Ministry for the
Environment
Manatū Mō Te Taiao

# New Zealand's Greenhouse Gas Inventory 1990–2007

New Zealand Government

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

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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 also forms an 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, land use, land-use change and forestry (LULUCF), and waste.

Only human-induced emissions and removals of greenhouse gases are reported in the inventory. This submission in 2009 includes a complete time series of emissions and removals from 1990 through to 2007 (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. Through the first commitment period of the Kyoto Protocol, supplementary information needs to be included in the inventory. In this inventory submission, New Zealand has reported supplementary information under the Kyoto Protocol in Annex 8. This includes information on transactions of Kyoto Protocol units during the 2008 calendar year.

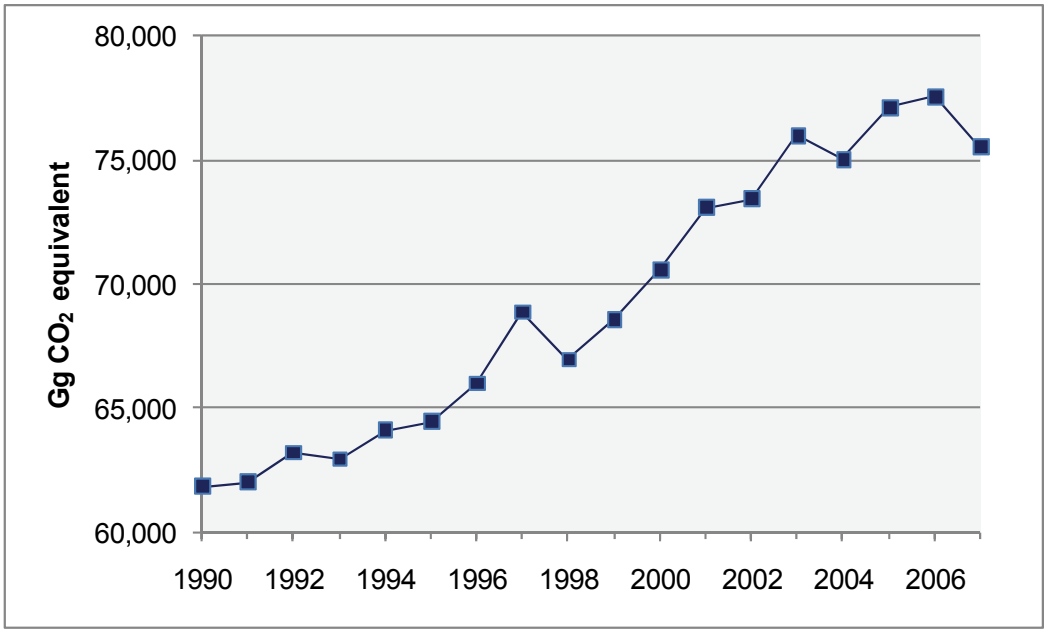
## National trends in New Zealand's emissions and removals

In 1990, New Zealand's total greenhouse gas emissions were 61,852.8 Gg $CO_2$ equivalent ($CO_2$-e). In 2007, total greenhouse gas emissions were 75,550.2 Gg $CO_2$-e equating to a 13,697.4 Gg $CO_2$-e (22.1 per cent) rise in emissions since 1990 (Figure 1.1). Net removals of $CO_2$ through forest sinks increased from 18,138.5 Gg $CO_2$ in 1990 to 23,836.0 Gg $CO_2$ in 2007.

Between 2006 and 2007 emissions decreased 2,048.9 Gg $CO_2$-e (2.6 per cent). This was due to two major factors. The first was a drought throughout the summer and autumn of 2007/2008. The drought affected many regions, leading to reduced livestock numbers and productivity. The reduction in livestock population, especially in sheep and deer, led to a 679.8 Gg $CO_2$-e (2.7 per cent) decrease in $CH_4$ emissions. Decreases in livestock productivity led to a 381.4 Gg $CO_2$-e (3.0 per cent) decrease in $N_2O$ emissions.

The second factor was the commissioning of Genesis Energy's combined cycle gas turbine at Huntly and the corresponding reduction in coal-fired electricity generation. This led to a decrease in emissions in the public electricity and heat production subcategory of 1,449.5 Gg $CO_2$-e (17.9 per cent) between 2006 and 2007.

**Figure 1.1 New Zealand's total greenhouse gas emissions from 1990 to 2007**




The predominant greenhouse gases emitted by New Zealand have changed since 1990. Whereas $CH_4$ and $CO_2$ contributed equally to New Zealand's emissions in 1990, in 2007 $CO_2$ was the major greenhouse gas in New Zealand's emissions profile (Table 1.1). This growth in emissions of $CO_2$ reflects the growth in emissions from the energy sector compared to the agriculture sector.

**Table 1.1 New Zealand's emissions of greenhouse gases in 1990 and 2007**

| Greenhouse gas emissions | Gg $CO_2$-equivalent | | Change from 1990 (Gg $CO_2$-equivalent) | Change from 1990 (%) |
|---|---|---|---|---|
| | 1990 | 2007 | | |
| $CO_2$ (excluding LULUCF) | 25,337.6 | 35,231.5 | 9,893.9 | 39.0 |
| $CH_4$ (excluding LULUCF) | 25,428.5 | 26,560.1 | 1,131.6 | 4.5 |
| $N_2O$ (excluding LULUCF) | 10,429.3 | 12,845.6 | 2,416.3 | 23.2 |
| HFCs | 0.0 | 856.6 | 856.6 | NA |
| PFCs | 642.2 | 41.7 | -600.5 | -93.5 |
| $SF_6$ | 15.2 | 14.7 | -0.5 | -3.3 |
| **Total** | **61,852.8** | **75,550.2** | **13,697.4** | **22.1** |

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

## Source and sink category emission estimates and trends

New Zealand's emissions profile is unique amongst developed nations. In 2007, 36,430.0 Gg $CO_2$-e (48.2 per cent) of total emissions were produced by the agriculture sector (Figure 1.2). By comparison, emissions from agriculture are typically 11 per cent of total emissions for 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. In 2007, emissions from the agriculture sector were 3,918.9 Gg $CO_2$-e (12.1 per cent) above the 1990 level of 32,511.1 Gg $CO_2$-e (Table 1.2 and Figure 1.3).

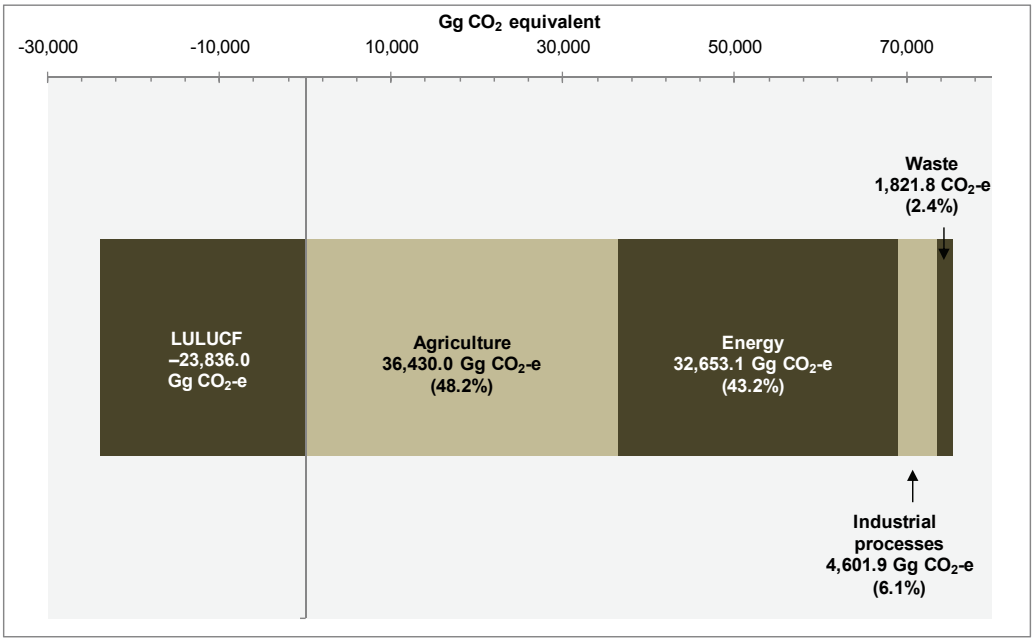
The energy sector is the other large component of New Zealand's emissions profile, comprising 32,653.1 Gg $CO_2$-e (43.2 per cent) of total emissions in 2007. Emissions from the energy sector were 9,200.3 Gg $CO_2$-e (39.2 per cent) above the 1990 level of 23,452.8 Gg $CO_2$-e (Table 1.2 and Figure 1.3). The growth in energy emissions since 1990 has primarily been from the road transport subcategory (an increase of 5,832.9 Gg $CO_2$-e or 76.2 per cent) and the public electricity and heat production subcategory (an increase of 3,167.9 Gg $CO_2$-e or 91.3 per cent). Emissions from thermal electricity generation vary from year to year depending on the water resources available for hydro generation, as 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 6.1 per cent and 2.4 per cent respectively of all greenhouse gas emissions in 2007. Due to improvements in solid waste disposal, emissions from the waste sector decreased 616.4 Gg $CO_2$-e (25.3 per cent) since 1990. Emissions from industrial processes increased 1,192.7 Gg $CO_2$-e (35.0 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, sequestering 23,836.0 Gg $CO_2$-e in 2007. Net removals increased 5,697.5 Gg $CO_2$-e (31.4 per cent) from the 1990 level of 18,138.5 Gg $CO_2$-e. Variations in planting rates of forestry 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 under the Kyoto Protocol only new planting and any deforestation after 31 December 1989, enters the accounting system.

**Figure 1.2 New Zealand's total greenhouse gas emissions by sector: 2007**




**Note:** The Industrial processes emissions shown here, includes emissions from the solvent and other product-use sector.

**Figure 1.3 Change in New Zealand's sectoral emissions from 1990 to 2007**

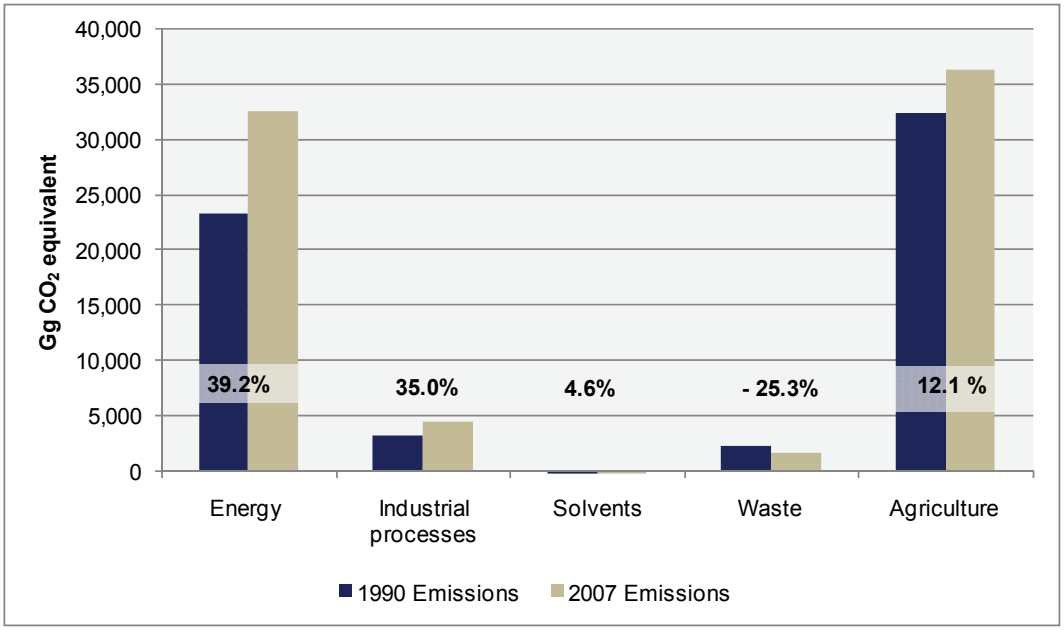



**Table 1.2 New Zealand's sectoral emissions of greenhouse gases in 1990 and 2007**

| Sector | Gg $CO_2$-equivalent | | Change from 1990 (Gg $CO_2$-equivalent) | Change from 1990 (%) |
|---|---|---|---|---|
| | 1990 | 2007 | | |
| Energy | 23,452.8 | 32,653.1 | 9,200.3 | 39.2 |
| Industrial processes | 3,409.2 | 4,601.9 | 1,192.7 | 35.0 |
| Solvent and other product use | 41.5 | 43.4 | 1.9 | 4.6 |
| Agriculture | 32,511.1 | 36,430.0 | 3,918.9 | 12.1 |
| Waste | 2,438.2 | 1,821.8 | –616.4 | –25.3 |
| Total (excluding LULUCF) | 61,852.8 | 75,550.2 | 13,697.4 | 22.1 |
| LULUCF (including $CH_4$ & $N_2O$) | –18,138.5 | –23,836.0 | –5,697.5 | 31.4 |
| **Net Total (including LULUCF)** | **43,714.3** | **51,714.2** | **7,999.9** | **18.3** |

# 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 including carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$) (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 projected that continued greenhouse gas emissions at, or above, current rates will cause further warming and induce many changes in the global climate system during the 21st century.

### 1.1.1 The United Nations Framework Convention on Climate Change

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

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

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

All countries that ratify the Climate Change Convention (henceforth called 'Parties') are required to address climate change. A part of the obligation is to monitor the trends in human-induced greenhouse gas emissions. The annual inventory of greenhouse gas emissions and removals fulfils this obligation. Parties are also obligated to protect and enhance carbon sinks (for example, forests), and implement measures that assist in national and/or regional climate change adaptation and mitigation. In addition, Parties listed as Annex II to the Climate Change Convention[1] (developed countries) commit to providing financial assistance to non-Annex I Parties.

Annex I Parties that ratified the Climate Change Convention also agreed to non-binding targets to reduce greenhouse gas emissions to 1990 levels by 2000.

[1] Annex II to the Climate Change Convention (a subset of Annex I) lists OECD member countries at the time Climate Change Convention was agreed.

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

### 1.1.2 The Kyoto Protocol

The Kyoto Protocol shares and strengthens the Climate Change Convention's objective, principles and institutions. Only Parties to the Climate Change Convention that have also become Parties to the Protocol (by ratifying, accepting, approving, or acceding to it) are bound by the Protocol's commitments. The goal is to reduce the aggregate emissions of the six greenhouse gases from Annex I Parties by at least 5 per cent below 1990 levels in the first commitment period (2008–2012). New Zealand's target is to ensure that average emissions over the first commitment period of the Kyoto Protocol are less than or equal to emissions in 1990.

Article 3 of the Kyoto Protocol states that 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 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 emitted in 1990 multiplied by five. The assigned amount does not include emissions and removals from the land use, land-use change and forestry sector (LULUCF) unless this sector was a source of emissions in 1990.

New Zealand's assigned amount is recorded as 309,564,733 metric tonnes $CO_2$ equivalent. 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). This report was 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, the time series of emissions and removals reported in each inventory submission are subject to change due to continuous improvement. Consequently, the level of emissions in 1990 reported in this submission is different (0.8 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 by removing $CO_2$ presently in the atmosphere by maintaining and increasing carbon sinks (for example, planting forests). Carbon sinks that meet Kyoto Protocol requirements create removal units. The removal units are added to a Party's assigned amount at the end of the first commitment period.

The Kyoto Protocol also defined three "flexibility mechanisms" to lower the overall costs of achieving its commitments. These are Clean Development Mechanism (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. 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 supplementary information with the submission of the annual greenhouse gas inventory. This becomes mandatory for the 1990–2008 inventory to be submitted in 2010, as this includes the first reporting year of the first commitment period. However, in order to fully participate in Kyoto mechanisms, a Party must submit a greenhouse gas inventory (required under the Climate Change Convention in 2007) that is complete with the appropriate supplementary information, and continue to do so until reporting is completed for all years of the commitment period.

The supplementary 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.

Annex 8 to this submission contains New Zealand's supplementary information under the Kyoto Protocol.

## 1.1.3 A national greenhouse gas inventory

New Zealand's greenhouse gas inventory is the official annual report of all human-caused emissions and removals of greenhouse gases in New Zealand. The inventory measures New Zealand's progress against New Zealand's obligations under the Climate Change Convention (Articles 4 and 12) and under 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 decisions are FCCC/SBSTA/2006/9 (UNFCCC, 2006). A complete inventory submission requires two components: the national inventory report and the common reporting format tables. Inventories are subject to an annual three-stage international expert review process administered by the Climate Change Convention secretariat. The reports from these reviews are available online (www.unfccc.int).

The inventory reports emissions and removals of the gases $CO_2$, $CH_4$, $N_2O$, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride ($SF_6$). The gases are reported under six sectors: energy, industrial processes, solvent and other product use, agriculture, land use, land-use change and forestry (LULUCF), and waste. 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 61,852.8 Gg $CO_2$-e. In 2007, total greenhouse gas emissions were 75,550.2 Gg $CO_2$-e, equating to a 13,697.4 Gg $CO_2$-e (22.1 per cent) rise since 1990. Net removals of $CO_2$ through forest sinks increased 31.4 per cent from 18,138.5 Gg $CO_2$-e in 1990 to 23,836.0 Gg $CO_2$-e in 2007.

Agricultural emissions contributed 48.2 per cent of New Zealand's total emissions in 2007. The large proportion of agricultural emissions creates a unique greenhouse gas

emission profile for New Zealand. In other developed countries the majority of emissions come from electricity production, transport and industrial processes.

In 2007, emissions from the energy sector accounted for 43.2 per cent of New Zealand's total emissions. The energy sector experienced the highest rate of growth in emissions of any sector, increasing 39.2 per cent from 1990 to 2007. 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 contributed 67 per cent of New Zealand's electricity generation in 2007 (Ministry of Economic Development, 2008b). 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).

Between 1990 and 2007, New Zealand's predominant greenhouse gases changed. Whereas $CH_4$ and $CO_2$ contributed equally to New Zealand's emissions in 1990, $CO_2$ was the major greenhouse gas in New Zealand's emissions profile in 2007 (Table 1.1). Growing emissions of $CO_2$ reflects the larger growth in emissions from the energy sector compared to the agriculture sector.

## 1.2 Institutional arrangements

The Climate Change Response Act (2002 – updated 26 September 2008) enables New Zealand to meet its international obligations under the Climate Change Convention and the Kyoto Protocol. Prime ministerial directive for the administration of the Climate Change Response Act names the Ministry for the Environment as New Zealand's "Inventory Agency". The Climate Change Response Act specifies the primary functions of the inventory agency, are to:

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

In carrying out its functions, the inventory agency must:

- identify source categories
- collect data by means of:
  - voluntary collection
  - collection from government agencies and other agencies that hold relevant information
  - collection in accordance with regulations made under this Part (if any)

- estimate the emissions and removals by sinks for each source category
- undertake assessments on uncertainties
- undertake procedures to verify the data
- retain information and documents to show how the estimates were determined.

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

### Inventory team

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

The Ministry for the Environment calculates estimates of emissions for the waste sectors and emissions and removals from the LULUCF sector.

The Ministry of Economic Development 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 surveys by consultants, contracted to the Ministry for the Environment.

The Ministry of Agriculture and Forestry provides some of the statistics for the agriculture sector and much of the data for removals from planted forestry in the LULUCF sector. In this submission, the Ministry of Agriculture and Forestry compiled the agriculture sector and provided increased input in compiling the LULUCF sector. Estimates provided by the Ministry of Agriculture and Forestry, 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

Consistent with the Climate Change Convention reporting guidelines, each inventory report is 15 months in arrears of the calendar year reported, allowing time for data to be collected and analysed. Sector-based data analysis, data entry into the Climate Change Convention common reporting format database, and quality checking occurs over the period October–December. The national inventory report is also updated over this three-month time period.

Once the sector-based emissions estimates are updated, the national inventory compiler at the Ministry for the Environment calculates the inventory uncertainty, undertakes the key

category assessment and further quality checking, and finalises the national inventory report. The inventory is reviewed within the Ministry for the Environment, Ministry of Economic Development and Ministry of Agriculture and Forestry before being approved and submitted to the Climate Change Convention secretariat.

The inventory and all required data for the submission to the Climate Change Convention secretariat are stored on the Ministry for the Environment's central computer network in a controlled file system. The inventory is available from the websites of the Ministry for the Environment and the Climate Change Convention.

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

## 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 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 Ministry of Economic Development and Statistics New Zealand (refer to Chapter 3 and Annex 2). New Zealand-specific emission factors are used for $CO_2$ emission calculations. Applicable IPCC default factors are used for non-$CO_2$ emissions where New Zealand emission factors are not available.

***Industrial processes and solvent and other product use:*** Activity data and $CO_2$ emissions are supplied directly to the Ministry of Economic Development by industry sources. The IPCC Tier 2 approach is used and emission factors are New Zealand specific. Activity data for the non-$CO_2$ gases are collected via an industry survey. Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach and $SF_6$ emissions from large users are assessed via the Tier 3a approach (IPCC, 2006).

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

***Land use, land-use change and forestry:*** The LULUCF sector 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 cropland, grassland, wetland, settlements and other land categories. Changes in land area for these categories are based on modified national land-cover databases reclassified to the IPCC LULUCF categories. At the time of compiling this

submission, this was 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 will further provide consistency 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 the model from the IPCC 2006 guidelines. A mix of New Zealand-specific and IPCC default parameters are used. Methane and $N_2O$ emissions from domestic and industrial wastewater handling are calculated using a refinement of the IPCC methodology (IPCC, 1996). There is no incineration of municipal waste in New Zealand. Emissions from incineration from medical, quarantine and hazardous wastes are estimated using the Tier 1 approach (IPCC, 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, and 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 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 2007 year are summarised in Table 1.5.1. The major contributions to the level analysis including LULUCF (Table 1.5.2) were $CH_4$ from enteric fermentation in domestic livestock (23.0 per cent), $CO_2$ from conversion to forest land (15.0 per cent) and $CO_2$ from road transportation (13.1 per cent).

The key categories that were identified as having the largest relative influence on New Zealand's emissions trend in 2007, including LULUCF, (Table 1.5.3), were $CO_2$ emissions from road transportation (20.5 per cent), $CH_4$ emissions from enteric fermentation in domestic livestock (18.7 per cent), and $CO_2$ emissions from forest land remaining forest land (12.2 per cent).

**Table 1.5.1 Summary of key categories for 2007 (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, trend |
| Emissions from the iron and steel industry | $CO_2$ | level |
| PFCs from aluminium production | PFCs | trend |
| Ammonia production | $CO_2$ | qualitative |
| Consumption of halocarbons and $SF_6$ - refrigeration & air conditioning | HFCs & PFCs | 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 | $CO_2$ | trend |
| Conversion to forest land | $CO_2$ | level, trend |
| Conversion to grassland | $CO_2$ | trend |
| Cropland remaining cropland | $CO_2$ | level |
| Conversion to cropland | $CO_2$ | trend |
| **Waste sector** | | |
| Emissions from solid waste disposal sites | $CH_4$ | level, trend |

## Table 1.5.2 (a & b) Key category analysis for 2007 – Tier 1 level assessment including LULUCF (a) and excluding LULUCF (b)

| (a) Tier 1 Category Level Assessment - including LULUCF | | | | |
|---|---|---|---|---|
| **IPCC Categories** | **Gas** | **2007 estimate (Gg $CO_2$-e)** | **Level assessment** | **Cumulative total** |
| Emissions from enteric fermentation in domestic livestock | $CH_4$ | 23326.38 | 23.0 | 23.0 |
| Conversion to forest land | $CO_2$ | 15253.73 | 15.0 | 38.0 |
| Mobile combustion - road vehicles | $CO_2$ | 13281.35 | 13.1 | 51.1 |
| Forest land remaining forest land | $CO_2$ | 9311.50 | 9.2 | 60.3 |
| Emissions from stationary combustion - gas | $CO_2$ | 8723.65 | 8.6 | 68.9 |
| Emissions from agricultural soils - animal production | $N_2O$ | 7346.67 | 7.2 | 76.1 |
| Emissions from stationary combustion - solid | $CO_2$ | 4473.87 | 4.4 | 80.5 |
| Indirect emissions from nitrogen used in agriculture | $N_2O$ | 3270.66 | 3.2 | 83.8 |
| Emissions from stationary combustion - liquid | $CO_2$ | 2644.94 | 2.6 | 86.4 |
| Direct emissions from agricultural soils | $N_2O$ | 1680.74 | 1.7 | 88.0 |
| Emissions from the iron and steel industry | $CO_2$ | 1646.24 | 1.6 | 89.7 |
| Emissions from solid waste disposal sites | $CH_4$ | 1437.95 | 1.4 | 91.1 |
| Mobile combustion - aviation | $CO_2$ | 915.10 | 0.9 | 92.0 |
| Consumption of halocarbons and $SF_6$ - refrigeration and air conditioning | HFCs & PFCs | 779.64 | 0.8 | 92.7 |
| Fugitive emissions from oil and gas operations | $CO_2$ | 754.57 | 0.7 | 93.5 |
| Emissions from manure management | $CH_4$ | 729.10 | 0.7 | 94.2 |
| Emissions from cement production | $CO_2$ | 687.90 | 0.7 | 94.9 |
| Cropland remaining cropland | $CO_2$ | 649.67 | 0.6 | 95.5 |

| (b) Tier 1 Category Level Assessment - excluding LULUCF | | | | |
|---|---|---|---|---|
| **IPCC Categories** | **Gas** | **2007 estimate (Gg $CO_2$-e)** | **Level assessment** | **Cumulative total** |
| Emissions from enteric fermentation in domestic livestock | $CH_4$ | 23326.38 | 30.9 | 30.9 |
| Mobile combustion - road vehicles | $CO_2$ | 13281.35 | 17.6 | 48.5 |
| Emissions from stationary combustion - gas | $CO_2$ | 8723.65 | 11.6 | 60.1 |
| Emissions from agricultural soils - animal production | $N_2O$ | 7346.67 | 9.7 | 69.8 |
| Emissions from stationary combustion - solid | $CO_2$ | 4473.87 | 5.9 | 75.7 |
| Indirect emissions from nitrogen used in agriculture | $N_2O$ | 3270.66 | 4.3 | 80.1 |
| Emissions from stationary combustion - liquid | $CO_2$ | 2644.94 | 3.5 | 83.6 |
| Direct emissions from agricultural soils | $N_2O$ | 1680.74 | 2.2 | 85.8 |
| Emissions from the iron and steel industry | $CO_2$ | 1646.24 | 2.2 | 88.0 |
| Emissions from solid waste disposal sites | $CH_4$ | 1437.95 | 1.9 | 89.9 |
| Mobile combustion - aviation | $CO_2$ | 915.10 | 1.2 | 91.1 |
| Consumption of halocarbons and $SF_6$ - refrigeration and air conditioning | HFCs & PFCs | 779.64 | 1.0 | 92.1 |
| Fugitive emissions from oil and gas operations | $CO_2$ | 754.57 | 1.0 | 93.1 |
| Emissions from manure management | $CH_4$ | 729.10 | 1.0 | 94.1 |
| Emissions from cement production | $CO_2$ | 687.90 | 0.9 | 95.0 |

**Table 1.5.3 Key category analysis for 2007 – 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 $CO_2$-e)** | **2007 estimate (Gg $CO_2$-e)** | **Trend assessment** | **Contribution to trend** | **Cumulative total** |
| Mobile combustion - road vehicles | $CO_2$ | 7516.28 | 13281.35 | 0.032 | 20.5 | 20.5 |
| Emissions from enteric fermentation in domestic livestock | $CH_4$ | 21818.97 | 23326.38 | 0.029 | 18.7 | 39.1 |
| Forest land remaining forest land | $CO_2$ | 5614.43 | 9311.50 | 0.019 | 12.2 | 51.3 |
| Emissions from agricultural soils - animal production | $N_2O$ | 6853.06 | 7346.67 | 0.009 | 5.8 | 57.0 |
| Emissions from solid waste disposal sites | $CH_4$ | 2063.21 | 1437.95 | 0.009 | 5.7 | 62.7 |
| Direct emissions from agricultural soils | $N_2O$ | 487.19 | 1680.74 | 0.009 | 5.5 | 68.3 |
| Conversion to forest land | $CO_2$ | 13059.41 | 15253.73 | 0.007 | 4.5 | 72.8 |
| Emissions from stationary combustion - gas | $CO_2$ | 7691.22 | 8723.65 | 0.006 | 4.0 | 76.8 |
| Consumption of halocarbons and $SF_6$ - refrigeration and air conditioning | HFCs & PFCs | 0.00 | 779.64 | 0.006 | 4.0 | 80.8 |
| PFCs from aluminium production | PFCs | 642.22 | 40.27 | 0.006 | 3.9 | 84.7 |
| Emissions from stationary combustion - solid | $CO_2$ | 3139.65 | 4473.87 | 0.005 | 3.0 | 87.7 |
| Emissions from stationary combustion - liquid | $CO_2$ | 2505.28 | 2644.94 | 0.004 | 2.3 | 90.0 |
| Fugitive emissions from oil and gas operations | $CO_2$ | 263.75 | 754.57 | 0.003 | 2.2 | 92.2 |
| Fugitive emissions from geothermal operations | $CO_2$ | 376.16 | 301.47 | 0.001 | 0.8 | 93.1 |
| Conversion to grassland | $CO_2$ | 482.70 | 436.83 | 0.001 | 0.8 | 93.9 |
| Emissions from cement production | $CO_2$ | 441.67 | 687.90 | 0.001 | 0.7 | 94.6 |
| Conversion to cropland | $CO_2$ | 37.35 | 128.68 | 0.001 | 0.4 | 95.0 |

| (b) Tier 1 Category Trend Assessment - excluding LULUCF | | | | | | |
|---|---|---|---|---|---|---|
| **IPCC Categories** | **Gas** | **Base year estimate (Gg $CO_2$-e)** | **2007 estimate (Gg $CO_2$-e)** | **Trend assessment** | **Contribution to trend** | **Cumulative total** |
| Mobile combustion - road vehicles | $CO_2$ | 7516.28 | 13281.35 | 0.045 | 26.6 | 26.6 |
| Emissions from enteric fermentation in domestic livestock | $CH_4$ | 21818.97 | 23326.38 | 0.036 | 21.3 | 48.0 |
| Direct emissions from agricultural soils | $N_2O$ | 487.19 | 1680.74 | 0.012 | 7.0 | 55.0 |
| Emissions from solid waste disposal sites | $CH_4$ | 2063.21 | 1437.95 | 0.012 | 7.0 | 62.0 |
| Emissions from agricultural soils - animal production | $N_2O$ | 6853.06 | 7346.67 | 0.011 | 6.6 | 68.6 |
| Consumption of halocarbons and $SF_6$ - refrigeration and air conditioning | HFCs & PFCs | 0.00 | 779.64 | 0.008 | 5.1 | 73.6 |
| PFCs from aluminium production | PFCs | 642.22 | 40.27 | 0.008 | 4.8 | 78.5 |
| Emissions from stationary combustion - gas | $CO_2$ | 7691.22 | 8723.65 | 0.007 | 4.3 | 82.7 |
| Emissions from stationary combustion - solid | $CO_2$ | 3139.65 | 4473.87 | 0.007 | 4.2 | 86.9 |
| Emissions from stationary combustion - liquid | $CO_2$ | 2505.28 | 2644.94 | 0.004 | 2.7 | 89.6 |
| Fugitive emissions from oil and gas operations | $CO_2$ | 263.75 | 754.57 | 0.005 | 2.8 | 92.4 |
| Fugitive emissions from geothermal operations | $CO_2$ | 376.16 | 301.47 | 0.002 | 1.0 | 93.4 |
| Emissions from cement production | $CO_2$ | 441.67 | 687.90 | 0.002 | 1.0 | 94.4 |
| Consumption of halocarbons and $SF_6$ - aerosols and metered dose inhalers | HFCs & PFCs | 0.00 | 75.57 | 0.001 | 0.5 | 94.8 |
| Fugitive emissions from coal mining and handling | $CH_4$ | 272.13 | 261.83 | 0.001 | 0.5 | 95.3 |

# 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 Ministry for the Environment developed a QA/QC plan in 2004, as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006), to formalise, document and archive the QA/QC procedures. The plan is annually updated in conjunction with New Zealand's inventory improvement plan. As a result of recommendations from recent reviews, New Zealand has increased QA/QC activities for this submission. Details are discussed in sections 1.6.1 and 1.6.2 below.

## 1.6.1 Quality control

For this inventory submission, the Ministry for the Environment used IPCC Tier 1 QC check sheets. The Tier 1 checks are based on the procedures suggested in the good practice guidance (IPCC, 2000). All key categories for the 2007 inventory year were checked.

Recent reviews under the Climate Change Convention have 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 this inventory submission, all sector-level data was entered into the common reporting format database by January 2009. The earlier deadline allowed two months for further quality checking at the sector level (between data spreadsheets and the common reporting format tables) and checking consistency between the common reporting format tables and the national inventory report. Corrections were made to any errors.

An additional person was contracted into the inventory team at the Ministry for the Environment from December through to February to complete quality checks on key categories for the 2007 inventory year. Checks included ensuring the data from the spreadsheets and models was accurately transferred to the common reporting format database and data from the database was accurately represented in the draft national inventory report. No significant errors within the source data spreadsheets or between the spreadsheets and the common reporting format database and the draft national inventory report were identified.

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

### 1.6.2 Quality assurance

New Zealand's inventory system is progressively improving its quality control and assurance system to ensure quality is built in at all stages of the inventory compilation process. In 2008, KMPG, a contractor, developed a risk register to highlight potential risks in the inventory data compilation process. The Ministry for the Environment will continue to use the risk register to assist in prioritising further improvements to the inventory.

For this submission, improvements focussed on building the capacity of the national inventory system. This involved recruitment within the national inventory team and providing documentation for the national inventory compiler role. This has lowered the risk of losing specialised knowledge of New Zealand's national inventory system.

Quality assurance reviews of individual sectors and categories were included in the national inventory plan and commissioned by the Ministry for the Environment. A list of previous quality assurance reviews, their major conclusions and follow up are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/).

Most of the energy and agriculture activity data is provided by Statistics New Zealand, who conducts its own rigorous quality assurance and quality control procedures on the data.

### 1.6.3 The Climate Change Convention annual inventory review

New Zealand's inventory was reviewed in 2001 and 2002 as part of a pilot study of the technical review process (UNFCCC, 2001a; 2001b; 2001c; 2003). The inventory was subject to detailed in-country, centralised and desk review procedures. The inventories submitted for the years 2001 and 2003 were reviewed in a centralised review process. The

2004 inventory was reviewed as part of the Kyoto Protocol initial review. This was an in-country review held from 19–24 February 2007. The 2007 and 2008 inventory submissions were reviewed during a centralised review in September 2008. In all instances, the reviews were conducted by an international team of experts review team nominated by Parties to the Climate Change Convention. Review reports are available from the Climate Change Convention website (www.unfccc.int).

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

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

New Zealand's consistency in meeting the reporting requirements allowed it to be one of the first four Parties to be eligible to participate in the Kyoto Protocol mechanisms. New Zealand's registry, the official transactions and balance of New Zealand's Kyoto units, was operational on 1 January 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.

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

The calculated uncertainty for New Zealand's total inventory (emissions and removals) in 2007 is ±16.7 per cent. The uncertainty in the overall trend from 1990 to 2007 is lower at ±4.5 per cent. The uncertainty in total emissions (excluding removals) is ±20.6 per cent, with ±5.5 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 comprised 12.2 per cent and 8.9 per cent respectively of New Zealand's total emissions and removals uncertainty in 2007. The uncertainty in these categories reflected 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 were also a major contribution to the uncertainty for 2007 at 6.2 per cent of New Zealand's total emissions and removals. In comparison, the uncertainty in $CO_2$ emissions from burning of fossil fuels was only 1.6 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 2.2 per cent, and $N_2O$ from agricultural soils with 1.1 per cent.

In most instances, the uncertainty values are determined by 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 2007 inventory.

# 1.8 Inventory completeness

The New Zealand inventory for the period 1990–2007 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 national inventory report and in the common reporting format tables.

The LULUCF data is 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 this data. Estimates using this system will be included in the 2010 inventory submission. Development of the LUCAS will also reduce uncertainty by using New Zealand-specific emission and removal factors, and will 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) stipulate that the 100-year global warming potentials contained in the IPCC Second Assessment Report (IPCC, 1995) are used in national inventories. The indirect effects on global warming of a number of gases (CO, $NO_x$, $SO_2$ and NMVOCs) cannot currently be quantified, and, consequently, these gases do not have global warming potentials. In accordance with the Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases that do not have global warming potentials are reported in the inventory but are not included in the inventory emissions total.

## Common Global Warming Potentials (100-year time period)

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

| | |
|---|---|
| $CO_2$ = 1 | HFC-32 = 650 |
| $CH_4$ = 21 | HFC-125 = 2,800 |
| $N_2O$ = 310 | HFC-134a = 1,300 |
| $CF_4$ = 6,500 | HFC-143a = 3,800 |
| $C_2F_6$ = 9,200 | HFC-227ea = 2,900 |
| $SF_6$ = 23,900 | |

## Conversion factors

| From element basis to molecular mass | From molecular mass to element basis |
|---|---|
| C → $CO_2$: C × 44/12 (3.67) | $CO_2$ → C: $CO_2$ × 12/44 (0.27) |

| | |
|---|---|
| $C \rightarrow CH_4$: C × 16/12 (1.33) | $CH_4 \rightarrow C$: $CO_2$ × 12/16 (0.75) |
| $N \rightarrow N_2O$: N × 44/28 (1.57) | $N_2O \rightarrow N$: $N_2O$ × 28/44 (0.64) |

## Notation keys

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

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

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

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

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

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

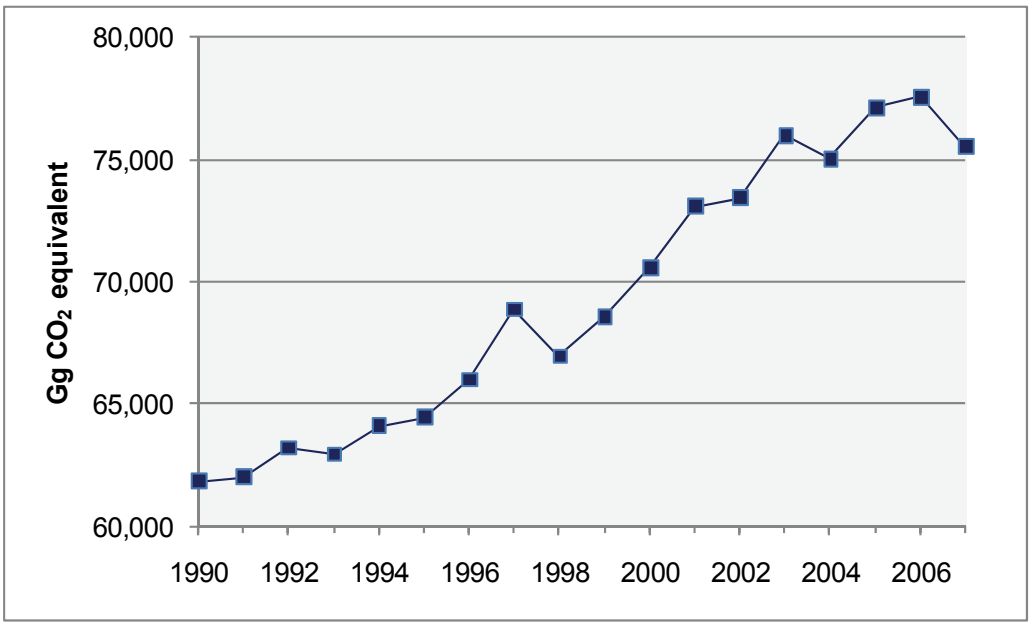
# Chapter 2: Trends in greenhouse gas emissions

## 2.1 Emission trends for aggregated greenhouse gas emissions

In 1990, New Zealand's total greenhouse gas emissions were 61,852.8 Gg carbon dioxide equivalent ($CO_2$-e). In 2007, total greenhouse gas emissions had increased by 13,697.4 Gg $CO_2$-e (22.1 per cent) to 75,550.2 Gg $CO_2$-e (Figure 2.1.1). Between 1990 and 2007, the average annual growth in overall emissions was 1.3 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.

**Figure 2.1.1 New Zealand's total greenhouse gas emissions from 1990 to 2007**




## 2.2 Emission trends by gas

Inventory reporting under the Climate Change Convention covers six direct greenhouse gases: $CO_2$, methane ($CH_4$), nitrous oxide ($N_2O$), sulphur hexafluoride ($SF_6$), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). Figure 2.2.1 shows New Zealand's 2007 profile by gas. Figure 2.2.3 shows the change in each direct greenhouse gas between 1990 and 2007. Trends in $CO_2$, $CH_4$ and $N_2O$ emissions over the period 1990–2007 are shown in Figure 2.2.3. In accordance with the Climate Change Convention reporting guidelines (UNFCCC, 2006), indirect greenhouse gases are included in inventory reporting but not in the national emissions 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 $CO_2$ from the atmosphere are reported in the LULUCF sector.

Carbon dioxide contributed the largest share of all 2007 emissions at 35,231.5 Gg $CO_2$-e (46.6 per cent). Carbon dioxide emissions increased 9,893.9 Gg $CO_2$-e (39.1 per cent) from the 1990 level of 25,337.6 Gg $CO_2$-e. Between 2006 and 2007, $CO_2$ emissions decreased 1,012.9 Gg $CO_2$-e (3.0 per cent). This was due to the commissioning of Genesis's Energy combined gas turbine at Huntly leading to a corresponding reduction in coal-fired electricity generation.

Methane (excluding LULUCF) contributed 26,560.1 Gg $CO_2$-e (35.2 per cent) of total emissions in 2007. Methane emissions grew by 1,131.6 Gg $CO_2$-e (4.5 per cent) from the 1990 level of 25,428.5 Gg $CO_2$-e. Between 2006 and 2007, $CH_4$ emissions decreased 1,012.9 Gg $CO_2$-e (2.8 per cent). This was due to a drought throughout the summer and autumn of 2007/2008. The drought affected many regions, leading to reduced livestock numbers and productivity. The reduction in livestock population, especially in sheep and deer, led to a 679.8 Gg $CO_2$-e (2.7 per cent) decrease in $CH_4$ emissions.

Nitrous oxide (excluding LULUCF) contributed 12,845.6 Gg $CO_2$-e (17.0 per cent) of emissions in 2007. Emissions increased by 2,416.3 Gg $CO_2$-e (23.2 per cent) from the 1990 level of 10,429.3 Gg $CO_2$-e. Between, 2006 and 2007 emissions decreased 383.2 Gg $CO_2$-e (2.9 per cent). This was due to the drought affecting livestock productivity. Nitrous oxide emission from the agriculture sector decreased 381.4 Gg $CO_2$-e (3.0 per cent).

Perfluorocarbons, $SF_6$ and HFCs contributed the remaining 913.0 Gg $CO_2$-e (1.2 per cent) of emissions in 2007.

Emissions of PFCs have decreased 600.5 Gg $CO_2$-e (93.5 per cent) from the 642.2 Gg $CO_2$-e in 1990, to 41.7 Gg $CO_2$-e in 2007.

Emissions of $SF_6$ have decreased 0.5 Gg $CO_2$-e (3.3 per cent), from the 1990 level of 15.2 Gg $CO_2$-e to the 2007 level of 14.7 Gg $CO_2$-e.

In 1990, no HFCs were used in New Zealand. In 2007, 856.6 Gg $CO_2$-e of HFC emissions were produced.

The growth in $CO_2$ emissions from 1990 and 2006 represented the increased emissions from the energy sector, particularly in road transport and energy generation. The growth in $N_2O$ is from the increase in emissions from animal excreta and the increase in the 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 2007. Emissions of PFCs have decreased due to improvements in the aluminium smelting process. Hydrofluorocarbon emissions have increased because of their use 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 Table 2.2.1 and Figure 2.2.1.

**Table 2.2.1 New Zealand's greenhouse gas emissions in 1990 and 2007**

| Greenhouse gas emissions | Gg $CO_2$-equivalent | | Change from 1990 (Gg $CO_2$-equivalent) | Change from 1990 (%) |
|---|---|---|---|---|
| | 1990 | 2007 | | |
| $CO_2$ (excluding LULUCF) | 25,337.6 | 35,231.5 | 9,893.9 | 39.0 |
| $CH_4$ (excluding LULUCF) | 25,428.5 | 26,560.1 | 1,131.6 | 4.6 |
| $N_2O$ (excluding LULUCF) | 10,429.3 | 12,845.6 | 2,416.3 | 23.2 |
| HFCs | 0.0 | 856.6 | 856.6 | NA |
| PFCs | 642.2 | 41.7 | -600.5 | -93.5 |
| $SF_6$ | 15.2 | 14.7 | -0.5 | -3.3 |
| **Total** | **61,852.8** | **75,550.2** | **13,697.4** | **22.1** |

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

**Figure 2.2.1 New Zealand's total greenhouse gas emissions by gas: 2007**

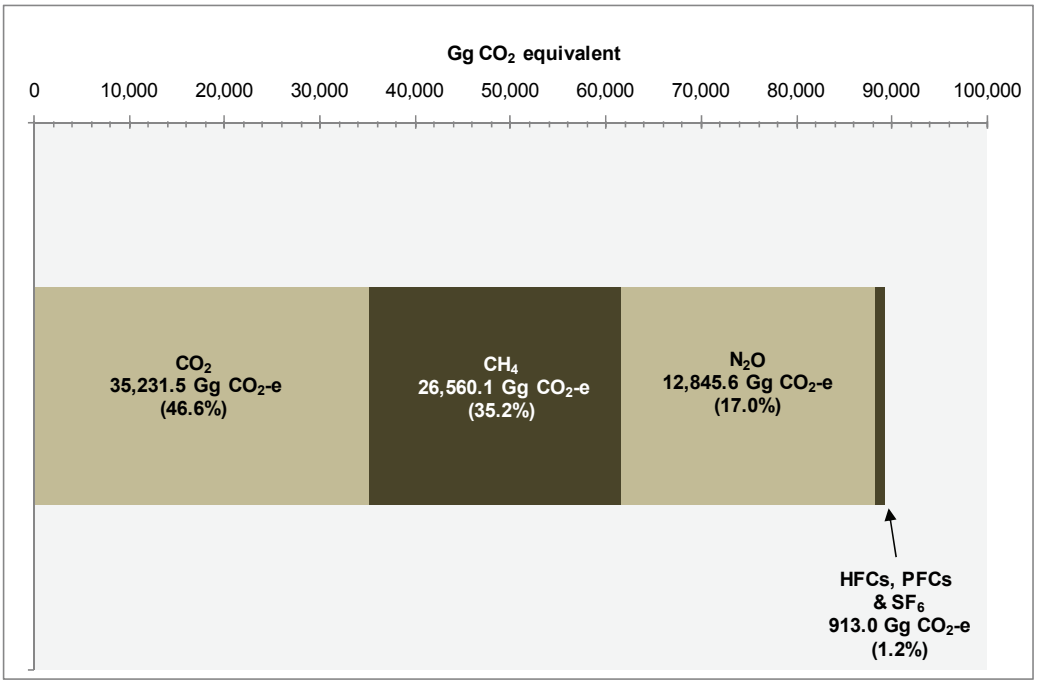
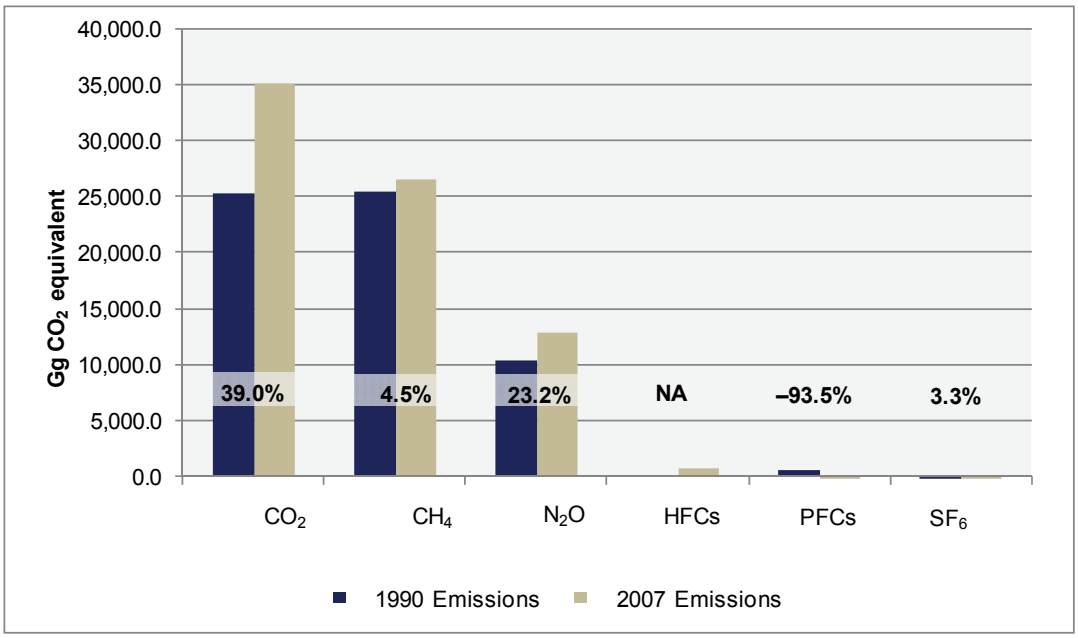
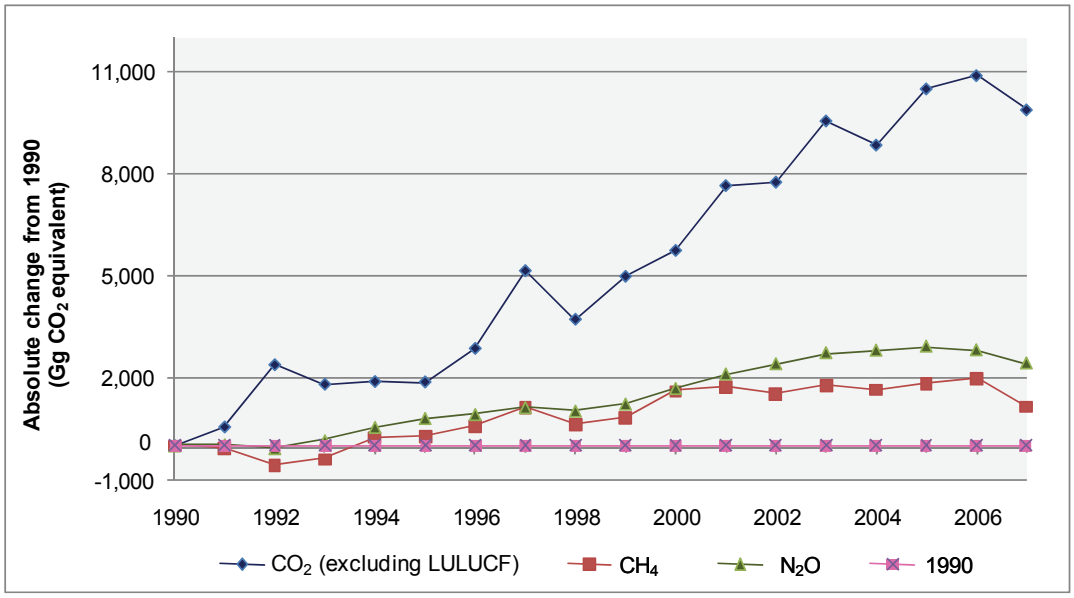


**Figure 2.2.2 Change in New Zealand's emissions 1990 to 2007 by gas**




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

**Figure 2.2.3 Change in New Zealand's emissions of $CO_2$, $CH_4$, and $N_2O$ from 1990 to 2007**




# 2.3 Emission trends by source

The agriculture sector was the largest source of emissions, contributing 36,430.0 Gg $CO_2$-e (48.2 per cent) of total emissions in 2007 (Table 2.3.1 and Figure 2.3.1). Consequently, New Zealand has a unique emissions profile. In other developed countries, agricultural emissions are typically around 11 per cent of national emissions. In 2007, New Zealand's agricultural emissions had increased by 3,918.9 Gg $CO_2$-e

(12.1 per cent) from the 1990 level of 32,511.1 Gg $CO_2$-e (Figure 2.3.2). The agriculture sector contributed 12,360.5 Gg $CO_2$-e (96.2 per cent) of New Zealand's total $N_2O$ emissions and 24,069.5 Gg $CO_2$-e (90.6 per cent) of total $CH_4$ emissions in 2007.

