

# **New Zealand's Greenhouse Gas Inventory 1990–2004**

**The National Inventory Report and Common  
Reporting Format**

Updated for Kyoto Protocol Initial Report Requirements

August 2006

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# Acknowledgements

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# Executive Summary

This annual inventory of emissions and removals of greenhouse gases forms part of New Zealand's obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The inventory is also a key 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<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>) from six sectors: energy, industrial processes, solvents, agriculture, land use, land-use change and forestry and waste. The indirect greenhouse gases carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>), sulphur dioxide (SO<sub>2</sub>) and non-methane volatile organic compounds (NMVOC) are also included in the inventory. However, only emissions and removals of the direct greenhouse gases, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub> are reported in New Zealand's total emissions under the UNFCCC and are accounted for under the Kyoto Protocol.

Only human-induced emissions and removals of greenhouse gases are included. A complete time-series of emissions and removals from 1990 through to 2004 (the current inventory year) are reported.

## Climate change and the international response

Greenhouse gases trap the warmth from the sun and make life on Earth possible. However, over the previous 50 to 100 years, the concentration of the greenhouse gases carbon dioxide, methane and nitrous oxide in the atmosphere have been increasing. The increased concentration produces an 'enhanced greenhouse effect' that causes the atmosphere to trap more heat and the climate to change. The climate changes ahead of us are expected to be much larger and happen more quickly than any recent natural changes.

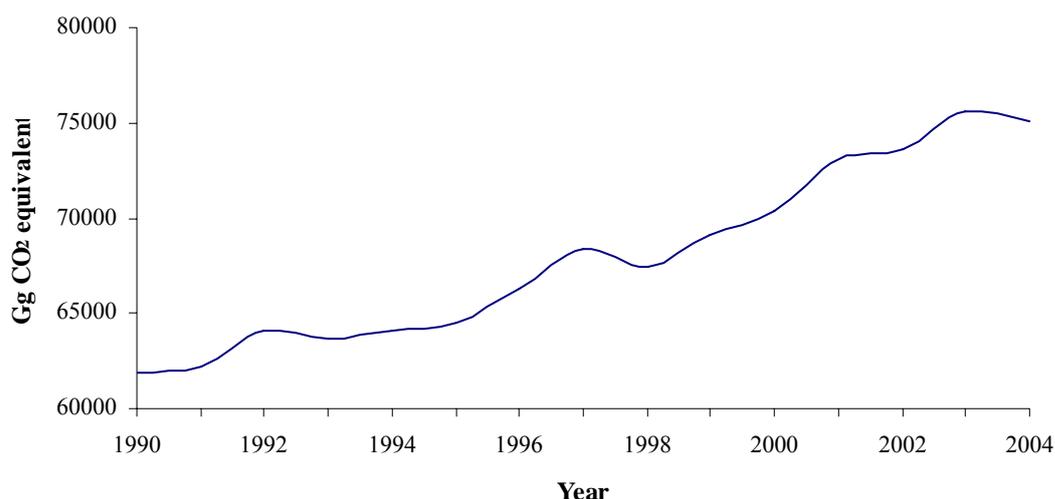
The long-term objective of the United Nations Framework Convention on Climate Change is to "stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". All countries that ratify the UNFCCC are required to address climate change through national or regional programmes, preparing for adaptation to the impacts of climate change and monitoring emissions trends via greenhouse gas inventories. Developed countries agreed to non-binding targets to reduce greenhouse gas emissions to 1990 levels by the year 2000.

Only a few countries made appreciable progress towards achieving their targets. The international community recognised that the UNFCCC alone was not enough to ensure greenhouse gas levels would be reduced to safe levels, and that more urgent action was needed. In 1997 the Kyoto Protocol was adopted. The Kyoto Protocol commits Annex I Parties that ratify the Protocol to individual, legally-binding targets to limit or reduce their greenhouse gas emissions. New Zealand ratified the Kyoto Protocol on 19 December 2002 with a target of 100 percent of the level of emissions in 1990. The Protocol came into force on 16 February 2005.

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

In 1990, New Zealand's total greenhouse gas emissions were equivalent to 61,893.00 Gg of CO<sub>2</sub>. In 2004, total greenhouse gas emissions were 75,088.19 Gg CO<sub>2</sub> equivalent equating to a 13,195.19 Gg (21.3 percent) rise since 1990 (Figure 1.1). Net removals of CO<sub>2</sub> through forest sinks increased from 18,977.92 Gg CO<sub>2</sub> in 1990 to 24,482.63 Gg CO<sub>2</sub> in 2004.

**Figure 1.1 New Zealand's total greenhouse gas emissions 1990–2004**



There have been changes in the relative amounts of the different greenhouse gases emitted. Whereas CH<sub>4</sub> and CO<sub>2</sub> contributed equally to New Zealand's emissions in 1990, CO<sub>2</sub> is now the major greenhouse gas in New Zealand's emissions profile (Table 1.1). This is caused by increased growth in the energy sector compared to the agriculture sector.

**Table 1.1 Emissions of greenhouse gases in 1990 and 2004**

| Greenhouse Gas Emissions                         | Gg CO <sub>2</sub> equivalent |                  | Change from 1990<br>(Gg CO <sub>2</sub> equivalent) | Change from 1990<br>(%) |
|--|-------------------------------|------------------|---|-------------------------|
|  | 1990                          | 2004             |   |                         |
| Net CO <sub>2</sub> emissions / removals         | 6,292.44                      | 9,473.50         | 3,181.06  | 50.6                    |
| CO <sub>2</sub> emissions (without LULUCF)       | 25,373.39                     | 34,038.90        | 8,665.51  | 34.2                    |
| CH <sub>4</sub>                                  | 25,665.22                     | 27,160.80        | 1,495.58  | 5.8                     |
| N <sub>2</sub> O                                 | 10,429.48                     | 13,264.95        | 2,835.47  | 27.2                    |
| HFCs   | 0.00                          | 597.36           | 597.36  | –                       |
| PFCs   | 515.60                        | 87.70            | –427.90   | –83.0                   |
| SF <sub>6</sub>                                  | 12.33                         | 21.49            | 9.16  | 74.3                    |
| <b>Total emissions without the LULUCF sector</b> | <b>61,893.00</b>              | <b>75,088.19</b> | <b>13,195.19</b>                                    | <b>21.3</b>             |

## Source and sink category emission estimates and trends

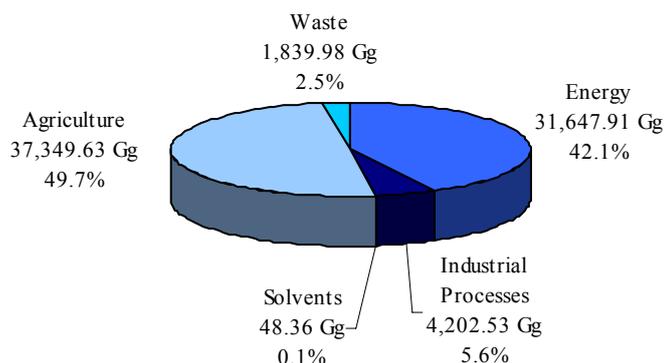
New Zealand is unusual amongst developed nations in that 49.7 percent of total emissions in 2004 were produced by the agriculture sector (Figure 1.2). By comparison, emissions from agriculture typically make up 12 percent of total greenhouse gas emissions across Annex 1 Parties. The agricultural emissions are predominantly CH<sub>4</sub> emissions from ruminant farm animals and N<sub>2</sub>O emissions from animal excreta and nitrogenous fertiliser use. The current level of emissions from the agriculture sector is 4,850.75 Gg (14.9 percent) above the 1990 level (Table 1.2).

The energy sector is the other large component of New Zealand's emissions profile comprising 42.1 percent of total emissions in 2004. Emissions from the energy sector are now 7,992.76 Gg (33.8 percent) above the 1990 level (Table 1.2). The growth in energy emissions since 1990 is primarily from road transport (an increase of 4,855.03 Gg or 62.7 percent) and electricity generation (an increase of 2,572.46 Gg or 73.6 percent). Emissions from thermal electricity generation vary from year to year depending on the water resources available for hydro generation. In 'dry' years there is a greater reliance on thermal electricity generation.

Emissions from the industrial processes and waste sectors are a much smaller component of New Zealand's emissions profile, comprising 5.6 percent and 2.5 percent respectively of all greenhouse gas emissions in 2004. Emissions from the waste sector are now 25.9 percent below the 1990 baseline with the majority of the reduction occurring from improvements in solid waste disposal. New Zealand's relatively small manufacturing base means that solvent use is lower than in many other countries.

The land-use, land-use change and forestry (LULUCF) sector represents a major sink for New Zealand removing 32.6 percent of all greenhouse gas emissions in 2004. Net removals in 2004 were 29.0 percent above net removals in 1990. Variations in planting rates and the impact of harvest regimes affect the size of this sink from year to year.

**Figure 1.2 New Zealand's sectoral emissions in 2004 (all figures Gg CO<sub>2</sub> equivalent)**



**Table 1.2 Sectoral emissions of greenhouse gases in 1990 and 2004**

| Sector                       | Gg CO <sub>2</sub> equivalent |            | Change from 1990 (Gg CO <sub>2</sub> equivalent) | Change from 1990 (%) |
|------------------------------|-------------------------------|------------|--|----------------------|
|                              | 1990                          | 2004       |  |                      |
| Energy                       | 23,655.15                     | 31,647.91  | 7,992.76   | 33.8                 |
| Industrial processes         | 3,214.61                      | 4,202.53   | 987.92   | 30.7                 |
| Solvent and other product    | 41.54                         | 48.36      | 6.82   | 16.4                 |
| Agriculture                  | 32,498.88                     | 37,349.63  | 4,850.75   | 14.9                 |
| Land-use change and forestry | -18,977.92                    | -24,482.63 | -5504.71   | 29.0                 |
| Waste                        | 2,482.81                      | 1,839.98   | -642.83  | -25.9                |

# Chapter 1: Introduction

## 1.1 Background

Greenhouse gases present in the Earth's atmosphere trap the warmth from the sun, keeping temperatures stable and preventing all the Earth's warmth from radiating away into space. Without these gases, Earth would be too cold to support life as we know it. We call these gases, primarily water vapour, carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), greenhouse gases because they act like the glass in a greenhouse. Until recently the greenhouse has existed in a state of natural balance, with the heat gained from the sun being matched by the heat lost by radiation back out to space. While there have been climatic changes in the past, there have been no significant climatic changes since the start of human civilization 10,000 years ago. Earlier changes have been either gradual, occurring over tens or hundreds of thousands of years, or when not gradual (when caused for example by major meteorite impacts) have extinguished much of the life on Earth.

In the last 50 to 100 years, human activity has changed markedly and rapidly. These changes have impacted significantly on the atmosphere. Worldwide there have been developments in transportation, agriculture and industry. These activities produce greenhouse gases, and as a consequence the concentration of these gases in Earth's atmosphere has increased. The greenhouse balance has been upset and more heat has been trapped. The Earth has begun to warm and the climate to change.

There is evidence of climate change effects, including raised temperatures and sea levels and the increased frequency of extreme weather events. The occurrence of these changes is projected to be more pronounced, and the rate of change more rapid.

### 1.1.1 The United Nations Framework Convention on Climate Change and the Kyoto Protocol

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

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

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

All countries that ratify the UNFCCC are required to address climate change through national or regional programmes. This includes preparing for adaptation to the impacts of climate change, protecting and enhancing carbon sinks (eg, forests), monitoring emissions trends via greenhouse gas inventories and, for developing countries, providing financial assistance to developing countries.

Developed countries party to the UNFCCC agreed to non-binding targets to reduce greenhouse gas emissions to 1990 levels by 2000.

Only a few countries made appreciable progress towards achieving their targets. The international community recognised that the UNFCCC alone was not enough to ensure greenhouse gas levels would be reduced to safe levels, and that more urgent action was needed. In response, Parties launched a new round of talks for stronger and more detailed commitments for developed countries. After two and a half years of negotiations, **the Kyoto Protocol** was adopted at 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.

The Kyoto Protocol shares the UNFCCC's objective, principles and institutions, but significantly strengthens the UNFCCC by committing Annex I Parties (OECD members and countries whose economies are in transition) to individual, legally-binding targets to limit or reduce their greenhouse gas emissions. Only Parties to the Convention that have also become Parties to the Protocol, by ratifying, accepting, approving, or acceding to it, are bound by the Protocol's commitments. Article 3 of the Kyoto Protocol states that the Annex I Parties ratifying the Protocol shall individually or jointly ensure that their aggregate anthropogenic greenhouse gas emissions do not exceed their "assigned amounts". The goal is to reduce aggregate emissions by at least 5 percent below 1990 levels in the commitment period 2008 to 2012.

The "assigned amount" is the maximum amount of emissions (measured as the equivalent in carbon dioxide) that a Party may emit over the commitment period in order to comply with its emissions target. New Zealand's target is 100 percent of the level in 1990. New Zealand's assigned amount over the commitment period is the gross emissions in 1990 multiplied by 5, ie, for the five years of the commitment period. Gross emissions do 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.

To achieve their targets, Annex I Parties must put in place domestic policies and measures to address emissions. This can be achieved in either of two ways: the quantity of greenhouse gases emitted can be reduced and carbon dioxide presently in the atmosphere can be removed using **carbon sinks** (eg, trees).

The Kyoto Protocol also defined three "flexibility mechanisms" to lower the overall costs of achieving its emissions targets:

- Clean Development Mechanism (CDM)
- Joint Implementation (JI)
- emissions trading.

These mechanisms enable Parties to access cost-effective opportunities to reduce emissions or to remove carbon from the atmosphere through action in other countries. While the cost of limiting emissions varies considerably from region to region, the benefit for the atmosphere is the same, wherever the action is taken. More information on these mechanisms can be obtained from the website of the UNFCCC ([www.unfccc.int](http://www.unfccc.int)).

## **New Zealand greenhouse gas emissions profile**

New Zealand's emissions have increased since 1990 as the economy has strengthened and grown. Much of New Zealand's economic growth is the result of developments in the agriculture sector. One half of New Zealand's emissions come from agriculture which contributes almost 7 percent of New Zealand's GDP. This creates a unique greenhouse gas emission profile for New Zealand with agriculture producing 49.7 percent of total emissions.

The typical Annex 1 Party has the majority of emissions from industrial processes, electricity production and transportation activity.

Another consequence of this economic growth has been the increasing greenhouse gas emissions from the energy sector. In 2004, New Zealand's emissions from this sector accounted for 42.1 percent of the total emissions, making it the second largest source after agriculture. Emissions from the energy sector have increased consistently since 1998 in response to increasing demands for energy from electricity generation, manufacturing industries, construction and transport. However, it should be noted that 75 percent of the energy currently consumed for electricity comes from renewable resources.

### **1.1.2 A national greenhouse gas inventory**

The development and publication of an annual inventory of all human-induced emissions and removals of greenhouse gases not controlled by the Montreal Protocol is part of New Zealand's obligations under the UNFCCC (Articles 4 and 12) and the Kyoto Protocol (Article 7). The inventory is the tool for measuring New Zealand's progress against these obligations. The content and format of the inventory is prescribed by the Intergovernmental Panel on Climate Change (IPCC, 1996; 2000; 2003) and relevant decisions of the Conference of the Parties (COP) to the UNFCCC, the most recent being FCCC/SBSTA/2004/8. A complete inventory submission requires two components: the national inventory report (NIR) and emissions and removal data in the common reporting format (CRF). Inventories are subject to an annual three-stage international review process administered by the UNFCCC secretariat.

The inventory reports emissions and removals of the gases carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>) from six sectors: energy, industrial processes, solvents, agriculture, land use, land-use change and forestry (LULUCF) and waste. The indirect greenhouse gases carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>) and non-methane volatile organic compounds (NMVOC) are also included in the inventory as is sulphur dioxide (SO<sub>2</sub>). However, only emissions and removals of the direct greenhouse gases, CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub> are reported in New Zealand's total emissions under the UNFCCC and are accounted for under the Kyoto Protocol.

Greenhouse gases vary in their radiative activity and in their atmospheric residence time. Emissions are converted into carbon dioxide equivalents to allow the integrated effect of emissions of the various gases to be compared. The national greenhouse gas inventory report presents emissions for each direct greenhouse gas as carbon dioxide equivalents (CO<sub>2</sub>-e). This conversion is achieved through global warming potentials (GWPs). Global warming potentials represent the relative warming effect or cumulative radiative forcing, of a unit mass of the gas when compared with the same mass of CO<sub>2</sub> over a specific period. The UNFCCC reporting requirements (FCCC/SBSTA/2004/8) specify that the 100-year GWPs contained in the IPCC Second Assessment Report (IPCC, 1995) are used in national inventories (see section 1.9). The indirect effects of a number of gases (CO, NO<sub>x</sub>, SO<sub>2</sub> and NMVOCs) cannot currently be quantified and consequently these gases do not have global warming potentials. In accordance with the UNFCCC reporting guidelines, gases that do not have global warming potentials are reported in the inventory but are not included in the inventory emissions total.

## 1.2 Institutional arrangements

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

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

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

The Ministry for the Environment (MfE) is responsible for overall development, compilation and submission of the annual inventory to the UNFCCC. The Ministry also produces estimates of emissions for the agriculture and waste sectors and emission and removals from the LULUCF sector (except for planted forests which is provided by the Ministry of Agriculture and Forestry).

The Ministry of Economic Development (MED) collects and processes all emissions from the energy sector and CO<sub>2</sub> emissions from the industrial processes sector. Emissions of the non-CO<sub>2</sub> gases from the industrial processes sector are obtained via industry survey by consultants, contracted to the Ministry for the Environment.

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

New Zealand’s national statistical agency, Statistics New Zealand provides many of the official statistics for the agriculture sector through regular agricultural census and provides statistics on oil consumption from the transport sector through the “Deliveries of Petroleum Fuels by Industry” survey.

## 1.3 Inventory preparation processes

New Zealand submits its national inventory to the UNFCCC secretariat by 15 April of each year. The inventory contains data from the base year (1990) to two years prior to the current calendar year. Generation of the data in the Common Reporting Format (CRF) and production of the National Inventory Report (NIR) occurs over the period February to April as activity data statistics and emission data become available from the various participating institutions mentioned in section 1.2 “Institutional Arrangements”. The national inventory compilation occurs at the Ministry for the Environment using the UNFCCC “CRF Reporter” software. Ministry officials also undertake quality control checks on the data, calculate the inventory

uncertainty and undertake the key category assessment. The inventory and all required data for the submission to the UNFCCC are stored on the Ministry's central computer network in a controlled file system. Once the inventory has gone through the initial quality checks at the UNFCCC Secretariat it is ready for public release (both as hard copy and on the Ministry for the Environment's website).

New Zealand is aware of the requirement under Article 5.1 of the Kyoto Protocol to have in place a national system for its greenhouse gas inventory. New Zealand will provide a formal description of the national system in the initial report for the Kyoto Protocol. Many of the arrangements detailed in the guidelines for national systems are described in this report. For example, designation of the national inventory agency and the assignment of responsibilities for the inventory preparation process.

## 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 UNFCCC guidelines on reporting and review (FCCC/SBSTA/2004/8). The concepts contained in *Good Practice Guidance* are being implemented in stages, according to sector priorities and national circumstances.

**Energy:** Greenhouse gas emissions from the energy sector are calculated using an IPCC Tier 1 approach. Activity data (fuel consumed) are multiplied by the emission factors of specific fuels. Activity data comes from industry-supplied information via the Ministry of Economic Development and Statistics New Zealand (refer Chapter 3 and Annex 2). CO<sub>2</sub> emission factors are usually New Zealand specific but applicable IPCC default factors are used for non-CO<sub>2</sub> emissions where New Zealand data are not available or are not well supported.

**Industrial processes:** CO<sub>2</sub> emissions and activity data for the industrial processes sector are supplied directly to the Ministry of Economic Development by industry sources. IPCC Tier 2 approaches are used and emission factors are country-specific. Activity data for the non-CO<sub>2</sub> gases are collated via industry survey through the Ministry for the Environment. Emissions of HFCs and PFCs are estimated using the IPCC Tier 2 approach and SF<sub>6</sub> emissions from large users are assessed via the Tier 3a approach (IPCC, 2000).

**Solvents:** Very small amounts of nitrous oxide are emitted during use in medical applications. Estimates of NMVOC emissions are calculated using a consumption-based approach. Activity data are obtained via a survey of industry.

**Agriculture:** Livestock population data are obtained from Statistics New Zealand, supplemented by estimates from the Ministry of Agriculture and Forestry. A Tier 2 (model) approach is used to estimate methane emissions from dairy, beef, sheep and deer animals. The methodology uses animal productivity data to estimate dry matter intake. Methane production is determined from this intake. The same dry matter intake data are used to calculate nitrous oxide emissions from animal excreta. A Tier 1 approach is used for non-significant animal species.

**Land use, land-use change and forestry:** The LULUCF inventory is completed using a mix of IPCC Tier 2 and Tier 1 approaches. A Tier 2 approach is used for the planted forest subcategory of forest land. Changes in planted forest stocks are assessed from national forest survey data and computer modelling of the planted forest estate. A Tier 1 approach is used for the categories

cropland, grassland, wetland, settlements and other land. Changes in land area for these categories are based on modified national land cover databases reclassified to the UNFCCC categories. The land-cover databases were mapped in 1997 and 2002. Data for all other years is extrapolated from the changes observed between 1997 and 2002. At present, the land-cover data is the best national data available for reporting the LULUCF sector. The reporting will be improved significantly as a result of the New Zealand Carbon Accounting System described in Annex 3.2.

**Waste:** Emissions from the waste sector are estimated using waste-survey data combined with population data. The calculation of emissions from solid-waste disposal uses an IPCC Tier 2 method with country-specific emission factors. Methane and nitrous oxide emissions from domestic and industrial wastewater handling are calculated using a refinement of the IPCC methodology (IPCC, 1996). New Zealand has tried to ascertain emissions from waste incineration but there is very little incineration that occurs and data is difficult to obtain. For this inventory they are reported to be negligible. Most regional and territorial councils have banned the open burning of waste and there is no incineration of municipal waste in New Zealand.

## 1.5 Key categories

The IPCC Good practice guidance (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 are identified within the inventory so that the resources available for inventory preparation are prioritised.

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

Following GPG-LULUCF (IPCC, 2003) the key category analysis is performed once for the inventory excluding LULUCF categories and then repeated for the full inventory including the LULUCF categories. Non-LULUCF categories that are identified as key in the first analysis but do not appear as key when the LULUCF categories are included are still be considered as key.

The key categories identified in the 2004 inventory are summarised in Table 1.5.1. The major contribution to the level analysis (Table 1.5.2 a & b) are from the LULUCF category “forest land remaining forest land” and from CH<sub>4</sub> emissions from enteric fermentation in domestic livestock at 25.4 percent and 23.0 percent of the total respectively. CH<sub>4</sub> emissions from enteric fermentation in domestic livestock are the largest single source of emissions comprising 31.7 percent of total emissions (Table 1.5.2 (b)). The next largest contribution to emissions is CO<sub>2</sub> emissions from road transportation that comprised 16.5 percent of total emissions in 2004.

The largest contribution to the trend analysis is from CO<sub>2</sub> emissions from road transportation and CH<sub>4</sub> emissions from enteric fermentation in domestic livestock. It is clear that these two categories have a major effect on the New Zealand inventory.

While CO<sub>2</sub> emissions from the industrial processes of ammonia and urea manufacture (CRF category 2B5) did not appear in the top 95 percent of categories for the quantitative level and trend analyses, the source is considered a qualitative key category because of the large increase in nitrogenous fertiliser use observed in the agriculture sector.

There were two modifications to the IPCC suggested source categories to reflect New Zealand's national circumstances. The category for fugitive emissions from geothermal operations was separated from the "fugitive emissions oil and gas" category and CO<sub>2</sub> emissions from ammonia and urea manufacture were included in the analysis. More information on the calculation of the level and trend analysis is included in Annex 1.

**Table 1.5.1 Summary of key categories in the 2004 inventory (including and excluding LULUCF activities)**

| <b>Quantitative method used: Tier 1</b>                       |                  |                                    |
|---|------------------|------------------------------------|
| <b>IPCC Source Categories</b>                                 | <b>Gas</b>       | <b>Criteria for Identification</b> |
| <b>Energy Sector</b>  |                  |                                    |
| CO <sub>2</sub> emissions from Stationary combustion - solid  | CO <sub>2</sub>  | level, trend                       |
| CO <sub>2</sub> emissions from Stationary combustion - liquid | CO <sub>2</sub>  | level, trend                       |
| CO <sub>2</sub> emissions from Stationary combustion - gas    | CO <sub>2</sub>  | level, trend                       |
| Mobile combustion - Road vehicles                             | CO <sub>2</sub>  | level, trend                       |
| Mobile combustion - Road vehicles                             | CH <sub>4</sub>  | trend                              |
| Mobile combustion - Aviation                                  | CO <sub>2</sub>  | level, trend                       |
| Fugitive emissions from Oil and Gas operations                | CO <sub>2</sub>  | level, trend                       |
| Fugitive emissions from Geothermal operations                 | CO <sub>2</sub>  | trend                              |
| <b>Industrial processes sector</b>                            |                  |                                    |
| Emissions from the iron and steel industry                    | CO <sub>2</sub>  | level                              |
| Emissions from Aluminium production                           | CO <sub>2</sub>  | level                              |
| PFC's from Aluminium production                               | PFC              | trend                              |
| Emissions from substitutes for Ozone depleting substances     | HFCs             | level, trend                       |
| <b>Agricultural Sector</b>                                    |                  |                                    |
| Emissions from enteric fermentation in domestic livestock     | CH <sub>4</sub>  | level, trend                       |
| Emissions from Manure Management                              | CH <sub>4</sub>  | level                              |
| Direct emissions from Agricultural soils                      | N <sub>2</sub> O | level, trend                       |
| Emissions from Animal deposition on Agricultural soils        | N <sub>2</sub> O | level, trend                       |
| Indirect emissions from Nitrogen used in Agriculture          | N <sub>2</sub> O | level                              |
| <b>LULUCF Sector</b>  |                  |                                    |
| Forest land remaining forest land                             | CO <sub>2</sub>  | level, trend                       |
| Cropland remaining cropland                                   | CO <sub>2</sub>  | level                              |
| Conversion to forest land                                     | CO <sub>2</sub>  | level, trend                       |
| Conversion to grassland                                       | CO <sub>2</sub>  | level                              |
| <b>Waste sector</b>   |                  |                                    |
| Emissions from solid waste disposal sites                     | CH <sub>4</sub>  | level, trend                       |

**Table 1.5.2 (a& b) Key category analysis for the 2004 inventory – Tier 1 level assessment including LULUCF (a) and excluding LULUCF (b)**

| <b>(a) Tier 1 Category Level Assessment - including LULUCF</b> |                  |                 |                   |                   |
|--|------------------|-----------------|-------------------|-------------------|
| <b>IPCC Categories</b>   | <b>Gas</b>       | <b>2004</b>     | <b>Level</b>      | <b>Cumulative</b> |
|  |                  | <b>estimate</b> | <b>assessment</b> | <b>total</b>      |
| <b>Gg</b>  |                  |                 |                   |                   |
| Forest land remaining forest land                              | CO <sub>2</sub>  | 26254.43        | 25.3              | 25.3              |
| Emissions from enteric fermentation in domestic livestock      | CH <sub>4</sub>  | 23823.54        | 23.0              | 48.3              |
| Mobile combustion - road vehicles                              | CO <sub>2</sub>  | 12416.93        | 12.0              | 60.2              |
| Emissions from agricultural soils - animal production          | N <sub>2</sub> O | 7530.74         | 7.3               | 67.5              |
| Emissions from stationary combustion - gas                     | CO <sub>2</sub>  | 7031.32         | 6.8               | 74.3              |
| Emissions from stationary combustion - solid                   | CO <sub>2</sub>  | 5808.96         | 5.6               | 79.9              |
| Indirect emissions from Nitrogen used in agriculture           | N <sub>2</sub> O | 3376.65         | 3.3               | 83.1              |
| Emissions from stationary combustion - liquid                  | CO <sub>2</sub>  | 2755.47         | 2.7               | 85.8              |
| Direct emissions from agricultural soils                       | N <sub>2</sub> O | 1805.26         | 1.7               | 87.5              |
| Emissions from the iron and steel industry                     | CO <sub>2</sub>  | 1731.51         | 1.7               | 89.2              |
| Emissions from solid waste disposal sites                      | CH <sub>4</sub>  | 1509.12         | 1.5               | 90.6              |
| Mobile combustion - aviation                                   | CO <sub>2</sub>  | 1192.23         | 1.1               | 91.8              |
| Conversion to forest land                                      | CO <sub>2</sub>  | 747.94          | 0.7               | 92.5              |
| Emissions from manure management                               | CH <sub>4</sub>  | 734.08          | 0.7               | 93.2              |
| Conversion to grassland  | CO <sub>2</sub>  | 666.44          | 0.6               | 93.9              |
| Cropland remaining cropland                                    | CO <sub>2</sub>  | 662.29          | 0.6               | 94.5              |
| Fugitive emissions from oil and gas operations                 | CO <sub>2</sub>  | 602.86          | 0.6               | 95.1              |

| <b>(b) Tier 1 Category Level Assessment - excluding LULUCF</b> |                  |                 |                   |                   |
|--|------------------|-----------------|-------------------|-------------------|
| <b>IPCC Categories</b>   | <b>Gas</b>       | <b>2004</b>     | <b>Level</b>      | <b>Cumulative</b> |
|  |                  | <b>estimate</b> | <b>assessment</b> | <b>total</b>      |
| <b>Gg</b>  |                  |                 |                   |                   |
| Emissions from enteric fermentation in domestic livestock      | CH <sub>4</sub>  | 23823.54        | 31.7              | 31.7              |
| Mobile combustion - road vehicles                              | CO <sub>2</sub>  | 12416.93        | 16.5              | 48.3              |
| Emissions from agricultural soils - animal production          | N <sub>2</sub> O | 7530.74         | 10.0              | 58.3              |
| Emissions from stationary combustion - gas                     | CO <sub>2</sub>  | 7031.32         | 9.4               | 67.7              |
| Emissions from stationary combustion - solid                   | CO <sub>2</sub>  | 5808.96         | 7.7               | 75.4              |
| Indirect emissions from nitrogen used in Agriculture           | N <sub>2</sub> O | 3376.65         | 4.5               | 79.9              |
| Emissions from stationary combustion - liquid                  | CO <sub>2</sub>  | 2755.47         | 3.7               | 83.6              |
| Direct emissions from agricultural soils                       | N <sub>2</sub> O | 1805.26         | 2.4               | 86.0              |
| Emissions from the iron and steel industry                     | CO <sub>2</sub>  | 1731.51         | 2.3               | 88.3              |
| Emissions from solid waste disposal sites                      | CH <sub>4</sub>  | 1509.12         | 2.0               | 90.3              |
| Mobile combustion - aviation                                   | CO <sub>2</sub>  | 1192.23         | 1.6               | 91.9              |
| Emissions from manure management                               | CH <sub>4</sub>  | 734.08          | 1.0               | 92.8              |
| Fugitive emissions from oil and gas operations                 | CO <sub>2</sub>  | 602.86          | 0.8               | 93.6              |
| Emissions from substitutes for ozone depleting substances      | HFCs             | 597.36          | 0.8               | 94.4              |
| Emissions from aluminium production                            | CO <sub>2</sub>  | 552.29          | 0.7               | 95.2              |

