health of some soil and water quality. It has also seen a recent trend for conversion of plantation forest to pasture (deforestation).

7.4.2 Methodological issues

Grassland remaining grassland

Living biomass

In GPG-LULUCF (section 3.4.1.1.1.1), the Tier 1 assumption is no change in living biomass. The rationale is that where management practices are static, biomass carbon stocks will be in an approximate steady-state where carbon accumulation through plant growth is roughly balanced by losses. New Zealand has reported "NE" in the CRF tables because the activity occurs but no estimate of removals or emissions is able to be calculated.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation "NE" is used in the CRF tables. GPG-LULUCF states there is not sufficient information to develop default coefficients for estimating the dead organic matter pool. For Tier 1 and 2 methods, changes in dead organic matter and inorganic carbon stocks should be assumed to be zero.

Soil carbon

To provide a Tier 1 estimate, New Zealand uses the IPCC default method for mineral soils (equation 3.4.8 of GPG-LULUCF). As noted in previous sections, mineral soils cover 99.93 per cent of New Zealand (Tate et al, 2004). The LCDB analysis used in the 2008 inventory submission does not provide sufficient information to determine whether there has been a change in land use and management in grassland for the 20 years before the inventory. Therefore for areas of grassland remaining grassland, the values for F_{LU}, F_{MG} and F_I are considered to be constant and consequently the calculation shows there is no net change in carbon stocks in soils.

Biomass Burning

Non-CO_2 emissions from wildfires in low producing grasslands (tussock and grassland with aboveground woody biomass) are reported in the LULUCF sector, while those from controlled (prescribed) burning of savannah are covered in the agriculture sector. CO_2 emissions resulting from natural disturbance events are not reported, as methods are applied that do not capture subsequent re-growth (GPG-LULUCF 3.2.1.4.2).

For low producing grassland with aboveground woody biomass the activity data is sourced from the NZ Fire Service and combines their categories for gorse, scrub and wetland. The GPG-LULUCF average default value for the proportion of pre-fire biomass consumed in temperate shrubland is 0.95 (GPG-LULUCF Table 3A.1.12). For New Zealand conditions, it has been suggested that the controlled burn value of 70% would be more appropriate (Wakelin, 2006). In the inventory, this has been applied to the total biomass (rather than above-ground only) using the more general initial grassland with aboveground woody biomass estimate of 136 t dm ha^{-1} (Hall et al 2001), rather than the specific 'pre-afforestation' biomass value used for Grassland (with woody vegetation) converted to forest land.

Wildfire in tussock grassland has not been reported previously in New Zealand's inventory. Although the area of tussock burned is similar to that of grassland with aboveground woody biomass, emissions are much lower because there is less biomass present. For wildfire in tussock, the assumptions used for controlled burning have been applied to the NZFS wildfire areas.

Land converted to grassland

Living biomass

New Zealand has applied the GPG-LULUCF Tier 1 method where the amount of carbon removed is estimated by multiplying the area converted annually by the difference between average carbon stocks in biomass before and following conversion and accounting for carbon in biomass that replaces cleared vegetation. Pre-conversion stocks and annual growth figures are shown in Tables 7.1.2 and 7.1.3. Carbon stocks in biomass immediately after conversion are assumed to be zero.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation "NE" is used in the CRF tables. No Tier 1 methodology exists for calculating emissions or removals from dead organic matter in the category "land converted to grassland".

Soil carbon

Land conversion to grassland can occur from all land uses. In New Zealand the primary change into grassland is from planted forest. New Zealand uses the methodology outlined in GPG-LULUCF (section 3.4.2.2.1.1). For Tier 1, the initial (pre-conversion) soil carbon stock is determined from a reference soil carbon stock together with stock change factors (F_{LU}, F_{MG}, F_I) appropriate for the previous land use as well as for grassland use. The stock change factors used by New Zealand are shown in Table 7.1.1.

7.4.3 Uncertainties and time-series consistency

Uncertainties can be analysed as uncertainty in activity data and uncertainty in variables such as emission factors, growth rates, and the effect of land management factors. The combined effect of uncertainty in grassland is estimated at ± 75 per cent (95 per cent confidence interval). As shown in Table 7.3.3.1, while uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two years (1997 and 2002) of mapped activity data is used. In addition mapping is not specific to IPCC categories.

7.4.4 Category-specific QA/QC and verification

Carbon-dioxide emissions from "land converted to grassland" are a key category (level and trend assessment). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.4.5 Category-specific recalculations

Recalculations were carried out for this category as emissions or removals from soils were not included in the CRF reporter for the previous submission as a result of changes to the CRF reporter database.

7.4.6 Category-specific planned improvements

The use of historic activity data for grassland is to be investigated. This would allow for improved estimates of land converted to grassland and grassland remaining grassland. Sector-level improvements resulting from the LUCAS are described in Annex 3.2.

7.5 Wetlands (CRF 5D)

7.5.1 Description

In 2006, the net emissions were 0.7 Gg CO_2-e. This estimate is constant over all inventory years. These emissions are from the subcategory “land converted to wetlands”. Wetlands are not a key category for New Zealand.

New Zealand has 425,000 kilometres of rivers and streams, and almost 4,000 lakes that are larger than 1 hectare. Damming, diverting and extracting water for power generation, irrigation and human consumption modify the nature of these waterways and can deplete flows and reduce groundwater levels.

Demand for accessible land has led to the modification of a large proportion of New Zealand’s wetland areas in order to provide pastoral land cover. Just over 10 per cent of the original wetland environment remains across New Zealand.

Section 3.5 of GPG-LULUCF defines wetlands as “land that is covered or saturated by water for all or part of the year (eg, peat land) and that does not fall into the forest land, cropland, grassland or settlements categories. It includes reservoirs as a managed subdivision and natural rivers and lakes as unmanaged subdivisions”. New Zealand has categorised LCDB land-cover classes for lakes, rivers and estuarine open water in the LCDB into the unmanaged wetlands category (Table 7.1.4). Other LCDB classes, eg, herbaceous freshwater vegetation, commonly thought of as wetlands in New Zealand, have been categorised as grassland following the GPG-LULUCF definitions.

Flooded lands are defined in GPG-LULUCF as “water bodies regulated by human activities for energy production, irrigation, navigation, recreation, etc., and where substantial changes in water area due to water level regulation occur. Regulated lakes and rivers, where the main pre-flooded ecosystem was a natural lake or river, are not considered as flooded lands”.

The LCDB does not separate out regulated water bodies where substantial changes in water area occur, and the majority of New Zealand’s hydro-electric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river. For this reason, all of New Zealand’s wetlands are categorised as unmanaged.

7.5.2 Methodological issues

Wetlands remaining wetlands

A methodology for this subcategory is addressed in the appendix (3A.3) to the GPG-LULUCF (“Wetlands Remaining Wetlands: Basis for future methodological development”). The appendix covers emissions from flooded land and extraction from peat land. Re-cultivation of peat land is included under the agriculture sector. For flooded land the LCDB data does not separate out regulated water bodies where substantial changes in water area occur. For this reason, figures are not reported for flooded land in “wetlands remaining wetlands”.

Land converted to wetlands

New Zealand has applied the GPG-LULUCF Tier 1 methodology for estimating the carbon stock change due to land conversion to flooded land (GPG-LULUCF equation 3.5.6). A key assumption is that all land converted to wetlands becomes flooded land. The method assumes that the carbon stock of land before conversion is lost in the first year following conversion. The carbon stock of the land before conversion is documented in Table 7.1.2. In Tier 1, it is assumed that the carbon stock after conversion is zero.

GPG-LULUCF does not provide guidance on carbon stock changes for soils due to land conversion to flooded land. Emissions of non-CO_2 gases from land converted to flooded land are covered in appendix 3a.3 of GPG-LULUCF but are not reported (note 3, CRF Table 5).

7.5.3 Uncertainties and time-series consistency

Uncertainties are estimated as ± 75 per cent based on the uncertainty for Tier 1 grassland carbon stocks (GPG-LULUCF Table 3.4.2) lost during conversion to wetlands. While uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two years (1997 and 2002) of mapped activity data is used. In addition mapping is not specific to IPCC categories.

7.5.4 Category-specific QA/QC and verification

No specific QA/QC and verification was used for wetlands.

7.5.5 Category-specific recalculations

There are no recalculations for this category.

7.5.6 Category-specific planned improvements

No specific improvements are planned for wetlands. Sector-level improvements resulting from the LUCAS are described in Annex 3.2.

7.6 Settlements (CRF 5E)

7.6.1 Description

In 2006, the net emissions from settlements were 97.2 Gg CO_2-e. This estimate is constant over all inventory years. These emissions are from the subcategory “land converted to settlements”. Settlements are not a key category for New Zealand.

This land-use category is described in GPG-LULUCF 3.6 as including “all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories”. Settlements include trees grown along streets, in public and private gardens, and in parks associated with urban areas. New Zealand has categorised the applicable LCDB land cover classes into the settlements category (Table 7.1.4). This showed that there was 215 kha of settlements remaining settlements from 1997 to 2002 with a net gain of 5.5 kha (Table 7.1.5). The largest single subcategory change in area was from high-producing grassland to settlements, averaging 1000 hectares per year.

7.6.2 Methodological issues

Settlements remaining settlements

A basic method for estimating CO_2 emissions and removals in settlements remaining settlements is provided in appendix 3a.4 of GPG-LULUCF. The methods and available default data for this land use are preliminary and based on an estimation of changes in carbon stocks per tree crown cover area or carbon stocks per number of trees as a removal factor. New Zealand does not have this level of activity data available and is unable to estimate emissions for this sub-category. Parties are not required to prepare estimates for this subcategory (note 3, CRF Table 5).

Land converted to settlements

The equation (3.6.1) for estimating change in carbon stocks associated with land-use conversions is the same as applied for other areas of land-use conversion, eg, land converted to cropland and grassland. The carbon stock of the land before conversion is documented in Table 7.1.2. The default assumptions for a Tier 1 estimate are that all living biomass present before conversion to settlements will be lost in the same year as the conversion takes place, and that carbon stocks in living biomass following conversion are equal to zero. GPG-LULUCF does not provide guidance on carbon stock changes for soils due to land conversion to settlements.

7.6.3 Uncertainties and time-series consistency

Uncertainties are estimated as ± 75 per cent based on the uncertainty for Tier 1 grassland carbon stocks (GPG-LULUCF Table 3.4.2). While uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two years (1997 and 2002) of mapped activity data is used. In addition mapping is not specific to IPCC categories.

7.6.4 Category-specific QA/QC and verification

No specific QA/QC and verification was used for settlements.

7.6.5 Category-specific recalculations

There are no recalculations for this category.

7.6.6 Category-specific planned improvements

No specific improvements are planned for settlements. Sector-level improvements resulting from the LUCAS are described in Annex 3.2.

7.7 Other land (CRF 5F)

7.7.1 Description

In 2006, the net emissions from other land were 39.8 Gg CO_2-e. Net emissions from other land are 13.1 Gg CO_2-e (48.8 per cent) higher than the 1990 level of 26.7 Gg CO_2-e. These emissions are from the subcategory “land converted to other land”. Other land is not a key category for New Zealand.

“Other land” is defined in GPG-LULUCF 3.7 as including bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five land-use categories. It mostly consists of steep, rocky terrain at high elevation, often covered in snow or ice. “Other land” is included in New Zealand’s land area for checking overall consistency of total land area and tracking conversions to and from other land. This category is less than 4 per cent of total New Zealand land area.

7.7.2 Methodological issues

Other land remaining other land

All of New Zealand’s land area is classified as “managed”. No guidance is provided in GPG-LULUCF for “Other land” that is managed.

Land converted to other land

Living biomass

The equation (GPG-LULUCF 3.7.1) for estimating change in carbon stocks associated with land-use conversions is the same as applied for other areas of land-use conversion, eg, land converted to cropland and grassland. The carbon stock of the land before conversion is documented in Table 7.1.2. The default assumptions for a Tier 1 estimate are that all living biomass present before conversion to other land will be lost in the same year as the conversion takes place, and that carbon stocks in living biomass following conversion are equal to zero. The LCDB analysis shows that land converted to other land between 1997 and 2002 was from the category “low producing grassland” (Table 7.1.5).

Soil carbon

New Zealand uses the IPCC methodology outlined in GPG-LULUCF (equation 3.7.3). For Tier 1, the initial (pre-conversion) soil carbon stock is determined from reference soil carbon stocks together with stock change factors (Table 7.1.1) appropriate for the previous land use. New Zealand uses a reference soil carbon stock of 83 t C ha^{-1} (refer to section 7.1.2.1 above). Soil carbon stocks in the inventory year are zero for land converted to other land.

7.7.3 Uncertainties and time-series consistency

Uncertainties are estimated as ± 75 per cent based on the uncertainty in carbon stocks lost during the conversion to other land, eg, GPG-LULUCF Table 3.4.2. While uncertainty in activity data is low, uncertainty in the IPCC default variables dominates the overall uncertainty in the estimate provided by New Zealand. However, uncertainty in activity data used in the inventory will be greater than assessed for the LCDB alone. Error is introduced from extrapolation as mapping is not repeated annually. Only two years (1997 and 2002) of mapped activity data is used. In addition mapping is not specific to IPCC categories.

7.7.4 Category-specific QA/QC and verification

No specific QA/QC and verification was used for other land.

7.7.5 Category-specific recalculations

There are no recalculations for this category.

7.7.6 Category-specific planned improvements

No specific improvements are planned for other land. Sector-level improvements resulting from the LUCAS are described in Annex 3.2.

7.8 Other (CRF 5G)

7.8.1 Description

This category includes emissions from the application of lime to forest and grassland. The lime used is agricultural lime, or ground limestone.

In 2006, the net emissions from this category were 676.1 Gg CO_2-e. Since the 1990 level of 373.8 Gg CO_2-e there has been an increase of other net emissions by 302.3 Gg CO_2-e (80.9 per cent).

7.8.2 Methodological issues

The calculation for CO_2 emissions from the liming of grassland soils is included in CRF worksheet 5.5. The calculation is based on GPG-LULUCF equation 3.4.11, including the total amount of limestone applied (provided by Statistics New Zealand) and a carbon conversion factor from limestone to carbon. New Zealand uses the IPCC (1996) default value of 0.12 for carbon conversion.

The survey data for the amount of lime applied is affected by several gaps in the time series. No survey was carried out in 1991, or for 1997 through 2001. Linear interpolation has been used to represent the data for these years. Since 2002 there has been a noted drop in the amount of lime applied. It is not clear why this decrease occurred but quantities do vary from year to year depending on a number of factors, including farming returns.

7.8.3 Uncertainties and time-series consistency

Uncertainties are estimated as ± 40 per cent based on sampling and survey respondent error.

7.8.4 Category-specific QA/QC and verification

Carbon-dioxide emissions from “liming” are a key category (level and trend assessment). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

7.8.5 Category-specific recalculations

Data for all years are no longer reported as three year averages, but as annual values.