Between 2006 and 2007, emissions from the agriculture sector decreased 1,061.2 Gg $CO_2$-e (2.8 per cent) (Figure 2.3.3). This was due to a drought throughout the summer and autumn of 2007/2008. The drought affected many regions, leading to reduced livestock numbers and productivity. The reduction in livestock population, especially in sheep and deer, led to a 679.8 Gg $CO_2$-e (2.7 per cent) decrease in $CH_4$ emissions. Decreases in livestock productivity led to a 3.0 per cent (381.4 Gg $CO_2$-e) decrease in $N_2O$ emissions.

The energy sector was the source of 32,653.1 Gg $CO_2$-e (43.2 per cent) of total emissions in 2007. In 2007, energy emissions had increased by 9,200.3 Gg $CO_2$-e (39.2 per cent) from the 1990 level of 23,452.8 Gg $CO_2$-e. This growth in emissions was primarily from electricity generation, heat production and transport.

Between 2006 and 2007, emissions from the energy sector decreased 1,357.5 Gg $CO_2$-e (4.0 per cent). This was due to the commissioning of Genesis Energy's combined cycle gas turbine at Huntly and the corresponding reduction in coal-fired electricity generation.

The industrial processes sector accounted for 4,601.9 Gg $CO_2$-e (6.1 per cent) of total emissions in 2007. Emissions from the industrial processes sector had increased 1,192.7 Gg $CO_2$-e (35.0 per cent) from the 1990 level of 3,409.2 Gg $CO_2$-e. This increase is mainly due to growth in emissions from metal production and due to the consumption of hydrofluorocarbons.

Between 2006 and 2007, emissions from the industrial processes sector increased by 368.1 Gg $CO_2$-e (8.7 per cent). This was caused by two factors. Firstly, there was an increase in HFCs and PFCs used as replacement refrigerants for CFCs and HCFCs, in refrigeration and air-conditioning equipment. Secondly, one cement company was running at full production in 2007.

In 2007, the solvent and other product use sector was a minor contributor to New Zealand's total greenhouse gas emissions. It was responsible for 43.4 Gg $CO_2$-e (less than 1 per cent) of total emissions in 2007.

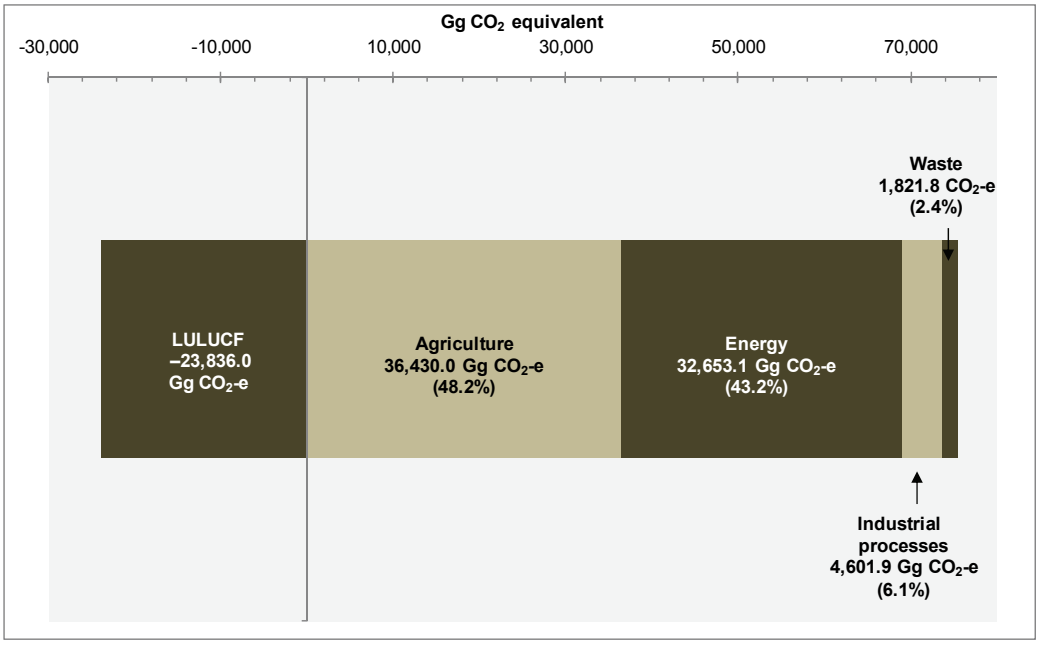
The waste sector accounted for 1,821.8 Gg $CO_2$-e (2.4 per cent) of total emissions in 2007. Emissions from the waste sector had decreased by 616.4 Gg $CO_2$-e (25.3 per cent) from the 1990 level of 2,438.2 Gg $CO_2$-e. This decrease is due to initiatives to improve solid waste management practices in New Zealand.

Under the LULUCF sector, net removals were estimated to be 23,836.0 Gg $CO_2$-e in 2007. LULUCF removals had increased by 5,697.5 Gg $CO_2$-e (31.4 per cent) from the 1990 level of 18,138.5 Gg $CO_2$-e. LULUCF removals fluctuate with the planting and harvesting of New Zealand's planted forest.

### Table 2.3.1 New Zealand's sectoral emissions of greenhouse gases in 1990 and 2007

| Sector | Gg $CO_2$-equivalent 1990 | Gg $CO_2$-equivalent 2007 | Change from 1990 (Gg $CO_2$-equivalent) | Change from 1990 (%) |
|---|---|---|---|---|
| Energy | 23,452.8 | 32,653.1 | 9,200.3 | 39.2 |
| Industrial processes | 3,409.2 | 4,601.9 | 1,192.7 | 35.0 |
| Solvent and other product use | 41.5 | 43.4 | 1.9 | 4.5 |
| Agriculture | 32,511.1 | 36,430.0 | 3,918.9 | 12.1 |
| Waste | 2,438.2 | 1,821.8 | –616.4 | –25.3 |
| Total (excluding LULUCF) | 61,852.8 | 75,550.2 | 13,697.4 | 22.1 |
| LULUCF (including $CH_4$ & $N_2O$) | –18,138.5 | –23,836.0 | –5,697.5 | 31.4 |
| **Net Total (including LULUCF)** | **43,714.3** | **51,714.2** | **7,999.9** | **18.3** |

### Figure 2.3.1 New Zealand's total greenhouse gas emissions by sector: 2007




**Note:** The Industrial processes emissions shown here, includes emissions from the solvents and other product use sector.

**Figure 2.3.2 Change in New Zealand's sectoral greenhouse gas emissions from 1990 to 2007**

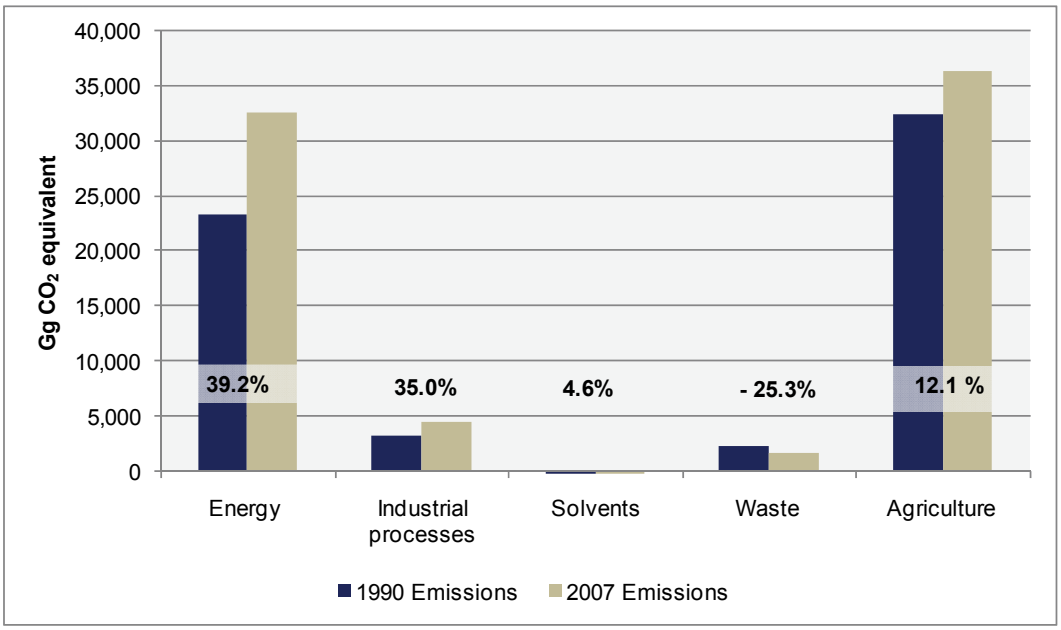
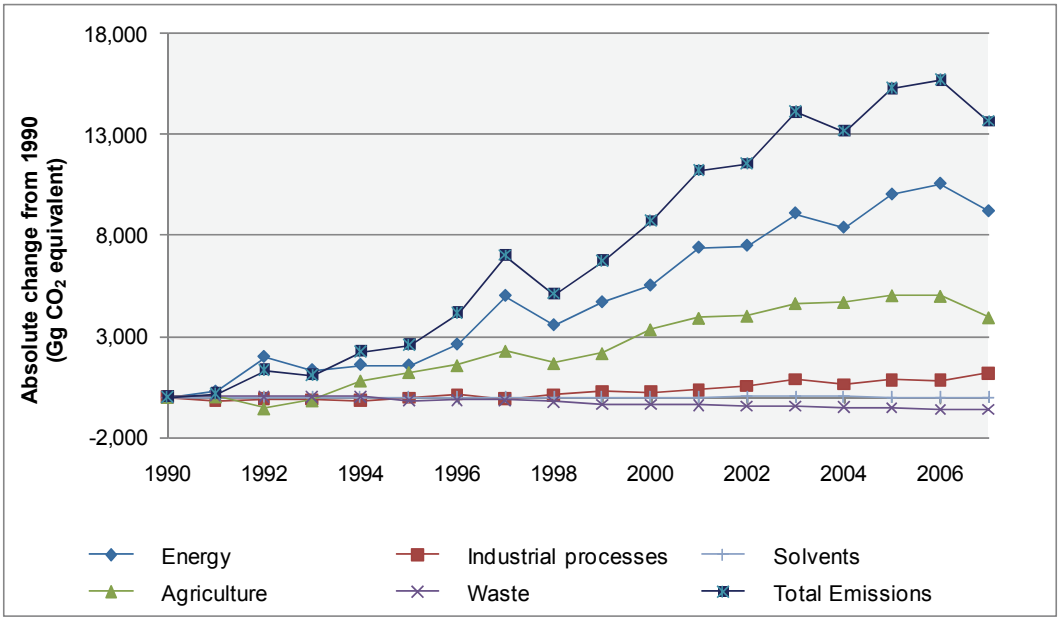



**Figure 2.3.3 Change in New Zealand's sectoral greenhouse gas emissions from 1990 to 2007**




# 2.4 Emission trends for indirect greenhouse gases and $SO_2$

The indirect greenhouse gas emissions $SO_2$, CO, $NO_x$ and NMVOC are also reported in the inventory. Emissions of these gases in 1990 and 2007 are shown in Table 2.4.1. There were increases in the emissions of all of these gases. Indirect greenhouse gases do not account towards New Zealand's greenhouse gas emissions total.

**Table 2.4.1 New Zealand's emissions of indirect greenhouse gases in 1990 and 2007**

| Gas | Gg of gas(es) | | Change from 1990 (Gg) | Change from 1990 (%) |
|---|---|---|---|---|
| | 1990 | 2007 | | |
| $NO_x$ | 108.2 | 158.8 | 50.6 | 46.8 |
| CO | 561.4 | 738.0 | 176.6 | 31.4 |
| NMVOC | 132.1 | 174.4 | 42.3 | 32.0 |
| $SO_2$ | 53.5 | 72.7 | 19.2 | 35.9 |
| **Total** | **855.2** | **1,143.9** | **288.7** | **33.8** |

Emissions of CO and $NO_x$ are largely from the energy sector. The energy sector produced 89.2 per cent of total CO emissions in 2007. The largest single source of CO emissions was from the road transportation subcategory. Similarly, the energy sector was the largest source of $NO_x$ emissions (97.9 per cent), with the road transportation subcategory dominating. Other large sources of $NO_x$ emissions were from the manufacturing industries, construction and energy industries subcategories.

The energy sector was also the largest producer of NMVOCs, producing 71.8 per cent of NMVOC emissions in 2007. Emissions from road transportation comprised 61.9 per cent of total NMVOC emissions. Other major sources of NMVOC were in the solvent and other product use sector (19.8 per cent) and the industrial processes sector (8.4 per cent).

In 2007, emissions of $SO_2$ from the energy sector comprised 84.0 per cent of total $SO_2$ emissions. The energy industries category contributed 18.7 per cent, manufacturing industries and construction, 29.8 per cent, and the transport category, 17.7 per cent, of total $SO_2$ emissions. The industrial processes sector contributed 16.0 per cent of $SO_2$. Aluminium production accounted for 9.7 per cent of $SO_2$ emissions.

# Chapter 3: Energy

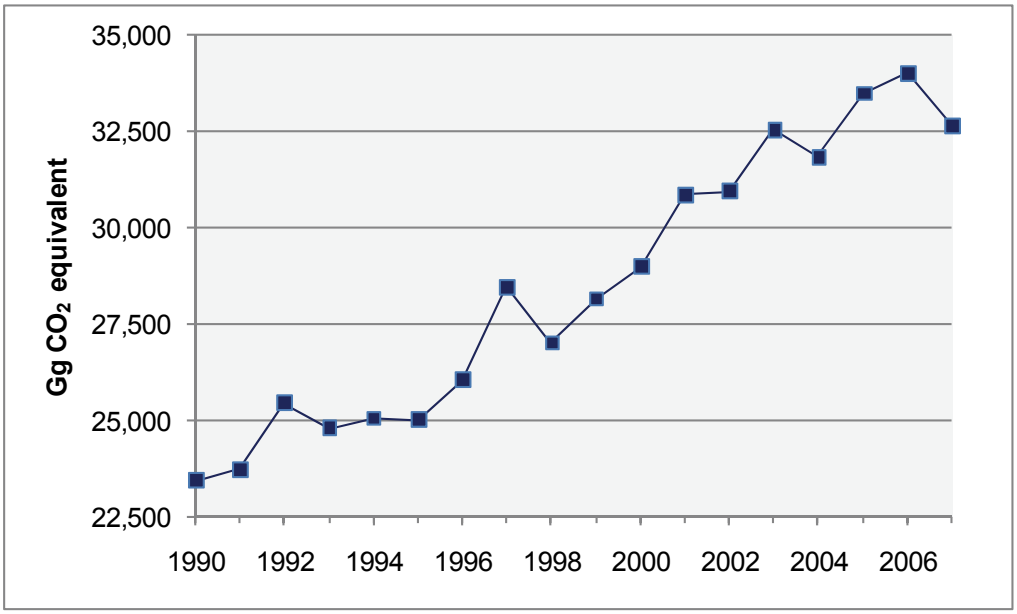
## 3.1 Sector overview

The energy sector produced 32,653.1 Gg carbon dioxide equivalent ($CO_2$-e) in 2007, representing 43.2 per cent of New Zealand's total greenhouse gas emissions. Emissions from the energy sector were 39.2 per cent (9,200.3 Gg $CO_2$-e) above the 1990 level of 23,452.8 Gg $CO_2$-e (Figure 3.1.1). The sources contributing most to this increase are emissions from the public electricity and heat production subcategory, an increase of 3,167.9 Gg $CO_2$-e (91.3 per cent), and the road transportation subcategory, an increase of 5,832.9 Gg $CO_2$-e (76.2 per cent). Emissions from the manufacture of solid fuels and the other energy industries subcategory have decreased by 1,442.2 Gg $CO_2$-e (–81.2 per cent) from 1990. This decrease is primarily due to the cessation of synthetic petrol production in 1997. Carbon dioxide emissions from the stationary combustion of solid, liquid and gaseous fuels were identified as key categories (level and trend) in 2007.

### Changes in emissions between 2006 and 2007

Between 2006 and 2009, emissions from the energy sector decreased by 1,357.5 Gg $CO_2$-e (4.0 per cent). This was due to the commissioning of Genesis Energy's combined cycle gas turbine at Huntly and the corresponding reduction in coal-fired electricity generation.

**Figure 3.1.1 New Zealand's energy sector emissions from 1990 to 2007**




## 3.2 Fuel combustion (CRF 1A)

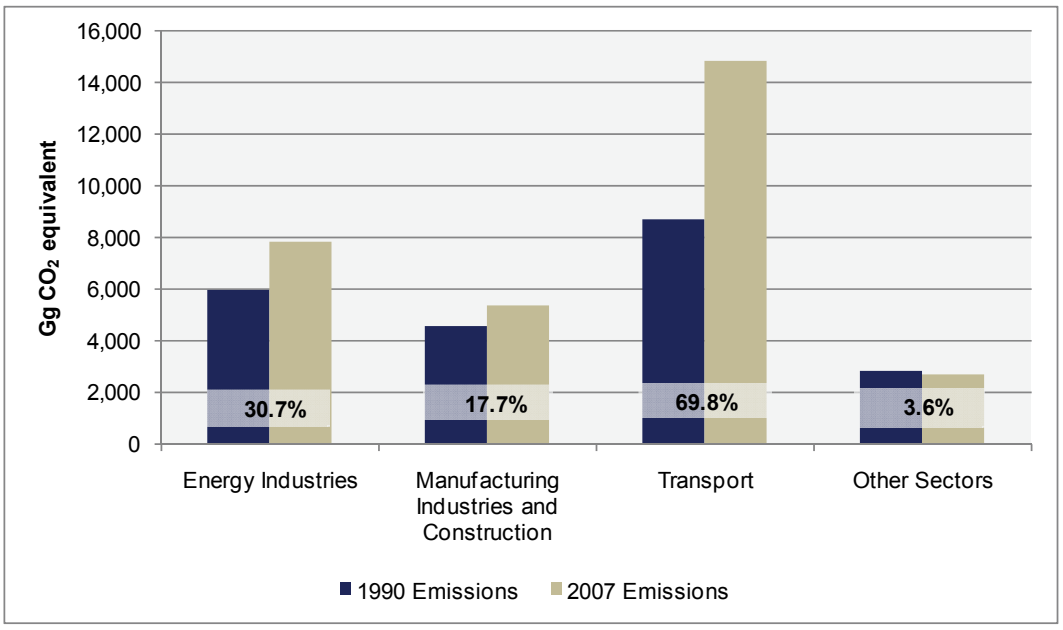
### Description

The fuel combustion category reports all fuel combustion activities from energy industries, manufacturing industries and construction, transport and other sectors subcategories (Figure 3.2.1). These subcategories use common activity data sources and emission factors. The common reporting tables require energy emissions to be reported

by subcategory. Apportioning energy activity data across subcategories is not as accurate as apportioning activity data by fuel type because of difficulties in allocating liquid fuel to the appropriate subcategories.

The activity data and emissions estimates for 2007 are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/). 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 New Zealand's emissions from the fuel combustion categories from 1990 to 2007: fuel combustion**




## Methodological issues

Energy activity data is compiled using the Ministry of Economic Development's energy database along with relevant New Zealand-specific emission factors. Greenhouse gas emissions are calculated by multiplying the emission factor of specific fuels by the activity data. A minority of emission factors are not able to be reported due to confidentiality reasons. These emission factors have been reported as confidential in the common reporting format tables.

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

### *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. The volume of petroleum fuels is based on weight, in tonnes. In previous inventory submissions, a single calorific value

was applied to convert the weight values into energy terms (petajoules). In the 2008 inventory submission, improvements were made to the data by applying year-specific calorific values to petrol and diesel data. For this inventory submission, year-specific calorific values were applied to all liquid fuel data. The Ministry of Economic Development updated the data to a time series of calorific values to better reflect changes in liquid fuel properties over time.

### *Activity data – solid fuels*

Statistics New Zealand also conducts the *New Zealand Coal Sales Survey* as a quarterly survey under the Statistics Act 1975. The survey covers coalmines and major resellers of coal in New Zealand. The three grades of coal estimated are bituminous, sub-bituminous and lignite coal. The coal sales questionnaire separates coal sales into seven end-use sectors. The sectoral shares of coal use that can be used for the inventory are based on CRL Energy Ltd's survey of sectoral coal use for 1990 and 1995. Data was interpolated between 1990 and 1995. The exceptions were for the coal used for iron and steel, residential household and the public electricity and heat production subcategories. The Ministry of Economic Development receives this information directly from companies.

Sectoral shares of coal were 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 Energy's annual coal tonnage for each sector by the total (excluding exports, steel, electricity and residential coal use), to provide sectoral shares of coal use for 1990 and 1995
- interpolating sectoral shares between 1990 and 1995
- year-specific calorific values for the different grades of coal were provided by CRL Energy Ltd between 1995 and 2007.

The 1995 calorific value was adopted for the years 1990–1994 in the absence of other data. This updated data has been incorporated in this inventory submission.

Further improvements in this inventory submission are that a consistent time series for three grades of coal were estimated instead of four grades of coal (bituminous, sub-bituminous, lignite, peat/coke) reported in previous submissions. Better alignment between the reference and sectoral approaches was achieved by including peat/coke under the bituminous grade.

### *Activity data – gaseous fuels*

The Ministry of Economic Development receives activity data on gaseous fuel from a variety of sources. Individual gas field operators provide information on the amount of gas extracted, vented and flared at each gas field. Vector Ltd provides data on processed gas, including the Kapuni gas field, and information on gas transmission and distribution throughout New Zealand. Large uses of gas, including electricity generation companies, provide their activity data directly to the Ministry of Economic Development. Finally, the Ministry of Economic Development surveys retailers and wholesalers on a quarterly basis to obtain activity data from small industrial, commercial and residential gas users.

### *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 (ie, 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 in 2003 (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 New Zealand-specific emission factors used in previous inventories. Where a New Zealand-specific value is not available, New Zealand uses either the IPCC value that best reflects New Zealand conditions or the mid-point value from the IPCC range. All emission factors from the 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 the IPCC default emission factors for $CH_4$ emissions in road transport. The default IPCC factor has been used since the 2007 inventory submission following a recommendation by the international expert review team.

### *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 fuel emission factors derived from the NZRC data on carbon content and calorific values. The liquid fuel emission factors are available on an annual basis. Improvements on emission factors have also been made when the fuel specifications of liquid fuels change, such as lower sulphur content of diesel oil in 2006.

### *Emission factors – solid fuels*

In previous inventory submissions, New Zealand's emissions from coal combustion in the public electricity and heat production subcategory were calculated using the emission factor for sub-bituminous coal of 92.99 kt $CO_2$/PJ (Baines, 1993). In 2008, the electricity generator contacted the Ministry of Economic Development to request an update of this value. The assumption was made that using the overall sub-bituminous value for the public electricity and heat production subcategory (91.20 kt$CO_2$/PJ) is consistent with other coal burning activities in New Zealand. This updated emission factor is included for the whole time series (1990–2007) for the public electricity and heat production subcategory.

### *Emission factors – gaseous fuels*

In previous inventory submissions, New Zealand used the gas production from the Maui and Kapuni gas fields reported in the New Zealand Energy Data File (Ministry of Economic Development, 2008b) to support the calculation of a weighted average annual $CO_2$ emission factor for natural gas. For this inventory submission, the average emission factor was calculated based on all the gas production fields (Ministry of Economic Development, 2008b). This method is more accurate as the decline in production of both Maui and Kapuni gas fields has been replaced by other new gas fields (eg, Pohukura) coming on stream. This updated emission factor was applied to a number of categories in the energy sector eg, the manufacturing industries and construction category and the road transportation subcategory.

New Zealand has one gas field, Kapuni, with a particularly high $CO_2$ content. Historically, this field has been valued by the petrochemicals industry as a feedstock. However, most of the gas from this field is now treated and the excess $CO_2$ removed. Separate emissions' factors were 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 5 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 the carbon content of the fuel and the corresponding $CO_2$ emissions during combustion. The low level of uncertainty in $CO_2$ emissions is important as $CO_2$ emissions comprised 96.7 per cent of energy sector emissions in 2007.

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) have not quantified the uncertainty in all of 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 New Zealand's emission estimates from fuel combustion (Ministry of Economic Development, 2006)**

| Gas | Uncertainty |
|---|---|
| $CO_2$ | ± 5% |
| $CH_4$ | ± 50% |
| $N_2O$ | ± 50% |
| $NO_x$ | ± 33% |
| CO | ± 50% |
| 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, heat production, petroleum refining, the manufacture of solid fuels and other energy industries.

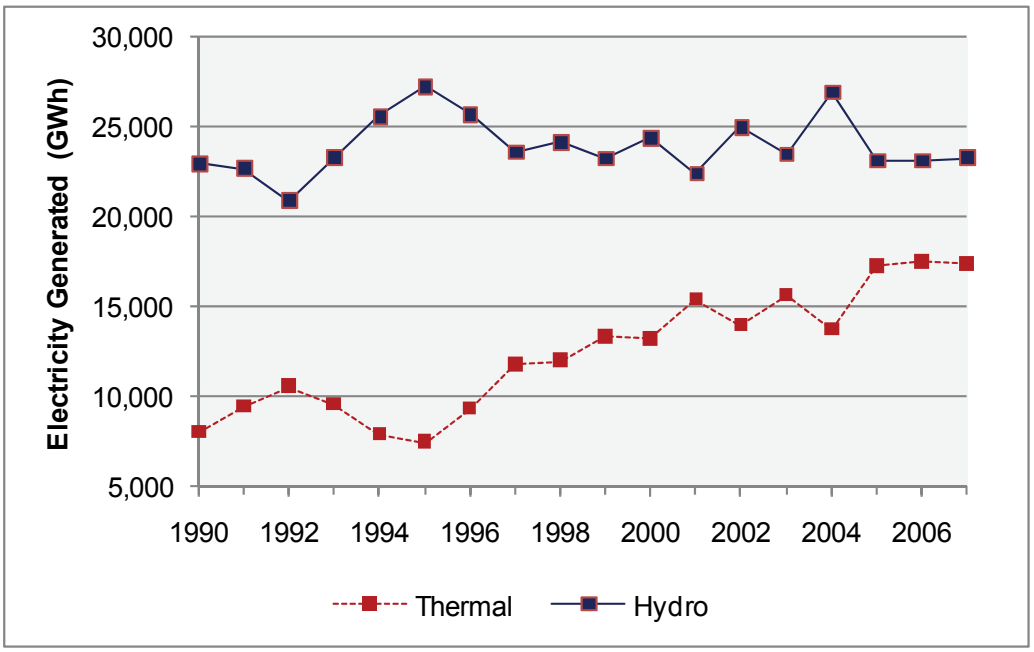
In 2007, emissions in the energy industries category totalled 7,867.4 Gg $CO_2$-e (24.1 per cent) of the energy sector. Emissions from energy industries have increased 1,849.4 Gg $CO_2$-e (30.7 per cent) since the 1990 level of 6,018.0 Gg $CO_2$-e. The public electricity and heat production subcategory accounted for 6,639.1 Gg $CO_2$-e (84.4 per cent) of the emissions from the energy industries category in 2007. This is an increase of 3,167.9 Gg $CO_2$-e (91.3 per cent) from the 1990 level of 3,471.1 Gg $CO_2$-e. Emissions from the public electricity and heat production subcategory have decreased by 17.9 per cent between 2006 and 2007. The major change influencing this reduction was the commissioning of Genesis Energy's combined cycle gas turbine at Huntly and the corresponding reduction in coal-fired generation.

New Zealand's electricity generation is dominated by hydroelectric generation. For the 2007 calendar year, hydro generation provided 55 per cent of New Zealand's electricity generation. A further 12 per cent came from other renewable sources (such as geothermal, wind and biomass) and waste heat sources. The remaining 33 per cent was provided by fossil fuel thermal generation plants using oil, gas and coal (Ministry of Economic Development, 2008b).

Greenhouse gas emissions from the public electricity and heat production subcategory show large inter-annual fluctuations, as the use of thermal power generation stations complements the hydroelectric generation available. New Zealand's hydro resources have limited storage capacity, with around 12 weeks of reservoir storage under normal circumstances (OECD/IEA, 2006). 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 shows net electricity production by fuel type from 1990 to 2007. The figure illustrates that on an annual basis when the level of hydroelectric generation decreases, the level of thermal electricity generation from fossil fuels (gas, coal and oil) increases.

**Figure 3.2.2 New Zealand's hydroelectric and thermal generation from 1990 to 2007**




## 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.

Around 7 per cent 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 the public electricity and heat production subcategory. Emissions from other co-generation plants are included within the manufacturing industries and construction category.

### *Petroleum refining*

The New Zealand Refining Company provides the Ministry of Economic Development with $CO_2$ emissions associated with activities from the petroleum refining subcategory. 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 to the Ministry of Economic Development by each individual gas field operator. Activity data for synthetic petrol production was provided by Methanex New Zealand while the plant was in operation. Production of synthetic petrol ceased in 1997.

The low implied emission factors (IEFs) for manufacturing of solid fuels and other energy industries subcategory for gaseous fuels between 1990 and 1996 were caused by the sequestration of carbon during the synthetic petrol production process.

### Uncertainties and time-series consistency

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

### 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 petajoules (PJ) of fuel for both solid and liquid fuels. For this inventory submission, year-specific calorific values have been introduced to improve the accuracy of the activity data between 1990 and 2007.

## 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 2007, emissions from the manufacturing industries and construction category accounted for 5,380.9 Gg $CO_2$-e (16.5 per cent) emissions from the energy sector. Emissions were 809.6 Gg $CO_2$-e (17.7 per cent) above the 1990 level of 4,571.3 Gg $CO_2$-e. A decline in methanol production between 2003 and 2004 caused a significant reduction in emissions from this category.

New Zealand has one methanol production plant. In order to protect the confidentiality of data from the plant, only emissions are reported in the common reporting format tables. Fuel consumption is confidential and the notation 'C', for confidential, is reported in the common reporting format tables.

Due to the confidentiality of the methanol activity data, the implied emission factor for gaseous fuel under the manufacturing industries and construction category does not fully capture the total amount of gas consumed in this category. Therefore, the implied emission factors for $CO_2$, $CH_4$ and $N_2O$ are not comparable with other countries. This also affects the gaseous fuel total for sectoral approach. The difference between the reference and sectoral approach for gaseous fuel can be explained by the unreported gas consumption data in the sectoral approach.

### Methodological issues

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

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. Carbon dioxide emissions are calculated by comparing the amount of carbon in the gas purchased by the plant with the amount stored in methanol as shown in Box 3.1.

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

Assumptions:

- Synthetic petrol is 85.8% carbon by weight.
- Methanol is 37.5% carbon by weight.
- $CO_2$ emissions factor for Maui gas is 52.2 kt/PJ (2007) (refer Annex 2).
- $CO_2$ emissions factor for Kapuni gas is 84.1 kt/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)*51.9 + (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 subcategory (including construction, food and beverage and dairy processing) was 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, 2008b). Data disaggregated by industry type, such as food processing, beverages and tobacco, is currently unavailable in New Zealand. Therefore, activity data and related emissions are reported as aggregate values under the other subcategory.

## 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 IPCC Tier 1 quality checks.

### Source-specific recalculations

In previous inventory submissions, constant calorific values were used to convert tonnes (t) of fuel to petajoules (PJ) of fuel. For this submission, year-specific calorific values have been introduced to improve the accuracy of the activity data between 1990 and 2007.

## 3.2.3 Fuel combustion: transport (CRF 1A3)

### Description

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

In 2007, the transport category was responsible for 14,877.2 Gg $CO_2$-e (45.6 per cent) of emissions from the energy sector, or 19.7 per cent of total emissions. Emissions increased 6,115.5 Gg $CO_2$-e (69.8 per cent) from the 8,761.7 Gg $CO_2$-e emitted in 1990. The transport emissions profile in 2007 was dominated by emissions from the road transportation subcategory. In 2007, road transport accounted for 13,482.7 Gg $CO_2$-e (90.6 per cent) of total transport emissions. This was an increase of 5,832.9 Gg $CO_2$-e (76.2 per cent) from the 1990 level of 7,649.9 Gg $CO_2$-e. Carbon dioxide emissions from road transport were identified as a key category (trend and level) in 2007. Carbon dioxide emissions from aviation were also identified as a key category (level) in 2007.

### Methodological issues

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

Activity data on the consumption of fuel by the transport sector came 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, 2008b).

#### *Road transportation*

The Tier 1 approach is used to calculate $CO_2$ from road transport in accordance with good practice, as this approach provides the most reliable estimate of $CO_2$ emissions (IPCC, 2000). New Zealand also uses the Tier 1 approach to estimate non-$CO_2$ emissions from road transport as data is not available to calculate emissions using the Tier 2 approach. Emission factors for $CO_2$ and non-$CO_2$ gases for the various fuel types used in the road transportation subcategory can be found in Annex 2.

#### *Railways*

For this inventory submission, emissions from railways (including both liquid and solid fuels) are estimated for the whole time series using a Tier 1 approach. New Zealand-specific emission factors are used for estimating $CO_2$ emissions and IPCC default emission factors are used for estimating $CH_4$ and $N_2O$ emissions.

#### *Navigation (domestic marine transport)*

Emissions from the navigation category in New Zealand are estimated using a Tier 1 approach with New Zealand-specific emission factors for estimating $CO_2$ emissions and IPCC default emission factors for $CH_4$ and $N_2O$.

There were no emissions from gas/diesel oil for 2007 as the sole fast ferry operator in New Zealand that used this fuel ceased operations in 2006.

*Civil aviation*

The New Zealand method for estimating emissions from the civil aviation category 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 was based on refuelling at the domestic and international terminals of New Zealand airports. New Zealand does not have the data to split the domestic and international components of fuel use for international flights with a domestic leg. This is because information on fuel use for civil aviation and navigation is only available from the oil companies rather than from the individual airlines or shipping companies.

### Uncertainties and time-series consistency

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

### Source-specific QA/QC and verification

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

### Source-specific recalculations

In the 2008 inventory submission, year-specific calorific values were applied to diesel and petrol activity data to improve accuracy. For this inventory submission, year-specific calorific values have been introduced for all liquid fuel types between 1990 and 2007.

## 3.2.4 Fuel combustion: other sectors (CRF 1A4)

### Description

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

In 2007, fuel combustion of the other sectors category accounted for 2,766.6 Gg $CO_2$-e (8.5 per cent) of the emissions from the energy sector. This is a decrease of 104.3 Gg $CO_2$-e (3.6 per cent) below the 1990 value of 2,870.9 Gg $CO_2$-e.

Emissions from the agricultural, forestry and fisheries subcategory were 1,277.3 Gg $CO_2$-e (46.2 per cent) of the other sectors category in 2007. This is an increase of 171.9 Gg $CO_2$-e (15.6 per cent) from the 1990 level of 1,105.4 Gg $CO_2$-e.

Emissions from the commercial and institutional subcategory were 917.2 Gg $CO_2$-e (33.2 per cent) of the other sectors category in 2007. This is a decrease of 244.6 Gg $CO_2$-e (21.1 per cent) from the 1990 level of 1,161.8 Gg $CO_2$-e.

Emissions from the residential subcategory were 572.1 Gg $CO_2$-e (20.7 per cent) of the other sectors category in 2007. This is a decrease of 31.6 Gg $CO_2$-e (5.2 per cent) from the 1990 level of 603.7 Gg $CO_2$-e.

### Methodological issues

Accurately partitioning energy use between categories is difficult. An example is allocating diesel consumption between the road transport and commercial/institutional

subcategories. Some transport-related emissions, particularly from commercial enterprises, may be captured under the commercial/institutional subcategory. The Ministry of Economic Development is working on improving the allocation of diesel consumption within New Zealand. It identified an anomaly in the time series between 2005 and 2006 for diesel use for road transport and commercial use. An interpolation method was used to recalculate emissions. This recalculation resulted in a small reallocation of diesel between the road transport and commercial/institutional subcategories for 2005 and 2006.

### 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).

### Source-specific QA/QC and verification

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

### Source-specific recalculations

In previous inventory submissions, constant calorific values were used to convert tonnes (t) of fuel to petajoules (PJ) of fuel. For this inventory submission, year-specific calorific values have been introduced to improve the accuracy of the activity data between 1990 and 2007.

The sixth centralised expert review report in 2008 highlighted missing estimates for gaseous fuels used in the agriculture, forestry, and fisheries subcategory for the whole time series. For this inventory submission, gas consumption and emission estimates for the subcategory have been provided for the years 2000 to 2007. No data is available prior to 2000.

### Source-specific planned improvements

During 2008, the Ministry of Economic Development investigated the allocation of liquid fuels, particularly diesel consumption between the road transport and commercial/ institutional subcategories. This work will continue in 2009.

# 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 subcategories: solid fuels and oil and natural gas.

In 2007, fugitive emissions from fuels accounted for 1,761.0 Gg $CO_2$-e (5.4 per cent) of emissions from the energy sector. This is an increase of 530.0 Gg $CO_2$-e (43.1 per cent) from the 1990 level of 1,231.0 Gg $CO_2$-e.

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

### Description

In 2007, fugitive emissions from the solid fuels subcategory produced 261.8 Gg $CO_2$-e (14.9 per cent) of emissions from the fugitive emissions category. This is a decrease of 10.3 Gg $CO_2$-e (3.8 per cent) from the 272.1 Gg $CO_2$-e reported in 1990.

New Zealand's fugitive emissions from the solid fuels subcategory are a by-product of coalmining operations. Methane is created during coal formation. The amount of $CH_4$ released during coalmining is dependant on the coal rank and the depth of the coal seam. In 2007, 71.7 per cent of the $CH_4$ from coalmining (including post-mining emissions) came from underground mining. This includes the emissions from post-under ground mining activities such as coal processing, transportation and use. There is no known flaring of $CH_4$ at coalmines and $CH_4$ is rarely captured for industrial uses. In 2007, New Zealand coal production was 4.8 million tonnes, a 17 per cent decrease from the 2006 production level of 5.8 million tonnes. This decrease was largely due to the response by New Zealand's largest coal producer to a decline in demand for exported coal (Ministry of Economic Development, 2008b).

## Methodological issues

The underground mining subcategory dominates fugitive emissions from coalmining. 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).

## Source-specific QA/QC and verification

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

## Source-specific recalculations

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 2007, fugitive emissions from the oil and natural gas subcategory totalled 1,499.2 Gg $CO_2$-e (85.1 per cent) of emissions from the fugitive emissions category. This is an increase of 540.3 Gg $CO_2$-e (56.4 per cent) from 958.8 Gg $CO_2$-e in 1990. Fugitive emissions from oil and gas operations ($CO_2$) were identified as a key category (level and trend) in 2007.

For this inventory submission, emission estimates were reallocated to the flaring combined subcategory to more accurately reflect the fact these emissions are a combination of venting and flaring emissions from oil and gas.

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 and between 2004 and 2005 is related to the drop in methanol production. Carbon dioxide previously sequestered during this separation 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, leaving some fugitive emissions as a result of incomplete combustion. There was a 19 per cent increase in emissions from processing and flaring between 2006 and 2007, in part due to the flaring at the offshore Tui gas field (Ministry of Economic Development, 2008a).

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 subcategory 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 subcategory. 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 have been excluded from the inventory. In 2007, emissions from geothermal operations were 365.9 Gg $CO_2$-e, a decrease of 66.6 Gg $CO_2$-e (15.4 per cent) since the 1990 level of 432.5 Gg $CO_2$-e. Carbon dioxide fugitive emissions from geothermal operations were identified as a key category (trend) in 2007.

### 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 Ltd, New Zealand's gas transmission company, supplies estimates of $CO_2$ released during the processing of the natural gas.

### *Gas transmission and distribution*

Carbon dioxide and $CH_4$ emissions from gas leakage occur almost exclusively from low-pressure distribution pipelines rather than from high-pressure transmission pipelines. Vector Ltd provides the estimates for these emissions from its high-pressure transmission system. In 2007, these emissions were 15 t of $CO_2$ and 120 t of $CH_4$ (Ministry of Economic Development, 2008a). 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 the oil-transport subcategory, the fuel activity data is the total New Zealand production of crude oil reported in the *Energy Data File* (Ministry of Economic Development, 2008b), 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.

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 $CO_2$ 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

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

## Source-specific recalculations

As no specific data was available to report emissions from venting and flaring activities for oil and gas exploration separately, estimates were reallocated to the combined subcategory (CRF 1B2C23).

Fugitive emissions from geothermal electricity generation have now included improved information on emissions from the Tarawera plant for the whole time series.

## 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 was performed for all years from 1990 to 2007.

The majority of the $CO_2$ emission factors for the reference approach are New Zealand specific. The natural gas emission factors used are estimated based on a production-derived, weighted average of emission factors from all gas production fields. This approach differs from previous inventory submissions, 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.

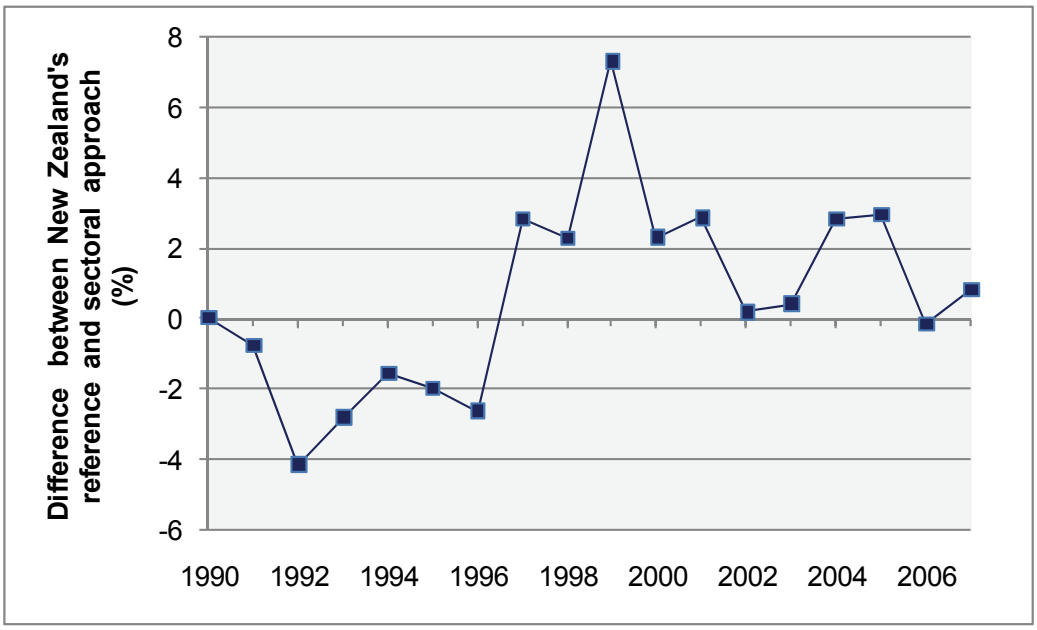
The activity data for the reference approach is obtained from "calculated" energy-use figures. These are derived as a residual figure from an energy-balance equation comprising production, imports, exports, stock change and international transport on the supply side. From this figure, energy use for transformation activities is subtracted to get apparent consumption. The activity data used for the sectoral approach is referred to as "observed" energy-use figures. These are based on surveys and questionnaires administered by 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, 2008b).

Comparison of the reference approach and sectoral approach in 2007 shows the sectoral total of $CO_2$ emissions is 0.8 per cent less than the reference total.

The difference in $CO_2$ emissions from the reference approach and the sectoral approach in solid fuel combustion is largely due to the stock change category in the reference approach. As mentioned earlier, Statistics New Zealand collects quarterly coal sales information on behalf of the Ministry of Economic Development, and the item "stock change" was not clearly defined. The Ministry of Economic Development will investigate this further once the conduction of the coal sales survey activity is taken over by the Ministry of Economic Development in the second half of 2009.

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 have been counted against crude oil in the reference approach.

**Figure 3.4.1 The 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 comes from the *Energy Data File* (Ministry of Economic Development, 2008b). This uses information from oil company survey returns provided to the Ministry for Economic Development. Data on fuel use by domestic transport is sourced from the *Deliveries of Petroleum Fuels by Industry* survey conducted 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 Carbon dioxide capture from flue gases and subsequent $CO_2$ storage

There was no $CO_2$ capture from flue gases and subsequent $CO_2$ storage occurring in New Zealand between 1990 and 2007.

## 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 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. Carbon dioxide emissions from this coal have been 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
- MS Excel worksheets containing the activity data for the sectoral approach are available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/). The sectoral activity data excludes energy sources containing carbon that is later stored in manufactured products, specifically methanol. Consequently, subsequent subtraction of emissions is not needed to account for this carbon sequestration. A worksheet to cover fugitive $CO_2$ and $CH_4$ emissions from geothermal electricity and heat generation plants has also been included.