**Table 1.5.3 Key category analysis for the 2004 inventory – Tier 1 trend assessment including LULUCF (a) and excluding LULUCF (b)**

| Tier 1 Category Trend Assessment - including LULUCF       |                  |           |             |               |                 |            |
|---|------------------|-----------|-------------|---------------|-----------------|------------|
| IPCC Categories   | Gas              | Base year | 2004        | trend         | Contribution to | Cumulative |
|   |                  | estimate  | Gg estimate | Gg assessment | trend           | total      |
| Mobile combustion - Road vehicles                         | CO <sub>2</sub>  | 7534.65   | 12416.93    | 0.036         | 18.4            | 18.4       |
| Emissions from enteric fermentation in domestic livestock | CH <sub>4</sub>  | 21806.54  | 23823.54    | 0.029         | 14.8            | 33.2       |
| Emissions from Stationary combustion - gas                | CO <sub>2</sub>  | 7679.40   | 7031.32     | 0.025         | 12.8            | 46.0       |
| Emissions from Stationary combustion - solid              | CO <sub>2</sub>  | 3227.01   | 5808.96     | 0.021         | 10.6            | 56.6       |
| Direct emissions from Agricultural soils                  | N <sub>2</sub> O | 475.17    | 1805.26     | 0.013         | 6.9             | 63.5       |
| Emissions from solid waste disposal sites                 | CH <sub>4</sub>  | 2179.23   | 1509.12     | 0.012         | 6.4             | 69.9       |
| Forest land remaining forest land                         | CO <sub>2</sub>  | 20624.90  | 26254.43    | 0.014         | 6.9             | 76.8       |
| Emissions from agricultural soils - animal production     | N <sub>2</sub> O | 6858.34   | 7530.74     | 0.009         | 4.4             | 81.2       |
| Emissions from substitutes for Ozone depleting substances | HFCs             | 0.00      | 597.36      | 0.007         | 3.4             | 84.6       |
| PFC's from Aluminium production                           | PFC              | 515.60    | 80.70       | 0.006         | 3.1             | 87.6       |
| Emissions from Stationary combustion - liquid             | CO <sub>2</sub>  | 2546.55   | 2755.47     | 0.004         | 1.9             | 89.5       |
| Conversion to forest land                                 | CO <sub>2</sub>  | 870.01    | 747.94      | 0.003         | 1.7             | 91.2       |
| Fugitive emissions from Oil and Gas operations            | CO <sub>2</sub>  | 263.75    | 602.86      | 0.003         | 1.6             | 92.8       |
| Mobile combustion - Aviation                              | CO <sub>2</sub>  | 772.83    | 1192.23     | 0.003         | 1.4             | 94.2       |
| Fugitive emissions from Geothermal operations             | CO <sub>2</sub>  | 357.34    | 279.67      | 0.002         | 0.9             | 95.1       |

| Tier 1 Category Trend Assessment - excluding LULUCF       |                  |           |          |            |                 |            |
|---|------------------|-----------|----------|------------|-----------------|------------|
| IPCC Categories   | Gas              | Base year | 2004     | trend      | Contribution to | Cumulative |
|   |                  | estimate  | estimate | assessment | to trend        | total      |
|   |                  | Gg        | Gg       |            |                 |            |
| Mobile combustion - Road vehicles                         | CO <sub>2</sub>  | 7534.65   | 12416.93 | 0.0360     | 20.2            | 20.2       |
| Emissions from enteric fermentation in domestic livestock | CH <sub>4</sub>  | 21806.54  | 23823.54 | 0.0289     | 16.2            | 36.4       |
| Emissions from Stationary combustion - gas                | CO <sub>2</sub>  | 7679.40   | 7031.32  | 0.0251     | 14.1            | 50.4       |
| Emissions from Stationary combustion - solid              | CO <sub>2</sub>  | 3227.01   | 5808.96  | 0.0208     | 11.7            | 62.1       |
| Direct emissions from Agricultural soils                  | N <sub>2</sub> O | 475.17    | 1805.26  | 0.0135     | 7.6             | 69.7       |
| Emissions from solid waste disposal sites                 | CH <sub>4</sub>  | 2179.23   | 1509.12  | 0.0125     | 7.0             | 76.6       |
| Emissions from agricultural soils - animal production     | N <sub>2</sub> O | 6858.34   | 7530.74  | 0.0087     | 4.9             | 81.5       |
| Emissions from substitutes for Ozone depleting substances | HFCs             | 0.00      | 597.36   | 0.0066     | 3.7             | 85.2       |
| PFC's from Aluminium production                           | PFC              | 515.60    | 80.70    | 0.0060     | 3.4             | 88.5       |
| Emissions from Stationary combustion - liquid             | CO <sub>2</sub>  | 2546.55   | 2755.47  | 0.0037     | 2.1             | 90.6       |
| Fugitive emissions from Oil and Gas operations            | CO <sub>2</sub>  | 263.75    | 602.86   | 0.0031     | 1.7             | 92.3       |
| Mobile combustion - Aviation                              | CO <sub>2</sub>  | 772.83    | 1192.23  | 0.0028     | 1.6             | 93.9       |
| Fugitive emissions from Geothermal operations             | CO <sub>2</sub>  | 357.34    | 279.67   | 0.0017     | 0.9             | 94.8       |
| Mobile combustion - Road vehicles                         | CH <sub>4</sub>  | 148.20    | 51.94    | 0.0014     | 0.8             | 95.6       |

## 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 UNFCCC guidelines (FCCC/CP/2000/4/8) to formalise, document and archive the QC and QA procedures. The plan is regularly reviewed and updated in conjunction with New Zealand's inventory improvement plan.

### 1.6.1 Quality control

During the preparation of the 2004 inventory, the Ministry for the Environment continued to develop the Tier 1 QC checklist first used in the preparation of the 2002 inventory. The Tier 1 quality checks are based on the procedures suggested in the *Good Practice Guidance* (IPCC, 2000). Further details (including examples of some of the checks carried out) are available in Annex 6. For the 2004 inventory, the Tier 1 QC checklists were used on all key categories and a selection of non-key categories.

In addition to the formal QC checks, data in the underpinning worksheets and entered into the UNFCCC secretariat's CRF Reporter database are checked visually for anomalies, errors and omissions. In the preparation of the 2004 inventory, the Ministry for the Environment used the quality control checking procedures included in the "CRF Reporter" database to ensure the data submitted to the UNFCCC secretariat was complete.

## **1.6.2 Quality assurance**

Quality assurance reviews of individual sectors and categories are commissioned by the Ministry for the Environment. As part of the QA procedures for the 2004 inventory, the quality control and assurance plan was updated incorporating a number of recommendations from a quality management review undertaken in 2004. A history of reviews, their key conclusions and follow up is included as QA documentation in Annex 6. In addition, the methodologies used in the agricultural and LULUCF sectors have undergone scientific peer-review before inclusion in New Zealand's inventory.

A large part of the data in the energy and agriculture sectors are compiled using data collected in national surveys. These surveys are conducted and administered by Statistics New Zealand, New Zealand's national statistics agency. Statistics New Zealand conducts its own rigorous quality assurance and quality control procedures on the data.

## **1.6.3 UNFCCC annual inventory review**

New Zealand's greenhouse gas inventory was reviewed in 2001 and 2002 as part of a pilot study of the technical review process (UNFCCC, 2001a, 2001b, 2002), where the inventory was subject to detailed in-country, centralised and desk review procedures. The inventories submitted for the years 2003-2005 were reviewed during a centralised review process. In all cases, the reviews were conducted by a review team comprised of experts nominated by Parties to the UNFCCC. Review reports are available from the UNFCCC website ([www.unfccc.int](http://www.unfccc.int)).

## **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). Good practice also notes that inventories prepared following the methodologies in the IPCC Good Practice Guidance 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<sub>2</sub>O fluxes from soils and waterways.

New Zealand has included a Tier 1 uncertainty analysis as required by the inventory guidelines (FCCC/SBSTA/2004/8) and good practice. 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<sub>2</sub> (Table A7.1). Table A7.2 calculates the uncertainty only in emissions, ie, excluding LULUCF removals.

The calculated uncertainty for New Zealand's total inventory (emissions and removals) in 2004 is  $\pm 17.0$  percent. However the uncertainty in the overall trend from 1990-2004 is lower at only

±4.3 percent. The uncertainty in total emissions is ±21.2 percent with ±5.0 percent uncertainty in the trend of emissions. The trend is critical to the UNFCCC and Kyoto Protocol reporting where New Zealand's emissions are compared to the 1990 baseline.

The high uncertainty in a given year is dominated by emissions of CH<sub>4</sub> from enteric fermentation (Chapter 6, section 6.2) and N<sub>2</sub>O emissions from agricultural soils (section 6.5). These categories comprise 12.2 percent and 9.0 percent respectively of the uncertainty as a percentage of New Zealand's total emissions and removals. The apparent high uncertainty in these categories reflects the inherent variability when estimating emissions from natural systems, eg, the uncertainty in cow dry-matter intake and CH<sub>4</sub> 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<sub>2</sub> from forest land are also a major contribution to the uncertainty for 2004 at 6.5 percent of New Zealand's total emissions and removals. In comparison, the uncertainty in CO<sub>2</sub> emissions from burning of fossil fuels is significantly lower at only 1.5 percent of the total.

Uncertainty in the trend is dominated by CO<sub>2</sub> emissions from the energy sector, at 2.6 percent of the trend. This is because of the size of the sector and that the uncertainty in energy activity data is greater than the uncertainty in energy emission factors. The other major contributors to trend uncertainty are removals of CO<sub>2</sub> by forest land (Chapter 7, section 7.2) and CH<sub>4</sub> from enteric fermentation in domestic livestock.

In most cases, the uncertainty values are determined by either expert judgement from sectoral or industry experts, by analysis of emission factors or activity data, or by referring to uncertainty ranges quoted in the IPCC documentation. A Monte Carlo simulation was used to determine uncertainty for CH<sub>4</sub> from enteric fermentation and N<sub>2</sub>O from agricultural soils in the 2001/2002 inventory. The 95 percent confidence intervals developed from the Monte Carlo simulation were extended to the 2004 inventory.

## 1.8 Inventory completeness

The New Zealand inventory for the 2004 year can be described as complete with all IPCC source and sink categories that occur in New Zealand or that have emissions assessed to be above a negligible level reported. Improvements have been made with the inclusion of estimates for all LULUCF categories from the base year for all years (compared to 1997-2003 in the 2005 submission) and estimates of CO<sub>2</sub> from soda ash use in industrial processes. There are some small sources which remain "not estimated" (NE), eg, CH<sub>4</sub> emissions from waste incineration. Explanations on why these are reported as NE are found under the appropriate sector chapters.

The LULUCF data is the best estimate possible using the data that is presently available. The New Zealand Carbon Accounting System (NZCAS) is being developed to improve the accuracy of this data and estimates using this system will be included when available. Development of the NZCAS will also reduce the uncertainty by using country-specific emission and removal factors and utilise spatial data mapped specifically for UNFCCC reporting. Details of the NZCAS development are included in Annex 3.2.

Emissions of CO<sub>2</sub> and CH<sub>4</sub> from geothermal electricity generation are also a significant source in New Zealand. These emissions are reported as fugitive emissions in the energy sector. Sites with naturally occurring emissions where there is no electricity generation are excluded from the inventory.

In accordance with good practice, New Zealand has focused its resources for inventory development on the key source categories and some categories considered to have negligible emissions are reported as 'not estimated'. Where this has occurred explanations have been provided in the NIR and in the CRF tables.

## 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 <sub>2</sub>  | carbon dioxide                         |
| CH <sub>4</sub>  | methane                                |
| N <sub>2</sub> O | nitrous oxide                          |
| PFCs             | perfluorocarbons                       |
| HFCs             | hydrofluorocarbons                     |
| SF <sub>6</sub>  | sulphur hexafluoride                   |
| CO               | carbon monoxide                        |
| NMVOG            | non-methane volatile organic compounds |
| NO <sub>x</sub>  | oxides of nitrogen                     |
| SO <sub>2</sub>  | sulphur dioxide                        |

### Common Global Warming Potentials

|                                       |                   |
|---------------------------------------|-------------------|
| CO <sub>2</sub> = 1                   | HFC-32 = 650      |
| CH <sub>4</sub> = 21                  | HFC-125 = 2,800   |
| N <sub>2</sub> O = 310                | HFC-134a = 1,300  |
| CF <sub>4</sub> = 6,500               | HFC-143a = 3,800  |
| C <sub>2</sub> F <sub>6</sub> = 9,200 | HFC-227ea = 2,900 |
| SF <sub>6</sub> = 23,900              |                   |

### Conversion Factors

From element basis to molecular mass

C → CO<sub>2</sub>: C x 44/12 (3.67)

C → CH<sub>4</sub>: C x 16/12 (1.33)

N → N<sub>2</sub>O: N x 44/28 (1.57)

From molecular mass to element basis

CO<sub>2</sub> → C: CO<sub>2</sub> x 12/44 (0.27)

CH<sub>4</sub> → C: CO<sub>2</sub> x 12/16 (0.75)

N<sub>2</sub>O → N: N<sub>2</sub>O x 28/44 (0.64)

**Indicators**

In the common reporting format tables, the following standard indicators 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 are no data or methodology available to derive an estimate of emissions. Even if emissions are considered to be negligible, an emission estimated should be reported, if calculated, or the notation key “NE” used.
- IE (included elsewhere) where emissions or removals are estimated but included elsewhere in the inventory (summary table 9 of the common reporting format tables details the source category where these emissions or removals are reported).
- C (confidential) where reporting at a disaggregated level could lead to the disclosure of confidential information.

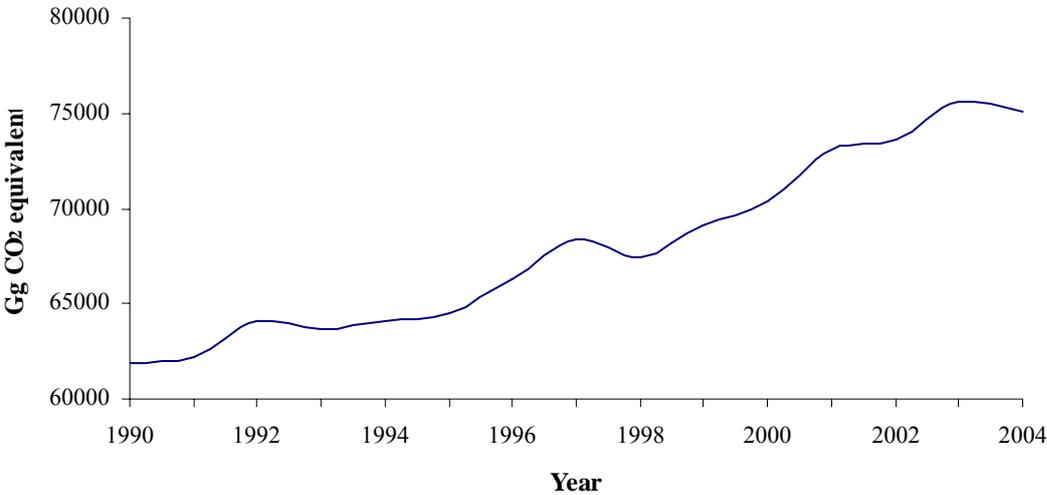
# Chapter 2: Trends in greenhouse gas emissions

## 2.1 Emission trends for aggregated greenhouse gas emissions

In 1990, New Zealand’s total greenhouse gas emissions were equivalent to 61,893.00 Gg of CO<sub>2</sub>. In 2004, total greenhouse gas emissions have increased by 13,225.19 Gg (21.3 percent) to 75,088.19 Gg CO<sub>2</sub> equivalent (Figure 2.1.1). Over the period 1990 to 2004, the average annual growth in overall emissions has been 1.4 percent per year.

Fluctuations in the trend are largely driven by emissions from public electricity generation. This category can show large year-to-year fluctuations because of the use of thermal stations to supplement the hydro-electric generation, during dry years. Generation in a year with normal rainfall requires lower gas and coal use and a year with less rainfall requires higher gas and coal use. This is a different trend from the steady increase in emissions from coal and gas used in electricity generation found in many other countries.

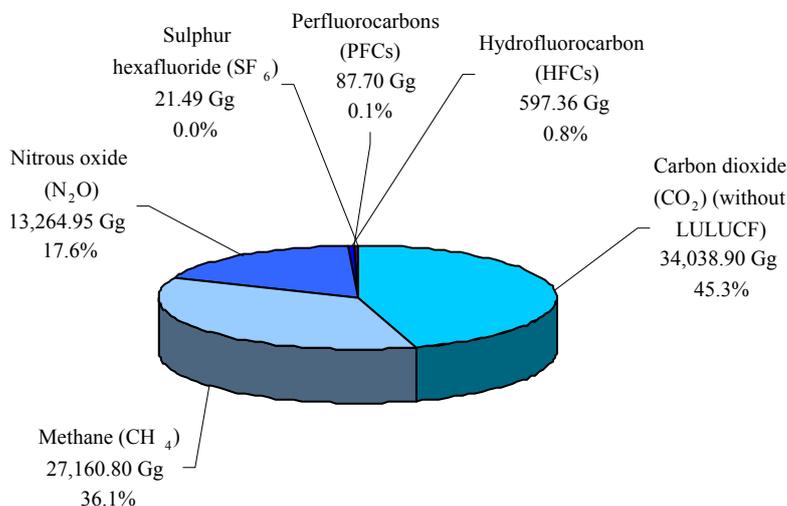
Figure 2.1.1 New Zealand’s total greenhouse gas emissions 1990–2004



## 2.2 Emission trends by gas

Carbon dioxide and methane dominate New Zealand’s increase in greenhouse gas emissions (Figures 2.2.1, 2.2.2 and Table 2.2.1). In 2004, these gases comprised 81.5 percent of total CO<sub>2</sub> equivalent emissions. Whereas CH<sub>4</sub> and CO<sub>2</sub> made equally large contributions to New Zealand’s emissions in 1990, CO<sub>2</sub> is now the major greenhouse gas in New Zealand’s emissions profile. The other major gas in New Zealand’s emissions profile is N<sub>2</sub>O.

**Figure 2.2.1 New Zealand's emissions by gas in 2004 (all figures Gg CO<sub>2</sub> equivalent)**



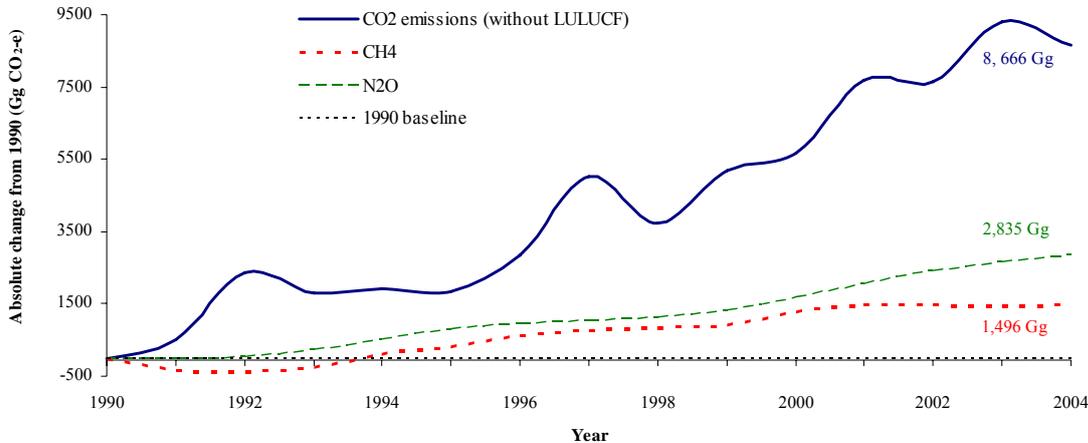
The growth in CO<sub>2</sub> represents the increased emissions from the energy sector. The growth in N<sub>2</sub>O is from increased emissions from animal excreta and the increased use of nitrogenous fertilisers in agriculture, eg, the amount of nitrogenous fertilisers used has increased six-fold since 1990.

Although the contribution of the other gases in the inventory is less than 1 percent of the total emissions, these gases have also undergone relative changes between 1990 and 2004. Emissions of PFCs have decreased 427.90 Gg due to improvements in the aluminium smelting process, and HFC emissions have increased from 0 to 597.36 Gg because of the use of HFCs as a substitute for the chlorofluorocarbons (CFCs) phased out under the Montreal Protocol.

**Table 2.2.1 Emissions of greenhouse gases 1990 and 2004**

| Greenhouse gas emissions                   | Gg CO <sub>2</sub> equivalent |           | Change from 1990 (Gg CO <sub>2</sub> equivalent) | Change from 1990 (%) |
|--|-------------------------------|-----------|--|----------------------|
|  | 1990                          | 2004      |  |                      |
| CO <sub>2</sub> emissions (without LULUCF) | 25,373.39                     | 34,038.90 | 8,665.51   | 34.2                 |
| CH <sub>4</sub>                            | 25,665.22                     | 27,160.80 | 1,495.58   | 5.8                  |
| N <sub>2</sub> O                           | 10,429.48                     | 13,264.95 | 2,835.46   | 27.2                 |
| HFCs                                       | 0.00                          | 597.36    | 597.36   | –                    |
| PFCs                                       | 515.60                        | 87.70     | –427.90  | –83.0                |
| SF <sub>6</sub>                            | 12.33                         | 21.49     | 9.16   | 74.3                 |

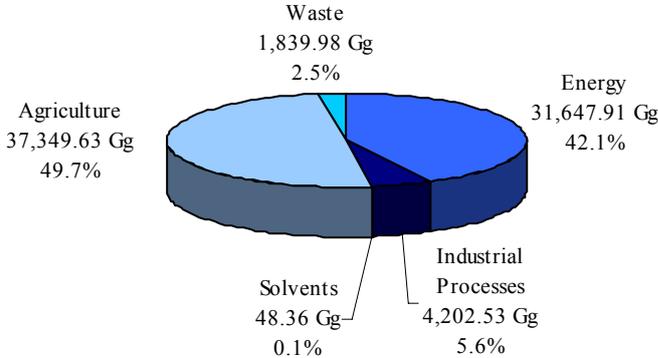
**Figure 2.2.2 Change in New Zealand’s emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from 1990–2004**



### 2.3 Emission trends by source

New Zealand is unusual amongst developed nations in the share of its total greenhouse gas emissions that come from agriculture (Figure 2.3.1 and Table 2.3.1). In 2004, 49.7 percent of New Zealand’s total emissions are produced by the **agriculture sector**, predominantly CH<sub>4</sub> from ruminant farm animals, eg, dairy cows and sheep, and N<sub>2</sub>O from animal excreta and nitrogenous fertiliser use. The current level of emissions from the agriculture sector is 14.9 percent above the 1990 level (Figure 2.3.2). More detailed information on the agriculture sector is contained in Chapter 6.

**Figure 2.3.1 New Zealand’s sectoral greenhouse gas emissions in 2004 (all figures Gg CO<sub>2</sub> equivalent, percentage of national total emissions in 2004)**



The **energy sector** is the other large component of New Zealand's emissions profile comprising 42.1 percent of total emissions (refer Chapter 3). Emissions from the energy sector in 2004 are 7,992.76 Gg (33.8 percent) over the 1990 level and represent the highest sectoral growth in emissions. The growth in emissions from 1990 is primarily from road transport (increased by 4,855.03 Gg or 62.7 percent) and electricity generation (increased by 2,572.46 Gg or 73.6 percent).

Emissions from the industrial processes and waste sectors are a much smaller component comprising 5.6 percent and 2.5 percent respectively of all greenhouse gas emissions in 2004. Emissions from the **industrial processes sector** have been increasing steadily and are now 987.82 Gg (30.7 percent) over the 1990 baseline. This growth is primarily from increased CO<sub>2</sub> emissions from cement production (an increase of 118.11 Gg or 32.2 percent) over 1990), urea (nitrogenous fertiliser) manufacture (an increase of 105.35 Gg or 38.6 percent) over 1990) and HFC consumption (from 0 in 1990 to 597.36 Gg in 2004). The increase has been offset by PFC emissions from aluminium manufacture decreasing by 427.90 Gg (83.0 percent) since 1990 as a result of improvements to the smelting process (refer to section 4.4.2).

Emissions from the **waste sector** are now 642.83 Gg CO<sub>2</sub> equivalent (-25.9 percent) below the 1990 baseline. The majority of the reduction has occurred in the solid waste disposal on land category. This is a result of a number of initiatives to improve solid waste management practices in New Zealand, including 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.

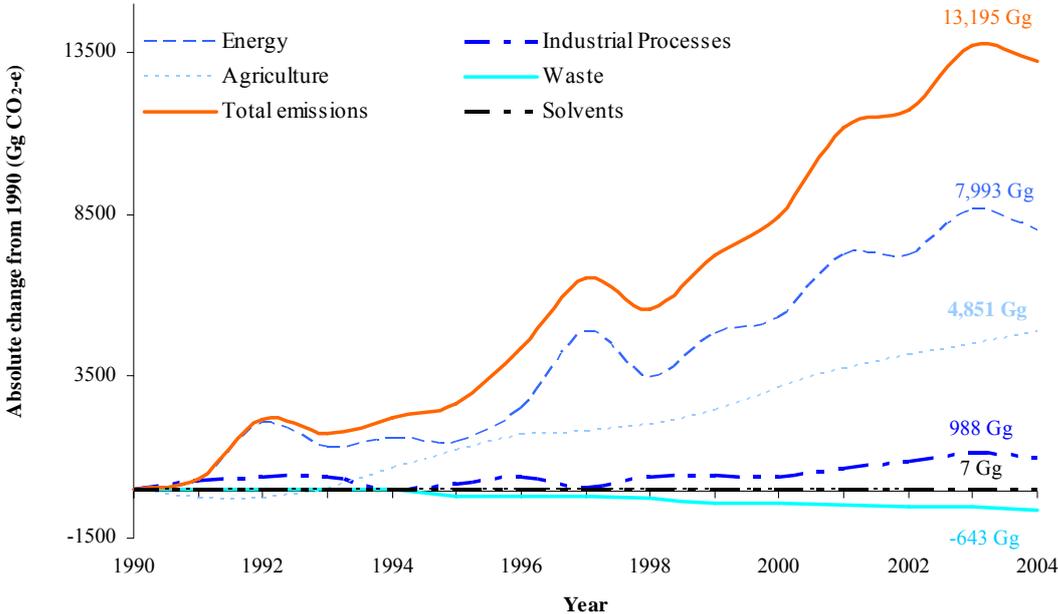
New Zealand's relatively small manufacturing base means that the **solvent sector** is much lower than in many other countries. In 2004, the solvent sector emitted 48.36 Gg of NMVOC.

**The Land use, Land-use Change and Forestry (LULUCF) sector** represents a major sink for New Zealand removing 32.7 percent of all greenhouse gas emissions in 2004. Net removals in 2004 were 29.0 percent above net removals in 1990. Variations in planting rates and the impact of harvest regimes affect the size of this sink from year to year.

**Table 2.3.1 Sectoral emissions of greenhouse gases in 1990 and 2004**

| Sector                       | Gg CO <sub>2</sub> equivalent |            | Change from 1990 (Gg CO <sub>2</sub> equivalent) | Change from 1990 (%) |
|------------------------------|-------------------------------|------------|--|----------------------|
|                              | 1990                          | 2004       |  |                      |
| Energy                       | 23,655.15                     | 31,647.91  | 7,992.76   | 33.8                 |
| Industrial processes         | 3,214.61                      | 4,202.53   | 987.92   | 30.7                 |
| Solvent and other product    | 41.54                         | 48.36      | 6.82   | 16.4                 |
| Agriculture                  | 32,498.88                     | 37,349.63  | 4,850.75   | 14.9                 |
| Land-use change and forestry | -18,977.92                    | -24,482.63 | -5504.71   | 29.0                 |
| Waste                        | 2,482.81                      | 1,839.98   | -642.83  | -25.9                |

**Figure 2.3.2 Change in sectoral greenhouse gas emissions from 1990–2004**



## 2.4 Emission trends for indirect greenhouse gases and SO<sub>2</sub>

The indirect greenhouse gases CO, NO<sub>x</sub> and NMVOC are also included in the inventory as is SO<sub>2</sub>. Emissions of these gases in 1990 and 2004 are shown in Table 2.4.1. There have been marked increases in the emissions of all gases. Indirect greenhouse gases are not included in New Zealand’s total greenhouse gas emissions.