7.8.6 Category-specific planned improvements

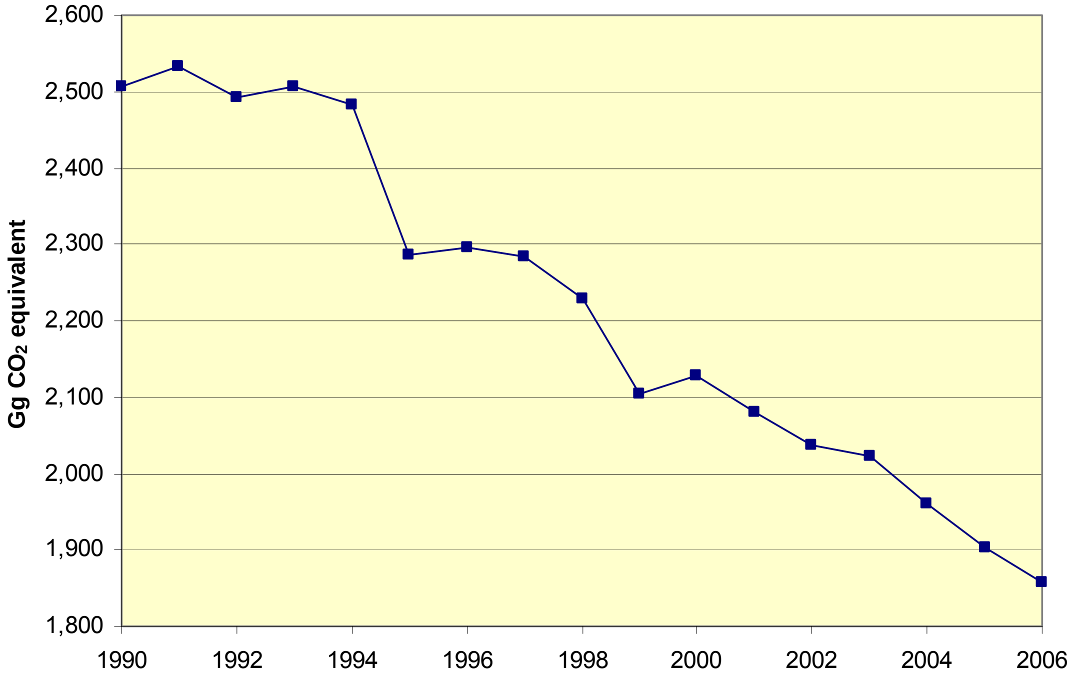
No specific improvements are planned for the “other” category.

Chapter 8: Waste

8.1 Sector overview

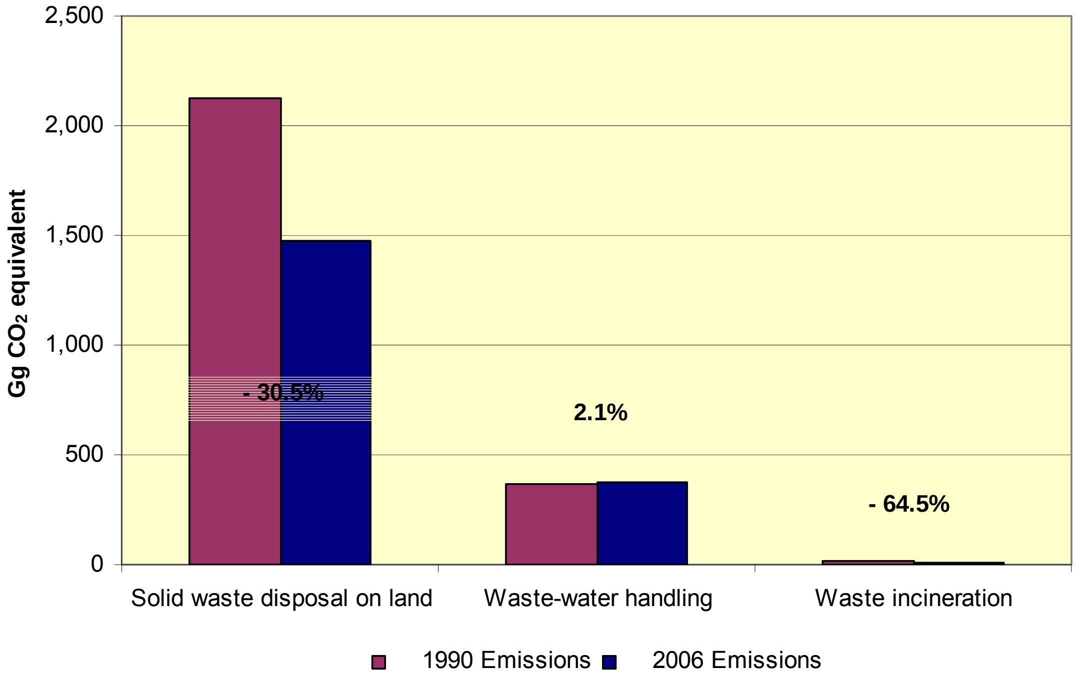
In 2006, the waste sector accounted for 1,857.8 Gg carbon dioxide equivalent (CO_2-e) (2.4 per cent) of total emissions. Emissions from the waste sector are now 647.8 Gg CO_2-e (25.9 per cent) below the 1990 baseline value of 2,505.7 Gg CO_2-e (Figure 8.1.1). The reduction has occurred in the "solid waste disposal on land category" as a result of initiatives to improve solid waste management practices and increase landfill gas capture rates in New Zealand.

Figure 8.1.1 Waste sector emissions from 1990 to 2006



Emissions from the waste sector are calculated from solid waste disposal on land, wastewater handling and waste incineration (Figure 8.1.2). Methane from solid waste disposal is a key category (level and trend assessment).

Figure 8.1.2 Change in emissions from the waste sector from 1990 to 2006 (all figures Gg CO_2-e)



Disposal and treatment of industrial and municipal waste can produce emissions of CO_2 and CH_4. The CO_2 is produced from the aerobic decomposition of organic material. These emissions are not included as a net emission because the CO_2 is considered to be reabsorbed in the following year. The CH_4 is produced as a by-product of anaerobic decomposition.

8.2 Solid waste disposal on land (CRF 6A)

8.2.1 Description

Solid waste disposal on land contributed 1,475.4 Gg CO_2-e (79.4 per cent) of emissions from the waste sector in 2006. This is a decrease of 646.1 Gg CO_2-e (30.5 per cent) from the 1990 level of 2,121.5 Gg CO_2-e.

Organic waste in solid waste disposal sites is broken down by bacterial action in a series of stages that result in the formation of CO_2 and CH_4. The CO_2 from aerobic decomposition is not reported in the inventory and assumed to be reabsorbed in the following year. The amount of CH_4 gas produced depends on a number of factors including the waste disposal practices (managed versus unmanaged landfills), the composition of the waste, and physical factors such as the moisture content and temperature of the solid waste disposal sites. The CH_4 produced can go directly into the atmosphere via venting or leakage, or it may be flared off and converted to CO_2.

In New Zealand, managing solid wastes has traditionally meant disposing of solid waste in landfills. In 1995, a National Landfill Census showed there were 327 legally operating landfills or solid waste disposal sites in New Zealand that accepted approximately 3,180,000 tonnes of solid waste (Ministry for the Environment, 1997). Since 1995 there have been a number of initiatives to improve solid waste management practices in New Zealand. These have included preparing guidelines for the development and operation of landfills, closure and management of landfill sites, and consent conditions for landfills under New Zealand's Resource Management Act (1991). As a result of these initiatives, a number of poorly located and substandard landfills have been closed and communities rely increasingly on modern regional disposal facilities for disposal of their solid waste. The 2002 Landfill Review and Audit reported that there were 115 legally operating landfills in New Zealand, a reduction of 65 per cent from 1995.

Recently, New Zealand's focus has been towards waste minimisation and resource recovery. In March 2002, the Government announced its New Zealand Waste Strategy (Ministry for the Environment, 2002a). The strategy sets targets for a range of waste streams as well as improving landfill practices by the year 2010. As part of the implementation and monitoring of the strategy, the Government developed the Solid Waste Analysis Protocol (Ministry for the Environment, 2002b) that provided a classification system, sampling regimes and survey procedures to measure the composition of solid waste streams.

8.2.2 Methodological issues

New Zealand has used the IPCC Tier 2 First Order Decay approach (IPCC, 2000) to report emissions from solid waste in the inventory. New Zealand uses country-specific values for the degradable organic carbon factor (0.15 Gg C/Gg waste), methane generation potential (L_o) (0.05 Gg C/Gg waste), and a methane generation rate constant (k) (0.06) based on waste composition and conditions at New Zealand landfills. The IPCC default oxidation correction factor of 0.1 is used (IPCC, 2000). The calculations for estimating emissions from the waste sector are included in the excel workbooks available for download with this report from the Ministry for the Environment's website.

The degradable organic carbon factor varies according to the composition of waste disposed to landfill. Linear extrapolations are used between years where no new data was available. Consistent and comparable data is only available for two years, 1995 and 2004, and reported in the National Waste Data Report (Ministry for the Environment, 1997 and the report on Waste Composition and Construction Waste Data (Waste Not Consulting, 2006). The estimate of DOC in 1995 (and 1990) was 0.14 Gg C/Gg waste, and in 2004 (and 2006) 0.15 Gg C/Gg waste.

Calculation of the methane generation potential is based on the same data contained in the reports in the paragraph above, and adjusted for changes in the management of landfilled waste through the methane correction factor. New Zealand SWAP baseline results as reported in the report on Waste Composition and Construction Waste Data (Waste Not Consulting, 2006). The methane generation potential was 0.04 Gg CH_4/Gg waste in 1995 (and 1990), and 0.05 Gg CH_4/Gg waste in 2006.

A methane generation rate constant of 0.06 is used for New Zealand's landfills. International measurements support a methane generation rate constant in the range of 0.03 to 0.2 (IPCC, 2000). The 0.03 represents a slow decay rate in dry sites and slowly degradable waste, whereas the 0.2 value represents high moisture conditions and highly degradable waste. The IPCC recommended value is 0.05 (IPCC, 2000). The relatively wet conditions in most regions of New Zealand mean that the methane generation rate constant is likely to be slightly above the 0.05 default value. This was confirmed by a comparison of CH_4 generation and recovery estimates to actual recovery rates at a limited number of solid waste disposal sites in New Zealand (SCS Wetherill Environmental, 2002).

There has been no new solid waste compositional data for 2005 and 2006, hence degradable organic content per Gg waste remained constant from 2004 values. However, the methane correction factor has been increasing due to closure of unmanaged landfills and increasing volumes being disposed to larger modern landfills. It is estimated that in 1995, 90 per cent of New Zealand's waste was disposed to managed solid waste disposal sites and 10 per cent to uncategorised sites (Ministry for the Environment, 1997)[3]. The IPCC (1996) default values are used for the carbon content of the various components of the solid waste stream.

Based on the 2006/07 National Landfill Census, the 2002 Landfill Review and Audit, and the 2006 report on Waste Composition and Construction Waste Data, it is estimated that the quantity of solid waste going to landfills in New Zealand in 2006 was equivalent to 2.08 kg per person per day. This shows a reduction in waste generation from 2.35 kg per person per day in 1995.

The fraction of degradable organic carbon that actually degrades (0.5) and the methane oxidation factor (0.1) are drawn from the Topical Workshop on Carbon Conversion and Methane Oxidation in Solid Waste Disposal Sites, held by the IPCC Phase II Expert Group on Waste on 25 October 1996. The workshop was attended by 20 international experts with knowledge of the fraction of degradable organic carbon that is converted to CH_4 and/or the oxidation of CH_4 by microbes in the soil cover.

The recovered CH_4 rate per year was estimated based on information from a 2005 survey of solid waste disposal sites that serve populations of over 20,000 in New Zealand (Waste Management New Zealand, 2005). There was no landfill gas collected in 1990 and 1991, with the first flaring system installed in 1992.

8.2.3 Uncertainties and time-series consistency

The overall estimated level of uncertainty is estimated at ± 20 per cent, which is the same uncertainty as the 2007 inventory submission, but an improvement on prior submissions. The improvement was due to the sampling and survey guidelines from the Solid Waste Analysis Protocol, the 2002 Landfill Audit and Review, and as assessment of comparability between data sources as performed in Waste Not Consulting (2006). Due to the unknown level of uncertainty associated with the accuracy of some of the input data it has not been possible to perform a statistical analysis to precisely determine uncertainty levels. Uncertainty in the data is primarily from uncertainty in total solid waste disposed to landfills and the recovered methane rate based on the 1997 National Waste Data Report (Ministry for the Environment).

The New Zealand waste composition categories from the Waste Not Consulting (2006) report do not exactly match the categories required for the IPCC degradable organic carbon calculation. The major difference is that in New Zealand's degradable organic carbon calculation, the putrescibles category includes food waste as well as garden waste. A separation into the IPCC categories was not feasible given the available data in the report by Waste Not Consulting (2006). The effect of this difference is managed by the use of IPCC default carbon contents which are similar for the non-food (17 per cent carbon content) and food categories (15 per cent carbon content). New Zealand has chosen to use the 15 per cent carbon content figure.

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[3] The 10 per cent of solid waste not disposed to "managed" solid waste disposal sites, went to sites that fell outside the definition of "managed", yet insufficient information is held about the sites to classify them as deep or shallow unmanaged solid waste disposal sites, hence the "unclassified" status. The inventory assumes that by 2010 all solid waste will be disposed to "managed" solid waste disposal sites, which has lead to a linearly increasing Methane Correction Factor in L_o calculations.

While using the 15 per cent figure may potentially underestimate annual emissions, it provides the best estimate for emission reductions between 1990 and 2006. This approach was recommended by the international review team (UNFCCC, 2007).

8.2.4 Source-specific QA/QC and verification

Methane from solid waste disposal was identified as a key category (level and trend assessment). In preparation for this inventory, the data for this category underwent Tier 1 quality checks.

A technical review of New Zealand's inventory recommended that gross CH_4 estimates from solid waste emissions should be compared with the IPCC Tier 1 and Tier 2 approaches (UNFCCC, 2001c). For the 2006 year, the Tier 2 value of gross annual CH_4 generation is 138.1 Gg CH_4 and the Tier 1 value is 158.0 Gg CH_4. The assumptions used to calculate net CH_4 emissions from gross CH_4 are the same for both tiers.

8.2.5 Source-specific recalculations

Municipal solid waste composition values for 2004 and 2005 were updated after discussion with the authors of the Waste Composition and Construction Data report (Waste Not Consulting, 2006). It was decided that the composition analysis in that report, which was based on SWAP baseline data for 2003, made appropriate adjustments for sampling errors including seasonal and geographical location issues. Use of that composition analysis for the 2004 year meant linear extrapolation back to 1995 for the 2003 year, and changes to the constant value used in 2005. This new data has lead to increased values of degradable organic carbon in MSW in 2003, 2004 and 2005.

The waste generation rate per capita increased for 2004 due to applying improved data which was published in a report on Waste Composition and Construction Waste Data (Waste Not Consulting, 2006).

The waste generation rate per capita decreased for 2005 due to extrapolating from recent national data that was published in the 2006/07 National Landfill Census (Ministry for the Environment, 2007).

The waste generation rate per capita increased for 1996, 2000 and 2004 due to changes in the formula used to adjust for calendar leap years. A similar adjustment decreased the DOC modelled as in landfills prior to 1990, thereby decreasing 1990 gross emissions onwards.

Recalculations were performed back to 1990 and have resulted in a decrease of 1.4 Gg CO_2-e in 1990 and an increase of 60.1 Gg CO_2-e in 2005.

8.2.6 Source-specific planned improvements

There are no specific improvements planned for this category.

8.3 Wastewater handling (CRF 6B)

8.3.1 Description

In 2006, wastewater handling produced 377.3 Gg CO_2-e (20.3 per cent) of emissions from the waste sector. This is an increase of 7.6 Gg CO_2-e (2.1 per cent) from the 1990 level of 369.7 Gg CO_2-e.

Wastewater from virtually every town in New Zealand with a population over 1,000 people is collected and treated in community wastewater treatment plants. There are approximately 317 municipal wastewater treatment plants in New Zealand and approximately 50 government or privately-owned treatment plants serving more than 100 people.