### 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 $SO_2$ recovered at the refinery are provided by the New Zealand Refining Company. All storage tanks at the refinery are equipped with floating roofs and all but two have primary seals installed.

### 3.4.7 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 2007 energy supply and demand balance for New Zealand is included in Annex 2.

# Chapter 4: Industrial processes

## 4.1 Sector overview

New Zealand's industrial processes sector totalled 4,601.9 Gg carbon dioxide equivalent ($CO_2$-e) in 2007, contributing 6.1 per cent of total greenhouse gas emissions. Emissions from industrial processes had increased by 1,192.7 Gg $CO_2$-e (35.0 per cent) above the 1990 level of 3,409.2 Gg $CO_2$-e (Figure 4.1.1). This sector is dominated by emissions from the metal production category ($CO_2$ and perfluorocarbons (PFCs)) at 49.2 per cent of industrial process emissions.

**Figure 4.1.1 New Zealand's industrial processes sector emissions from 1990 to 2007**

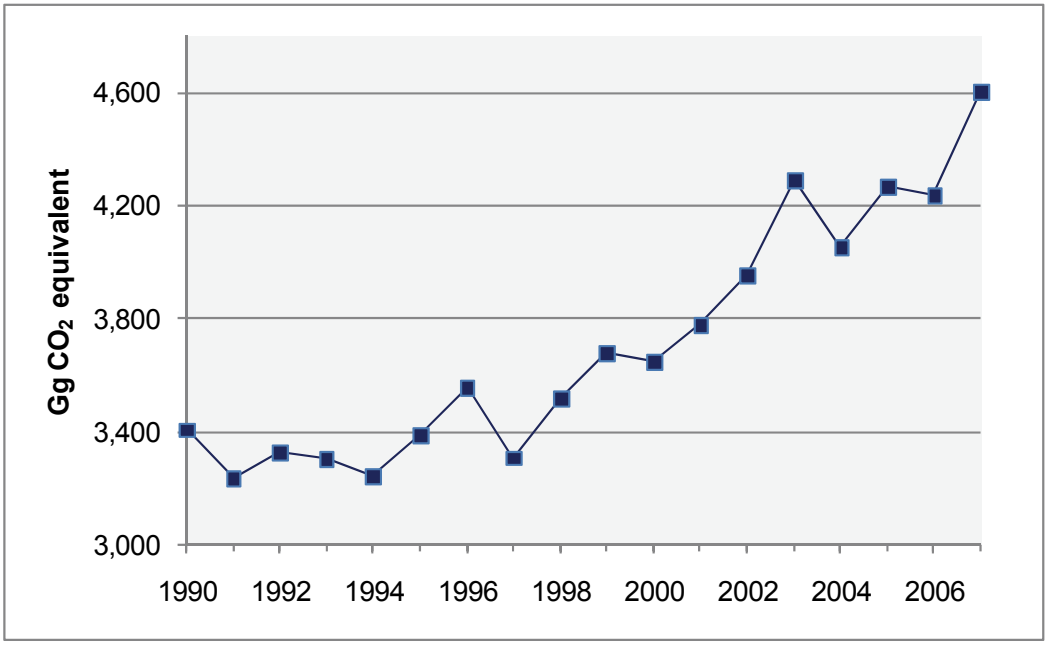
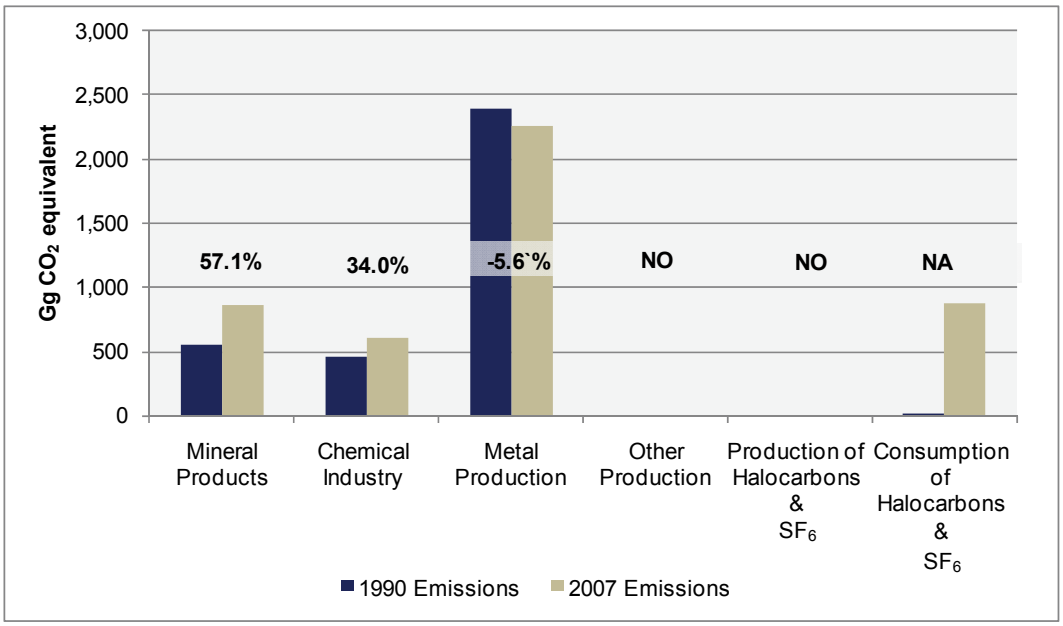


**Figure 4.1.2 New Zealand's change in industrial processes sector emissions from 1990 to 2007**




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

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

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

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

## Changes in emissions between 2006 and 2007

Between 2006 and 2007, emissions from the industrial processes sector increased by 368.1 Gg $CO_2$-e (8.7 per cent). The largest increase of 236.5 Gg $CO_2$-e (37.2 per cent) was from the consumption of halocarbons and $SF_6$. This was due to HFCs and PFCs used as replacement refrigerants for CFCs and HCFCs, in refrigeration and air-conditioning equipment.

Between 2006 and 2007, emissions from the mineral products category increased by 146.8 Gg $CO_2$-e (20.6 per cent). This was largely due to one cement company running at full production.

### 4.1.1 Methodological issues

Emissions of $CO_2$ from industrial processes are compiled by the Ministry of Economic Development from information collected through industry surveys. The results are reported in *New Zealand Energy Greenhouse Gas Emissions 1990–2007* (Ministry of Economic Development, 2008a).

Most of the activity data for the non-$CO_2$ gases is collated via an industry survey. Between 1990 and 2007, the only known $CH_4$ emissions from the industrial processes sector came from methanol production. Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach. Sulphur hexafluoride emissions from large users are assessed via the Tier 3a approach (IPCC, 2000).

Emission factors and activity data is included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/). Due to commercial sensitivity, some activity data has been classified as confidential.

### 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.

### 4.1.3 Sector-specific QA/QC

For this submission, six of New Zealand's industrial process companies were visited by members of the national inventory team. This provided an opportunity for the national inventory team to assess the QA/QC procedures employed by the companies and enhance the team's understanding of processes involved. The visits also provided an opportunity for the visited companies to increase their understanding of the inventory reporting requirements. The increased explanation of the inter-annual variations in aluminium emissions (section 4.4.2) is one result of these meetings.

## 4.2 Mineral products (CRF 2A)

### 4.2.1 Description

In 2007, the mineral products category accounted for 860.4 Gg $CO_2$-e (18.7 per cent) of emissions from the industrial processes sector. Emissions in this category have grown 312.8 Gg $CO_2$-e (57.1 per cent) from the 1990 level of 547.5 Gg $CO_2$-e. There are no known emissions of $CH_4$ or $N_2O$ from the mineral products category.

This category includes emissions produced from the production of cement and lime, soda ash production and use, asphalt roofing, limestone and dolomite use, road paving with asphalt, and glass production. In 2007, cement production accounted for 687.9 Gg $CO_2$-e (80.0 per cent) of emissions from the mineral products category. In the same year, lime

production accounted for 124.3 Gg $CO_2$-e (14.4 per cent) and the use of limestone and soda ash contributed 48.2 Gg $CO_2$-e (5.6 per cent). Only the emissions related to the calcination process for lime and cement production are included in this category. The emissions from the combustion of coal, used to provide heat for the calcination process, are reported in the energy sector.

## 4.2.2 Methodological issues

### Cement production

In 2007, $CO_2$ emissions from cement production were a key category both in the level and trend assessment (Table 1.5.1). There are two cement production companies operating in New Zealand in 2007, Holcim New Zealand Ltd and Golden Bay Cement Ltd. Both companies produce general purpose, portland cement. Holcim New Zealand Ltd also produces general, blended cement. From 1995 to 1998 inclusive, another smaller cement company, Lee Cement Ltd, was also operating.

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

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

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

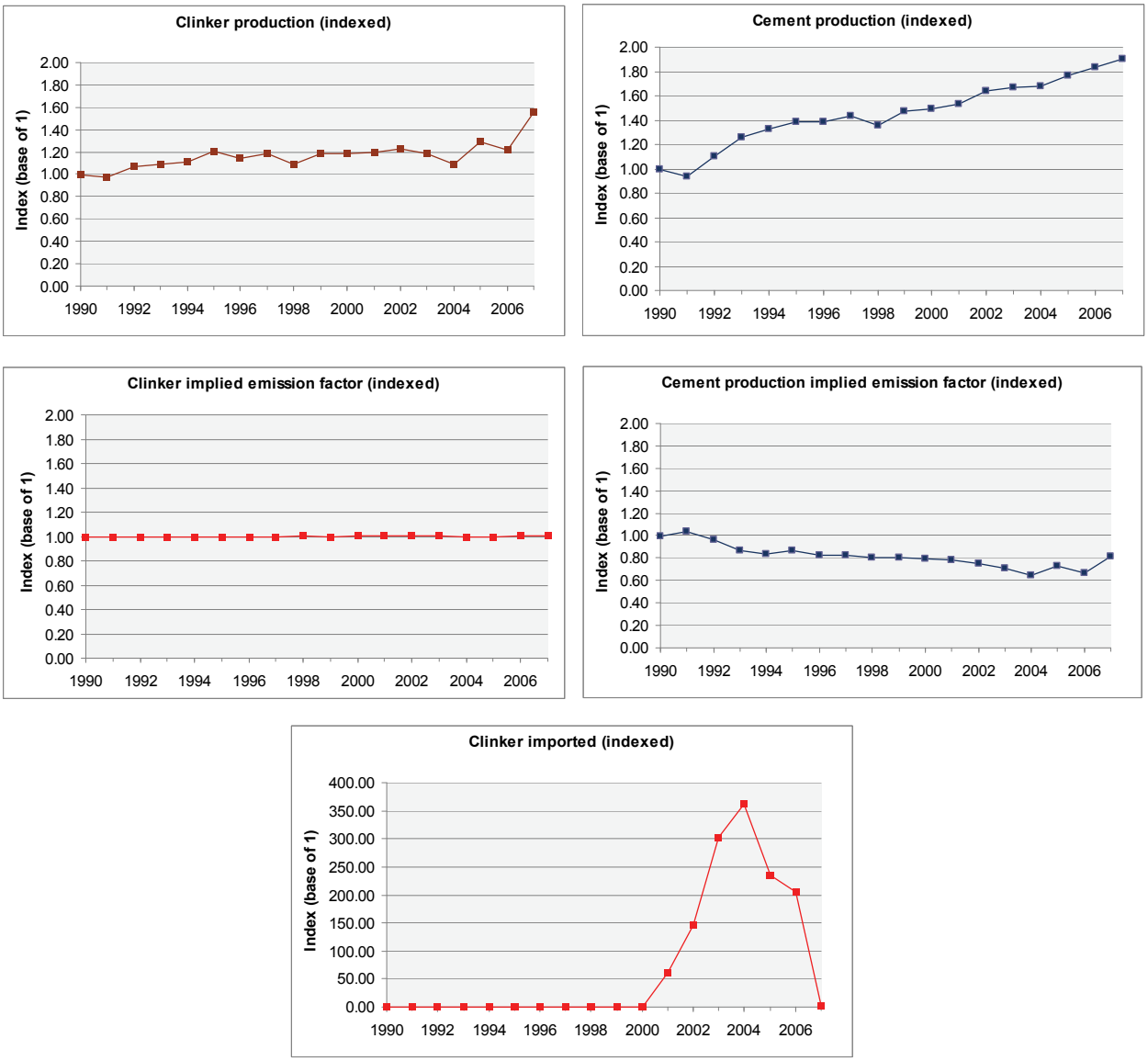
The cement companies supply their emission data to the Ministry of Economic Development during an annual survey. A plant-specific, cement-kiln dust correction factor is included in Holcim New Zealand Ltd's $CO_2$ emissions calculation. Cement-kiln dust is a mix of calcined and uncalcined raw materials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

Figure 4.2.1 shows the trends in New Zealand clinker and cement production, imported clinker and the implied emission factor for clinker and for cement for the 1990–2007 time series. In general, the figure shows clinker and cement production increasing over the time series 1990–2007. Relatively, over the same time series, cement production has increased greater than clinker production. The cement-implied emission factor decreased between 2000 and 2004 with increasing amounts of imported clinker. Meanwhile, the implied emission factor for clinker remained relatively unchanged.

A change in national standards for cement production in 1995, permitting mineral additions to cement of up to 5 per cent by weight (CCANZ, 1995), has also resulted in less $CO_2$ emissions per tonne of cement produced. The increase in clinker production from 2006 to 2007 is due to one of New Zealand's cement companies running at full production in 2007.

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

**Figure 4.2.1 New Zealand's cement production data including clinker production, clinker imports and cement and clinker-implied emission factor (indexed)**



## Lime production

In 2007, lime production in New Zealand was not a key category. There are four companies (McDonalds Ltd, Taylors Lime Ltd, Websters Hydrated Lime Ltd and Perrys Group Ltd) producing burnt lime in New Zealand. All four companies produce high-calcium lime, and two companies produce hydrated lime.

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

Carbon dioxide and $SO_2$ emission data from lime production are supplied to the Ministry of Economic Development by the lime production companies. Emissions are calculated by multiplying lime activity data by an emission factor (IPCC, 2000). Given the limited data availability before 2002, a single New Zealand-specific emission factor based on the typical levels of impurities in the lime produced in New Zealand was applied for 1990–2002. Since 2002, plant-specific emission factors have been used. In alignment with good practice, a correction factor is applied to the hydraulic lime produced. There has been little change in the implied emission factor varying from 0.72 t $CO_2$/t lime to 0.71 t $CO_2$/t lime from 1990 to 2007.

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

## Limestone and dolomite use

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

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

## Soda ash production and use

There is no soda ash production in New Zealand. A survey of the industrial processes sector estimated $CO_2$ emissions resulting from the use of soda ash in glass production in 2005 (CRL Energy, 2006). The glass manufacturer provided information on the amount of imported soda ash used in 2005. The manufacturer also provided approximate proportions of recycled glass over the previous 10 years to enable $CO_2$ emissions from soda ash to be estimated from 1996 to 2005. This is because the amount of soda ash used is in fixed proportion to the production of new (rather than recycled) glass. Linear extrapolation was used to estimate activity data from 1990 to 1995. Updated activity data

for subsequent years was provided by the glass manufacturer through an external consultant. The IPCC default emission factor of 415 kg $CO_2$ per tonne of soda ash was applied to the soda ash activity data to calculate the $CO_2$ emissions.

## Asphalt roofing

There is one company manufacturing asphalt roofing in New Zealand, Bitumen Supply Ltd. Default IPCC (1996) emission factors of 0.05 kg NMVOC per tonne of product and 0.0095 kg CO/t product respectively were used to calculate NMVOC and CO emissions. A survey of indirect greenhouse gases was last conducted for the 2005 calendar year. In the absence of updated data, activity data for 2005 has been used for 2006 and 2007.

## Road paving with asphalt

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

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

The revised 1996 IPCC guidelines (IPCC, 1996) make no reference to cut-back bitumen but do provide default emission factors for the low rates of $SO_2$, $NO_x$, 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 a method (Box 4.1) for calculating total NMVOC emissions from the use of solvents in the roading industry. The industrial processes survey for the 2005 calendar year (CRL Energy, 2006) showed that the fraction by weight of bitumen used to produce chip-seal has been changing over recent years as methods of laying bitumen have improved. From 1990 to 2001, the fraction by weight of bitumen used to produce chip-seal was 0.80. From 2002 to 2003, it was 0.65 and, from 2004, the fraction was 0.60. The emissions of NMVOCs were updated to reflect this changing fraction.

In the absence of updated data, activity data for 2005 was extrapolated for 2006 and 2007.

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

NMVOC emitted = A x B x C x D

where

A = The amount of bitumen used for road paving

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

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

D = The fraction of solvent emitted (0.75)

### Glass production

There is one major glass manufacturer in New Zealand, O-I New Zealand. The IPCC guidelines (IPCC, 1996) state that NMVOCs may be emitted from the manufacture of glass and suggest a default emissions factor of 4.5 kg NMVOC per tonne of glass output. It has been assumed that the IPCC default emission factor for NMVOC was based on total glass production that 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 for the 2007 calendar year (CRL Energy, 2008).

## 4.2.3 Uncertainties and time-series consistency

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

**Table 4.2.1 Uncertainty in New Zealand's non-$CO_2$ emissions from the mineral products category**

| 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%<br>$SO_2$: : ±10% |

## 4.2.4 Source-specific QA/QC and verification

In 2007, $CO_2$ emissions from cement production were a key category (level assessment). In the preparation of this inventory, the data for these emissions underwent IPCC Tier 1 quality checks.

## 4.2.5 Source-specific recalculations

New Zealand provided $CO_2$ estimates for limestone, coke and electrode use for the first time in the 2008 submission. The emissions were separated from the industrial process emissions (excluding fuel combustion emissions reported in the energy section) from steel and iron production. In this submission, New Zealand has instead, separated emissions from limestone, coke and electrode use from total iron and steel emissions (including emissions from fuel 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 2007, emissions from the chemical industry category comprised 603.2 Gg $CO_2$-e (13.0 per cent) of emissions from the industrial processes sector. Emissions have increased by 153.1 Gg $CO_2$-e (34.0 per cent) from the 1990 level of 450.1 Gg $CO_2$-e. In 2007, $CO_2$ emissions from ammonia production accounted for 360.1 Gg $CO_2$-e (59.7 per cent) of emissions in the chemical industry category. In 2007, ammonia production was a qualitative key category (Table 1.5.1).

Methane emissions from the chemical industry category have decreased 27.4 Gg $CO_2$-e (60.0 per cent) between 2004 and 2007. The only known source of $CH_4$ in the industrial processes sector is from methanol production. The decrease in $CH_4$ emissions was due to the closure of the Motunui methanol production plant in November 2004. In 2007, there was only 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 Ministry of Economic Development by Balance Agri-nutrients Ltd who operates 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 (52.2 kt/PJ). The proportion of gas from each of these fields used in ammonia production changed on an annual basis. This explains the fluctuation in the $CO_2$ implied emission factor over the 1990–2007 time series.

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

### Formaldehyde

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

### Methanol

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 used to calculate $CO_2$ emissions is shown in Box 3.1.

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, 2006). The NMVOC emissions factor, 5 kg NMVOC/t product, was estimated in 2001 from American Petroleum Institute methods

for calculating vapour emissions from storage tanks. Emission factors for $NO_x$ (0.9 kg $NO_x$/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 during the manufacture of superphosphate fertiliser produces indirect emissions of $SO_2$. In New Zealand there are two companies, Balance Agri-nutrients and Ravensdown, producing superphosphate. Each company owns two production plants. Three plants produce sulphuric acid. One plant imports the sulphuric acid.

Activity data supplied in 2005 has been used for 2006 and 2007. Plant-specific emission factors used in previous years were applied to the 2007 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 10 times too high for the New Zealand industry. Consequently, emission estimates are based on emission factors supplied by industry.

### Hydrogen

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

## 4.3.3 Uncertainties and time-series consistency

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

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

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

### 4.3.4 Source-specific QA/QC and verification

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

### 4.3.5 Source-specific recalculations

The recalculations in ammonia production were due to updated emission factors. In this submission, the weighted average of all gas fields has been applied.

## 4.4 Metal production (CRF 2C)

### 4.4.1 Description

The metal production category reports $CO_2$ emissions from the production of iron and steel, ferroalloys, aluminium and magnesium. The major metal production activities occurring in New Zealand are the production of steel (from ironsand and scrap steel) and aluminium. A small amount of $SF_6$ was used in a magnesium foundry until around 1998. New Zealand has no production of coke, sinter or ferroalloys. In 2007, $CO_2$ emissions from the iron and steel production subcategory were a key category (level assessment), and perfluorocarbon emissions from the aluminium production subcategory were a key category in the trend analysis.

In 2007, emissions from the metal production category were 2,265.6 Gg $CO_2$-e (49.2 per cent) of emissions from the industrial processes sector. Emissions from this category decreased 5.6 per cent from the 1990 level of 2,399.2 Gg $CO_2$-e. Carbon dioxide emissions accounted for 98.2 per cent of emissions in this category with another 1.8 per cent from PFCs. In 2007, the level of $CO_2$ emissions increased by 471.1 Gg $CO_2$-e (26.9 per cent) above the 1990 level. Perfluorocarbon emissions have decreased from the 642.2 Gg $CO_2$-e in 1990 to 40.3 Gg $CO_2$-e in 2007, a decrease of 601.9 Gg $CO_2$-e (93.7 per cent). This decrease is due to improvements made by the aluminium smelter. These improvements are discussed further in the following section.

### 4.4.2 Methodological issues

#### Iron and steel

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

The majority of the $CO_2$ emissions from the iron and steel subcategory are produced through the production of iron from titanomagnetite ironsand. The $CO_2$ emissions arise from the use of coal as a reducing agent and the consumption of other carbon-bearing materials such as electrodes. The carbon content of the ironsand is negligible with iron (in the form of magnetite) the predominant chemical in the sand (Ure, 2000), and has therefore not been counted for.

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.

The IPCC Tier 2 approach is used for calculating $CO_2$ emissions from the iron and steel plant operated by New Zealand Steel Ltd. Emissions from pig iron and steel production are not estimated separately as all of the pig iron is transformed into steel. A plant specific emission factor is applied to the sub-bituminous coal used as a reducing agent. The emission factor is calculated based on the specific characteristics of the coal used.

Care has been taken not to double-count coal use for iron and steel-making. New Zealand energy statistics for coal are disaggregated into coal used in steel making and coal used in other industries and sectors. The coal used in the iron-making process acts both as a reductant and an energy source. However, 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, whereas gas used in the production has been reported in the energy sector.

Pacific Steel Ltd 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 is 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 t$CO_2$/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, 2006).

## Aluminium

There is only one aluminium smelter in New Zealand, Rio Tinto Alcan Ltd (NZAS). The smelter produces aluminium from raw material using the centre worked prebaked (CWPB) technology. In 2007, aluminium emissions were 619.3 Gg $CO_2$-e, a decrease of 466.2 Gg $CO_2$-e (42.9 per cent) from the 1990 level of 1,085.5 Gg $CO_2$-e. In 2007, emissions from aluminium production were a key category for New Zealand (trend).

Aluminium production is a source for $CO_2$ and PFC emissions. Carbon dioxide is emitted during the oxidation of the carbon anodes. The PFCs are emitted from the cells during anode effects. An anode effect occurs when the aluminium oxide concentration in the reduction cell electrolyte is low. The emissions from combustion of various fuels used in

the aluminium production process, such as heavy fuel oil, LPG, petrol and diesel, are included in the energy sector. The indirect emissions are reported at the end of this section.

NZAS calculates the process $CO_2$ emissions using the *Aluminium Sector Addendum* to the World Business Council for Sustainable Development and the World Resources Institute Greenhouse Gas Protocol, released in October 2006 by the IPCC and International Aluminium Institute (IAI). The IPCC/IAI method breaks the prebake anode process into three stages (baked anode consumption, pitch volatiles consumption and packing coke consumption).

Estimates of PFC emissions are also supplied by NZAS to the Ministry of Economic Development. The PFC emissions from aluminium smelting are calculated using the IPCC/IAI Tier 2 methodology summarised below:

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

The smelter captures every anode effect, both count and duration, through its process control software. All monitoring data is logged and stored electronically to provide the anode effect minutes per cell day value. This is then multiplied by the tonnes of hot metal, the slope factor and the global warming potential to provide an estimate of $CF_4$ and $C_2F_6$ emissions. The slope values of 0.143 for $CF_4$ and 0.0173 for $C_2F_6$ are applied as they 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.

As Figure 4.4.1 indicates, the emissions from aluminium production have fluctuated over the time series. These fluctuations are identified and explained in Table 4.4.1 Data for 1991 and 1992 has been interpolated, due to limited data availability.

**Figure 4.4.1 New Zealand's aluminium production and emission data**

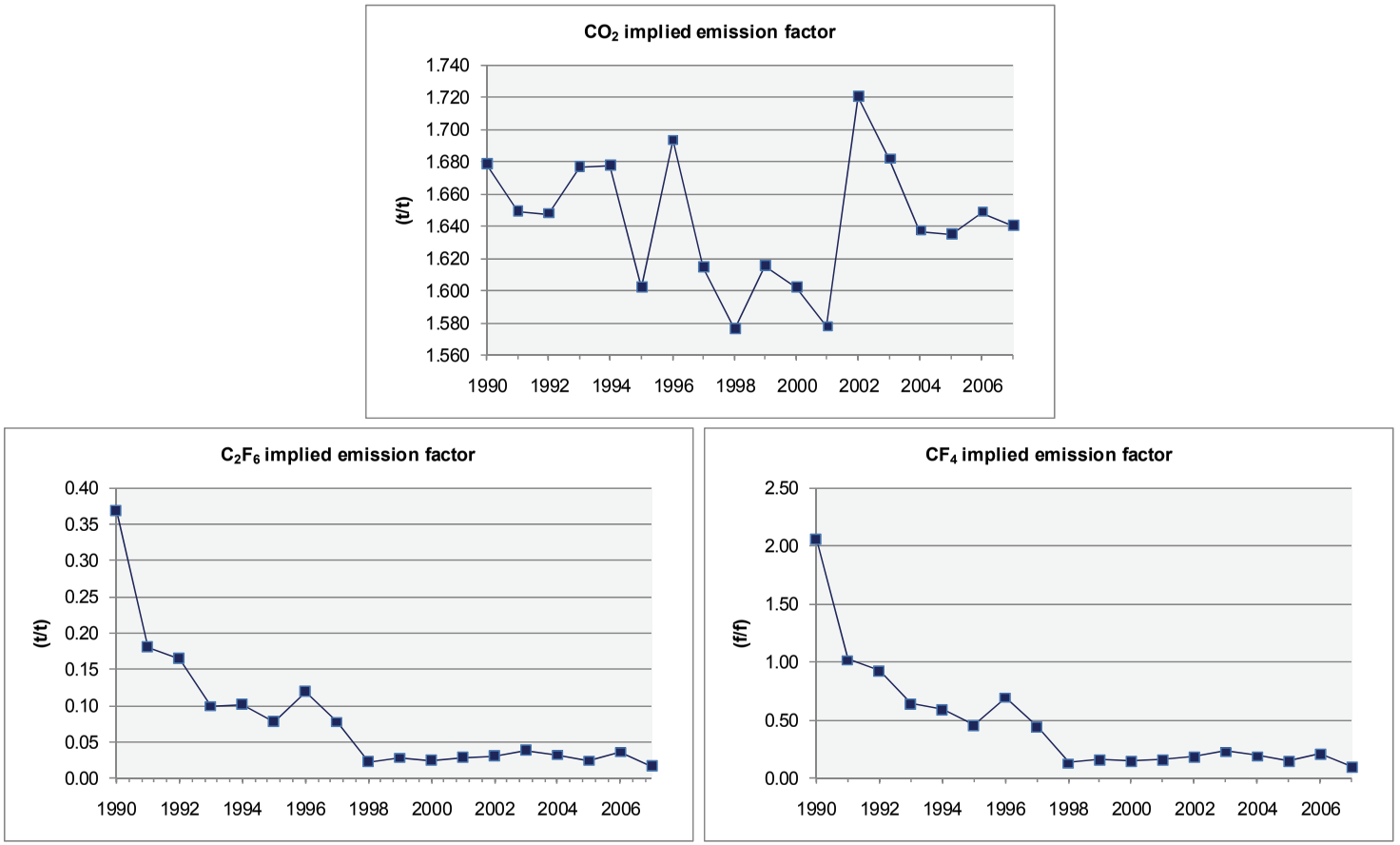


**Table 4.4.1 Variations in New Zealand's aluminium emissions and the reasons**

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

Aluminium production also produces indirect emissions. The most significant are CO emissions from the anode preparation. There is also a small amount of CO emitted during the electrolysis reaction in the cells. For estimates of indirect greenhouse gases, plant specific emission factors were used for CO and $SO_2$. Sulphur dioxide emissions are calculated from the input sulphur levels and direct monitoring. An industry supplied value of 110 kg CO per tonne (IPCC range 135–400 kg CO per tonne) was based on measurements and comparison with Australian CO emission factors. The IPCC default emission factor was used for $NO_x$ emissions.

## Other metal production

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

The only other metals produced in New Zealand are gold and silver. Companies operating in New Zealand confirm they do not emit indirect gases ($NO_x$, CO and $SO_2$) with one using the Cyanisorb recovery process to ensure everything is kept under negative pressure to ensure no gas escapes to the atmosphere. Gold and silver production processes are listed in IPCC (1996) as sources of non-$CO_2$ emissions. However, no details or emission factors are provided and no published information on emission factors has been identified. Consequently, no estimation of emissions from this source has been included 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, 2006). These are documented in Table 4.4.1.

**Table 4.4.1 Uncertainty in New Zealand's non-$CO_2$ emissions from the metal production category**

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

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

## 4.4.4 Source-specific QA/QC and verification

Carbon dioxide emissions from the iron and steel production and aluminium production subcategories were key categories in 2007. Perfluorocarbon emissions from aluminium production were also a key category (trend assessment). In the preparation of this inventory, the data for these subcategories underwent IPCC Tier 1 quality checks.

## 4.4.5 Source-specific recalculations

The time series for emissions from steel production have been updated. New Zealand separated emissions from limestone, coke and electrodes used in the iron and steel-making process from the industrial process $CO_2$ emissions for the first time in the 2008 inventory submission. In this submission, emissions from the use of limestone, coke and electrodes were instead separated from total emissions, including energy emissions from steel production. This is a more accurate way of reporting these emissions. Emissions from steel production were also recalculated for one company between 2000–2006 based on fuel input, production figures and estimated $CO_2$.

The PFC emissions from aluminium production have been updated based on the current dataset supplied by NZAS. Data for 1991 and 1992 remained unavailable for this submission. In the previous submission, the interpolation of these years was supplemented by industry assumptions. However, after discussions with NZAS, a linear regression of the data was used in this submission, with no assumptions influencing the data. The Ministry for the Environment has been working closely with NZAS to improve the consistency, completeness and accuracy of the time series. Further improvements will be included in the 2010 submission.

# 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 2007, emissions from this category totalled 7.4 Gg NMVOC. This was an increase of 1.5 Gg NMVOC from the 1990 level of 5.9 Gg $CO_2$-e.

## 4.5.2 Methodological issues

### Pulp and paper

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

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

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

### Food and drink

Emissions of NMVOCs are produced during the fermentation of cereals and fruits in the manufacture of alcoholic beverages. These emissions are also produced during all processes in the food chain that follow after the slaughtering of animals or harvesting of crops. Estimates of indirect greenhouse gas emissions for the period 1990–2005 have been calculated using New Zealand production figures from Statistics New Zealand and relevant industry groups with default IPCC emission factors (IPCC, 1996). No New Zealand-specific emission factors could be identified. Subsequent NMVOC estimates from food and drink have been estimated using linear extrapolation as no industry survey was conducted. In 2007, NMVOC emissions were estimated to be 6.6 Gg, an increase of 1.4 Gg from the 1990 level of 5.2 Gg.

## 4.5.3 Uncertainties and time-series consistency

Uncertainties in non-$CO_2$ emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy, 2006). These are documented in Table 4.5.3.1.

**Table 4.5.3.1 Uncertainty in New Zealand's non-$CO_2$ emissions from the other production category**

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

### 4.5.4 Source-specific QA/QC and verification

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

### 4.5.5 Source-specific recalculations

There are no source-specific recalculations performed for this category in this 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

In 2007, emissions from the consumption of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) totalled 858.0 Gg $CO_2$-e (18.6 per cent) of emissions from the industrial processes sector. There was no consumption of HFCs or PFCs in 1990. The first consumption of HFCs in New Zealand was reported in 1992 and the first consumption of PFCs in 1995. The large increase in HFC emissions is due to the replacement of ozone-depleting CFCs and HCFCs with HFCs. In 2007, emissions from the consumption of HFCs were identified as a key category (level and trend assessment).

In 2007, sulphur hexafluoride ($SF_6$) emissions were 14.7 Gg $CO_2$-e, this is an increase of 2.4 Gg $CO_2$-e (19.2 per cent) from the 1990 level of 12.3 Gg $CO_2$-e. The majority of $SF_6$ emissions are from use in electrical equipment.

Hydrofluorocarbons and PFCs are used in a wide range of equipment and products from refrigeration systems to aerosols. No HFCs or PFCs are manufactured within New Zealand. Perfluorocarbons are produced from the aluminium-smelting process (as discussed in section 4.4.2). The use of synthetic gases, especially HFCs, has increased since the mid-1990s when 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 subcategories:

- 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 subcategories: electrical equipment and "other". In New Zealand, one electricity company accounts for 75–80 per cent of total $SF_6$ used in electrical equipment.

## 4.7.2 Methodological issues

### HFCs/PFCs

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

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

Potential emissions for HFCs and PFCs are included for completeness as required by the Climate Change Convention reporting guidelines (UNFCCC, 2006). Potential emissions for HFCs and PFCs have been calculated using the IPCC Tier 1b approach. Very little data is available on bulk imports of individual HFC and PFC gases into New Zealand. 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 New Zealand's halocarbon and $SF_6$ calculation methods and emission factors**

| HFC source | Calculation method | Emission factor |
|---|---|---|
| Aerosols (including metered does inhalers) | IPCC 2006 Equation 7.6 | IPCC default factor of 50% of the initial charge per year |
| Foam | IPCC 2006 | 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<br>First fill: 0.5% |
| Stationary refrigeration/ air conditioning | IPCC 2006 Equation 7.9 | N/A |
| Fire protection | IPCC 2006 | Top-down approach using emission rate of 1.5% |
| **$SF_6$ 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% of total holdings)<br>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 and metered dose inhalers

New Zealand reports HFC 134a emissions from metered dose inhalers and other aerosols separately. Aerosols accounted for 26.0 Gg $CO_2$-e in 2007, an increase of 24.4 Gg $CO_2$-e from the 1996 level of 1.6 Gg $CO_2$-e. The use of HFCs in aerosols is not known to have occurred in New Zealand before 1996. In 2007, metered dose inhalers accounted for 49.6 Gg $CO_2$-e, an increase of 49.1 Gg $CO_2$-e from the 1995 level of 0.5 Gg $CO_2$-e. The consumption of HFCs in metered dose inhalers is not known to have occurred in New Zealand before 1995. Aerosols and metered dose inhalers are not a key subcategory.

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

The Tier 1b method, equation 7.6 (IPCC, 2006), is used to calculate HFC 134a emissions from aerosol use in New Zealand. This is a mass-balance approach, based on import and sales data. The default emission factor of 0.50 per cent of the initial charge is applied to the sales of aerosol and metered dose inhalers.

Data on the total number of doses contained in metered dose inhalers used from 1999 to 2007 is provided by Pharmac, New Zealand's government pharmaceutical purchasing agency. The weighted average quantity of propellant per dose is calculated from information supplied by industry. Activity data from 1995 to 1998 is based upon expert opinion (CRL Energy, 2008).

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

## Solvents

A survey of distributors of solvent products and solvent recycling firms did not identify any use of HFCs or PFCs as solvents (CRL Energy, 2008).

## Foam

In New Zealand, only emissions from closed-cell foam (hard foam) are known to occur. In 2007, emissions from the use of HFC-134a in hard foam blowing were 0.12 Gg $CO_2$-e. This is an increase of 0.05 Gg $CO_2$-e (80 per cent) from the 2000 level of 0.07 Gg $CO_2$-e. There is no known use of HFC-134a in foam blowing before 2000 within New Zealand.

The HFC-245fa/365mfc mixture is only known to be used in New Zealand in foam blowing from 2004 to 2007. These emissions are estimated to have increased from 0.1 tonne in 2004 to 0.6 tonne in 2007. However, a global warming potential for this mixture has not been agreed by the IPCC and UNFCCC. This mixture is reported in the common reporting format tables "Information on additional greenhouse gases", as recommended by the in-country review team (UNFCCC, 2007).

For 2007, activity data was provided by the sole supplier of HFCs for foam blowing (CRL Energy, 2008).

The IPCC (2006) Tier 2 method is used to calculate emissions from foam blowing. The recommended default emission factor of 10 per cent of the initial charge in the first year and 4.5 per cent annual loss of the initial charge over an assumed 20-year lifetime is applied.

## Stationary refrigeration/air conditioning

Hydrofluorocarbon and PFC emissions from stationary refrigeration and air conditioning were 573.4 Gg $CO_2$-e in 2007. This is an increase from the 1992 level of 1.43 Gg $CO_2$-e. In 1992, only HFC-134a was used, while in 2007 HFCs 32, -23, -152a, -134a, -125 and PFC-218 ($C_3F_8$) were consumed. There was no use of HFCs and PFCs before 1992.

The increase in emissions from 1992 to 2007 is due to HFCs and PFCs used as replacement refrigerants for CFCs and HCFCs in refrigeration and air-conditioning equipment (section 4.7.1).

New Zealand uses a top-down Tier 2b (Box 3.1) approach and New Zealand-specific data to obtain actual emissions from stationary refrigeration and air conditioning. Equation 7.9 (IPCC, 2006) is used to calculate emissions.

**Box 4.1: Equation 7.9 (IPCC, 2006)**

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

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

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

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

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

Commercial refrigeration includes central rack systems used in supermarkets, 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, 2008).

## Mobile air conditioning

In 2007, HFC-134a emissions from mobile air conditioning were 206.3 Gg $CO_2$-e, an increase over the 1994 level of 6.3 Gg $CO_2$-e. There was no use of HFCs as refrigerants for mobile air conditioning in New Zealand before 1994. This increase can largely be attributed to pre-installed, air-conditioning units in a large number of second-hand vehicles imported from Japan, as well as reflecting the global trend of increasing use of air conditioning in new vehicles.

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

New Zealand has used a Tier 2b method, mass-balance approach (Box 3.2). This approach does not require emission factors (except for the minor first-fill component) as it is based on chemical sales and not equipment leak rates.

**Box 3.2. Equation 3.44 (IPCC, 2000)**

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

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

Detailed information on the assumptions that have been used in the calculation of emissions from mobile air conditioning can be found in the report on HFC emissions in New Zealand (CRL Energy, 2008).

## Fire protection

In 2007, HFC-227ea emissions from fire protection were 1.3 Gg $CO_2$-e, an increase over the 1994 level of 0.06 Gg $CO_2$-e. There was no use of HFCs in fire protection systems before 1994 in New Zealand. The increase was due to HFCs used as substitutes to halon in portable and fixed fire protection equipment.

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

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

## Electrical equipment

In 2007, $SF_6$ emissions from electrical equipment were 11.8 Gg $CO_2$-e, an increase over the 1990 level of 9.5 Gg $CO_2$-e.

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

Actual emissions are calculated using the IPCC (2000) Tier 3a approach for the utility responsible for 75 per cent of the total $SF_6$ held in electrical switchgear equipment. This data is supplemented by data from other utilities. The additional data enables a Tier 2b approach to be taken for the rest of the industry (CRL Energy, 2008).

Activity and emissions data is provided by the two importers of $SF_6$ and New Zealand's main users of $SF_6$, the electricity transmission, generation and distribution companies (CRL Energy, 2008.)

A Tier 1a method is used to calculate potential emissions of $SF_6$, using total annual imports of $SF_6$ into New Zealand. Potential $SF_6$ emissions are usually two to three times greater than actual emissions in a given year. However, in 2005, potential emissions were less than actual emissions because there was less $SF_6$ imported compared with previous

years. Import data for 2006 and 2007 shows potential $SF_6$ emissions are again greater than actual emissions.

### Other $SF_6$ applications

Emissions from other $SF_6$ applications in 1990 and 2007 were 2.9 Gg $CO_2$-e. In New Zealand, other applications include medical uses for eye surgery, tracer gas studies, magnesium casting, plumbing services, tyre manufacture, and industrial machinery equipment. A Tier 2 method (IPCC, 2000) is applied and no emission factor is used as 100 per cent is assumed to be emitted over a short period of time.

Activity data for 2007 was provided by one main supplier for eye surgery, scientific use, plumbing, tyre manufacture and industry. Scientific use was also discussed with the National Institute of Water and Atmosphere and the Institute of Geological and Nuclear.

## 4.7.3 Uncertainties and time-series consistency

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

**Table 4.7.2 New Zealand's uncertainties in the consumption of halocarbons and $SF_6$ category (CRL Energy, 2008)**

| HFC source | Uncertainty estimates |
|---|---|
| Aerosols | Combined uncertainty ±54% |
| Metered dose inhalers | Combined uncertainty ±10% |
| Solvents | Not occurring |
| Foam | Combined uncertainty ±70% |
| Stationary refrigeration/air conditioning | Combined uncertainty ±41% |
| Mobile air conditioning | Combined uncertainty ±36% |
| Fire protection | Combined uncertainty ±32% |
| **$SF_6$ source** | **Uncertainty estimates** |
| Electrical equipment | Combined uncertainty ±22% |
| Other applications | ±60% |

## 4.7.4 Source-specific QA/QC and verification

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

## 4.7.5 Source-specific recalculations

The recalculations for the consumption of halocarbons and $SF_6$ subcategory resulted in an increase of 21.6 Gg $CO_2$-e (3.5 per cent) for the 2006 inventory year. This was largely due to an increase to contractors that resulted in updated assumptions.

- Supply assumptions for the R404A (52 per cent HFC-143a, 44 per cent HFC-125 and 4 per cent HFC-134a) have been updated for the 2002 inventory year. In

previous submissions, New Zealand assumed that R134A (100 per cent HFC-134a) imports should be reduced by 30 tonnes. Based upon expert opinion, New Zealand now assumes that 15 t of the reduction to R134A and 15 t to R404A. The result is a decrease of about 6 t each for HFC-125 and HFC-143a, and a 12.6 tonne increase in HFC-134a emissions in 2002 in this submission, compared with estimates in the 2008 submission.

- Bulk import data for HFC-134a was reduced by 3.3 t per year from 2004–2006. This was due to new information from suppliers. Exported HFC-134a data was also updated for the same reason.
- For 2006, an import of 2.3 t of R410A has been included based upon updated data.
- An estimate has been provided for HFC contained in the pre-charged refrigeration systems on new ships (mainly luxury boats). This was 0.5 tonne R404A from 1997–2002 then 1.0 tonne R404A from 2003–2007.
- Updated assumptions for pre-charged container units for 2006. This resulted in a 1.8 tonne reduction in 2006 and reductions for the phase-in period, 1.1 and 0.4 tonne increases for 1996 and 1997 respectively. This has a very minor impact on emissions as some of the equipment is assumed to be retired after 10 years in operation.
- Assumptions for pre-charged container units were changed for 2006 (1.8 tonne reduction) and for the phase-in period (1.1 and 0.4 tonne increases for 1996 and 1997 respectively). This has a very minor impact on emissions as some of the equipment is assumed to be retired after 10 years in operation.
- Assumptions were updated following the provision of more detailed information on the current sales distribution of new dairy refrigeration units. This led to a decrease in the amount charged into new equipment and the phase-in period of about 2.2 t for 1998–2001, 0.6 tonne for 2002–2003, 1.5 tonne for 2004, and 2.4 t for 2006–2006. Subsequently, HFC-134a, HFC-125 and HFC-143a (from R404a) emissions have increased.
- The HFC amounts collected for destruction were previously based on a few analyses from 2005 with previous years estimated back to 2000. In this submission, all actual analyses have been provided, improving uncertainties for this factor. The result is estimate increases of 0.14, 0.21, 0.48, 0.00, 0.95, 1.46, 0.46 and 0.01 t for 1999–2006 respectively.
- The assumption that between 2000 and 2006, quantities of HFC-23, HFC-152a and HFC-32 in 2000–2003 were destroyed, has been updated in this submission. It has instead been assumed there is no destruction for these HFCs in these years, as based on the data available this year, there is no known source of supply.
- There was a small error corrected for HFC imports for fire protection. These imports have now been subtracted from total HFC/PFC bulk chemical imports in 2001. It has been assumed that 20.6 t of "other gases" were all HFC-134a. By subtracting 1.4 t for fire protection, the "other gases" were reduced to 19.2 t. The result is that stationary refrigeration and air-conditioning bulk HFC imports and actual emissions of HFC-134a were revised to be 1.4 t lower in 2001 than compared with the 2008 submission.
- A minor correction to the "manufactured for New Zealand use" calculation term, included a 0.2 tonne of R410A that was previously omitted for commercial air-conditioning equipment manufactured in New Zealand in 2006.

Sulphur hexafluoride emissions from electrical equipment have been recalculated from 2000 to 2006, due to increased availability of $SF_6$ holdings' inventories for most electrical

users and some maintenance monitoring records. This has improved understanding of the total nameplate capacity in each year and therefore the assumed losses. The largest change was the decrease of 5.8 per cent in 2000.

The recalculations of other applications of $SF_6$ are due to increased availability of supplier data in 2007. This data has been interpolated back to 2000.

# 4.8 Other (CRF 2G)

## 4.8.1 Description

### Panel products

Activity data is obtained from industry and supplemented with statistics from the Ministry of Agriculture and Forestry. The NMVOC emission factors for particle board 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 particle board and fibreboard production in New Zealand. There is no information in the IPCC guidelines (1996) for this category.

Estimates of NMVOC emissions from panel products in 2007 were 1.3 Gg. This is an increase of 0.5 Gg over the 1990 level of 0.8 Gg.

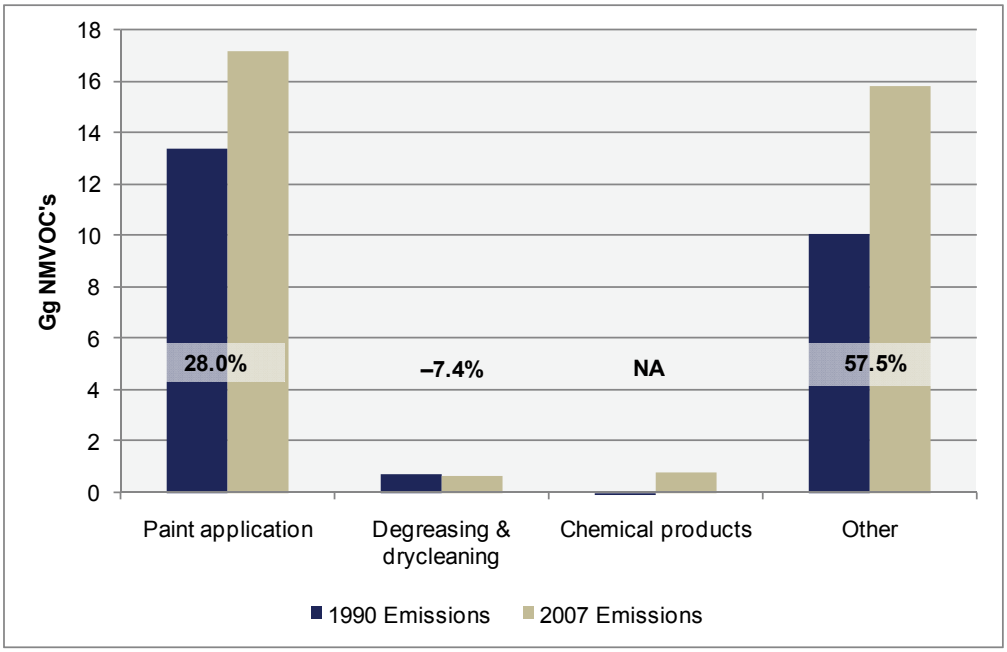
# Chapter 5: Solvent and other product use

## 5.1 Sector overview (CRF 3)

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

In 2007, emissions from the solvent and other product use sector were 34.5 Gg of NMVOC. This was a decrease of 10.2 Gg (42.0 per cent) from the 1990 level of 24.3 Gg. The categories dominating the sector are NMVOC emissions from paint application and other domestic and commercial-use (Figure 5.1.1) subcategories.