**Table 2.4.1 Emissions of indirect greenhouse gases and SO<sub>2</sub> in 1990 and 2004**

| Gas             | Gg of gas(es) |        | Change from 1990 (Gg) | Change from 1990 (%) |
|-----------------|---------------|--------|-----------------------|----------------------|
|                 | 1990          | 2004   |                       |                      |
| NO <sub>x</sub> | 135.34        | 157.45 | 22.11                 | 16.3                 |
| CO              | 474.61        | 611.57 | 136.96                | 28.9                 |
| NMVOC           | 133.86        | 169.72 | 35.86                 | 26.8                 |
| SO <sub>2</sub> | 54.28         | 75.51  | 21.23                 | 39.1                 |

Emissions of CO and NO<sub>x</sub> come largely from the energy sector. The energy sector produced 93.6 percent of total CO emissions in 2004. The largest single source was road transportation. Similarly, the energy sector was the largest source of NO<sub>x</sub> emissions (98.3 percent), with road transportation again dominating. Other large sources of NO<sub>x</sub> emissions are from manufacturing industries and construction and energy industries.

The energy sector was also the largest producer of NMVOC's and SO<sub>2</sub>. The energy sector produced 70.1 percent of NMVOC emissions in 2004 with emissions from road transportation comprising 62.7 percent of total NMVOC emissions. Other major sources of NMVOC's are in the solvent and other product use sector (18.8 percent) and the industrial processes sector (10.4 percent).

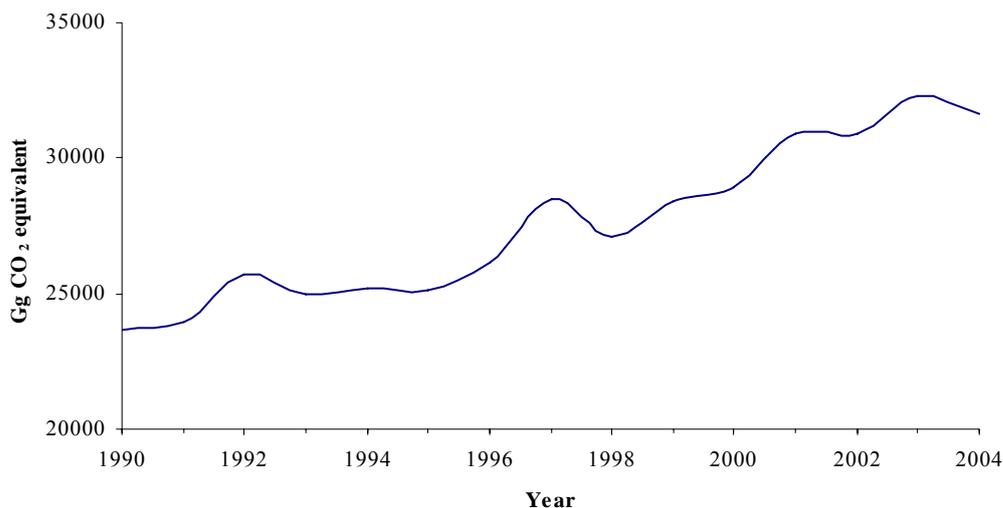
Emissions of SO<sub>2</sub> from the energy sector comprised 85.2 percent of total SO<sub>2</sub> emissions. The manufacturing industries and construction and energy industries made up 54.0 percent of total SO<sub>2</sub> emissions. The other source of SO<sub>2</sub> was from the industrial processes sector.

# Chapter 3: Energy

## 3.1 Sector overview

The energy sector produced 31,647.91 Gg CO<sub>2</sub> equivalent in 2004 and represented 42.4 percent of New Zealand's total greenhouse gas emissions. Emissions from the energy sector are now 33.8 percent above the 1990 baseline value of 23,655.15 Gg CO<sub>2</sub> equivalent (Figure 3.1.1). The sources contributing most to this increase since 1990 are emissions from “road transportation” (an increase of 62.7 percent) and public electricity and heat production (an increase of 73.6 percent) subcategories. Emissions from the “manufacture of solid fuels and other energy industries” subcategory have decreased by 1482.58 Gg CO<sub>2</sub> equivalent (83.4 percent) from 1990, mainly due to the ceasing of synthetic petrol production in 1997.

**Figure 3.1.1 Energy sector emissions 1990–2004**

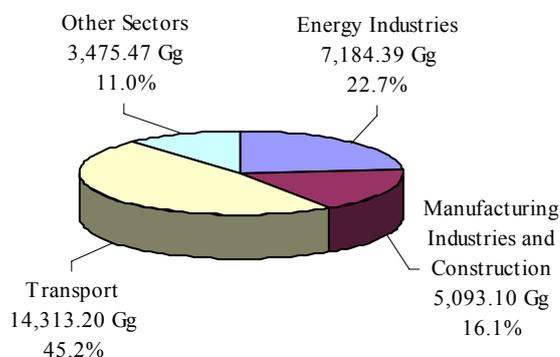


## 3.2 Fuel combustion (CRF 1.A)

### 3.2.0.1 Description

The “fuel combustion” category includes all emissions from fuel combustion activities, specifically: energy and transformation industries, manufacturing industries, transport and other subcategories – namely commercial, residential and agriculture/forestry/fisheries (Figure 3.2.1). These subcategories use common activity data sources and emission factors. Details on the activity data and emission factors are included in Annex 2. Annex 8.1 shows the calculation worksheets used for the 2004 inventory. Information about methodologies, emission factors, uncertainty and quality assurance relevant to several subcategories are discussed below.

**Figure 3.2.1 Emissions from the energy sector: fuel combustion category in 2004 (all figures Gg CO<sub>2</sub> equivalent)**



### 3.2.0.2 Methodological issues

Energy sector emissions for New Zealand's inventory are compiled from the Ministry of Economic Development (MED)'s energy database along with the relevant emission factors (Annex 2). Generally, greenhouse gas emissions are calculated by multiplying the emission factor of specific fuels by the activity data. There are only a few occasions where emission factors are unavailable due to confidentiality reasons and instances where natural gas was used as a feedstock.

The fuel combustion category is separated into two sources of emissions – stationary combustion and mobile combustion. CO<sub>2</sub> emissions from the stationary combustion of gas, solid and liquid fuels are identified as key categories for New Zealand in the 2004 inventory. The relevant good practice decision tree (Figure 2.1 in IPCC, 2000) identifies that to meet good practice, emissions should be estimated using data from sectors correcting for stored carbon and oxidation (a Tier 1 sectoral approach). New Zealand has data on fuels combusted by sector but not by plant. The methodologies used for the energy sector are consistent with the Tier 1 sectoral approach. Good practice for methodological choice in the mobile combustion (transport) category is discussed in Section 3.2.3 – Fuel combustion: transport.

#### *Emission factors*

New Zealand emission factors are based on the GCV (Gross Calorific Value). This is because energy use in New Zealand is conventionally reported in gross terms with some minor exceptions (refer Annex 2). New Zealand did commission a review of all emission factors used in the energy sector in 2003 (Hale and Twomey, 2003). In accordance with good practice, where there was a significant difference between country-specific and IPCC default emission factors, and the country-specific factors could not be supported, New Zealand reverted to the IPCC default emission factors (refer to Annex 2). The new emission factors recommended by the review and agreed by a review panel were first used in the 2002 inventory. They have been used in all subsequent inventories.

Prior to the 2002 inventory, the CO<sub>2</sub> emission factors used in inventories for the transport “category” were sourced from the New Zealand Energy Information Handbook (Baines, 1993). These are replaced with the emission factors for individual liquid fuels derived from the New

Zealand Refining Company data on carbon content and calorific values (Annex 2) as a result of the 2003 review of energy sector emission factors. When the fuel specifications of key liquid fuels are modified over time these will be noted and the emission factors altered according to the updated carbon content and the calorific values of the modified fuels.

### 3.2.0.3 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<sub>2</sub> emissions is relatively low at ±5 percent and is primarily due to uncertainty in activity data rather than emission factors (IPCC, 2000). This is due to the direct relationship between fuels' carbon content and the corresponding CO<sub>2</sub> emissions during combustion. The low level of uncertainty in CO<sub>2</sub> emissions is important as CO<sub>2</sub> emissions comprise 99.6 percent of emissions in the energy sector. Details of how uncertainty in CO<sub>2</sub> emissions is assessed are provided under each fuel type in Annex 2.

In comparison, emissions of the non-CO<sub>2</sub> gases are much less certain as they vary with the combustion conditions. Many of the non-CO<sub>2</sub> emission factors used by New Zealand are the IPCC default values and the IPCC Guidelines (1996) often do not quantify the uncertainty in the default emission factors. The uncertainties proposed in Table 3.2.1 are thought to be reasonably accurate but lack a rigorous foundation (MED, 2005).

**Table 3.2.1 General uncertainty ranges for emission estimates from fuel combustion (MED, 2005)**

| Gas              | Uncertainty |
|------------------|-------------|
| CO <sub>2</sub>  | ± 5%        |
| CH <sub>4</sub>  | ± 50%       |
| N <sub>2</sub> O | ± 50%       |
| NO <sub>x</sub>  | ± 33%       |
| CO               | ± 50%       |
| NMVOC            | ± 50%       |

## 3.2.1 Fuel combustion – Energy industries (CRF 1A1)

### 3.2.1.1 Description

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

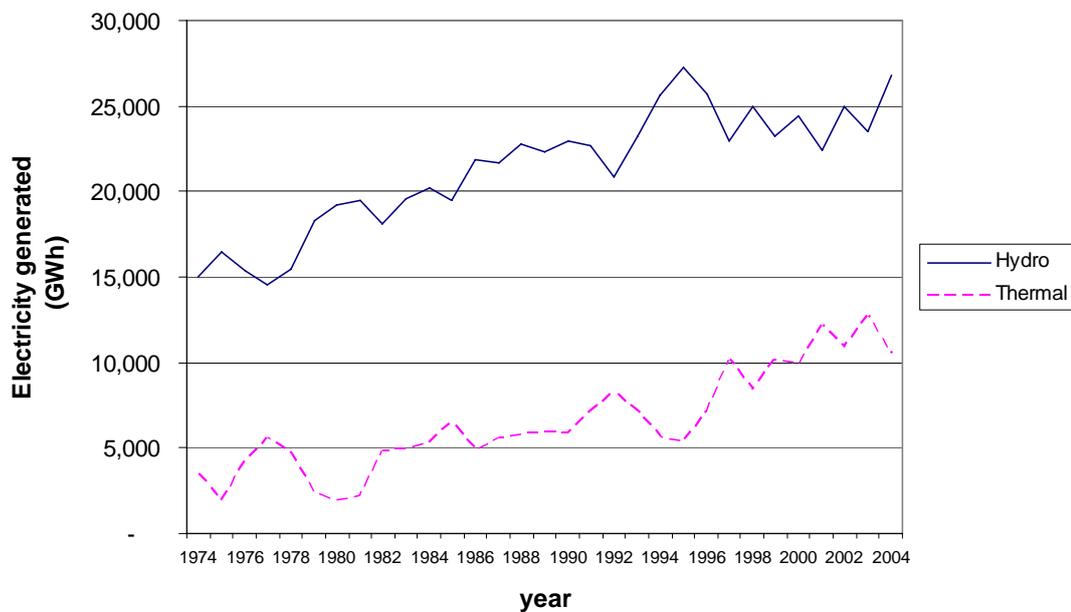
Emissions in the “energy industries” category totalled 7,184.39 Gg CO<sub>2</sub> equivalent in 2004 and have increased 1,139.42 Gg CO<sub>2</sub> equivalent (18.8 percent) since 1990. The emissions profile in 2004 is dominated by emissions from “public electricity and heat production” which contributed 84.4 percent of the CO<sub>2</sub> equivalent emissions from the “energy industries” category.

New Zealand's electricity generation is dominated by hydro-electric generation. On average, 67 percent of annual electricity needs are met by hydro-electric generation. Geothermal power contributes another 7 percent and there are also contributions from other renewable sources such as wind and co-generation using wood. The balance is provided by thermal generation using natural gas and coal.

Greenhouse gas emissions from public electricity generation show large year-to-year fluctuations because use of thermal stations complements the hydro-electric generation available. Generation in a 'normal' hydro year requires lower gas and coal use and 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 used in electricity generation found in many other countries.

Figure 3.2.2, which shows net electricity production by fuel type from 1974 to 2004, clearly illustrates that on an annual basis when the level of hydro-electric generation decreases, the level of thermal generation (gas, coal and oil) increases. It should be noted that since 1998 there has been added thermal capacity of approximately 700 MW from new gas combined cycle plants, which is mainly responsible for the rise above 10,000 GWh.

**Figure 3.2.2 Hydro-electric and thermal generation 1974–2004**



### 3.2.1.2 Methodological issues

#### *Public electricity and heat generation*

The CO<sub>2</sub> emissions from coal use in electricity generation are derived from coal use figures provided by the sole electricity generator that uses coal. The data for liquid fuel use are from the 'Delivery of Petroleum fuels by Industry' survey compiled by Statistics New Zealand (refer to Annex 2).

A large percentage of New Zealand's electricity is supplied by co-generation (otherwise 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. In accordance with

1996 IPCC guidelines, where electricity and heat production is the primary activity of the enterprise operating the co-generation plant, emissions should be included in the “manufacturing industries” category. However, where electricity generation is the primary activity the emissions should be included in the “electricity and heat production” category.

For New Zealand’s inventory the enterprise in question is taken to encompass both the industrial facility proper and the attached co-generation plant. According to this classification, there is only one plant determined to produce electricity as its primary purpose. The emissions from this plant are included under “electricity and heat production” while emissions from other co-generation plants are included under the “manufacturing industries and construction (other)” subcategory.

#### *Petroleum refining*

Energy use data for “petroleum refining” subcategory are supplied to the MED by the New Zealand Refining Company Limited. For the refinery, a weighted-average CO<sub>2</sub> emissions factor is estimated based on the fuel used. The main liquid fuel used is fuel oil and the main gas is refinery gas. As there are no data available concerning non-CO<sub>2</sub> emissions from the refinery, IPCC default (IPCC, 1996) emission factors for industrial boilers are used.

#### *Manufacturing of solid fuels and other energy industries*

The low implied emission factors (IEF’s) for “manufacturing of solid fuels and other energy industries” subcategory for gaseous fuels between 1990 and 1996 are caused by carbon sequestration in the process of producing synthetic petrol. In 1997, production of synthetic petrol in New Zealand ceased.

New Zealand has a gas field with particularly high CO<sub>2</sub> content (the Kapuni field– refer Annex 2). Most of the gas from this field is subsequently treated and the excess CO<sub>2</sub> is removed. The carbon content, and therefore the CO<sub>2</sub> emission factor, for this gas is lower for end users than when it is used by the gas field itself. Therefore the CO<sub>2</sub> implied emission factor for “manufacturing of solid fuels and other energy industries” subcategory is significantly higher than the CO<sub>2</sub> implied emission factor for typical gaseous fuels for other energy sub-categories. The sequestration of carbon in synthetic petrol made up for this difference prior to 1997.

#### *Emission factors*

CO<sub>2</sub> and non-CO<sub>2</sub> emission factors for fossil fuels are discussed in detail in Annex 2. Wood is also used for energy production. For wood consumption, the CO<sub>2</sub> emissions factor is 104.2 kt CO<sub>2</sub> /PJ. This is calculated from the IPCC default emission factors, assuming the NCV is 5 percent less than the GCV. In line with good practice (IPCC, 2000) carbon dioxide emissions from wood used for energy production are not included in the greenhouse gas emissions total.

The worksheets used for calculating emissions from the “energy industries” category are shown in Annex 8.1.

### **3.2.1.3 Uncertainties and time-series consistency**

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

### **3.2.1.4 Source-specific QA/QC and verification**

The review of energy sector emission factors (Hale and Twomey, 2003) encompassed the emission factors used in the “manufacturing industries and construction” subcategory. In

preparation of the 2004 inventory, the data for electricity production and petroleum refining underwent a Tier 1 QC checklist.

### **3.2.1.5 Source-specific recalculations**

Data revision by the MED has resulted in the minor recalculation of the “energy industries” category.

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

### **3.2.2.1 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.

Emissions in the “manufacturing industries and construction” category totalled 5,093.10 Gg CO<sub>2</sub> equivalent in 2004. The level of emissions in 2004 has reduced by 14.3 percent compared to 2003, and is 10.4 percent over the 1990 baseline. The largest single source in 2004 is the “chemicals” subcategory, made up entirely of emissions from natural gas consumption in the manufacture of methanol. Emissions from this subcategory have halved since 2002, largely due to a decline in the availability of low-priced natural gas. However, emissions still comprised 15.9 percent of emissions from “manufacturing industries and construction category”.

### **3.2.2.2 Methodological issues**

The energy data for methanol production is supplied directly to MED. CO<sub>2</sub> emissions are calculated by comparing the amount of carbon in the gas purchased by the plants with the amount stored in methanol (refer Box 3.1). The data for gas use in iron and steel-making is also supplied direct to MED. The data for other industry uses of gas are from the energy supply and demand balance tables in the Energy Data File (MED, 2005).

### Box 3.1 Calculation of CO<sub>2</sub> emissions from methanol production (MED, 2005)

#### Assumptions

- Synthetic petrol is 85.8% carbon by weight.
- Methanol is 37.5% carbon by weight.
- CO<sub>2</sub> emissions factor for Maui gas is 52.8 kt / PJ (2002) (refer Annex 2).
- CO<sub>2</sub> emissions factor for Kapuni gas is 84.1kt /PJ.
- CO<sub>2</sub> emissions factor for mixed feed gas is 62.4 kt/PJ.

The resulting calculations are:

- Weight of carbon in gas to Methanex = [(PJ Maui)\*52.8 + (PJ Kapuni)\*84.1 + (PJ mixed feed)\*62.4] \*12/44 kilotonnes.
- Weight of carbon in 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<sub>2</sub> = [(weight of carbon in gas to Methanex)-(weight of carbon sequestered)] \* 44/12 kilotonnes.

Liquid fuel data are extracted from the *Deliveries of Petroleum Fuels by Industry* survey conducted by Statistics New Zealand. Coal consumption data are determined from the New Zealand Coal Sales Survey also conducted by Statistics New Zealand. These sources of activity data are further described in Annex 2. A considerable amount of coal is used in the production of steel, however virtually all of the coal is used in a direct reduction process to remove oxygen from iron sand and not as a fuel. Emissions are therefore included in the industrial processes sector.

In the CRF tables, disaggregated activity data according to fuel types and corresponding CO<sub>2</sub> emissions have been provided for only the “iron and steel” and “chemicals” sub-categories. The reason for this is that detailed energy use statistics by industries (according to complete Australia New Zealand Standard Industrial Classification (ANZSIC) codes, similar to the International Standard Industrial Classification of All Economic Activities (ISIC) codes) are collected and reported in New Zealand for electricity consumption only. For the other energy/fuel types such as gas, liquid fuel and coal, data are collected and reported at a much more aggregated level. This is a reflection of the historical needs and practices of energy statistics collection in New Zealand. Gas use statistics by industries according to ANZSIC codes have been collected since 2001 and will be incorporated when they have been adequately verified. The subcategory “chemicals” relates to gas used by Methanex.

The worksheets used for calculating emissions from the “manufacturing industries and construction” category are shown in Annex 8.1.

### 3.2.2.3 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).

### **3.2.2.4 Source-specific QA/QC and verification**

In preparation of the 2004 inventory, the data for CO<sub>2</sub> emissions from stationary combustion – manufacturing industries and construction underwent a Tier 1 QC checklist.

### **3.2.2.5 Source-specific recalculations**

Data revision by the MED has resulted in the minor recalculation of the “manufacturing industries and construction” category.

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

### **3.2.3.1 Description**

This category comprises emissions from fuels combusted in transportation, including civil aviation, road transport, rail transport and national navigation. Emissions from international marine and aviation bunkers are reported but not included in the total emissions.

Emissions from the “transport” category totalled 14,313.20 Gg CO<sub>2</sub> equivalent in 2004 and have increased 5,456.45 Gg CO<sub>2</sub> equivalent (61.6 percent) from the 8,856.75 Gg CO<sub>2</sub> equivalent emitted in 1990. The emissions profile in 2004 is dominated by emissions from the “road transportation” subcategory which accounted for 87.2 percent of total transport emissions. CO<sub>2</sub> emissions from the “road transportation” subcategory was identified as having a major influence on the trend in New Zealand’s greenhouse gas emissions in the key category trend analysis (Table 1.5.3).

### **3.2.3.2 Methodological issues**

Emissions from transportation are compiled from the MED’s energy database. It is good practice to use a Tier 1 approach (total fuel consumed multiplied by an emission factor) for calculating CO<sub>2</sub> emissions as this provides the most reliable estimate of emissions using country-specific and IPCC default emission factors.

Activity data on the consumption of fuel by the transport sector are extracted from the *Wholesale deliveries* census conducted by Statistics New Zealand. LPG and CNG consumption figures are reported in the Energy Data file (MED, 2005).

#### *Road transport*

The Tier 1 approach has been used to calculate CO<sub>2</sub> from road transport which is consistent with good practice (IPCC, 2000). Good practice encourages the use of a Tier 2 approach for calculating emissions of CH<sub>4</sub> and N<sub>2</sub>O. However emissions from these gases are more complicated to estimate accurately because emission factors depend on vehicle technology, fuel and operating characteristics. The Ministry of Transport (MoT) has been developing a vehicle fleet model which was used as a quality check for the CO<sub>2</sub> emissions from road transport in the 2003 inventory. This model however currently is unable to provide accurate emission factors for the non CO<sub>2</sub> gases. New Zealand therefore estimates CH<sub>4</sub> and N<sub>2</sub>O emissions from road transport using a Tier 1 approach. Emission factors of CO<sub>2</sub> and non-CO<sub>2</sub> gases for various fuel types can be found in Annex 2.

#### *Navigation*

Good practice in methodology choice for navigation in New Zealand is to use a Tier 1 approach with country-specific emission factors for estimating CO<sub>2</sub> emissions and IPCC default emission factors for CH<sub>4</sub> and N<sub>2</sub>O (IPCC 2000). The current New Zealand methodology meets good practice. Prior to the 2002 inventory, New Zealand specific emission factors were used for CH<sub>4</sub> and N<sub>2</sub>O emissions from fuel oil in domestic transport. The 2003 review of emission factors recommended reverting to the IPCC default factors (Hale and Twomey, 2003).

#### *Aviation*

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

The worksheets used for calculating emissions from the “transport” category are shown in Annex 8.1.

### **3.2.3.3 Uncertainties and time-series consistency**

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

### **3.2.3.4 Source-specific QA/QC and verification**

CO<sub>2</sub> emissions from road transport and aviation are identified as key categories for New Zealand in the 2004 inventory. In preparation of the 2004 inventory, the data for these emissions underwent a Tier 1 QC checklist.

### **3.2.3.5 Source-specific recalculations**

Data revision by the MED has resulted in the minor recalculation of the “transport” category.

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

### **3.2.4.1 Description**

This sector comprises emissions from fuels combusted in the “commercial/institutional” subcategory, the “residential” subcategory and the “agriculture, forestry and fisheries” subcategory.

Emissions from fuel combustion of the “other sectors” category totalled 3,475.47 Gg CO<sub>2</sub> equivalent in 2004 and are 543.51 Gg CO<sub>2</sub> equivalent (18.5 percent) over the 1990 baseline value of 2,931.96 Gg CO<sub>2</sub> equivalent. The emissions contribution in 2004 is divided between the “commercial and institutional” subcategory (49.1 percent), and the “agriculture, forestry and fisheries” subcategory (33.7 percent), with the “residential” subcategory comprising the remaining 17.3 percent of emissions.

#### **3.2.4.2 Methodological issues**

The energy activity data are obtained from the same sources as other energy categories (Annex 2). However, in partitioning energy use between categories, emissions from the “agriculture, forestry and fisheries” subcategory are likely to be underestimated (MED, 2005). This is because there are no separate estimates of fuel use by this group, apart from liquid fuels and coal used in agriculture. However, these emissions have been included in other sectors such as industry and transport and are therefore included in New Zealand’s total emissions.

The worksheets used for calculating emissions from the “other sectors” category are shown in Annex 8.1.

#### **3.2.4.3 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).

#### **3.2.4.4 Source-specific QA/QC and verification**

In preparation of the 2004 inventory, the data for the “other sectors” category underwent a Tier 1 QC checklist as part of a selection of non-key categories chosen for quality checking. As this category is a non-key source and was not on the list of non-key categories to undergo quality checks for 2004 it did not undergo a Tier 1 quality check for this inventory submission.

#### **3.2.4.5 Source-specific recalculations**

There were no recalculations for this category.

### **3.3 Fugitive emissions from fuels (CRF 1B)**

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

##### **3.3.1.1 Description**

Fugitive emissions arise from the production, processing, transmission, storage and use of fuels, and from non-productive combustion. Fugitive emissions from the “solid fuels” category produced 311.88 Gg CO<sub>2</sub> equivalent in 2004. This is an increase of 39.75 Gg CO<sub>2</sub> equivalent (14.6 percent) from the 272.13 Gg CO<sub>2</sub> equivalent reported in 1990. New Zealand’s fugitive emissions from the “solid fuels” category are a product of coal mining operations.

Methane is created during coal formation. The amount of CH<sub>4</sub> released during coal mining is dependant on the coal rank and the depth of the coal seam. Surface mines are assumed to emit relatively little CH<sub>4</sub> compared to underground mines. In 2004, 75 percent of the CH<sub>4</sub> from coal mining (including post-mining emissions) came from underground mining. There is no flaring of CH<sub>4</sub> at coal mines and CH<sub>4</sub> is rarely captured for industrial uses. Methane is also emitted during post-mining activities such as coal processing, transportation and utilisation.

### 3.3.1.2 Methodological issues

Good practice in methodology choice for estimating fugitive emissions from coal mining is to focus on the sub-source category that dominates the emissions. New Zealand therefore focuses on estimating emissions from underground mining. The current New Zealand methodology is a Tier 1 approach using the top end of the IPCC default range in emission factors (Table 3.3.1). New Zealand continues to use a New Zealand specific emission factor for underground mining of sub-bituminous coal (Beamish and Vance, 1992). In 2004, coal production from underground mining by weight was 255 kt bituminous coal and 472 kt sub-bituminous coal. The calculation worksheets used for fugitive emissions are shown in Annex 8.1.

**Table 3.3.1 Methane release factors for New Zealand coal**

| Activity                           | Release factors (t CH <sub>4</sub> /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.

### 3.3.1.3 Uncertainties and time-series consistency

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

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

In preparation of the 2004 inventory, the data for the “solid fuels” category underwent a Tier 1 QC checklist as part of a selection of non-key categories chosen for quality checking. As this category is a non-key source, and was not on the list of non-key sources to undergo quality checks for 2004, it did not undergo a Tier 1 quality check for this inventory submission.

### 3.3.1.5 Source-specific recalculations

There were no recalculations for this category.

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

### 3.3.2.1 Description

Fugitive emissions from the “oil and natural gas” category comprised 1,269.86 Gg CO<sub>2</sub> equivalent in 2004. This is an increase of 333.66 Gg CO<sub>2</sub> equivalent (35.7 percent) from 936.20 Gg CO<sub>2</sub> equivalent in 1990.

The main source of emissions from the production and processing of natural gas is the Kapuni gas treatment plant. The plant removes CO<sub>2</sub> from a portion of the Kapuni gas (a high CO<sub>2</sub> gas

when untreated) before it enters the distribution network. Although emissions from source are not technically due to flaring, they are included under this category due to confidentiality concerns. CO<sub>2</sub> is also produced when natural gas is flared at the wellheads of other fields. The combustion efficiency of flaring is 95-99 percent (MED, 2005), leaving some fugitive emissions due to the incomplete combustion.

Fugitive emissions also occur in transmission and distribution of the natural gas. The large increase in CO<sub>2</sub> emissions for this source between 2003 and 2004 (from 367 to 601 Gg CO<sub>2</sub> equivalent) is related to the drop in methanol production. As discussed earlier, methanol production has dropped significantly since 2002. Carbon previously sequestered during this process is now being released as fugitive emissions from venting at the Kapuni Gas Treatment Plant.

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

### **3.3.2.2 Methodological issues**

The methodologies for natural gas are based on a data from field operators or calculated from supplied energy data and country-specific emission factors. This conforms to good practice in methodology choice (IPCC, 2000). The major categories are discussed further in this section. The calculation worksheets used for fugitive emissions are shown in Annex 8.1.

#### *Venting and flaring from oil and gas production*

The CO<sub>2</sub> released through flaring is either supplied directly by field operators or calculated from the supplied energy data using the emission factors from Baines (1993). The Natural Gas Corporation (NGC) supplies estimates of CO<sub>2</sub> released during processing. These values are aggregated to derive annual emissions.

#### *Gas transmission and distribution*

Gas leakage occurs almost exclusively from low-pressure 'distribution' pipelines rather than from high-pressure 'transmission' pipelines. Approximate estimates of annual leakage in 2004 from transmission pipelines, provided by NGC, are less than 25 tonnes of CO<sub>2</sub> and approximately 183 tonnes of CH<sub>4</sub> (MED, 2005). Therefore, the gas quantity shown in the worksheets excludes the gas used in electricity generation and by others that take their gas directly from the transmission network. The NGC estimates that around 3.5 percent of the gas entering the distribution system is unaccounted for and that around half of this (1.75 percent) is actually lost through leakage, whilst the other half is unaccounted for due to metering errors and theft. The split between fugitive CO<sub>2</sub> and CH<sub>4</sub> emissions is based on gas composition data.

#### *Oil transport, refining and storage*

Fugitive emissions from Oil Transport, Refining and Storage sub-categories are calculated using an IPCC Tier 1 approach with activity data and emission factors. For Oil Transport, the fuel activity data is the total New Zealand production of crude oil reported in the Energy Data File (MED, 2005), and the CH<sub>4</sub> emission factor is the midpoint of the IPCC default value range (0.745 t CH<sub>4</sub> / PJ). Emissions from refining and storage are both based on oil intake at New Zealand's single oil refinery. The CH<sub>4</sub> emission factor for refining is the same as that for transportation, while the emission factor for storage is 0.14 t CH<sub>4</sub> / PJ (a New Zealand specific

emission factor). The combined emissions factor for refining and storage is 0.885 t CH<sub>4</sub> / PJ, derived by adding the emissions factors for refining and storage together.