Although most of the treatment processes are aerobic and therefore produce no CH_4, there are a significant number of plants that use partially anaerobic processes such as oxidation ponds or septic tanks. Small communities and individual rural dwellings are generally served by simple septic tanks followed by ground soakage trenches.

Large quantities of industrial wastewater are produced by New Zealand's primary industries. Most of the treatment is aerobic and any CH_4 from anaerobic treatment is flared. There are a number of anaerobic ponds that do not have CH_4 collection, particularly serving the meat processing industry. These are the major sources of industrial wastewater CH_4 in New Zealand.

8.3.2 Methodological issues

Methane emissions from domestic wastewater treatment

Methane emissions from domestic wastewater handling have been calculated using a refinement of the IPCC methodology (IPCC, 1996). A population using each municipal treatment plant in New Zealand has been assessed (SCS Wetherill Environmental, 2002; Beca, 2007). Where industrial wastewater flows to a municipal wastewater treatment plant, an equivalent population for that industry has been calculated based on a biological oxygen demand (BOD) loading of 70 g per person per day.

Populations not served by municipal wastewater treatment plants have been estimated and their type of wastewater treatment assessed (SCS Wetherill Environmental, 2002; Beca, 2007). The plants have been assigned to one of nine typical treatment processes. A characteristic emissions factor for each treatment is calculated from the proportion of biological oxygen demand to the plant that is anaerobically degraded multiplied by the CH_4 conversion factor (SCS Wetherill Environmental, 2002; Beca, 2007).

It is good practice to use country-specific data for the maximum methane producing capacity factor (B_o). Where no data are available, the revised 1996 IPCC guidelines (IPCC, 1996) recommend using B_o of 0.25 CH_4/kg COD (chemical oxygen demand) or 0.6 kg CH_4/kg BOD. The IPCC biological oxygen demand value is based on a 2.5 scaling factor of chemical oxygen demand (IPCC, 2000). New Zealand has used these IPCC default factors in the 2008 inventory submission.

Methane emissions from industrial wastewater treatment

The IPCC default methodology is also used to calculate emissions from industrial wastewater treatment. For each industry, an estimate is made of the total industrial output in tonnes per year, the average chemical oxygen demand load going to the treatment plant and the proportion of waste degraded anaerobically. Methane is only emitted from wastewater being treated by anaerobic processes. Industrial wastewater that is discharged into a sewer with no anaerobic pre-treatment is included in the domestic wastewater section of the inventory.

Methane emissions from sludge

The organic solids produced from wastewater treatment are known as sludge. In New Zealand, the sludge from wastewater treatment plants is typically sent to landfills. Any CH_4 emissions from landfilled sludge are reported under the solid waste disposal sites category. Other sources of emissions from sludge are discussed below.

In large treatment plants in New Zealand, sludge is handled anaerobically and the CH_4 is almost always flared or used.[4] Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds.

Oxidation ponds accumulate sludge on the pond floor. In New Zealand, these are typically only desludged every 20 years. The sludge produced is well stabilised with an average age of approximately 10 years. It has a low biodegradable organic content and is considered unlikely to be a significant source of CH_4 (SCS Wetherill Environmental, 2002; Beca, 2007).

Sludge from septic tank clean-out, known as “septage”, is often removed to the nearest municipal treatment plant. In those instances, it is included in the CH_4 emissions from domestic wastewater treatment. There are a small number of treatment lagoons specifically treating septage. These lagoons are likely to produce a small amount of CH_4 and their effect is included in the calculations.

Nitrous oxide emissions from domestic wastewater treatment

New Zealand’s calculation uses a modification of the IPCC methodology (IPCC, 1996). The IPCC method calculates nitrogen production based on the average per capita protein intake; however in New Zealand, raw sewage nitrogen data are available for many treatment plants. The raw sewage nitrogen data are used to calculate a per capita domestic nitrogen production of 13 g/day and a per capita wastewater nitrogen value of 4.75 kg/person/year. The IPCC default method uses an emissions factor (EF_6) to calculate the proportion of raw sewage nitrogen converted to N_2O. New Zealand uses the IPCC default value of 0.01 kg N_2O–N /kg sewage N.

Nitrous oxide emissions from industrial wastewater treatment

The IPCC does not offer a methodology for estimating N_2O emissions from industrial wastewater handling. Emissions are calculated using an emissions factor (kg N_2O–N/kg wastewater N) to give the proportion of total nitrogen in the wastewater converted to N_2O. The total nitrogen was calculated by adopting the chemical oxygen demand load from the CH_4 emission calculations and using a ratio of chemical oxygen demand to nitrogen in the wastewater for each industry.

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[4] An exception is the Christchurch sewage treatment plant that uses anaerobic lagoons for sludge treatment. Based on volatile solids reduction measurements in the lagoons they estimate CH_4 production of 0.46 Gg/year plus an additional 0.16 Gg/year from unburned CH_4 from the digester-gas fuelled engines.

8.3.3 Uncertainties and time-series consistency

Methane from domestic wastewater

It is not possible to perform rigorous statistical analyses to determine uncertainty levels because of biases in the collection methods (SCS Wetherill Environmental, 2002). The uncertainty reported for wastewater values is based on an assessment of the reliability of the data and the potential for important sources to have been missed from the data. It is estimated that domestic wastewater CH_4 emissions have an accuracy of –40 per cent to +60 per cent (SCS Wetherill Environmental, 2002; Beca, 2007).

Methane from industrial wastewater

The method used in estimating CH_4 emissions from industrial wastewater treatment limits the ability to undertake a statistical analysis of uncertainty.

Total CH_4 production from industrial wastewater has an estimated accuracy of ± 40 per cent based on assessed levels of uncertainty in the input data (SCS Wetherill Environmental, 2002, Beca 2007).

Nitrous oxide from wastewater

There are very large uncertainties associated with N_2O emissions from wastewater treatment and no attempt has been made to quantify this uncertainty. The IPCC default emissions factor, EF_6, has an uncertainty of –80 per cent to +1,200 per cent (IPCC, 1996) meaning that the estimates have only order of magnitude accuracy.

8.3.4 Source-specific QA/QC and verification

No specific quality checks were carried out for this category.

8.3.5 Source-specific recalculations

The inventory of emissions from domestic and commercial waste water treatment has been updated following the development of a national treatment facility database in 2006. New total organic product data for 2006 was used to recalculate CH_4 emissions from 2002–2005, resulting in a decrease of estimated emissions of 0.8 Gg CH_4 for 2005 (Beca, 2007).

Improvements to the accuracy of calculations for emissions of CH_4 from industrial waste water treatment resulted in recalculations for emissions estimates for all years from 1990. The recalculations resulted in a decrease of 0.2 Gg CO_2-e in 1990 and a decrease of 10.7 Gg CO_2-e in 2005.

8.3.6 Source-specific planned improvements

No improvements are planned for this category.

8.4 Waste incineration (CRF 6C)

8.4.1 Description

In 2006, waste incinerations accounted for 5.1 Gg CO_2-e (0.3 per cent) of waste emissions. This is a decrease of 9.3 Gg CO_2-e (64.5 per cent) from the 1990 level of 14.5 Gg CO_2-e.

New Zealand has previously not estimated emissions from waste incineration as they were considered to be negligible. There is no incineration of municipal waste in New Zealand. The only incineration is for small specific waste streams including medical, quarantine and hazardous wastes, and these practices have been declining since the early 1990's due to introduced environmental regulations and alternative technologies, primarily sterilisation techniques. Resource consents under New Zealand's Resource Management Act control non-greenhouse gas emissions from these incinerators.

In 2004, New Zealand introduced national environmental standards for air quality. The standards effectively require all existing low temperature waste incinerators in schools and hospitals to obtain resource consent by 2006, irrespective of existing planning rules. Incinerators without consents will be prohibited.

8.4.2 Methodology

The IPCC methodology (2006) IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 2: Stationary Combustion, Volume 1, Chapter 3: Uncertainties and Volume 5, Chapter 5: Incineration and Open Burning of Waste was used to estimate direct greenhouse gas emissions of CO_2, CH_4 and N_2O. The 2006 IPCC guidelines (IPCC, 2006) were used to calculate emissions from the incineration of waste as the revised 1996 IPCC guidelines (IPCC, 1996) did not contain methodologies for estimating emissions from waste incineration. New Zealand considers the 2006 IPCC guidelines (IPCC, 2006) contain the most appropriate and current methodologies for estimating emissions from waste incineration.

Incineration devices that do not control combustion air to maintain adequate temperature, and do not provide sufficient residence time for complete combustion are considered as open burning systems (IPCC 2006). This excluded many small facilities that may have burned plastics and other mixed waste, such as at schools.

Only CO_2 resulting from burning of carbon in waste that is fossil in origin is included under the IPCC methodology, such as in plastics, synthetic textiles, rubber, liquid, solvents and waste oil. Biogenic CO_2 such as from paper, cardboard and food is excluded in accordance with the 2006 IPCC guidelines (IPCC, 2006). Also excluded were emissions from waste to energy incineration facilities, which are reported within the energy sector of the national greenhouse gas inventory.

Default compositional values from Volume 5 Waste: Chapter 2: Table 2.6 of IPCC 2006 were used to estimate the fossil fuel derived carbon. These were 27.5% for hazardous waste (being the mean of the recommended range) and 25% for clinical waste.

Many incinerators were quarantine waste incinerators. The 2006 IPCC guidelines (IPCC, 2006) do not have a default category for quarantine incinerators. Only three default classifications were available: clinical waste, hazardous waste or sewage sludge. None of these categories appropriately represents quarantine waste, which contains paper, plastics, food and dunnage. However for the purposes of the calculations, the composition of quarantine was assumed to be more closely aligned with clinical waste than with the other categories. This is because clinical waste may also contain paper, plastics and biological matter (SKM, 2007).

Estimates of direct emissions were made using the default Tier 1 emission calculations (IPCC, 2006). Default factors for a Tier 1 assessment were used in the calculation of CO_2 and N_2O. Default emission factors for the calculation of CH_4 were taken from the 2006 IPCC guidelines (Volume 2, Chapter 2).

8.4.3 Uncertainties and time-series consistency

The measurement of uncertainty in the data collected from each individual site was difficult to quantify. For most sites, tonnes per year of waste incinerated was obtained from file information or this was calculated from a mass burn rate (kg per hour) and assumed operating hours on a annul basis. Estimates based on consented limits are likely to be over estimates of the actual waste burnt.

The annual rates were projected for the corresponding number of years of operation. This provided an estimated total amount of wet waste incinerated from 1990 to 2006.

As per the recommendation for uncertainties relating to activity data (IPCC 2006 Volume 5, Section 5.7.2), the conservative estimated uncertainty for the amount of wet waste incinerated is around ± 10 per cent. The estimated value in the 2006 IPCC guidelines is ± 5 per cent. This uncertainty has been increased to ± 10 per cent due to the lack of detailed data. The uncertainty for the data is likely to be greater than this, particularly where projections are based on a mass burn rate and assumed operating hours (SKM, 2007).

The data collected for the composition of waste was not detailed. Therefore, as per the recommendation for uncertainties relating to emission factors (IPCC 2006 Volume 5, Section 5.7.1), the estimated uncertainty for default CO_2 factors is ± 40 per cent. Default factors used in the calculation of CH_4 and N_2O emissions have a much higher uncertainty (IPCC 2006 Volume 5, Section 5.7.1); hence the default estimated uncertainty for default CH_4 and N_2O factors is ± 100 per cent (SKM, 2007).

8.4.4 Source-specific QA/QC and verification

All data collected was from reliable sources and all default emission factors for emissions calculations were extracted from the 2006 IPCC guidelines. All calculations were externally and internally reviewed. Hand calculations were used to check calculations. Limited information was provided by some individual sites, which meant that activity data had to be interpolated and extrapolated. This could have lead to inaccuracies in the quantification of the total waste incinerated annually. There was generally no detailed information about the actual composition of the waste incinerated; only the consented types of waste allowed.

8.4.5 Source-specific planned improvements

No improvements are planned for this category.

Chapter 9: Other

New Zealand does not report any emissions under the UNFCCC category 7, “Other”.

Chapter 10: Recalculations and improvements

This chapter summarises the recalculations and improvements made to the New Zealand greenhouse gas inventory following submission of the 1990-2005 inventory. The chapter summarises material that has already been described in Chapters 3–8.

Each year the inventory is updated (existing activity data and/or emissions factors may be improved) and extended (the inventory includes a new inventory year). The inventory may also be expanded to include emissions from additional sources if a new source has been identified within the context of the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003). Recalculations may also occur if activity data and emission factors have become available for sources that were previously reported as “NE” (not estimated) due to a lack of data.

The use of revised methodologies and activity data in any sector will result in recalculation of the whole time-series from 1990 to the current inventory. This means estimates of emissions in a given year may differ from emissions reported in the previous inventory.

10.1 Explanations and justifications for recalculations

10.1.1 Energy sector

In previous inventory submissions, constant calorific values were used to convert tonnes (t) of fuel to peta joules (PJ) of fuel. For the 2008 inventory submission year-specific calorific values have been introduced for all fuel types to improve the accuracy of the activity data between 1990 and 2006. Recalculations for the entire energy sector have resulted in a decrease of 78.4 Gg CO_2-e in 1990 and an increase of 100.3 Gg CO_2-e in 2005.

10.1.2 Industrial processes sector

Mineral products

Activity data and the CO_2 emissions attributed to cement production have been updated and recalculated for the years 1995–1998. The revision has been due to the inclusion of data from a small cement company operating in New Zealand who produced clinker from 1995–1998. This data had not been included in previous submissions.

Emissions arising from limestone, coke and electrodes used in the iron and steel making process have been reported separately from the rest of the process CO_2 emissions for the first time in the 2008 inventory submission. Data provided by the iron and steel companies cannot be broken down any further (ie, limestone emissions on their own). Emissions from limestone/coke/electrode use make up 1 to 2 per cent of total process iron and steel emissions. This has resulted in recalculations for the 1990–2005 time series for the mineral products (limestone and dolomite use) category.

Recalculations for the “mineral products” category resulted in an increase of 17.1 Gg CO_2-e in 1990 and 44.0 Gg CO_2-e in 2005.

Chemical industry

There was a minor recalculation for ammonia production for 2003 due to rounding. No other recalculations took place in the “chemical” industry category in the 2008 inventory submission.

Metal production

New Zealand has been able to separate emissions arising from limestone, coke and electrodes used in the iron and steel making process from the rest of the process CO_2 emissions for the first time in the 2008 inventory submission. This has resulted in recalculations for the 1990–2005 time series for the metal production (iron and steel production) category.

Activity data and resulting CO_2 and PFC emissions from aluminium production was updated for the 1990–2006 time series. Rio Tinto Aluminium provided a new time series of data to reflect CO_2 and PFC emissions calculated using the methodologies outlined in the Aluminium Sector Addendum to the WBCSD/WRI Greenhouse Gas Protocol. The addendum was released in October 2006 by the IPCC and International Aluminium Institute (IAI).

Recalculations have resulted in a decrease of 31.8 Gg CO_2-e in 1990 and a decrease of 29.3 Gg CO_2-e in 2005.

Consumption of halocarbons, PFCs and SF_6

As a result of a thorough survey of the HFC and PFC importers and distributors in 2007 (CRL Energy Limited, 2007) estimates of gas stocks and emissions over the time series have been revised. The main changes have occurred within the stationary refrigeration and mobile air conditioning sub-sectors. Further explanations can be found in section 4.7.5. The recalculations have resulted in an increase of 0.4 Gg CO_2-e in 1992 (the first year HFCs were used in New Zealand) and a decrease of 79.4 Gg CO_2-e in 2005.