**Figure 5.1.1 Change in New Zealand's emissions of NMVOC from the solvent and other product use sector from 1990 to 2007 (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 2007, $N_2O$ emissions from anaesthesia use totalled 0.14 Gg $N_2O$ or 43.4 Gg carbon dioxide equivalent ($CO_2$-e). This was an increase of 0.006 Gg (4.5 per cent) since the 1990 level of 0.13 Gg.

### 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 Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1996). Two basic approaches for estimating emissions – consumption and production-based estimates – are documented. The IPCC guidelines note that for many applications of solvents, the end uses are too small scale, diverse and dispersed to be tracked directly. Therefore, emission estimates are generally based on total consumption and an assumption that once these products are sold to end users, they are applied and emissions produced relatively rapidly. For most surface coating and general solvent use, this approach is recommended. The New Zealand inventory estimates solvent emissions with a consumption-based approach. Activity data is obtained by an industry survey (CRL Energy, 2006) and extrapolated for the 2006 and 2007 calendar years. Details of emission estimates for solvent and other product use are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate//).

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

Activity and emissions data for 2006 and 2007 were extrapolated from the 2005 survey data. Consumption and emissions from paints and thinners were based on information from Nelson (1992) and the Auckland Regional Council (1997). Additional activity data for 1993 to 1996 was provided by the New Zealand Paint Manufacturers' Association.

### Degreasing and dry-cleaning

Dry-cleaning activity and emission data were extrapolated from 2005 activity data for the 2006 and 2007 calendar years. Most dry-cleaners in New Zealand use perchloroethylene and a small number use white spirits. Trichloroethylene has never been used in dry-cleaning but it is used in degreasing, for instance, in the leather manufacturing industry. In general, solvent losses from the dry-cleaning industry have reduced substantially as closed circuit machines and refrigerated recovery units are increasingly used. Consumption of perchloroethylene and trichloroethylene are assumed to equal the volume of imports. Import data was supplied by Statistics New Zealand. Degreasing is not estimated in New Zealand.

### Chemical products (manufacturing and processing)

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

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

The emissions for 2007 are the same as for 2006.

### Other – printing ink use

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

Due to data availability, data has remained unchanged since 2005.

### Other – aerosols

Approximately 25 million aerosol units are sold in New Zealand each year. The average propellant charge is 84 grams and 95 per cent are hydrocarbon-based. Total NMVOC emissions in 2007 were 1.8 Gg. This is based on the assumption that the units are fully discharged within two years of purchase.

### Other – domestic and commercial use

This category includes NMVOC emissions from domestic and commercial solvent use in the following areas: household products, toiletries, rubbing compounds, windshield washing fluids, adhesives, polishes and waxes, space deodorants, and laundry detergents and treatments. Emissions for this category are based on a per capita emission factor. The emission factor used is 2.54 kg NMVOC/capita/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, 2006). Population data is from the Statistics New Zealand website. As at December 2007, the population was estimated to be 4.25 million.

### $N_2O$ for anaesthesia

The sole importer of bulk $N_2O$ into New Zealand provided activity data for the 2007 calendar year. The importer supplies its competitor with its requirements so the figure represents full coverage of $N_2O$ use in New Zealand. Most of the $N_2O$ is used for anaesthesia and the production of Entonox (a half-and-half mixture of nitrous oxide and oxygen for pain relief). There is a very small amount used in motor sports and 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, 2006). The overall uncertainties are shown in Table 5.1.1

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

| HFC source | 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

There have been some changes made to notation keys to increase transparency in the common reporting format tables. The notation keys for $CO_2$, $SO_2$, CO and $NO_x$ are now NE, as no detailed IPCC methodologies are available to estimate these emissions.

## 5.1.6 Source-specific planned improvements

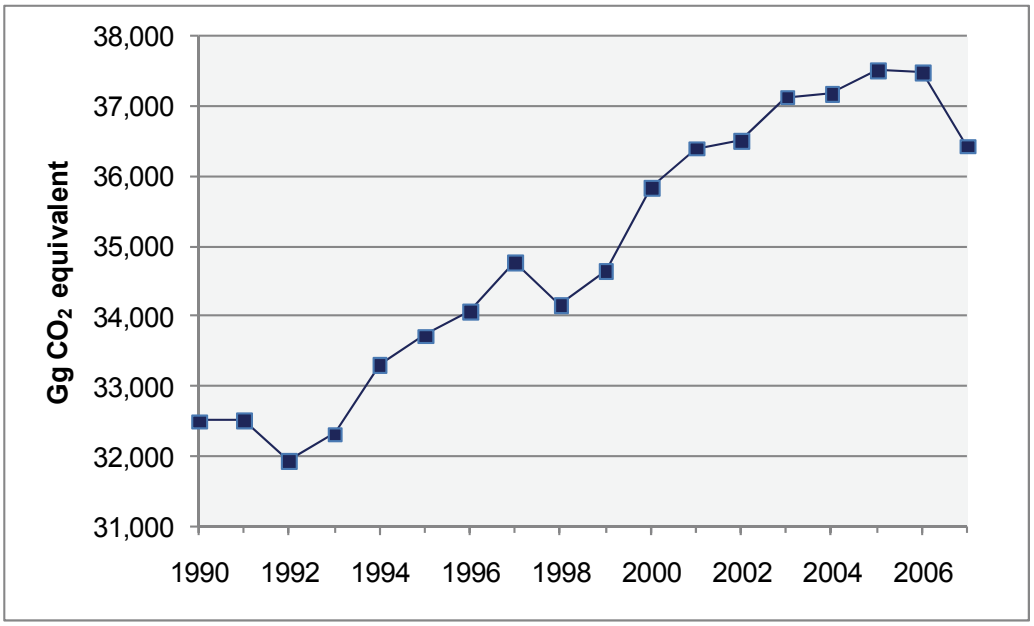
There are no planned improvements for this sector. There are large uncertainties, however, the emission levels from the solvents and other products sector are negligible compared with other sectors. In accordance with good practice, New Zealand will continue to focus its inventory development on key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

# Chapter 6: Agriculture

## 6.1 Sector overview

In 2007, the agriculture sector contributed 36,430.0 Gg carbon dioxide equivalent (Gg $CO_2$-e) (48.2 per cent) of New Zealand's total greenhouse gas emissions. Emissions in this sector had increased by 3,918.9 Gg $CO_2$-e (12.1 per cent) from the 1990 level of 32,511.1 Gg $CO_2$-e (Figure 6.1.1). This increase is primarily due to a 1,507.4 Gg $CO_2$-e (6.9 per cent) increase in methane ($CH_4$) emissions from the enteric fermentation category and a 2,254.7 Gg $CO_2$-e (22.4 per cent) increase in nitrous oxide ($N_2O$) emissions from the agricultural soils category.

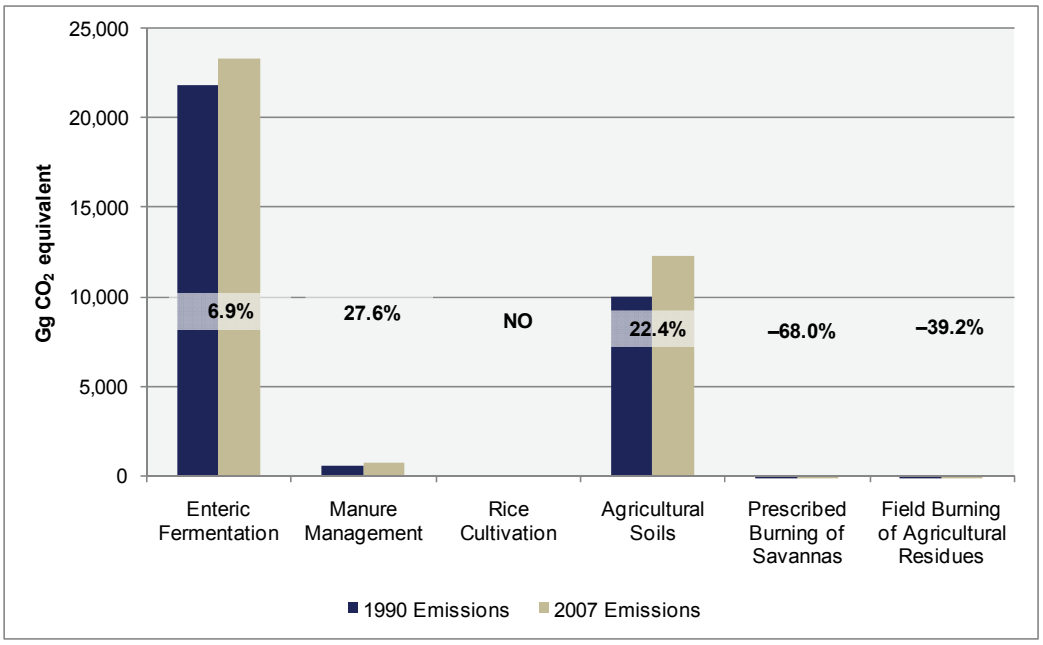
**Figure 6.1.1 New Zealand agricultural sector emissions from 1990 to 2007**




In 2007, $CH_4$ emissions from enteric fermentation were 64.0 per cent (23,326.4 Gg $CO_2$-e) of agricultural emissions and 30.9 per cent of New Zealand's total emissions. Nitrous oxide emissions from the agricultural soils category were 33.8 per cent (12,298.1 Gg $CO_2$-e) of agricultural emissions and 16.3 per cent of total emissions.

Agriculture is a major component of the New Zealand economy, and agricultural products comprise 56 per cent of total merchandise exports (Ministry of Agriculture and Forestry, 2008). This is facilitated by the favourable temperate climate, the abundance of agricultural land and the unique farming practices used in New Zealand. These practices include the 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 New Zealand's emissions from the agricultural sector from 1990 to 2007**




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

Since 1990, there have been changes in the proportions of the main livestock species farmed in New Zealand. 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 also increased by 50 per cent since 1990 and the types of produce grown have changed (Ministry of Agriculture and Forestry, 2008). There is now less cultivated land area for barley, wheat, and fruit but more for grapes (for wine production) and vegetables than in 1990. There has also been a net increase in land planted in forestry, therefore taking land out of agricultural production.

There was a gradual increase in the implied emission factors for dairy cattle and beef cattle from 1990 to 2007. This is expected because the applied method 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.

## Changes in emissions between 2006 and 2007

Total agricultural emissions in 2007, were 1,061.2 Gg $CO_2$-e (2.8 per cent) lower than the 2006 level. This was largely due to a decrease in the population of sheep (1,621,117 or 4.0 per cent), deer (190,895 or 12.0 per cent), and non-dairy cattle (45,519 or 1.0 per cent). There were also decreases in animal performance statistics. For example, milk yield per head decreased by 4.0 per cent, non-dairy cattle weight decreased by 10.6 percent, and sheep weight decreased by 2.7 per cent. The drought that affected many regions of New Zealand throughout the summer and autumn of 2007/2008 was the main cause for these decreases in animal performance (Ministry of Agriculture and Forestry, 2008).

### 6.1.1 Methodological issues for the agriculture sector

New Zealand uses a June year for all animal statistics as this reflects the natural biological cycle for animals in the southern hemisphere. The models developed to estimate agricultural emissions work on a monthly time step, beginning on the 1 July of one year and ending on the 30 June of the next year. To calculate emissions for single calendar years (January–December), emission data from the last six months of a July–June year are combined with the first six months' emissions of the next July to June year.

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

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

## 6.2 Enteric fermentation (CRF 4A)

### 6.2.1 Description

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

In 2007, $CH_4$ emissions from the enteric fermentation category were identified as the largest key category for New Zealand in the level assessment (excluding land use, land-use change and forestry (LULUCF)). In accordance with Intergovernmental Panel on Climate Change (IPCC) good practice guidance (IPCC, 2000), the methodology for estimating $CH_4$ emissions from enteric fermentation in domestic livestock was revised to a Tier 2 modelling approach for the 2003 inventory submission. All subsequent inventory submissions have used this Tier 2 approach.

In 2007, enteric fermentation was the largest single emissions category of New Zealand's inventory, contributing 23,326.4 Gg $CO_2$-e. This represented 30.9 per cent of New Zealand's total $CO_2$-e emissions and 64.0 per cent of agricultural emissions. Cattle contributed 13,824.3 Gg $CO_2$-e (59.3 per cent) of emissions from the enteric fermentation category, and sheep contributed 8,789.4 Gg $CO_2$-e (37.7 per cent) of emissions from this category. Emissions from the enteric fermentation category in 2007 were 1,507.4 Gg $CO_2$-e (6.9 per cent) above the 1990 level of 21,819.0 Gg $CO_2$-e. Since 1990, there were changes in the source of emissions within the enteric fermentation category. The largest increase came from emissions from dairy cattle. In 2007, dairy cattle were responsible for 8,531.2 Gg $CO_2$-e, an increase of 3,519.8 Gg $CO_2$-e (70.2 per cent) from the 1990 level of 5,011.4 Gg $CO_2$-e. Meanwhile, there have been decreases in emissions from sheep and minor livestock populations such as goats, horses and swine. In 2007, emissions from sheep were 8,789.4 Gg $CO_2$-e, a decrease of 2,490.6 Gg $CO_2$-e (22.1 per cent) from the 1990 level of 11,280.0 Gg $CO_2$-e.

## 6.2.2 Methodological issues

### Emissions from cattle, sheep and deer

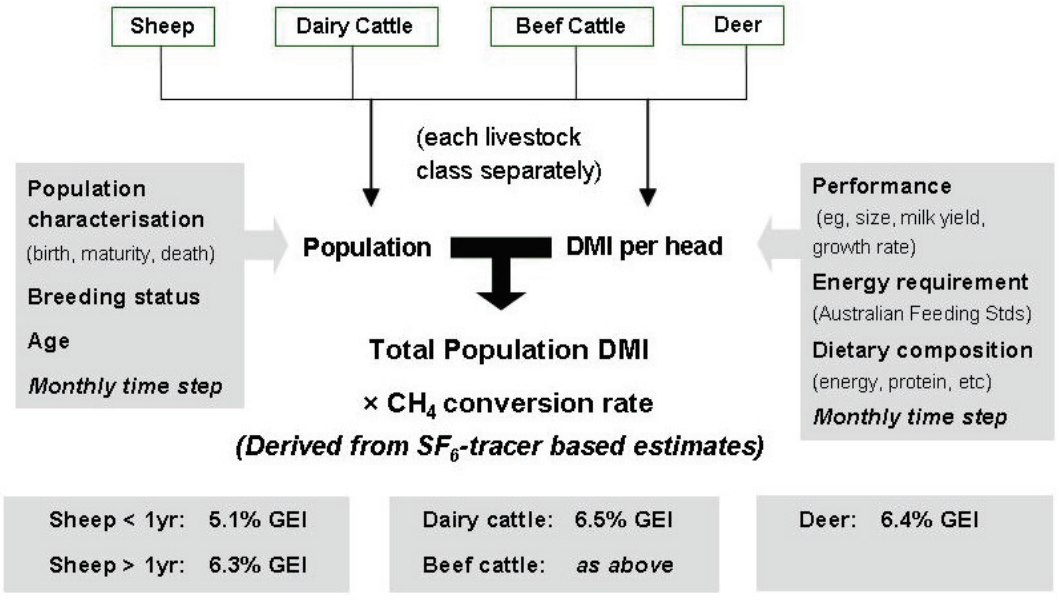
New Zealand's Tier 2 method (Clark et al, 2003) uses a detailed livestock population characterisation and livestock productivity data to calculate feed intake for the four largest categories in the New Zealand ruminant population (dairy cattle, beef cattle, sheep and deer). The amount of $CH_4$ emitted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

*Livestock population data*

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

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

**Figure 6.2.1 Schematic diagram of how New Zealand's emissions from enteric fermentation are calculated**




**Note:** GEI is the gross energy intake and DMI is the dry-matter intake.

*Livestock productivity data*

Productivity data comes from Statistics New Zealand and industry statistics. To ensure consistency, the same data sources are used each year. This ensures the data provides a time series that reflects changing farming practices, even if there is uncertainty surrounding the absolute values.

Obtaining data on the productivity of ruminant livestock in New Zealand, and how it has changed over time, is a difficult task. Some of the information collected is complete and collected regularly. For example, the slaughter weights of all livestock exported from New Zealand are collected by the Ministry of Agriculture and Forestry from all slaughter plants in New Zealand. This information is used as a surrogate for changes in animal liveweight over time. Other information, 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 MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/). The data includes average estimated liveweights, milk yields and milk composition of dairy cows, average liveweights of beef cattle (beef cows, heifers, bulls and steers), average liveweights of sheep (ewes and lambs), and average estimated liveweights of deer (breeding and growing hinds and stags).

***Dairy cattle*:** Data on milk production is provided by Livestock Improvement Corporation Ltd, a dairy-farmer-owned company providing services to the dairy, beef and deer industries (2008). This data includes the amount of milk processed through New Zealand dairy factories and milk for the domestic market. 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 is taken from the Livestock Improvement Corporation's national statistics. For all years, lactation length is assumed to be 280 days.

Average liveweight data for dairy cows is obtained by taking into account the proportion of each breed in the national herd and its age structure based on data from the Livestock Improvement Corporation. Dairy cow liveweights are only available from the Livestock Improvement Corporation from 1996 onwards. For earlier years in the time series, liveweights were estimated using the trend in liveweights from 1996 to 2007, 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 are applied between births and weaning, when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

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

***Beef cattle*:** The principal source of information for estimating productivity for beef cattle is livestock slaughter statistics provided by the Ministry of Agriculture and Forestry. All growing beef animals are assumed to be slaughtered at two years of age and the average weight at slaughter for the three subcategories (heifers, steers and bulls) is estimated from the carcass weight at slaughter. Liveweights at birth are assumed to be 9 per cent of an

adult cow weight for heifers and 10 per cent of an adult cow weight for steers and bulls. As with dairy cattle, growth rates of all growing animals are divided into two periods: birth to weaning, and weaning to slaughter, as higher growth rates are applied before weaning when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period.

The carcass weights obtained from the Ministry of Agriculture and Forestry slaughter statistics do not separate carcass weights of adult dairy cows and adult beef cows. Therefore, a number of assumptions[2] are made in order to estimate the liveweights of beef breeding cows. A total milk yield of 800 litres per breeding beef cow is assumed.

***Sheep***: Livestock slaughter statistics from the Ministry of Agriculture and Forestry are used to estimate the liveweights of adult sheep and lambs, assuming killing-out percentages of 43 per cent for ewes and 45 per cent for lambs. Lamb liveweights at birth are assumed to be 9 per cent of the adult ewe weight, with all lambs assumed to be born on 1 September. Growing breeding and non-breeding ewe hoggets are assumed to reach full adult size at the time of mating when aged 20 months. Adult wethers are assumed to be the same weight as adult breeding females. No within-year pattern of liveweight change is assumed for either adult wethers or adult ewes. All ewes rearing a lamb are assumed to have a total milk yield of 100 litres. Breeding rams are assumed to weigh 40 per cent more than adult ewes. Wool growth (greasy fleece growth) is assumed to be 5 kg/annum in mature sheep (ewes, rams and wethers) and 2.5 kg/annum in growing sheep and lambs.

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

### *Dry-matter intake calculation*

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

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[2] The number of beef breeding cows was assumed to be 25 per cent of the total beef breeding cow herd and other adult cows slaughtered were assumed to be dairy cows. The carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing-out percentage of 40 per cent. The total weight of dairy cattle slaughtered was calculated (carcass weight × number slaughtered) and then deducted from the national total carcass weight of slaughtered adult cows. This figure was then divided by the number of beef cows slaughtered to obtain an estimate of the carcass weight of adult beef cows. Liveweights were calculated assuming a killing-out percentage of 50 per cent.

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

### *Monthly energy concentrations*

A single data-set of monthly energy concentrations of the diets consumed by beef cattle, dairy cattle, sheep and deer is used for all years in the time series. This is because there is no comprehensive published data available that allow the estimation of a time series dating back to 1990. The data used is derived from farm surveys on commercial cattle and sheep farms.

### *Methane emissions per unit of feed intake*

There are a number of published algorithms and models[3] of ruminant digestion for estimating $CH_4$ emissions per unit of feed intake. The data requirements of the digestion models make them difficult to use in generalised national inventories and none of the methods have high predictive power when compared against experimental data. Additionally, the relationships in the models have been derived from animals fed indoors on diets unlike those consumed by New Zealand's grazing ruminants.

Since 1996, New Zealand scientists have been measuring $CH_4$ emissions from grazing cattle and sheep using the $SF_6$ tracer technique (Lassey et al, 1997; Ulyatt et al, 1999). New Zealand now has one of the largest data-sets in the world of $CH_4$ emissions determined using the $SF_6$ technique on grazing ruminants. To obtain New Zealand-specific values, published and unpublished data on $CH_4$ emissions from New Zealand were collated and average values for $CH_4$ emissions from different categories of livestock were obtained. Sufficient data was available to obtain values for adult dairy cattle, sheep more than one year old and growing sheep (less than one year old). This data is presented in Table 6.2.1 together with 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 applied in this submission. Table 6.2.2 shows a time series of $CH_4$ implied emission factors for dairy cattle, beef cattle, sheep and deer. Measurements using open-circuit respiration chamber techniques that provided complete gas balances were conducted to further confirm the $SF_6$ tracer technique.

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

**Table 6.2.1 Methane emissions from New Zealand measurements and IPCC 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 |

[3] 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.

**Table 6.2.2 Time series of New Zealand's implied emission factors for enteric fermentation (EF) (kg $CH_4$ per animal per annum)**

| Year | Dairy cattle | Beef cattle | Sheep | Deer |
|---|---|---|---|---|
| 1990 | 69.4 | 50.7 | 9.3 | 18.8 |
| 1991 | 71.6 | 51.9 | 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 | 54.2 | 9.6 | 19.7 |
| 1995 | 71.6 | 53.3 | 9.4 | 20.6 |
| 1996 | 74.1 | 54.6 | 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 | 54.1 | 10.2 | 21.3 |
| 2000 | 77.2 | 56.1 | 10.7 | 21.8 |
| 2001 | 77.6 | 57.0 | 10.7 | 21.7 |
| 2002 | 76.8 | 56.6 | 10.7 | 21.6 |
| 2003 | 79.8 | 56.1 | 10.7 | 21.6 |
| 2004 | 78.1 | 57.0 | 11.0 | 21.7 |
| 2005 | 79.1 | 57.7 | 11.1 | 22.2 |
| 2006 | 78.8 | 58.6 | 10.9 | 22.2 |
| 2007 | 77.2 | 57.4 | 10.9 | 22.3 |

## Emissions from other farmed species

A Tier 1 approach is adopted for minor livestock 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 0.2 per cent of total enteric $CH_4$ emissions in 2007.

### *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 were not a key category in 2007 and in the absence of data to develop New Zealand emissions' factors, IPCC default values were used.

***Goats*:** Enteric $CH_4$ from goats was not a key category in 2007. There is no published data available to attempt a detailed categorisation of the performance characteristics, as has been done for the major livestock categories. New Zealand uses a country-specific value of 9 kg $CH_4$/head/yr. This was calculated by assuming a default $CH_4$ emission value from goats for all years that is equal to the per head value of the average sheep in 1990 (ie, total sheep emissions/total sheep population). The goat emission factor is not indexed to sheep over time because there is no data to support the kind of productivity increases that have been seen in sheep.

## 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 2007 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 New Zealand's uncertainty in the annual estimate of enteric fermentation emissions for 1990, 2001 and 2007, estimated using Monte Carlo simulation (1990, 2001) and the 95 per cent confidence interval (2007)**

| 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 |
| 2007 | 1,110.8 | 522.1 | 1,699.5 |

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

Uncertainty in the annual estimate is dominated by variance in the measurements of the "$CH_4$ per unit of intake" factor. For the measurements made used to determine 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 estimates of energy requirements, herbage quality and population data are much smaller (0.005–0.05).

## 6.2.4 Source-specific QA/QC and verification

In 2007, $CH_4$ from enteric fermentation was identified as a key category (level and trend assessment). In preparation for this inventory, the data for this category underwent Tier 1 quality checks.

Methane emission rates measured for 20 dairy cows and scaled up to a herd have been corroborated using micrometeorological techniques. Laubach and Kelliher (2004) used the integrated horizontal flux technique and the flux gradient technique to measure $CH_4$ flux above a dairy herd. Both techniques are comparable, within estimated errors, to scaled-up animal emissions. The emissions from the cows measured by integrated horizontal flux and averaged over three campaigns are 329 (±153) g $CH_4$/day/cow compared to 365 (±61) g $CH_4$/day/cow for the scaled-up measurements reported by Waghorn et al, (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

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database, 2008).

### 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 $CH_4$ emission data. 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 on improving on-farm inventories. The consortium is funded from both public and private sector sources. 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

In 2007, emissions from the manure management category comprised 787.1 Gg $CO_2$-e (2.2 per cent) of emissions from the agriculture sector. Emissions from manure management had increased by 170.3 Gg $CO_2$-e (27.6 per cent) from the 1990 level of 616.7 Gg $CO_2$-e.

Livestock manure is composed principally of organic material. When the manure decomposes in the absence of oxygen, methanogenic bacteria produce $CH_4$. The amount of $CH_4$ emissions is related to the amount of manure produced and the amount that decomposes anaerobically. Methane from manure management was identified as a key category (level assessment) for 2007.

The manure management category also includes $N_2O$ emissions related to manure handling before the manure is added to the soil. The amount of $N_2O$ emissions depends on the system of waste management and the duration of storage. With New Zealand's extensive use of all-year-round grazing systems, this category contributed a relatively small amount of $N_2O$ – 58.0 Gg $CO_2$-e – in 2007. In comparison, $N_2O$ emissions from the agricultural soils category totalled 12,298.1 Gg $CO_2$-e in 2007.

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

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

## 6.3.2 Methodological issues

### Methane from manure management

The IPCC Tier 2 approach to calculate $CH_4$ emissions from ruminant animal wastes in New Zealand has been used since the 2006 inventory submission. The Tier 2 approach is based on the methods recommended by Saggar et al (2003) in a review commissioned by the Ministry of Agriculture and Forestry.

The approach relies on (1) an estimation of the total quantity of faecal material produced; (2) the partitioning of this faecal material between that deposited directly onto pastures and that stored in anaerobic lagoons; and (3) the development of New Zealand-specific emission factors for the quantity of $CH_4$ produced per unit of faecal dry-matter deposited directly onto pastures, and that stored in anaerobic lagoons. Table 6.3.2 summarises the key variables in the calculation of $CH_4$ from manure management.

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

| 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 IPCC default emission factors are used to calculate emissions.

#### *Dairy cattle*

***Faecal material deposited directly onto pastures:*** The quantity of faecal dry-matter produced is obtained by multiplying the quantity of feed eaten by the dry-matter digestibility of the feed, minus the feed retained in product. These feed intake and dry-

matter digestibility estimates are used in the enteric $CH_4$ and $N_2O$ Tier 2 model calculations. Consistent with the $N_2O$ inventory, 95 per cent of faecal material arising from dairy cows is assumed to be deposited directly onto pastures (Ledgard and Brier, 2004). The quantity of $CH_4$ produced per unit of faecal dry-matter is 0.98 g $CH_4$/kg. This value is obtained from New Zealand studies on dairy cows (Saggar et al, 2003; Sherlock et al, 2003).

***Faecal material stored in anaerobic lagoons:*** Five per cent of faecal material arising from dairy cows is assumed to be stored in anaerobic lagoons. The 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 the total volume of effluent stored. Annual $CH_4$ emissions are estimated using the data of McGrath and Mason (2002). McGrath and Mason (2002) calculated specific emissions values of 0.33–6.21 kg $CH_4/m^2$/year from anaerobic lagoons in New Zealand. The mean value of 3.27 $CH_4/m^2$/year of this range is assumed in the New Zealand Tier 2 calculations.

### *Beef cattle, sheep and deer*

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

Beef cattle, sheep and deer are not housed in New Zealand and all faecal material is deposited directly onto pastures.

No specific studies have been conducted in New Zealand on $CH_4$ emissions from beef cattle faeces and values obtained from dairy cattle studies (0.98 g $CH_4$/kg) are used (Saggar et al, 2003; Sherlock et al, 2003).

The quantity of $CH_4$ produced per unit of sheep faecal dry-matter is 0.69g $CH_4$/kg. This value is obtained from New Zealand studies on sheep (Carran et al, 2003).

There are no New Zealand studies on $CH_4$ emissions from deer manure and values obtained from sheep and cattle are used. The quantity of $CH_4$ produced per unit of faecal dry-matter is assumed to be 0.92 g $CH_4$/kg. This value is the average value obtained from all New Zealand studies on sheep (Carran et al, 2003) and dairy cattle (Saggar et al, 2003; Sherlock et al, 2003).

## Nitrous oxide from manure management

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

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

The $N_{ex}$ values are calculated from the nitrogen intake less the nitrogen in animal products. Nitrogen intake is determined from feed intake and the nitrogen content of the feed. Feed intake and animal productivity values are the same as used in the Tier 2 model for determining $CH_4$ emissions (Clark et al, 2003). The nitrogen content of feed is estimated from a review of over 6000 pasture samples of dairy and sheep and beef systems (Ledgard et al, 2003).

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

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

**Table 6.3.3 $N_{ex}$ values for New Zealand's main livestock classes over time (kg/head/year)**

| | Sheep N | Non-dairy Cattle N | Dairy Cattle N | Deer N |
|---|---|---|---|---|
| 1990 | 12.61 | 65.51 | 103.87 | 24.88 |
| 1991 | 12.83 | 66.98 | 107.02 | 25.64 |
| 1992 | 12.80 | 67.78 | 107.49 | 26.83 |
| 1993 | 12.93 | 69.26 | 109.80 | 27.06 |
| 1994 | 12.96 | 70.15 | 106.85 | 26.20 |
| 1995 | 12.81 | 68.95 | 106.50 | 27.42 |
| 1996 | 13.32 | 70.82 | 109.81 | 27.76 |
| 1997 | 13.89 | 71.48 | 110.46 | 27.84 |
| 1998 | 14.01 | 71.48 | 108.50 | 28.06 |
| 1999 | 13.97 | 70.00 | 111.96 | 28.24 |
| 2000 | 14.58 | 72.60 | 113.41 | 28.91 |
| 2001 | 14.72 | 73.71 | 113.95 | 28.85 |
| 2002 | 14.68 | 73.14 | 113.12 | 28.74 |
| 2003 | 14.66 | 72.38 | 117.40 | 28.67 |
| 2004 | 15.07 | 73.61 | 115.23 | 28.88 |
| 2005 | 15.20 | 74.60 | 116.43 | 29.47 |
| 2006 | 15.02 | 75.81 | 115.67 | 29.58 |
| 2007 | 14.97 | 74.05 | 113.62 | 29.68 |

## 6.3.3 Uncertainties and time-series consistency

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

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

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 the uncertainty in $CH_4$ 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 2007. In preparation for this inventory submission, the data for this category underwent Tier 1 quality checks.

### 6.3.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database, 2008).

### 6.3.6 Source-specific planned improvements

The National Institute of Water and Atmospheric Research (NIWA) has recently completed a project on continuous measurement of anaerobic lagoon 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 common reporting format tables.

## 6.5 Agricultural soils (CRF 4D)

### 6.5.1 Description

In 2007, the agricultural soils category contributed 12,298.1 Gg $CO_2$-e (16.3 per cent) to New Zealand's total emissions and 95.7 per cent to total $N_2O$ emissions. Emissions were 2,254.7 Gg $CO_2$-e (22.4 per cent) above the 1990 level of 10,043.4 Gg $CO_2$-e. The category comprises three subcategories. Each of these subcategories has been identified as a key category. The subcategories are:

- direct $N_2O$ emissions from agricultural soils as a result of adding nitrogen in the form of synthetic fertilisers, animal waste, biological fixation in crops, inputs from crop residues and sewage sludge. Direct $N_2O$ soil emissions contributed 1,680.7 Gg $CO_2$-e (13.7 per cent) to emissions from the agricultural soils category in 2007. This was an increase of 1,193.5 Gg $CO_2$-e (245.0 per cent) from the 1990 level of 487.2 Gg $CO_2$-e. Direct $N_2O$ emissions from agricultural soils were identified as a key category (level and trend assessment)
- indirect $N_2O$ from nitrogen lost from the field as $NO_3$, $NH_3$ or $NO_x$. In 2007, indirect $N_2O$ emissions from nitrogen used in agriculture contributed 3,270.7 Gg $CO_2$-e (26.6 per cent) to emissions from the agricultural soils category. This was an increase of 567.5 Gg $CO_2$-e (21.0 per cent) from the 1990 level of 2,703.1 Gg $CO_2$-e. Indirect N2O emissions from agricultural soils were identified as a key category (level assessment)
- direct $N_2O$ emissions from animal production (the pasture, range and paddock animal waste management system). Nitrous oxide emissions from animal production contributed 7,346.7 Gg $CO_2$-e (59.7 per cent) to emissions from the agricultural soils category. This is an increase of 493.6 Gg $CO_2$-e (7.2 per cent) from

the 1990 level of 6,853.1 Gg $CO_2$-e. Direct $N_2O$ emissions from agricultural soils were identified as a key category (level and trend assessment). Direct $N_2O$ emissions from animal production were identified as a key category (trend and level assessment).

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

## 6.5.2 Methodological issues

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

Three New Zealand-specific emission factors and parameters are used in the inventory: $EF_1$, $EF_{3(PR\&P)}$ and $Frac_{LEACH}$. The emission factor, $EF_1$ (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 MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/).

### Animal production ($N_2O$)

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

The emissions calculation is based on the livestock population multiplied by nitrogen excretion ($N_{ex}$) values and the percentage of the population on the pasture, range and paddock animal waste management system. The $N_{ex}$ values and allocation to animal waste management systems are discussed in section 6.3. The $N_{ex}$ values have been calculated based on the same animal intake and animal productivity values used for calculating $CH_4$ emissions for the different animal classes and species in the Tier 2 model. This ensures the same base values are used for both the $CH_4$ and $N_2O$ emission calculations.

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

days at each trial site or until urine-treated pasture measurements dropped back to background emission levels.

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

- environmental (climate) data is not used to estimate $N_2O$ emissions using the 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.

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

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

## Incorporation of the mitigation technology DCD into the agriculture inventory

A methodology to incorporate a $N_2O$ mitigation technology, the nitrification inhibitor dicyandiamide (DCD), into the agriculture sector of the inventory has been developed. A detailed description of the methodology can be found in Clough et al (2008). The $N_2O$ emissions reported in the agricultural soils category for 2007 take into account the use of nitrification inhibitors on dairy farms using the methodology described in Clough et al (2008). For the 2007 calendar year, DCD mitigated 28.8 Gg $CO_2$-e, a 0.2 per cent decrease in total agricultural $N_2O$ emissions.

Dicyandiamide is an environmentally safe, and long researched, nitrification inhibitor that has been demonstrated to reduce $N_2O$ emissions and nitrate leaching in pastoral grassland systems grazed by ruminant animals. There have been 28 peer-reviewed, published New Zealand studies on the use and effects of DCD.

The method to incorporate DCD mitigation of $N_2O$ emissions into New Zealand's agricultural inventory is by an amendment to the existing IPCC methodology. Activity data on livestock numbers is drawn from Statistics New Zealand's annual agricultural survey. This survey has recently included questions on the area that DCD is applied to on grazed pastures.

The DCD product is applied to pastures based on research that has identified good management practice to maximise $N_2O$ emission reductions. This is at a rate of 10kg/ha of DCD applied twice per year in autumn and early spring within seven days of the application of excreta or fertiliser nitrogen. "Good practice" application methods are by slurry or granule.

Changes to the emission factors $EF_{3PR\&P}$, $EF_1$ and parameter $Frac_{LEACH}$ were established for use with DCD application. These emission factors and parameters were modified based on comprehensive field-based research that showed significant reductions in $N_2O$ emissions and nitrate leaching where DCD was applied.

The peer-reviewed literature on DCD use in grazed pasture systems was critically reviewed and it was determined that on a national basis, reductions in $EF_1$, $EF_{3PR\&P}$, and $Frac_{LEACH}$ of 67 per cent, 67 per cent and 53 per cent could be made respectively (Clough et al, 2008).

The reductions in the emission factors and parameters are used along with the fraction of dairy land treated with DCD to calculate DCD weighting factors.

$$DCD\ weighting\ \ factor = \ (1 - \frac{\%\ reduction\ in\ EF_x}{100} \times \frac{DCD\ treated\ \ area}{Effective\ dairy\ area})$$

The appropriate weighting factor is then used as an additional multiplier in the current methodology for calculating indirect and direct emissions of $N_2O$ from grazed pastures. The calculations use a modified $EF_{3PR\&P}$ of 0.0098 and $Frac_{LEACH}$ of 0.0687 for dairy grazing area in the months that DCD is applied (May to September). The modified emission factors are based on information from the agricultural census that 3.5 per cent of the effective dairying area in New Zealand received DCD in 2007.

**Table 6.5.1 Emission factors and parameters for DCD calculations**

| | NZ emission factor or parameter value for untreated area (kg $N_2O$-N/kg N) | Reduction from DCD treatment (%) | Proportion land treated with DCD (%) | Final modified emission factor or parameter |
|---|---|---|---|---|
| $EF_{3PR\&P}$ | 0.01 | 67 | 3.5 | 0.0098 |
| $EF_1$ | 0.01 | 67 | 3.5 | 0.0098 |
| $Frac_{LEACH}$ | 0.07 | 53 | 3.5 | 0.0687 |

All other emission factors and parameters relating to animal excreta and fertilizer use ($Frac_{GASM}$, $Frac_{GASF}$, $EF_4$ and $EF_5$) remain unchanged when DCD is used as an $N_2O$ mitigation technology. Based on the physico-chemical reaction of DCD in the soil, DCD should have no effect on ammonia volatilisation during May to September when DCD is applied. This is supported by the results of field studies (Clough et al, 2008).

The derivations of the modified emission factors and the resulting calculations are included in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/).

The method will be refined over time to reflect any updated information that may arise from ongoing research into this area.

## Indirect $N_2O$ from nitrogen used in agriculture

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

Research studies and a literature review in New Zealand have shown lower rates of nitrogen leaching than are suggested in the revised 1996 IPCC guidelines (IPCC, 1996).

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

The IPCC estimates were closer for farms using high rates of nitrogen fertiliser, indicating that the IPCC-based estimates for nitrogen leaching associated with animal excreta were too high for New Zealand. When the IPCC method was applied to field sites where nitrogen leaching was measured (four large-scale, multi-year animal grazing trials), it resulted in values that were double the measured values. This indicated that a value of 0.07 for $Frac_{LEACH}$ more closely followed actual field leaching in New Zealand (Thomas et al, 2005). The 0.07 value has been adopted and is used for all years as it best reflects New Zealand's national circumstances.

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 oxides of nitrogen ($NO_x$).

## Direct $N_2O$ emissions from agricultural soils

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

Data on nitrogen fertiliser use is provided by the New Zealand Fertiliser Manufacturers' Research Association (FertResearch) from sales records for 1990 to 2007. There has been a six-fold increase in elemental nitrogen applied through nitrogen-based fertiliser over the 1990–2007 time series from 51,633 t in 1990 to 315,920 t in 2007. The calculation of $N_2O$ that is emitted indirectly through synthetic fertiliser and animal waste being spread on agricultural soils is shown in the MS Excel worksheets available with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/). Some of the nitrogen contained in these compounds is emitted into the atmosphere as ammonia ($NH_3$) and nitrogen oxides ($NO_x$) through volatilisation, returning to the ground during rainfall and then re-emitted as $N_2O$. This is calculated as an indirect emission of $N_2O$. A review by Sherlock et al (2008) suggests that the $NH_3$ emission factor may be 50 per cent too high. These results are being internationally peer reviewed.

The calculation for animal waste includes all manure that is spread on agricultural soils, irrespective of the animal waste management system it was initially stored in. This includes all agricultural waste in New Zealand except for emissions from the pasture range and paddock animal waste management system. New Zealand uses a country-specific value for $EF_1$ of 0.01 kg $N_2O$-N/kg N (Kelliher and de Klein, 2006).

Direct $N_2O$ emissions from organic soils are calculated by multiplying the area of cultivated organic soils by an emission factor ($EF_2$). Analysis identified 202,181 hectares of organic soils in New Zealand. 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 ($EF_2$ equal to 8 kg $N_2O$-N/kg N) for all years of the time series.

## 6.5.3 Uncertainties and time-series consistency

Uncertainties in $N_2O$ emissions from agricultural soils were assessed for the 1990 and 2002 inventory using a Monte Carlo simulation of 5000 scenarios with the @RISK software (Kelliher et al, 2003) (Table 6.5.1). 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 2007 data, the uncertainty in the annual estimate was calculated using the 95 per cent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value ie, in 2002, the uncertainty in annual emissions was +74 per cent and –42 per cent.

**Table 6.5.2 New Zealand's uncertainties in $N_2O$ emissions from agricultural soils for 1990, 2002 and 2007 estimated using Monte Carlo simulation (1990, 2002) and the 95 per cent confidence interval (2007)**

| Year | $N_2O$ emissions from agricultural soils (Gg/annum) | 95% CI min (Gg/annum) | 95% CI max (Gg/annum) |
|---|---|---|---|
| 1990 | 32.4 | 18.8 | 56.4 |
| 2002 | 39.6 | 23.0 | 68.9 |
| 2007 | 39.8 | 23.1 | 69.2 |

The overall inventory uncertainty analysis shown in Annex 7 demonstrates that the uncertainty in annual emissions from agricultural soils is a major contributor to uncertainty in the total estimate and to the uncertainty in the trend from 1990. The uncertainty between years was assumed to be correlated. Therefore, the uncertainty is mostly in the emissions' factors and the uncertainty in the trend is much lower than uncertainty for an annual estimate.

The Monte Carlo numerical assessment is also used to determine the effects of variability in the nine most influential parameters on uncertainty of the calculated $N_2O$ emissions in 1990 and 2002. These parameters are shown in Table 6.5.2, together with their percentage contributions to the uncertainty. There was no recalculation of the influence of parameters for the 2007 data. The Monte Carlo analysis confirmed that uncertainty in parameter $EF_{3(PR\&P)}$ has the most influence on total uncertainty, accounting for 91 per cent of the uncertainty in total $N_2O$ emissions in 1990. This broad uncertainty reflects natural variance in $EF_3$, determined largely by the vagaries of the weather and soil type.

**Table 6.5.3 Percentage contribution of the nine most influential parameters on the uncertainty of New Zealand's total $N_2O$ emissions for 1990 and 2002**

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

### 6.5.4 Source-specific QA/QC and verification

In 2007, $N_2O$ emissions from the direct soil emissions and pasture range and paddock manure subcategories were key categories (level and trend assessment), and $N_2O$ from the indirect emissions category was also a key category (level assessment). In preparation for this inventory, the data for these categories underwent Tier 1 quality checks.

### 6.5.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database, 2008).

### 6.5.6 Source-specific planned improvements

New Zealand scientists are continuing to research $N_2O$ emission factors for New Zealand's pastoral soils. This includes development of New Zealand-specific emission factors for sheep and cattle dung and emission factors for New Zealand hill country pastures. New Zealand is also continuing research to refine the methodology used to estimate $N_2O$ emission reductions using dicyandiamide (DCD) nitrification inhibitors.

An extensive review of $Frac_{GASM}$ and $Frac_{GASF}$ emission factors has been carried out assessing international and New Zealand data. Preliminary results suggest the emission factors are currently too high. The review will be internationally peer assessed.

## 6.6 Prescribed burning of savanna (CRF 4E)

### 6.6.1 Description

In 2007, prescribed burning of savanna was not a key category in New Zealand. The inventory includes burning of tussock (*Chionochloa*) grassland in the South Island for pasture renewal and weed control. The amount of burning has been steadily decreasing over the past 50 years as a result of changes in lease tenure and a reduction in grazing pressure. In 2007, prescribed burning emissions accounted for 1.0 Gg $CO_2$-e, a 2.2 Gg $CO_2$-e (68.0 per cent) reduction in emissions from the 3.2 Gg $CO_2$-e reported in 1990.

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

### 6.6.2 Methodological issues

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

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

### 6.6.3 Uncertainties and time-series consistency

The same emission factors and sources of data were used for the whole time series. This gives confidence in comparing emissions through the time series. The major sources of uncertainty are the percentage of consented area actually burnt in that season, extrapolation of biomass data from two study sites for all areas of tussock, and that many of the other parameters are the IPCC default values (ie, the carbon content of the live and dead components, the fraction of the live and dead material that oxidises, and the nitrogen to carbon ratio for the tussocks). Uncertainty in the New Zealand biomass data has been quantified at ±6 per cent (Payton and Pearce, 2001). However, many IPCC parameters vary by ±50 per cent and some parameters do not have uncertainty estimates.

### 6.6.4 Source-specific QA/QC and verification

There was no source-specific QA/QC for this category in 2007.

### 6.6.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database, 2008).

## 6.7 Field burning of agricultural residues (CRF 4F)

### 6.7.1 Description

Burning of agricultural residues produced 17.5 Gg $CO_2$-e in 2007. This was a decrease of 11.3 Gg $CO_2$-e (–39.2 per cent) below the level of 28.7 Gg $CO_2$-e in 1990. Burning of agricultural residues was not identified as a key category in 2007.

New Zealand reports emissions from burning barley, wheat and oats residue in this category. Maize and other crop residues are not burnt in New Zealand.

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

## 6.7.2 Methodological issues

The emissions from burning agricultural residues are estimated using the equation on page 4.82 of the revised 1996 IPCC guidelines. This calculation uses crop production statistics, the ratio of residue to crop product, the dry-matter content of the residue, the fraction of residue actually burned, the fraction of carbon oxidised, and the carbon fraction of the residue. These parameters were multiplied to calculate the carbon released. The emissions of $CH_4$, CO, $N_2O$ and $NO_x$ were calculated using the carbon released and an emissions ratio. Nitrous oxide and $NO_x$ emissions' calculations also used the nitrogen to carbon ratio.

IPCC good practice guidance suggests that an estimate of 10 per cent of residue burned may be appropriate for developed countries, but also notes that the IPCC 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 is highly desirable (IPCC, 2000)." For the years 1990 to 2003, it was estimated that 50 per cent of stubble was burnt. For the years 2004 to 2007, experts assessed this to have decreased to 30 per cent. These values were developed from opinions of the Ministry of Agriculture and Forestry officials working with the arable production sector (M. Doak, pers com).

## 6.7.3 Uncertainties and time-series consistency

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

## 6.7.4 Source-specific QA/QC and verification

There was no source-specific QA/QC for this category in 2007.

## 6.7.5 Source-specific recalculations

All activity data was updated with the latest available data (Statistics New Zealand table builder and Infoshare database, 2008).

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

## 7.1 Sector overview

In 2007, net removals from the LULUCF sector were 23,836.0 Gg carbon dioxide equivalent ($CO_2$-e). Net removals had increased by 5,697.5 Gg $CO_2$-e (31.4 per cent) over the 1990 removals of 18,138.5 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 2007.

Carbon dioxide emissions and removals in the LULUCF sector are primarily controlled by uptake from plant photosynthesis and release from respiration, emissions from harvesting production forests, and the decomposition of organic material. Nitrous oxide ($N_2O$) can be emitted from the ecosystem as a by-product of nitrification and de-nitrification and the burning of organic matter. Other gases released during biomass burning include methane ($CH_4$), carbon monoxide (CO), other oxides of nitrogen ($NO_x$), and non-$CH_4$ volatile organic compounds (NMVOC). All emissions and removals from the LULUCF sector are excluded from national totals unless otherwise specified. This is consistent with Climate Change Convention reporting guidelines.