#### *Geothermal operations*

Estimates of CO<sub>2</sub> and CH<sub>4</sub> are obtained directly from the geothermal field operators. Analyses of the gases emitted from the geothermal fields occur on a routine basis (at least once a year) and are carried out by a single independent laboratory.

No fuel is burnt in the geothermal operations as the process harnesses the energy in tapped geothermal fluid. High pressure steam (26 bar) is used to power the main electricity-producing back pressure turbines. In some plants, the low pressure exhaust steam is then used to drive secondary (binary) turbines. The gases CO<sub>2</sub> and CH<sub>4</sub> dissolved in the geothermal fluid are released along with steam.

### **3.3.2.3 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.

### **3.3.2.4 Source-specific QA/QC and verification**

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

### **3.3.2.5 Source-specific recalculations**

Data revision by the MED has resulted in the minor recalculation of the “oil and natural gas” category.

## **3.4 Other information**

### **3.4.1 Comparison of sectoral approach with reference approach**

The calculation for the reference approach identifies the apparent consumption of fuels in New Zealand from production, import and export data. This information is included as a check for combustion related emissions (IPCC, 2000). The check is performed for all years from 1990 to 2004.

The majority of the CO<sub>2</sub> emission factors for the reference approach are New Zealand specific (Annex 2: Table A2.1). The natural gas emission factors used, which differ from year to year are estimated based on a production derived weighted average of emission factors for each of New Zealand’s gasfields. This differs from previous inventories, where the emissions factors were estimated from the sectoral approach analysis by dividing aggregated CO<sub>2</sub> emissions (including carbon later stored) by aggregate energy use.

Comparison of the reference approach and sectoral approach total in 2004 shows the reference total of CO<sub>2</sub> emissions is 1.46 percent less than the sectoral total (Table 3.4.1). This is mainly related to the differences in energy consumption, although, it is difficult to compare energy consumption in the reference approach with energy consumption in the sectoral approach.

The activity data for the reference approach are obtained from ‘calculated’ energy use figures. These are derived as a residual figure from an energy balance equation comprising production, imports, exports, stock change and international transport on the supply side from which energy use for transformation activities is subtracted. The activity data used for the sectoral approach are referred to as ‘observed’ energy use figures. These are based on surveys and questionnaires administered by Statistics New Zealand on behalf of the MED or by the MED itself. The differences between ‘calculated’ and the ‘observed’ figures are reported as statistical differences in the energy balance tables contained in the Energy Data File (MED, 2005).

The energy use and calculated emissions for the major fuel categories are not directly comparable between the reference and sectoral approaches. Firstly the reference approach counts non-energy sector use of fuels such as gas in urea production, coal in steel production and bitumen use, while 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 in the sectoral approach, combustion of refinery gas is included under gaseous fuels consumption but this is not the case in the reference approach. This is because refinery gas is a by-product of the refining process derived from the crude oil inputs. Consequently, in the reference approach the emissions from the combustion of refinery gas are counted against crude oil.

The time-series comparison with the IEA data (IEA Statistics, 2005) shows that the differences between the sectoral and reference approach reported in CRF 2004 are generally less than those reported by the IEA. There are clear differences in the early part of the time-series and there is a clear trend narrowing the difference between the two sources that indicates stronger correlation in the reporting process developed over the annual inventory preparation process.

The percentage difference between the CRF 2004 and the IEA sectoral approaches is quite large. New Zealand will endeavour to investigate why there is such a large degree of disagreement between the two series.

**Table 3.4.1 Percentage difference between the reference and sectoral approach for New Zealand's inventory and the IEA reference and sectoral comparison**

| Year | Difference between New Zealand's reference and sectoral approach (%) | Difference between the IEA reference and sectoral approach | Difference between CRF 2004 and IEA sectoral approaches |
|------|--|--|---|
| 1990 | -4.98  | 4.80   | -1.20   |
| 1991 | -2.81  |  |   |
| 1992 | -6.39  |  |   |
| 1993 | -5.01  |  |   |
| 1994 | -7.40  |  |   |
| 1995 | -3.40  | 8.45   | -8.08   |
| 1996 | 1.96   |  |   |
| 1997 | 2.46   |  |   |
| 1998 | -0.21  | 7.09   | -11.56  |
| 1999 | 2.69   | 1.05   | -12.61  |
| 2000 | -0.03  | 3.44   | -13.23  |
| 2001 | 0.68   | 2.94   | -12.64  |
| 2002 | -0.90  | -2.53  | -14.26  |
| 2003 | -0.40  | 1.30   | -6.40   |
| 2004 | 1.46   |  |   |

### 3.4.2 International bunker fuels

The data on fuel use by international transportation come from the Energy Data File (MED, 2005). This sources information from oil company returns provided to the MED. Data on fuel use by domestic transport are sourced from the "Deliveries of Petroleum Fuels by Industry" survey undertaken by Statistics New Zealand.

### 3.4.3 Feedstocks and non-energy use of fuels

The fuels supplied to industrial companies are used both as fuel and as feedstock. The emissions are calculated using the total fuel supplied to each company (this includes fuel used as feedstock) and estimating the difference between the carbon content of the fuels used and the carbon sequestered in the final output (this is based on the industry production and the chemical composition of the products). This difference is assumed to be the amount of carbon emitted as CO<sub>2</sub>. An example of the calculation for methanol is shown in Box 3.1 above. A considerable amount of coal is used in the production of steel, however virtually all of the coal is used in a direct reduction process to remove oxygen from ironsand and not as a fuel.

### **3.4.4 CO<sub>2</sub> capture from flue gases and subsequent CO<sub>2</sub> storage**

There is no CO<sub>2</sub> capture from flue gases and subsequent CO<sub>2</sub> storage occurring in New Zealand.

### **3.4.5 Country-specific issues**

Energy sector reporting shows very few areas of divergence from the IPCC methodology. The differences that exist are listed below:

- A detailed subdivision of the manufacturing and construction source category as requested by the IPCC reporting tables is currently not available due to historical needs and practices of energy statistics collection in New Zealand.
- Some gas usage data from large industrial consumers in New Zealand and some emission factors for gas have been withheld for confidentiality reasons.
- Some of the coal production activity data in the reference approach is used in steel production. The CO<sub>2</sub> emissions from this coal are accounted for under the 'industrial processes' sector and have been netted out of the energy reference approach using the "Estimating the carbon stored in products" Table (refer to Worksheet 1.1, Annex 8).
- The activity data shown in the CO<sub>2</sub> worksheets (Worksheet 1.2, Annex 8) under the sectoral approach exclude energy sources containing carbon that is later stored in manufactured products (rather than emitted during combustion), specifically methanol. This means that there is no subsequent downward adjustment required in carbon emissions and is necessary to preserve the confidentiality of the gas-use data mentioned above.
- An additional worksheet is included to cover fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> from geothermal fields where electricity or heat generation plants are in operation.

### **3.4.6 Ozone precursors and SO<sub>2</sub> from oil refining**

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

### **3.4.7 Energy balance**

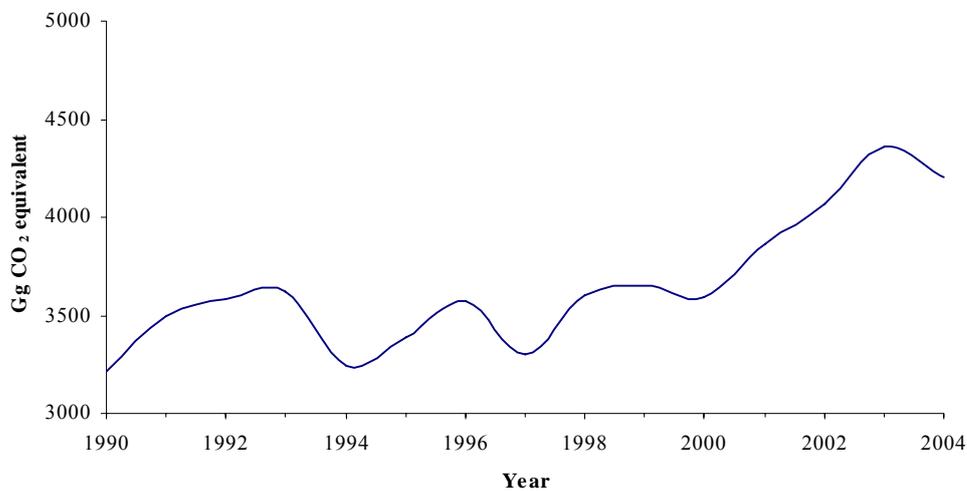
A table showing the 2004 energy supply and demand balance for New Zealand is included in Annex 2 of this report.

# Chapter 4: Industrial processes

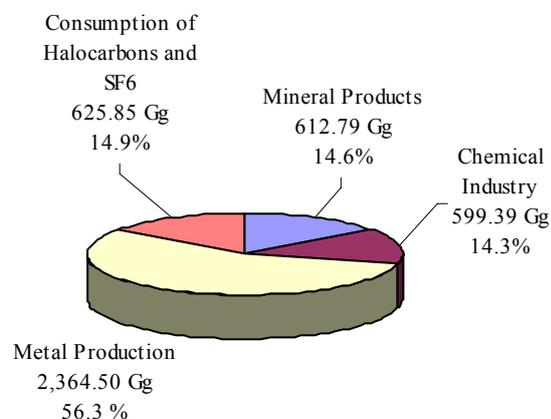
## 4.1 Sector overview

New Zealand's industrial processes sector totalled 4202.53 Gg CO<sub>2</sub> equivalent in 2004 and represented 5.6 percent of total greenhouse gas emissions. Emissions from industrial processes are now 987.92 Gg CO<sub>2</sub> equivalent (30.7 percent) above the 1990 baseline of 3214.61Gg CO<sub>2</sub> equivalent (Figure 4.1.1). The sector is dominated by emissions from the metal production category (carbon dioxide (CO<sub>2</sub>) and perfluorocarbons (PFCs)) at 56.3 percent of sectoral emissions.

**Figure 4.1.1 Industrial processes sector emissions 1990–2004**



**Figure 4.1.2 Industrial processes sector emissions in 2004 (all figures Gg CO<sub>2</sub> equivalent)**



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

New Zealand has a relatively small number of plants emitting non-energy related greenhouse gases from industrial processes. However, there are six industrial processes in New Zealand that emit significant quantities of CO<sub>2</sub> (MED, 2005);

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

The industrial processes categories use a few common data sources and emission factors. For this reason, general information about methodologies and uncertainties are included in this section as an overview.

#### **4.1.1 Methodological issues**

Emissions of CO<sub>2</sub> from industrial processes are compiled by the Ministry of Economic Development (MED) from information collected through industry survey. The results are reported in the publication *New Zealand Energy Greenhouse Gas Emissions 1990-2004* (MED, 2005).

Data on non-CO<sub>2</sub> emissions are gathered through a questionnaire distributed directly to industry via consultants contracted to the Ministry for the Environment. The questionnaire requests information on greenhouse gas emissions and production, as well as on any relationship the companies have established between the two. This information is supplemented by information from industry groups and other statistical sources. The IPCC default emission factors are applied to industry production data where no country-specific information is available. Full details of emission estimates and aggregate emission factors are included in the worksheets for this sector (Annex 8.2).

#### **4.1.2 Uncertainties**

The number of companies in New Zealand producing CO<sub>2</sub> from industrial processes is small and the emissions of CO<sub>2</sub> supplied by the companies are considered to be accurate to  $\pm 5$  percent (MED, 2005). The uncertainty surrounding estimates of non-CO<sub>2</sub> emissions is greater than for CO<sub>2</sub> emissions and varies with the particular gas and category. Uncertainty of non-CO<sub>2</sub> emissions is discussed under each category.

## 4.2 Mineral products (CRF 2A)

### 4.2.1 Description

Emissions from the “mineral products” category comprised 612.79 Gg CO<sub>2</sub> equivalent in 2004. Overall, emissions in the “mineral products” category have grown by 158.80 Gg equivalent (35.0 percent) from the 1990 level of 453.99 Gg CO<sub>2</sub> equivalent. There are no emissions of CH<sub>4</sub> or N<sub>2</sub>O from the mineral products category.

This category includes emissions produced from chemical transformations in the production of cement and lime, soda ash production and use, asphalt roofing, limestone and dolomite use, road paving with asphalt and glass production. The emissions profile is dominated by production of cement (79 percent) and lime (20 percent). For both lime and cement production, only the emissions related to the calcination process are included in this category with the emissions from the combustion of coal reported in the energy sector.

### 4.2.2 Methodological issues

#### Cement production

Since 1997, estimates of CO<sub>2</sub> emissions from cement production have been calculated by multiplying the amount of clinker produced by a plant-specific emission factor for clinker, in accordance with IPCC Tier 2 methodology (IPCC, 1996). The emission factors used are based on the CaO and MgO content of the clinker produced. Therefore, emissions from the decomposition of MgCO<sub>3</sub> into MgO and CO<sub>2</sub> are included along with emissions from the decomposition of CaCO<sub>3</sub>. Two cement companies currently operating in New Zealand take account of CO<sub>2</sub> emissions from non-recycled cement kiln dust.

For the years 1990 to 1997, emissions are calculated using a Tier 1 approach. Total cement production is multiplied by a country-specific emission factor (0.51 t CO<sub>2</sub> / t cement). Clinker data, which is required for the Tier 2 approach, cannot be provided by the companies for the years 1990-1996. Clinker data was recorded by the companies from 1997-2004 so the Tier 2 approach has been able to be implemented for this time period. The use of both Tier 1 and Tier 2 approaches for this time series is unavoidable as this the only dataset on CO<sub>2</sub> emissions from cement production available in New Zealand.

The cement production activity data in the CRF reporter shows an increase from 1996-2004 however the CO<sub>2</sub> implied emission factor for cement production has decreased over the same period. After 1996 the demand for cement in New Zealand increased. The local cement companies had to import clinker to meet this demand. CO<sub>2</sub> emissions from cement production using the Tier 2 approach are only calculated from locally produced clinker (IPCC, 2000). The decrease in the CO<sub>2</sub> implied emission factor can be explained by the increase in cement production over the period 1997-2004 while the CO<sub>2</sub> emissions have remaining relatively steady due to the increase in imported clinker and a change in national standards for cement production (reducing the relative levels of clinker required to produce a given amount of cement).

SO<sub>2</sub> is emitted in small quantities from the cement making process. The amount of SO<sub>2</sub> is determined by the sulphur content of the raw material (limestone). The IPCC guidelines (IPCC, 1996) report that 70-95 percent of the SO<sub>2</sub> will be absorbed by the alkaline clinker product. New

Zealand uses a SO<sub>2</sub> emissions factor calculated using industry specific information. This emission factor has been updated with improved information from industry available during 2005. The emission factor was able to be calculated using information from a sulphur mass balance study on one company's dry kiln process. This was able to determine the split between sulphur originated in the fuel and sulphur in the raw clinker material as sodium and potassium salts. The average emission factor is calculated as 0.64 kg SO<sub>2</sub>/t clinker and is weighted to take into account the relative activity of the two cement companies.

### **Lime production**

There are three companies in New Zealand which make up the lime industry. Carbon dioxide emissions from lime production are supplied to the Ministry of Economic Development by industry. Emissions are calculated by multiplying the amount of lime produced by an emission factor. Prior to 2002, a single New Zealand specific emission factor based on the typical levels of impurities in the lime produced in New Zealand was applied to all lime. This is the only available information available for this source for the years 1990-2001. From 2002, the emission factors used were plant-specific as the companies were able to supply this information for these more recent years. There has been little change to the implied emission factor – from 0.72 t CO<sub>2</sub> / t lime in 2001 to 0.73 t CO<sub>2</sub> / t lime from 2002 to 2004.

The SO<sub>2</sub> emissions emitted during lime production vary depending on the processing technology and the input materials. An industrial processes survey undertaken in 2005 resulted in an updated value for the average SO<sub>2</sub> emission factor. The average emission factor is 0.48 kg SO<sub>2</sub>/t lime and is weighted to take sulphur measurements at the various lime plants into account.

### **Limestone and dolomite use**

All limestone use in New Zealand is used for making lime or cement. Therefore emissions arising from these processes are reported under the cement and lime production categories as specified in the IPCC 1996 guidelines (section 2.5.1).

### **Soda ash production and use**

There is no soda ash production in New Zealand. A survey of the industrial processes sector in 2005 was able to make some estimates of carbon dioxide emissions resulting from the use of soda ash in glass production after consultation with the sole glass manufacturer in New Zealand. The manufacturer was able to provide information on the amount of imported soda ash it utilised in 2005. It also provided approximate proportions of recycled glass over the last 10 years to enable back calculations because the soda ash amount is in fixed proportion to the production of new (rather than recycled) glass. Linear extrapolation of activity data from 1990 to 1995 was carried out in the absence of actual data. The IPCC default emission factor of 415 kg CO<sub>2</sub> per tonne of soda ash is applied to calculate the CO<sub>2</sub> emissions.

### **Asphalt roofing**

There is only one company manufacturing asphalt roofing in New Zealand. Emissions are calculated using activity data supplied by the company. The industrial processes survey undertaken in 2005 revealed an updated estimation of activity data for this source. The data has been updated and back calculated for the entire time series. Emission factors for NMVOC and CO are from the IPCC Guidelines (IPCC, 1996).

## Road paving with asphalt

Data on emission rates and bitumen production are provided by the three main road paving companies. Estimates of national consumption of bitumen for road paving are confirmed by the New Zealand Bitumen Contractors Association. In New Zealand, approximately 40 percent of the bitumen used for road paving is used for asphalt and 60 percent is for chip-seal resealing. Solvents are rarely added to asphalt, so asphalt paving is not considered a significant source of emissions. The main emissions from the road paving industry are from chip-seal resealing. New Zealand still uses a wet 'cut-back' bitumen method rather than bitumen emulsions common in other countries. The average solvent content in bitumen has been reducing in recent years as methods of laying bitumen have improved (CRL Energy Ltd, 2006).

The IPCC Guidelines (1996) make no reference to cut-back bitumen but do provide default emission factors for the low rates of SO<sub>2</sub>, NO<sub>x</sub>, CO and NMVOC emissions from the 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. Since the bitumen content of asphalt in New Zealand is only 6 percent, there is no possibility of this level of NMVOC emissions. For the 2002 inventory, the New Zealand Bitumen Contractors Association provided the methodology shown in Box 4.1 for calculating the total NMVOC emissions from the use of solvents in the roading industry.

The industrial processes survey undertaken in 2005 showed that the fraction of weight of bitumen used to produce chip-seal has been changing over recent years as methods of laying bitumen have improved. From 1990 to 2001 the fraction by weight of bitumen used to produce chip-seal was 0.80. From 2002 to 2003 it was 0.65 and in 2004 the fraction was 0.60. The emissions of NMVOCs in the CRF have been updated for the time-series to reflect this changing fraction.

### Box 4.1 Calculation of NMVOC emissions from road paving asphalt

$$\text{NMVOC emitted} = A \times B \times C \times D$$

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 only one major glass manufacturer in New Zealand. The IPCC Guidelines (1996) report that NMVOC may be emitted from the manufacture of glass and provide a default emissions factor of 4.5 kg NMVOC per tonne of glass output. The industrial processes survey undertaken in 2005 was able to obtain estimates of CO<sub>2</sub> from soda ash use (see soda ash paragraph above) and SO<sub>2</sub> emissions from sodium sulphate decomposition. It has been assumed that the IPCC emissions factor is based on total glass production which includes recycled glass input. Activity data has been updated with estimates for years prior to 1995 extrapolated. NO<sub>x</sub> and CO emissions are assumed to be associated with fuel use while NMVOC and SO<sub>2</sub> emissions are assumed to be associated with the industrial process because they are associated with the raw materials.

### 4.2.3 Uncertainties and time-series consistency

Uncertainties in CO<sub>2</sub> emissions are assessed as  $\pm 5$  percent as discussed in section 4.1.2. Uncertainties in non-CO<sub>2</sub> emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy Ltd, 2006).

**Table 4.2.1 Uncertainty in non-CO<sub>2</sub> emissions from the mineral products industry**

| Product                  | Uncertainty in activity data           | Uncertainty in emission factors   |
|--------------------------|--|---|
| Cement                   | 0%                                     | $\pm 40\%$  |
| Lime                     | $\pm 1\%$                              | $\pm 80\%$  |
| Asphalt roofing          | $\pm 30\%$ ( $\pm 50\%$ for 1990–2000) | $\pm 40\%$  |
| Road paving with asphalt | $\pm 10\%$                             | $\pm 15\%$ (chip-seal fraction and solvent emission fraction) to $\pm 25\%$ (solvent dilution). |
| Glass                    | 0%                                     | NMVOC: $\pm 50\%$<br>SO <sub>2</sub> : $\pm 10\%$   |

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

CO<sub>2</sub> emissions from cement production has, in past inventories, been identified as a key source category. In the 2004 inventory, CO<sub>2</sub> from cement production was not identified as a key source category (level assessment) but was in 1990. In preparation of this inventory, the data for these emissions underwent Tier 1 QC checks.

In the process of compiling non-CO<sub>2</sub> emissions, activity data are double checked with industry experts where possible to verify the data. The small number of companies in this category facilitates the complete coverage of the category.

### 4.2.5 Source-specific recalculations

The inclusion of estimates of CO<sub>2</sub> arising from the use of soda ash in the glass production industry has been included for the first time in the 2004 inventory for all years from and including 1990. This has resulted in CO<sub>2</sub> emissions attributed to the mineral products category being recalculated for the entire time series.

## 4.3 Chemical industry (CRF 2B)

### 4.3.1 Description

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

Emissions from the chemical industry category comprised 599.39 Gg CO<sub>2</sub> equivalent emissions in 2004 and have increased 154.03 Gg CO<sub>2</sub> equivalent (34.6 percent) from the 445.37 Gg CO<sub>2</sub>

equivalent estimated in 1990. CO<sub>2</sub> emissions from ammonia/urea production account for 68.3 percent of emissions in this category.

### **4.3.2 Methodological issues**

#### **Ammonia/urea**

Ammonia is manufactured in New Zealand by the catalytic steam reforming of natural gas at New Zealand's sole ammonia/urea plant. The total amount of gas supplied to the plant is provided to the MED by the firm operating the plant. CO<sub>2</sub> emissions are calculated based on the assumption that all of the carbon in the gas used to produce the urea is eventually released. Emissions are calculated by multiplying the quantities of the different types of gas used by their respective emission factors (Annex 2.3). 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.

For the 2004 inventory emissions from urea production have been allocated to the "ammonia production" category. This was recommended in the review of New Zealand's 2003 inventory. In the 2003 inventory they were reported under a country-specific category "urea production".

Non-CO<sub>2</sub> emissions are considered by industry experts to all be arising from fuel combustion and are covered in the energy sector.

#### **Formaldehyde**

Formaldehyde is produced at five plants in New Zealand. NMVOC emissions are calculated from company supplied activity data and a country-specific emission factor of 1.5 kg NMVOC/t of product. Emissions of CO and CH<sub>4</sub> were undetectable for at least two plants representing 60 percent of total formaldehyde production.

#### **Methanol**

Methanol is produced at two plants in New Zealand. The process to calculate CO<sub>2</sub> emissions is shown in Box 3.1 (energy sector: manufacturing industries and construction). Emissions are reported in the energy sector.

The major non-fuel related emissions from the process are NMVOCs. Emissions are calculated from company supplied activity data and emission factors. The NMVOC emissions factor was estimated in 2001 from American Petroleum Institute methods for calculating vapour emissions from storage tanks. NO<sub>x</sub> and CO emission factors were measured in 1999. It is assumed the IPCC default factor for CH<sub>4</sub> (2g CH<sub>4</sub>/kg production) is appropriate for New Zealand (CRL Energy Ltd, 2006).

#### **Fertiliser**

Superphosphate is produced by two companies (each with three plants) in New Zealand. Most of these plants produce sulphuric acid as a first step while one plant now imports acid. Both companies have supplied activity data and emission factors for sulphur dioxide (SO<sub>2</sub>). Sulphur dioxide is the only indirect greenhouse gas emitted from the production of superphosphate fertiliser. The majority of these emissions are released during sulphuric acid production. No reference is made to superphosphate production in the IPCC Guidelines (1996). A default emissions factor of 17.5 kg SO<sub>2</sub> (range of 1 to 25) per tonne of sulphuric acid is recommended but it is assessed by New Zealand industry experts to be a factor of two to ten times too high for

the New Zealand industry. Emission estimates are therefore based on industry supplied emission factors and activity levels. Checks were made between the supplied emission factors for superphosphate and one set was identified as an outlier. The SO<sub>2</sub> emission factor for the other company was assessed to be appropriate for both companies' superphosphate output.

## Hydrogen

Emissions of CO<sub>2</sub> from hydrogen production are supplied directly to the MED from the two companies involved. Most hydrogen produced in New Zealand is made by the New Zealand Refining Company as a feedstock at the Marsden Point refinery. Another firm produces a small amount which is converted to hydrogen peroxide. The hydrogen is produced from CH<sub>4</sub> and steam. CO<sub>2</sub> is a by-product of the reaction and is vented to the atmosphere. The implied emission factor is 6.45 kt CO<sub>2</sub> per kt of hydrogen produced (MED, 2005).

### 4.3.3 Uncertainties and time-series consistency

Uncertainties in CO<sub>2</sub> emissions are assessed as  $\pm 5$  percent as discussed in section 4.1.2. Uncertainties in non-CO<sub>2</sub> emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy Ltd, 2006). These are documented in Table 4.3.1.

**Table 4.3.1 Uncertainty in non-CO<sub>2</sub> emissions from the chemical industry**

| Product       | Uncertainty in activity data                           | Uncertainty in emission factors   |
|---------------|--|---|
| Ammonia /Urea | $\pm 0\%$  | $\pm 30\%$  |
| Formaldehyde  | $\pm 2\%$  | $\pm 50\%$ (NMVOCs)   |
| Methanol      | 0%   | $\pm 50\%$ (NO <sub>x</sub> and CO)<br>$\pm 30\%$ (NMVOCs)<br>$\pm 80\%$ (CH <sub>4</sub> ) |
| Fertiliser    | $\pm 10\%$ sulphuric acid<br>$\pm 10\%$ superphosphate | $\pm 15\%$ sulphuric acid<br>$\pm 25$ to $\pm 60\%$ superphosphate<br>(varies per plant)    |

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

This category was checked in 2003 as part of quality control checks of non key categories so was not included in the schedule of non key categories to be checked in the 2004 inventory.

### 4.3.5 Source-specific recalculations

Ammonia was allocated from a country-specific category created during the 2003 inventory "urea production" to the "ammonia production" category as recommended by the international review team (UNFCCC, 2006).

Activity data has been estimated for all years for formaldehyde and EF for NMVOCs changed from IPCC default to a country-specific one (1.5 kg NMVOC/tonne formaldehyde).

## 4.4 Metal production (CRF 2C)

### 4.4.1 Description

The metal production category reports emissions from the production of iron and steel, ferroalloys, aluminium and the SF<sub>6</sub> used in aluminium and magnesium foundries. The major metal production activities occurring in New Zealand are the production of iron, steel and aluminium. These sources are both key source categories for New Zealand (Table 1.5.2). PFC emissions from aluminium production are a key category in the trend analysis (Table 1.5.3). New Zealand has no production of coke, sinter or ferroalloys.

Emissions from the “metal production” category rose 2.5 percent from the 2,305.79 Gg CO<sub>2</sub> equivalent recorded in 1990. CO<sub>2</sub> emissions account for 96.6 percent of emissions in this category with another 3.4 percent from PFCs. In 2004, the level of CO<sub>2</sub> emissions has increased by 496.48 Gg CO<sub>2</sub> equivalent (27.8 percent) over the 1990 baseline. However, the level of PFCs has decreased from the 515.60 Gg CO<sub>2</sub> equivalent in 1990 to 80.70 Gg CO<sub>2</sub> equivalent in 2004, a decrease of 434.90 Gg CO<sub>2</sub> equivalent (84.3 percent).

The decrease in PFC emissions is because the sole aluminium smelter in New Zealand now has a low anode effect duration by world standards. Anode effects are caused by depletion of alumina. The modern technology now in use introduces alumina into the pot quickly and extinguishes the anode effect. The smelter feeds alumina in relatively large quantities by modern standards (50 kg per feed compared to 2 kg per feed).

### 4.4.2 Methodological issues

#### Iron and steel

New Zealand calculates emissions from iron and steel manufacture based on the quantities of the reducing agents used and the quantities of other non-fuel carbon-bearing ingredients used in the process such as electrodes. An allowance is made for the carbon sequestered in the steel.

There are two steel producers in New Zealand. The smaller plant, which produces approximately 200 kt of steel a year, operates an electric arc furnace, turning scrap metal into steel. As this plant does not perform the operation of turning iron-ore into iron, emissions from this plant are comparatively small – less than 25kt of CO<sub>2</sub> emissions per year. The other much larger steel plant produces steel from titanomagnetite ironsand and therefore produces the bulk of the emissions. A direct reduction process is used to smelt iron, where the primary reducing agent is sub-bituminous coal rather than coke, as in the traditional blast furnace method of smelting. The emission factor applied to the sub-bituminous coal used as a reducing agent is 93.7 kt CO<sub>2</sub> / PJ. This emission factor is calculated based on the specific characteristics of the coal the plant uses. The molten pig-iron is converted to steel in a KOBM oxygen steel making furnace. Prior to 1998, the plant also melted over 100,000 t per year of scrap in an electric arc furnace.

New Zealand uses a modification of the Tier 2 approach for calculating emissions from iron and steel production. Firstly, New Zealand does not account for emissions from pig iron and steel production separately as all of the pig iron is transformed into steel. Secondly, the carbon in the ironsand, thought to be negligible, is not accounted for. Thirdly, due to lack of data, the carbon in the scrap metal consumed by the largest steel plant when it operated an electric arc furnace is not accounted for, although this omission should also have a negligible effect on emissions

estimates. Finally, also due to a lack of data, for the years prior to 2000, emissions from the plant operating the electric arc furnace 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 (around 0.1 t CO<sub>2</sub> / t steel). The Ministry of Economic Development advises this should not have a large effect on total iron and steel emissions, given emissions from this plant are small.