10.1.3 Solvents and other products

The 2007 industrial processes survey (CRL Energy Limited, 2007) revealed some inconsistencies in the activity data for N_2O use in New Zealand for the period 2002–2005. The activity data for the period was updated by linear interpolation. The recalculations have resulted in a decrease of 4.0 Gg CO_2-e in 2005.

10.1.4 Agriculture sector

For the 2008 inventory submission all agricultural activity data is reported using single year values rather than 3-year averaged values. This change was introduced in the agriculture and LULUCF sectors to allow more time for inventory quality checking prior to submission. The recalculations have resulted in an increase of 1.8 Gg CO_2-e in 1990 and an increase of 133.9 Gg CO_2-e in 2005.

10.1.5 LULUCF

For the 2008 inventory submission all LULUCF activity data is also reported using single year values rather than 3-year averaged values. Other recalculations made in the LULUCF sector were mainly to the forest land category. The recalculations were made to reflect:

- The new age class distribution and hence the new carbon yield table.
- Updated harvesting and new planting data.
- Use of single year values instead of three-year averages.
- New assumptions for clearance of grassland with aboveground woody biomass and biomass burning.

There were also minor recalculations made in the grasslands category due to revised activity data.

The recalculations have increased removals by 1,527.1 Gg CO_2-e in 1990 and decreased removals by 818.9 Gg CO_2-e in 2005.

10.1.6 Waste

Solid Waste

Municipal solid waste composition values for the years from 2003 to 2005 were updated to reflect the revision of sampling errors outlined in the Waste Composition and Construction Data Report (Waste Not Consulting, 2006).

The waste generation rate per capita decreased for 2005 due to extrapolating from recent national data that was published in the 2006/07 National Landfill Census (Ministry for the Environment, 2007).

The waste generation rate per capita increased for 1996, 2000 and 2004 due to changes in the formula used to adjust for calendar leap years. A similar adjustment decreased the DOC modelled as in landfills prior to 1990, thereby decreasing 1990 gross emissions onwards.

Recalculations resulted in a decrease of 1.4 Gg CO_2-e in 1990 and an increase of 60.1 Gg CO_2-e in 2005.

Waste Water

The inventory of emissions from domestic and commercial waste water treatment has been updated following the development of a national treatment facility database in 2006. New total organic product data for 2006 was used to recalculate CH_4 emissions from 2002 to 2005.

Improvements to the accuracy of calculations for emissions of CH_4 from industrial waste water treatment resulted in recalculations for emissions estimates for all years from 1990.

The recalculations resulted in a decrease of 0.2 Gg CO_2-e in 1990 and a decrease of 10.7 Gg CO_2-e in 2005.

Incinerated Waste

New Zealand has included emissions from incinerated waste for the first time in the 2008 inventory submission. The inclusion of emissions from incinerated waste has increased total emissions in 1990 by 14.5 Gg CO_2-e and 6.0 Gg CO_2-e in 2006.

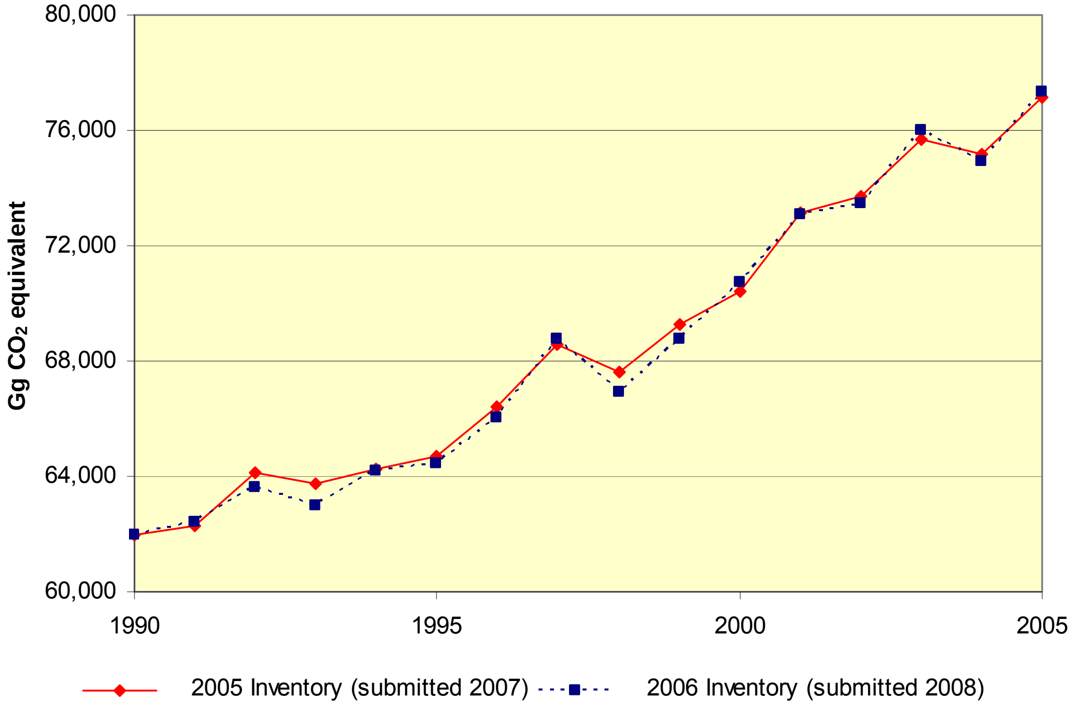
10.2 Implications for emission levels

The overall effect of all recalculations in the 2008 inventory submission is shown in Figure 10.3.1. There is a 0.1 per cent (47.7 Gg CO_2-e) increase in emissions for the base year, 1990 and a 0.3 per cent (194.6 Gg CO_2-e) increase in emissions for the 2005 year.

10.3 Implications for emission trends

In New Zealand's 2007 inventory submission (1990-2005), emissions were 24.7 per cent above the level reported in 1990. As a result of the recalculations in the 2008 inventory submission, total emissions for 2005 were 24.9 per cent above 1990. Changes in trends for individual sectors (excluding solvents) are discussed in the following sections. Solvents are not included because emissions are insignificant throughout the time-series.

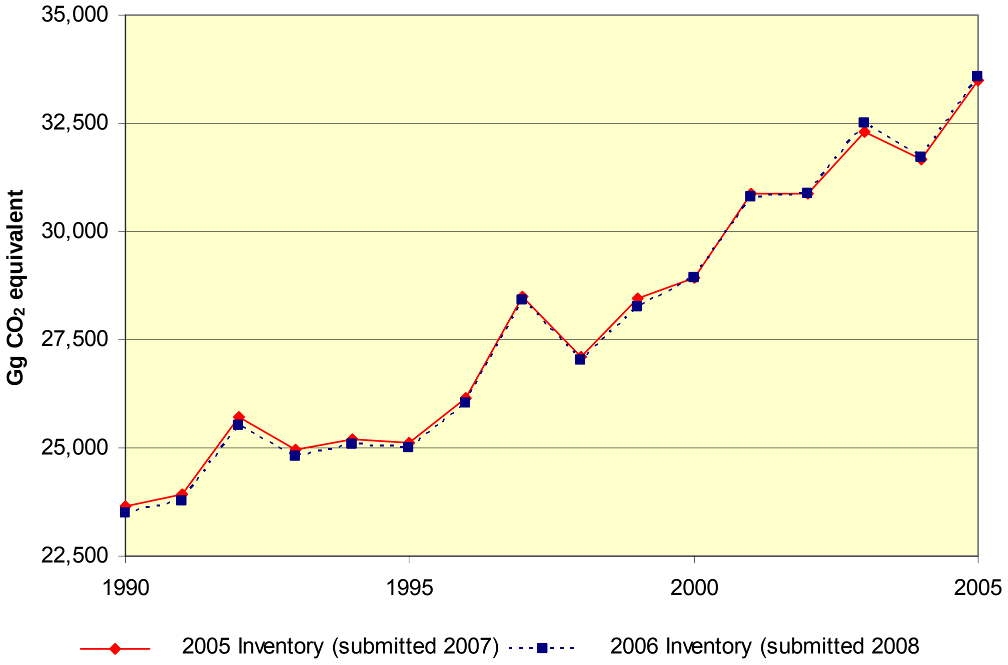
Figure 10.3.1 Effect of recalculation on total greenhouse gas emissions



Energy sector

The recalculations made within the energy sector (Figure 10.3.2) are explained in section 10.1.1. Emissions in 1990 have decreased 78.4 Gg CO_2-e and increased by 100.3 Gg CO_2-e in 2005 (Figure 10.3.2). The recalculations have resulted in a reduction in total emissions in 1990 of 0.1 per cent and an increase of 0.2 per cent in 2005.

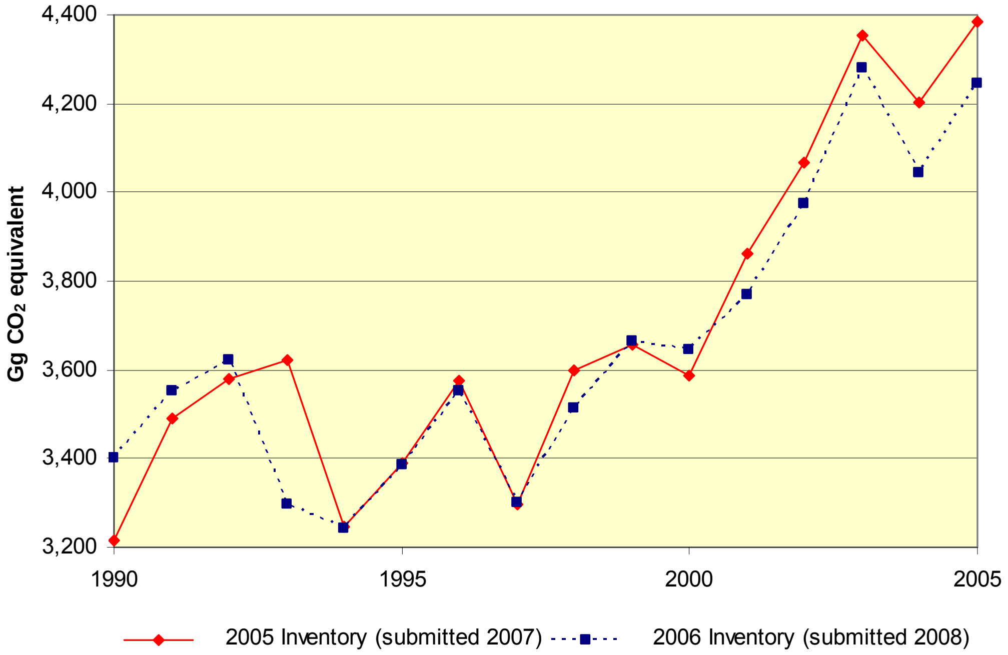
Figure 10.3.2 Effect of recalculation on the energy sector



Industrial processes

The recalculations made within the industrial processes sector (Figure 10.3.3) are explained in section 10.1.2. Emissions in 1990 have increased 111.4 Gg CO_2-e and decreased 91.0 Gg CO_2-e in 2005. The recalculations have resulted in an increase in total emissions in 1990 of 0.2 per cent and a decrease of 0.1 per cent in 2005.

Figure 10.3.3 Effect of recalculation on the industrial processes sector

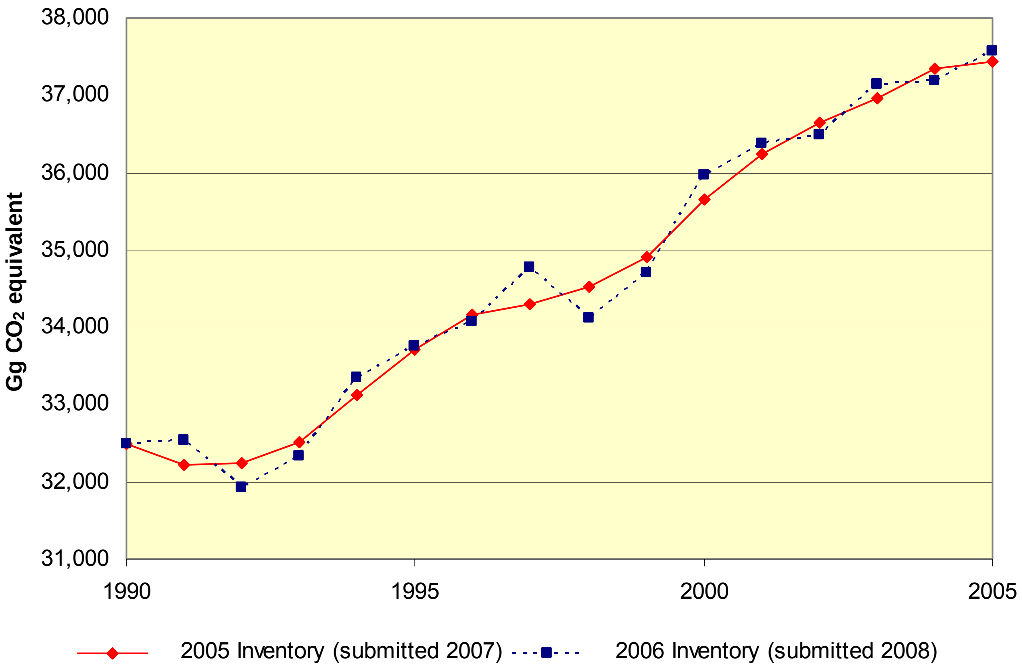


Agriculture

Calculating emissions using single year activity data instead of 3-year averages for the agriculture sector resulted in the recalculation of the whole time series (Figure 10.3.4).

Emissions in 1990 have increased 1.8 Gg CO_2-e and 133.9 Gg CO_2-e in 2005. The recalculations have not resulted in a change in total emissions in 1990 but have increased total emissions by 0.2 per cent in 2005.

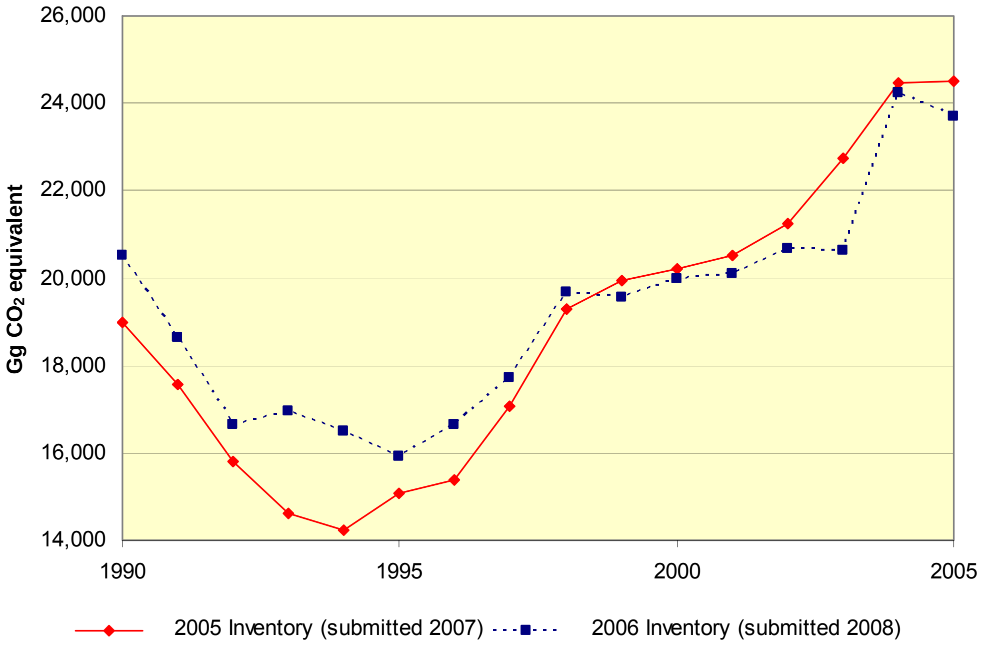
Figure 10.3.4 Effect of recalculation on the agriculture sector



LULUCF

Calculating emissions using single year activity data instead of 3-year averages for the LULUCF sector resulted in the recalculation of the whole time series (Figure 10.3.5). There were significant recalculations made to the forest land category as explained in section 10.1.5. The forest land category recalculations have resulted in an increase in net removals from 1990 to 1998. In 1990 removals increased by 1,416.2 Gg CO_2-e. From 1999 until 2005 recalculated net removals decreased. In 2005, net removals are 818.9 Gg CO_2-e lower than they were in the 2007 inventory submission. The recalculations for the LULUCF sector have resulted in a decrease in total emissions of 3.7 per cent in 1990 and an increase in total emissions of 1.5 per cent in 2005.