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 reach or 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 reach or 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 Annual emissions/removals for the three major land uses from 1990 to 2007**

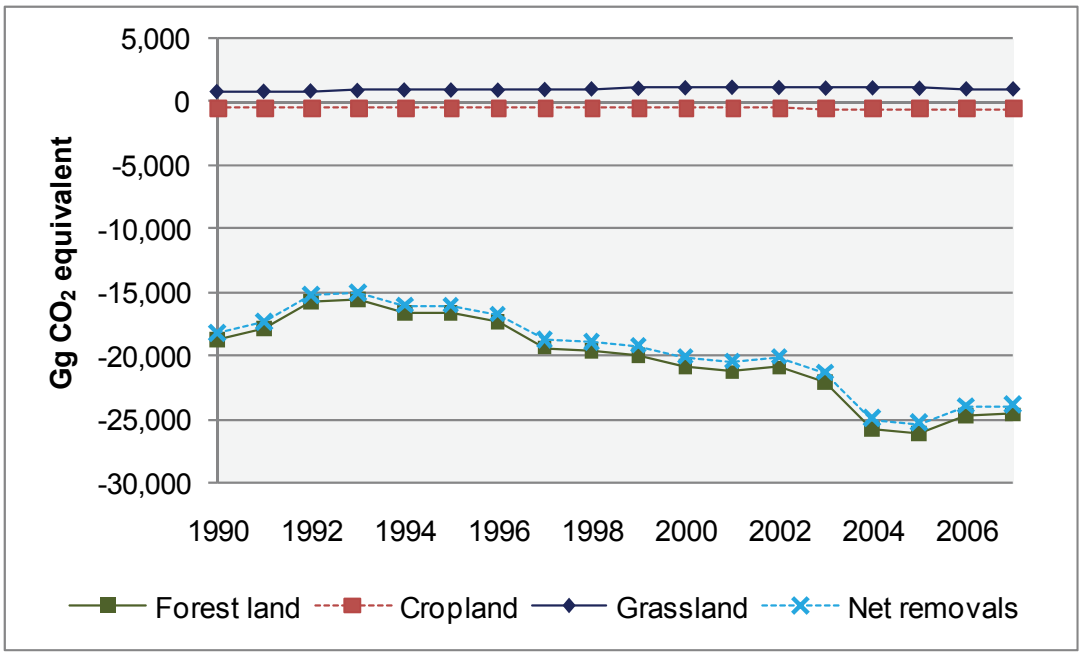
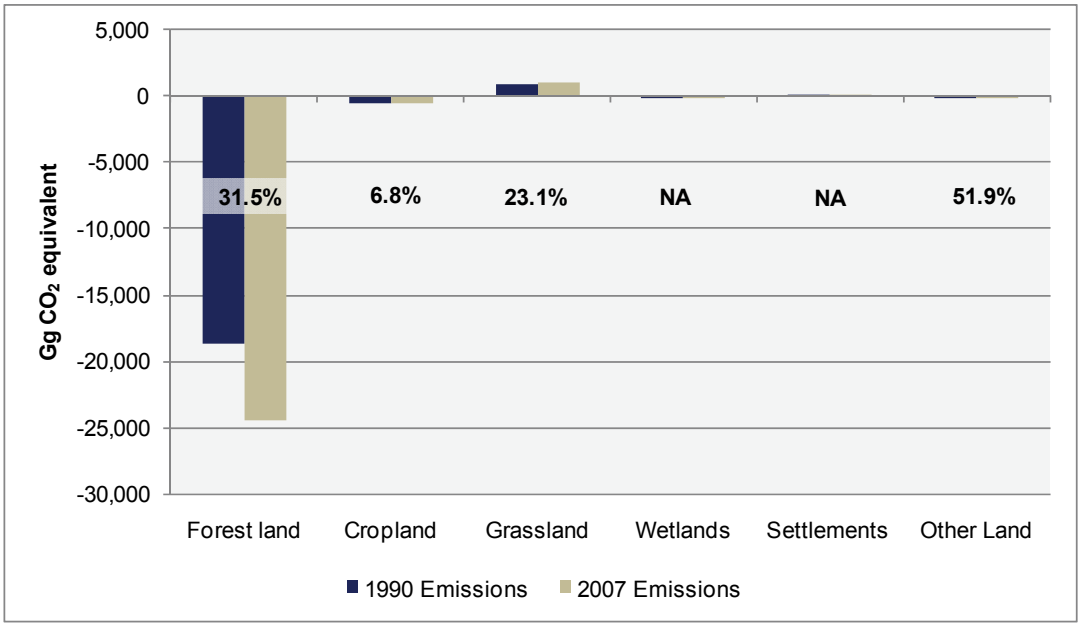



**Figure 7.1.2 Change in New Zealand's emissions/removals from the LULUCF sector (net emissions and removals by land-use category) from 1990 to 2007**




**Note:** The per cent change for wetlands 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 to have covered around 75 per cent of New Zealand's total land area. Forestry now covers approximately 38 per cent of New Zealand. This includes natural forest, planted forest and shrubland that meets the threshold for forestry. Figures 7.1.3 and 7.1.4 show the IPCC land-use categories for New Zealand in 2002 (from the Land Cover Database of 2002). Nearly all lowland areas have been cleared of natural forest and are used 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 carbon (Scott et al, 2001). Establishment of pastures has 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 uses a combination of Tier 1 and Tier 2 methods 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, with the exception of the biomass pools for the planted forest category. Key categories identified for the LULUCF sector are forest land remaining forest land (level and trend), conversion to forest land (level), conversion to grassland (trend), conversion to cropland (trend), and cropland remaining cropland (level). Forest land remaining forest land and conversion to forest land are key subcategories. Therefore, a Tier 2 modelling approach using New Zealand-specific data is used to estimate removals and emissions (excluding soils) from these key subcategories.

To improve the transparency and accuracy of reporting in the LULUCF sector, and to meet the supplementary reporting requirements for Article 3.3 of the Kyoto Protocol, New Zealand is developing the Land Use and Carbon Analysis System (LUCAS). The LUCAS programme 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 Climate Change Convention and the Kyoto Protocol, and will be reported in the 2010 inventory submission onwards.

### Representation of land areas

#### *Tier 1 approach for all land use – excluding planted forest*

Land areas are calculated 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 were reclassified to reflect the IPCC land-use categories. The land-cover databases were mapped in 1997 and 2002. Data for all other years was extrapolated from the changes observed between 1997 and 2002.

The LCDB1 and LCDB2 are examples of the wall-to-wall mapping of Approach 3 as described in GPG-LULUCF. Although, the LCDBs were not specifically developed for use in Climate Change Convention reporting, they are the only national land-cover/land-use spatial databases available that provide recent information and that can be mapped to the LULUCF land-use categories (Table 7.1.1). LCDB1 and LCDB2 include national

vegetation classes, other than forests, including woody vegetation. These vegetation classes were classified within the forest-land and grassland categories based on an assessment of whether the species would usually grow to over five metres in height *in situ* and, therefore, meet the forestry definition and the minimum size of the land-cover unit.

At the time of compiling this submission, New Zealand does not have complete land-use data for 1990. Until the 1990 mapping component of the LUCAS project is completed, the extrapolations back from the LCDBs provide the best data available for the inventory. Figure 7.1.4 provides the annual area for each IPCC land-use category for the inventory reporting period (derived from both the Tier 1 and Tier 2 land area data).

Work is underway to improve the estimates of land "converted" and "remaining" within each land-use category. At present, only conversions since 1990 are captured in the Tier 1 method. An assessment of land-use change in the 20 years prior to 1990 will be included in future inventory submissions, making use of historic data from sources such as the Food and Agriculture Organisation of the United Nations Statistics (FAOSTAT database http://faostat.fao.org) and national estimates eg, agricultural census and surveys, and the National Exotic Forest Description (NEFD).

**Table 7.1.1 Mapping of LCDB land-cover classification to the IPCC land-use categories**

| IPCC category | LCDB class |
|---|---|
| **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. |
| **Cropland** | |
| CM (perennial) | Orchards, vineyards, and other perennial crops. |
| CM (annual) | Short-rotation cropland. |
| **Grassland** | |
| GM (low prod) | Alpine grass/herbfield, depleted tussock grassland, fernland, gorse and broom, grey scrub, low-producing grassland, major linear shelterbelts, matagouri, mixed exotic shrubland, sub-alpine shrubland, tall tussock grassland, flaxland, herbaceous freshwater vegetation, herbaceous saline vegetation and mangrove. |
| GM (high prod) | High-producing exotic grassland. |
| **Wetlands** | |
| W (unmanaged) | Estuarine open water, lakes, ponds and rivers. |
| **Settlements** | |
| S | Built-up area, dump, surface mine, transport infrastructure, urban parkland/open space. |
| **Other land** | |
| O | Alpine gravel, rock, coastal sand, gravel landslides, permanent snow, ice, rivers and lakeshore gravel and rock. |

Table 7.1.2 shows a simplified land-use change matrix developed from LCDB1 and LCDB2 for the years 1997 and 2002. A land-use change matrix for 2006–2007 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:

- increased planted forest area of almost 140,000 hectares (a 7 per cent increase), mostly from conversion of grassland, that decreased by 135,000 hectares (2 per cent)
- increased area of settlements by 5,500 hectares (2.5 per cent) mostly from conversion of grassland
- increased area of cropland by 4,500 hectares (7 per cent), mostly perennial cropland.

### *Tier 2 approach for planted forest*

The National Exotic Forest Description (NEFD) is an annual survey of forest growers that provides estimates of the area of forest by age, species, silvicultural regime and location. The NEFD data includes the separation of planted forest into "converted" and "remaining" categories, based on forest rotation information provided within the survey.

**Figure 7.1.3 New Zealand's total area for each land use from 1990 to 2007 (all figures kha and based on both Tier 1 and Tier 2 data)**

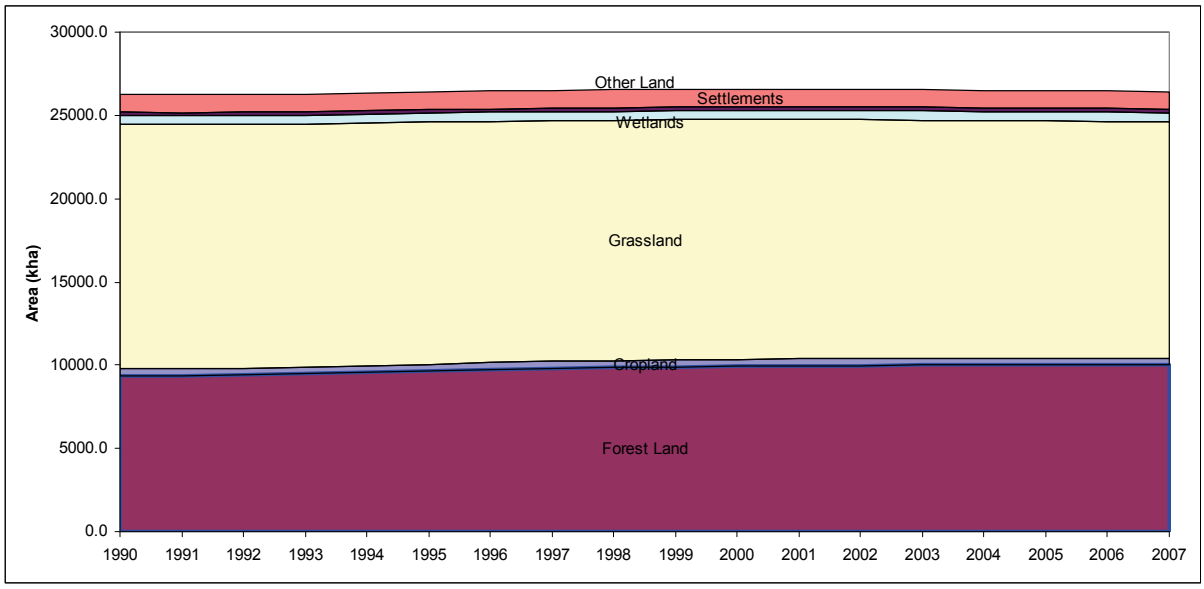


**Figure 7.1.4 Land use in New Zealand in 2002: IPCC land-use categories (mapped from LCDB2)**

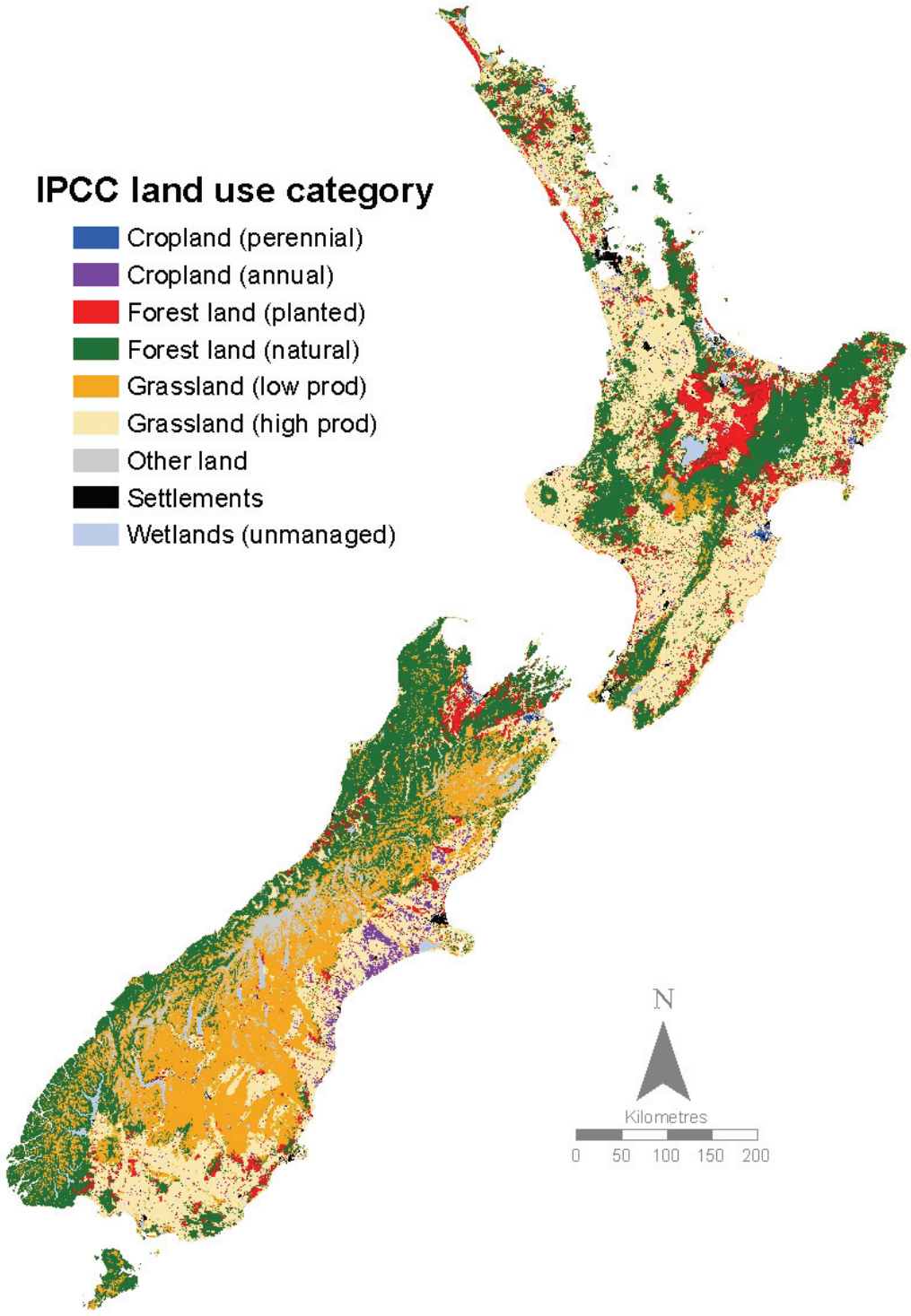


**Table 7.1.2 New Zealand's land-use change matrix between 1997 and 2002 (all areas in thousands of hectares) (IPCC land-use classes derived from LCDB1 and LCDB2)**

| 2002 \ 1997 | | 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% |

**Notes:** Areas are shown here if they are greater than 0.1 kha. Smaller areas are not thought to represent an actual land-use change.

Columns and rows may not total due to rounding. Shaded cells indicate land remaining in each category.

## Models and Calculations

### *Tier 1 approach for all land use excluding planted forest*

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. These factors are tabulated in Tables 7.1.3 and 7.1.4.

**Table 7.1.3 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 | 224.8 t C $ha^{-1}$ | All living biomass and dead organic matter | 1st rotation, 28 years old (Wakelin, 2008). |
| Annual cropland | 0 t C $ha^{-1}$ | All living biomass | Annual crops are harvested. GPG-LULUCF only considers perennial crops (Table 3.4.8). |
| *Perennial cropland* | 63 t C $ha^{-1}$ | Above-ground biomass only* | GPG-LULUCF Table 3.3.2. Temperate (all moisture regimes). |
| *High-producing grassland* | 1.35 t C $ha^{-1}$ | Above-ground 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 $ha^{-1}$ | Above-ground 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 biomass* | 29 t C $ha^{-1}$ | Above-ground biomass only* | Clearance of grassland woody vegetation prior to planting with forest (Wakelin, 2007). |

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

**Table 7.1.4 Annual growth in biomass for land converted to another land use**

| Land use | Value | Pools | Source/Reference |
|---|---|---|---|
| Natural forest | T1 = 2.2 t C $ha^{-1}$ | All living biomass | 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, $C_{frac}$ = 0.5). |
| Planted forest | T1 = 8.9 t C $ha^{-1}$ Varies | All living biomass and dead organic matter | Tier 1 – GPG-LULUCF 3A1.6 and 3A1.8 (Gw=14.5 tonnes dm $ha^{-1}$ (Pinus), R=0.23, $C_{frac}$= 0.5).<br>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 $ha^{-1}$ 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 $ha^{-1}$ | Above-ground biomass only* | GPG-LULUCF Table 3.3.8 (temperate all moisture regimes). |
| High-producing grassland | 6.75 t C $ha^{-1}$ | Above-ground 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 $ha^{-1}$ | Above-ground 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

### *Tier 2 approach for planted forest*

Models are used to derive forest carbon from stem volume yield tables and to calculate removals and emissions. Further detail of the modelling for planted forest is given in section 7.2.2.

### *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 the type of land use; (2) a management factor ($F_{MG}$) that for permanent cropland represents different types of tillage used; 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 7.1.5.

**Table 7.1.5 Soil stock change factors selected from GPG-LULUCF Tables 3.3.4 and 3.4.5**

| Land use | FLU (Land use) | FMG (Management) | FI (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 |

New Zealand applies the default inventory time period of 20 years in calculating the Tier 1 estimates. New Zealand uses 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, that is:

$$105 \text{ t C ha}^{-1} \div 1 \div 1.14 \div 1.11 = 83 \text{ t C ha}^{-1}.$$

For the Tier 2 analysis, it is assumed that where there is no land-use change (for example, forest land remaining forest land), the soil carbon stock does not change.

### *Liming*

Information on the amount of lime applied is aggregated nationally, with limestone and dolomite both reported together under the limestone subcategory. Estimates of lime application by land use are calculated based on information for fertiliser application gathered through the Agricultural Production Survey. The results of these calculations showed that on average around 94 per cent of the lime was applied to grassland, with the remaining 6 per cent to cropland. Emissions associated with liming were reallocated in this inventory submission and are now reported under grassland and cropland categories.

### *Biomass burning*

Biomass burning takes place either as a controlled burn or as wildfire on forest land or grassland. Reporting at a national level is based on the total areas of grassland or forest land burned. Burning of crop stubbles and prescribed burning of savannah are reported in the agriculture sector. Activity data (eg, areas burned, initial biomass density) and other

variables related to biomass burning (eg, fuel consumption) are used in the Tier 1 method. Due to climate and vegetation types, the incidence of vegetation wildfires is low in New Zealand compared to many other countries. Biomass burning is not a significant source of emissions in New Zealand.

Emissions resulting from natural disturbance events in natural forests and grasslands are not reported because the subsequent regrowth is not captured in the inventory. In this situation, GPG-LULUCF (3.2.1.4.2.) states that "if methods are applied that do not capture removals by regrowth after natural disturbances, then it is not necessary to report the $CO_2$ emissions associated with natural disturbance events". In the case of wildfire in planted forest land, the $CO_2$ emissions are captured by the stock change calculation if the fire damaged area was harvested and replanted, or if the stand is allowed to grow on with a reduced net stocked area. Carbon dioxide emissions may be underestimated in the instance where a damaged stand had reached maturity without a reduction in its net stocked area. However, the total area of wildfires in planted forests is small and, therefore, this is not regarded as a significant source of error.

# 7.2 Forest land (CRF 5A)

## 7.2.1 Description

In 2007, forest land contributed 24,527.9 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 and deforestation. Net removals from forest land had increased by 5,891.4 (31.5 per cent) over the 1990 level of 18,649.3 Gg $CO_2$-e. In 2007, forest land remaining forest land and conversion to forest land were key categories (trend and level assessment).

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 is used when forest is mapped by the LUCAS project and reported in future inventory submissions. To complete this 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).

The IPCC Guidelines and GPG-LULUCF defines managed forest land as: "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 dominated carbon stock changes in the LULUCF sector. Forestry now covers approximately 38 per cent of New Zealand. This includes natural and planted forest, and shrubland that meets the definition of forestry. In New Zealand, there has been considerable afforestation since 1990, and some deforestation of planted forests has occurred since 2004.

For inventory reporting, two subcategories are used to cover all of New Zealand's forests: natural forest and planted forest.

### *Natural forest*

Natural forest is a term used to distinguish New Zealand's native forests from planted production forests. Native forest ecosystems comprise 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. New Zealand has approximately 8.2 million hectares of natural forest including shrublands (based on LCDB2 estimates).

Government controls on natural forest clearance (deforestation) were first imposed in the late nineteenth century, but demand for timber and agricultural land resulted in further forest clearance. By the 1970s, 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 planted forests.

Further government administrative changes in 1987 resulted in the 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 permits by a 1993 amendment to the Forests Act of 1949. The amendment exempted West Coast publicly owned forests and forests on specific Māori-owned lands. Further government controls resulted in the cessation of any logging of natural forest on public land including 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. 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 natural 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.

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 to the Forest Amendment Act (2004) of outlined restrictions will continue to exempt the SILNA forests although logging has further reduced in these forests.

Removals of $CO_2$ in natural forest are calculated using an IPCC Tier 1 approach. Preliminary results showed 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 0.3–2.5 Tg C $yr^{-1}$ (Tate et al, 2000). For this reason, removals were set to emissions in the common reporting format tables. Results from analysis of the Carbon Monitoring System (CMS) data within natural forests as part of the LUCAS programme will enable New Zealand to provide improved estimates (refer to Annex 3.2).

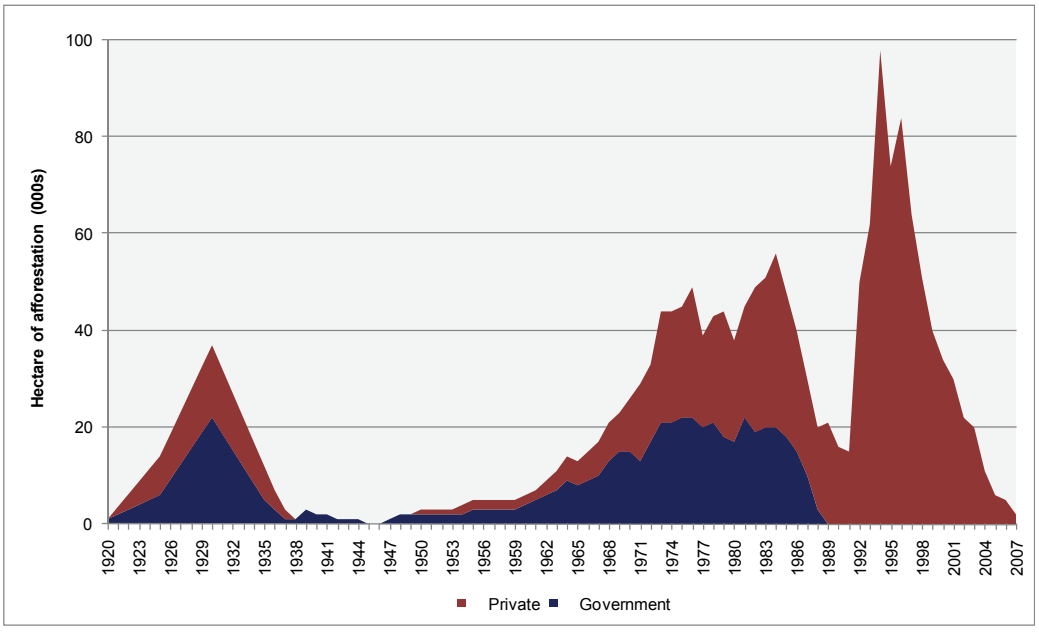
### *Planted forest*

New Zealand has a substantial estate of planted forests, created specifically for timber supply purposes. New Zealand's planted forests are intensively managed and there is well-established data on the estate's extent and characteristics. Having a renewable timber resource has allowed New Zealand to protect and sustainably manage its natural forests. *Pinus radiata* is the dominant species, making up around 90 per cent of the planted forest area. These forests are usually composed of stands of trees of a single-age class and all forests have relatively standard silviculture regimes applied.

Between 1990 and 2007, it is estimated that around 680,000 hectares of new forest was established as a result of afforestation activities. In 2007, plantation forestry covered an estimated 1.8 million hectares of New Zealand (around 7 per cent of the total land area). A large planted forest resource enables New Zealand to sustainably manage its publicly and privately-owned natural forest.

The new planting rate (land reforested or afforested) over the last 30 years was, on average, 40,000 hectares per year (Figure 7.2.1). While new planting rates were high from 1992 to 1998 (averaging 69,000 hectares per year), since 1998 the rate of new planting rapidly declined and is now at very low levels. In 2007, it was estimated that only 2,000 hectares of new forest was established (the lowest level since 1950). Some of the land that was not replanted was converted into grassland. The very low levels of new planting, and conversion of some forest land to grassland, were due to the relative profitability of some forms of pastoral farming (particularly dairy farming) compared to forestry.

**Figure 7.2.1 Annual forest planting in New Zealand from 1920 to 2007**




## 7.2.2 Methodological issues

### Forest land remaining forest land

*Natural forest (Tier 1)*

A small amount of harvesting took place that was exempt from the sustainable management plan requirement (section 7.2.1). This harvesting was 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 was carried out on a sustainable basis. Estimates of harvesting from exempted natural forests were provided by the Ministry of Agriculture and Forestry. Stem wood volumes were converted to oven-dry weight using a factor of 0.5 (GPG-LULUCF equation 3.2.4) and then expanded to include non-stem wood biomass using a factor of 2.04 as used by Wakelin, (2008). These New Zealand-specific factors are within the ranges given by GPG-LULUCF (Tables 3A1.9-1 and 3A1.10).

Results from analysis of the natural forest plot collected as part of the LUCAS project will enable New Zealand to provide improved estimates in future submissions (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 involved:

- the annual NEFD surveys
- stem wood volume yield tables are compiled periodically for combinations of species, silvicultural regime and location
- the C_change models (Beets et al, 1999) were 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) was used to recalculate historic estimates of $CO_2$ removals and emissions by time shifting the latest available data backwards.

### *Planted forest survey data*

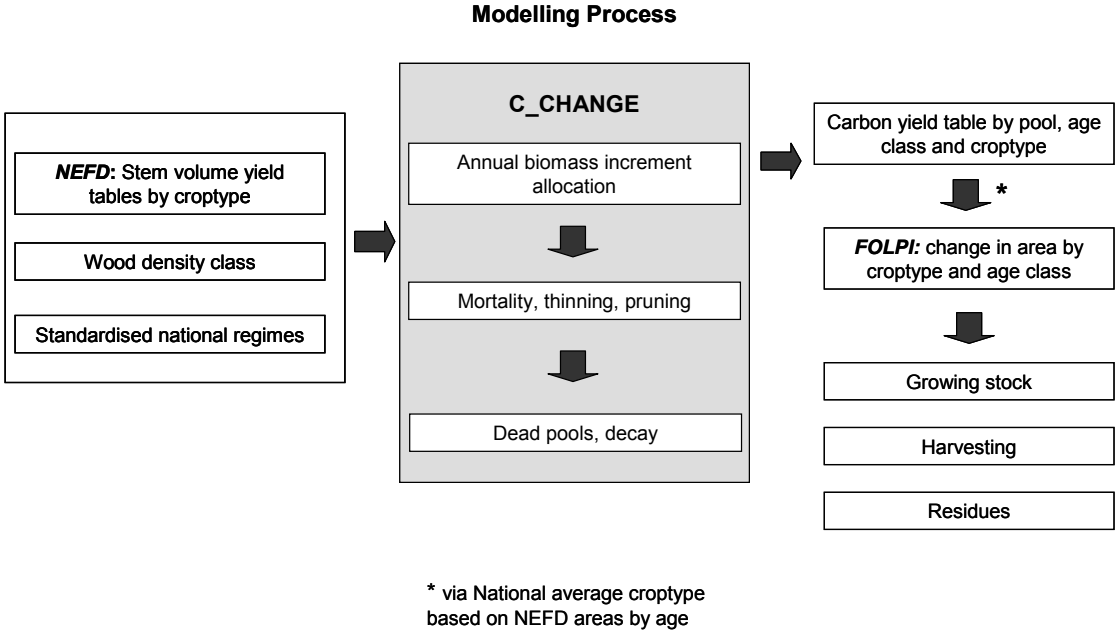
The results of the NEFD survey, as at 1 April 2007, were used to calculate removals and emissions provided in this submission. This latest information provided new forest area data along with data on new planting, restocking and harvesting and merchantable, stem wood volume by crop type and age for the 2007 year (Ministry of Agriculture and Forestry, 2008).

A crop type is an aggregate of forest stands that are similar with respect to species, silviculture and location. Each crop type had a yield table that provided estimated volumes of stem wood per hectare, by age. The total forest area after harvest for the year ending March 2007 was based on: (a) the latest area estimates provided by the 2007 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 activity data was collected by the Ministry of Agriculture and Forestry. These estimates are revised and recalculated annually as provisional estimates are replaced by confirmed actual statistics.

### *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 (see Box 7.2).

**Figure 7.2.2 Planted forest inventory modelling process**




**Note:** * refers to the national average yield table.

**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 carbon fraction for litter is 0.37, initial investigations suggest that the carbon fraction in the litter pool in planted forests in New Zealand is higher. A New Zealand-specific factor of 0.5 is used (Wakelin, 2008).

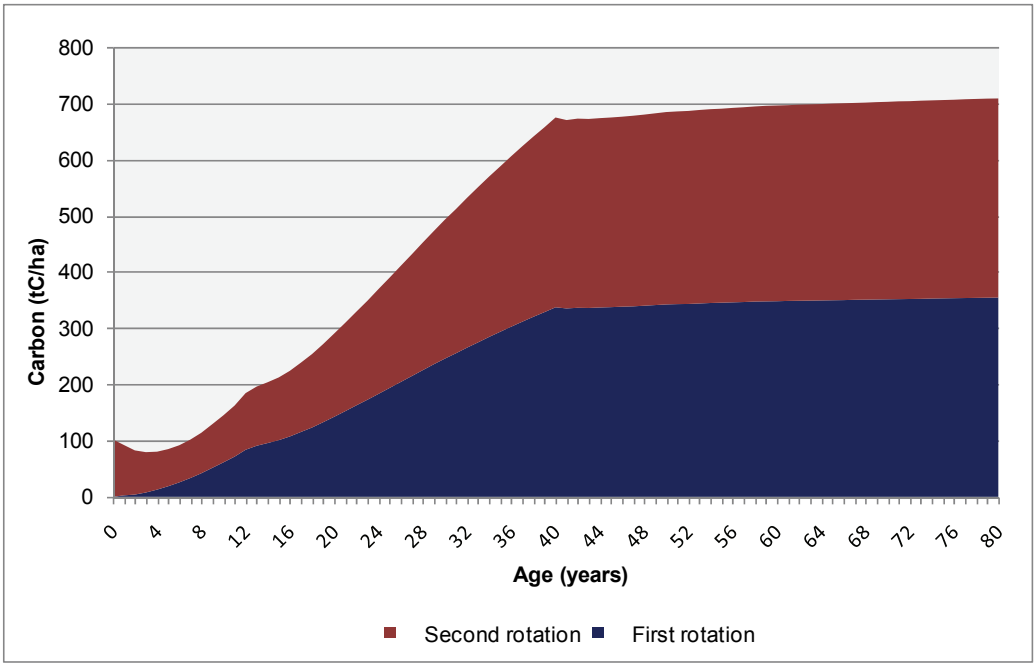
For this submission, C_change was used to create a corresponding carbon yield table for each wood volume yield table, based on wood density and management assumptions appropriate to the species, regime and region. The allometric equations used were based on data for *Pinus radiata*. Approximately 10 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 have on the accuracy of calculations of total biomass, but current research and data collection will enable the impact to be assessed in future inventory submissions. The output from C_change was a dry-matter yield table with estimates of dry-matter per hectare by age class for each component. These were aggregated into the IPCC non-soil pools and converted to carbon using a carbon fraction of 0.5. 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. Total carbon yield by stand age and rotation are shown in Figure 7.2.3 below.

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 were the LULUCF results for 1990–2007. These results included:

- stem wood volume harvested from the planted estate, hence CO2 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 provided the change in carbon stock between harvested forests and this year's unharvested forests.

**Figure 7.2.3 Total carbon yield by stand age and rotation**




The method in this submission included the use of information on rotation number obtained through the NEFD survey to define the historic afforestation and restocking time series. This allows for a more accurate separation into the forest land remaining forest land, and land converted to forest-land categories, than was previously possible. Existing planted forest areas were allocated to one of two crop types, representing first and second rotation stands respectively. This separation was required so that the carbon stock in residues (resulting from harvesting a previous crop) could be correctly accounted for. In previous inventory submissions, the allocation was made by assuming areas planted before 1970 were first rotation. For areas planted in 1970 or later, the first rotation allocation was based on national afforestation statistics. Any remaining area in planting years 1970–2003 was assumed to be second rotation. For this submission, NEFD rotation information was used in the modelling. As a result, there was a higher proportion of

second rotation area present in 1990, with correspondingly lower net carbon uptake due to the presence of decaying harvest residues.

In this submission, estimated deforestation of planted forests was explicitly modelled for the years 2004–2007. This included some deforestation of immature post-1989 stands. Significant deforestation of planted forests is a relatively recent phenomenon. In previous inventory submissions, these deforested areas were not explicitly modelled. Further detail on this improvement is provided in section 7.2.5.

### *Biomass burning*

For the forest land remaining forest-land category there is no controlled burning in New Zealand. The inventory only reports emissions that resulted from wildfire, where the IPCC default temperate forest fuel consumption rate of 45 per cent of total biomass was 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). For this submission, the NZFS data was used from June 2001–June 2008, with the average over this period applied back to 1990. Activity data for wildfire is generally of poor quality, but it is estimated 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. Carbon dioxide emissions may be underestimated in the instance where a damaged stand has reached maturity without a reduction in its net stocked area. However, the total area of wildfires in planted forests is small and, therefore, this is not regarded as a significant source of error.

## Land converted to forest land

Previously, New Zealand only reported emissions from the clearance of non-forest vegetation for afforestation purposes in this category. Now carbon stock changes due to afforestation are reported here for one full rotation before the area is transferred into the forest land remaining forest-land category. The modelled rotation length for 1990–2007 varies, with an annual average of 27–29 years. Forest yield and carbon contents are as described for forest land remaining forest land above.

Data on the amount of land clearance for new forest planting were sourced from the annual NEFD survey. The information included the proportion of new forest planted that occurred on grassland. This includes woody vegetation that falls below and was not expected to exceed, without human intervention, the threshold used to define forest land for New Zealand under the Kyoto Protocol.

Data was available from 1993 to 2007. Based on this activity data, it was assumed that the proportion of new forest planting on grassland with woody vegetation was 20 per cent before 1993. This activity data was used to estimate emissions resulting from the clearance of woody vegetation prior to afforestation planting.

### *Biomass burning*

It was estimated that 25 per cent of the land converted to forest land was cleared using controlled burning, with a New Zealand-specific fuel consumption rate of 70 per cent of above-ground biomass (Wakelin, 2007). The remainder of the above-ground biomass and all biomass on cleared but unburned sites were assumed to decay over 10 years (IPCC, 1996). Current research aims to quantify emissions from the burning of residues that resulted from the conversion of planted forests to grassland. Emissions of $CO_2$ from controlled burns for afforestation were reported as a stock change in the grassland

category. Carbon dioxide emissions resulting from natural disturbance events were not reported, as subsequent regrowth is not part of the calculation methods (GPG-LULUCF 3.2.1.4.2).

Wildfire emissions are reported under forest land remaining forest land, as the wildfire incidence data does not identify wildfires by rotation number.

## 7.2.3 Uncertainties and time-series consistency

*Pinus radiata* had been widely studied in New Zealand because of its significance in the forestry industry. 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* outer-wood 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 are 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 than 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 (Table 7.2.3.1) but it is difficult to quantify the overall error due to the assumptions implicit in the models. Some uncertainties within the C-change model are well characterised (Hollinger et al, 1993). Combining the uncertainties indicated that the proportional error in the carbon sequestration estimates is likely to be at least ± 16 per cent.

**Table 7.2.3.1 Uncertainty in emissions and removals from planted forest**

| Variable | Uncertainty (95% confidence interval) |
|---|---|
| **Uncertainty in land area** | |
| NEFD Survey | ± 5% |
| Uncertainty in biomass accumulation rates | |
| C_change model: wood density | ± 3% |
| C_change model: carbon allocation | ± 15% |
| C_change model: carbon content | ± 5% |
| NEFD yield tables | ± 5% |
| **Combined uncertainty** | **± 16%** |

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 model runs indicate that the precision of the carbon stock estimates could be of the order of ± 25 per cent. As part of the development of 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 were 6.2 per cent of New Zealand's total emissions and removals uncertainty in 2007 (Annex 7). Forest land introduced 2.2 per cent uncertainty into the trend in the national total from 1990 to 2007.

## 7.2.4 Source-specific QA/QC and verification

The forest land remaining forest land ($CO_2$) and land converted to forest land ($CO_2$) were key categories in 2007 (for both the level and trend assessment).

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

The data was also 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 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 LCDB estimates and the annual results of Statistics New Zealand's Agricultural Production Survey. The NEFD tables have been subject to review (eg, Jaakko Poyry Consulting, 2003; Manley, 2004) and are in the process of being revised.

The 2007 planted forests removals and emissions were compared for consistency with the 2006 estimates (Wakelin, 2008), with both level and trend being similar.

## 7.2.5 Source-specific recalculations

The main changes in the data for the 2009 inventory submission were due to:

*NEFD data*

The classification of planted forests into first or subsequent rotations in the NEFD data was updated for this submission, as new data for approximately 94 per cent of the total planted forest area was available this year. This information allows for separation into appropriate converted and remaining categories and was used for the first time in calibrating historic activity data. A greater proportion of the total area has been identified as second rotation throughout the time series from 1990. Second rotation stands have a lower net uptake of carbon than first rotation stands of the same age due to the presence of decaying harvest residues. This reduces net uptake compared with previous estimates.

*Modelling process*

Significant deforestation of areas of planted forest is a recent phenomenon, only occurring since 2004. In previous submissions, deforested areas were not explicitly modelled. Any deforested areas were removed from the NEFD data for the whole time series. Therefore, using NEFD survey data meant that derived historic age class distributions did not include information of the areas deforested. This approach was revised for this submission to explicitly model estimated deforestation of planted forests for the years 2004–2007, including some deforestation of immature post-1989 stands. This was an improvement in the modelling process.

Deforestation is represented as an instantaneous emission but these emissions were not able to be separated from harvested emissions for this submission and are captured in the forest land remaining forest land or grassland converted to forest-land categories. Further work is required to refine the estimates of deforestation activity data and associated emissions and to allow this to be reported against the correct category. The Tier 1 estimates of planted forest deforestation emissions previously reported under forest land

converted to grassland have been removed to avoid double counting. Natural forest deforestation and soil emissions are still accounted through the Tier 1 analysis in this submission.

### 7.2.6 Source-specific planned improvements

This inventory includes a provisional estimate of 10,000 hectares of deforestation in 2007. Updated information in April 2009 indicates the area of deforestation in 2007 was in the range of 15,000–20,000 hectares. The recalculation for the updated area will be included in the 2010 submission.

The revised modelling process to better account for deforestation has provided more accurate estimates of total emissions and removals for forest land. However, emissions due to the conversion of planted forest to grassland will be explicitly separated in the modelling and reported under the grassland land-use category. This will be reported in the 2010 submission.

Development of the LUCAS will enable New Zealand to improve reporting of the LULUCF sector in the 2010 submission. Further details are included in Annex 3.2.

## 7.3 Cropland (CRF 5B)

### 7.3.1 Description

In 2007, cropland accounted for 510.3 Gg $CO_2$-e of net removals. Net removals from cropland had increased 32.6 Gg $CO_2$-e (6.8 per cent) from the 1990 level of 477.7 Gg $CO_2$-e. In 2007, the cropland remaining cropland category ($CO_2$) and the conversion to cropland ($CO_2$) categories were key categories (level and trend assessment respectively).

Cropland in New Zealand is separated into two subcategories, annual and perennial. Cropland comprised less 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 shelter belts.

The amount of carbon stored in, emitted or removed from permanent cropland depends on crop type, management practices, and soil and climate variables. Annual crops are harvested each year, with no long-term storage of carbon in biomass. However, 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 are calculated using IPCC Tier 1 emission and removal factors and activity data from the LCDB analysis described in section 7.1.2.

## 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 to be 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 Table 3.3.2 of the GPG-LULUCF. New Zealand uses 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. When the results from LUCAS are included in future submissions, it will be assumed that perennial cropland will be reported in the converted land category for the default 20-year period. Beyond the 20-year period it will be assumed that it reaches a "steady state" where growth equals losses with no net change in emissions/removals.

### *Dead organic matter*

New Zealand has not reported estimates of dead organic matter in this category. The notation "NE" is used in the commoning report format tables. Sufficient information is not available to estimate carbon stock change in dead organic matter pools within the cropland remaining cropland subcategory (IPCC, 2003).

### *Soil carbon*

Mineral soils comprise 99.9 per cent of New Zealand soils (Tate et al, 2004). To provide a Tier 1 estimate, New Zealand uses the IPCC default method for mineral soils (equation 3.3.3, GPG-LULUCF). 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 7.1.5. 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.

### *Liming*

Lime used in New Zealand is agricultural lime, or ground limestone. The calculation of $CO_2$ emissions from the liming of cropland soils is based on GPG-LULUCF equation 3.4.11, using the total amount of limestone applied (provided by Statistics New Zealand) and a carbon conversion factor from limestone to carbon. New Zealand used 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 to 2001. Linear interpolation was used to represent the data for these years. Since 2002 there was a decrease 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.

### 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. These are shown in Tables 7.1.3 and Table 7.1.4.

#### *Dead organic matter*

New Zealand does not report estimates of dead organic matter in this category. The notation "NE" is used in the common reporting format tables. Sufficient information is not available 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*

To calculate soil carbon stocks, New Zealand follows 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).

#### *Nitrous oxide emissions*

Nitrous oxide 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. A New Zealand-specific value of 0.01 kg N2O-N/kg N is used (Kelliher et al, 2006)
- 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 broken down into uncertainty in activity data, and uncertainty in other 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. However, uncertainty in activity data used in the inventory is 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, the 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) |
| **Uncertainty in liming** | ± 40% |
| **Combined uncertainty** | ± 75% |

### 7.3.4 Category-specific QA/QC and verification

In 2007, the cropland remaining cropland category ($CO_2$) and the conversion to cropland ($CO_2$) categories were key categories (level and trend assessment respectively). In the preparation of this inventory submission, the data in this category underwent IPCC Tier 1 quality checks.

### 7.3.5 Category-specific recalculations

The $N_2O$ emissions were updated using the New Zealand-specific $N_2O$ emission factor, $EF_1$, to be consistent with emission calculations in the agriculture sector. The time series was recalculated to reflect this change. In addition, recalculations were carried out for the time series due to the inclusion of liming within this land-use category.

### 7.3.6 Category-specific planned improvements

The use of historic activity data for cropland is being investigated. This will allow for improved estimates of the land converted to cropland and cropland remaining cropland categories to be reported in future inventory submissions. New Zealand will also investigate the potential use of country-specific emission factors for the cropland category.

## 7.4 Grassland (CRF 5C)

### 7.4.1 Description

In 2007, the net emissions from grassland were 1,063.7 Gg $CO_2$-e. This was an increase of 199.8 Gg $CO_2$-e (23.1 per cent) from the 1990 level of 863.9 Gg $CO_2$-e. These emissions were from land converted to grassland and grassland remaining grassland categories. Carbon dioxide emissions from conversion to grassland were identified as a key category (trend) for 2007.

In New Zealand, grassland covers a range of land-cover types. Two grassland subcategories are used in this submission, namely low producing and high producing. Low-producing grassland consists of either native tussock land 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 as the main land use. Most New Zealand agriculture is based on extensive pasture systems with animals grazed outdoors year-round. There has been 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 common reporting format tables because the activity occurs but no estimate of removals or emissions was able to be calculated.

#### *Dead organic matter*

New Zealand has not reported estimates of dead organic matter in this category. The notation "NE" is used in the common reporting format tables. GPG-LULUCF states there is insufficient 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*

Mineral soils cover 99.93 per cent of New Zealand (Tate et al, 2004). To provide a Tier 1 estimate, New Zealand uses the IPCC default method for mineral soils (equation 3.4.8 of GPG-LULUCF). The LCDB analysis used in this 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 $F_I$ were considered as constant and, consequently, the calculation shows there was no net change in carbon stocks in soils.

#### *Biomass Burning*

Non-carbon dioxide emissions from wildfires in low-producing grasslands (tussock and grassland with above-ground woody biomass) are reported in the LULUCF sector, while those from controlled (prescribed) burning of savannah are covered in the agriculture sector. Carbon dioxide emissions that resulted from natural disturbance events are not reported, as subsequent regrowth is not part of the calculation (GPG-LULUCF 3.2.1.4.2).

For low-producing grassland with above-ground woody biomass, the activity data is sourced from the NZFS 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 per cent would be more appropriate (Wakelin, 2006). This was applied to the total biomass (rather than above ground only) using the more general initial grassland with above-ground woody biomass estimate of 136 t dm hectare$^{-1}$ (Hall et al, 2001), rather than the specific "pre-afforestation" biomass value used for grassland (with woody vegetation) converted to forest land.

In previous submissions, emissions from wildfire in tussock grassland were not reported. Although the area of tussock burned is similar to that of grassland with above-ground

woody biomass, emissions were much lower because there was less biomass present. For wildfire in tussock, the assumptions used for controlled burning were applied to the NZFS wildfire areas.

#### *Liming*

Lime used in New Zealand is agricultural lime, or ground limestone. The calculation of $CO_2$ emissions from the liming of grassland soils is based on GPG-LULUCF equation 3.4.11, using the total amount of limestone applied (provided by Statistics New Zealand) and a carbon conversion factor from limestone to carbon. New Zealand used 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 was used to represent the data for these years. Since 2002, there was a decrease in the amount of lime applied. It was not clear why this decrease occurred but quantities do vary from year to year depending on a number of factors, including farming returns.

### Land converted to grassland

#### *Living biomass*

To calculate carbon stock changes in living biomass, New Zealand applies the GPG-LULUCF Tier 1 method. 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 accounts for carbon in biomass that replaces cleared vegetation. Pre-conversion stocks and annual growth figures are shown in Tables 7.1.3 and 7.1.4. Carbon stock changes from planted forest to grassland conversion were not included in the Tier 1 analysis, but were captured in the Tier 2 analysis (forest-land category). Carbon stocks in biomass immediately after conversion were assumed to be zero.

#### *Dead organic matter*

New Zealand has not reported estimates of dead organic matter in this category. The notation "NE" is used in the common reporting format tables. No Tier 1 method exists for calculating emissions or removals from dead organic matter in the land converted to grassland category.

#### *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 method 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 7.1.5.

## 7.4.3 Uncertainties and time-series consistency

Uncertainties can be broken down into uncertainty in activity data, and uncertainty in other 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. However, uncertainty in activity data used in the inventory is 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, the mapping is not specific to IPCC categories.

### 7.4.4 Category-specific QA/QC and verification

Carbon dioxide emissions from the land converted to grassland ($CO_2$) and grassland remaining grassland ($CO_2$) categories were key categories (level assessment) in 2007. In the preparation of this inventory submission, the data in these categories underwent Tier 1 quality checks.

### 7.4.5 Category-specific recalculations

The inclusion of liming within this land-use category caused recalculations for the whole time series.

### 7.4.6 Category-specific planned improvements

The use of historic activity data for grassland is being investigated. This will allow for improved estimates of the land converted to grassland and grassland remaining grassland categories to be reported in future inventory submissions. In addition, the deforestation emissions resulting from the conversion of planted forest to grassland will be reported in this category rather than under the forest-land category as at present. Sector level improvements resulting from the LUCAS are described in Annex 3.2.

## 7.5 Wetlands (CRF 5D)

### 7.5.1 Description

In 2007, the net emissions from wetlands were 0.7 Gg $CO_2$-e. This estimate is constant over the time series. These emissions are from the land converted to wetlands category. Wetlands were not a key category in 2007.

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 categorised LCDB land-cover classes for lakes, rivers and estuarine open water into the unmanaged wetlands category (Table 7.1.4). Other LCDB classes (eg, herbaceous freshwater vegetation, commonly thought of as wetlands in New Zealand), were categorised as grassland following the GPG-LULUCF definitions.