Care has been taken not to double-count coal use for steel-making in the energy-sector as well as the industrial processes sector. New Zealand energy statistics for coal are disaggregated into coal used in steel making and coal used in other industries and sectors.

The non-CO<sub>2</sub> emission factors are based on measurements in conjunction with mass balance (for SO<sub>2</sub>) and technical reviews (CRL Energy Ltd, 2006).

## **Aluminium**

CO<sub>2</sub> emissions and production data are supplied by New Zealand's sole aluminium smelter. The technology type used on site is Centre Work Pre Bake (CWPB). Carbon anode oxidation is responsible for almost 90 percent of the CO<sub>2</sub> emissions from aluminium production. The carbon consumption is multiplied by 3.812 to convert C to CO<sub>2</sub> (as compared with 3.666 if the standard atomic weights ratio of 44/12 is used). This number is specific to Comalco smelters to take into account some other process losses (Bloor, 2005). Other emissions come from fuel combustion (various fuels are used-heavy fuel oil, LPG, petrol and diesel) and are included in the energy sector (MED, 2005; Bloor, 2005).

The IPCC default emission factor is used for NO<sub>x</sub> emissions. Plant specific emission factors are used for CO and SO<sub>2</sub>. An industry supplied value of 110 kg CO per tonne (IPCC range 135–400 kg CO per tonne) is based on measurements and comparison with Australian CO emission factors. SO<sub>2</sub> emissions are calculated from the input sulphur levels and direct monitoring.

Emissions of the two PFCs (CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub>) from the production of aluminium are supplied by the operator of New Zealand's sole aluminium smelter. The PFC emissions from aluminium smelting are calculated using a Tier 2 method. This involves using the IPCC default coefficients for Centre Worked Prebake technology in the slope equation together with smelter-specific operating parameters. Anode effect frequency is multiplied by duration. The smelter captures every anode effect both in terms of count and of duration through its process control software. All monitoring data are logged and stored electronically, with no data estimated, to give the value known as "anode effect minutes per cell day". This value is then multiplied by the hot metal tonnes and the slope factor to provide an estimate of CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emissions. The IPCC default slope coefficients of 0.14 and 0.018 for Centre Worked Pre Bake technology are used. The smelter advises that there are no plans by the smelter company to directly measure PFC emissions in the future so a smelter specific long term relationship between measured emissions and operating parameters is not likely to be established in the near future.

## **Other metal production**

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<sub>x</sub>, CO and SO<sub>2</sub>) 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<sub>2</sub> 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 inventory for 2004.

### 4.4.3 Uncertainties and time-series consistency

Uncertainty in CO<sub>2</sub> emissions is assessed as ± 5 percent as discussed in section 4.1.2. Uncertainties in non-CO<sub>2</sub> emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy Ltd, 2006). These are documented in Table 4.4.1.

**Table 4.4.1 Uncertainty in non-CO<sub>2</sub> emissions from the metal industry**

| Product        | Uncertainty in activity data | Uncertainty in emission factors  |
|----------------|------------------------------|--|
| Iron and steel | 0%                           | ± 20–30% (CO)<br>± 70% (NO <sub>x</sub> )  |
| Aluminium      | 0%                           | ± 5% (SO <sub>2</sub> )<br>± 40% (CO)<br>± 50% (NO <sub>x</sub> )<br>± 30% (PFCs) <sup>1</sup> |

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

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

CO<sub>2</sub> emissions from iron and steel production and aluminium production are key categories for New Zealand. These sources have undergone a Tier 1 QC check in preparation of the 2004 inventory.

### 4.4.5 Source-specific recalculations

There are no source specific recalculations performed for this category for this inventory 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 2004, emissions from this category totalled 7.14 Gg NMVOC. This was an increase of 1.24 Gg NMVOCs since 1990.

## 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.

Mechanical pulp production in 2004 was responsible for 54 percent of all pulp production with chemical production responsible for 46 percent. 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 because using the IPCC default factors appears likely to significantly over-estimate emissions in the New Zealand context. In absence of better information the NMVOC emission factor applied to the chemical pulping processes is also applied to the thermomechanical pulp processes to estimate the emissions from that source (CRL Energy Ltd, 2006). Emissions of CO and NO<sub>x</sub> from these processes are more likely to be fuel combustion related.

### Food and drink

NMVOC are produced during the fermentation of cereals and fruits in the manufacture of alcoholic beverages. They are also produced during all processes in the food chain which occur after the slaughtering of animals or harvesting of crops. Estimates of emissions 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.

## 4.5.3 Uncertainties and time-series consistency

Uncertainties in non-CO<sub>2</sub> emissions are assessed by the contractor from the questionnaires and correspondence with industry sources (CRL Energy Ltd, 2006). These are documented in Table 4.5.1.

**Table 4.5.1 Uncertainty in non-CO<sub>2</sub> 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**

No specific QA/QC activities are performed for this category. However, where possible, activity data are cross-referenced between companies and industry associations to verify the data.

#### **4.5.5 Source-specific recalculations**

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

### **4.6 Production of halocarbons and SF<sub>6</sub> (CRF 2E)**

New Zealand does not manufacture halocarbons and SF<sub>6</sub>. Emissions from consumption are reported under section 4.7

### **4.7 Consumption of halocarbons and SF<sub>6</sub> (CRF 2F)**

#### **4.7.1 Description**

Emissions from hydrofluorocarbons (HFCs) totalled 625.85 Gg CO<sub>2</sub> equivalent in 2004. This is an increase of 462.84 Gg CO<sub>2</sub> equivalent (283.9 percent) from the 1995 level of 163.01 Gg CO<sub>2</sub> equivalent. This large increase is due to the replacement of CFCs and HCFCs with HFCs. HFC emissions are identified as a key category in the level and trend analysis of the 2004 inventory (Tables 1.5.2 and 1.5.3). SF<sub>6</sub> emissions have increased from 12.14 Gg CO<sub>2</sub> equivalent in 1995 to 21.49 Gg CO<sub>2</sub> equivalent in 2004, an increase of 77.0 percent.

HFCs and PFCs are used in a wide range of equipment and products from refrigeration systems to aerosols. No HFCs or PFCs are manufactured within New Zealand, however PFCs are produced from the aluminium smelting process (discussed in the metal production category). The use of HFCs/PFCs 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 source categories:

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

The emissions inventory for SF<sub>6</sub> is broken down into two source categories: electrical equipment and 'other'. In New Zealand, one electricity company accounts for 80-90 percent of the charge of SF<sub>6</sub> used in electrical equipment.

## **4.7.2 Methodological issues**

### **HFCs/PFCs**

Information on bulk imports of HFCs and PFCs each year is based on data supplied by the Ministry of Economic Development. This information is derived from an annual survey of all importers and distributors of these chemicals. In past surveys (up until 2001), the Ministry of Economic Development had compiled a detailed breakdown of bulk HFCs using information from import licences for a range of mixtures that included HFCs and PFCs. This analysis has not been carried out for four years. Consequently there is no longer an accurate independent check on the total imports reported by bulk chemical suppliers.

Activity data was collected directly from importers and distributors to identify the end users of imported bulk HFCs and PFCs. This information was used to determine the proportion of bulk chemical used in each sub-source category.

Several additional importers were identified for this survey compared to the previous survey carried out in 2004. The New Zealand methodology follows the IPCC Tier 2 approach which accounts for the time lag between consumption and emissions of the chemicals. A summary of calculation methods and emission factors for HFCs is included in Table 4.7.1.

Potential emissions for HFCs and PFCs have been calculated using the Tier 1b approach. Due to a lack of disaggregated HFC data for refrigeration, potential emissions from refrigeration could not be calculated for each specific HFC chemical and as a result the total potential emissions for consumption of halocarbons are underestimated.

**Table 4.7.1 Halocarbon and SF<sub>6</sub> calculation methods and emission factors**

| HFC source                                | Calculation method       | Emission factor  |
|---|--------------------------|--|
| Aerosols                                  | IPCC GPG 2001 Eqn 3.35   | IPCC default factor of 50% of the initial charge per year  |
| Foam                                      | IPCC GPC 2001 Table 3.17 | IPCC default factor of 10% initial charge in first year and 4.5% annual loss of initial charge over an assumed 20 year lifetime  |
| Mobile air conditioning                   | IPCC GPG 2001 Eqn 3.44   | Top-down approach does not require emission factors  |
| Stationary refrigeration/air conditioning | IPCC GPG 2001 Eqn 3.40   | Top-down approach does not require emission factors  |
| Fire protection                           | IPCC GPG 2001 Eqn 3.51   | Bottom-up approach using emission rate of 0.015  |
| SF <sub>6</sub> source                    | Calculation method       | Emission Factor  |
| Electrical equipment                      | IPCC GPG 2001 Eqn 3.17   | Tier 3 approach based on overall consumption and disposal with country-specific EF of 1% and this was supplemented by information from equipment manufacturers and servicing contractors using IPCC default EF of 2% (Tier 2b approach). |
| Other applications                        | IPCC GPG 2001 Eqn 3.22   | No emission factor required as 100% is emitted within two years  |

## Aerosols

Activity data on aerosol usage are provided by the only New Zealand aerosol manufacturer using HFCs and the Aerosol Association of Australia/New Zealand. The New Zealand manufacturer also provided activity data on annual HFC use, domestic and export sales and product loading emission rates. Data on the total number of doses contained in Metered Dose Inhalers (MDIs) used from 1999 to 2004 are provided by the sole New Zealand supplier. The weighted average quantity of propellant per dose was calculated from information supplied by industry. There were no HFCs used in aerosols prior to 1996 and HFC-134a was not used in metered dose inhalers (MDIs) before 1995.

## 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 Ltd, 2006a).

## Foam

The survey revealed one New Zealand manufacturer importing HFCs for foam blowing and some of the products are exported overseas for use in refrigeration manufacture. There is insufficient data to estimate the proportion of HFC emissions exported (CRL Energy 2006a). The manufacturer started HFC usage in 2000. From 2000 to 2003 the HFC used was HFC 134a. From 2004, a mixture of HFC-245fa/365mfc has been imported for use.

## Stationary refrigeration/air conditioning

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

The amount of new refrigerant used to charge all other equipment (which is 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 minus 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.

In terms of household refrigeration it is estimated that on average there are about 2.2 refrigerators and freezers per household in New Zealand (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. In most cases these types of systems are assembled and charged on site, although some imported units may already be pre-charged. Self-contained commercial equipment includes frozen food display cases, reach-in refrigerators and freezers, beverage merchandisers and vending machines.

New Zealand uses a top down Tier 2 approach and country-specific data to obtain HFC emissions from stationary refrigeration and air conditioning (IPCC equation 3.40, IPCC, 2001).

### **Mobile air conditioning (MAC)**

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

New Zealand uses the Tier 2 top down approach (IPCC equation 3.44, IPCC, 2001). First-fill emissions are calculated from vehicle fleet numbers provided by the New Zealand Transport Registry Centre and assumptions made on the percentage MAC installations. Operation and disposal data are obtained from industry survey and the New Zealand Transport Registry Centre.

### **Fire protection**

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

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

The method selected for estimating emissions from this sub-source category is the bottom-up approach. For each year, an emission rate of 1.5 percent is applied to the total amount of HFC installed to get annual HFC-227ea emissions.

## SF<sub>6</sub>

Actual and potential emissions of SF<sub>6</sub> result primarily from the use of SF<sub>6</sub> in electrical switchgear. For the 2004 inventory, emissions are calculated using the Tier 3c approach for the majority of electrical switchgear emissions and supplemented by information from equipment manufacturers and servicing contractors. One firm representing 80-90 percent of the total SF<sub>6</sub> held in equipment provided sufficient information for the Tier 3 approach. A Tier 2b approach was taken for the rest of the industry. SF<sub>6</sub> questionnaires were sent to the two importers of SF<sub>6</sub> and New Zealand's main users of SF<sub>6</sub>, the electricity transmission, generation and distribution companies (CRL Energy Ltd, 2006a). Potential emissions of SF<sub>6</sub> were calculated and included in the 2004 inventory.

### 4.7.3 Uncertainties and time-series consistency

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

**Table 4.7.2 Uncertainties in HFC/PFC calculations (from CRL Energy Ltd, 2006a)**

| HFC source                                | Uncertainty estimates  |
|---|--|
| Aerosols                                  | ±56% for aerosol imports, ±60% in locally manufactured aerosols and ±10% from emissions from MDIs.   |
| Solvents                                  | Not occurring.   |
| Foam                                      | ±50% in activity level and ±50% in emission factors.   |
| Stationary refrigeration/air conditioning | ±10% on total HFC/PFC imported and in locally charged equipment.<br>±30% in factory charged equipment.<br><br>±28% in total HFC/PFC proportion used for charging new commercial refrigeration units. |
| Mobile air conditioning                   | Combined uncertainty ±43%.   |
| Fire protection                           | Combined uncertainty ±32%.   |
| SF <sub>6</sub> source                    | Uncertainty estimates  |
| Electrical equipment                      | Combined uncertainty ±20%.   |
| Other applications                        | ±30% for tracer usage activity data.<br><br>±50% for medical use activity data.  |

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

In preparation of the 2004 inventory, the data for consumption of halocarbons and SF<sub>6</sub> underwent a Tier 1 QC check. During the collection and calculation of data, activity data provided by industry are verified against national totals where possible and unreturned questionnaires and anomalous data are followed up and verified to ensure an accurate record of activity data.

### **4.7.5 Source-specific recalculations**

The 2005 survey for industrial processes was redesigned for HFCs from stationary refrigeration and air conditioning to capture more importers of HFCs and PFCs and to better identify the refrigerant associated with imported and exported factory charged refrigeration and air-conditioning units. This has resulted in HFC and PFC emissions higher (up to 3.6 times higher) than in previous inventory submissions. The approach used is assessed by industry experts to represent an upper limit for HFC/PFC emissions from commercial refrigeration and air conditioning but is the most accurate and complete data available. This survey has resulted in HFC and PFC emissions for this category being recalculated for the entire time series.

SF<sub>6</sub> data has been updated for the years 1991–1992 and 2000–2003.

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

# Chapter 5: Solvent and other product use

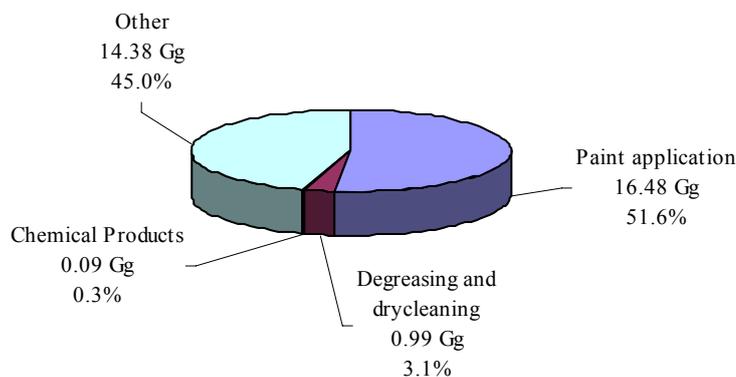
## 5.1 Sector overview (CRF 3)

Solvents and related compounds are a significant source of emissions of NMVOC. Some solvents have been banned under the Montreal Protocol and there is an international trend away from solvent use in paints towards water-based (acrylic) paints.

This sector includes emissions from chemical cleaning substances used in dry cleaning, printing, metal degreasing and a variety of industrial and household uses. Also included are emissions from paints, lacquers, thinners and related materials. Emissions arise from the evaporation of the volatile chemicals when solvent based products are exposed to air.

Emissions from the solvents and other product use sector in 2004 comprised 31.94 Gg of NMVOC. This is an increase of 4.23 Gg (15.2 percent) from 27.71 Gg in 1990. The categories dominating the sector are NMVOC emissions from paint application and domestic and commercial use (Figure 5.1.1).

**Figure 5.1.1 Emissions of NMVOC from the solvent and other product use sector in 2004 (all figures Gg NMVOC)**



In 2004, N<sub>2</sub>O emissions from anaesthesia use totalled 0.16 Gg N<sub>2</sub>O or 48.36 Gg CO<sub>2</sub> equivalent. This is a small increase on 1990 emissions from anaesthesia which totalled 0.13 Gg N<sub>2</sub>O.

### 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 (due to quality and price reasons).

## **5.1.2 Methodological issues**

The IPCC revised guidelines (IPCC, 1996) do not provide detailed methodologies for emissions from solvents and other product use. It does however document two basic approaches for estimating emissions: consumption and production-based estimates. 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. Information is obtained via a survey of industry and industry organisations (CRL Energy Ltd, 2006). Worksheets for the solvents and other products sector are included in Annex 8.3.

Emission factors are developed based on the likely ultimate 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 four categories of solvents and other products specified in the CRF are detailed below.

### **Paint application**

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

### **Degreasing and dry cleaning**

Most drycleaners in New Zealand use perchloroethylene and a few 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 drycleaning 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 information is supplied by Statistics New Zealand.

### **Chemical products (manufacturing and processing)**

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

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

### **Other – printing ink use**

One major printing ink company with approximately 50 percent of the solvent ink market share provided a breakdown on the type of ink used. Approximately 50 percent of inks used are oil

inks (paste inks) which contain high boiling temperature oils. These are evaporated off during “heat setting” but it is understood that the volatiles are generally treated in a solvent burner that minimises emissions. The remaining 50 percent of inks are liquid of which 60 percent are solvent inks (the remaining 40 percent are water based).

### **Other – aerosols**

Approximately 25 million aerosol units are sold in New Zealand each year. Based on the assumptions that the units are fully discharged within two years of purchase, the average propellant charge is 84 grams and 95 percent are hydrocarbon based, total NMVOC emissions in 2004 were 1.9 Gg.

### **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 (USEPA, 1985). It is assumed that the emissions rate per capita derived by the United States Environmental Protection Agency (USEPA) is applicable to the average product use in New Zealand (CRL Energy Ltd, 2006). Population figures are from the Statistics New Zealand website.

### **N<sub>2</sub>O for anaesthesia**

Activity data for 2004 was obtained from the sole importer of bulk N<sub>2</sub>O into New Zealand. The importer supplies its competitor with its requirements so the figure represents full coverage of N<sub>2</sub>O use in New Zealand. Most of the N<sub>2</sub>O is used for anaesthesia and the production of Entonox (a 50/50 mix 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 Ltd, 2006). The overall uncertainties are assessed to be:

- paint application:  $\pm 40$  percent
- degreasing/drycleaning:  $\pm 30$  percent
- chemical product emissions:  $\pm 20$  percent
- printing, aerosols and domestic/commercial use:  $\pm 50$  percent,  $\pm 20$  percent and  $\pm 60$  percent respectively.
- N<sub>2</sub>O for anaesthesia:  $\pm 10$  percent for annual imports.

## **5.1.4 Source-specific QA/QC and verification**

The consumption data from Auckland Regional Council (1997) and Nelson (1992) were compared to import data and discrepancies analysed and clarified by the consultant. There are considerable uncertainties and inconsistencies in applying the USEPA per capita emission

factors based on international experience. Nevertheless, there is generally very little information available on New Zealand use of the various products and their consequent NMVOC emissions.

### **5.1.5 Source-specific recalculations**

Data in this sector for the 2004 inventory are derived using the same method used for previously reported data. No changes have been made to the methodology.

### **5.1.6 Source-specific planned improvements**

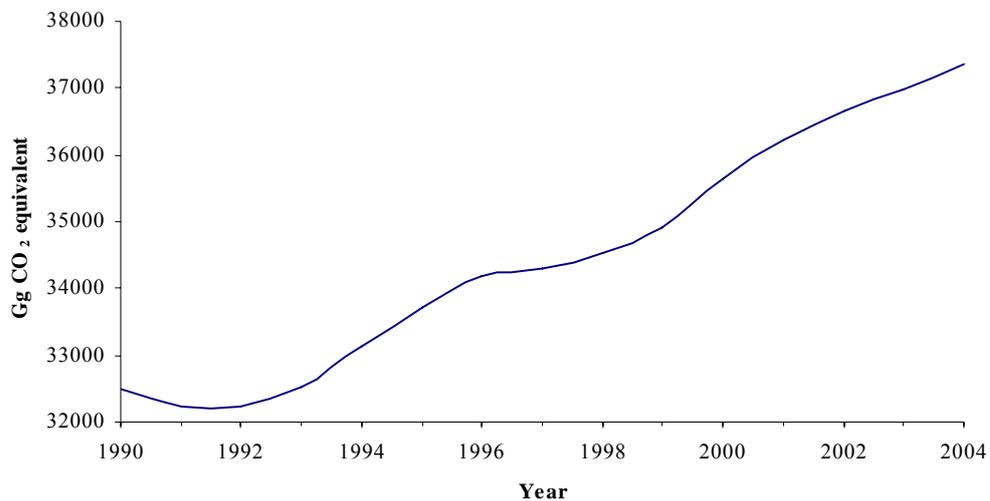
There are no planned improvements for this sector. There are large uncertainties, however the emission levels from the solvents and other products sector are negligible compared to other sectors. In accordance with Good Practice, New Zealand will continue to focus its inventory development on key source categories (IPCC, 2001).

# Chapter 6: Agriculture

## 6.1 Sector overview

The agriculture sector emissions totalled 37,349.63 Gg CO<sub>2</sub> equivalent and represented 49.7 percent of all greenhouse gas emissions in 2004. Emissions in this sector are now 4,850.75 Gg CO<sub>2</sub> equivalent (14.9 percent) higher than the 1990 level of 32,498.88 Gg CO<sub>2</sub> equivalent (Figure 6.1.1). The increase is primarily attributable to a 2,017.00 Gg CO<sub>2</sub> equivalent (9.2 percent) increase in CH<sub>4</sub> emissions from enteric fermentation and a 2,677.28 Gg CO<sub>2</sub> equivalent (26.7 percent) increase in N<sub>2</sub>O emissions from the agricultural soils category.

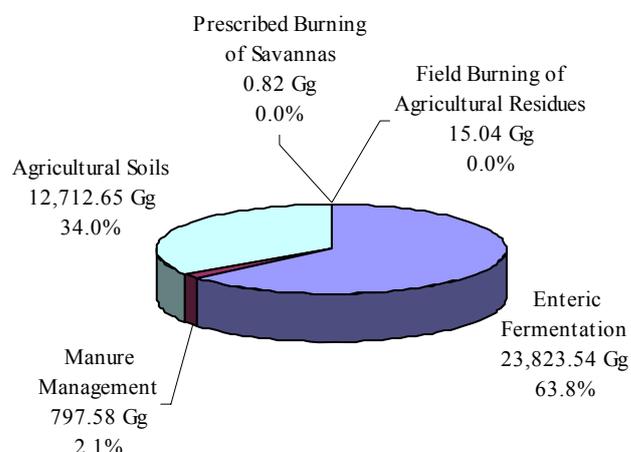
**Figure 6.1.1 Agricultural sector emissions from 1990 to 2004**



Emissions of CH<sub>4</sub> from enteric fermentation dominate the sector producing 63.8 percent of CO<sub>2</sub> equivalent emissions in the sector (Figure 6.1.2) and 31.7 percent of New Zealand's total emissions. N<sub>2</sub>O emissions from agricultural soils are the other major component of the sector comprising 34.0 percent of agricultural CO<sub>2</sub> equivalent emissions.

Agriculture is the principal industry of New Zealand and agricultural products are the predominant component of exports. This is due to several factors: 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 Emissions from the agricultural sector in 2004 (all figures Gg CO<sub>2</sub> equivalent)**



Since 1984, there have been changes in the balance of livestock species. There has been a trend for increased dairy and deer production due to prevailing good world prices. This has been counterbalanced by land coming out of sheep production and consequently decreased sheep numbers. Beef numbers have remained relatively static. There have also been productivity increases across all major animal species and classes. The land area used for horticulture has not changed significantly since 1990 although the types of produce grown have changed with less grain but more vegetables, fruit and grapes for wine production. There has also been an expansion of the land used for plantation forestry.

New Zealand uses a June year for all animal statistics as this reflects the natural biological cycle for animals in the southern hemisphere. The models developed to estimate emissions work on a monthly timeframe commencing in July of one year and finishing in June of the next year. To obtain emissions for single calendar years (January to December) emissions from the last six months of a July to June year are combined with the first 6 months emissions of the next July to June year. All emissions in the inventory are reported on a rolling three-year average of the emissions calculated for single January – December years. To ensure consistency, a single livestock population characterisation and feed intake estimate is used when estimating CH<sub>4</sub> emissions from enteric fermentation, CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management and N<sub>2</sub>O emissions from animal wastes deposited directly onto pasture. A complete time-series of the agriculture data are shown in Annex 8.4 and information on livestock population census and survey procedures are included in Annex 3.1.

## 6.2 Enteric fermentation (CRF 4A)

### 6.2.1 Description

In 2004, emissions from enteric fermentation comprised 23,823.54 Gg CO<sub>2</sub> equivalent. This represents 31.7 percent of New Zealand's total CO<sub>2</sub> equivalent emissions and is the largest single category of emissions in the New Zealand inventory. The category is dominated by emissions from cattle (dairy and non-dairy) which represent 58.5 percent of emissions from enteric fermentation. The current level of emissions from enteric fermentation is 9.2 percent

above the 1990 level, however there have been large changes within the category. The largest increase has been in emissions from dairy cattle which have increased 71.1 percent since 1990. This increase has been offset by decreases in emissions from sheep (-19.7 percent) and minor livestock populations such as goats horses and swine.

CH<sub>4</sub> is produced as a by-product of digestion in ruminants, eg, cattle, and some non-ruminant animals such as swine and horses. Ruminants are the largest source of CH<sub>4</sub> as they are able to digest cellulose. The amount of CH<sub>4</sub> released depends on the type, age and weight of the animal, the quality and quantity of feed and the energy expenditure of the animal.

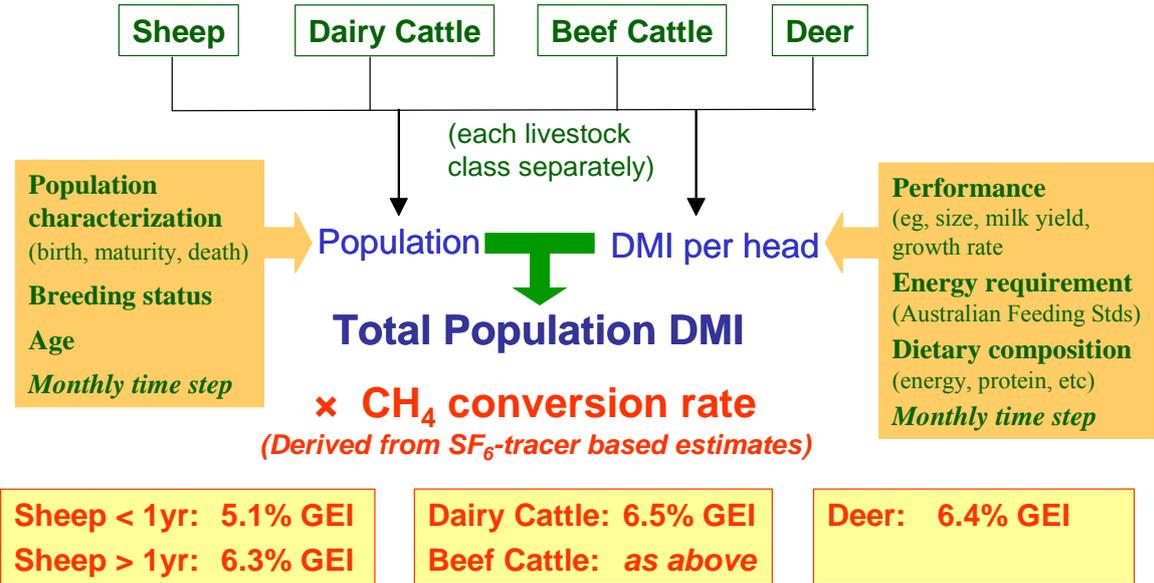
CH<sub>4</sub> emissions from enteric fermentation have been identified as the largest key category for New Zealand in the level assessment (excluding LULUCF). In accordance with good practice (IPCC, 2001), the methodology for estimating CH<sub>4</sub> emissions from enteric fermentation in domestic livestock was revised to a Tier 2 modelling approach for the 2001 inventory. All subsequent inventories have used this Tier 2 approach.

### 6.2.2 Methodological issues

New Zealand’s methodology 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<sub>4</sub> emitted is calculated using CH<sub>4</sub> emissions per unit of feed intake (figure 6.2.1). The calculation process is explained in the full description of the Tier 2 approach in Annex 3.1 and Clark *et al*, (2003).

There has been a gradual increase in the implied emission factors for dairy cattle and beef cattle from 1990 to 2004. This is to be expected because the methodology is able to use animal performance data that reflects the increased levels of productivity achieved by New Zealand farmers since 1990. Increases in animal weight and animal performance (milk yield) require increased feed intake by the animal to meet energy demands. Increased feed intake produces increased CH<sub>4</sub> emissions per animal. The increases in productivity are shown in the agricultural worksheets in Annex 8.4 and in the detailed description in Annex 3.1.

Figure 6.2.1 Schematic of New Zealand’s enteric methane calculation methodology



## 6.2.3 Uncertainties and time-series consistency

### Animal numbers

Many of the calculations in this sector require livestock numbers. Both census and survey methods are used with surveys occurring in the intervening years between each census. Detailed information from Statistics New Zealand on the census and survey methods is included in Annex 3.1.2.

### Methane emissions from enteric fermentation

In the 2001 inventory, the CH<sub>4</sub> 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; Table 6.2.1). For the 2004 inventory, the uncertainty in the annual estimate was calculated using the 95 percent confidence interval determined from the Monte Carlo simulation as a percentage of the mean value, ie, in 2001, the uncertainty in annual emissions was  $\pm 53$  percent.