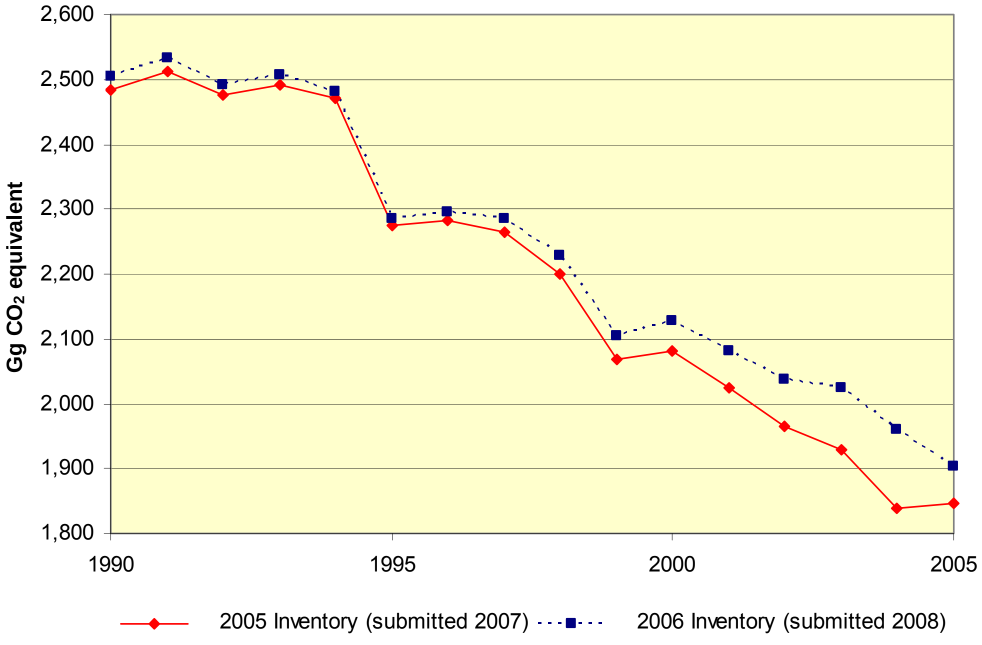
Figure 10.3.5 Effect of recalculation on LULUCF net removals



Waste

The recalculations made within the waste sector (Figure 10.3.6) are explained in section 10.1.2. Emissions in 1990 have increased 12.9 Gg CO_2-e and 9.0 Gg CO_2-e in 2005. The recalculations have resulted in an increase in total emissions in 1990 of 0.02 per cent and an increase of 0.07 per cent in 2005.

Figure 10.3.6 Effect of recalculation on the waste sector



10.4 Recalculations in response to the review process and planned improvements

10.4.1 Response to the review process

The UNFCCC secretariat facilitated an in-country review of New Zealand's national system and Kyoto Protocol base year inventory as part of the Kyoto Protocol initial review process. This review took place in Wellington from 19–24 February 2007.

The final review report was published on the Climate Change Convention website in August 2007 (UNFCCC, 2007). The review report recommends New Zealand intensify the time and resources directed at implementing the QA/QC plan with the aim of reducing the number of minor errors and inconsistencies. New Zealand has responded to the recommendation by changing the inventory compilation schedule to allow more time for quality checking. For the 2008 inventory submission all sector level data was entered into the CRF Reporter by January 2008. The earlier deadline allowed two months for more quality checking at the sector level (between data spreadsheets and the CRF tables) and checking consistency between the CRF tables and the NIR. A consequence of the earlier deadline is activity data has changed from 3 year averages to single year values for the agriculture and LULUCF sectors.

KPMG were contracted for 3 months to complete quality checks on key category data and to develop data quality objectives to further advance the implementation of New Zealand's QA/QC plan. KPMG checked the calculations and assumptions used in the key spreadsheets and models were consistently applied, that the data from the spreadsheets and models were accurately transferred to the CRF Reporter and data from the CRF tables was accurately represented in the draft NIR. Automatic checks using an excel tool highlighted any unique formulae and hard coded data. KPMG did not identify any significant errors within the source data spreadsheets or between the spreadsheets and the CRF Reporter and the NIR.

KMPG developed a risk register to highlight potential risks in the inventory data compilation process. The Ministry for the Environment intends to use the risk register on a regular basis to prioritise further improvements to the New Zealand inventory.

10.4.2 Planned improvements

Priorities for inventory development are guided by the analysis of key categories (level and trend), uncertainty surrounding existing emission and removal estimates and recommendations received from previous international reviews of New Zealand's inventory. The inventory improvement plan and the quality control and quality assurance plan are updated annually to reflect current and future inventory development. As discussed in 10.4.1 the development of a risk register will also help New Zealand prioritise improvements to the inventory.

Planned improvements to methodologies and emission factors are discussed under each sector as appropriate.

10.5 Summary of recent improvements to the inventory

New Zealand's QA/QC and improvement plans ensure continuous improvement of the inventory. Tables 10.5.1 to 10.5.3 show the improvements made to the inventory from the 2001 to 2008 inventory submissions.

Table 10.5.1 Improvements made to New Zealand’s 2001 to 2004 inventory submissions

<table>
<tr><th colspan="2" rowspan="2">Area of improvement</th><th colspan="8">Inventory submission year</th></tr>
<tr><th>2001</th><th>2002</th><th colspan="2">2003</th><th colspan="4">2004</th></tr>
<tr><td colspan="2">National System</td><td></td><td></td><td colspan="2"></td><td colspan="2">Complete CRF tables</td><td colspan="2">Explanatory text increased</td></tr>
<tr><td rowspan="6">Sector</td><td>Energy</td><td></td><td></td><td colspan="2"></td><td colspan="4">Explanatory text increased</td></tr>
<tr><td>Industrial Processes</td><td>HFCs, PFCs and SF$_6$ upgraded to Tier 2 method</td><td>Lime & Dolomite included</td><td colspan="2"></td><td>Upgraded Tier 3 methodology for SF$_6$ electrical equipment</td><td colspan="2">CH$_4$ from methanol production reported back to 1997</td><td>Explanatory text increased</td></tr>
<tr><td>Solvents</td><td></td><td></td><td colspan="2"></td><td colspan="4">Anaesthesia use of N$_2$O included</td></tr>
<tr><td>Agriculture</td><td></td><td></td><td>CH$_4$ ruminant emissions upgraded to Tier 2</td><td>N$_2$O EF & excretion rates revised</td><td colspan="4"></td></tr>
<tr><td>LULUCF</td><td></td><td></td><td colspan="2"></td><td colspan="4"></td></tr>
<tr><td>Waste</td><td></td><td>Solid Waste upgraded to Tier 2</td><td colspan="2"></td><td colspan="4"></td></tr>
<tr><td colspan="2">QA/QC</td><td></td><td></td><td colspan="2"></td><td colspan="2">Plan developed</td><td colspan="2">Trial of Tier 1 quality check sheets</td></tr>
</table>

Table 10.5.2 Improvements made to New Zealand’s 2005 to 2007 inventory submissions

Area of improvement		Inventory submission year					
		2005			2006		2007
National system		Explanatory text increased	UNFCCC CRF reporter tool applied				
Sector	Energy	Coal emission factors revised	Explanatory text increased	Vehicle fleet model used to verify CO_2 emissions	Included national energy balance		
	Industrial Processes	CH_4 from methanol production reported for entire time series	Explanatory text increased		Improving halocarbon data collection, especially HFC from air conditioning units	Included soda ash CO_2 emissions	
	Solvents						
	Agriculture	Included horse excreta N_2O emissions	Explanatory text increased	Reallocated dairy excreta between lagoons & pasture	CH_4 manure management upgraded to Tier 2	N_2O emission factor (EF1) changed to be country specific	Calculation spreadsheets improved by reducing the number of externally linked sheets.
	LULUCF	Added emissions & removals for all categories where AD available					
	Waste						
QA/QC		Extension of Tier 1 QC checks to incl. number of non-key sources			Extension of Tier 1 QC checks to include a number of non-key source		

Table 10.5.3 Improvements made to New Zealand's inventory submission for 2008

Area of improvement		Improvements made			
National system		Explanatory text increased			
Sector	Energy	Updated constant calorific values to year-specific values for all fuel types			
	Industrial Processes	Cement activity data updated	Separated limestone, coke & electrode emissions from iron & steel	Updated activity data for aluminium time series	Updated activity data on HFC and PFC consumption
	Solvents	2002 - 2005 time series updated based upon updated activity data			
	Agriculture	All data recalculated to single year values			
	LULUCF	All data recalculated to single year values. Forestland removals updated based upon updated carbon yields; harvesting & new planting data; new assumptions for the clearance of grassland with aboveground woody biomass and biomass burning.			
	Waste	Solid waste emissions updated 2003 - 2005 to correct sampling errors	Domestic & commercial wastewater emissions were updated 2002-2005 based on new organic product data	Industrial waste water time series updated	Incinerated waste data included
QA/QC		Inventory compilation deadline moved to allow more time for CRF and NIR quality checking. KPMG quality checked key category data for consistency between data spreadsheets, the CRF Reporter and the NIR. Risk register established.			

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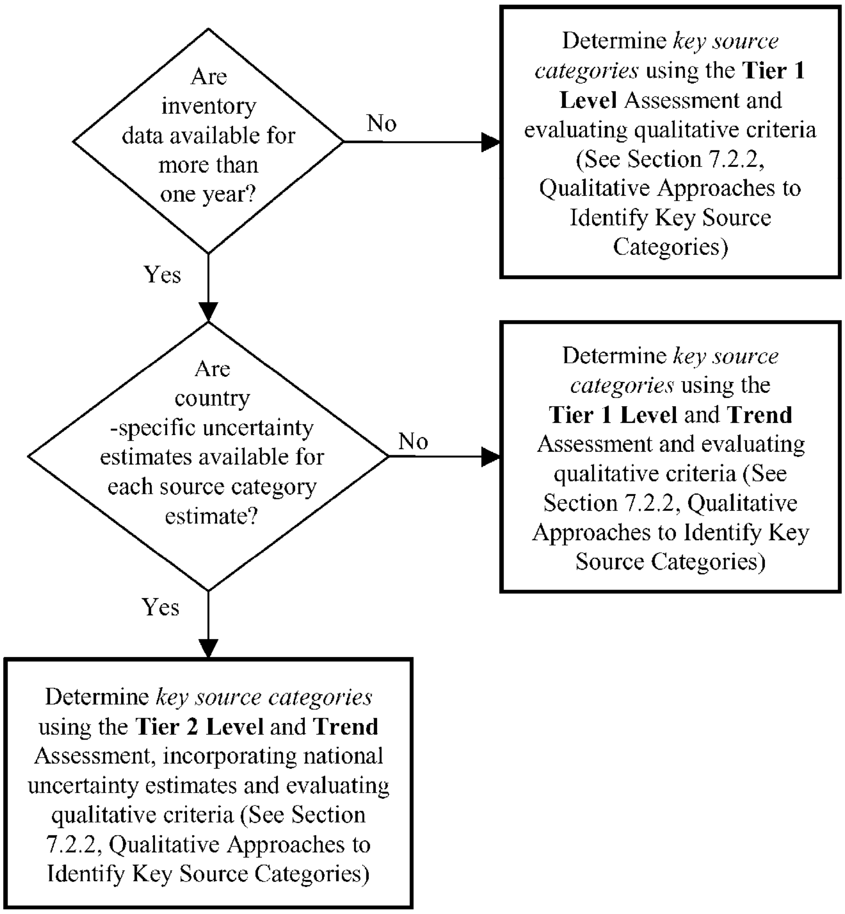
Annexes to New Zealand’s National Inventory Report for 2006

Annex 1: Key categories

A1.1 Methodology used for identifying key categories

The key categories in the New Zealand inventory have been assessed according to the methodologies provided in good practice guidance (IPCC, 2000). The methodology applied was determined using the decision tree shown in Figure A1.1.

Figure A1.1 Decision tree to identify key source categories (Figure 7.1 (IPCC, 2000))



For the 2006 inventory the Tier 1 level and trend assessment were applied including the 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 GPG-LULUCF. The "excluding LULUCF" level and trend assessments are calculated as per equations 7.1 and 7.2 of good practice guidance (IPCC, 2000). Key categories are defined as those categories whose cumulative percentages, when summed in decreasing order of magnitude, contributed 95 per cent of the total level or trend.

A1.2 Disaggregation

The classification of categories follows the classification outlined in Table 7.1 of good practice guidance (IPCC, 2000) by:

- Identifying categories at the level of IPCC categories using CO_2 equivalent emissions and considering each greenhouse gas from each category separately.
- Aggregating categories that use the same emission factors.
- Including LULUCF categories at the level shown in GPG-ULUCF Table 5.4.1.

There was one modification to the suggested categories to reflect New Zealand's national circumstances. The "fugitive emissions from fuels–oil and natural gas" category was divided into two categories: "fugitive emissions from oil and gas operations" and "fugitive emissions from geothermal operations". This is to reflect that New Zealand generates a significant amount of energy from geothermal sources that cannot be included as oil or gas operations.

A1.3 Tables 7.A1–7.A3 of the IPCC Good Practice Guidance

Table A1.1 Results of the key category level analysis for 99 per cent of the total emissions and removals for New Zealand in 2006. Key categories are those that comprise 95 per cent of the total.