New Zealand follows the definition of flooded land provided in the *2006 Guidelines for Agriculture Forestry Other Land Use* as "water bodies where human activities have caused changes in the amount of surface area covered by water, typically through water level regulation. Examples of flooded land include reservoirs for the production of hydroelectricity, irrigation and navigation. Regulated lakes and rivers that do not have substantial changes in water area in comparison with the pre-flooded ecosystem are not considered as flooded land".

The LCDB does not separate out regulated water bodies where substantial changes in water area occur, and the majority of New Zealand's hydroelectric schemes are based on rivers and lakes where the main pre-flooded ecosystem is 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 method 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 the wetlands remaining wetlands category.

### Land converted to wetlands

New Zealand has applied the GPG-LULUCF Tier 1 method 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 was 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, common reporting format 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. However, uncertainty in activity data used in the inventory is 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, the mapping is not specific to IPCC categories.

## 7.5.4 Category-specific QA/QC and verification

No specific QA/QC and verification was performed for the wetlands category.

## 7.5.5 Category-specific recalculations

There are no recalculations for this category.

## 7.5.6 Category-specific planned improvements

The use of historic activity data for wetlands is being investigated. This will allow for improved estimates of "land converted to wetlands" and "wetlands remaining wetlands" to be reported in future inventories. Sector-level improvements to result from the LUCAS are described in Annex 3.2.

# 7.6 Settlements (CRF 5E)

## 7.6.1 Description

In 2007, the net emissions from settlements were 97.2 Gg $CO_2$-e. This estimate is constant over the time series. These emissions are from the land converted to settlement category. Settlements were not a key category in 2007.

This land-use category described in GPG-LULUCF 3.6 includes "all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories". Settlements include trees grown along streets, in public and private gardens, and in parks associated with urban areas. New Zealand categorised the applicable LCDB land-cover classes into the settlements category. This showed 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. Due to data availability, New Zealand is not able to provide these estimates. However, reporting is not a requirement to prepare estimates for this subcategory (note 3, common reporting format table 5).

### Land converted to settlements

The equation (3.6.1 GPG LULUCF) 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 is 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. However, uncertainty in activity data used in the inventory is 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, the mapping is not specific to IPCC categories.

## 7.6.4 Category-specific QA/QC and verification

No specific QA/QC and verification was performed for the settlements category in 2007.

### 7.6.5 Category-specific recalculations

There are no recalculations for this category.

### 7.6.6 Category-specific planned improvements

The use of historic activity data for settlements is being investigated. This will allow for improved estimates of the land converted to settlements and settlements remaining settlements categories to be reported in future inventory submissions. Improvements to result from the LUCAS are described in Annex 3.2.

## 7.7 Other land (CRF 5F)

### 7.7.1 Description

In 2007, the net emissions from other land were 40.6 Gg $CO_2$-e. Net emissions from other land were 13.9 Gg $CO_2$-e (51.9 per cent) higher than the 1990 level of 26.7 Gg $CO_2$-e. These emissions are from land converted to other land category. Other land was not a key category in 2007.

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 consisted of steep, rocky terrain at high elevation, often covered in snow or ice. Other land was 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 four 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 7.1.3. The default assumptions for a Tier 1 estimate are that all living biomass present before conversion to other land is 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 7.1.2).

##### *Soil carbon*

New Zealand uses the IPCC method 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. However, uncertainty in activity data used in the inventory is 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, the mapping is not specific to IPCC categories.

### 7.7.4 Category-specific QA/QC and verification

No specific QA/QC and verification was performed for the other land category.

### 7.7.5 Category-specific recalculations

There are no recalculations for this category.

### 7.7.6 Category-specific planned improvements

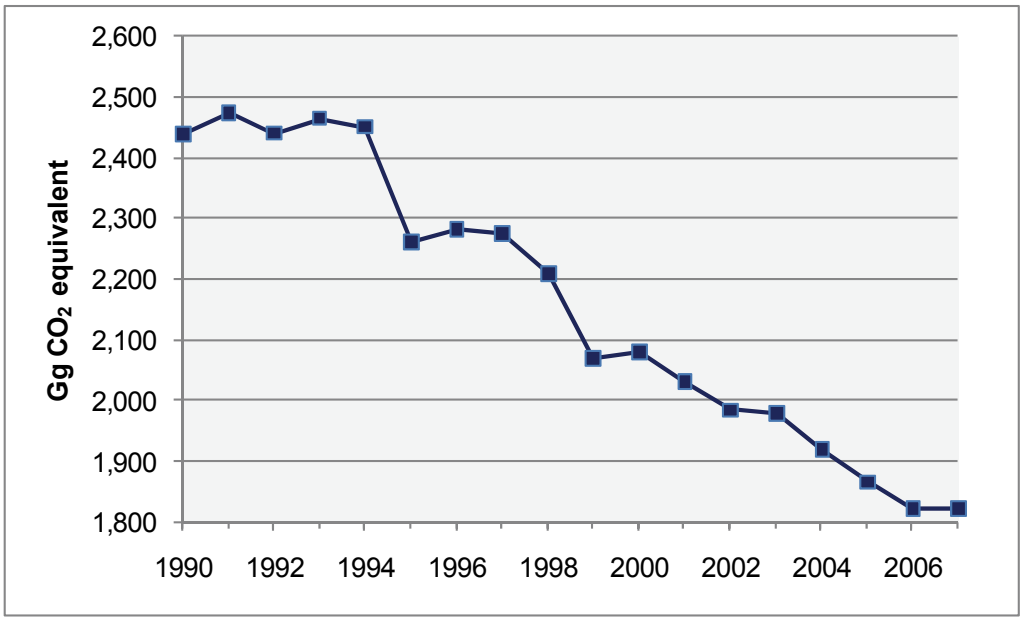
The use of historic activity data for other land is being investigated. This will allow for improved estimates of the land converted to other land and other land remaining other land categories to be reported in future inventory submissions. Sector level improvements resulting from the LUCAS are described in Annex 3.2.

# Chapter 8: Waste

## 8.1 Sector overview

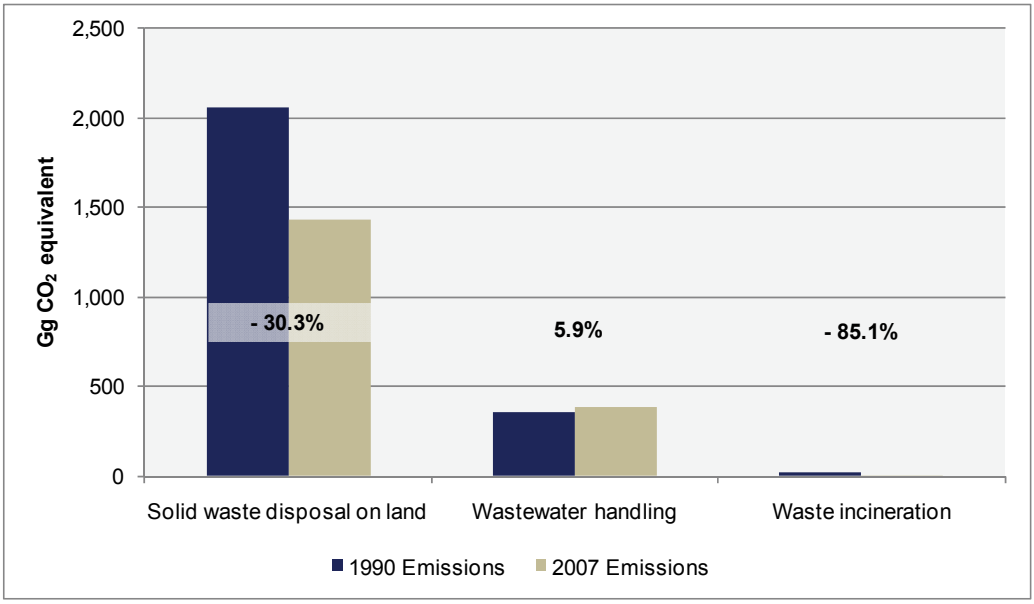
In 2007, the waste sector accounted for 1,821.8 Gg carbon dioxide equivalent ($CO_2$-e) (2.4 per cent) of total emissions. Emissions from the waste sector were 616.4 Gg $CO_2$-e (25.3 per cent) below the 1990 baseline value of 2,438.2 Gg $CO_2$-e (Figure 8.1.1). This reduction occurred in the solid waste disposal on land subcategory as a result of initiatives to improve solid waste management practices and increase the rate of landfill gas capture in New Zealand.

**Figure 8.1.1 Waste sector emissions from 1990 to 2007**




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 was a key category (level and trend assessment) in 2007.

**Figure 8.1.2 Change in emissions from the waste sector from 1990 to 2007**




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 1,438.0 Gg $CO_2$-e (78.9 per cent) of emissions from the waste sector in 2007. This was a decrease of 625.3 Gg $CO_2$-e (30.3 per cent) from the 1990 level of 2,063.2 Gg $CO_2$-e. Methane emissions from solid waste were identified as a key category (level and trend) for 2007.

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 t of solid waste (Ministry for the Environment, 1997). Since 1995, there have been a number of initiatives to improve solid waste management practices in New Zealand. These have included preparing guidelines for the development and operation of landfills, closure and management of landfill sites, and consent conditions for landfills under New Zealand's Resource Management Act (1991). As a result of these initiatives, a number of poorly located and substandard landfills have been closed and communities

rely increasingly on modern regional disposal facilities for disposal of their solid waste. The 2006 Landfill Census reported there were 60 legally operating municipal landfills in New Zealand, a reduction of 82 per cent from 1995 (Ministry for the Environment, 2007). The same census reported that 3,156,000 t of solid waste was deposited in 2006.

New Zealand's focus regarding waste is towards waste minimisation and resource recovery. In March 2002, the Government announced the New Zealand Waste Strategy (Ministry for the Environment, 2002a). The Strategy sets targets for a range of waste streams as well as for improving landfill practices by the year 2010. As part of the implementation and monitoring of the Strategy, the Government developed the Solid Waste Analysis Protocol (Ministry for the Environment, 2002b) that provided a classification system, sampling regimes and survey procedures to measure the composition of solid waste streams. In 2008, the Government passed the Waste Minimisation Act that imposes a levy of $10 per tonne of municipal solid waste from 1 July 2009, extends product stewardship regimes, and enables regulations to require landfill operators and others to report on various waste targets and measures. Reporting under this Act will significantly improve New Zealand's knowledge of solid waste volumes and composition.

### 8.2.2 Methodological issues

New Zealand has used a first order decay approach with the Intergovernmental Panel on Climate Change (IPCC) model contained in the IPCC 2006 guidelines to report emissions from solid waste in the inventory. New Zealand uses default values for starting year, delay time, degradable organic carbon content of specific waste streams, and the default "wet temperate" values for methane generation rate constants (k) for each compositional type. New Zealand-specific activity data on current and historic waste disposal and waste composition is used. An oxidation correction factor of 0.1 is used as landfills in New Zealand are capped and are categorised as well managed (IPCC, 2006).

The calculations for estimating emissions from the waste sector, including the IPCC 2006 workbook tables, are included in the MS Excel worksheets available with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/). Some modifications were made to the standard tables, including the addition of an assumptions worksheet that documents the sources of data and judgements made for the method described above. Another additional worksheet provides an estimate of emissions using the IPCC 1996 Tier 1 calculations. These estimates were used for a quality assurance check as described in section 8.2.4.

New Zealand does not have sufficient data to be able to categorise solid waste as either municipal solid waste or industrial waste, as many municipal landfills accept industrial waste. All national data is therefore contained in the municipal solid waste class.

Activity data on solid waste composition was documented for 1995 and 2004 (Ministry for the Environment, 1997; Waste Not Consulting, 2006). Linear extrapolations and interpolations were used between years where no new data was available. The estimate of degradable organic carbon in 1995 (and 1990) was 0.15 Gg C/Gg waste, and increased over time to 0.17 Gg C/Gg waste in 2004 (and 2007) mainly through increases in the proportion of wood waste going to landfill.

Calculation of the $CH_4$ generation potential is based on the same data contained in Ministry for the Environment (1997) and Waste Not Consulting (2006) reports, and adjusted for changes in the management of landfilled waste through the $CH_4$ correction factor. In 1990, 1995 and 2007, the $CH_4$ generation potential was 0.05 Gg $CH_4$/Gg waste.

There is no New Zealand-specific composition data on the specific half-lives of solid waste. Consequently, New Zealand uses the IPCC default $CH_4$ generation rate for a wet temperate climate. This climate type is considered the best fit for New Zealand's complex climate systems and geography.[4]

There has been no new data on solid waste composition since 2004. Consequently, the value for degradable organic content per Gg of waste has remained constant since 2004. However, the $CH_4$ correction factor has been increasing due to the closure of unmanaged landfills and increasing volumes being disposed to larger, modern landfills. It is estimated that, in 1995, 90 per cent of New Zealand's waste was disposed to managed solid waste disposal sites and 10 per cent to uncategorised sites (Ministry for the Environment, 1997)[5]. The IPCC (2006) default values are used for the carbon content of the various components of the solid waste stream.

Total waste to landfill has been estimated for the years 1995, 1998, 2002, 2003, 2004 and 2006. Based on the 2006/07 National Landfill Census, the 2002 Landfill Review and Audit, and the 2006 report 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 749.4 kilograms per person per year. This is a reduction of 12.6 per cent in waste generation from 858.0 kg per person per year in 1995. The 2006 data on kilograms of solid waste per person per day was extrapolated for 2007 using estimated national population data. The reduction in solid waste per person per day since 1995 is due to waste minimisation initiatives from central and local government and increased recycling.

New Zealand uses the IPCC 2006 default value for the fraction of degradable organic carbon that actually degrades (0.5).

The rate of recovered $CH_4$ per year is estimated based on information from a 2005 survey of solid waste disposal sites that serve populations of over 20,000 in New Zealand (Waste Management New Zealand, 2005). There was no landfill gas collected in 1990 and 1991, with the first flaring system installed in 1992. The consultants surveyed 18 landfills known to have installed, or that were planning to install, landfill gas systems. The method involved initial modelling of the major landfills that had good operational data, to establish benchmarks for the $CH_4$ generation potential (Lo), the $CH_4$ generation rate constant (k), and system recovery efficiency. This information was then used as a starting point for preparing estimates for other sites, with adjustments made based on knowledge of site conditions, system design, and assessed operating performance. The landfill $CH_4$ recovery data was then compiled for all of the sites. The consultants used the IPCC (1996) first order decay model. The quality assurance and quality control worksheet was used to check the data.

The benchmarks for the $CH_4$ generation potential (Lo) and the $CH_4$ generation rate constant (k) for landfills with gas recovery systems developed by Waste Management New Zealand are not the same as the values used to estimate New Zealand's gross $CH_4$ emissions in the IPCC 2006 worksheets. Waste Management New Zealand assumed higher Lo and k values because it argued waste would be managed to biodegrade and

[4] Mean average temperatures vary from 10 degrees Celsius in the south to 16 degrees in the north (NIWA). Mean annual precipitation ranges from 600 to 1600 mm (NIWA). Mean annual potential evapo-transpiration ranges from 200 mm to 1100 mm (Tait A, and Woods R, 2007).

[5] The 10 per cent of solid waste not disposed to "managed" solid waste disposal sites, went to sites that fell outside the definition of "managed", yet insufficient information is held about the sites to classify them as deep or shallow, unmanaged solid waste disposal sites, hence the "unclassified" status. This submission, assumed that, by 2010, all solid waste would be disposed to "managed" solid waste disposal sites. This has lead to a linearly increasing $CH_4$ correction factor.

emit $CH_4$ faster at landfills with gas recovery systems. This methodological inconsistency probably results in an underestimation of gross and net national $CH_4$ emissions from solid waste disposal. It will be remedied for the 2010 inventory submission.

### 8.2.3 Uncertainties and time-series consistency

The overall estimated level of uncertainty is estimated at ±20 per cent. This level of uncertainty is the same as the 2008 inventory submission, but an improvement on prior submissions. The improvement was due to the utilisation of the IPCC 2006 spreadsheet model, the 2002 Landfill Audit and Review, and an assessment of comparability between data sources as performed in Waste Not Consulting (2006). Due to the unknown level of uncertainty associated with the accuracy of some of the input data, it has not been possible to perform a statistical analysis to precisely determine uncertainty levels. The incomplete dataset makes statistical analysis impractical. Uncertainty in the data is primarily from uncertainty in changes to solid waste composition since 1990 and actual recovered $CH_4$, based on the 1997 National Waste Data Report (Ministry for the Environment, 1997), the Waste Composition and Construction Waste Data (Waste Not Consulting, 2006) and the Landfill Methane Recovery Estimate Report (Waste Management New Zealand, 2005).

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

### 8.2.4 Source-specific QA/QC and verification

Methane from solid waste disposal was identified as a key category (level and trend assessment) in 2007. In preparation for this inventory submission, the data for this category underwent Tier 1 quality checks.

The data and associated text for the solid waste subcategory was peer reviewed by the Caledonian Environment Centre as part of the QA/QC procedures implemented before this inventory was submitted.

A centralised review of New Zealand's inventory (UNFCCC, 2001c) recommended that gross $CH_4$ estimates from solid waste emissions should be compared with the IPCC Tier 1 and Tier 2 approaches. For the 2007 year, the IPCC (2006) Tier 2 value of gross annual $CH_4$ generation was 131.9 Gg $CH_4$ and the IPCC (1996) Tier 1 value was 179.3 Gg $CH_4$. The assumptions used to calculate net $CH_4$ emissions from available activity data were the same for both Tier approaches.

### 8.2.5 Source-specific recalculations

Municipal solid waste composition values for all years prior to 2004 were updated to remove nappies from the paper classification. The National Waste Data Report (Ministry for the Environment, 1997) included nappies within "paper", whereas the Solid Waste Analysis Protocol as reported in the Waste Composition Data report (Waste Not Consulting, 2006) separated these categories. The proportion of nappies that made up solid waste disposal in landfills prior to 2004 is assumed to be the same as the 2004

value. This is due to no existing national data before 2004. This recalculation improved the accuracy of national waste composition estimates for all years prior to 2004. It also reduced the estimates of degradable organic carbon in solid waste for those years, because nappies are assumed to have lower degradable carbon content than paper.

The use of the IPCC 2006 spreadsheet model has resulted in many recalculations in this inventory submission. Firstly, this submission has used the default six-month delay in the anaerobic decomposition process, whereas earlier submissions from New Zealand did not account for this. Secondly, this submission has used default IPCC 2006 degradable organic carbon (DOC) values for decomposable waste. These default values differ for textiles and wood from the values published in IPCC 1996 guidelines and used in earlier submissions. Thirdly, this submission has applied individual half life (k) values to separate categories of waste, whereas earlier submissions used a weighted average for mixed municipal waste. Finally, the starting year for the model was changed from 1940 in earlier submissions, to the default IPCC 2006 spreadsheet model of 1950 for this submission.

Recalculations were performed back to 1990 and have resulted in a decrease of 58.3 Gg $CO_2$-e in 1990 and a decrease of 35.6 Gg $CO_2$-e in 2006.

### 8.2.6 Source-specific planned improvements

New estimates of landfill gas collected will be developed for the next inventory submission.

## 8.3 Wastewater handling (CRF 6B)

### 8.3.1 Description

In 2007, wastewater handling produced 381.7 Gg $CO_2$-e (21.0 per cent) of emissions from the waste sector. This was an increase of 21.3 Gg $CO_2$-e (5.9 per cent) from the 1990 level of 360.4 Gg $CO_2$-e.

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

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

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

### 8.3.2 Methodological issues

#### Methane emissions from domestic wastewater treatment

Methane emissions from domestic wastewater handling have been calculated using a refinement of the IPCC method (IPCC, 1996). The population using each municipal

treatment plant in New Zealand has been determined (SCS Wetherill Environmental, 2002; Beca, 2007). Where industrial wastewater flows to a municipal wastewater treatment plant, an equivalent population for that industry has been calculated based on a biological oxygen demand (BOD) loading of 70 g per person per day.

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

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

New Zealand uses a value of 0.026 kg BOD/1000 person/yr, as it is equivalent to the IPCC high-range default value for the Oceania region of 70g/person/day.

Methane removal via flaring or energy use is known to occur at eight plants in New Zealand. They all use anaerobic digesters as a component of the treatment. However, because these plants are categorised as "centralised aerobic treatment plant, well managed" according to the 2006 IPCC guidelines, the $CH_4$ emission factor is zero. The $CH_4$ generated in those plants is an abnormality by that classification, as all the $CH_4$ generated is flared or used for energy production The net result is no $CH_4$ emission and no $CH_4$ flared volumes are included in the equation.

## Methane emissions from industrial wastewater treatment

The IPCC 2006 default method is also used to calculate emissions from industrial wastewater treatment. Three industries were identified as having organic-rich wastewaters that are treated anaerobically. These are (in order of significance): meat processing, pulp and paper, and dairy processing. The meat industry is divided into kills and rendering, because the emissions from kills are calculated based on a pro-rata of previous inventories, and actual carcass numbers, whereas emissions from rendering are calculated based on wastewater volume. The dairy industry predominantly uses aerobic treatment. There is only one remaining factory that uses anaerobic treatment. The wastewater is covered and the majority of the captured biogas (55 per cent $CH_4$) is used to operate the boilers. The remainder is flared.

For each industry, an estimate is made of the total industrial output in tonnes per year. The IPCC 2006 default values for wastewater generated and chemical oxygen demand are used. The exception is for the pulp and paper industry where the chemical oxygen demand (COD)/t product is determined from industry figures of biochemical oxygen demand (BOD)/t product, using a conversion factor of COD = 2.2 × BOD.

For meat processing (rendering), total organic wastewater is a function of the IPCC 2006 default COD value (4.1kg COD/$m^3$) and site-specific estimates of wastewater treatment activity. For dairy processing, the IPCC 2006 default method is followed.

## Methane emissions from sludge

The organic solids produced from wastewater treatment are known as sludge. In New Zealand, the sludge from wastewater treatment plants is typically sent to landfills.

In large treatment plants in New Zealand, sludge is handled anaerobically and the $CH_4$ is almost always flared or used.[6] Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds.

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

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

## Nitrous oxide emissions from domestic wastewater treatment

New Zealand's calculation uses the IPCC 2006 method (IPCC, 2006). The IPCC method calculates nitrogen production based on the average per capita protein intake. A value of 36.135 kg N/person/year is assumed for 1990 to 2007. This is the maximum value as reported to the Food and Agriculture Organisation of the United Nations by New Zealand, and was used as there was no discernable trend between 1990 and 2007. Default IPCC 2006 values are used for the fraction of nitrogen in protein, fraction of non-consumption protein, fraction of industrial and commercial co-discharged protein, and nitrogen removed with sludge. The IPCC default emission factor of 0.005 kg $N_2O$-N/kg N is used.

## Nitrous oxide emissions from industrial wastewater treatment

The 2006 IPCC guidelines state that, compared with domestic wastewater, the $N_2O$ emissions from industrial wastewater are insignificant and can therefore be ignored. However, this statement does not take into account the significance of the meat industry in New Zealand in relation to nitrogenous-rich wastewaters. Due to the prevalence of anaerobic treatment plants within the meat industry, New Zealand has chosen to report $N_2O$ emissions from this source.

The 2006 IPCC guidelines do not have a method for calculating $N_2O$ emissions from industrial wastewater. 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 is calculated by adopting the chemical oxygen demand load from the $CH_4$ emission calculations and using a ratio of chemical oxygen demand to nitrogen in the wastewater for each industry.

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

## 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 data collection methods (SCS Wetherill Environmental, 2002). The uncertainty reported for wastewater values is based on an assessment of the reliability of the data and the potential for important sources to have been missed from the data. It is estimated that domestic wastewater $CH_4$ emissions have an accuracy of –25 per cent to +40 per cent (SCS Wetherill Environmental, 2002; Beca, 2007). This is less uncertainty than reported in previous submissions, due to the added confidence in activity data provided by the new national wastewater treatment database.

### Methane from industrial wastewater

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

### Nitrous oxide from wastewater

There are very large uncertainties associated with $N_2O$ emissions from wastewater treatment and no attempt has been made to quantify this uncertainty. The IPCC default emissions factor, $EF_6$, has an uncertainty of –80 per cent to +1200 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 industrial wastewater treatment has been updated with adjustments made to activity data for both the pulp and paper processing and meat-processing categories. This new data adjusted total organic product estimates for all years from 1990 and resulted in a decrease of 15.2 Gg $CO_2$-e in 1990 and a decrease of 10.7 Gg $CO_2$-e in 2006.

The estimates of total organics in wastewater (TOW) before 1997 from domestic and commercial sources were adjusted to reflect population growth. In earlier submissions, the constant total organic waste (TOW) value, first established in 1997, was used back to 1990. This improvement to TOW estimates resulted in recalculations in the years 1990 to 1996, with a decrease of 15.5 Gg $CO_2$-e in 1990 and no change to the 2006 estimate.

Improvements to the accuracy of calculations for emissions of $CH_4$ from industrial wastewater 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 2006.

## 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 2007, waste incineration accounted for 2.2 Gg $CO_2$-e (0.1 per cent) of waste emissions. This was a decrease of 12.4 Gg $CO_2$-e (85.1 per cent) from the 1990 level of 14.6 Gg $CO_2$-e.

There is no incineration of municipal waste in New Zealand. The only incineration is for small specific waste streams including medical, quarantine and hazardous wastes. The practice of incinerating these waste streams has declined since the early 1990s due to environmental regulations and alternative technologies, primarily improved sterilisation techniques. Consents under New Zealand's Resource Management Act control non-greenhouse gas emissions from these incinerators.

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

## 8.4.2 Methodology

The 2006 IPCC guidelines (IPCC, 2006) are used to calculate emissions from the incineration of waste as the revised 1996 IPCC guidelines (IPCC, 1996) do not contain methods for estimating emissions from waste incineration. New Zealand considers the 2006 IPCC guidelines (IPCC, 2006) contain the most appropriate and current methodologies for estimating emissions from waste incineration.

Incineration devices that do not control combustion air to maintain adequate temperature, and do not provide sufficient residence time for complete combustion, are considered as open burning systems (IPCC 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 that from paper, cardboard and food, is excluded in accordance with the 2006 IPCC guidelines (IPCC, 2006). Also excluded are emissions from waste to energy incineration facilities, as they are reported within the energy sector of the inventory.

Default compositional values from the IPCC 2006 guidelines are used to estimate the fossil fuel-derived carbon. These values are 27.5 per cent for hazardous waste (being the mean of the recommended range) and 25 per cent for clinical waste.

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

Estimates of direct emissions are made using the default Tier 1 methodology (IPCC, 2006). Default emission factors for $CO_2$, $CH_4$ and $N_2O$ are taken from the 2006 IPCC guidelines. New Zealand uses the mid point where these emission factors are presented as a range.

The default emission factor for industrial waste is used for hazardous waste, and the default emission factor for municipal/industrial waste is used for clinical waste. As the $CH_4$ factors are presented as kg/TJ, the calorific value for the relevant waste is needed to convert the figures to Gg/yr. The calorific value was sourced from chapter 11 of the *New Zealand Energy Information Handbook* (Baines, 1993). Only the gross calorific value was available from the energy handbook, so this value was used, although it is noted this is inconsistent with the IPCC approach that uses net values.

The Japanese emission factor is used for sewage sludge. The IPCC 2006 guidelines note that the most detailed observations of $CH_4$ emissions from waste incineration have been made in Japan (Volume 5: section 5.4.2).

### 8.4.3 Uncertainties and time-series consistency

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

The annual rates were projected for the corresponding number of years of operation. This provided an estimated total amount of wet waste incinerated from 1990 to 2007.

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 increased to ±10 per cent due to the lack of detailed data. The uncertainty for the data is likely to be greater than this, particularly where projections are based on a mass burn rate and assumed operating hours (SKM, 2007).

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

### 8.4.4 Source-specific QA/QC and verification

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

### 8.4.5 Source-specific recalculations

Recalculations have been performed for all years from 1990 to 2006 after adjusting for several modelling errors. These recalculations resulted in a 0.1 Gg $CO_2$-e increase in estimated emissions in 1990 and a 3.0 Gg $CO_2$-e decrease in estimated emissions in 2006.

### 8.4.6 Source-specific planned improvements

No improvements are planned for this category.

# Chapter 9: Other

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

# Chapter 10: Recalculations and improvements

This chapter summarises the recalculations and improvements made to the New Zealand greenhouse gas inventory following submission of the 1990–2006 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 (each inventory submission includes a new inventory year). The inventory may also be expanded to include emissions from additional sources if a new source has been identified within the context of the revised 1996 IPCC guidelines (IPCC, 1996) and good practice guidance (IPCC, 2000 and 2003). Recalculations may also occur if activity data and emission factors have become available for sources that were previously reported as "NE" (not estimated) 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 submission.

## 10.1 Explanations and justifications for recalculations

### 10.1.1 Energy sector

Recalculations for the entire energy sector have resulted in a decrease of 46.3 Gg $CO_2$-e in 1990 and a decrease of 58.7 Gg $CO_2$-e in 2006 due to applying year-specific calorific values for all fuel types (section 3.2.2).

### 10.1.2 Industrial processes sector

In this submission, New Zealand has recalculated the following within the industrial processes sector:

- carbon dioxide estimates for steel and limestone, coke and electrodes (section 4.2.5 and 4.4.5) were calculated from total steel emissions including the emissions from energy. This would correct any underestimates from previous submissions where these estimates were calculated from total steel emissions excluding energy
- emissions from ammonia production due to updated emission factors. These factors are now gas-field specific (section 4.3.5)
- perfluorocarbon emissions from aluminium productions due to applying the current supplied data (section 4.4.5)
- the 1991 and 1992 estimates for aluminium production, $CO_2$ and PFC emissions due to revised interpolation of values (section 4.4.5) that exclude any influence of assumptions used in previous submissions
- hydrofluorocarbon and PFC emissions from refrigeration and mobile air-conditioning due to corrections, updated assumptions and the inclusion of new activity data (section 4.7.5)

- sulphur hexafluoride emissions from electrical equipment due to an increase in activity data availability (section 4.7.5).

### 10.1.3 Solvents and other products

As described in section 5.1.5, New Zealand has changed the notation keys applied in the common reporting format tables for $CO_2$, $SO_2$, CO and $NO_x$ are now "NE" as no detailed IPCC methodologies are available to estimate these emissions.

### 10.1.4 Agriculture

All activity data reported in the agriculture sector has been updated with the latest available data (Statistics NZ table builder and Infoshare database, 2008).

### 10.1.5 LULUCF

The net uptake of forest land was recalculated in this submission due to planted forest data into first or subsequent rotations now available (section 7.2.5). Emissions from deforestation were also updated due to revised modelling (section 7.2.5).

Emissions from cropland were recalculated due to an updated emission factor. The apportioning of emissions from liming of soils between the cropland and grassland categories led to recalculations (section 7.3.5).

### 10.1.6 Waste

Emissions from municipal solid waste were recalculated due to updated composition values for all years prior to 2004, and due to the application of the IPCC (2006) spreadsheet (section 8.2.5).

Emissions from wastewater were recalculated due to adjustments made to activity data (section 8.3.5).

The corrections made to modelling errors led to recalculations of emissions from waste incineration in this submission (section 8.4.5).

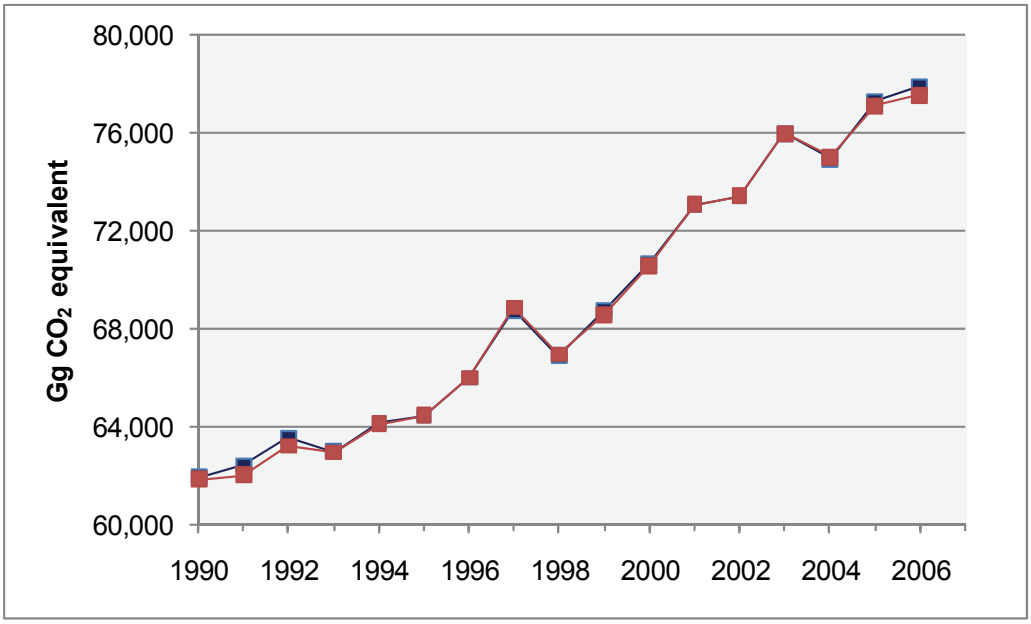
## 10.2 Implications for emission levels

The overall effect of all recalculations in the 2009 inventory submission is shown in Figure 10.3.1. There is a 0.2 per cent (95.0 Gg $CO_2$-e) decrease in emissions for the base year, 1990 and a 0.3 per cent (269.0 Gg $CO_2$-e) decrease in emissions for the 2006 year.

## 10.3 Implications for emission trends

In New Zealand's 2008 inventory submission (1990–2006), emissions were 25.7 per cent above the level reported in 1990. As a result of the recalculations in the 2009 inventory submission, total emissions for 2006 were 25.5 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 negligible throughout the time series.

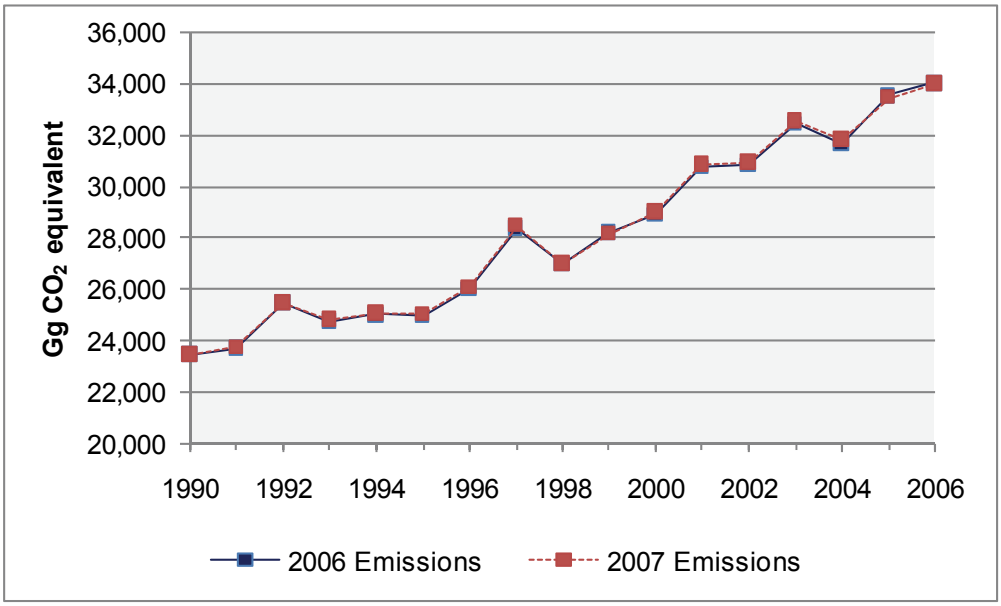
**Figure 10.3.1 Effect of recalculations on total greenhouse gas emissions**




## 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 46.3 Gg $CO_2$-e and decreased by 58.7 Gg $CO_2$-e in 2006 (Figure 10.3.2). These recalculations were responsible for a 0.1 per cent decrease of the 1990 recalculation in total emissions and a 0.1 per cent decrease of the recalculation for the 2006 year.

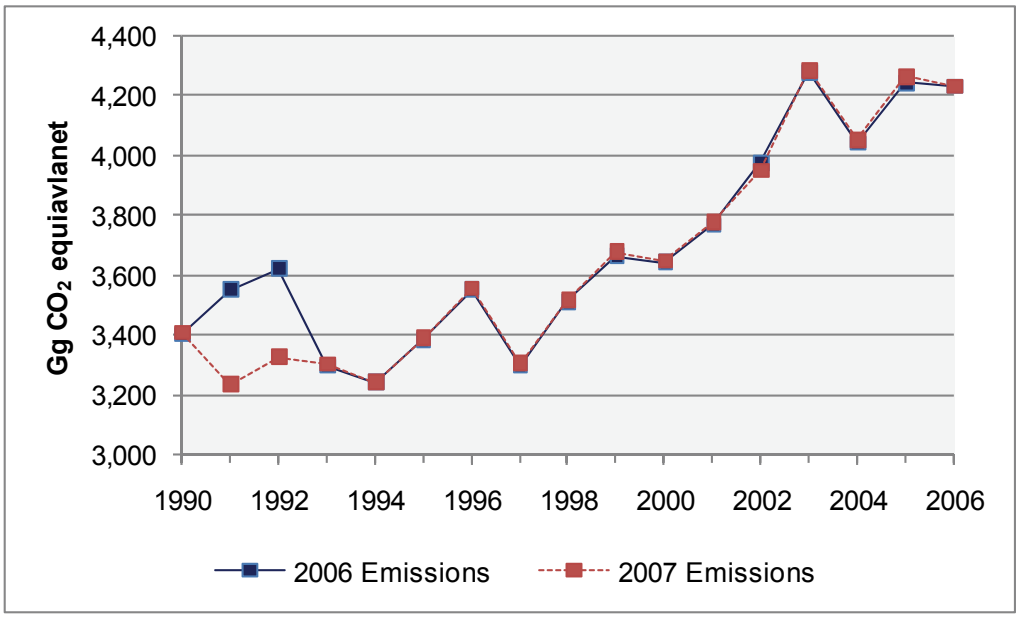
**Figure 10.3.2 Effect of recalculation on the energy sector**



## 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 6.5 Gg $CO_2$-e and increased 0.7 Gg $CO_2$-e in 2006. These recalculations were responsible for a 0.011 per cent increase of the 1990 recalculation in total emissions and a 0.001 per cent increase of the recalculation for the 2006 year.

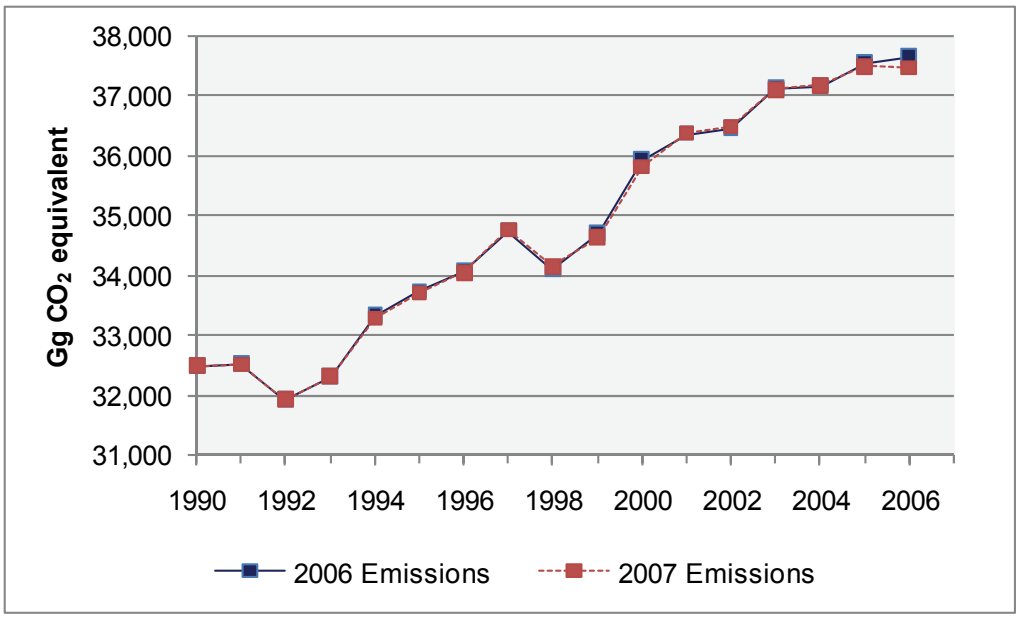
**Figure 10.3.3 Effect of recalculation on the industrial processes sector**




## Agriculture

Emissions in 1990 have increased 12.2 Gg $CO_2$-e and 176.4 Gg $CO_2$-e in 2006. These changes were responsible for a 0.02 per cent increase of the 1990 recalculation in total emissions and a 0.2 per cent decrease of the recalculation for the 2006 year.

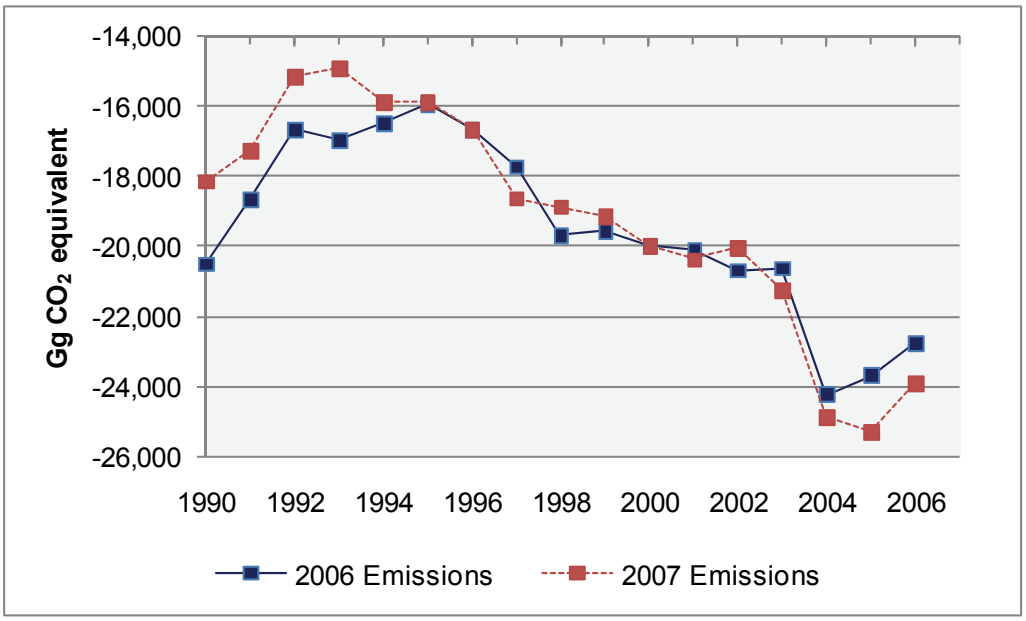
**Figure 10.3.4 Effect of recalculation on the agriculture sector**



## LULUCF

The recalculations made within the LULUCF sector (Figure 10.3.5) are explained in section 10.1.5. The recalculations have resulted in a decrease to total net LULUCF emissions and removals of 1,128.1 Gg $CO_2$-e in 2006 and an increase of 2,369.2 Gg $CO_2$-e in 1990.

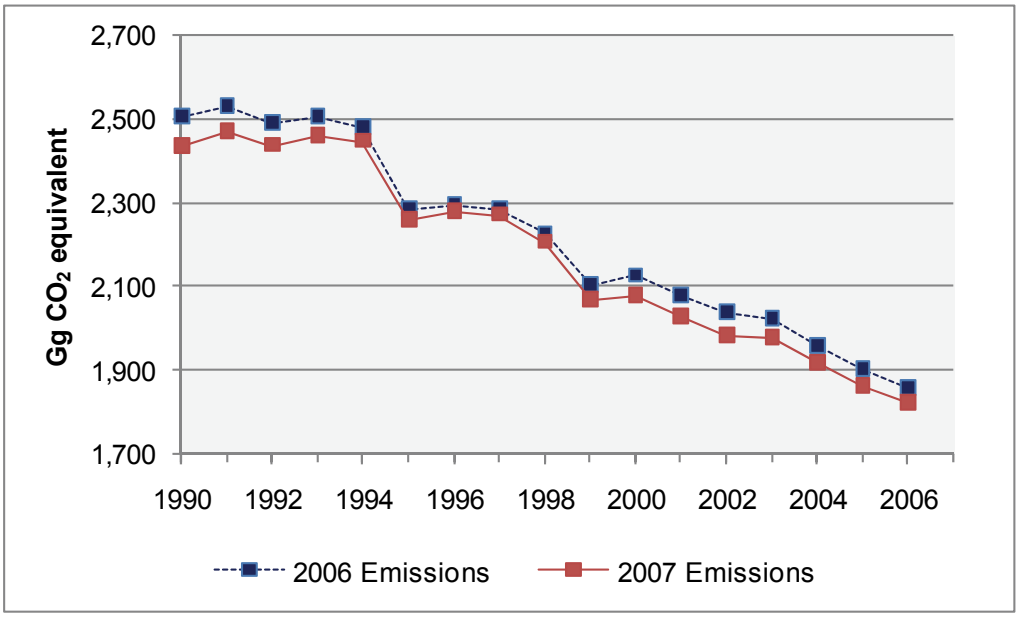
**Figure 10.3.5 Effect of recalculation on LULUCF net removals**




## Waste

The recalculations made within the waste sector (Figure 10.3.6) are explained in section 10.1.6. Emissions in 1990 have decreased 67.5Gg $CO_2$-e and 34.6 Gg $CO_2$-e in 2006. The recalculations were responsible for a 0.1 per cent decrease of the 1990 recalculation in total emissions and a 0.1 per cent decrease of the recalculation for the 2006 year.

**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

In response to past review reports, New Zealand has improved transparency and QA/QC. Following the 2008 inventory submission, members of the national inventory team visited many of New Zealand's industrial companies. These meetings enhanced the national inventory team's knowledge of the processes and the quality assurance procedures applied at the plants. The meetings also increased the companies' knowledge of national inventory reporting requirements and emission calculation methods. An example of an improvement from these visits is the increased explanation provided in this submission for the variation in the time series for emissions from aluminium production.

The capacity of the national system has increased since the 2008 inventory submission. The Ministry of Agriculture and Forestry has employed inventory staff for the agriculture and LULUCF sectors. The Ministry for the Environment has employed a back-up for the national inventory compiler. Further, documentation of the national submission, compiler role has increased. In compiling this inventory, another person was employed from December to February to assist with quality checking.

The cross-government inventory team was provided with more formal guidelines for compiling this submission. A memo detailing deadlines, processes and areas of improvement to focus on was distributed to all sector experts. The deadline for all chapters and final estimates of numbers was moved back to late November. This allowed more time for quality checking. Regular one-on-one meetings were established between the national inventory compiler and the sector experts. Regular meetings were established between managers involved in the cross-government inventory team.

During 2008, CRL Energy was contracted to provide activity data and emission calculations for the consumption of HFCs, PFCs and $SF_6$ for the 2007–2012 calendar years.

## 10.4.2 Planned improvements

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

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

# 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 10.5.4 show the improvements made to the inventory from the 2001 to the 2009 inventory submissions.