The overall inventory uncertainty analysis shown in Annex 7 (Good Practice Table 6.1) demonstrates that the uncertainty in annual emissions from enteric fermentation is 12.0 percent of New Zealand's total emissions and removals for 2004, and is the largest single component affecting the national total. However in the trend from 1990 to 2004, the uncertainty from enteric fermentation is only 1.9 percent of the trend in emissions and removals. The uncertainty between years is assumed to be correlated, therefore the uncertainty is mostly in the emission factors and the uncertainty in the trend is much lower than uncertainty for an annual estimate.

**Table 6.2.1 Uncertainty in the annual estimate of enteric methane emissions 1990, 2001 and 2004 and the 95 percent confidence interval ( $\pm 1.96$  standard deviations from the mean) estimated using Monte Carlo simulation**

| Year | Enteric CH <sub>4</sub> emissions (Gg/annum) | 95% CI Min | 95% CI Max |
|------|--|------------|------------|
| 1990 | 1,015.5                                      | 478.1      | 1,552.9    |
| 2001 | 1,099.4                                      | 517.6      | 1,681.2    |
| 2004 | 1,134.5                                      | 534.1      | 1,734.9    |

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

Uncertainty in the annual estimate is dominated by variance in the measurements used to determine the 'CH<sub>4</sub> per unit of intake' factor. For the measurements made of this factor, the standard deviation divided by the mean is equal to 0.26. This uncertainty is thought to be mostly natural variation from one animal to the next. Uncertainties in the estimation of energy requirements, herbage quality and population data are thought to be much smaller (0.005–0.05), so these variables play a much smaller role.

## 6.2.4 Source-specific QA/QC and verification

CH<sub>4</sub> emission rates measured for 20 selected dairy cows scaled up to a herd have been corroborated using micrometeorological techniques. *Laubach and Kelliher* (2005) used the integrated horizontal flux (IHF) technique and the flux gradient technique to measure CH<sub>4</sub> flux above a dairy herd. Both techniques are comparable, within estimated errors, to scaled-up animal emissions. The emissions from the cows measured by IHF and averaged over three campaigns are 329 (±153) g CH<sub>4</sub>/day/cow compared to 365 (± 61) g CH<sub>4</sub>/day/cow for the scaled-up measurements reported by *Waghorn et al.* (2002) and *Waghorn et al.* (2003).

## 6.2.5 Source-specific recalculations

The provisional livestock population data for 2004 was updated to final population numbers, and the corresponding three-year average populations for 2003, 2004 and 2005 updated.

## 6.2.6 Source-specific planned improvements

A national inter-institutional ruminant CH<sub>4</sub> expert group was formed to identify the key strategic directions for research into the CH<sub>4</sub> inventory and mitigation, and to develop a collaborative approach to improve the certainty of CH<sub>4</sub> emissions. This is funded through the Ministry of Agriculture and Forestry. A private sector funded Pastoral Greenhouse Gas Research Consortium has been established to carry out research primarily into mitigation technologies and management practices but also on-farm inventory considerations. The implementation of the Tier 3 approach for CH<sub>4</sub> emissions from enteric fermentation and manure management is a consequence of the research conducted by the expert group and continues to be improved. Validation of the SF<sub>6</sub> technique is also occurring through intercomparison with calorimeter estimates through collaborative research between Australian and New Zealand scientists.

# 6.3 Manure management (CRF 4B)

## 6.3.1 Description

Emissions from the manure management category comprised 797.58 Gg CO<sub>2</sub> equivalent (2.1 percent) of emissions from the agriculture sector.

Livestock manure is composed principally of organic material. When the manure decomposes in the absence of oxygen, methanogenic bacteria produce CH<sub>4</sub>. The emissions of CH<sub>4</sub> are related to the amount of manure produced and the amount that decomposes anaerobically. CH<sub>4</sub> from manure management has been identified as a key category for New Zealand in the 2004 key category level assessment (Table 1.5.2).

This category also includes emissions of N<sub>2</sub>O related to manure handling before the manure is added to the soil. The amount of N<sub>2</sub>O released depends on the system of waste management and the duration of storage. With New Zealand's extensive use of all year round grazing systems, this category is relatively small at 63.50 Gg CO<sub>2</sub> equivalent of N<sub>2</sub>O in 2004. In comparison, agricultural soil emissions of N<sub>2</sub>O totalled 12,712.65 Gg CO<sub>2</sub> equivalent.

## 6.3.2 Methodological issues

### Methane

Methane emissions from ruminant animal wastes in New Zealand have been recalculated using an IPCC Tier 2 approach. This replaces the Tier 1 approach used in previous inventory submissions. The methodology adopted is based on the methods recommended by Saggar *et al* (2003) in a review commissioned by the Ministry of Agriculture and Forestry.

The approach is based on (1) an estimation of the total quantity of faecal material produced, (2) the partitioning of this faecal material between that deposited directly onto pastures and that stored in anaerobic lagoons and (3) the development of specific New Zealand emission factors for the quantity of methane produced per unit of faecal dry matter produced.

The quantity of faecal dry matter produced is calculated by multiplying the feed intake by the dry matter digestibility of the feed. The feed intake estimates and dry matter digestibility's are the same as in the current enteric methane and nitrous oxide inventories.

In New Zealand only dairy cows have a fraction (5 percent) of the excreta stored in an anaerobic lagoon waste system. The remaining 95 percent of excreta from dairy cattle is deposited directly on pasture. All other ruminant species (sheep, beef cattle, deer and goats) deposit all faecal material directly onto pastures. Values for the quantity of CH<sub>4</sub> produced per unit of faecal dry matter deposited on pastures for cattle are obtained from New Zealand research by Saggar *et al*, 2003 and Sherlock *et al*, 2003. The value for sheep comes from a New Zealand study by Carran *et al*, 2003. The mean of cattle and sheep values is used for deer so as no values for deer are available. Methane emissions from anaerobic lagoons are estimated using a water dilution rate (Heatley 2001), the average depth of a lagoon and the emissions data from lagoons (McGrath and Mason 2002).

**Table 6.3.1 Derivation of methane emissions from manure management**

| Animal species | Proportion of faecal material deposited on pasture | CH <sub>4</sub> from animal waste on pastures (g CH <sub>4</sub> /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 <sub>4</sub> from anaerobic lagoon (g CH <sub>4</sub> /M <sup>2</sup> /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<sub>4</sub> emissions from manure management for swine, horses and poultry. These are minor livestock categories in New Zealand and emissions estimates for these species use IPCC default emission factors (refer to the agricultural worksheets in Annex 8.4).

### Nitrous oxide

For the N<sub>2</sub>O calculation, six alternative regimes for treating animal manure, known as animal waste management systems (AWMS) are identified in the 1996 IPCC Guidelines. New Zealand farming uses four AWMS; (1) anaerobic lagoons, (2) pasture, range and paddock, (3) solid storage and dry-lot, and (4) other systems (poultry without bedding and swine deep litter). With

the exception of dairy cattle, animals were allocated to the different AWMS according to the information provided in the IPCC 1996 guidelines for the Oceania region as Ministry of Agriculture and Forestry considered these were applicable to New Zealand farming practices. For dairy cattle, New Zealand specific data from Ledgard and Brier (2004) was used.

The “pasture, range and paddock” AWMS is the predominant regime for animal waste in New Zealand. All sheep, goats, deer and non-dairy cattle excreta are allocated to the pasture, range and paddock AWMS. For dairy cattle, 95 percent of excreta is allocated to pasture, range and paddock and 5 percent is allocated to anaerobic lagoons. Emissions from the “pasture, range and paddock” AWMS are reported in the “Agricultural soils” category.

The calculation for nitrogen in each animal waste management system is shown in the agricultural worksheets in Annex 8.4. A time series of nitrogen excreta ( $N_{ex}$ ) values used for calculating animal production  $N_2O$  emissions is also shown in the worksheets in Annex 8.4. The  $N_{ex}$  values show an increase over time reflecting the increases in animal production. The nutrient input/output model OVERSEER<sup>®</sup> (Wheeler *et al.*, 2003) is used to determine the annual quantities of nitrogen deposited in excreta by grazing animals. The OVERSEER<sup>®</sup> model uses the same animal populations and feed intake from the Tier 2 model used to determine methane emissions (Clark *et al.*, 2003), and an assessment of feed nitrogen content modified by farm type.

### **6.3.3 Uncertainties and time-series consistency**

Emission factors from manure and manure management systems, the livestock population, nitrogen excretion rates and the usage of the various manure management systems are the main factors causing uncertainty in  $N_2O$  emissions from manure management (IPCC, 2000). New Zealand uses the IPCC default values for  $EF_3$  (direct emissions from waste) for all AWMS except for  $EF_{3PRP}$  (manure deposited on pasture, range and paddock). The value of  $EF_{3PRP}$  which is a country-specific factor is 0.01 kg  $N_2O-N/kg$  N. The IPCC default values have uncertainties of -50 percent to +100 percent (IPCC, 2000).

The overall inventory uncertainty analysis shown in Annex 7 (Good Practice Table 6.1) demonstrates that the effect of uncertainty in annual emissions from manure management is relatively minor compared to the effect from  $CH_4$  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 for New Zealand in the 2003 inventory. In preparation of the 2004 inventory, the data for this category underwent a Tier 1 quality check (refer Annex 6 for examples).

### **6.3.5 Source-specific recalculations**

Methane from manure management is a key category. To ensure consistency with good practice, the methodology was upgraded to a Tier 2 approach for the 2004 inventory. The entire time series (1990–2004) has been recalculated.

### 6.3.6 Source-specific planned improvements, if applicable

No source specific improvements are planned during 2006.

## 6.4 Rice cultivation (CRF 4C)

### 6.4.1 Description

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

## 6.5 Agricultural soils (CRF 4D)

### 6.5.1 Description

The agricultural soils category is the category of the majority of N<sub>2</sub>O emissions in New Zealand comprising 12,712.65 Gg CO<sub>2</sub> equivalent in 2004. Emissions are 2,677.28 Gg CO<sub>2</sub> equivalent (26.7 percent) over the level in 1990. The category comprises three sub-categories:

- direct N<sub>2</sub>O emissions from animal production (the pasture, range and paddock AWMS)
- indirect N<sub>2</sub>O from nitrogen lost from the field as NO<sub>x</sub> or NH<sub>3</sub>
- direct N<sub>2</sub>O emissions from agricultural soils as a result of adding nitrogen in the form of synthetic fertilisers, animal waste, biological fixation, inputs from crop residues and sewage sludge.

All of these sub-categories have been identified as key categories for New Zealand (Tables 1.5.2 and 1.5.3). Direct soil emissions from animal production is the third largest key category comprising 7,530.74 Gg CO<sub>2</sub> equivalent, indirect N<sub>2</sub>O from nitrogen used in agriculture comprised 3,376.64 Gg CO<sub>2</sub> equivalent and direct N<sub>2</sub>O emissions from agricultural soils comprised 1,805.26 Gg CO<sub>2</sub> equivalent.

CO<sub>2</sub> emissions from limed soils are reported in the LULUCF sector.

### 6.5.2 Methodological issues

N<sub>2</sub>O emissions are determined using the IPCC 1996 approach where emission factors dictate the fraction of nitrogen deposited on the soils that is emitted into the atmosphere as N<sub>2</sub>O. The two main inputs in New Zealand are from nitrogen fertiliser and the excreta deposited during animal grazing.

The worksheets for the agricultural sector (Annex 8.4) document the emission factors and other parameters used in New Zealand's calculations. Three New Zealand specific factors/parameters have been used: EF<sub>1</sub>, EF<sub>3(PR&P)</sub> and Frac<sub>LEACH</sub>. The EF<sub>3(PR&P)</sub> emission factor and Frac<sub>LEACH</sub> were extensively reviewed for the 2001 submission, and a new value for Frac<sub>LEACH</sub> was used from the 2001 inventory onwards and back-calculated to 1990. Data on EF<sub>1</sub> was reviewed during 2006 and the recommendation by *Kelliher and de Klein* (2006) to use a country-specific factor of 1 percent has been adopted.

## Animal production (N<sub>2</sub>O)

Direct soil emissions from animal production refers to the N<sub>2</sub>O produced from the pasture, range and paddock AWMS. This AWMS is the predominant regime for animal waste in New Zealand as 95 percent of dairy cattle and 100 percent of sheep, deer and non-dairy cattle are allocated to it. The emissions calculation is based on the livestock population multiplied by nitrogen excretion (N<sub>ex</sub>) values and the percentage of the population on the pasture, range and paddock AWMS. The N<sub>ex</sub> and allocation to AWMS are discussed in section 6.3.2 nitrous oxide. The N<sub>ex</sub> values have been calculated using the model OVERSEER<sup>®</sup> (Wheeler *et al.*, 2003) based on the same animal intake values used for calculating CH<sub>4</sub> emissions for the different animal classes and species. This ensures that the same base values are used for both CH<sub>4</sub> and N<sub>2</sub>O emission calculations.

New Zealand uses a country-specific emission factor for EF<sub>3(PRP)</sub> of 0.01 (Carran *et al.*, 1995., Muller *et al.*, 1995; de Klein *et al.*, 2003 and Kelliher *et al.*, 2003). Considerable research effort has gone into establishing a country-specific value for EF<sub>3(PRP)</sub>. Field studies have been performed as part of a collaborative research effort called NzOnet. The parameter EF<sub>3(PRP)</sub> has been measured by NzOnet researchers in the Waikato (Hamilton), Canterbury (Lincoln) and Otago (Invermay) regions for pastoral soils of different drainage class (de Klein *et al.*, 2003). These regional data are comparable because the same measurement methods were used at the three locations. The percentage of applied nitrogen (as urine or dung) emitted as N<sub>2</sub>O, and environmental variables, were measured in three separate trials that began in autumn 2000, summer 2002, and spring 2002. Measurements were carried out for up to 250 days or until urine treated pasture measurements dropped back to background emission levels.

Kelliher *et al.* (2003) assessed all available EF<sub>3(PRP)</sub> data, its distribution with respect to pastoral soil drainage class, to determine an appropriate national, annual mean value. The complete EF<sub>3(PRP)</sub> data set of NzOnet was synthesised using the national assessment of pastoral soils drainage classes. This study recognises that (1) environmental (climate) data are not used to estimate N<sub>2</sub>O emissions using the IPCC 1996 methodology, (2) the N<sub>2</sub>O emission rate can be strongly governed by soil water content, (3) soil water content depends on drainage that can moderate the effects of rainfall and drought, and (4) as a surrogate for soil water content, drainage classes of pastoral soils can be assessed nationally using a geographic information system. In New Zealand, earlier analysis showed the distribution of drainage classes for pasture land is highly skewed with 74 percent well-drained, 17 percent imperfectly drained and 9 percent poorly drained (Sherlock *et al.*, 2001).

The research and analysis to date indicates that if excreta is separated into urine and dung components, EF<sub>3</sub> for urine and dung could be set to 0.007 and 0.003, respectively. However, it is recognised that the dung EF<sub>3</sub> data are limited. Research by NzOnet is continuing into the possibility of separate emission factors for dung and urine. Combining urine and dung EF<sub>3</sub> values, the dairy cattle total excreta EF<sub>3</sub> is 0.006. Conservatively rounding the total excreta EF<sub>3</sub> of 0.006 provides a country-specific value of 0.01 for EF<sub>3(PRP)</sub>. The IPCC default value of EF<sub>3(PRP)</sub> is 0.02.

## Indirect N<sub>2</sub>O from nitrogen used in agriculture

The N<sub>2</sub>O emitted indirectly from nitrogen lost from agricultural soils through leaching and run-off is shown in the agricultural worksheets in Annex 8.4. This nitrogen enters water systems and eventually the sea with quantities of N<sub>2</sub>O being emitted along the way. The amount of nitrogen that leaches is a fraction that is deposited or spread on land (Frac<sub>LEACH</sub>).

Research studies in New Zealand together with a literature review have shown lower rates of nitrogen leaching than is suggested in the IPCC guidelines. In inventories reported prior to 2003, a New Zealand parameter for  $\text{Frac}_{\text{LEACH}}$  of 0.15 was used. However, IPCC based estimates for different farm systems were found on average to be 50 percent higher than those estimated using the OVERSEER<sup>®</sup> (Wheeler *et al.*, 2003) nutrient budgeting model. The model provides average estimates of the fate of N for a range of pastoral, arable and horticultural systems. In pastoral systems, N leaching is determined by the amount of N in fertiliser, dairy farm effluent and that excreted in urine and dung by grazing animals. The latter is calculated from the difference between N intake by grazing animals and N output in animal products, based on user inputs of stocking rate or production and an internal database with information on the N content of pasture and animal products. The IPCC estimates were closer for farms using high rates of N fertiliser, indicating that the IPCC based estimates for N leaching associated with animal excreta were too high. When the IPCC methodology was applied to field sites where N 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  $\text{Frac}_{\text{LEACH}}$  more closely followed actual field emissions (Thomas *et al.*, 2005) and this value was adopted and used for all years as it reflects New Zealand's national circumstances.

### **Direct N<sub>2</sub>O emissions from agricultural soils**

Direct emissions from agricultural soils are calculated in the six tables shown in Annex 8.4 (worksheet 4.5).

The emissions 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 collected together and an emissions factor applied to calculate total direct emissions from non-organic soils.

Nitrogen fertiliser use is determined by the Zealand Fertiliser Manufacturers' Research Association (FertResearch) from sales records for 1990 to 2004. A rolling three year average is used to calculate inventory data. There has been a six fold increase in nitrogen fertiliser use over the time series, from 51,787 tonnes in 1990 to 310,716 tonnes in 2004. The calculation of N<sub>2</sub>O that is emitted indirectly through synthetic fertiliser and animal waste being spread on agricultural soils is shown in the agricultural worksheets in Annex 8.4. Some of the nitrogen contained in these compounds is emitted into the atmosphere as ammonia (NH<sub>3</sub>) and nitrogen oxides (NO<sub>x</sub>) through volatilisation, which returns to the ground during rainfall and is then re-emitted as N<sub>2</sub>O. This is shown as an indirect emission of N<sub>2</sub>O.

The calculation for animal waste includes all manure that is spread on agricultural soils irrespective of which AWMS it was initially stored in. This includes all waste in New Zealand except for emissions from the pasture range and paddock AWMS. New Zealand uses a country-specific value for EF<sub>1</sub> of 0.01 kg N<sub>2</sub>O-N/kg N (Kelliher and de Klein, 2006).

Direct N<sub>2</sub>O emissions from organic soils are calculated by multiplying the area of cultivated organic soils by an emission factor. Recent analysis identified 202,181 hectares of organic soils of which it is estimated that 5 percent (ie, 10,109 ha) are cultivated on an annual basis (Kelliher *et al.*, 2003). New Zealand uses the IPCC default emissions factor (EF<sub>2</sub> equal to 8 kg N<sub>2</sub>O-N/kg N) for all years of the time-series.

### 6.5.3 Uncertainties and time-series consistency

Uncertainties in N<sub>2</sub>O emissions from agricultural soils are assessed for the 1990, 2001 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 that of pastoral soil drainage whereby 74 percent of soils are classified as well-drained, while only 9 percent are classified as poorly drained. For the 2004 inventory, the uncertainty in the annual estimate was calculated using the 95 percent 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 percent and -42 percent.

**Table 6.5.1 Uncertainties in N<sub>2</sub>O emissions from agricultural soils for 1990, 2002 and 2004 estimated using Monte Carlo simulation (1990, 2002) and the 95 percent CI (2004)**

| Year | N <sub>2</sub> O emissions from agricultural soils (Gg/annum) | 95% CI Min | 95% CI Max |
|------|---|------------|------------|
| 1990 | 31.9  | 17.2       | 58.2       |
| 2002 | 40.6  | 23.4       | 70.4       |
| 2003 | 41.0  | 23.6       | 71.1       |

The overall inventory uncertainty analysis shown in Annex 7 (Good Practice Table 6.1) demonstrates that the uncertainty in annual emissions from agricultural soils is a major contributor to uncertainty in the total estimate and trend from 1990. The uncertainty between years is assumed to be correlated, therefore the uncertainty is mostly in the emission factors and the uncertainty in the trend is much lower than uncertainty for an annual estimate. Uncertainty in the N<sub>2</sub>O emissions contributes 9.0 percent of the uncertainty in New Zealand's total emissions and removals in 2004 and 1.1 percent to the trend in emissions and removals from 1990–2004.

The Monte Carlo numerical assessment was also used to determine the effects of variability in the nine most influential parameters on uncertainty of the calculated N<sub>2</sub>O emissions in 1990 and 2001. 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 2004 inventory. The Monte Carlo analysis confirmed that uncertainty in parameter EF<sub>3(PRP)</sub> has the most influence on total uncertainty accounting for 91 percent of the uncertainty in total N<sub>2</sub>O emissions in 1990. This broad uncertainty reflects natural variance in EF<sub>3</sub> determined largely by the vagaries of the weather and soil type.

**Table 6.5.2 Percentage contribution of the nine most influential parameters on the uncertainty of total N<sub>2</sub>O emissions inventories for 1990 and 2001**

| Parameter             | 1990                          | 2001                          |
|-----------------------|-------------------------------|-------------------------------|
|                       | % contribution to uncertainty | % contribution to uncertainty |
| EF <sub>3(PRP)</sub>  | 90.8                          | 88.0                          |
| EF <sub>4</sub>       | 2.9                           | 3.3                           |
| Sheep N <sub>ex</sub> | 2.5                           | 1.8                           |
| EF <sub>5</sub>       | 2.2                           | 2.8                           |
| Dairy N <sub>ex</sub> | 0.5                           | 0.7                           |
| Frac <sub>GASM</sub>  | 0.5                           | 0.5                           |

|                       |     |     |
|-----------------------|-----|-----|
| EF <sub>1</sub>       | 0.3 | 2.4 |
| Beef N <sub>ex</sub>  | 0.2 | 0.3 |
| Frac <sub>LEACH</sub> | 0.1 | 0.2 |

## 6.5.4 Source-specific QA/QC and verification

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

## 6.5.5 Source-specific recalculations

Nitrous oxide from agricultural soils is a key category. To ensure consistency with good practice, the EF<sub>1</sub> emission factor was changed to a country-specific emission factor of 1 percent. The agricultural soils category has therefore been recalculated for the entire time-series (1990–2004).

## 6.5.6 Source-specific planned improvements

The work of N<sub>2</sub>Onet will continue in order to better quantify N<sub>2</sub>O emission factors for New Zealand's pastoral agriculture.

# 6.6 Prescribed burning of Savanna (CRF 4E)

## 6.6.1 Description

Prescribed burning of savanna is not a key category for New Zealand. The New Zealand inventory includes burning of tussock (*Chionochloa*) grassland in the South Island for pasture renewal and weed control. The amount of burning has been steadily decreasing since 1959 as a result of changes in lease tenure and a reduction in grazing pressure. In 2004, total emissions accounted for 0.82 Gg CO<sub>2</sub> equivalent - a 2.51 Gg CO<sub>2</sub> equivalent (75.4 percent) reduction from the 3.33 Gg CO<sub>2</sub> equivalent reported in 1990.

The IPCC Guidelines (1996) state that in agricultural burning, the CO<sub>2</sub> 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<sub>2</sub> are considered to be zero. However the by-products of incomplete combustion, CH<sub>4</sub>, CO, N<sub>2</sub>O and NO<sub>x</sub>, 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 however instead of using total grassland and a fraction burnt, New Zealand uses statistics of the total amount of tussock grassland that has been granted a consent (a legal right) under New Zealand's Resource Management Act (1991) for burning. Only those areas with a consent are legally allowed to be burned. Expert opinion

obtained from land managers in local government is that approximately 20 percent of the area allowed to be burnt is actually burnt in a given year.

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

### **6.6.3 Uncertainties and time-series consistency**

The same sources of data and emission factors are used for all years. This gives confidence in comparing emissions through the time-series from 1990 and 2004. The major sources of uncertainty are the percentage of consented area actually burnt in that season, that biomass data from two study sites are extrapolated for all areas of tussock, and that many of the other parameters (ie, the carbon content of the live and dead components, the fraction of the live and dead material that oxidise and the N:C ratio for the tussocks) are the IPCC default values. Uncertainty in the New Zealand biomass data has been quantified at  $\pm 6$  percent (Payton and Pearce, 2001), however many IPCC parameters vary by  $\pm 50$  percent and some parameters lack uncertainty estimates.

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

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

### **6.6.5 Source-specific recalculations**

There were no recalculations for the 2004 inventory.

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

### **6.7.1 Description**

Burning of agricultural residues produced 15.04 Gg CO<sub>2</sub> equivalent in 2004. Emissions are currently 10.19 Gg CO<sub>2</sub> equivalent lower (–40.4 percent) than the level of 25.24 Gg CO<sub>2</sub> equivalent in 1990. Burning of agricultural residues is not identified as a key category for New Zealand.

New Zealand reports emissions from burning barley, wheat and oats residue in this category. Maize residue is not burnt in New Zealand. New Zealand uses three-year averages of crop production in combination with the IPCC default emission ratios and residue statistics. Oats are included under the same emission factors as barley.

Burning of crop residues is not considered to be a net source of CO<sub>2</sub> because the CO<sub>2</sub> released into the atmosphere is reabsorbed during the next growing season. However, the burning is a source of emissions of CH<sub>4</sub>, CO, N<sub>2</sub>O and NO<sub>x</sub> (IPCC, 1996). Burning of residues varies between years due to climatic conditions and is becoming a declining source.

## **6.7.2 Methodological issues**

The emissions from burning of agricultural residues are estimated in accordance with the IPCC guidelines (IPCC, 1996). The calculation uses crop production statistics, the ratio of residue to crop product, the dry matter content of the residue, the fraction of residue actually burned, the fraction of carbon oxidised and the carbon fraction of the residue (Annex 8.4). These figures are multiplied to calculate the carbon released. The emissions of CH<sub>4</sub>, CO, N<sub>2</sub>O and NO<sub>x</sub> are calculated using the carbon released and an emissions ratio. N<sub>2</sub>O and NO<sub>x</sub> emissions calculations also use the nitrogen to carbon ratio.

Good practice suggests that an estimate of 10 percent of residue burnt may be appropriate for developed countries but also notes that the IPCC defaults “are very speculative and should be used with caution. The actual percentage burned varies substantially by country and crop type. This is an area where locally developed, country-specific data are highly desirable.”(IPCC, 2001). For the years 1990 to 2003 it is estimated that 50 percent of stubble is burnt. For the year 2004 experts assessed this percentage dropped to 30 percent. These figures are developed from expert opinion of the Ministry of Agriculture and Forestry officials working with the arable production sector.

## **6.7.3 Uncertainties and time-series consistency**

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

## **6.7.4 Source-specific QA/QC and verification**

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

## **6.7.5 Source-specific recalculations**

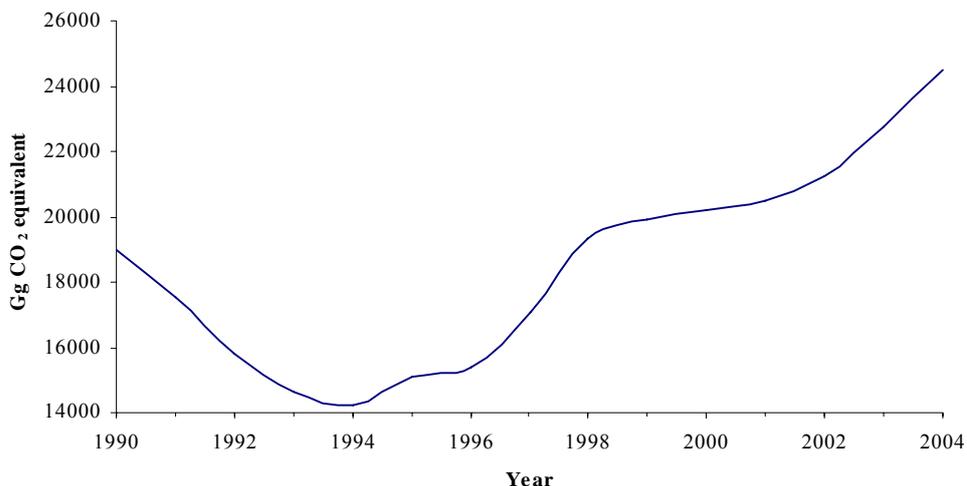
There are no recalculations for this category.

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

## 7.1 Sector overview

The land use, land-use change and forestry (LULUCF) sector represented the removal of approximately 32.8 percent of all New Zealand's greenhouse gas emissions in 2004. Net removals from the LULUCF sector in 2004 totalled 24,482.63 Gg CO<sub>2</sub> equivalent and are 29.0 percent above net removals in 1990 (Figure 7.1.1).

Figure 7.1.1 LULUCF sector net removals from 1990 to 2004



### 7.1.1 A history of LULUCF in New Zealand

Prior to the first human settlement by Polynesians in about 1250 AD, approximately 75 percent of New Zealand's land area was estimated as natural forest. The forest area had reduced to about 60 percent by the mid-nineteenth century and was further reduced to the current approximate 23 percent coverage by subsequent European settlement, the latter due largely to deforestation and clearance for pastoral grazing land. Deforestation (subsequent to human settlement) is estimated to have resulted in vegetation C losses of 3,400,000 Gg C (Scott et al., 2001). Establishment of pastures probably slightly increased mineral soil C, however some losses of C due to erosion are also possible (Tate et al., 2003a).

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

Government administrative changes in 1987 resulted in reservation of about 5 million hectares (18 percent of New Zealand's total land area) of Crown-owned natural forests. Currently, New Zealand has 6.4 million hectares of natural forest. 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 1949. The amendment still exempted West Coast Crown-owned forests and forests on specific Maori-owned lands. However, further Government controls resulted in the cessation of logging of the West Coast Crown-owned forests in March 2002. Timber harvested from privately owned natural forests and from forests on exempted Maori lands has continued at a low level since the 1993 controls were imposed. Current proposed legislative changes will continue to exempt the Maori lands although logging has further reduced in these forests.