(a) Tier 1 Category Level Assessment - including LULUCF

IPCC Categories	Gas	2006	Level	Cumulative
Forest land remaining forest land	CO_2	25859.65	23.9	23.9
Emissions from enteric fermentation in domestic livestock	CH_4	24110.67	22.3	46.2
Mobile combustion - road vehicles	CO_2	12606.68	11.7	57.8
Emissions from stationary combustion - gas	CO_2	7938.09	7.3	65.2
Emissions from agricultural soils - animal production	N_2O	7609.13	7.0	72.2
Emissions from stationary combustion - solid	CO_2	6754.95	6.2	78.5
Indirect emissions from nitrogen used in agriculture	N_2O	3387.22	3.1	81.6
Emissions from stationary combustion - liquid	CO_2	3008.08	2.8	84.4
Conversion to forest land	CO_2	2127.72	2.0	86.3
Direct emissions from agricultural soils	N_2O	1736.81	1.6	87.9
Emissions from the iron and steel industry	CO_2	1622.36	1.5	89.4
Emissions from solid waste disposal sites	CH_4	1475.39	1.4	90.8
Mobile combustion - aviation	CO_2	1114.18	1.0	91.8
Emissions from manure management	CH_4	743.13	0.7	92.5
Cropland remaining cropland	CO_2	679.95	0.6	93.1
Other-emissions from liming	CO2	676.11	0.6	93.8
Conversion to grassland	CO_2	661.04	0.6	94.4
Fugitive emissions from oil and gas operations	CO_2	657.47	0.6	95.0
Emissions from substitutes for ozone depleting substances	HFCs & PFCs	601.35	0.6	95.5
Emissions from cement production	CO_2	560.66	0.5	96.1
Emissions from aluminium production	CO_2	552.76	0.5	96.6
Fugitive emissions from coal mining and handling	CH_4	450.20	0.4	97.0
Emissions from ammonia/urea production	CO_2	381.63	0.4	97.3
Mobile combustion - marine	CO_2	324.89	0.3	97.6
Fugitive emissions from geothermal operations	CO_2	305.68	0.3	97.9
Fugitive emissions from oil and gas operations	CH_4	302.17	0.3	98.2
Emissions from hydrogen production	CO_2	227.76	0.2	98.4
Emissions from wastewater handling	CH_4	209.88	0.2	98.6
Emissions from wastewater handling	N_2O	167.40	0.2	98.8
Mobile combustion - rail	CO_2	155.16	0.1	98.9
Mobile combustion - road vehicles	N_2O	136.78	0.1	99.0

Table A1.2 Results of the key category level analysis for 99 per cent of the total emissions and removals for New Zealand in 1990. Key categories are those that comprise 95 per cent of the total.

(a) Tier 1 Category Level Assessment - including LULUCF				
IPCC Categories	**Gas**	**Base year estimate Gg**	**Level assessment**	**Cumulative total**
Emissions from enteric fermentation in domestic livestock	CH_4	21810.44	25.6	25.6
Forest land remaining forest land	CO_2	21397.92	25.1	50.6
Emissions from Stationary combustion - gas	CO_2	7691.14	9.0	59.7
Mobile combustion - road vehicles	CO_2	7534.97	8.8	68.5
Emissions from agricultural soils - animal production	N_2O	6850.46	8.0	76.5
Emissions from stationary combustion - solid	CO_2	3148.78	3.7	80.2
Indirect emissions from nitrogen used in agriculture	N_2O	2702.16	3.2	83.4
Emissions from stationary combustion - liquid	CO_2	2546.55	3.0	86.4
Emissions from solid waste disposal sites	CH_4	2121.53	2.5	88.9
Emissions from the iron and steel industry	CO_2	1312.27	1.5	90.4
Mobile combustion - aviation	CO_2	772.83	0.9	91.3
Conversion to grassland	CO_2	704.22	0.8	92.1
PFC's from aluminium production	PFC	641.68	0.8	92.9
Emissions from manure management	CH_4	578.59	0.7	93.6
Cropland remaining cropland	CO_2	538.67	0.6	94.2
Direct emissions from agricultural soils	N_2O	487.19	0.6	94.8
Emissions from aluminium production	CO_2	443.27	0.5	95.3
Emissions from cement production	CO_2	441.67	0.5	95.8
Other (including liming)	CO2	373.83	0.4	96.2
Fugitive emissions from geothermal operations	CO_2	357.34	0.4	96.7
Emissions from ammonia/urea production	CO_2	274.53	0.3	97.0
Fugitive emissions from coal mining and handling	CH_4	272.13	0.3	97.3
Fugitive emissions from oil and gas operations	CO_2	263.48	0.3	97.6
Fugitive emissions from oil and gas operations	CH_4	258.74	0.3	97.9
Mobile combustion - marine	CO_2	247.82	0.3	98.2
Emissions from wastewater handling	CH_4	222.73	0.3	98.5
Emissions from hydrogen production	CO_2	152.29	0.2	98.6
Emissions from wastewater handling	N_2O	146.92	0.2	98.8
Conversion to forest land	CO_2	141.28	0.2	99.0

Table A1.3 Results of the key category trend analysis for 99 per cent of the total emissions and removals for New Zealand in 2006. Key categories are those that comprise 95 per cent of the total.

(a) Tier 1 Category Trend Assessment - including LULUCF						
IPCC Categories	**Gas**	**Base year estimate Gg**	**2006 estimate Gg**	**Trend assessment**	**Contribution to trend**	**Cumulative total**
Emissions from enteric fermentation in domestic livestock	CH_4	21810.44	24110.67	0.034	16.0	16.0
Mobile combustion - road vehicles	CO_2	7534.97	12606.68	0.032	15.2	31.2
Emissions from Stationary combustion - solid	CO_2	3148.78	6754.95	0.029	13.5	44.7
Conversion to forest land	CO_2	141.28	2127.72	0.020	9.4	54.2
Emissions from Stationary combustion - gas	CO_2	7691.14	7938.09	0.018	8.4	62.6
Emissions from solid waste disposal sites	CH_4	2121.53	1475.39	0.012	5.8	68.3
Direct emissions from agricultural soils	N_2O	487.19	1736.81	0.011	5.4	73.8
Forest land remaining forest land	CO_2	21397.92	25859.65	0.011	5.0	78.8
Emissions from agricultural soils - animal production	N_2O	6850.46	7609.13	0.010	4.9	83.7
PFC's from aluminium production	PFC	641.68	82.49	0.007	3.5	87.2
Emissions from substitutes for Ooone depleting substances	HFCs & PFCs	0.00	601.35	0.006	2.9	90.1
Fugitive emissions from oil and gas operations	CO_2	263.48	657.47	0.003	1.6	91.7
Conversion to grassland	CO_2	704.22	661.04	0.002	1.1	92.7
Other (including liming)	CO2	373.83	676.11	0.002	1.0	93.7
Emissions from stationary combustion - liquid	CO_2	2546.55	3008.08	0.002	0.9	94.7
Fugitive emissions from geothermal operations	CO_2	357.34	305.68	0.001	0.7	95.4
Mobile combustion - aviation	CO_2	772.83	1114.18	0.001	0.7	96.1
Fugitive emissions from coal mining and handling	CH_4	272.13	450.20	0.001	0.5	96.6
Conversion to cropland	CO_2	37.35	123.31	0.001	0.4	96.9
Emissions from wastewater handling	CH_4	222.73	209.88	0.001	0.3	97.3
Mobile combustion - rail	CO_2	78.01	155.16	0.001	0.3	97.6
Mobile combustion - road vehicles	N_2O	64.40	136.78	0.001	0.3	97.8
Emissions from ammonia/urea production	CO_2	274.53	381.63	0.000	0.2	98.0
Emissions from hydrogen production	CO_2	152.29	227.76	0.000	0.2	98.2
Mobile combustion - road vehicles	CH_4	69.00	52.19	0.000	0.2	98.4
Emissions from the iron and steel industry	CO_2	1312.27	1622.36	0.000	0.1	98.5
Non-CO_2 emissions from stationary combustion	N_2O	75.67	120.94	0.000	0.1	98.6
Conversion to settlement	CO_2	97.16	97.16	0.000	0.1	98.7
Emissions from limestone & dolomite use	CO_2	17.13	44.70	0.000	0.1	98.8
Fugitive emissions from oil and gas operations	CH_4	258.74	302.17	0.000	0.1	99.0

Annex 2: Methodology and data collection for estimating emissions from fossil fuel combustion

New Zealand emission factors are based on GCV (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 GCV to NCV (net calorific value) follows the Organisation for Economic Co-operation and Development (OECD) and International Energy Agency (IEA) assumptions:

- NCV = 0.95 x GCV for coal and liquid fuels
- NCV = 0.90 x GCV for gas.

Emission factors for gas, coal, biomass and liquid fuels used in New Zealand are shown in Tables A2.1–A2.3.

Table A2.1 CO_2 emission factors used in the energy sector

	Emission factor (t CO_2/TJ)	Emission factor (t C/TJ)
Gas		
Maui	52.0 (2006)	14.2 (2006)
Treated	53.5 (2006)	14.6 (2006)
Kapuni LTS	84.1	22.9
Weighted average of Maui and Kapuni treated	52.3 (2006)	14.3 (2006)
Methanol – mixed feed (1990–1994)	62.4	17.0
Methanol – LTS (1990–1994)	84.0	22.9
Kaimiro	65.2	17.8
Ngatoro	53.1	14.5
Rimu	53.7	14.6
Waihapa/Ngaere + Tariki/Ahuroa (1990)*	56.2	15.3
Waihapa/Ngaere + Tariki/Ahuroa (2002)	54.2	14.8
McKee	54.3	14.8
Mangahewa	52.3	14.3
Turangi	55.6	15.2
Pohokura	55.1	15.0
Liquid fuels		
Regular petrol (all petrol 1990–1995)	66.2	18.1
Petrol – premium (1996 and onwards)	67.0	18.3
Diesel	69.5	19.0
Aviation fuels	68.1	18.6
Av gas	65.0	17.7
Other	72.9	19.9
Fugitive – flared	65.1	17.8

	Emission factor (t CO_2/TJ)	Emission factor (t C/TJ)
LPG	60.4	16.5
Heavy fuel oil	73.5	20.0
Light fuel oil	72.0	19.6
Averaged fuel oil	73.0	19.9
Bitumen (asphalt)	76.1	20.8
Biomass		
Biogas	101.0	27.5
Wood (industrial)	104.2	28.4
Wood (residential)	104.2	28.4
Coal		
All sectors (sub bit)	91.2	24.9
All sectors (bit)	88.8	24.2
All sectors (lignite)	95.2	26.0

* For the years 1991–2001, the emissions factors for these gas streams are interpolated between the 1990 and 2002 values.

Table A2.2 CH_4 emission factors used in the energy sector

	Emission factor t CH_4/PJ	Source
Natural gas		
Electricity – boilers	2.745	IPCC Tier 2 (Table 1–15) average for natural gas boilers and large gas-fired turbines >3 MW
Commercial	1.08	IPCC Tier 2 (Table 1–19) natural gas boilers
Residential	0.9	IPCC Tier 2 (Table 1–18) gas heaters
Domestic transport (CNG)	567	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	0.855	IPCC Tier 2 (Table 1–15) residual oil boilers – normal firing
Electricity – distillate oil	0.855	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	1.045	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	0.665	IPCC Tier 2 (Table 1–19) distillate oil boilers
Commercial – LPG	1.045	IPCC Tier 2 (Table 1–18) propane/butane furnaces
Residential – distillate oil	0.665	IPCC Tier 2 (Table 1–18) distillate oil furnaces
Residential – LPG	1.045	IPCC Tier 2 (Table 1–18) propane/butane furnaces
Agriculture – stationary	3.8	IPCC Tier 2 (Table 1–49) diesel engines (agriculture)

	Emission factor t CH_4/PJ	Source
Mobile sources		
LPG	28.5	IPCC Tier 2 (Table 1–44) passenger cars (uncontrolled)
Petrol – 1990 onwards	18.525	IPCC Tier 2 (Table 1–27) passenger cars (uncontrolled – mid-point of average g/MJ)
Diesel – 1990 onwards	3.8	IPCC Tier 2 (Table 1–32) passenger cars (uncontrolled – g/MJ)
Navigation (fuel oil and diesel)	6.65	IPCC Tier 2 (Table 1–48) ocean-going ships
Aviation fuel/kerosene	1.9	IPCC Tier 2 (Table 1–48) jet and turboprop aircraft
Coal		
Combustion		
Electricity generation	0.665	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	0.665	IPCC Tier 2 (Table 1–16) dry bottom, wall fired coal boilers
Commercial	9.5	IPCC Tier 2 (Table 1–19) coal boilers
Residential	285	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	IPCC Tier 1 (Table 1–7) wood – residential
Biogas	1.08	IPCC Tier 2 (Table 1–19) gas boilers

Table A2.3 N_2O emission factors used in the energy sector

	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	0.285	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	0.285	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	0.285	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	28.5	IPCC Tier 2 (Table 1–49) diesel engines – agriculture

	Emission factor t N_2O/PJ	Source
Mobile sources		
LPG	0.57	IPCC Tier 1 (Table 1–8) oil – all sources except aviation
Petrol	1.425	IPCC Tier 2 (Table 2.7 in GPG (IPCC, 2000))
		US gasoline vehicles (uncontrolled)
Diesel	3.705	IPCC Tier 2 (Table 2.7 in GPG (IPCC, 2000)) all US diesel vehicles
Fuel oil (ships)	1.9	IPCC Tier 2 (Table 1–48) ocean going ships
Aviation fuel/kerosene	1.9	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)	3.8	IPCC Tier 1 (Table 1–8) wood/wood waste – all uses
Biogas	2.07	IPCC Tier 2 (Table 1–19) natural gas boilers

A2.1 Emissions from liquid fuels

A2.1.1 Activity data and uncertainties

The Delivery of Petroleum Fuels by Industry Survey conducted by Statistics New Zealand is assumed to have a five per cent uncertainty associated with the sectoral energy allocation although the annual totals are likely to be more certain (Ministry of Economic Development, 2006).

Because the survey is run as a census there is no sampling error. The main sources of non-sample error are:

- Respondent error: Statistics New Zealand makes every effort to confirm values supplied by respondents, and given assurances of accuracy. Statistics New Zealand is bound to accept them. If a discrepancy is discovered at a later date, revised values are supplied at the earliest possible opportunity.
- Processing error: there is always the possibility of error, however, Statistics New Zealand has thorough checking procedures to ensure that the risk of processing errors is minimised.

A2.1.2 Emission factors and uncertainties

Carbon dioxide emission factors are described in Table A2.1. The CO_2 emission factors for oil products are from the New Zealand Refining Company, import data from industry and from

Baines (1993[5]). The New Zealand Refining Company estimates the uncertainty in emission factors to be within five per cent (Ministry of Economic Development, 2006).

A2.2 Emissions from solid fuels

A2.2.1 Activity data and uncertainties

The New Zealand Coal Sales Survey conducted by Statistics New Zealand is an ongoing quarterly survey. The survey began in 1981. The survey is a full coverage of the sector and therefore there are no sampling errors. Non-sampling errors in the survey data may result from errors in the sample frame (eg, units with the wrong New Zealand Standard Industrial Classification), respondent error (eg, wrong values supplied) and errors made during processing survey results or non-response imputation. Statistics New Zealand adopts procedures to detect and minimise these potential errors.

The process of dividing coal use between different sectors will introduce uncertainty larger than the uncertainty in total coal sales. Uncertainty is also introduced from the assumption that coal used by sector is an average of the different ranks. These assumptions are thought to introduce an uncertainty of ± 5 per cent (Ministry of Economic Development, 2006).

The sectoral partitioning used for coal was examined in 2003 by officials from the Ministry for the Environment. There was concern in extrapolating sectoral allocations from 1995 to 2002 given some probable changes in sectoral coal usage. However, New Zealand coal industry experts did not consider a survey could be justified because of the difficulty and expense in collating and verifying data from a number of sectors. In addition, the major categories of coal exports, coal used by the residential sector and coal used for steel production and electricity generation are all known accurately and are not affected by the sectoral partitioning.

A2.2.2 Emission factors and uncertainties

The CO_2 emission factors for coal are shown in Table A2.1. The non-CO_2 emission factors are shown in Tables A2.2 and A2.3. The estimated uncertainty in coal emission factors is taken as ± 3 per cent (Ministry of Economic Development, 2006). An uncertainty of ± 2 per cent is used for the sub-bituminous coal used in public electricity generation. All New Zealand values are within 2 per cent of the revised 1996 IPCC default values (IPCC, 1996).

A2.3 Emissions from gaseous fuels

A2.3.1 Activity data and uncertainties

Vector Limited has contracts with large gas users that allow metering errors of ± 2 per cent. Whenever the error between the meter-reading and actual gas supplied exceeds 2 per cent, adjustments are made to the reported quantities of gas supplied. The uncertainty is therefore assumed to have an upper limit of ± 2 per cent (Ministry of Economic Development, 2006).