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

| Area of improvement | | Inventory submission year | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2001 | 2002 | 2003 | | 2004 | | |
| National System | | | | | | Complete common reporting format tables | | Explanatory text increased |
| Sector | Energy | | | | | Explanatory text increased | | |
| | Industrial Processes | HFCs, PFCs and $SF_6$ upgraded to Tier 2 method | Lime and Dolomite included | | | Upgraded Tier 3 methodology for $SF_6$ electrical equipment | $CH_4$ from methanol production reported back to 1997 | Explanatory text increased |
| | Solvents | | | | | Anaesthesia use of $N_2O$ included | | |
| | Agriculture | | | $CH_4$ ruminant emissions upgraded to Tier 2 | $N_2O$ EF and excretion rates revised | | | |
| | LULUCF | | | | | | | |
| | Waste | | Solid Waste upgraded to Tier 2 | | | | | |
| QA/QC | | | | | | Plan developed | Trial of Tier 1 quality check sheets | |

**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 CO2 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 and pasture | $CH_4$ manure management upgraded to Tier 2 | $N_2O$ emission factor (EF1) changed to be New Zealand-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 include number of non-key sources | | | Extension of Tier 1 QC checks to include a number of non-key sources | | |

**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 petrol and diesel | | | |
| | Industrial Processes | Cement activity data updated | Separated limestone, coke and electrode emissions from iron and 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<br>Forest-land removals updated based upon updated carbon yields; harvesting and new planting data; new assumptions for the clearance of grassland with above-ground woody biomass and biomass burning | | | |
| | Waste | Solid waste emissions updated 2003–2005 to correct sampling errors | Domestic and 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<br>KPMG quality checked key category data for consistency between data spreadsheets, the CRF Reporter and the NIR<br>Risk register established | | | |

### Table 10.5.4 Improvements made to New Zealand's inventory submission for 2009

| Area of improvement | | Improvements made | | | |
|---|---|---|---|---|---|
| National system | | An additional person has been recruited and trained in the national inventory compiler role at the Ministry for the Environment<br>Additional people were recruited for the agriculture and LULUCF sectors in the Ministry of Agriculture and Forestry<br>Increased documentation for the national inventory compiler role.<br>Sector experts provided with formal inventory compilation guidelines<br>Regular meetings established between the managers involved in the inventory cross-government team and between the sector experts and the national inventory compiler<br>All calculations used in Article 3.3 LUCAS project have been included in a calculation and reporting application (under development) | | | |
| Sector | Energy | Year-specific calorific values for all fuel types updated and the inclusion of the weighted annual average $CO_2$ emission factor for natural gas | | | |
| | Industrial Processes | Emissions from limestone, coke and electrodes use were separated from total iron and steel emissions (including emissions from fuel combustion) | The emission factors for ammonia were updated based on the weighted average of all gas fields | Increased explanation provided for variations in the time series for emissions from aluminium production | Interpolation of 1991 and 1992 data for aluminium production |
| | Industrial Processes (cont) | Collection of data for F-gases for industrial processes contracted for a 5-year period with the one provider | Increased information provided and revision of some of the assumptions for consumption of HFCs, PFCs and $SF_6$ | | |
| | Solvents | Changes made to some of the notations keys | | | |
| | Agriculture | Inclusion of nitrification inhibitor mitigation technology under the agriculture soils category | | | |
| | LULUCF | Forest-land data apportioned over converted and remaining categories | Emissions from liming of soils were apportioned over grassland and cropland | Cropland New Zealand-specific $N_2O$ emission factor updated | |
| | Waste | Nappies were removed from the solid waste composition values prior to 2004 | The IPCC (2006) spreadsheet model has been applied for solid waste | Estimated total organic waste prior to 1997 was adjusted for population growth | Improved accuracy of estimated $CH_4$ estimates |
| QA/QC | | Inventory compilation deadline moved to allow more time for quality checking of the common reporting format database and the national inventory report<br>Quality checked key category data for consistency between data spreadsheets, the common reporting format tables and the national inventory report<br>An extra person recruited December–February to assist with quality checking<br>Risk register established and used to help prioritise inventory improvements<br>The quality assurance of the waste sector was completed before submission | | | |

# References

## General references


IPCC. 1995. Houghton JT, Meira Filho LG, Callender BA, Harris N, Kattenberg A, Maskell K (Eds). *Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change*. Cambridge University Press: UK. 572.

IPCC. 1996. Houghton JT, Meira Filho LG, Lim B, Treanton K, Mamaty I, Bonduki Y, Griggs DJ, Callender BA (Eds). IPCC/OECD/IEA. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.* UK Meteorological Office: Bracknell.

IPCC. 2000. Penman J, Kruger D, Galbally I, Hiraishi T, Nyenzi B, Emmanul S, Buendia L, Hoppaus R, Martinsen T, Meijer J, Miwa K, Tanabe K (Eds). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2001. Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Xiaosu D (Eds). *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge University Press: UK. 944.

IPCC. 2003. Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Tanabe K, Wagner F (Eds). *Good Practice Guidance for Land Use, Land-use Change and Forestry*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2006. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (Eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3. Industrial Processes and Product Use.* IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2006. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (Eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

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

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

UNFCCC. 2001a. FCCC/WEB/IRI (1)/2000/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2000.* Desk Review (20 June 2001).

UNFCCC .2001b. FCCC/WEB/IRI (2)/2000/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2000*. In-country Review (20 July 2001).

UNFCCC. 2001c. FCCC/WEB/IRI (3)/2000/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2000.* Centralised Review (30 May 2001).

UNFCCC. 2003. FCCC/WEB/IRI (1)/2002/NZL. *Report of the individual review of the greenhouse gas inventory of New Zealand submitted in the year 2002*. Desk Review (13 October 2003).

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

UNFCCC. 2007. FCCC/IRR/2007/NZL. New Zealand. *Report of the review of the initial report of New Zealand.* In-country Review (19–24 February 2007).

United Nations. 1992. United Nations Framework Convention on Climate Change.

## Specific references for Chapter 3: Energy

Baines JT. 1993. *New Zealand Energy Information Handbook: energy data conversion factors and definitions*. Taylor Baines and Associates: Christchurch, New Zealand.

Beamish BB, Vance WE. 1992. Greenhouse Gas Contributions from Coal Mining in Australia and New Zealand. *Journal of the Royal Society of New Zealand*, 22 (2).

Hale and Twomey Ltd. 2003. *Review of Energy Sector Greenhouse Gas Emissions' Factors*. Report to Energy Modelling and Statistics Unit, Ministry of Economic Development.

Ministry of Economic Development. 2006. *New Zealand Energy Greenhouse Gas Emissions 1990–2005*. Ministry of Economic Development: New Zealand.

Ministry of Economic Development. 2008a. *New Zealand Energy Greenhouse Gas Emissions 1990–2007*. Ministry of Economic Development: New Zealand.

Ministry of Economic Development. 2008b. *New Zealand Energy Data File*. Ministry of Economic Development: New Zealand.

OECD/IEA. 2006. *Energy Policies of IEA Countries: New Zealand 2006 Review.* International Energy Agency: Paris.

## Specific references for Chapter 4: Industrial processes

Cement and Concrete Association of New Zealand (CCANZ). 1995. *The state of the standards.* New Zealand Concrete Construction. October/November 1995 p40.

CRL Energy Ltd. 2006. Hennessy W, Maxwell D. *Inventory of Non-$CO_2$ Greenhouse Gas Emissions from Industrial Sources and Solvents for New Zealand 2004–2005*. A report by CRL Energy Ltd to the Ministry for the Environment: New Zealand.

CRL Energy Ltd. 2008. Hennessy W. *Inventory of HFC, PFC & $SF_6$ Emissions for New Zealand 2007*. A report by CRL Energy Ltd to the Ministry for the Environment: New Zealand.

Ministry of Economic Development. 2008a. *New Zealand Energy Greenhouse Gas Emissions 1990–2007*. Ministry of Economic Development: New Zealand.

Ministry of Economic Development. 2008b. *New Zealand Energy Data File*. Ministry of Economic Development: New Zealand.

Roke L. 2006. *Personal communication*. Fisher and Paykel: New Zealand.

Ure CR. 2000. Alternative Iron-making at BHP New Zealand Steel. *58th Electric Furnace Conference and 17th Process Technology Conference*. Orlando, FL, USA: 12–15 November 2000. pp 535–546.

World Business Council for Sustainable Development (WBCSD). 2005. The Cement $CO_2$ Protocol: $CO_2$ Accounting and Reporting Standard for the Cement Industry. Switzerland.

## Specific references for Chapter 5: Solvent and other product use

Auckland Regional Council. 1997. *Auckland Air Emissions Inventory*. Report by the Victorian Environmental Protection Agency: New Zealand.

CRL Energy Ltd. 2006. Hennessy W, Maxwell D. *Inventory of Non-$CO_2$ Greenhouse Gas Emissions from Industrial Sources and Solvents for New Zealand 2004–2005*. A report by CRL Energy Ltd to the Ministry for the Environment: New Zealand.

Nelson, P. 1992. Waste Control and Pollution Prevention in the Paint Industry. *Surface Coatings Australia* (July).

United States EPA. 1985. *Compilation of Air Pollutant Emission Factors, Vol. 1: Stationary Point and Area Sources, 5th edition* (commonly known as AP-42). United States Environmental Protection Agency.

## Specific references for Chapter 6: Agriculture

CSIRO. 1990. *Feeding Standards for Australian Livestock: Ruminants*.

Carran RA, Theobold PW, Evans JP. 1995. Emissions of nitrous oxide from some grazed pasture soils. *New Zealand and Australian Journal of Soil Research* 33: 341–352.

Carran RA, Dewar D, Theobald PW. 2003. *Methane and nitrous oxide emissions from sheep dung.* Report prepared for the Ministry of Agriculture and Forestry by the New Zealand Pastoral Agricultural Research Institute. 29.

Clark H. 2008. *Guidelines to Accompany Computerised Inventory.* Report to the Ministry of Agriculture and Forestry, 42pp.

Clark H, Brookes I, Walcroft A. 2003. *Enteric methane emissions from New Zealand ruminants 1990–2001 calculated using an IPCC Tier 2 approach.* Report prepared for the Ministry of Agriculture and Forestry (March 2003).

Clough TJ, Kelliher FM, Clark H, and van der Weerden TJ. 2008. *Incorporation of the Nitrification Inhibitor DCD into New Zealand's 2009 National Inventory.* Report to the Ministry of Agriculture and Forestry, 37pp.

de Klein CAM, Barton L, Sherlock RR, Li Z, Littlejohn RP. 2003. *Estimating a nitrous oxide emission factor for animal urine from some New Zealand pastoral soils. Australian Journal of Soil Research* 41: 381–399.

Grainger C, Clarke T, McGinn SM, Auldist MJ, Beauchemin KA, Hannah MC, Waghorn GC, Clark H, Eckard RJ. 2007. *Methane emissions from dairy cows measured with sulphur hexafluoride ($SF_6$) tracer and chamber techniques*. Journal of Dairy Science. In press.

Heatley P. 2001. *Dairying and the environment: managing farm dairy effluent*. New Zealand Dairy Research Institute: Palmerston North, New Zealand.

Kay RNB. 1995. Body Size, Patterns of Growth, and Efficiency of Production in Red Deer. In: *Biology of Deer Production*. Fennessey PF, Drew KR (Eds). *Royal Society of New Zealand Bulletin 22:* 411–421.

Kelliher FM, Clough T, Newsome P, Pitcher-Campbell S, Shephard G. 2002. $N_2O$ emissions from organic soils. Report for the Ministry of Agriculture and Forestry (June 2002).

Kelliher FM, Ledgard SF, Clark H, Walcroft AS, Buchan M, Sherlock RR. 2003. *A Revised Nitrous Oxide Emissions Inventory for New Zealand 1990–2001.* Report for the Ministry of Agriculture and Forestry (March 2003).

Kelliher FM; de Klein CAM; Li Z; Sherlock RR. 2005. *Review of nitrous oxide emission factor ($EF_3$) data*. Report prepared for the Ministry of Agriculture and Forestry. 20.

Kelliher FM, de Klein CAM. 2006. *Review of New Zealand's fertiliser nitrous oxide emission factor ($EF_1$) data.* A Report for the Ministry for the Environment (April 2006): New Zealand.

Lassey KR, Ulyatt MJ, Martin RJ, Walker CF, Shelton ID. 1997. Methane Emissions Measured Directly from Grazing Livestock in New Zealand. *Atmospheric Environment* 31: 2905–2914.

Laubach J, Kelliher FM. 2004. Measuring methane emission rates of a dairy cow herd by two micrometeorological techniques. *Agricultural and Forest Meteorology* 125: 279–303.

Ledgard SF, Webby R, Hawke M. 2003. *Improved estimation of N excretion by grazing animals to improve $N_2O$ emission inventories*. Report prepared for the Ministry of Agriculture and Forestry. 29.

Ledgard S, Brier G. 2004. Estimation of the proportion of animal excreta transferred to the farm dairy effluent system. Report prepared for Ministry of Agriculture and Forestry: New Zealand.

Livestock Improvement Corporation Limited 2008. Dairy Statistics 2006–2007.

McGrath RJ, Mason IG. 2002. An observational method for assessment of biogas production from an anaerobic waste stabilisation pond treating farm dairy wastewater. Presented IWA Specialised Conference on Waste Stabilisation Ponds (April 2002): Auckland, New Zealand.

Ministry of Agriculture and Forestry. 2008. Situation and Outlook for New Zealand Agriculture and Forestry (SONZAF). Available at http://www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/sonzaf/2008/

Muller C, Sherlock RR, Williams PH. 1995. Direct field measurements of nitrous oxide emissions from urine-affected and urine-unaffected pasture in Canterbury. In: *Proceedings of the workshop on fertilizer requirements of grazed pasture and field crops: macro and micronutrients.* Currie LD, Loganathan P (Eds). Occasional Report No. 8, ISSN 0112–9902: 7. Massey University: Palmerston North. 243–34.

Payton IJ, Pearce G. 2001. *Does fire deplete physical and biological resources of tall-tussock (Chionochloa) grasslands? The latest attempt at some answers.* Bushfire 2001. Australasian Bushfire Conference, 3–6 July 2001, Christchurch, New Zealand. 243–249.

Saggar S, Clark H, Hedley C, Tate K, Carran A, Cosgrove G. 2003. *Methane emissions from animal dung and waste management systems, and its contribution to national budget.* Landcare Research Contract Report: LC0301/02. Prepared for the Ministry of Agriculture and Forestry: New Zealand. 39.

Sherlock RR, Johnston G, Kelliher F, Newsome P, Walcroft A, de Klein CAM, Ledgard S. 2001. *A desktop study of regional variations in nitrous oxide emissions.* Report prepared for the Ministry of Agriculture and Forestry: New Zealand.

Sherlock RR, de Klein C, Li Z. 2003. *Determination of $N_2O$ and $CH_4$ emission factors from animal excreta, following a summer application in three regions of New Zealand.* A final report of an NzOnet study prepared for Ministry of Agriculture and Forestry: New Zealand. 27.

Statistics New Zealand. 2008. Agriculture Statistics table builder and Infoshare database. Available at http://www.stats.govt.nz/products-and-services/table-builder/tablebuilder-tables-agriculture.htm and http://www.stats.govt.nz/Infoshare/database/snz/databaseTree.asp

Thomas SM, Ledgard SF, Francis GS. 2005. Improving estimates of nitrate leaching for quantifying New Zealand's indirect nitrous oxide emissions. *Nutrient Cycling in Agroecosystems* 73: 213–226.

Ulyatt MJ, Baker SK, McCrabb GJ, Lassey KR. 1999. Accuracy of the $SF_6$ Tracer Technology and Alternatives for Field Measurements. *Australian Journal of Agricultural Research* 50: 1329–1334.

Waghorn G, Molano G, Lassey K. 2002. *Estimates of whole herd methane production from cows at the Lincoln University Dairy Farm in January and March 2002*. A preliminary report to Landcare Research (unpublished): New Zealand. 17.

Waghorn G, Molano G, Cavanagh A. 2003. *An estimate of whole herd methane production from cows at the Lincoln University Dairy Farm in October 2003.* Final report prepared for Landcare Research NZ Ltd., AgResearch: Palmerston North. 23.

Wheeler DM, Ledgard SF, De Klein CAM, Monaghan PL, Carey PL, McDowell RW, Johns KL. 2003. OVERSEER® Nutrient budgets – moving towards on-farm resource accounting. *Proceedings of the New Zealand Grassland Association 2003.*

## Specific references for Chapter 7: Land use, land-use change and forestry

Beets PN, Robertson K, Ford-Robertson JB, Gordon J, Maclaren JP. 1999. *Description and Validation of C-change: A Model for Simulating Carbon Content in Managed Pinus Radiata Stands*. New Zealand Journal of Forestry Science 29(3): 409–427.

Beets PN, Gilchrist K, Jeffreys M. 2001. *Wood density of radiata pine: effect of nitrogen supply*. Forest Ecology and Management 145: 173–180.

Challands N. 2007. *Personal communication.* New Zealand Fire Service: New Zealand.

Garcia O. 1984. Nagumo H *et al* (eds). FOLPI: a forestry-oriented linear programming interpreter. *IUFRO symposium on Forest Management, Planning and Managerial Economics.* University of Tokyo: Japan. 293–305.

Hollinger DY, Maclaren JP, Beets PN, Turland J. 1993. *Carbon sequestration by New Zealand's plantation forests.* New Zealand Journal of Forest Science 23(2).

Hall G, Wiser S, Allen R, Moore T, Beets P, Goulding C. 1998. *Estimate of the carbon stored in New Zealand's indigenous forest and scrub vegetation for 1990.* Report for the Ministry for the Environment, Landcare Research and Forest Research: Hamilton, New Zealand.

Hall GMJ, Wiser SK, Allen RB, Beets PN, Goulding CJ. 2001. Strategies to estimate national forest carbon stocks from inventory data: the 1990 New Zealand baseline. Global Change Biology 7, 389–403.

Jaakko Poyry Consulting. 2003. *Small forest owners yield table evaluation.* Contract report prepared for the Ministry of Agriculture and Forestry: New Zealand.

Kelliher FM, de Klein CAM. 2006. *Review of New Zealand's fertiliser nitrous oxide emission factor ($EF_1$) data.* A Report for the Ministry for the Environment (April 2006): New Zealand.

Manley B, Papps S, Threadgill J, Wakelin S. 1991. *Application of FOLPI, A Linear Programming Estate Modelling System for Forest Management Planning*. Ministry of Forestry, FRI Bulletin No. 164.

Manley. 2004. *Review of NEFD Yield Table Structure.* Contract report prepared for the Ministry of Agriculture and Forestry: New Zealand.

Ministry of Agriculture and Forestry. 2008. *National Exotic Forest Description* as at 1 April 2007 (June 2008).

Scott NA, Tate KR, Giltrap DJ, Newsome PF, Davis MR, Baisden WT, Saggar S, Trotter CM, Walcroft AS, White JD, Trustrum NA, Stephens PR. 2001. Critical issues in quantifying land-use change effects on New Zealand's terrestrial carbon budget: Deforestation, afforestation and reforestation. *Extended Abstracts Volume 1*, Sixth International Carbon Dioxide Conference, Sendai, Japan, October 2001. Organizing Committee of the Sixth International Carbon Dioxide Conference, Tohoku University: Japan. 559–562.

Tate KR, Scott NA, Parshotam A, Brown L, Wilde RH, Giltrap DJ, Trustrum NA, Gomez B, Ross DJ. 2000. A multi-scale analysis of a terrestrial carbon budget: Is New Zealand a source or sink of carbon? *Agriculture, Ecosystems & Environment* 82 (1–3) (December 2000). 229–246.

Tate KR, Barton JP, Trustrum NA, Baisden WT, Saggar S, Wilde RH, Giltrap DA, Scott NA. 2003a. *Monitoring and modelling soil organic carbon stocks and flows in New Zealand. In: Soil Organic Carbon and Agriculture: Developing Indicators for Policy Analysis*. Scott-Smith. CA (Ed). Proceedings of an OECD Expert Meeting, Ottawa, Canada, October 2002. Agriculture and Agri-Food Canada and Organisation for Economic Co-operation and Development: Paris. 329.

Tate KR, Wilde RH, Giltrap DJ, Baisden WT, Saggar S, Trustrum NA, Scott NA. 2003b. *Current approaches to soil carbon monitoring in New Zealand.* Proceedings of carbon measurement and monitoring forum (CASGMS). Manhattan, Kansas, 15–17 October, 2003.

Tate KR, Wilde RH, Giltrap DJ, Baisden WT, Saggar S, Trustrum NA, Scott NA. 2004. *Soil carbon changes and uncertainties with New Zealand land-use change*. Singh B (2004). *Supersoil 2004*: Proceedings of the 3rd Australian New Zealand Soils Conference, University of Sydney, Australia, 5–9 December 2004. www.regional.org.au/au/asssi/supersoil2004

Thompson S, Gruner I, Gapare N. 2004. *New Zealand Land Cover Database Version 2. Illustrated Guide to Target Classes.* Report for the Ministry for the Environment: New Zealand.

Wakelin SJ. 2006. *Review of LULUCF Biomass Burning Assumptions in New Zealand's Greenhouse Gas Inventory*. Report for the Ministry for the Environment.

Wakelin SJ. 2007. *Carbon Inventory of New Zealand's Planted Forests – Calculations revised in October 2007 for New Zealand's 2006 Greenhouse Gas Inventory*. Report for the Ministry of Agriculture and Forestry.

Wakelin SJ. 2008. *Carbon Inventory of New Zealand's Planted Forests – Calculations revised in October 2008 for New Zealand's 2007 Greenhouse Gas Inventory*. Report for the Ministry of Agriculture and Forestry.

## Specific references for Chapter 8: Waste

Beca (2007) *National Greenhouse Gas Inventory from Wastewater Treatment and Discharge*. Unpublished.

IPCC. 2006. Eggleston S, Buendia L, Miwa K, Ngara T, Tanabe K (Eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories volume 5, Waste*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

Ministry for the Environment. 1997. *National Waste Data Report*. Ministry for the Environment: New Zealand.

Ministry for the Environment. 2002a. *The New Zealand Waste Strategy*. Ministry for the Environment: New Zealand.

Ministry for the Environment. 2002b. *Solid Waste Analysis Protocol*. Ministry for the Environment: New Zealand.

Ministry for the Environment. 2007. http://www.mfe.govt.nz/publications/waste/2006-07-national-landfill-census-oct07/index.html

SCS Wetherill Environmental. 2002. *National Greenhouse Gas Inventory from the Waste Sector 1990–2020*. A report for the Ministry for the Environment: New Zealand.

SKM. 2007. *Greenhouse Gases from the Waste Incineration Sector*. Unpublished.

Waste Management New Zealand. 2005. *Landfill Methane Recovery Estimate and National Greenhouse Gas Inventory from the Waste Sector*. Report commissioned by the Ministry for the Environment: New Zealand.

Waste Not Consulting. 2006. *Waste Composition and Construction Waste Data*. Unpublished.

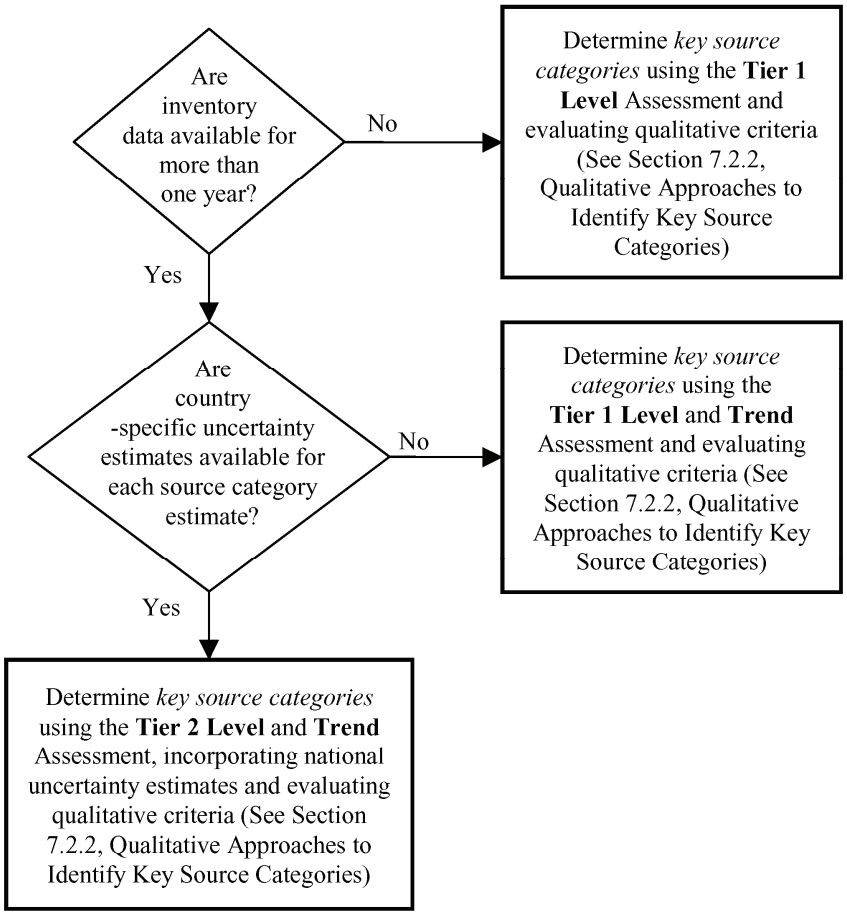
# Annexes to New Zealand's National Inventory Report for 2007

# 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 this inventory submission, 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 the oil and natural gas category – was divided into two categories: fugitive emissions from oil and gas operations and fugitive emissions from geothermal operations. This is to reflect that New Zealand generates a significant amount of energy from geothermal sources that cannot be included as oil or gas operations.

# A1.3 Tables 7.A1–7.A3 of the IPCC Good Practice Guidance

**Table A1.1 Results of the key category level analysis for 99 per cent of the total emissions and removals for New Zealand in 2007. Key categories are those that comprise 95 per cent of the total.**

| (a) Tier 1 Category Level Assessment - including LULUCF | | | | |
|---|---|---|---|---|
| **IPCC Categories** | **Gas** | **2007 estimate (Gg $CO_2$-e)** | **Level assessment** | **Cumulative total** |
| Emissions from enteric fermentation in domestic livestock | $CH_4$ | 23326.38 | 23.0 | 23.0 |
| Conversion to forest land | $CO_2$ | 15253.73 | 15.0 | 38.0 |
| Mobile combustion - road vehicles | $CO_2$ | 13281.35 | 13.1 | 51.1 |
| Forest land remaining forest land | $CO_2$ | 9311.50 | 9.2 | 60.3 |
| Emissions from stationary combustion - gas | $CO_2$ | 8723.65 | 8.6 | 68.9 |
| Emissions from agricultural soils - animal production | $N_2O$ | 7346.67 | 7.2 | 76.1 |
| Emissions from stationary combustion - solid | $CO_2$ | 4473.87 | 4.4 | 80.5 |
| Indirect emissions from nitrogen used in agriculture | $N_2O$ | 3270.66 | 3.2 | 83.8 |
| Emissions from stationary combustion - liquid | $CO_2$ | 2644.94 | 2.6 | 86.4 |
| Direct emissions from agricultural soils | $N_2O$ | 1680.74 | 1.7 | 88.0 |
| Emissions from the iron and steel industry | $CO_2$ | 1646.24 | 1.6 | 89.7 |
| Emissions from solid waste disposal sites | $CH_4$ | 1437.95 | 1.4 | 91.1 |
| Mobile combustion - aviation | $CO_2$ | 915.10 | 0.9 | 92.0 |
| Consumption of halocarbons and $SF_6$ - refrigeration and air conditioning | HFCs & PFCs | 779.64 | 0.8 | 92.7 |
| Fugitive emissions from oil and gas operations | $CO_2$ | 754.57 | 0.7 | 93.5 |
| Emissions from manure management | $CH_4$ | 729.10 | 0.7 | 94.2 |
| Emissions from cement production | $CO_2$ | 687.90 | 0.7 | 94.9 |
| Cropland remaining cropland | $CO_2$ | 649.67 | 0.6 | 95.5 |
| Emissions from aluminium production | $CO_2$ | 579.05 | 0.6 | 96.1 |
| Conversion to grassland | $CO_2$ | 436.83 | 0.4 | 96.5 |
| Fugitive emissions from oil and gas operations | $CH_4$ | 378.72 | 0.4 | 96.9 |
| Fugitive emissions from geothermal operations | $CO_2$ | 301.47 | 0.3 | 97.2 |
| Mobile combustion - marine | $CO_2$ | 300.11 | 0.3 | 97.5 |
| Fugitive emissions from coal mining and handling | $CH_4$ | 261.83 | 0.3 | 97.7 |
| Emissions from hydrogen production | $CO_2$ | 224.90 | 0.2 | 98.0 |
| Emissions from wastewater handling | $CH_4$ | 202.49 | 0.2 | 98.2 |
| Emissions from wastewater handling | $N_2O$ | 179.19 | 0.2 | 98.3 |
| Emissions from ammonia/urea production | $CO_2$ | 360.06 | 0.4 | 98.7 |
| Mobile combustion - rail | $CO_2$ | 164.88 | 0.2 | 98.9 |
| Mobile combustion - road vehicles | $N_2O$ | 147.48 | 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 $CO_2$-e)** | **Level assessment** | **Cumulative total** |
| Emissions from enteric fermentation in domestic livestock | $CH_4$ | 21818.97 | 26.6 | 26.6 |
| Conversion to forest land | $CO_2$ | 13059.41 | 15.9 | 42.5 |
| Emissions from stationary combustion – gas | $CO_2$ | 7691.22 | 9.4 | 51.9 |
| Mobile combustion – road vehicles | $CO_2$ | 7516.28 | 9.2 | 61.0 |
| Emissions from agricultural soils – animal production | $N_2O$ | 6853.06 | 8.3 | 69.4 |
| Forest land remaining forest land | $CO_2$ | 5614.43 | 6.8 | 76.2 |
| Emissions from stationary combustion – solid | $CO_2$ | 3139.65 | 3.8 | 80.0 |
| Indirect emissions from nitrogen used in agriculture | $N_2O$ | 2703.13 | 3.3 | 83.3 |
| Emissions from stationary combustion – liquid | $CO_2$ | 2505.28 | 3.1 | 86.4 |
| Emissions from solid waste disposal sites | $CH_4$ | 2063.21 | 2.5 | 88.9 |
| Emissions from the iron and steel industry | $CO_2$ | 1310.88 | 1.6 | 90.5 |
| Mobile combustion – aviation | $CO_2$ | 771.68 | 0.9 | 91.4 |
| PFCs from aluminium production | PFCs | 642.22 | 0.8 | 92.2 |
| Emissions from manure management | $CH_4$ | 578.70 | 0.7 | 92.9 |
| Cropland remaining cropland | $CO_2$ | 515.64 | 0.6 | 93.5 |
| Direct emissions from agricultural soils | $N_2O$ | 487.19 | 0.6 | 94.1 |
| Conversion to grassland | $CO_2$ | 482.70 | 0.6 | 94.7 |
| Emissions from aluminium production | $CO_2$ | 443.27 | 0.5 | 95.3 |
| Emissions from cement production | $CO_2$ | 441.67 | 0.5 | 95.8 |
| Fugitive emissions from geothermal operations | $CO_2$ | 376.16 | 0.5 | 96.3 |
| Grassland remaining grassland | $CO_2$ | 350.80 | 0.4 | 96.7 |
| Fugitive emissions from coal mining and handling | $CH_4$ | 272.13 | 0.3 | 97.0 |
| Fugitive emissions from oil and gas operations | $CO_2$ | 263.75 | 0.3 | 97.3 |
| Fugitive emissions from oil and gas operations | $CH_4$ | 262.63 | 0.3 | 97.7 |
| Mobile combustion – marine | $CO_2$ | 244.24 | 0.3 | 98.0 |
| Emissions from wastewater handling | $CH_4$ | 206.95 | 0.3 | 98.2 |
| Emissions from wastewater handling | $N_2O$ | 153.47 | 0.2 | 98.4 |
| Emissions from hydrogen production | $CO_2$ | 152.29 | 0.2 | 98.6 |
| Emissions from ammonia/urea production | $CO_2$ | 277.67 | 0.3 | 98.9 |
| Conversion to settlement | $CO_2$ | 97.16 | 0.1 | 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 2007. 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 ($Gg CO_2$-e)** | **2007 estimate ($Gg CO_2$-e)** | **Trend assessment** | **Contribution to trend** | **Cumulative total** |
| Mobile combustion - road vehicles | $CO_2$ | 7516.28 | 13281.35 | 0.032 | 20.5 | 20.5 |
| Emissions from enteric fermentation in domestic livestock | $CH_4$ | 21818.97 | 23326.38 | 0.029 | 18.7 | 39.1 |
| Forest land remaining forest land | $CO_2$ | 5614.43 | 9311.50 | 0.019 | 12.2 | 51.3 |
| Emissions from agricultural soils - animal production | $N_2O$ | 6853.06 | 7346.67 | 0.009 | 5.8 | 57.0 |
| Emissions from solid waste disposal sites | $CH_4$ | 2063.21 | 1437.95 | 0.009 | 5.7 | 62.7 |
| Direct emissions from agricultural soils | $N_2O$ | 487.19 | 1680.74 | 0.009 | 5.5 | 68.3 |
| Conversion to forest land | $CO_2$ | 13059.41 | 15253.73 | 0.007 | 4.5 | 72.8 |
| Emissions from stationary combustion - gas | $CO_2$ | 7691.22 | 8723.65 | 0.006 | 4.0 | 76.8 |
| Consumption of halocarbons and $SF_6$ - refrigeration and air conditioning | HFCs & PFCs | 0.00 | 779.64 | 0.006 | 4.0 | 80.8 |
| PFCs from aluminium production | PFCs | 642.22 | 40.27 | 0.006 | 3.9 | 84.7 |
| Emissions from stationary combustion - solid | $CO_2$ | 3139.65 | 4473.87 | 0.005 | 3.0 | 87.7 |
| Emissions from stationary combustion - liquid | $CO_2$ | 2505.28 | 2644.94 | 0.004 | 2.3 | 90.0 |
| Fugitive emissions from oil and gas operations | $CO_2$ | 263.75 | 754.57 | 0.003 | 2.2 | 92.2 |
| Fugitive emissions from geothermal operations | $CO_2$ | 376.16 | 301.47 | 0.001 | 0.8 | 93.1 |
| Conversion to grassland | $CO_2$ | 482.70 | 436.83 | 0.001 | 0.8 | 93.9 |
| Emissions from cement production | $CO_2$ | 441.67 | 687.90 | 0.001 | 0.7 | 94.6 |
| Conversion to cropland | $CO_2$ | 37.35 | 128.68 | 0.001 | 0.4 | 95.0 |
| Consumption of halocarbons and $SF_6$ - aerosols and metered dose inhalers | HFCs & PFCs | 0.00 | 75.57 | 0.001 | 0.4 | 95.4 |
| Fugitive emissions from coal mining and handling | $CH_4$ | 272.13 | 261.83 | 0.001 | 0.4 | 95.8 |
| Indirect emissions from nitrogen used in agriculture | $N_2O$ | 2703.13 | 3270.66 | 0.001 | 0.4 | 96.2 |
| Mobile combustion - road vehicles | $N_2O$ | 64.49 | 147.48 | 0.001 | 0.3 | 96.5 |
| Mobile combustion - rail | $CO_2$ | 84.76 | 164.88 | 0.000 | 0.3 | 96.8 |
| Fugitive emissions from oil and gas operations | $CH_4$ | 262.63 | 378.72 | 0.000 | 0.3 | 97.1 |
| Emissions from wastewater handling | $CH_4$ | 206.95 | 202.49 | 0.000 | 0.3 | 97.4 |
| Mobile combustion - aviation | $CO_2$ | 771.68 | 915.10 | 0.000 | 0.2 | 97.6 |
| Emissions from hydrogen production | $CO_2$ | 152.29 | 224.90 | 0.000 | 0.2 | 97.8 |
| Mobile combustion - road vehicles | $CH_4$ | 69.10 | 53.91 | 0.000 | 0.2 | 97.9 |
| Emissions from Aluminium production | $CO_2$ | 443.27 | 579.05 | 0.000 | 0.2 | 98.1 |
| Emissions from the iron and steel industry | $CO_2$ | 1310.88 | 1646.24 | 0.000 | 0.1 | 98.2 |
| Emissions from lime production | $CO_2$ | 81.62 | 124.26 | 0.000 | 0.1 | 98.3 |
| Conversion to settlement | $CO_2$ | 97.16 | 97.16 | 0.000 | 0.1 | 98.4 |
| Emissions from limestone & dolomite use | $CO_2$ | 18.53 | 43.73 | 0.000 | 0.1 | 98.6 |
| Emissions from ammonia/urea production | $CO_2$ | 277.67 | 360.06 | 0.000 | 0.1 | 98.6 |
| Non-$CO_2$ emissions from stationary combustion | $N_2O$ | 68.83 | 100.74 | 0.000 | 0.1 | 98.7 |
| Emissions from waste incineration | $CO_2$ | 12.91 | 0.93 | 0.000 | 0.1 | 98.8 |
| Emissions from manure management | $CH_4$ | 578.70 | 729.10 | 0.000 | 0.1 | 98.9 |
| Emissions from agricultural residue burning | $CH_4$ | 21.38 | 13.16 | 0.000 | 0.1 | 98.9 |
| Forest land remaining forest land | $CH_4$ | 16.02 | 32.57 | 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 × GCV for coal and liquid fuels
- NCV = 0.90 × 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 Gross $CO_2$ emission factors used in the energy sector in 2007 (before oxidation)

| | Emission factor (t $CO_2$/TJ) | Emission factor (t C/TJ) | Source |
|---|---|---|---|
| **Gas** | | | |
| Maui | 52.2 | 14.2 | 1 |
| Kapuni Treated | 53.2 | 14.5 | 1 |
| Kapuni LTS | 84.1 | 22.9 | 2 |
| Weighted average for distributed gas | 53.8 | 14.7 | |
| Methanol – mixed feed (1990–1994) | 62.4 | 17.0 | 3 |
| Methanol – LTS (1990–1994) | 84.0 | 22.9 | 3 |
| Kaimiro | 65.2 | 17.8 | 2 |
| Ngatoro | 53.1 | 14.5 | 3 |
| Rimu | 53.7 | 14.6 | 3 |
| Waihapa/Ngaere + Tariki/Ahuroa (1990)* | 56.2 | 15.3 | 3 |
| Waihapa/Ngaere + Tariki/Ahuroa (2002) | 54.2 | 14.8 | 3 |
| McKee | 54.3 | 14.8 | 3 |
| Mangahewa | 52.3 | 14.3 | 3 |
| Turangi | 55.6 | 15.2 | 3 |
| Pohokura | 55.1 | 15.0 | 3 |
| **Liquid fuels** | | | |
| Regular petrol | 66.4 | 18.1 | 4 |
| Petrol – premium | 66.8 | 18.2 | 4 |
| Diesel (50 ppm) | 69.4 | 18.9 | 4 |
| Aviation fuels | 68.4 | 18.7 | 4 |
| Av gas | 65.9 | 18.0 | 4 |
| Fugitive – flared | 65.1 | 17.8 | 4 |
| LPG | 60.4 | 16.5 | 4 |
| Heavy fuel oil | 73.6 | 20.0 | 4 |
| Light fuel oil | 72.9 | 19.6 | 4 |
| Bitumen (asphalt) | 76.9 | 20.8 | 4 |
| **Biomass** | | | |
| Biogas | 101.0 | 27.5 | 5 |
| Wood (industrial) | 104.2 | 28.4 | 5 |
| Wood (residential) | 104.2 | 28.4 | 5 |
| **Coal** | | | |
| All sectors (sub bit) | 91.2 | 24.9 | 2 |
| All sectors (bit) | 88.8 | 24.2 | 2 |
| All sectors (lignite) | 95.2 | 26.0 | 2 |

* For the years 1991–2001, the emissions' factors for these gas streams are interpolated between the 1990 and 2002 values.

1. Derived by the transmission operator (Vector Ltd) through averaging daily gas composition data
2. New Zealand Energy Information Handbook (Baines, 1993)
3. Specific gas field operator
4. New Zealand Refinery Company
5. IPCC guidelines (1996).

## Table A2.2 Methane emission factors used in the energy sector (before oxidation)

| | 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 | 0.19 | IPCC Tier 2 (Table 1–49) diesel engines (agriculture) |
| **Mobile sources** | | |
| LPG | 28.5 | IPCC Tier 2 (Table 1–44) passenger cars (uncontrolled) |
| Petrol | 18.525 | IPCC Tier 2 (Table 1–27) passenger cars (uncontrolled – mid-point of average g/MJ) |
| Diesel | 3.8 | IPCC Tier 2 (Table 1–32) passenger cars (uncontrolled – g/MJ) |
| Navigation (fuel oil and diesel) | 6.65 | IPCC Tier 2 (Table 1–48) ocean-going ships |
| Aviation fuel/kerosene | 1.9 | 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 Nitrous oxide emission factors used in the energy sector (before oxidation)

| | 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 | 0.38 | IPCC Tier 2 (Table 1–49) diesel engines – agriculture |
| **Mobile sources** | | |
| LPG | 0.57 | IPCC Tier 1 (Table 1–8) oil – all sources except aviation |
| Petrol | 1.425 | 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 has a ±5 per cent uncertainty associated with the sectoral energy allocation. However, certainty is likely to be greater for the annual totals (Ministry of Economic Development, 2006).

As the survey is run as a census there is no sampling error. The 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: 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[7]). The New Zealand Refining Company estimates a ±5 per cent uncertainty in emission factors (Ministry of Economic Development, 2006).

# A2.2 Emissions from solid fuels

## A2.2.1 Activity data and uncertainties

The *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, has 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 greater uncertainty than the uncertainty in total coal sales. Uncertainty is also introduced from the assumption that coal used by sector is an average of the different ranks. These assumptions are thought to introduce an uncertainty of ±5 per cent (Ministry of Economic Development, 2006).

The sectoral partitioning used for coal was examined in 2003 by the Ministry for the Environment. There was concern in extrapolating sectoral allocations from 1995 to 2002 given some probable changes in sectoral coal usage. However, New Zealand coal industry experts did not consider a survey could be justified due to 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.

[7] The LPG $CO_2$ emissions factor was confirmed by checks of 2002 gas data.

### A2.2.2 Emission factors and uncertainties

The $CO_2$ emission factors for coal are shown in Table A2.1. The non-$CO_2$ emission factors are shown in Tables A2.2 and A2.3. The estimated uncertainty in coal emission factors is ±3 per cent (Ministry of Economic Development, 2006). An uncertainty of ±2 per cent is used for the sub-bituminous coal used in public electricity generation. All New Zealand emissions' factors are ±2 per cent of the revised 1996 IPCC default values (IPCC, 1996).

## A2.3 Emissions from gaseous fuels

### A2.3.1 Activity data

Vector Limited, a gas transmission and distribution company, has contracts with large gas users that allow metering errors of ±2 per cent. Whenever the error between the meter-reading and actual gas supplied exceeds 2 per cent, adjustments are made to the reported quantities of gas supplied. Consequently, uncertainty is assumed to have an upper limit of ±2 per cent (Ministry of Economic Development, 2006).

### A2.3.2 Emission factors

As discussed in section 3.2.1.5, New Zealand now uses all of the gas production data reported in the *New Zealand Energy Data File* (Ministry of Economic Development, 2008b) to support the calculation of a weighted average annual $CO_2$ emission factor for natural gas. This average emission factor is applied to a number of categories in the energy sector, such as the manufacturing industries and construction category.

The emission factors for each gas stream are shown in Table A2.1. The $CO_2$ emission factors for distributed gas are shown in Table A2.4.

**Table A2.4 Variation in $CO_2$ emission factors for distributed natural gas (before oxidation)**

| Year | National Average (kt $CO_2$ / PJ) |
|---|---|
| 1990 | 53.2 |
| 1991 | 52.7 |
| 1992 | 52.7 |
| 1993 | 52.5 |
| 1994 | 52.3 |
| 1995 | 52.1 |
| 1996 | 52.3 |
| 1997 | 52.3 |
| 1998 | 52.2 |
| 1999 | 51.9 |
| 2000 | 52.0 |
| 2001 | 52.0 |
| 2002 | 52.4 |
| 2003 | 52.3 |
| 2004 | 52.4 |
| 2005 | 52.3 |
| 2006 | 52.7 |
| 2007 | 53.3 |

# A2.4 Energy balance for year ended December 2007

## Table A2.5 New Zealand energy balance for year ended December 2007 (Ministry of Economic Development, 2008b)

| *Converted into Petajolues 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 | Petrol | Diesel | Fuel Oil | Av. Fuel/ Kero | Others | Total | Natural Gas | Hydro | Geothermal | Solar | Wind | Biogas | Wood | Total | | | |
| Indigenous Production | 63.59 | 57.13 | 120.72 | 4.12 | **124.84** | 87.69 | 5.75 | | | | | | **93.44** | **169.81** | 84.66 | 93.86 | 0.30 | 3.37 | 2.83 | 43.57 | **228.59** | | 1.12 | **617.80** |
| + Imports | 3.50 | 13.61 | 17.12 | 0.01 | **17.13** | 212.08 | 4.14 | 50.41 | 40.43 | 0.01 | 11.55 | 7.83 | **326.45** | | | | | | | | | | | **343.58** |
| - Exports | 63.67 | | 63.67 | 0.00 | **63.67** | 75.29 | 0.00 | 0.68 | 0.00 | 4.68 | 0.00 | 0.00 | **80.66** | | | | | | | | | | | **144.33** |
| - Stock Change | | | 9.29 | | **9.29** | 4.53 | 0.43 | 1.65 | 0.93 | -3.65 | 0.15 | -0.38 | **3.66** | **0.03** | | | | | | | | | | **12.98** |
| - International Transport | | | | | | | | 0.00 | 1.34 | 12.17 | 38.57 | 0.00 | **52.07** | | | | | | | | | | | **52.07** |
| **TOTAL PRIMARY ENERGY** | **3.42** | **70.74** | **64.87** | **4.13** | **69.00** | **219.94** | **9.46** | **48.08** | **38.16** | **-13.19** | **-27.17** | **8.21** | **283.50** | **169.79** | **84.66** | **93.86** | **0.30** | **3.37** | **2.83** | **43.57** | **228.59** | | **1.12** | **752.00** |
| **ENERGY TRANSFORMATION** | | | **-44.63** | | **-44.63** | **-218.11** | **-0.72** | **65.82** | **73.43** | **24.66** | **39.74** | **6.11** | **-9.07** | **-100.98** | **-84.66** | **-84.08** | | **-3.37** | **-2.55** | **-8.14** | **-182.80** | **141.59** | **-1.12** | **-197.01** |
| Electricity Generation | | | -26.07 | | **-26.07** | | | | | | | | | **-75.35** | -84.66 | -76.35 | | -3.37 | -1.67 | | **-166.05** | **145.08** | | **-122.39** |
| Cogeneration | | | -0.85 | | **-0.85** | | | | | | | | | **-18.39** | | -1.73 | | | -0.87 | -8.14 | **-10.74** | **10.73** | -1.12 | **-20.37** |
| Oil Production | | | | | | -218.11 | | 66.84 | 72.76 | 24.32 | 38.94 | 14.20 | **-1.04** | | | | | | | | | | | **-1.04** |
| Other Transformation | | | -17.69 | | **-17.69** | | | | | | | | | **-2.13** | | | | | | | | **2.07** | | **-17.75** |
| Losses and Own Use | | | -0.03 | | **-0.03** | | -0.72 | -1.02 | 0.67 | 0.34 | 0.80 | -8.09 | **-8.03** | **-5.11** | | -6.00 | | | | | **-6.00** | **-16.28** | | **-35.45** |
| ***Non-energy Use*** | | | | | | | | | | | | ***-14.32*** | ***-14.32*** | ***-23.70*** | | | | | | | | | | ***-38.02*** |
| **CONSUMER ENERGY (calculated)** | | | **20.24** | **4.13** | **24.37** | | **8.74** | **113.90** | **111.59** | **11.47** | **12.57** | **0.00** | **260.10** | **45.11** | | **9.78** | **0.30** | **0.00** | **0.28** | **35.43** | **45.80** | **141.59** | **0.00** | **516.97** |
| **Agriculture** | | | **1.45** | **0.01** | **1.46** | | | **0.93** | **8.17** | **1.64** | **0.22** | | **10.96** | **1.81** | | | | | | | | | **6.23** | | **20.45** |
| Agriculture and Hunting | | | 1.45 | 0.01 | **1.46** | | | 0.91 | 5.87 | 0.01 | 0.22 | | **7.00** | **1.81** | | | | | | | | | 5.76 | | **16.03** |
| Fishing | | | | | | | | 0.02 | 2.31 | 1.64 | 0.00 | | **3.96** | | | | | | | | | | 0.46 | | **4.42** |
| **Industrial** | | | **13.47** | **3.68** | **17.15** | | **2.92** | **1.74** | **13.25** | **1.51** | **0.15** | | **19.58** | **30.79** | | **5.82** | | | | **27.63** | **33.45** | **54.89** | | **155.85** |
| Other Primary Industry | | | | | | | | 0.01 | 3.39 | 0.71 | 0.00 | | **4.11** | **0.22** | | | | | | | | 1.18 | | **5.50** |
| Food Processing | | | | | | | | 0.00 | 0.04 | 0.10 | 0.00 | | **0.14** | **11.40** | | | | | | | | 7.83 | | **19.36** |
| Textiles | | | | | | | | | | | | | | | | | | | | | | 0.60 | | **0.60** |
| Wood, Pulp, Paper and Printing | | | | | | | | | | | | | | **6.23** | | | | | | | | 13.25 | | **19.49** |
| Chemicals | | | | | | | | | | | | | | **7.39** | | | | | | | | 2.87 | | **10.26** |
| Non-metallic Minerals | | | | | | | | | | | | | | **5.42** | | | | | | | | 0.88 | | **6.30** |
| Basic Metals | | | | | | | | | 0.00 | | | | | | | | | | | | | 24.25 | | **24.25** |
| Mechanical/Electrical Equipment | | | | | | | | | | | | | | | | | | | | | | 0.94 | | **0.94** |
| Building and Construction | | | | | | | | 0.01 | 1.65 | 0.01 | 0.08 | | **1.75** | **0.13** | | | | | | | | 0.82 | | **2.69** |
| Unallocated | | | 13.47 | 3.68 | **17.15** | | 2.92 | 1.73 | 8.17 | 0.70 | 0.07 | | **13.58** | | | 5.82 | | | | 27.63 | **33.45** | **2.27** | | **66.46** |
| **Commercial** | | | **3.47** | **0.53** | **4.00** | | **3.12** | **1.15** | **28.52** | **4.55** | **14.24** | | **51.58** | **4.83** | | **3.86** | | | **0.28** | **0.00** | **4.14** | **32.65** | | **97.21** |
| Transport Industry** | | | 0.08 | | **0.08** | | 1.56 | 0.82 | 26.60 | 4.23 | 13.55 | | 46.76 | 0.25 | | | | | | | | 2.53 | | **49.62** |
| Other Commercial | | | 3.39 | 0.53 | **3.92** | | 1.55 | 0.33 | 1.93 | 0.32 | 0.69 | | 4.82 | 4.58 | | 3.86 | | | 0.28 | | **4.14** | 30.12 | | **47.59** |
| **Residential** | | | **0.25** | **0.30** | **0.55** | | **2.70** | **0.00** | **0.00** | **0.00** | **0.00** | | **2.71** | **5.61** | | **0.10** | **0.30** | | | **7.80** | **8.20** | **46.69** | | **63.76** |
| **Unallocated**** | | | | | | | | **110.04** | **60.89** | **0.00** | **0.02** | | **170.94** | | | | | | | | | | | **170.94** |
| **CONSUMER ENERGY (observed)** | | | **18.64** | **4.52** | **23.16** | **0.00** | **8.74** | **113.86** | **110.84** | **7.71** | **14.63** | **0.00** | **255.77** | **43.03** | **0.00** | **9.78** | **0.30** | **0.00** | **0.28** | **35.43** | **45.80** | **140.46** | **0.00** | **508.21** |
| Statistical Differences | | | 1.59 | -0.39 | **1.20** | | 0.00 | 0.04 | 0.75 | 3.76 | -2.06 | 0.00 | **4.33** | **2.08** | | 0.00 | 0.00 | | 0.00 | 0.00 | **0.00** | **1.14** | 0.00 | **8.75** |

# 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. See **http://www.stats.govt.nz/datasets/primary-production/agriculture-production.htm** for information about surveys and census before 2006 and **http://www.stats.govt.nz/products-and-services/hot-off-the-press/agricultural-production/agricultural-production-statistics-final-jun07-hotp.htm** for information about the 2007 census.