New Zealand has a substantial estate of planted forests, mainly comprised of *Pinus radiata*, created specifically for timber supply purposes and has well-established data on this estate's extent and characteristics. These forests have removed and stored substantially more CO<sub>2</sub> over the period 1990 to 2004 than has been emitted through forest harvesting of both the combined planted and natural forests. The new planting rate (land reforested or afforested) over the last 30 years has been, on average, 43,000 hectares per year. In the period 1992 to 1998 new planting rates were high (averaging 69,000 hectares per year). Since 1998 the rate of new planting has declined and in 2004, 10,600 hectares of new forest was established. Between 1990 and 2004 it is estimated that 671,000 hectares of new forest has been established as a result of afforestation and reforestation activities.

Having a large planted forest resource enables New Zealand to sustainably manage its Crown and privately owned natural forest. Less than 0.1 percent of New Zealand's total forest production is now harvested from natural forests.

### **7.1.2 Methodological issues for LULUCF in New Zealand**

Six broad categories of land are described in GPG-LULUCF. The categories are consistent with the 1996 IPCC Guidelines and the requirements of Articles 3.3 and 3.4 of the Kyoto Protocol. The land categories are:

- Forest land – all land with woody vegetation consistent with national thresholds used to define forest land. It also includes systems with vegetation that currently fall below, but is expected to exceed, the threshold of the forest land category.
- Cropland – arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category.
- Grassland – rangelands and pasture land that is not considered as cropland. It also includes systems with vegetation that falls below and is not expected to exceed, without human intervention, the threshold used 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.

A current lack of land use and land-use change data consistent with the IPCC land category classification, covering the period 1990 through to 2004, limits reporting in this sector. Research is being conducted on the carbon pools and fluxes in New Zealand's soils and natural forests through the Carbon Monitoring System (CMS) plots. The focus of the CMS activities is specifically to fulfil New Zealand's reporting requirements for the UNFCCC LULUCF inventory and the Kyoto Protocol. Details of the monitoring system are included in Annex 3.2.

### **7.1.2.1 Representation of land areas**

To estimate land areas in each LULUCF land category, New Zealand has used an analysis of two existing land-cover maps of New Zealand – the Land Cover Databases 1 and 2 (respectively, LCDB1 and LCDB2) (Thompson et al, 2004). The LCDB1 and LCDB2 are an example of the wall-to-wall mapping of Approach 3 as described in GPG-LULUCF. The LCDBs were not specifically developed for use in UNFCCC reporting, however they have been used by New Zealand as they are the only national land cover/land use spatial databases available that provide current information and can be reasonably mapped to the LULUCF land categories. The land categories to be mapped and monitored through NZCAS will be designed specifically for reporting under the UNFCCC and the Kyoto Protocol, and will replace LCDB data in the inventory in the future.

The LCDB1 was completed in 2000 using SPOT satellite imagery acquired over the summer of 1996/97. LCDB2 was released in July 2004 and used Landsat 7 ETM+ satellite imagery acquired over the summer of 2001/02. During processing of LCDB2, the classifications in LCDB1 were checked, corrected and integrated into the LCDB2 database. The inventory uses the corrected LCDB1 data. There are 43 land-cover/land-use classes mapped in LCDB 1 and 2, and these are mutually exclusive and additive to 100 percent of the surface area of New Zealand. Additional information on the processing to generate LCDB 1 and 2 is included in Annex 3.3. To complete the UNFCCC inventory, the land-cover classes in the LCDB 1 and 2 were mapped to the applicable LULUCF categories (Table A3C.1).

New Zealand does not presently have land use data for 1990. The 1990 data will be developed as part of the New Zealand Carbon Accounting System (NZCAS) described in Annex 3.2. In the 2004 inventory New Zealand has completed the 1990 LULUCF sector by linear extrapolation of the 1997 data. An analysis to complete 1990 using a 1985 map of New Zealand vegetative cover and classification system was initiated, however the differences in map scale between 1985 (1:1,000,000) and 1997 (1:50,000) meant the data was inconsistent between 1990 and 1997 and the remainder of the time series. To ensure consistency throughout the time series, New Zealand extrapolated backwards to 1990 from the 1997 data.

Table 7.1.1 shows a simplified land-use change matrix developed from LCDB1 and LCDB2 for the years 1997 and 2002. More details of the conversions between categories and subdivisions are included in each land-use category in the NIR. Land-use change matrices including subdivisions of land categories and the annual changes interpolated for the periods 1997–1998, 1998–1999, 1999–2000, 2000–2001 and 2001–2002 are included in the worksheets accompanying the LULUCF sector. A land-use change matrix for 2002–2004 was generated by extrapolating previous annual trends.

**Table 7.1.1 Land use change matrix between LCDB1 (1997) and LCDB2 (2002)**

|               |        | Land area categories from LCDB1 (1997) (kha) |         |          |        |        |         | Total    |
|---------------|--------|--|---------|----------|--------|--------|---------|----------|
|               |        | F  | C       | G        | W      | S      | O       |          |
| LCDB2<br>2002 | F      | 10097.57                                     | 0.02    | 130.88   | 0.00   | 0.06   | 0.06    | 10228.59 |
|               | C      | 0.22   | 412.91  | 4.32     | 0.00   | 0.00   | 0.01    | 417.44   |
|               | G      | 5.11   | 0.00    | 14360.63 | 0.00   | 0.06   | 0.21    | 14366.01 |
|               | W      | 0.00   | 0.00    | 0.67     | 531.24 | 0.04   | 0.01    | 531.96   |
|               | S      | 0.56   | 0.02    | 5.03     | 0.00   | 214.84 | 0.00    | 220.46   |
|               | O      | 0.19   | 0.00    | 0.06     | 0.00   | 0.00   | 1056.84 | 1057.09  |
|               | Total  | 10103.65                                     | 412.95  | 14501.58 | 531.24 | 215.00 | 1057.13 | 26821.56 |
| Net           | 124.94 | 4.49   | -135.57 | 0.72     | 5.46   | -0.03  | 0.00    |          |

F= forest land, C=cropland, G=grassland, W= wetland, S=Settlement and O=Other lands.

### 7.1.2.2 Inventory carbon pools

Greenhouse gas inventory for land-use categories involves estimation of changes in carbon stock from five carbon pools, ie, aboveground biomass, belowground biomass, dead wood, litter, and soil organic matter, as well as emissions of non-CO<sub>2</sub> gases from such pools. For UNFCCC inventory reporting purposes, the pools are grouped into changes in living biomass (aboveground biomass and belowground biomass), changes in dead organic matter (dead wood and litter) and changes in soil organic matter.

### 7.1.2.3 Land-use factors and carbon stocks

Changes in carbon pools within a land-use category and between categories uses a number of variables of the stocks and growth in the living biomass, and the effect on land-use factors on soil carbon stocks. The variables appear in the Tier 1 equations for all land-use categories. For transparency, these factors are tabulated in tables 7.1.3.1, 7.1.3.2 and 7.1.3.3.

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 C stock changes associated with type of land use, 2) a management factor ( $F_{MG}$ ) that for permanent cropland represents different types of tillage and 3) an input factor ( $F_I$ ) representing different levels of C inputs to soil.

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

**Table 7.1.3.1 Land-use factors used across land-use categories**

| Land use                 | Stock change factors selected from GPG-LULUCF (GPG-LULUCF tables 3.3.4 and 3.4.5) |        |       |
|--------------------------|---|--------|-------|
|                          | $F_{LU}$  | $FM_G$ | $F_I$ |
| 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     |

**Table 7.1.3.2 Living biomass carbon stocks in land use prior to conversion**

| Land use                 | Value                      | Source/Reference  |
|--------------------------|----------------------------|---|
| Natural forest           | 182 t C ha <sup>-1</sup>   | 364 tonnes dm ha <sup>-1</sup> (Hall et al, 1998) • carbon fraction of dry matter (0.5)                                     |
| Planted forest           | 223.2 t C ha <sup>-1</sup> | 1st rotation, 28 years old (Wakelin, 2006)  |
| Annual cropland          | 0 t C ha <sup>-1</sup>     | Annual crop is harvested. GPG-LULUCF only considers perennial crops (Table 3.4.8)   |
| Perennial cropland       | 63 t C ha <sup>-1</sup>    | GPG-LULUCF Table 3.3.2. Temperate (all moisture regimes)  |
| High-producing grassland | 1.35 t C ha <sup>-1</sup>  | 2.7 tonnes dm ha <sup>-1</sup> (GPG-LULUCF Table 3.4.2, warm temperate – wet climate) • carbon fraction of dry matter (0.5) |
| Low-producing grassland  | 0.8 t C ha <sup>-1</sup>   | 1.6 tonnes dm ha <sup>-1</sup> (GPG-LULUCF Table 3.4.2, warm temperate – wet climate) • carbon fraction of dry matter (0.5) |
|                          | 63 t C ha <sup>-1</sup>    | 63 t C ha <sup>-1</sup> assumed for grassland woody vegetation.   |

**Table 7.1.3.3 Annual growth in living biomass for land converted to another land use**

| Land use                 | Value                       | Source/Reference   |
|--------------------------|-----------------------------|--|
| Natural forest           | NE /                        | New Zealand's natural forests are assumed to be approximately in steady-state (Tate <i>et al.</i> , 2000)  |
|                          | T1=4.3 t C ha <sup>-1</sup> | Tier 1 – GPG-LULUCF 3A.1.5 and 3A.1.8 ( $G_w=3.5$ tonnes dm ha <sup>-1</sup> (an average of the conifer (3.0) and broadleaf (4.0) values), $R = 0.24$ , $C_{frac} = 0.5$ ) |
| Planted forest           | IE /                        | Tier 2 – Included in C_Change modelling (Beets et al, 1999, Wakelin, 2004)   |
|                          | T1=8.9 t C ha <sup>-1</sup> | Tier 1 – GPG-LULUCF 3A.1.6 and 3A.1.8 ( $G_w=14.5$ tonnes dm ha <sup>-1</sup> (pinus), $R = 0.23$ , $C_{frac} = 0.5$ )   |
| Annual cropland          | 5 t C ha <sup>-1</sup>      | GPG-LULUCF Table 3.3.8 (– temperate all moisture regimes)  |
| Perennial cropland       | 2.1 t C ha <sup>-1</sup>    | GPG-LULUCF Table 3.3.8 (– temperate all moisture regimes)  |
| High-producing grassland | 6.75 t C ha <sup>-1</sup>   | 13.5 tonnes dm ha <sup>-1</sup> (GPG-LULUCF Table 3.4.9, warm temperate – wet climate), $C_{frac} = 0.5$   |
| Low-producing grassland  | 3.05 t C ha <sup>-1</sup>   | 6.1 tonnes dm ha <sup>-1</sup> (GPG-LULUCF Table 3.4.9, warm temperate – dry climate), $C_{frac} = 0.5$  |

## 7.2 Forest land (CRF 5A)

New Zealand has not adopted a final national definition of forest to be used in reporting for the Kyoto Protocol. This definition requires New Zealand to state the minimum area, length (and thus width) of land areas categorised as forest land. This definition will be used when spatial information from the NZCAS is calculated and available for reporting. To enable New Zealand to complete the 2004 inventory and include information under the updated LULUCF guidance and CRF tables, the categories of forest land used in the LCDB1 and LCDB2 were applied. This is an area of one (1) hectare and a width of 100 metres. This definition of land mapped as forest land is not New Zealand's national definition to be applied under the Kyoto Protocol when the NZCAS is operational.

The LCDB1 and 2 also includes a shrubland vegetation cover category, which does not exist as a LULUCF category. Land-cover classes within the shrubland category were assigned to the grassland category as they do not meet the forest land criteria that New Zealand expects to formally adopt for the Kyoto Protocol (namely, 1 hectare, 30 percent canopy cover, 5 metres height and 100 metres width). The allocation of classes is shown in Table A3C.1.

New Zealand has adopted the definition of managed forest land as provided in the IPCC Guidelines and GPG-LULUCF: "Forest management is the process of planning and implementing practices for stewardship and use of the forest aimed at fulfilling relevant ecological, economic and social functions of the forest." New Zealand's natural forests are considered managed forests due to their primary management for ecological, biodiversity, and social functions.

### 7.2.1 Description

Forest land accounted for net CO<sub>2</sub> removals of 25,506.49 Gg CO<sub>2</sub> in the 2004 inventory. This figure includes removals from the growth of planted forests, emissions from the conversion of land to planted forest and from the very small amount of harvesting of natural forests.

Natural forest is a term used to distinguish New Zealand's indigenous forests from planted production forests. Natural forests are managed for a range of conservation, biodiversity, recreation, purposes. 99.9 percent of New Zealand's wood needs are met from planted forests and the Crown does not harvest any timber from New Zealand's natural forests. The natural forest harvest reported in the inventory refers to harvest of forests on land granted to Maori (New Zealand's indigenous people) under the South Island Landless Natives Act (SILNA) 1906. These are currently exempt from the indigenous forestry provisions of the Forests Act that apply to all privately owned indigenous forests and required a sustainable forest management plan or permit prior to any harvesting. Approximately 50,000 ha are in the SILNA. There is no specific data to estimate growth in these forests. The NZCAS will provide data for similar forests in similar locations to the SILNA forests.

Removals of CO<sub>2</sub> in natural forest are not calculated. This is because country-specific data are not available (refer the development of the CMS plots in Annex 3.2) and the growth rates provided for mixed broadleaf/coniferous forest in GPG-LULUCF are considered too high. Preliminary results are that New Zealand's natural forests are approximately in steady-state or a possible small sink of carbon, ie, changes in vegetation carbon stock lie between 0.3 to -2.5 Tg C yr<sup>-1</sup> (Tate *et al.*, 2000). Results from the CMS monitoring will enable New Zealand to provide a better estimate.

## 7.2.2 Methodological issues

### Forest land remaining forest land (Tier 2)

New Zealand has calculated the removal of CO<sub>2</sub> by planted forests and emissions from planted forests through harvesting using a modelling approach and country-specific data. Compared to many forest ecosystems, total biomass in New Zealand's planted forests is relatively straightforward to estimate. Approximately 90 percent of the forest area is planted in *Pinus radiata*, a forest is usually composed of stands of trees of a single age class and all forests have relatively standard silviculture regimes applied. The methodology applied for UNFCCC inventory is:

- A survey of forest growers is undertaken annually to estimate the area of forest by age, species, silvicultural regime and location.
- Stem wood volume yield tables are compiled periodically for combinations of species, silvicultural regime and location.
- The C\_Change model (Beets *et al.*, 1999) is used to derive forest biomass and carbon from the stem volume yield tables. C\_Change was previously known as the CARBON/DRYMAT model.
- The Forestry Oriented Linear Programming Interpreter (FOLPI) (Garcia, 1984; Manley *et al.*, 1991) is used to time-shift the estate forwards to forecast future forest growth and forest management, including harvesting.
- The model also recalculates historic estimates of CO<sub>2</sub> removals and emissions by time-shifting the latest available data backwards.

#### *Planted forest survey data*

The results of the National Exotic Forest Description (NEFD) survey as at 1 April 2004 are used to calculate removals and emissions provided in the 2004 inventory. This latest information brings in new forest-area data along with data on new planting, restocking and harvesting for the 2004 year (MAF, 2005).

The NEFD survey provides estimates of the forest area and merchantable stem wood volume (via yield tables) by crop-type and age. A crop-type is an aggregate of forest stands that are similar, in respect to species, silviculture and location. Each crop-type has a yield table that provides estimated volumes of stem wood per hectare by age. The total forest area after harvest for the year ending March 2004 is based on (a) the latest area estimates provided by the 2004 NEFD, (b) an estimate of the area to be planted during the year, (c) an estimate of the area harvested during the year. The total estate area for the years before 2003 has been estimated through back-calculations using this latest NEFD area data combined with new planting and harvesting time series information. The area of new land planting is based on the MAF statistics. These estimates are revised and recalculated annually as provisional estimates are replaced by confirmed actual areas.

#### *Modelling*

The C\_Change model estimates carbon stock per hectare, by component and annual age-class, from stem wood volume data (Box 7.1).

### Box 7.1 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 understorey) 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. Carbon is taken as being 50% of biomass.

For the 2004 inventory, 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 still based on data for *Pinus radiata*, when in fact around 10 percent of the estate is made up of other species such as Douglas-fir (5 percent) (*Pseudotsuga menziesii*), other exotic softwoods (2 percent), and exotic hardwoods (3 percent).

To simplify the subsequent modelling, all crop-types were then aggregated to form a single, national area weighted crop-type and associated area-weighted national yield table.

The second of the two models, FOLPI is a linear programming model used to optimise the management of forest estates over time. The model simulates actual rates of planting and harvesting where time series data exists. Carbon stock estimates are calculated for March years and are reported as three-year averages as per the IPCC approach. The assumption is that the stem wood removed at harvest for both permanent and planted forests is oxidised in the year of harvest. The FOLPI model uses the biomass and carbon stocks at one point in time to give total carbon stocks for each modelled year and changes in carbon stocks between those years. Among the outputs of the FOLPI model are the LULUCF inventory results for 1990 to 2004. These results include:

- Stem wood volume harvested from the planted estate, hence CO<sub>2</sub> emitted in that harvest.
- Total stock of estate carbon after harvesting in each year (accounting also for the decay of non-stem wood carbon left after harvesting).

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

#### *Emissions from natural forest harvesting*

Estimates of any harvesting from natural forests are provided by the MAF. Stem wood volumes are converted to oven-dry weight using a factor of 0.5 (accounting for wood moisture) and then expanded to include non-stem wood biomass using a factor of 2.04 (Waklin, 2006). As for planted forest harvesting, emissions from harvesting natural forests are potential maximums rather than actual emissions as much of the carbon contained in the harvested stem wood ends up as wood products produced from the harvested timber rather than being oxidised at the time of harvest.

## Land converted to forest land

Data on the amount of land clearance for new forest planting are sourced from the MAF. The information includes the proportion of new forest planting that occurs on grassland with woody vegetation that falls below and is not expected to exceed, without human intervention, the threshold used to define forest land. Data are available from 1993 to the present and it is assumed that prior to 1993, the proportion was 20 percent. It is assumed that 25 percent of the vegetation biomass is burnt on-site and that the remainder is left to decay.

The quantity of on-site biomass for both grassland woody vegetation and natural forest, used in the land conversion and biomass burning calculations (see Annex 8.5), is now based on the provisional results of research (adapted from Hall *et al.*, 1998). The values reported (136 t dm/ha for grassland with woody vegetation and 364 t dm/ha for mature natural forest) are based on a national area-weighted average for biomass per hectare for a range of the principal classes.

It has been assumed that the biomass fuel consumption rate in fires in both forest biomass and grassland with woody vegetation is 90 percent. This fuel consumption rate is double the IPCC default value and the resulting non-CO<sub>2</sub> emissions are likely to be over-estimated. Work is underway to improve biomass burning assumptions in the inventory.

### *Wildfire burning*

Only non-CO<sub>2</sub> emissions from wildfires are reported in the inventory (consistent with the IPCC default method). Emissions from wildfires are based on fire reports collected by the National Rural Fire Authority. These reports show the area of forest and grassland with woody vegetation burnt. It is assumed that all forest burning occurs in natural forest. In planted forests, fires occur infrequently and fire-damaged trees are usually salvaged and appear in harvest statistics. Some of the areas reported in the Fire Authority statistics involve land clearing and it is not specified whether this is for agricultural or forestry purposes. This implies that there may be double counting between these figures and those allocated to land clearing for new forest planting. However the most common cause of wildfires is escapes from land clearance burns, and in New Zealand these are mostly in the high country. The Ministry of Agriculture and Forestry assesses the possibility of double counting as relatively minor.

## Forest removals and emissions calculated via a Tier 1 approach

The LCDB1 and LCDB2 analysis used to complete the LULUCF inventory allows calculating a coarse Tier 1 estimate for the categories “forest land remaining forest land” and “land converted to forest land”. These estimates are reported in the NIR to support the modelling approach.

### *Living biomass*

For the category “forest land remaining forest land”, the calculation follows the Tier 1 procedure outlined in GPG-LULUCF equation 3.2.4 using parameters from tables 3A.1.5 for natural forest, 3A.1.6 for plantation forest and root-shoot ratios from table 3A.1.8. The values chosen for the carbon stocks and growth rates (Gw and R) are documented in table 7.1.3.2.

### *Dead organic matter*

In the Tier 1 calculation, the average transfer rate into the dead wood pool equals the transfer rate out of the dead wood pool. The net change is zero (GPG-LULUCF).

### *Soil carbon*

In the Tier 1 calculation it is assumed that when forest remains forest, the carbon stock in soil organic matter does not change. For land converted to forest, New Zealand has followed the

Tier 1 method outlined in GPG-LULUCF 3.2.2.3. For Tier 1, the initial soil C stock is determined from the same reference soil C stocks used for all land uses, together with stock change factors ( $F_{LU}$ ,  $F_{MG}$ ,  $F_I$ ) appropriate for the previous land use. The stock change factors used by New Zealand's Tier 1 calculation are listed in table 7.1.3.1. New Zealand has used 83 tonnes C ha<sup>-1</sup> for reference C stock in soils (Tate *et al*, 2003).

Decreases in the carbon stock of forest land from harvest were calculated according to GPG-LULUCF equation 3.2.9 – “annual other losses of carbon”. This equation was used in preference to the equation for commercial felling (equation 3.2.7) to keep calculations consistent with the LCDB analysis used for other land categories, ie, equation 3.2.7 is based on the extracted roundwood volume rather than the area of forest harvested or disturbed (equation 3.2.9). The annual area of deforestation was calculated from the total area of LCDB1 forest classes that had changed to “harvested forest” in LCDB2, divided by the 5 years. Carbon stocks in living biomass for planted and natural forest were those documented in table 7.1.3.2. Under the Tier 1 methodology, it is assumed that all above ground biomass is lost.

Decreases in living biomass carbon stocks associated with land converted to forest was also included in the Tier 1 calculation. For the Tier 1 estimate, it was assumed that the land category of “low producing grassland converted to planted forest” was equivalent in area to the clearance of grassland with woody vegetation for forest planting. The value of living biomass carbon stocks in perennial crop land prior to conversion provided in GPG-LULUCF (63 t C ha<sup>-1</sup>) was used as an approximation of the C stock in grassland woody vegetation biomass. This value is very similar to the value used in the Tier 2 modelling of 68 t C ha<sup>-1</sup> from Hall *et al* (1998) (136t dm ha<sup>-1</sup> \* 0.5 (carbon fraction of dry matter)).

Table 7.2.1 compares the results from the modelled and Tier 1 approaches for the 2003 inventory. The results for the living biomass stock are similar (11.0 percent different) however the different approaches mean that the two estimates will always differ. The primary reasons for this are the different methodologies use in assessing planted forest estate and planting rates, ie, comparing annual NEFD survey vs. remote sensing and extrapolation of previous interpolated planting trends, the lack of forest age data from the LCDB analysis, mapping of LCDB classes to LULUCF categories and the selection of GPG defaults for Gw and R compared to country-specific modelling data.

**Table 7.2.1 Comparison of the Tier 2 and Tier 1 approaches for forest land in 2003**

|  | Area (kha)          |        |            | Living biomass stock (Gg C) |        |            |
|--|---------------------|--------|------------|-----------------------------|--------|------------|
|  | modelled/<br>actual | tier 1 | difference | modelled/<br>actual         | tier 1 | Difference |
| Forest land remaining forest (planted) | 1878                | 2046   | 8.9%       | 6977                        | 7742   | 11.0%      |
| Land converted to planted forest land  | 18                  | 26     | 44%        | -237                        | -291   | 22.8%      |

### 7.2.3 Uncertainties and time-series consistency

A process of using the models to time-shift the forest estate forwards to represent future forest growth and forest management, and backwards to improve historical estimates, is performed to minimise errors. As the estimation of carbon stocks is continuously being improved, both past and future years are recalculated.

Attempts have been made to quantify the uncertainties in the CO<sub>2</sub> removal estimates for planted forests. However, it is difficult to quantify the overall error due to the assumptions implicit in the models. Some uncertainties within the C-Change (CARBON/ DRYMAT) model are well characterised (Hollinger *et al.*, 1993). These include  $\pm 3$  percent for wood density,  $\pm 15$  percent for carbon allocation and  $\pm 5$  percent for carbon content. Combining the uncertainties indicates that the proportional error in the carbon sequestration estimates is likely to be at least  $\pm 16$  percent. The total national planted area is considered to be accurate to within  $\pm 5$  percent (MAF, 2005) and the yield tables are assumed to be accurate to within  $\pm 5$  percent.

A sensitivity analysis was conducted using the above accuracy ranges for total planted area and commercial yield, and a proportional uncertainty error of  $\pm 16$  percent. The C-Change (CARBON/ DRYMAT) model runs indicate that the precision of the carbon stock estimates could be of the order of  $\pm 25$  percent. As part of the Carbon Accounting System, research has been commissioned to better quantify uncertainty. No uncertainty estimates are currently available for emissions from harvesting of natural forests.

Including the forest land category in the overall inventory uncertainty analysis (Annex 7) shows that removals from forest land are 6.5 percent of New Zealand's total emissions and removals uncertainty in 2004. This is the third largest source of uncertainty in New Zealand's total for a given year. Forest land introduces 2.2 percent uncertainty into the trend in the national total from 1990 to 2004. This is the second largest impact on the trend after CO<sub>2</sub> emissions from the energy sector.

## **7.2.4 Source-specific QA/QC and verification**

The information presented in the NIR and the variables chosen for calculation were reviewed by officials of the MfE and the MAF. Calculated estimates were visually assessed for obvious errors in calculations. For forest land, the Tier 2 modelled values were compared against a Tier 1 value. 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 datasets used is the National Exotic Forest Description (NEFD). The NEFD is New Zealand's official source of statistics on planted production forests and as such is subject to formalised data checking procedures. Each NEFD report is reviewed by a technical NEFD Committee prior to publication. In addition broad comparisons of forest areas reported in the NEFD reports are made with independent sources of information such as the Land Cover Database estimates and the annual results of Statistics New Zealand's Agricultural Production Survey. NEFD Yield tables have been subject to review (eg. Jaakko Poyry Consulting 2003, Manley 2004) and are in the process of being revised.

The 2004 planted forests removals and emissions have been compared for consistency with the 2003 estimates (Wakelin S, *Carbon Inventory of NZ's Planted Forests [Calculations revised as at February 2006]*, Forest Research, Contract Report, February 2006).

## **7.2.5 Source-specific recalculations**

New proportions of area by NEFD regime are used to weight the carbon yield in the 2004 inventory. Area data and carbon yields underlying the models in recent reports are similar to those used previously. The main changes in the national carbon yield table were due to the use of 89 croptype yield tables in the area-weighting procedure, rather than just four. This means that the national yield table better reflects the diversity represented in the NEFD data. Regimes

were modelled based on averages from permanent soil plot data, rather than as notional NEFD regimes. This had the effect of smoothing fluctuations during the period of silvicultural activity and also a minor effect on predicted root/shoot biomass ratios. In addition, dead fine roots were removed from the yield table to avoid double counting with soil carbon estimates from the soil CMS (or other sources).

Back-casting and recalculation of 1990-2003 values has been included as in previous years. That is, previous estimates have been replaced with those from the current model. The process of using the forest models to time-shift the forest estate forwards to represent future forest growth and forest management, and backwards to improve historical estimates, is performed to minimise errors. As the estimation of carbon stocks is continuously being improved, both past and future years are recalculated.

Land previously reported as non-forest scrubland is classified as grassland as per GPG-LULUCF definitions.

## **7.2.6 Source-specific planned improvements**

New Zealand's development of the CMS and the NZCAS will enable New Zealand to revise the time-series in the LULUCF inventory, and reduce the uncertainty by using country-specific emission and removal factors and UNFCCC category specific activity data. Details of the research are included in Annex 3.2.

Improvements in NEFD area capture are ongoing. Survey respondents are now being asked to specify whether or not stands are first rotation, which should provide a more accurate breakdown than the current approach.

Ongoing research is aiming to improve carbon modelling, including partitioning in species other than radiata pine, plantation understorey carbon, biomass decay rates and biomass burning assumptions.

## **7.3 Cropland (CRF 5B)**

### **7.3.1 Description**

The 2003 inventory was the first inventory where New Zealand has reported emissions and removals from cropland remaining cropland and from land converted to cropland. In 2004, the net CO<sub>2</sub> removals were 549.72 Gg CO<sub>2</sub>. Cropland is a key category for New Zealand.

Cropland includes all annual and perennial crops as well as temporary fallow land. Annual crops include cereals, oils seeds, vegetables, root crops and forages. Perennial crops include orchards, vineyards and plantations except where these lands meet the criteria for forest land.

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

## 7.3.2 Methodological issues

Emissions and removals have been calculated using IPCC Tier 1 emission and removal values and activity data from the LCDB analysis described in section 7.1 and Annex 3.3. To align with the methodologies provided in GPG-LULUCF, cropland was partitioned into annual and perennial cropland for the UNFCCC inventory.

### Cropland remaining cropland

#### *Living biomass*

As per GPG-LULUCF, the change in biomass is only estimated for perennial woody crops. For annual crops, increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year – thus there is no net accumulation of biomass carbon stocks.

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

#### *Dead organic matter*

The GPG-LULUCF state that there is not sufficient information to provide a basic approach with default parameters to estimate carbon stock changes in dead organic matter pools in cropland remaining cropland. The notation ‘NE’ is used in the CRF tables.

#### *Soil carbon*

To provide a Tier 1 estimate, New Zealand uses the IPCC default method for mineral soils (equation 3.3.3 of GPG-LULUCF). Mineral soils comprise 99.93 percent of New Zealand soils. This equation compares the soil organic carbon stock in the inventory year, with the soil organic carbon stock in “T” years prior to the inventory. New Zealand uses the IPCC default value of 20 years for “T”. The soil organic carbon stock is calculated from a reference carbon stock multiplied by the three land use and management factors shown in table 7.1.3.1.

Changes in soil carbon stock are caused by changes in the land use and management factors ( $F_{LU}$ ,  $F_{MG}$  and  $F_I$ ). 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 prior to 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 eg,  $(83*0.82*1*1.16)-(83*0.82*1*1.16))*\text{Area}/20 = 0$ . The values for  $F_{LU}$ ,  $F_{MG}$  and  $F_I$  are from table 3.3.4 in GPG-LULUCF.