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[5] The LPG CO_2 emissions factor was confirmed by checks of 2002 gas data.

A2.3.2 Emission factors and uncertainties

As discussed in section 3.2.1.5, New Zealand now uses the Maui and Kapuni gas production data reported in the New Zealand Energy Data File (Ministry of Economic Development, 2007b) to support the calculation of a weighted average annual CO_2 emission factor for natural gas. This average emission factor is applied to a number of categories in the energy sector, such as the "manufacturing industries and construction category".

The emission factors for the various gas fields in New Zealand are shown in Table A2.1. The emission factors are calculated by averaging daily gas composition data supplied by industry. Taking annual bounds, it is estimated that the uncertainty in the natural gas emission factors is ± 1.7 per cent (Ministry of Economic Development, 2006).

Table A2.4 Variation in CO_2 emission factors for natural gas

Year	Maui (kt CO_2 / PJ)	Treated (kt CO_2 / PJ)	Average (kt CO_2 / PJ)
1990	53.2	52.4	53.1
1991	52.9	52.8	52.9
1992	52.9	52.8	52.8
1993	52.6	52.5	52.6
1994	52.4	52.2	52.4
1995	52.1	52.9	52.2
1996	52.2	52.9	52.3
1997	52.3	52.4	52.3
1998	52.1	52.2	52.1
1999	51.8	52.4	51.9
2000	52.1	52.1	52.1
2001	51.9	52.6	52.0
2002	52.3	52.5	52.3
2003	52.0	52.6	52.1
2004	51.9	53.7	52.2
2005	52.0	52.6	52.1
2006	52.0	53.5	52.3

A2.4 Energy balance for year ended December 2006

Table A2.5 New Zealand energy balance for year ended December 2006 (Ministry of Economic Development, 2007b)

Energy Supply and Demand Balance December Year 2006

	Converted into Petajoules using Gross Calorific Values	COAL					OIL								GAS	RENEWABLES							ELEC-TRICITY	WASTE HEAT	TOTAL
		Bituminous	Sub-bitum.	Bituminous& Sub-bitum.	Lignite	Total	Crudes/ Feedstocks	LPG/ NGL	Motor Gasoline	Diesel	Fuel Oil	Av. Fuel/ Kero	Others	Total	Natural Gas	Hydro	Geo-thermal	Solar	Wind	Biogas	Wood	Total			
SUPPLY	Indigenous Production	89.54	59.44	148.98	4.01	152.99	38.90	7.87						46.77	152.53	84.43	89.03	0.24	2.22	2.30	42.21	220.43		1.10	573.82
	+ Imports	1.85	26.47	28.32	0.04	28.35	215.83	1.91	42.55	34.59	0.00	9.73	6.77	311.38											339.74
	- Exports	85.24		85.24	0.00	85.24	33.51	0.30	0.00	0.47	3.85	0.00	0.00	38.13											123.36
	- Stock Change			3.69		3.69	-9.98	0.34	2.55	2.68	2.31	0.43	-0.58	-2.25	0.00										1.44
	- International Transport								0.00	1.52	10.57	35.35	0.00	47.44											47.44
	TOTAL PRIMARY ENERGY	6.15	85.91	88.37	4.05	92.42	231.19	9.14	40.00	29.92	-16.73	-26.05	7.35	274.83	152.53	84.43	89.03	0.24	2.22	2.30	42.21	220.43		1.10	741.31
	ENERGY TRANSFORMATION			-70.30		-70.30	-231.30	-0.78	72.56	78.51	25.42	42.49	6.17	-6.93	-89.52	-84.43	-79.30		-2.22	-2.02	-7.49	-175.46	140.94	-1.10	-202.37
	of which Electricity Generation			-50.99		-50.99									-61.28	-84.43	-71.82		-2.22	-1.16		-159.63	144.93		-126.96
	Cogeneration			-0.69		-0.69									-21.39		-1.48			-0.86	-7.49	-9.83	9.67	-1.10	-23.34
	Oil Production						-231.30		69.62	76.27	23.93	42.23	13.93	-5.32											-5.32
	Other Transformation			-18.60		-18.60									-2.11								2.13		-18.58
	Losses and Own Use			-0.03		-0.03		-0.78	2.93	2.23	1.49	0.26	-7.76	-1.62	-4.74		-6.00					-6.00	-15.79		-28.17
	Non-energy Use												*-13.52*	*-13.52*	*-23.21*										*-36.72*
	CONSUMER ENERGY (calculated)			18.07	4.05	22.12		8.37	112.56	108.43	8.69	16.44	0.00	254.38	39.81		9.73	0.24	0.00	0.28	34.72	44.97	140.94	0.00	502.22
DEMAND	**Agriculture**			1.96	0.02	1.98			1.05	9.18	1.67	0.24		12.14	1.87								5.40		21.40
	of which Agriculture and Hunting			1.96	0.02	1.98			1.02	6.44	0.00	0.23		7.70	1.87								5.09		16.65
	Fishing								0.03	2.74	1.67	0.01		4.44									0.31		4.75
	Industrial			12.85	3.52	16.37		2.92	0.48	12.33	1.13	0.17		17.02	28.43		5.77				26.87	32.64	55.39		149.85
	of which Other Primary Industry								0.01	3.08	0.32	0.01		3.42	0.20								1.21		4.83
	Food Processing								0.00	0.06	0.12	0.00		0.18	10.60								8.53		19.30
	Textiles																						0.66		0.66
	Wood, Pulp, Paper and Printing														7.05								12.75		19.80
	Chemicals														4.82								2.89		7.71
	Non-metallic Minerals														5.68								0.92		6.60
	Basic Metals									0.00													24.31		24.31
	Mechanical/Electrical Equipment																						1.18		1.18
	Building and Construction								0.01	2.43	0.01	0.10		2.54	0.09								0.86		3.49
	Unallocated			12.85	3.52	16.37		2.92	0.46	6.76	0.68	0.06		10.88			5.77				26.87	32.64	2.07		61.96
	Commercial			3.32	0.49	3.82		1.44	0.09	2.04	0.26	0.78		4.61	4.99		3.86			0.28		4.14	28.00		45.56
	Residential			0.25	0.43	0.69		2.58	0.00	0.00	0.00	0.00		2.58	6.94		0.10	0.24			7.85	8.19	44.44		62.83
	National Transport			0.08		0.08		1.42	110.26	84.11	4.45	16.58		216.82	0.19								2.41		219.51
	CONSUMER ENERGY (observed)			18.47	4.47	22.94		8.37	111.88	107.66	7.51	17.77	0.00	253.18	42.42		9.73	0.24		0.28	34.72	44.97	135.64	0.00	499.15
	Statistical Differences			-0.40	-0.41	-0.82		0.00	0.68	0.77	1.18	-1.32	0.00	1.20	-2.61		0.00	0.00		0.00	0.00	0.00	5.30	0.00	3.07

Annex 3: Detailed methodological information for other sectors

A3.1 The agriculture sector

A3.1.1 Uncertainty of animal population data

Details of the surveys and census are included to provide an understanding of the livestock statistics process and uncertainty values. The information documented is from Statistics New Zealand. Full details of the surveys are available from Statistics New Zealand's website **www.stats.govt.nz/datasets/primary-production/agriculture-production.htm**.

Agricultural Production Surveys

The target population for the 2006 Agricultural Production Census was all units that were engaged in agricultural production activity (including livestock, cropping, horticulture and forestry) or that owned land that was intended for agricultural activity during the year ended 30 June 2006. The response rate was 86 per cent. These businesses represent 88 per cent of the total estimated value of agricultural output. Statistics New Zealand imputes using a random 'hot deck' procedure for values for farmers and growers who did not return a completed questionnaire. Table A3.1.1 gives the sample errors based on a 95 per cent confidence level for the survey data collected in 2006.

Table A3.1.1 Final sampling error and imputation levels for the 2006 Agricultural Production Survey

Statistic	Sample errors at 95% confidence interval (%)	Percentage of total estimate imputed
Ewe hogget's put to ram	4	13
Breeding ewes 2 tooth and over	2	13
Total number of sheep	2	12
Lamb born to ewe hogget's	5	**13**
Lambs born to ewes	2	**13**
Beef cows and heifers (in calf) 2 years and over	3	**13**
Beef cows and heifers (in calf) 1–2 years	6	**12**
Total number of beef cattle	2	**13**
Calves born alive to beef heifers/cows	3	13
Dairy cows and heifers, in milk or calf	3	15
Total number of dairy cattle	3	15
Calves born alive to dairy heifers/cows	4	15
Female deer mated	3	12
Total number of deer	4	12
Fawns born on farm and alive at 4 months	3	12
Area of potatoes harvested	8	4
Area of wheat harvested	19	10
Area of barley harvested	12	10

The 1999 livestock survey

The frame for the 1999 Agricultural Production Survey was based on a national database of farms called AgriBase which is maintained by AgriQuality New Zealand Ltd (formerly Ministry of Agriculture and Forestry Quality Management). A sample survey was conducted to obtain estimates of livestock on farms and area sown in grain and arable crops for the 30 June 1999 year. Questionnaires were sent to approximately 35,000 farms. The overall response rate for the survey was 85.7 per cent. The remaining units were given imputed values based on either previous data or on the mean value of similar farms.

A3.1.2 Key parameters and emission factors used in the agricultural sector

Table A3.1.2.1 Parameter values for agriculture emissions of nitrous oxide

Parameter (Fraction)	Fraction of the parameter	Source	Parameter value
$Frac_{BURN}$	Crop residue burned in fields	Ministry of Agriculture and Forestry (expert opinion)	0.5
$Frac_{BURNL}$	Legume crop residue burned in fields	Ministry of Agriculture and Forestry (expert opinion)	0
$Frac_{FUEL}$	Livestock nitrogen excretion in excrements burned for fuel	Practice does not occur in New Zealand	0
$Frac_{GASF}$	Total synthetic fertiliser emitted as NO_x or NH_3	IPCC (1996) Reference Manual Table 4.19	0.1
$Frac_{GASM}$	Total nitrogen emitted as NO_x or NH_3	IPCC (1996) Table 4.19	0.2
$Frac_{GRAZ}$	Livestock nitrogen excreted and deposited onto soil during grazing	See Table 6.3.1	Livestock specific
$Frac_{LEACH}$	Nitrogen input to soils that is lost through leaching and run-off	Thomas et al (2002)	0.07
$Frac_{NCRBF}$	Nitrogen in N-fixing crops	IPCC (1996) Reference Manual Table 4.19	0.03
$Frac_{NCR0}$	Nitrogen in non-N-fixing crops	IPCC (1996) Reference Manual Table 4.19	0.015
$Frac_{R}$	Crop residue removed from the field as crop	IPCC (1996) Reference Manual Table 4.19	0.45

Table A3.1.2.2 Emission factor for agriculture emissions of nitrous oxide

Emission factor	Emissions	Source	
EF_1	Direct emissions from nitrogen input to soil	Kelliher and de Klein (2006)	0.01
EF_2	Direct emissions from organic soil mineralisation due to cultivation	IPCC (2000) Table 4.17	8
EF_{3AL}	Direct emissions from waste in the anaerobic lagoons AWMS	IPCC (2000) Table 4.12	0.001
EF_{3SSD}	Direct emissions from waste in the solid waste and drylot AWMS	IPCC (2000) Table 4.12	0.02
EF_{3PRP}	Direct emissions from waste in the pasture range and paddock AWMS	Carran et al (1995); Muller et al 1995; de Klein et al (2003)	0.01
EF_{3OTHER}	Direct emissions from waste in other AWMSs	IPCC (2000) Table 4.	0.005
EF_4	Indirect emissions from volatising nitrogen	IPCC (2000) Table 4.18	0.01
EF_5	Indirect emissions from leaching nitrogen	IPCC (2000) Table 4.18	0.025

Table A3.1.2.3 Emission factor for Tier 1 enteric fermentation livestock and manure management

Emission factor	Emissions	Source	
EF_{GOATS}	Enteric fermentation – Goats	NZ specific (see Annex 3.1 of NIR)	9
EF_{HORSES}	Enteric fermentation – Horses	IPCC (2000) Table 4.5	18
EF_{SWINE}	Enteric fermentation – Swine	IPCC (2000) Table 4.5	1.5
MM_{GOATS}	Manure management – Goats	IPCC (2000) Table 4.5	0.18
MM_{HORSES}	Manure management – Horses	IPCC (2000) Table 4.5	2.08
MM_{SWINE}	Manure management – Swine	IPCC (2000) Table 4.5	20
$MM_{POULTRY}$	Manure management – Poultry	IPCC (2000) Table 4.5	0.117

A3.2 Additional information for the LULUCF sector: the Land Use and Carbon Analysis System (LUCAS)

A3.2.1 Background

The aim of the Land Use and Carbon Analysis System (LUCAS) project is to develop a robust and comprehensive data gathering, management, analysis and reporting system which is consistent with good practice guidance (IPCC, 2000 and 2003) and designed to:

- Be appropriate for UNFCCC LULUCF sector reporting.
- Enable reporting under Article 3.3 of the Kyoto Protocol for the first commitment period.
- Support and underpin New Zealand climate change policy development through to 2012 and beyond.

A3.2.2 Approach

Data Collection

Data collection is separated into three components; forest related, soil related and land-use mapping. Data collection methodologies have been designed to provide unbiased carbon estimates at the national scale. The methods are supported by relevant scientific research. Analysis of the data will provide nationally applicable values for carbon stock and stock change for each of the five carbon pools. The data collection methodologies and the resulting approach to data analysis are being reviewed to provide transparency and to ensure that the activities within the LUCAS project are widely understood.

Natural forests

Natural forest plots have been established on a systematic 8 km grid across New Zealand. Collection of the data from these plots occurred over a five year period and was completed in early 2007. The analysis of these data is underway, the results of which will determine the carbon-status of these managed forests. The next steps include improving the allometric models and to refine future data collection requirements. This analysis will report the results for each of the four biomass carbon pools.

Planted forests

A planted forest carbon inventory and country-specific parameters are being developed for New Zealand to provide an unbiased estimate with known uncertainty for reporting and accounting purposes. Carbon stock estimates will be derived from plot measurements for the four biomass carbon pools. Most – around 90 per cent – of the planted forests in New Zealand are exotic, primarily *Pinus Radiata*.

Forests planted after the 1st January, 1990

Change in carbon stocks in forests planted after January 1st 1990 will be determined by measurement of trees within plots established on a 4 km grid across New Zealand. A combination of field measurements and airborne LiDAR (Light Detecting and Ranging) will be used. The field measurement programme is underway and will be completed at the end of 2008. LiDAR data capture is planned for February – April 2008. The LiDAR data will be calibrated against the field measurements. For forest plots that are inaccessible, LiDAR data will be processed to provide the total amount of carbon per plot. The total carbon per plot will be separated into the four biomass carbon pools using a specific carbon allocation model. The measurement process will be repeated at the end of the first commitment period, based on the same set of plots. Where new planting covers a point on the 4 km grid, new plots will be established.

Forests planted before the 31st December, 1989

The LUCAS system will also establish the change in carbon stocks in New Zealand's forests planted before December 31st 1989. The post January 1st 1990 forests approach will be applied, but it is expected that the measurement plots will be on a coarser grid network. It is expected that plot measurements will only be made in the middle of the commitment period, and make use of models to forward- and back-cast carbon values to cover the five year commitment period.