#### Agricultural production surveys

The target population for the 2007 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 2007. The response rate was 87 per cent. These businesses represent 89 per cent of the total estimated value of agricultural output. Statistics New Zealand imputes using a random "hot deck" procedure for values for farmers and growers who did not return a completed questionnaire. The imputation levels for the 2007 Agricultural Production Census are given in Table A3.1.1.

The 2007 Agricultural Production Census was not subject to sampling error. Sampling error arises from selecting a sample of businesses and weighting the results, rather than taking a complete enumeration, and is not applicable when there is a census. Non-sampling error arises from biases in the patterns of response and non-response, inaccuracies in reporting by respondents, and errors in the recording and classification of data. Statistics NZ adopts procedures to detect and minimise these types of errors, but they may still occur and are not easy to quantify.

**Table A3.1.1 Imputation levels for the 2007 Agricultural Production Census**

| Statistic | Percentage of total estimate imputed |
|---|---|
| Ewe hoggets put to ram | 11 |
| Breeding ewes, 2 tooth and over | 12 |
| Total number of sheep | 12 |
| Lamb born to ewe hoggets | 11 |
| Lambs born to ewes | 11 |
| Beef cows and heifers (in calf) 2 years and over | 11 |
| Beef cows and heifers (in calf) 1–2 years | 11 |
| Total number of beef cattle | 11 |
| Calves born alive to beef heifers/cows | 11 |
| Dairy cows and heifers, in milk or calf | 16 |
| Total number of dairy cattle | 15 |
| Calves born alive to dairy heifers/cows | 11 |
| Female deer mated | 10 |
| Total number of deer | 10 |
| Fawns born on farm and alive at 4 months | 10 |
| Area of potatoes harvested | 9 |
| Area of wheat harvested | 11 |
| Area of barley harvested | 12 |

## 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) | 0.3 |
| $Frac_{BURNL}$ | 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 $N_2O$

| Emission factor | Emissions | Source | |
|---|---|---|---|
| $EF_1$ | Direct emissions from nitrogen input to soil | Kelliher and de Klein (2006) | 0.01 kg $N_2O$-N/kg N |
| $EF_2$ | Direct emissions from organic soil mineralisation due to cultivation | IPCC (2000) Table 4.17 | 8 kg $N_2O$-N/ha-yr |
| $EF_{3AL}$ | Direct emissions from waste in the anaerobic lagoons AWMS | IPCC (2000) Table 4.12 | 0.001 kg $N_2O$-N/kg N excreted |
| $EF_{3SSD}$ | Direct emissions from waste in the solid waste and drylot AWMS | IPCC (2000) Table 4.12 | 0.02 kg $N_2O$-N/kg N excreted |
| $EF_{3PRP}$ | 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 kg $N_2O$-N/kg N excreted |
| $EF_{3OTHER}$ | Direct emissions from waste in other AWMSs | IPCC (2000) Table 4. 13 | 0.005 kg $N_2O$-N/kg N excreted |
| $EF_4$ | Indirect emissions from volatising nitrogen | IPCC (2000) Table 4.18 | 0.01 kg $N_2O$-N/kg $NH_x$-N |
| $EF_5$ | Indirect emissions from leaching nitrogen | IPCC (2000) Table 4.18 | 0.025 kg $N_2O$-N/kg N leached & runoff |

### 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 | 9 kg/head/yr |
| $EF_{HORSES}$ | Enteric fermentation – Horses | IPCC (1996) Table 4.3 | 18 kg/head/yr |
| $EF_{SWINE}$ | Enteric fermentation – Swine | IPCC (1996) Table 4.3 | 1.5 kg/head/yr |
| $MM_{GOATS}$ | Manure management – Goats | IPCC (1996) Table 4.5 | 0.18 kg/head/yr |
| $MM_{HORSES}$ | Manure management – Horses | IPCC (1996) Table 4.5 | 2.1 kg/head/yr |
| $MM_{SWINE}$ | Manure management – Swine | IPCC (1996) Table 4.6 | 20 kg/head/yr |
| $MM_{POULTRY}$ | Manure management – Poultry | IPCC (1996) Table 4.5 | 0.117 kg/head/yr |

# A3.2 Supplementary 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) programme is to develop a robust and comprehensive data gathering, data management, analysis and reporting system that is consistent with IPCC good practice guidance for Land Use, Land-use Change and Forestry (GPG-LULUCF) 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, soil 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 Kyoto carbon pools. The data collection methodologies and the data analysis approach are being independently reviewed to provide transparency and published in the international scientific literature to ensure the activities within the LUCAS programme are widely understood.

### Natural forests

Natural forest permanent inventory plots have been established on a systematic eight-kilometre grid across New Zealand. Collection of the data from these plots occurred over a five-year period and was completed in early 2007. The subsequent results will determine the carbon-status of these managed forests. Currently, quality assurance and checking is on schedule to be completed by July 2009. Required re-measurement work is underway.

### Planted forests

A planted forest carbon inventory and New Zealand-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 species in New Zealand are exotic, primarily *Pinus radiata*.

#### *Forests planted after the 31 December 1989*

Change in carbon stocks in forests planted after 31 December 1989 (called "post-1989 planted forests") will be determined by measurement of trees within permanent inventory plots established on a four-kilometre grid across New Zealand. A combination of field measurements and airborne LiDAR (Light Detection and Ranging) are being used. The

field measurement programme was completed at the end of 2008. LiDAR data capture occurred during February–June 2008. The LiDAR data has yet to 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 forest planting covers a point on the four-kilometre grid, new plots will be established. The 2008 LiDAR mapping is already completed, while the quality assurance and checking is due to be completed by April, 2009.

### *Forests planted before 1 January 1990*

The LUCAS programme will also establish the change in carbon stocks in New Zealand's forests planted before 1 January 1990 – these are called pre-1990 planted forests. The post-1989 planted forest approach will be applied, but it is expected that the measurement plots will be on a coarser grid network (on an eight-kilometre grid intersects). It is planned that plot measurements will only be made in the middle of the commitment period, and will be used to forward- and back-cast carbon values to cover the five-year commitment period. Data analysis is scheduled for 2010.

## Soils

Soil carbon changes very slowly in response to land-use changes. A New Zealand-specific soil carbon model is being used. Soil data for input to the model either exists from previous soil mapping programmes across New Zealand, has been collected under the natural forests work stream, or has been collected through a number of related research programmes and a specific soil sampling programme. Collation of this data and initial analysis was completed at the end of 2008. This data will allow estimates of soil carbon change where land-use changes occur. The key drivers of change are: soil type, climate, topography, and the nature of land-use change. 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. The quality assurance/quality checking of soil carbon changes is due to be completed by July 2009. The remaining soil deliverables are being prioritised.

## 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
- determine 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 99 per cent completed and is scheduled to be concluded in April 2009. 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 is due to be delivered by August 2009. Currently, four of 16 New Zealand regions have been mapped. Mapping of land use at 2008 will use cloud-free, SPOT-5 satellite imagery. This imagery has being captured over the 2006/07 and 2007/08 summers (November to March).

The LUCAS programme will be using 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. As the MODIS is not high enough to map deforestation at one hectare, the actual area of harvesting and deforestation will be determined from high resolution satellite systems or aerial photography. MODIS data will also be used to update forest changes in the 2008 land-use map, particularly those changes that occurred immediately prior to 1 January 2008.

The forest area estimates will be available for use by the New Zealand's Emissions Trading Scheme (ETS). The ETS is the price-based mechanism established to reduce net greenhouse gas emissions below business-as-usual levels, and to comply with international obligations, including our Kyoto Protocol obligations. The forestry sector was the first sector to enter the ETS – effective 1 January 2008. It is expected that LUCAS-derived, forest area estimates will be used to verify applications to the Forestry ETS and to establish whether deforestation is being satisfactorily reported by forest-land owners.

### Database system

A component of the LUCAS programme is the development of a database to store and manipulate all data. The modular database system will achieve the following objectives:

- provide a transparent system for data and calculations
- provide a 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 common reporting format reports for the LULUCF sector and reporting under Article 3.3 of the Kyoto Protocol.

The calculation and reporting application is under development.

## 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 has being developed for the LUCAS project. This is being implemented across all LUCAS activities. It is consistent with New Zealand's greenhouse gas inventory QAQC plan and with IPCC good practice guidance (IPCC, 2000 and 2003).

# Annex 4: Carbon dioxide reference approach and comparison with sectoral approach, and relevant information on the national energy balance

Information on the $CO_2$ reference approach and a comparison with sectoral approach is provided in section 3.4.1. A table of the national energy balance for the 2007 calendar year is provided in Annex 2.

# Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

An assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in section 1.8.

# Annex 6: 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 MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/).

# 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 Climate Change Convention inventory guidelines (UNFCCC, 2006) and IPCC good practice guidance (IPCC, 2000 and 2003). Uncertainties in the categories are combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. LULUCF categories have been included using the absolute value of any removals of $CO_2$ (Table A7.1). Table A7.2 calculates the uncertainty only in emissions 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 the emission or the removal factor uncertainty and zero in the activity data uncertainty
- if uncertainty is not correlated across years, the uncertainty is entered as the uncertainty in the activity data and as zero in the emission or the removal factor uncertainty.

In the Tier 1 method, uncertainties in the trend are estimated using two sensitivities:

- Type A sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and a greenhouse gas in both the base year and the current year.
- Type B sensitivity is the change in the difference of total emissions between the base year and the current year, expressed as a percentage. Further, this change results from a 1 per cent increase in emissions of a given source category and gas in the current year only.

Uncertainties that are fully correlated between years are associated with Type A sensitivities, and uncertainties that are not correlated between years are associated with Type B sensitivities.

In Tables A7.1 and A7.2, the figure labelled "Uncertainty in the trend" is an estimate of the total uncertainty in the trend in emissions since the base year. This is expressed as the number of percentage points in the 95 per cent confidence interval in the per cent change in emissions since the base year ie, "since 1990, gross emissions have gone up by 23 per cent ±5.5 per cent". The total uncertainty in the trend is calculated by combining the contribution of emissions factor uncertainty and activity data uncertainty to the trend across all categories using equation 3.1 (IPCC, 2006).

The values for individual categories are an estimate of the uncertainty introduced into the trend by the category in question.

**Table A7.1 The uncertainty calculation (including LULUCF removals) for *New Zealand's Greenhouse Gas Inventory 1990–2007* (IPCC Tier 1)**

| IPCC source category | Gas | Base year emissions or absolute value of removals | Year t emissions or absolute value of removals | Activity data uncertainty | Emission or removal factor uncertainty | Combined uncertainty | Combined uncertainty as a per cent of the national total in year t | Type A sensitivity | Type B sensitvity | Uncertainty in the trend in national total introduced by emission or removal factor uncertainty | Uncertainty in trend in national total introduced by activity data uncertainty | Uncertainty introduced into the trend in the national total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy sector | $CO_2$ | 22,593.0 | 31,559.9 | 5 | 0 | 5.0 | 1.6 | 0.0426 | 0.3861 | 0.0000 | 2.7301 | 2.7 |
| Industrial processes sector | $CO_2$ | 2,731.6 | 3,670.6 | 5 | 0 | 5.0 | 0.2 | 0.0034 | 0.0449 | 0.0000 | 0.3175 | 0.3 |
| LULUCF sector - forest land | $CO_2$ | 18,673.8 | 24,565.2 | 5 | 25 | 25.5 | 6.2 | 0.0167 | 0.3005 | 0.4171 | 2.1250 | 2.2 |
| LULUCF sector other land use categories | $CO_2$ | 1,160.3 | 1,353.7 | 15 | 184 | 184.6 | 2.5 | -0.0011 | 0.0166 | -0.1976 | 0.3513 | 0.4 |
| CRF6C - waste incineration | $CO_2$ | 12.9 | 0.9 | 10 | 40 | 41.2 | 0.0 | -0.0002 | 0.0000 | -0.0074 | 0.0002 | 0.0 |
| Energy sector | $CH_4$ | 716.4 | 831.9 | 5 | 50 | 50.2 | 0.4 | -0.0007 | 0.0102 | -0.0355 | 0.0720 | 0.1 |
| CRF2A - mineral products | $CH_4$ | 0.0 | 0.0 | | | | | | | | | |
| CRF2B - chemical industry | $CH_4$ | 20.2 | 18.3 | 0 | 80 | 80.0 | 0.0 | -0.0001 | 0.0002 | -0.0066 | 0.0000 | 0.0 |
| CRF4A - enteric fermentation | $CH_4$ | 21,819.0 | 23,326.4 | 2 | 53 | 53.0 | 12.2 | -0.0461 | 0.2854 | -2.4438 | 0.8071 | 2.6 |
| CRF4B - manure management | $CH_4$ | 578.7 | 729.1 | 2 | 100 | 100.0 | 0.7 | 0.0001 | 0.0089 | 0.0125 | 0.0252 | 0.0 |
| CRF4E- prescribed burning | $CH_4$ | 2.7 | 0.9 | 20 | 60 | 63.2 | 0.0 | 0.0000 | 0.0000 | -0.0019 | 0.0003 | 0.0 |
| CRF4F - burning of residues | $CH_4$ | 21.4 | 13.2 | 50 | 40 | 64.0 | 0.0 | -0.0002 | 0.0002 | -0.0066 | 0.0114 | 0.0 |
| LULUCF sector | $CH_4$ | 49.9 | 62.1 | 10 | 35 | 36.4 | 0.0 | 0.0000 | 0.0008 | 0.0001 | 0.0107 | 0.0 |
| CRF 6A - solid waste disposal | $CH_4$ | 2,063.2 | 1,438.0 | 0 | 20 | 20.0 | 0.3 | -0.0138 | 0.0176 | -0.2752 | 0.0000 | 0.3 |
| CRF 6B - wastewater handling | $CH_4$ | 207.0 | 202.5 | 0 | 20 | 20.0 | 0.0 | -0.0007 | 0.0025 | -0.0134 | 0.0000 | 0.0 |
| CRF6C - waste incineration | $CH_4$ | 0.0 | 0.0 | 10 | 100 | 100.5 | 0.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0 |
| Energy sector | $N_2O$ | 143.4 | 261.3 | 5 | 50 | 50.2 | 0.1 | 0.0010 | 0.0032 | 0.0509 | 0.0226 | 0.1 |
| Solvents - $N_2O$ use | $N_2O$ | 41.5 | 43.4 | 10 | 0 | 10.0 | 0.0 | -0.0001 | 0.0005 | 0.0000 | 0.0075 | 0.0 |
| CRF4D - agricultural soils | $N_2O$ | 10,043.4 | 12,298.1 | 5 | 73 | 73.2 | 8.9 | -0.0022 | 0.1504 | -0.1595 | 1.0638 | 1.1 |
| CRF4B - manure management | $N_2O$ | 38.0 | 58.0 | 5 | 100 | 100.1 | 0.1 | 0.0001 | 0.0007 | 0.0131 | 0.0050 | 0.0 |
| CRF4E - prescribed burning | $N_2O$ | 0.5 | 0.2 | 20 | 60 | 63.2 | 0.0 | 0.0000 | 0.0000 | -0.0003 | 0.0001 | 0.0 |
| CRF4F - burning of residues | $N_2O$ | 7.4 | 4.3 | 50 | 40 | 64.0 | 0.0 | -0.0001 | 0.0001 | -0.0024 | 0.0037 | 0.0 |
| LULUCF sector | $N_2O$ | 5.7 | 17.0 | 10 | 35 | 36.4 | 0.0 | 0.0001 | 0.0002 | 0.0043 | 0.0029 | 0.0 |
| CRF6B - wastewater handling | $N_2O$ | 153.5 | 179.2 | 0 | 1200 | 1200.0 | 2.1 | -0.0001 | 0.0022 | -0.1683 | 0.0000 | 0.2 |
| CRF6C - waste incineration | $N_2O$ | 1.6 | 1.2 | 10 | 100 | 100.5 | 0.0 | 0.0000 | 0.0000 | -0.0010 | 0.0002 | 0.0 |
| CRF2F | HFCs | 0.0 | 856.6 | 24 | 0 | 24.0 | 0.2 | 0.0105 | 0.0105 | 0.0000 | 0.3557 | 0.4 |
| CRF2C | PFCs | 642.2 | 41.7 | 0 | 30 | 30.0 | 0.0 | -0.0092 | 0.0005 | -0.2775 | 0.0000 | 0.3 |
| CRF2F | $SF_6$ | 15.2 | 14.7 | 5 | 20 | 20.6 | 0.0 | -0.0001 | 0.0002 | -0.0010 | 0.0013 | 0.0 |
| **Total emissions/removals** | | **81,742.5** | **101,548.2** | | **Uncertainty in the year** | | **16.7%** | | **Uncertainty in the trend** | | | **4.5%** |

**Table A7.2 The uncertainty calculation (excluding LULUCF removals) for *New Zealand's Greenhouse Gas Inventory 1990–2007* (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 | $CO_2$ | 22,593.0 | 31,559.9 | 5 | 0 | 5 | 2.1 | 0.0637 | 0.5098 | 0.0000 | 3.6047 | 3.6 |
| Industrial processes sector | $CO_2$ | 2,731.6 | 3,670.6 | 5 | 0 | 5 | 0.2 | 0.0054 | 0.0593 | 0.0000 | 0.4193 | 0.4 |
| CRF6C - waste incineration | $CO_2$ | 12.9 | 0.9 | 10 | 40 | 41 | 0.0 | -0.0002 | 0.0000 | -0.0096 | 0.0002 | 0.0 |
| Energy sector | $CH_4$ | 716.4 | 831.9 | 5 | 50 | 50 | 0.6 | -0.0007 | 0.0134 | -0.0350 | 0.0950 | 0.1 |
| CRF2A - mineral products | $CH_4$ | 0.0 | 0.0 | | | | | | | | | |
| CRF2B - chemical industry | $CH_4$ | 20.2 | 18.3 | 0 | 80 | 80 | 0.0 | -0.0001 | 0.0003 | -0.0082 | 0.0000 | 0.0 |
| CRF4A - enteric fermentation | $CH_4$ | 21,819.0 | 23,326.4 | 2 | 53 | 53 | 16.4 | -0.0536 | 0.3768 | -2.8394 | 1.0657 | 3.0 |
| CRF4B - manure management | $CH_4$ | 578.7 | 729.1 | 2 | 100 | 100 | 1.0 | 0.0004 | 0.0118 | 0.0358 | 0.0333 | 0.0 |
| CRF4E - prescribed burning | $CH_4$ | 2.7 | 0.9 | 20 | 60 | 63 | 0.0 | 0.0000 | 0.0000 | -0.0024 | 0.0004 | 0.0 |
| CRF4F - burning of residues | $CH_4$ | 21.4 | 13.2 | 50 | 40 | 64 | 0.0 | -0.0002 | 0.0002 | -0.0084 | 0.0150 | 0.0 |
| LULUCF sector | $CH_4$ | 49.9 | 62.1 | 10 | 35 | 36 | 0.0 | 0.0000 | 0.0010 | 0.0007 | 0.0142 | 0.0 |
| CRF 6A - solid waste disposal | $CH_4$ | 2,063.2 | 1,438.0 | 0 | 20 | 20 | 0.4 | -0.0175 | 0.0232 | -0.3496 | 0.0000 | 0.3 |
| CRF 6B - wastewater handling | $CH_4$ | 207.0 | 202.5 | 0 | 20 | 20 | 0.1 | -0.0008 | 0.0033 | -0.0163 | 0.0000 | 0.0 |
| CRF6C - waste incineration | $CH_4$ | 0.0 | 0.0 | 10 | 100 | 100 | 0.0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0 |
| Energy sector | $N_2O$ | 143.4 | 261.3 | 5 | 50 | 50 | 0.2 | 0.0014 | 0.0042 | 0.0695 | 0.0298 | 0.1 |
| Solvents - $N_2O$ use | $N_2O$ | 41.5 | 43.4 | 10 | 0 | 10 | 0.0 | -0.0001 | 0.0007 | 0.0000 | 0.0099 | 0.0 |
| CRF4D - agricultural soils | $N_2O$ | 10,043.4 | 12,298.1 | 5 | 73 | 73 | 11.9 | 0.0005 | 0.1986 | 0.0338 | 1.4047 | 1.4 |
| CRF4B - manure management | $N_2O$ | 38.0 | 58.0 | 5 | 100 | 100 | 0.1 | 0.0002 | 0.0009 | 0.0185 | 0.0066 | 0.0 |
| CRF4E- prescribed burning | $N_2O$ | 0.5 | 0.2 | 20 | 60 | 63 | 0.0 | 0.0000 | 0.0000 | -0.0004 | 0.0001 | 0.0 |
| CRF4F - burning of residues | $N_2O$ | 7.4 | 4.3 | 50 | 40 | 64 | 0.0 | -0.0001 | 0.0001 | -0.0030 | 0.0049 | 0.0 |
| LULUCF sector | $N_2O$ | 5.7 | 17.0 | 10 | 35 | 36 | 0.0 | 0.0002 | 0.0003 | 0.0057 | 0.0039 | 0.0 |
| CRF6B - wastewater handling | $N_2O$ | 153.5 | 179.2 | 0 | 1200 | 1200 | 2.8 | -0.0001 | 0.0029 | -0.1607 | 0.0000 | 0.2 |
| CRF6C - waste incineration | $N_2O$ | 1.6 | 1.2 | 10 | 100 | 100 | 0.0 | 0.0000 | 0.0000 | -0.0012 | 0.0003 | 0.0 |
| CRF2F | HFCs | 0.0 | 856.6 | 120 | 50 | 130 | 1.5 | 0.0138 | 0.0138 | 0.6919 | 2.3482 | 2.4 |
| CRF2C | PFCs | 642.2 | 41.7 | 0 | 30 | 30 | 0.0 | -0.0120 | 0.0007 | -0.3600 | 0.0000 | 0.4 |
| CRF2F | $SF_6$ | 15.2 | 14.7 | 5 | 20 | 21 | 0.0 | -0.0001 | 0.0002 | -0.0013 | 0.0017 | 0.0 |
| **Total emissions/removals** | | **61,908.4** | **75,629.3** | | **Uncertainty in the year** | | **20.6%** | | **Uncertainty in the trend** | | | **5.5%** |

# Annex 8: Supplementary information under Article 7.1 of the Kyoto Protocol

This Annex includes the supplementary information required for the first commitment period of the Kyoto Protocol. This includes information on changes made to the national system, the New Zealand Emission Units Register (New Zealand's national registry) and additional information under Articles 3.3, 3.4 and 3.14 of the Kyoto Protocol.

## A8.1 National system

The major change in the national system since the 2008 inventory submission (Table 10.5.4) has been the shift in responsibility for compilation of the agriculture sector. The Ministry of Agriculture and Forestry has taken over this responsibility from the Ministry for the Environment. For details of recent changes to New Zealand's national system refer to the national system table provided in the MS Excel worksheets available for download with this inventory submission from the Ministry for the Environment's website.

## A8.2 New Zealand's national registry

Changes made to New Zealand's national registry in response to the *Standard Independent Assessment Report for New Zealand's National Registry for the reporting period January 2008–December 2008,* are provided in Table A8.2.1. The information for the administrator of New Zealand's national registry has changed since the 2008 inventory submission. Updated details, as supplied to the ITL administrator by New Zealand's national focal point on 17 December 2008, are detailed in Table A8.2.2. New Zealand's response to the expert review team's recommendations (UNFCCC, 2007) is included in Table A8.2.3. Publicly accessible information on New Zealand's national registry is included in Table A8.2.4.

### A8.2.1 Assigned amount and commitment period reserve

New Zealand's national registry holds New Zealand's assigned amount of 309,564,733 metric tonnes of carbon dioxide equivalent ($CO_2$-e).

The commitment period reserve of 278,608,260 metric tonnes ($CO_2$-e) is 90 per cent of the assigned amount, fixed after the initial review in 2007.

### A8.2.2 Holdings and transactions of Kyoto Protocol units

Please refer to the standard reporting format tables below (Tables A8.1–6). These tables are also provided in the MS Excel worksheets available for download with this report from the Ministry for the Environment's website (http://www.mfe.govt.nz/publications/climate/).

## Tables A8.1.2 Copies of the standard report format tables (ie Tables 1–6) from New Zealand national registry

| | |
|---|---|
| Party | New Zealand |
| Submission year | 2009 |
| Reported year | 2008 |
| Commitment period | 1 |

### Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

| Account type | Unit type | | | | | |
|---|---|---|---|---|---|---|
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| Party holding accounts | 309564733 | NO | NO | NO | NO | NO |
| Entity holding accounts | NO | NO | NO | NO | NO | NO |
| Article 3.3/3.4 net source cancellation accounts | NO | NO | NO | NO | | |
| Non-compliance cancellation accounts | NO | NO | NO | NO | | |
| Other cancellation accounts | NO | NO | NO | NO | NO | NO |
| Retirement account | NO | NO | NO | NO | NO | NO |
| tCER replacement account for expiry | NO | NO | NO | NO | NO | |
| lCER replacement account for expiry | NO | NO | NO | NO | | |
| lCER replacement account for reversal of storage | NO | NO | NO | NO | | NO |
| lCER replacement account for non-submission of certification report | NO | NO | NO | NO | | NO |
| **Total** | 309564733 | NO | NO | NO | NO | NO |

| | |
|---|---|
| Party | New Zealand |
| Submission year | 2009 |
| Reported year | 2008 |
| Commitment period | 1 |

**Table 2 (a). Annual internal transactions**

| Transaction type | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Article 6 issuance and conversion** | | | | | | | | | | | | |
| Party-verified projects | | 120000 | | | | | 120000 | | NO | | | |
| Independently verifed projects | | NO | | | | | NO | | NO | | | |
| **Article 3.3 and 3.4 issuance or cancellation** | | | | | | | | | | | | |
| 3.3 Afforestation and reforestation | | | NO | | | | NO | NO | NO | NO | | |
| 3.3 Deforestation | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Forest management | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Cropland management | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Grazing land management | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Revegetation | | | NO | | | | NO | NO | NO | NO | | |
| **Article 12 afforestation and reforestation** | | | | | | | | | | | | |
| Replacement of expired tCERs | | | | | | | NO | NO | NO | NO | NO | |
| Replacement of expired lCERs | | | | | | | NO | NO | NO | NO | | |
| Replacement for reversal of storage | | | | | | | NO | NO | NO | NO | | NO |
| Replacement for non-submission of certification report | | | | | | | NO | NO | NO | NO | | NO |
| **Other cancellation** | | | | | | | NO | NO | NO | 800 | NO | NO |
| **Sub-total** | | 120000 | NO | | | | 120000 | NO | NO | 800 | NO | NO |

| Transaction type | Retirement | | | | | |
|---|---|---|---|---|---|---|
| | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Retirement** | NO | NO | NO | NO | NO | NO |

| | |
|---|---|
| Party | New Zealand |
| Submission year | 2009 |
| Reported year | 2008 |
| Commitment period | 1 |

**Table 2 (b). Annual external transactions**

| | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Transfers and acquisitions** | | | | | | | | | | | | |
| CH | NO | NO | NO | 25020 | NO | NO | NO | NO | NO | NO | NO | NO |
| GB | NO | NO | NO | NO | NO | NO | NO | NO | NO | 15000 | NO | NO |
| JP | NO | NO | NO | 88 | NO | NO | NO | NO | NO | NO | NO | NO |
| **Sub-total** | NO | NO | NO | 25108 | NO | NO | NO | NO | NO | 15000 | NO | NO |

**Additional information**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Independently verified ERUs | | | | | | | | NO | | | | |

**Table 2 (c). Total annual transactions**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total (Sum of tables 2a and 2b)** | NO | 120000 | NO | 25108 | NO | NO | 120000 | NO | NO | 15800 | NO | NO |

| | |
|---|---|
| Party | New Zealand |
| Submission year | 2009 |
| Reported year | 2008 |
| Commitment period | 1 |

**Table 3. Expiry, cancellation and replacement**

| Transaction or event type | Expiry, cancellation and requirement to replace | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unit type | | Unit type | | | | | |
| | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Temporary CERs (tCERS)** | | | | | | | | |
| Expired in retirement and replacement accounts | NO | | | | | | | |
| Replacement of expired tCERs | | | NO | NO | NO | NO | NO | |
| Expired in holding accounts | NO | | | | | | | |
| Cancellation of tCERs expired in holding accounts | NO | | | | | | | |
| **Long-term CERs (lCERs)** | | | | | | | | |
| Expired in retirement and replacement accounts | | NO | | | | | | |
| Replacement of expired lCERs | | | NO | NO | NO | NO | | |
| Expired in holding accounts | | NO | | | | | | |
| Cancellation of lCERs expired in holding accounts | | NO | | | | | | |
| Subject to replacement for reversal of storage | | NO | | | | | | |
| Replacement for reversal of storage | | | NO | NO | NO | NO | | NO |
| Subject to replacement for non-submission of certification report | | NO | | | | | | |
| Replacement for non-submission of certification report | | | NO | NO | NO | NO | | NO |
| **Total** | | | NO | NO | NO | NO | NO | NO |

| | |
|---|---|
| Party | New Zealand |
| Submission year | 2009 |
| Reported year | 2008 |
| Commitment period | 1 |

**Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year**

| Account type | Unit type | | | | | |
|---|---|---|---|---|---|---|
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| Party holding accounts | 309420003 | NO | NO | NO | NO | NO |
| Entity holding accounts | 24730 | 120000 | NO | 9308 | NO | NO |
| Article 3.3/3.4 net source cancellation accounts | NO | NO | NO | NO | | |
| Non-compliance cancellation accounts | NO | NO | NO | NO | | |
| Other cancellation accounts | NO | NO | NO | 800 | NO | NO |
| Retirement account | NO | NO | NO | NO | NO | NO |
| tCER replacement account for expiry | NO | NO | NO | NO | NO | |
| lCER replacement account for expiry | NO | NO | NO | NO | | |
| lCER replacement account for reversal of storage | NO | NO | NO | NO | | NO |
| lCER replacement account for non-submission of certification report | NO | NO | NO | NO | | NO |
| **Total** | 309444733 | 120000 | NO | 10108 | NO | NO |

| | |
|---|---|
| Party | New Zealand |
| Submission year | 2009 |
| Reported year | 2008 |
| Commitment period | 1 |

**Table 5 (a). Summary information on additions and subtractions**

| | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| **Starting values** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** |
| Issuance pursuant to Article 3.7 and 3.8 | 309564733 | | | | | | | | | | | |
| Non-compliance cancellation | | | | | | | NO | NO | NO | NO | | |
| Carry-over | NO | NO | | NO | | | | | | | | |
| **Sub-total** | 309564733 | NO | | NO | | | NO | NO | NO | NO | | |
| **Annual transactions** | | | | | | | | | | | | |
| Year 0 (2007) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 1 (2008) | NO | 120000 | NO | 25108 | NO | NO | 120000 | NO | NO | 15800 | NO | NO |
| Year 2 (2009) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 3 (2010) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 4 (2011) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 5 (2012) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 6 (2013) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 7 (2014) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 8 (2015) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **Sub-total** | NO | 120000 | NO | 25108 | NO | NO | 120000 | NO | NO | 15800 | NO | NO |
| **Total** | 309564733 | 120000 | NO | 25108 | NO | NO | 120000 | NO | NO | 15800 | NO | NO |

**Table 5 (b). Summary information on replacement**

| | Requirement for replacement | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unit type | | Unit type | | | | | |
| | **tCERs** | **lCERs** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** |
| **Previous CPs** | | | NO | NO | NO | NO | NO | NO |
| Year 1 (2008) | | NO | NO | NO | NO | NO | NO | NO |
| Year 2 (2009) | | NO | NO | NO | NO | NO | NO | NO |
| Year 3 (2010) | | NO | NO | NO | NO | NO | NO | NO |
| Year 4 (2011) | | NO | NO | NO | NO | NO | NO | NO |
| Year 5 (2012) | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 6 (2013) | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 7 (2014) | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 8 (2015) | NO | NO | NO | NO | NO | NO | NO | NO |
| **Total** | NO | NO | NO | NO | NO | NO | NO | NO |

**Table 5 (c). Summary information on retirement**

| | Retirement | | | | | |
|---|---|---|---|---|---|---|
| | Unit type | | | | | |
| **Year** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** |
| Year 1 (2008) | NO | NO | NO | NO | NO | NO |
| Year 2 (2009) | NO | NO | NO | NO | NO | NO |
| Year 3 (2010) | NO | NO | NO | NO | NO | NO |
| Year 4 (2011) | NO | NO | NO | NO | NO | NO |
| Year 5 (2012) | NO | NO | NO | NO | NO | NO |
| Year 6 (2013) | NO | NO | NO | NO | NO | NO |
| Year 7 (2014) | NO | NO | NO | NO | NO | NO |
| Year 8 (2015) | NO | NO | NO | NO | NO | NO |
| **Total** | NO | NO | NO | NO | NO | NO |

| | |
|---|---|
| Party | New Zealand |
| Submission year | 2009 |
| Reported year | 2008 |
| Commitment period | 1 |

**Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions**

| | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| | | | | | | | | | | | | |

**Table 6 (b). Memo item: Corrective transactions relating to replacement**

| | Requirement for replacement | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unit type | | Unit type | | | | | |
| | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| | | | | | | | | |

**Table 6 (c). Memo item: Corrective transactions relating to retirement**

| | Retirement | | | | | |
|---|---|---|---|---|---|---|
| | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| | | | | | | |

**No problems found!**

### Table A8.2.1 Changes made to New Zealand's national registry

| Section subheading | New Zealand's response |
|---|---|
| 15/CMP.1 Annex I.E paragraph 11: Standard electronic format | Refer to standard electronic format attachment. |
| 15/CMP.1 Annex I.E paragraph 12: List of discrepant transactions | No discrepant transactions for the reporting period, pursuant to Decision 15/CMP.1 Annex I.E, paragraph 12. |
| 15/CMP.1 Annex I.E paragraph 13 & 14: List of clean development mechanism notifications | No clean development mechanism notifications were received by the New Zealand national registry during the reporting period. |
| 15/CMP.1 Annex I.E paragraph 15: List of non-replacements | No non-replacement clean development mechanism notifications were received by the New Zealand national registry during the reporting period. |
| 15/CMP.1 Annex I.E paragraph 16: List of invalid units | No invalid units ITL notifications were received by the New Zealand national registry during the reporting period. |
| 15/CMP.1 Annex I.E paragraph 17: Actions and changes to address discrepancies | No actions or changes were required to address discrepancies during the reporting period. |
| 15/CMP.1 Annex I.E paragraph 18: CPR calculation | CPR level as at 31 December 2008:<br>CPR limit: 278,608,260<br>Units held: 309,574,041<br>CPR level: 309,574,041<br><br>Opening units as at 1 January 2008 (AAUs) 309,564,733<br><br>Add units transferred from overseas registries (CERs) 25,108<br>Less units transferred to overseas registries (CERs) 15,000<br>Less units voluntarily cancelled (CERs) 800<br>Less AAUs (converted to ERUs) 120,000<br>Add ERUs (converted from AAUs) 120,000<br><br>Closing units as at 31 December 2008 309,574,041<br><br>CPR Level comprised of:<br>AAUs 309,444,733<br>ERUs (converted from AAUs) 120,000<br>CERs 9,308<br>309,574,041 |
| 15/CMP.1 Annex II.E paragraph 32.(a): Change in the name or contact for the national registry | Changes were made to the contact information for the administrator, main contact, alternative contact and release manager due to a change of office location in December 2008.<br>The National Focal Point advised the ITL administrator of these changes as per the RSA Replacement Form. |
| 15/CMP.1 Annex II.E paragraph 32.(b): Change in cooperation arrangement | No change was made to the cooperation arrangement for the reporting period. |
| 1/CMP.1 Annex II.E paragraph 32.(c): Change to the database or the capacity of the national registry | No change was made to the database or the capacity of New Zealand's national registry for the reporting period. |
| 15/CMP.1 Annex II.E paragraph 32.(d): Change in the conformance to technical standards | No change was made to the conformance to technical standards of New Zealand's national registry for the reporting period. |
| 15/CMP.1 Annex II.E paragraph 32.(e): Change in the discrepancy procedures | No change was made to the discrepancies procedures of New Zealand's national registry for the reporting period. |

| Section subheading | New Zealand's response |
|---|---|
| 15/CMP.1 Annex II.E paragraph 32.(f): Change in security | No change was made in security of New Zealand's national registry for the reporting period. |
| 15/CMP.1 Annex II.E paragraph 32.(g): Change in the list of publicly available information | Refer to the list of publicly available information. |
| 15/CMP.1 Annex II.E paragraph 32.(h): Change to the internet address | New Zealand's national registry's internet address is now www.eur.govt.nz. In the 2008 inventory submission, the internet address of the website was provided as www.nzeur.govt.nz. |
| 15/CMP.1 Annex II.E paragraph 32.(i) – Change to the data integrity measures | No change was made to the data integrity measures of New Zealand's national registry for the reporting period. |
| 15/CMP.1 Annex II.E paragraph 32.(j) – Change of the test results | No significant testing has been performed within New Zealand's national registry for the reporting period. |

### Table A8.2.2 Information for the administrator of New Zealand's national registry

| | |
|---|---|
| **Organisation designated as the administrator for New Zealand's national registry** | Name: Ministry of Economic Development<br>Postal address: PO Box 1473, 33 Bowen Street Wellington 6011, New Zealand<br>Phone number: +64 4 462 4289<br>Fax number: +64 4 978 3661<br>Web site address: www.med.govt.nz/ |
| **Contact person** | Name: Ms Shirley Flaherty<br>Position: Chief Advisor, Ministry of Economic Development<br>Postal address: PO Box 1473, 33 Bowen Street Wellington 6011, New Zealand<br>Phone number: +64 4 462 4289<br>Fax number: +64 4 978 3661<br>Email address: shirley.flaherty@med.govt.nz |
| **Alternative contact person** | Name: Ms Anita Dahya<br>Position: Project Manager, Ministry of Economic Development<br>Postal address: PO Box 1473, 33 Bowen Street Wellington 6011, New Zealand<br>Phone number: +64 4 474 2843<br>Fax number: +64 4 978 3661<br>Email address: anita.dahya@med.govt.nz |
| **Release Manager** | Name: Ms Anca Slusanschi<br>Position: Project Manager, Emissions Trading Registry Development, Ministry of Economic Development<br>Postal address: PO Box 1473, 33 Bowen Street Wellington 6011, New Zealand<br>Phone number: +64 4 474 2665<br>Fax number: +64 4 978 3661<br>Email address: anca.slusanschi@med.govt.nz |

### Table A8.2.3 Previous recommendations for New Zealand from the expert review team (UNFCCC, 2007)

| Previous annual review recommendations | New Zealand addressed the recommendation as follows |
|---|---|
| The expert review team recommended that New Zealand provide a more detailed description of the database structure and the capacity of New Zealand's national registry. | New Zealand's national registry uses Microsoft SQL server 2005 SP2 (including the relevant hot fixes) for the database. The database is comprised of one schema to store application or programme data (including all data pertaining to user transactions through the web) and also the data that manages the content of the web, the business rules and other backend processing data.<br><br>New Zealand's national registry has a complex system of metadata used to control aspects of the system configuration. This allows for the separation of the true system data (accounts, transactions, people, etc) from the system-descriptive data (configuration, display settings, help content, etc).<br><br>The infrastructure consists of a web server / SQL server pair in Production, Standby, DR and Test. Both the production site (WNI) and the DR / Test site (AKI) have VPN connectivity to the ITL in the United Kingdom.<br><br>The production environment consists of two servers; one hosting the web site (Internet Information Server 6.0) and the other hosting the SQL server database. The database data is located on a SAN attached disk. The DBA team manages the database and has set up log shipping to the Auckland DR servers. The log shipping is configured to dump and copy the transaction logs to Auckland every five minutes, with a complete copy of the database being sent to Auckland every evening.<br><br>The production servers have a local machine policy configured to get NTP time from a Wellington-based server. The web server has a 34GB (RAID 1+0) disk with 2GB RAM. The SQL Server has a C: drive of 34GB (RAID 1+0) and an E: drive SAN attached of 30GB.<br><br>There are two servers set up in a "warm standby" mode. The servers have images created from the two production servers, but have had their Host names and IP addresses changed, and are patched into the internal network. The web server has a 34GB (RAID 1+0) disk with 2GB RAM. The SQL Server has a C: drive of 34GB (RAID 1+0) and an E: drive SAN attached of 30GB. |
| The expert review team recommended that New Zealand provide a more detailed overview of how the security measures and procedures employed in New Zealand's national registry to prevent unauthorised manipulations and to prevent operator error are kept up to date. | The servers for New Zealand's national registry are physically located on secure floor space, where only authorised personnel have access. The server's electronic location is accessed through a Hypertext Transport Protocol Secure (HTTPS) over a Secure Sockets Layer (SSL) security protocol.<br><br>New Zealand's national registry application also contains:<br><br>• an audit log – triggered by every insert, update or deletion in any database table – that keeps a record of the entire database/application activity<br><br>• an event log – that tracks exchanges in a more detailed fashion than the audit log<br><br>• a transaction log – that contains information specific to each allowance trade or transfer made. |
| The expert review team recommended that New Zealand provide more detailed information on a list of information that is publicly accessible. | During the in-country review visit, the expert review team was provided with a list of information publicly accessible.<br><br>For completeness, refer to the attached List of Publicly Accessible Information in New Zealand's national registry. |

## Table A8.2.4 List of the publicly accessible information in New Zealand's national registry

| Type of information to be made public pursuant to part E of the Annex to 13/CMP.1, paragraph 44 to 48 | Publicly available on New Zealand's national registry website (yes/no) | Information availability under New Zealand's climate change legislation |
|---|---|---|
| 44. Each national registry shall make non-confidential information publicly available and provide a publicly accessible user interface through the Internet that allows interested persons to query and view it. | | |
| 45. The information referred to in paragraph 44 above shall include up-to-date information for each account number in that registry on the following: | | |
| (a) Account name: the holder of the account. | Yes | Up to date |
| (b) Account type: the type of account (holding, cancellation or retirement). | Yes | Up to date |
| (c) Commitment period: the commitment period with which a cancellation or retirement account is associated. | Yes | Up to date |
| (d) Representative identifier: the representative of the account holder, using the Party identifier (the two-letter country code defined by ISO 3166) and a number unique to that representative within the Party's registry. | Yes (this is known as the account number in New Zealand's national registry) | Up to date |
| (e) Representative name and contact information: the full name, mailing address, telephone number, facsimile number and email address of the representative of the account holder. | Yes | Up to date |
| 46. The information referred to in paragraph 44 shall include the following Article 6 project information, for each project identifier against which the Party has issued ERUs: | | |
| (a) Project name: a unique name for the project. | Yes | Up to date |
| (b) Project location: the Party and town or region in which the project is located. | Yes | Up to date |
| (c) Years of ERU issuance: the years when ERUs have been issued as a result of the Article 6 project. | Yes | Up to date |
| (d) Reports: downloadable electronic versions of all publicly available documentation relating to the project, including proposals, monitoring, verification and issuance of ERUs, where relevant, subject to the confidentiality provisions in decision 9/CMP.1. | This information is published on the JISC Interface website for JI Projects and is not replicated on the New Zealand's national registry website (www.eur.govt.nz)<br>Proposals are not included as this is considered to be confidential information | n/a |
| 47. The information referred to in paragraph 44 shall include the following holding and transaction information relevant to the national registry, by serial number, for each calendar year (defined according to Greenwich Mean Time): | | |
| (a) The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year. | Yes | Annually by 31 January for the beginning of the previous calendar year. |
| (b) The total quantity of AAUs issued on the basis of the assigned amount pursuant to Article 3, paragraphs 7 and 8. | Yes | Annually by 31 January for the previous calendar year. |
| (c) The total quantity of ERUs issued on the basis of Article 6 projects. | Yes | Annually by 31 January for the previous calendar year |

| Type of information to be made public pursuant to part E of the Annex to 13/CMP.1, paragraph 44 to 48 | Publicly available on New Zealand's national registry website (yes/no) | Information availability under New Zealand's climate change legislation |
|---|---|---|
| (d) The total quantity of ERUs, CERs, AAUs and RMUs acquired from other registries and the identity of the transferring accounts and registries. | Yes | Annually by 31 January for the previous calendar year |
| (e) The total quantity of RMUs issued on the basis of each activity under Article 3, paragraphs 3 and 4. | Yes | Annually by 31 January for the previous calendar year |
| (f) The total quantity of ERUs, CERs, AAUs and RMUs transferred to other registries and the identity of the acquiring accounts and registries. | Yes | Annually by 31 January for the previous calendar year |
| (g) The total quantity of ERUs, CERs, AAUs and RMUs cancelled on the basis of activities under Article 3, paragraphs 3 and 4. | Yes | Annually by 31 January for the previous calendar year |
| (h) The total quantity of ERUs, CERs, AAUs and RMUs cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1. | Yes | Annually by 31 January for the previous calendar year |
| (i) The total quantity of other ERUs, CERs, AAUs and RMUs cancelled. | Yes | Annually by 31 January for the previous calendar year |
| (j) The total quantity of ERUs, CERs, AAUs and RMUs retired. | Yes | Annually by 31 January for the previous calendar year |
| (k) The total quantity of ERUs, CERs, and AAUs carried over from the previous commitment period. | Yes | Annually by 31 January for the previous calendar year |
| (l) Current holdings of ERUs, CERs, AAUs and RMUs in each account. | No, annually by 31 January for the beginning of the previous calendar year.<br>Refer to paragraph 47(a) | N/A |
| 48. The information referred to in paragraph 44 shall include a list of legal entities authorised by the Party to hold ERUs, CERs, AAUs and/or RMUs under its responsibility. | Yes | Up to date |

# A8.3 Information on activities under Articles 3.3 and 3.4 of the Kyoto Protocol

Information on emissions and removals from activities under Article 3.3 will be reported in the 2010 inventory submission.

New Zealand has not elected any activities under Article 3.4.

# A8.4 Information on activities under Article 3.14 of the Kyoto Protocol

Information on how New Zealand is meeting its obligations under Article 3.14 will be reported in the 2010 inventory submission.