Soils

Soil carbon changes very slowly in response to land-use changes. A New Zealand-specific soil carbon model will be used within the LUCAS database to model this. Soil data for input to the model have been collected under the natural forests work stream and through a number of related research programmes and a specific soil sampling programme. Collation of these data and initial analysis is scheduled to complete mid 2008. These data will allow estimates of soil carbon for different soil types, climate and land-cover/land-use variables in New Zealand. The soils data will be analysed to identify gaps in its coverage across the country. Where significant gaps exist in important land-use areas, further samples and analysis will be performed.

Land use mapping

The LUCAS system has been designed to achieve the following objectives in relation to land use mapping:

- Determine changes in land use between 1990 and the start of the first commitment period by providing a New Zealand-wide map of land use at 1990 and at 2008.
- Determine changes in land use through the first commitment period by providing a New Zealand-wide map of land use at 2012.
- Determining where forests have been harvested, and where deforestation has occurred.

Land use will be mapped as per the UNFCCC categories, namely forest land, cropland, grassland, wetlands, settlements and other land.

Mapping of land use at 1990 is scheduled to be completed towards the end of 2008. The 1990 mapping uses a combination of Landsat 4 and Landsat 5 as well as some SPOT 2 satellite imagery and aerial photography. To assist in the interpretation of the 1990 imagery, land use at 2000–2001 is being determined first, and used to track land use back to 1990. The 2000–2001 mapping is using Landsat ETM+ imagery and aerial photography.

Mapping of land use at 2008 will use SPOT 5 satellite imagery. This imagery is being captured over the 2006/07 and 2007/08 summers (November to March). Mapping of land use will be concluded during 2009.

The LUCAS project is evaluating the use of medium spatial resolution (250 m) MODIS satellite imagery to identify the location and timing of forest harvesting. The intention is to create cloud-free MODIS images of New Zealand on an annual basis. The actual area of harvesting, and deforestation will be determined from high resolution satellite systems or aerial photography. If MODIS proves unsuitable, New Zealand may use satellite radar to identify the location and timing of forest harvesting.

Central database

A component of the LUCAS project is the development of a database to store and manipulate all data. The database will achieve the following objectives:

- Provide a transparent system for data and calculations.
- Provide a single repository for the storing, versioning and validation of plot measurements.
- Store static land use layers and LUCAS derived polygon layers to determine land use and land-use change area nationally.
- Calculate carbon stocks per hectare for land uses and soils based on the plot and spatial data collected.
- Produce the CRF reports for the LULUCF sector and reporting under Article 3.3 of the Kyoto Protocol.

A3.2.3 Statistical design and uncertainty

The statistical methods and assumptions will be independently reviewed to ensure they are consistent with best practice statistical design. Opportunities for ongoing improvement of data collection systems will be sought, while considering the cost-effectiveness of alternatives.

Uncertainty in estimated carbon values will be determined as the data collection, land-use mapping and analysis approaches are developed. The uncertainty information will be used to prioritise future improvements in methodologies and data collection.

A3.2.4 Quality Assurance

A quality assurance framework is being developed for the LUCAS project. Once the framework has been agreed, it will be consistently implemented across all LUCAS activities. This will be consistent with New Zealand's QAQC plan and IPCC good practice guidance (IPCC, 2000 and 2003).

Annex 4: CO_2 reference approach and comparison with sectoral approach, and relevant information on the national energy balance

Information on the CO_2 reference approach and a comparison with sectoral approach is provided in section 3.4.1. The section also includes a comparison with the International Energy Agency reference and sectoral approach for New Zealand.

Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

An assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in section 1.8.

Annex 6: Quality assurance and quality control

A description of the quality control and assurance processes New Zealand undertakes is contained in sections 1.6 and 10.4.1. An example of the quality control checks undertaken for each key category is provided in the excel workbooks available for download with this report from the Ministry for the Environment's website.

Annex 7: Uncertainty analysis (Table 6.1 of the IPCC Good Practice Guidance)

Uncertainty estimates are an essential element of a complete emissions inventory. The purpose of uncertainty information is not to dispute the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice (IPCC, 2000). Good practice guidance also notes that inventories prepared following the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003) will typically contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable N_2O fluxes from soils and waterways (IPCC, 2000).

New Zealand has included a Tier 1 uncertainty analysis as required by the UNFCCC inventory guidelines (UNFCCC, 2006) and IPCC good practice guidance (IPCC, 2000 and 2003). Uncertainties in the categories are combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. LULUCF categories have been included using the absolute value of any removals of CO_2 (Table A7.1). Table A7.2 calculates the uncertainty only in emissions, ie, excluding LULUCF removals.

A7.1 Tier 1 uncertainty calculation

The uncertainty in activity data and emission/removal factors shown in Table A7.1 and A7.2 are equal to half the 95 per cent confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95 per cent confidence interval is that the value corresponds to the familiar plus or minus value when uncertainties are loosely quoted as "plus or minus x per cent". Where uncertainty is highly asymmetrical, the larger percentage difference between the mean and the confidence limit is entered. Where only the total uncertainty is known for a category then:

- If uncertainty is correlated across years, the uncertainty is entered as emission or removal factor uncertainty and 0 in activity data uncertainty.
- If uncertainty is not correlated across years, the uncertainty is entered as uncertainty in activity data and 0 in emission or removal factor uncertainty.

In the Tier 1 methodology, uncertainties in the trend are estimated using two sensitivities:

- Type A sensitivity: the change in the difference in the national total between the base year and the current year, expressed as a percentage, resulting from a 1 per cent increase in emissions of a given source category and gas in both the base year and the current year.
- Type B sensitivity: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting 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 will be associated with Type A sensitivities, and uncertainties that are not correlated between years will be associated with Type B sensitivities.

In Tables A7.1 and A7.2, the figure labelled “uncertainty in the trend” is an estimate of the total uncertainty in the trend, calculated from the entries above by summing the squares of all the entries and taking the square root. The values for the individual categories are an estimate of the uncertainty introduced into the trend by the category in question.

Table A7.1 Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990–2006 including LULUCF removals (IPCC Tier 1)

Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990 - 2006 including LULUCF (following IPCC Tier 1)

IPCC Source category	Gas	Base year emissions or absolute value of removals	Year t emissions or absolute value of removals	activity data uncertainty	emission or removal factor uncertainty	combined uncertainty	combined uncertainty as a % of the national total in year t	type A sensitivity	type b sensitvity	Uncertainty in the trend in national totals 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
Energy sector	CO_2	22640.92	32865.18	5	0	5	1.53	0.0494	0.3869	0.0000	2.7360	2.74
Industrial processes sector	CO_2	2,728.50	3,519.01	5	0	5	0.16	0.0008	0.0414	0.0000	0.2930	0.29
LULUCF sector - forest land	CO_2	21539.20	27987.36	5	25	25	6.64	0.0085	0.3295	0.2119	2.3299	2.34
LULUCF sector other land use categories	CO_2	1404.86	1601.97	15	184	185	2.75	-0.0021	0.0189	-0.3821	0.4001	0.55
CRF6C-waste incineration	CO_2	12.80	3.76	10	40	41	0.00	-0.0001	0.0000	-0.0059	0.0006	0.01
Energy sector	CH_4	708.03	931.39	5	50	50	0.44	0.0004	0.0110	0.0207	0.0775	0.08
CRF2A - mineral products	CH_4	0.00	0.00									
CRF2B - chemical industry	CH_4	20.16	16.98	0	80	80	0.01	-0.0001	0.0002	-0.0080	0.0000	0.01
CRF4A - enteric fermentation	CH_4	21810.44	24110.67	2	53	53	11.89	-0.0411	0.2839	-2.1773	0.8029	2.32
CRF4B - manure management	CH_4	578.59	743.13	2	100	100	0.69	0.0001	0.0087	0.0126	0.0247	0.03
CRF4E- prescribed burning	CH_4	2.73	0.88	20	60	63	0.00	0.0000	0.0000	-0.0018	0.0003	0.00
CRF4F - burning of residues	CH_4	21.38	11.01	50	40	64	0.01	-0.0002	0.0001	-0.0076	0.0092	0.01
LULUCF sector	CH_4	42.68	49.36	10	35	36	0.02	-0.0001	0.0006	-0.0019	0.0082	0.01
CRF 6A - Solid waste disposal	CH_4	2121.53	1475.39	0	20	20	0.27	-0.0142	0.0174	-0.2849	0.0000	0.28
CRF 6B - wastewater handling	CH_4	222.73	209.88	0	20	20	0.04	-0.0008	0.0025	-0.0170	0.0000	0.02
CRF6C-waste incineration	CH_4	0.01	0.00	10	100	100	0.00	0.0000	0.0000	0.0000	0.0000	0.00
Energy sector	N_2O	150.18	272.73	5	50	50	0.13	0.0010	0.0032	0.0486	0.0227	0.05
Solvents-N_2O use	N_2O	41.54	40.30	10	0	10	0.00	-0.0001	0.0005	0.0000	0.0067	0.01
CRF4D -Agricultural soils	N_2O	10039.82	12733.15	5	73	73	8.67	0.0003	0.1499	0.0207	1.0600	1.06
CRF4B - manure management	N_2O	38.04	65.02	5	100	100	0.06	0.0002	0.0008	0.0199	0.0054	0.02
CRF4E- prescribed burning	N_2O	0.50	0.16	20	60	63	0.00	0.0000	0.0000	-0.0003	0.0001	0.00
CRF4F - burning of residues	N_2O	7.36	3.60	50	40	64	0.00	-0.0001	0.0000	-0.0027	0.0030	0.00
LULUCF sector	N_2O	4.92	15.12	10	35	36	0.01	0.0001	0.0002	0.0037	0.0025	0.00
CRF6B - wastewater handling	N_2O	146.92	167.40	0	1200	1200	1.87	-0.0002	0.0020	-0.2625	0.0000	0.26
CRF6C-waste incineration	N_2O	1.66	1.37	10	100	100	0.00	0.0000	0.0000	-0.0009	0.0002	0.00
CRF2F	HFCs	0.00	592.95	120	50	130	0.72	0.0070	0.0070	0.3490	1.1847	1.24
CRF2C	PFCs	641.68	90.89	0	30	30	0.03	-0.0085	0.0011	-0.2548	0.0000	0.25
CRF2F	SF_6	12.33	13.24	5	20	21	0.00	0.0000	0.0002	-0.0006	0.0011	0.00
Total emissions/removals		**84939.53**	**107521.91**		**Uncertainty in the year**		**16.6%**		**Uncertainty in the trend**			**4.6%**

Table A7.2 Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990–2006 excluding LULUCF removals (IPCC Tier 1)

Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990 - 2006 excluding LULUCF removals (following IPCC Tier 1)

IPCC Source category	Gas	Base year emissions	Year t emissions	activity data uncertainty	emission factor uncertainty	combined uncertainty	combined uncertainty as a % of the total emissions in year t	type A sensitivity	type b sensitvity	Uncertainty in the trend in national totals introduced by emission factor uncertainty	Uncertainty in trend in national total introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions
Energy sector	CO_2	22640.92	32865.18	5	0	5	2.11	0.0708	0.5301	0.0000	3.7485	3.75
Industrial processes sector	CO_2	2,728.50	3,519.01	5	0	5	0.23	0.0014	0.0568	0.0000	0.4014	0.40
CRF6C-waste incineration	CO_2	12.80	3.76	10	40	41	0.00	-0.0002	0.0001	-0.0080	0.0009	0.01
Energy sector	CH_4	708.03	931.39	5	50	50	0.60	0.0007	0.0150	0.0333	0.1062	0.11
CRF2A - mineral products	CH_4	0.00	0.00									
CRF2B - chemical industry	CH_4	20.16	16.98	0	80	80	0.02	-0.0001	0.0003	-0.0108	0.0000	0.01
CRF4A - enteric fermentation	CH_4	21810.44	24110.67	2	53	53	16.41	-0.0531	0.3889	-2.8169	1.1000	3.02
CRF4B - manure management	CH_4	578.59	743.13	2	100	100	0.95	0.0003	0.0120	0.0255	0.0339	0.04
CRF4E- prescribed burning	CH_4	2.73	0.88	20	60	63	0.00	0.0000	0.0000	-0.0025	0.0004	0.00
CRF4F - burning of residues	CH_4	21.38	11.01	50	40	64	0.01	-0.0003	0.0002	-0.0102	0.0126	0.02
LULUCF sector	CH_4	42.68	49.36	10	35	36	0.02	-0.0001	0.0008	-0.0024	0.0113	0.01
CRF 6A - Solid waste disposal	CH_4	2121.53	1475.39	0	20	20	0.38	-0.0192	0.0238	-0.3843	0.0000	0.38
CRF 6B - wastewater handling	CH_4	222.73	209.88	0	20	20	0.05	-0.0011	0.0034	-0.0226	0.0000	0.02
CRF6C-waste incineration	CH_4	0.01	0.00	10	100	100	0.00	0.0000	0.0000	0.0000	0.0000	0.00
Energy sector	N_2O	150.18	272.73	5	50	50	0.18	0.0014	0.0044	0.0677	0.0311	0.07
Solvents-N_2O use	N_2O	41.54	40.30	10	0	10	0.01	-0.0002	0.0007	0.0000	0.0092	0.01
CRF4D -Agricultural soils	N_2O	10039.82	12733.15	5	73	73	11.96	0.0018	0.2054	0.1322	1.4523	1.46
CRF4B - manure management	N_2O	38.04	65.02	5	100	100	0.08	0.0003	0.0010	0.0277	0.0074	0.03
CRF4E- prescribed burning	N_2O	0.50	0.16	20	60	63	0.00	0.0000	0.0000	-0.0005	0.0001	0.00
CRF4F - burning of residues	N_2O	7.36	3.60	50	40	64	0.00	-0.0001	0.0001	-0.0036	0.0041	0.01
LULUCF sector	N_2O	4.92	15.12	10	35	36	0.01	0.0001	0.0002	0.0050	0.0034	0.01
CRF6B - wastewater handling	N_2O	146.92	167.40	0	1200	1200	2.58	-0.0003	0.0027	-0.3346	0.0000	0.33
CRF6C-waste incineration	N_2O	1.66	1.37	10	100	100	0.00	0.0000	0.0000	-0.0012	0.0003	0.00
CRF2F	HFCs	0.00	592.95	120	50	130	0.99	0.0096	0.0096	0.4782	1.6231	1.69
CRF2C	PFCs	641.68	90.89	0	30	30	0.03	-0.0115	0.0015	-0.3463	0.0000	0.35
CRF2F	SF_6	12.33	13.24	5	20	21	0.00	0.0000	0.0002	-0.0007	0.0015	0.00
Total emissions/removals		**61995.47**	**77932.57**		**Uncertainty in the year**		**20.6%**		**Uncertainty in the trend**			**5.4%**

Annex 8: Supplementary information under Article 7.1 of the Kyoto Protocol

No major changes have occurred to New Zealand's national system since the 2007 inventory submission. The registry administrator information has changed since the initial report was submitted in August 2006. Updated details, as supplied to the ITL Administrator by New Zealand's national focal point on 30 January 2008, are detailed below.

Registry Administrator

Name	Shirley Flaherty	Anita Dahya
Position	Group Manager	Project Manager
Organisation	Ministry of Economic Development	Ministry of Economic Development
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The New Zealand Emission Units Register (the national registry) has received our assigned amount of 309,564,733 metric tonnes and is ready for transactions using the Kyoto mechanisms. There was no transfer or acquisition of units in 2007. If units are transferred or acquired under the Kyoto mechanisms during the 2008 calendar year New Zealand will report these transactions in the 2009 inventory submission through the SEF report.

Information on emissions and removals from activities under Article 3.3 and information under Article 3.14 will be reported in New Zealand's inventory submission from 2010.