### Land converted to cropland

#### *Living biomass*

The Tier 1 method is the same approach for all conversions and provided in equation 3.3.8 of GPG-LULUCF. The calculation is based on multiplying the annual area of land converted to cropland, by the carbon stock change per area for that type of conversion and including changes in carbon stocks from one year of cropland growth.

At 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 and country-specific values where possible. These are shown in tables 7.1.3.2 and 7.1.3.3.

#### *Dead organic matter*

GPG-LULUCF states that there is not sufficient information to provide a basic approach with default parameters to estimate carbon stock change in dead organic matter pools in land converted to cropland. The notation “NE” is used in the CRF tables.

#### *Soil carbon*

New Zealand has followed the method outlined in GPG-LULUCF (3.3.2.2.1.1). For Tier 1, the initial soil C stock is determined from the same reference soil C 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 7.1.2.3 in this inventory).

#### *N<sub>2</sub>O emissions*

These 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<sub>2</sub>O from N in the soil. The global default value of 0.0125 kg N<sub>2</sub>O-N/kg N is used.
- C:N ratio: The default ratio of C to N in soil organic matter (15) is used.

### **7.3.3 Uncertainties and time-series consistency**

Uncertainties can be analysed as uncertainty in activity data and uncertainty in variables such as emission factors, growth rates, the effect of land management factors etc. It is the uncertainty in the IPCC default variables that dominates the overall uncertainty in the estimate provided by New Zealand. The combined effect of uncertainty in cropland is estimated at ±75 percent (95 percent CI).

| <b>Variable</b>                                  | <b>Uncertainty (95% CI)</b>    |
|--|--------------------------------|
| Uncertainty in cropland remaining cropland       | ± 75%                          |
| LCDB1 (user accuracy 93.9%)                      | ± 6%                           |
| LCDB2 (assumed to be equal to LCDB1)             | ± 6%                           |
| Uncertainty in biomass accumulation rates        | ± 75% (GPG-LULUCF table 3.3.2) |
| Uncertainty from land converted to cropland      | ± 75%                          |
| Carbon stocks in previous land use               | ± 75%                          |
| Estimated uncertainty in land management factors | ± 12% (GPG-LULUCF table 3.3.4) |

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

No specific QA/QC and verification was used for cropland. Sector-level procedures are described in section 7.2.4 forest land.

### **7.3.5 Category-specific recalculations**

There are no recalculations for this category.

### **7.3.6 Category-specific planned improvements**

No specific improvements are planned for cropland. Sector-level improvements resulting from the NZCAS are described in section 7.2.6 forest land.

## **7.4 Grassland (CRF 5C)**

### **7.4.1 Description**

Grasslands in New Zealand can vary greatly in their degree and intensity of management, ranging from the extensively managed rangelands of the South Island high country, to low producing grasslands with woody vegetation cover, to the intensively managed dairy pasture in the Waikato and Taranaki regions. Grasslands generally have vegetation dominated by perennial grasses, with grazing as the predominant land use, and are distinguished from “forest” land by having a woody vegetation cover of less than the threshold used in the forest definition. In 2004, the net emissions from grassland were 666.44 Gg CO<sub>2</sub>. These emissions are from the subcategory “land converted to grassland”.

### **7.4.2 Methodological issues**

#### **Grassland remaining grassland**

##### *Living biomass*

In GPG-LULUCF, the Tier 1 assumption is no change in living biomass. The rationale is that in grassland 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 NA in the CRF tables because the activity occurs but there are no removals or emissions associated with it.

##### *Dead organic matter*

No estimate is calculated as GPG-LULUCF state that not enough information is available to develop default coefficients for estimating the dead organic matter pool. For Tier 1 and 2 methods, changes in dead organic matter and inorganic carbon stocks should be assumed to be zero.

##### *Soil carbon*

To provide a Tier 1 estimate, New Zealand uses the IPCC default method for mineral soils (equation 3.4.8 of GPG-LULUCF). As noted in previous sections, mineral soils cover 99.93

percent of New Zealand (Tate *et al.*, 2004). The LCDB analysis used in the 2004 inventory does not provide sufficient information to determine whether there has been a change in land use and management in grassland for the 20 years prior to the inventory. Therefore for areas of grassland remaining grassland, the values for  $F_{LU}$ ,  $F_{MG}$  and  $F_I$  are considered to be constant and consequently the calculation shows there is no net change in carbon stocks in soils.

#### *Liming of grassland*

The calculation for CO<sub>2</sub> emissions from the liming of grassland soils is included in worksheet 5.5. The calculation is based on the total amount of limestone sold (provided by Statistics New Zealand) and a carbon conversion factor from limestone to carbon. New Zealand uses the IPCC (1996) default value of 0.12 for carbon conversion.

### **Land converted to grassland**

Living biomass. New Zealand has applied the GPG-LULUCF Tier 1 method where the amount of carbon removed is estimated by multiplying the area converted annually by the difference between average carbon stocks in biomass prior to and following conversion and accounting for carbon in biomass that replaces cleared vegetation. Pre-conversion stocks and annual growth figures are tabulated in tables 7.1.3.2 and 7.1.3.3. Carbon stocks in biomass immediately after conversion are assumed to be zero.

#### *Dead organic matter*

No Tier 1 methodology is provided in GPG-LULUCF.

#### *Soil carbon*

Land conversion to grassland can occur from all land uses. In New Zealand the primary change into grassland is from forest land to grassland. New Zealand uses the methodology outlined in GPG-LULUCF (3.4.2.2.1.1). For Tier 1, the initial (pre-conversion) soil C stock is determined from a reference soil C 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 tabulated in table 7.1.2.1.

## **7.4.3 Uncertainties and time-series consistency**

It is the uncertainty in the IPCC default variables that dominates the overall uncertainty in the estimate provided by New Zealand. The combined effect of uncertainty in grassland is estimated at  $\pm 75$  percent (95 percent CI).

**Table 7.4.3.1 Uncertainty in emissions and removals from grassland**

| <b>Variable</b>                                  | <b>Uncertainty (95% CI)</b>         |
|--|-------------------------------------|
| Uncertainty in grassland remaining grassland     | $\pm 75\%$                          |
| LCDB1 (user accuracy 93.9%)                      | $\pm 6\%$                           |
| LCDB2 (assumed to be equal to LCDB1)             | $\pm 6\%$                           |
| Uncertainty in biomass accumulation rates        | $\pm 75\%$ (GPG-LULUCF table 3.4.2) |
| Uncertainty from land converted to grassland     | $\pm 75\%$                          |
| Carbon stocks in previous land use               | $\pm 75\%$                          |
| Estimated uncertainty in land management factors | $\pm 12\%$ (GPG-LULUCF table 3.3.4) |

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

No specific QA/QC and verification was used for grassland. Sector-level procedures are described in section 7.2.4.

#### **7.4.5 Category-specific recalculations**

There are no recalculations for this category.

#### **7.4.6 Category-specific planned improvements**

No specific improvements are planned for grassland. Sector-level improvements resulting from the NZCAS are described in section 7.2.6.

### **7.5 Wetland (CRF 5D)**

#### **7.5.1 Description**

GPG-LULUCF defines wetlands as “land that is covered or saturated by water for all or part of the year (eg, peat land) and that does not fall into the forest land, cropland, grassland or settlements categories”. “It includes reservoirs as a managed subdivision and natural rivers and lakes as unmanaged subdivisions”. New Zealand has categorised LCDB land cover classes for lakes, rivers and estuarine open water in the LCDB into the unmanaged wetlands category (Annex 3.3). Other LCDB classes, eg, herbaceous freshwater vegetation, commonly associated as a wetland in New Zealand, have been categorised as grassland following the GPG-LULUCF definitions. In 2004, the net emissions were 0.72 Gg CO<sub>2</sub>. These emissions are from the subcategory “land converted to wetland”. Wetlands are not a key category for New Zealand.

#### **7.5.2 Methodological issues**

##### **Wetland remaining wetland**

A methodology for this category is not covered in GPG-LULUCF but is addressed in Appendix 3a.3 Wetlands Remaining Wetlands: Basis for future methodological development. The appendix covers emissions from peat land and flooded land. GPG-LULUCF defines flooded lands as “water bodies regulated by human activities for energy production, irrigation, navigation, recreation, etc., and where substantial changes in water area due to water level regulation occur. Regulated lakes and rivers, where the main pre-flooded ecosystem was a natural lake or river, are not considered as flooded lands”.

New Zealand has not reported emissions from flooded land because of a lack of data, ie, the LCDB does not separate out regulated water bodies where substantial changes in water area occur, and because the majority of New Zealand’s hydro electric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river. The CRF tables for LULUCF do not require Parties to prepare estimates for this category (Footnote 3, CRF Table 5).

## **Land converted to wetland**

New Zealand has applied the GPG-LULUCF Tier 1 methodology for estimating the carbon stock change due to land conversion to flooded land (GPG-LULUCF equation 3.5.6). This method assumes that the carbon stock of land prior to conversion is lost in the first year following conversion. The carbon stock of the land prior to conversion is documented in table 7.1.3.2. In Tier 1, it is assumed that the carbon stock after conversion is zero.

GPG-LULUCF does not provide guidance on carbon stock changes from soils due to land conversion to flooded land. Emissions of non-CO<sub>2</sub> gases from land converted to flooded land are covered in Appendix 3a.3 of GPG-LULUCF but are not reported (note 3, CRF Table 5).

### **7.5.3 Uncertainties and time-series consistency**

Uncertainties are estimated as  $\pm 75$  percent based on the uncertainty for Tier 1 grassland carbon stocks (GPG-LULUCF table 3.4.2) lost during conversion to wetland.

### **7.5.4 Category-specific QA/QC and verification**

No specific QA/QC and verification was used for wetland. Sector-level procedures are described in section 7.2.4 forest land.

### **7.5.5 Category-specific recalculations**

There are no recalculations for this category.

### **7.5.6 Category-specific planned improvements**

No specific improvements are planned for wetland. Sector-level improvements resulting from the NZCAS are described in section 7.2.6 forest land.

## **7.6 Settlement (CRF 5E)**

### **7.6.1 Description**

This land-use category is described in GPG-LULUCF as including “all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other land-use categories”. Settlement includes trees grown along streets, in public and private gardens, and in different kinds of parks where the parks are associated to urban areas. In 2004, the net emissions from settlements were 97.16 Gg CO<sub>2</sub>. These emissions are from the subcategory “land converted to settlement”. Settlement is not a key category for New Zealand.

New Zealand has categorised the applicable LCDB land cover classes into the settlement category (Annex 3.3). The LCDB analysis showed that there was 214.84 kha of settlement remaining settlement from 1997 to 2002 with a net gain of 5.46 kha (Table 7.1.1). The largest single category change in area was from high producing grassland converted to settlement, averaging 1000 hectares per year.

## **7.6.2 Methodological issues**

### **Settlement remaining settlement**

GPG-LULUCF provides a basic method for estimating CO<sub>2</sub> emissions and removals in settlements remaining settlements in Appendix 3a.4 of GPG-LULUCF. The methods and available default data for this land-use are preliminary and based on an estimation of changes in carbon stocks per tree crown cover area or carbon stocks per number of trees as a removal factor. New Zealand does not have this level of activity data available. The CRF tables for LULUCF do not require Parties to prepare estimates for this category (note 3, CRF Table 5.)

### **Land converted to settlement**

The fundamental equation 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 prior to conversion is documented in table 7.1.3.2. The default assumptions for a Tier 1 estimate are that all living biomass present before conversion to settlements will be lost in the same year as the conversion takes place, and that carbon stocks in living biomass following conversion are equal to zero.

## **7.6.3 Uncertainties and time-series consistency**

Uncertainties are estimated as  $\pm 75$  percent based on the uncertainty for Tier 1 grassland carbon stocks (GPG-LULUCF Table 3.4.2).

## **7.6.4 Category-specific QA/QC and verification**

No specific QA/QC and verification was used for settlement. Sector-level procedures are described in section 7.2.4 forest land.

## **7.6.5 Category-specific recalculations**

There are no recalculations for this category.

## **7.6.6 Category-specific planned improvements**

No specific improvements are planned for settlement. Sector-level improvements resulting from the NZCAS are described in section 7.2.6 forest land.

## **7.7 Other land (CRF 5F)**

### **7.7.1 Description**

“Other Land” is defined in GPG-LULUCF as including bare soil, rock, ice, and all unmanaged land areas that does not fall into any of the other five land-use categories. “Other Land” is included in New Zealand’s land area for checking overall consistency of land area and tracking conversions to and from other land. In 2004, the net emissions from other land were 38.16 Gg

CO<sub>2</sub>. These emissions are from the subcategory “land converted to other land”. Other land is not a key category for New Zealand.

## **7.7.2 Methodological issues**

### **Other land remaining other land**

Change in carbon stocks and non-CO<sub>2</sub> emissions and removals in unmanaged “Other Land Remaining Other Land” do not need to be assessed under GPG-LULUCF. No guidance is provided in GPG-LULUCF for “Other Land” that is managed.

### **Land converted to other land**

#### *Living biomass*

The fundamental equation 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 prior to conversion is documented in table 7.1.3.2. The default assumptions for a Tier 1 estimate are that all living biomass present before conversion to other land will be lost in the same year as the conversion takes place, and that carbon stocks in living biomass following conversion are equal to zero.

#### *Soil carbon*

New Zealand uses the IPCC methodology outlined in GPP LULUCF (equation 3.7.3). For Tier 1, the initial (pre-conversion) soil C stock is determined from reference soil C stocks together with stock change factors (Table 7.1.2.1) appropriate for the previous land use. New Zealand uses a reference soil C stock of 83 t C ha<sup>-1</sup>. 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 percent based on the uncertainty in carbon stocks lost during the conversion to other land, eg, GPG-LULUCF table 3.4.2.

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

No specific QA/QC and verification was used for other land. Sector-level procedures are described in section 7.2.4 forest land.

## **7.7.5 Category-specific recalculations**

There are no recalculations for this category.

## **7.7.6 Category-specific planned improvements**

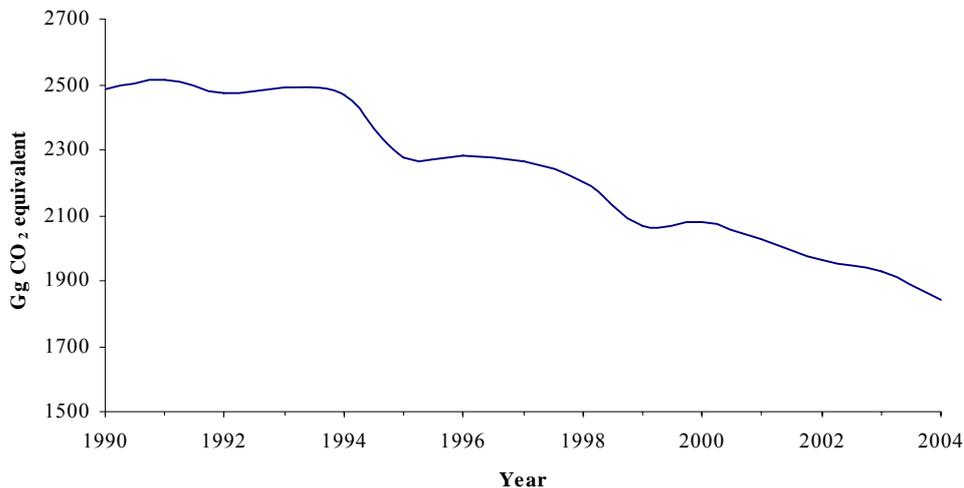
No specific improvements are planned for other land. Sector-level improvements resulting from the NZCAS are described in section 7.2.6 forest land.

# Chapter 8: Waste

## 8.1 Sector overview

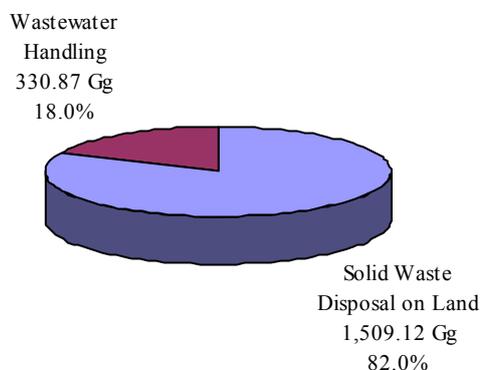
The waste sector totalled 1,839.98 Gg CO<sub>2</sub> equivalent in 2004 and this represented 2.5 percent of all greenhouse gas emissions. Emissions in 2004 are now 642.83 Gg CO<sub>2</sub> equivalent (25.9 percent) below the 1990 baseline value of 2,482.81 Gg CO<sub>2</sub> equivalent (Figure 8.1.1). The reduction has occurred in the solid waste disposal on land category as a result of initiatives to improve solid waste management practices and increase landfill gas capture rates in New Zealand.

**Figure 8.1.1 Waste sector emissions from 1990 to 2004**



Emissions from the waste sector are calculated in three components (Figure 8.1.2): solid waste disposal on land, wastewater handling and waste incineration (not shown in figure as emissions are negligible). CH<sub>4</sub> from solid waste disposal was identified as a key category for New Zealand in 2004 (Tables 1.5.2 and 1.5.3).

**Figure 8.1.2 Waste sector emissions in 2004 (all figures Gg CO<sub>2</sub> equivalent)**



Disposal and treatment of industrial and municipal waste can produce emissions of CO<sub>2</sub> and CH<sub>4</sub>. The CO<sub>2</sub> is produced from the decomposition of organic material. These emissions however are not included as a net emission as the CO<sub>2</sub> is considered to be reabsorbed in the following year. The most important gas is the CH<sub>4</sub> produced as a by-product of anaerobic decomposition.

## **8.2 Solid waste disposal on land (CRF 6A)**

### **8.2.1 Description**

Organic waste in solid waste disposal sites (SWDS) is broken down by bacterial action in a series of stages that result in the formation of CO<sub>2</sub> and CH<sub>4</sub>. The amount of gas produced depends on a number of factors including the waste disposal practices (managed vs. unmanaged landfills), the composition of the waste, and physical factors such as the moisture content and temperature of the SWDS. The CH<sub>4</sub> produced can go directly into the atmosphere via venting or leakage, or it may be flared off and converted to CO<sub>2</sub>.

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

Recently, New Zealand's national focus has been towards waste minimization and resource recovery. In March 2002, the Government announced its New Zealand Waste Strategy (MfE, 2002). The strategy sets targets for a range of waste streams as well as improving landfill

practices by the year 2010. As part of the implementation and monitoring of the strategy, the Government developed the Solid Waste Analysis Protocol (MfE, 2002a) that provided a classification system, sampling regimes and survey procedures to measure the composition of solid waste streams.

## 8.2.2 Methodological issues

New Zealand has used both the IPCC Tier 1 and Tier 2 approaches to calculate emissions from solid waste. The data reported in the inventory follow the IPCC Tier 2, first order decay approach (IPCC, 2000). New Zealand uses country-specific values for the degradable organic carbon factor (DOC), methane generation potential ( $L_0$ ), and a methane generation rate constant ( $k$ ) based on conditions at New Zealand landfills. The IPCC default oxidation correction factor of 0.1 is used (IPCC, 2000). Worksheets showing the waste sector calculations are included in Annex 8.6.

Data on municipal solid waste (MSW) generation rates, waste composition, the fraction of degradable organic carbon (DOC) and the percentage of MSW disposed to SWDS are obtained from the National Waste Data Report (MfE, 1997), the Landfill Review and Audit (MfE, 2002) and the Solid Waste Analysis Protocol baseline results (SWAP; MfE, 2003) surveys for the periods 1995, 2002 and 2003. The proportion of waste for each type of SWDS is obtained from the 2003 SWAP baseline results. It is estimated that in 1995, 90 percent of New Zealand's waste is disposed to managed SWDS and 10 percent to uncategorised sites (MfE, 1997)<sup>1</sup>. The IPCC (1996) default values are used for the carbon content of the various components. Calculation of the methane generation potential is also based on the New Zealand Solid Waste Analysis Protocol baseline results.

Based on the 2002 Landfill Review and Audit and using the SWAP classification system, it is estimated that the quantity of solid waste landfilled in New Zealand in 2004 was equivalent to 2.09 kg per person per day. This shows a reduction in waste generation from 2.39 kg per person per day in 1995.

A methane generation rate constant of 0.06 is used for New Zealand's landfills. International measurements support a methane generation rate constant in the range of 0.03 to 0.2 (IPCC, 2000). The 0.03 represents a slow decay rate in dry sites and slowly degradable waste, whereas the 0.2 value represents high moisture conditions and highly degradable waste. The IPCC recommended value is 0.05 (IPCC, 2000). The relatively wet conditions in most regions of New Zealand mean that the methane generation rate constant is likely to be slightly above the 0.05 default value. This was confirmed by a comparison of CH<sub>4</sub> generation and recovery estimates to actual recovery rates at a limited number of SWDS in New Zealand (SCS Wetherill Environmental, 2002).

The fraction of DOC that actually degrades (0.5) and the methane oxidation factor (0.1) are drawn from the Topical Workshop on Carbon Conversion and Methane Oxidation in Solid Waste Disposal Sites, held by the IPCC Phase II Expert Group on Waste on 25 October 1996. The workshop was attended by 20 international experts with knowledge of the fraction of

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<sup>1</sup> The 10% of solid waste not disposed to 'managed' SWDS, 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 SWDS, hence the 'unclassified' status. The inventory assumes that by 2010 all solid waste will be disposed to 'managed' SWDS, which has led to a linearly increasing Methane Correction Factor in  $L_0$  calculations.

degradable organic carbon that is converted to CH<sub>4</sub> and/or the oxidation of CH<sub>4</sub> by microbes in the soil cover.

The recovered CH<sub>4</sub> rate per year was estimated based on information from a 2005 survey of SWDS that serve populations of over 20,000 in New Zealand. (Waste Management New Zealand, 2005).

### **8.2.3 Uncertainties and time-series consistency**

The overall estimated level of uncertainty is estimated at ±20 percent, which is the same uncertainty as the 2003 inventory, but an improvement on prior submissions. The improvement was due to the sampling and survey guidelines from the Solid Waste Analysis Protocol and the 2002 Landfill Audit and Review. Due to the unknown level of uncertainty associated with the accuracy of some of the input data it has not been possible to perform a statistical analysis to precisely determine uncertainty levels. Uncertainty in the data is primarily from uncertainty in waste statistics based on the 1997 National Waste Data Report (total solid waste disposed to landfills and the recovered methane rate).

The New Zealand waste composition categories from the Solid Waste Analysis Protocol do not exactly match the categories required for the IPCC DOC calculation. The major difference is that in New Zealand's DOC 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 Solid Waste Analysis Protocol baseline report. This effect of this difference is mediated by the use of IPCC default carbon contents which are similar for the non-food (17 percent carbon content) and food categories (15 percent carbon content).

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

The Tier 1 and Tier 2 approaches have been used for solid waste emission estimates and the gross CH<sub>4</sub> results compared, as recommended from the technical review of New Zealand's greenhouse gas inventory conducted in May 2001 (UNFCCC, 2001c). For the 2004 inventory, the Tier 2 value of gross annual methane generation is 125.6 Gg CH<sub>4</sub> and the Tier 1 value is 129.8 Gg CH<sub>4</sub>. The assumptions used to calculate net CH<sub>4</sub> emissions from gross CH<sub>4</sub> are the same for both tiers.

CH<sub>4</sub> from solid waste disposal was identified as a key category for New Zealand in 2004. In preparation of the 2004 inventory, the data underwent Tier 1 QC procedures (refer Annex 6 for examples).

### **8.2.5 Source-specific recalculations**

CH<sub>4</sub> recovery figures were updated due to a survey of operators in 2005. The analysis showed that recovery technology uptake happened at a much slower rate than anticipated in the mid-1990s. However the rate has increased and is now consistent with previous estimates (of landfills with capture systems in place).

Some minor corrections were made to the modelling (formula) attributes in the spreadsheet for the CH<sub>4</sub> emissions from managed solid waste disposal. This included the consistency of the half-life component. Accuracy of variables such as the CH<sub>4</sub> generation potential and CH<sub>4</sub> correction factors were improved by using data to five decimal places. Additionally, the annual MSW generation was recalculated by using 365.25 days instead of 365.

Recalculations were performed back to 1990 and have resulted in an additional 0.1Gg net CH<sub>4</sub> emissions being reported in 1990. Net CH<sub>4</sub> emissions for 2003 have increased 8.32 Gg. Of that increase, 98 percent is due to improved CH<sub>4</sub> recovery estimates.

## **8.2.6 Source-specific planned improvements**

There are no specific improvements planned for this category.

## **8.3 Wastewater handling (CRF 6B)**

### **8.3.1 Description**

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

While most of the treatment processes are aerobic and therefore produce no CH<sub>4</sub>, 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.

Very large quantities of high-strength industrial wastewater are produced by New Zealand's primary industries. Most of the treatment uses aerobic treatment and any CH<sub>4</sub> from anaerobic treatment is flared. There are however a number of anaerobic ponds that do not have CH<sub>4</sub> collection, particularly serving the meat processing industry. These are the major sources of industrial wastewater CH<sub>4</sub> in New Zealand.

### **8.3.2 Methodological issues**

#### **Methane emissions from domestic wastewater treatment**

CH<sub>4</sub> emissions from domestic wastewater handling have been calculated using a refinement of the IPCC methodology (IPCC, 1996). A population has been assessed for each municipal treatment plant in New Zealand. Where industrial wastewater flows to a municipal wastewater treatment plant, an equivalent population for that industry has been calculated based on a BOD (Biological Oxygen Demand) 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. 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 BOD to the plant that is anaerobically degraded multiplied by the CH<sub>4</sub> conversion factor. The emissions calculations are shown in Annex 8.6.

It is good practice to use country-specific data for the maximum methane producing capacity factor (B<sub>0</sub>). Where no data are available, the 1996 IPCC methodology recommends using B<sub>0</sub> of 0.25 CH<sub>4</sub> / kg COD (Chemical Oxygen Demand) or 0.6 kg CH<sub>4</sub> / kg BOD. The IPCC BOD value is based on a 2.5 scaling factor of COD (IPCC, 2000). New Zealand uses a B<sub>0</sub> of 0.25 CH<sub>4</sub> / kg COD but calculates a country-specific value of 0.375 kg CH<sub>4</sub> / kg BOD, based on a

scaling-up factor of 1.5\*COD. The New Zealand scaling factor is based on information from New Zealand waste sector experts (SCS Wetherill Environmental, 2002) and research (Metcalf and Eddy, 1992).

### **Methane emissions from industrial wastewater treatment**

The IPCC default methodology is also used to calculate emissions from industrial wastewater treatment. For each industry, an estimate is made of the total industrial output in tonnes per year, the average COD load going to the treatment plant and the proportion of waste degraded anaerobically (refer to Annex 8.6). CH<sub>4</sub> is only emitted from wastewater being treated by anaerobic processes. Industrial wastewater that is discharged into a sewer with no anaerobic pre-treatment is included in the domestic wastewater section of the inventory.

### **Methane emissions from sludge**

The organic solids produced from wastewater treatment are known as sludge. In New Zealand, the sludge from wastewater treatment plants is typically landfilled. Any CH<sub>4</sub> emissions from landfilled sludge are reported under the SWDS category. Other sources of emissions from sludge are discussed below.

In large treatment plants in New Zealand, sludge is handled anaerobically and the CH<sub>4</sub> is almost always flared or used<sup>2</sup>. Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds.

Oxidation ponds accumulate sludge on the pond floor. In New Zealand, these are typically only desludged every 20 years. The sludge produced is well stabilised with an average age of approximately 10 years. It has a low biodegradable organic content and is considered unlikely to be a significant source of CH<sub>4</sub> (SCS Wetherill Environmental, 2002).

Sludge from septic tank clean-out, known as septage, is often removed to the nearest municipal treatment plant. In those cases, it is included in the CH<sub>4</sub> emissions from domestic wastewater treatment. Where sludge is landfilled, the CH<sub>4</sub> production is included under solid waste disposal. There are a small number of treatment lagoons specifically treating septage. These lagoons are likely to produce a small amount of CH<sub>4</sub> and their effect is included in the calculations.

### **Nitrous oxide emissions from domestic wastewater treatment**

New Zealand's calculation uses a modification of the IPCC methodology (IPCC, 1996).

The IPCC method calculates nitrogen production based on the average per capita protein intake; however in New Zealand, raw sewage nitrogen data are available for many treatment plants. The raw sewage nitrogen data is used to calculate a per capita domestic nitrogen production of 13 g/day and a per capita wastewater nitrogen figure of 4.75 kg/person/year. The IPCC default method uses an emissions factor (EF<sub>6</sub>) to calculate the proportion of raw sewage nitrogen converted to N<sub>2</sub>O. New Zealand uses the IPCC default value of 0.01 kg N<sub>2</sub>O-N /kg sewage N (Annex 8.6).

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<sup>2</sup> An exception is the Christchurch sewage treatment plant that uses anaerobic lagoons for sludge treatment. Based on volatile solids reduction measurements in the lagoons they estimate CH<sub>4</sub> production of 0.46 Gg/year plus an additional 0.16 Gg/year from unburned CH<sub>4</sub> from the digester-gas fuelled engines.

## **Nitrous oxide emissions from industrial wastewater treatment**

The IPCC does not offer a methodology for estimating N<sub>2</sub>O emissions from industrial wastewater handling. Emissions are calculated using an emissions factor (kg N<sub>2</sub>O-N / kg wastewater N) to give the proportion of total nitrogen in the wastewater converted to N<sub>2</sub>O. The total nitrogen was calculated by adopting the COD load from the CH<sub>4</sub> emission calculations and using a ratio of COD to nitrogen in the wastewater for each industry (Annex 8.6)

### **8.3.3 Uncertainties and time-series consistency**

#### **Methane from domestic wastewater**

It is not possible to perform rigorous statistical analyses to determine uncertainty levels because of biases in the collection methods (SCS Wetherill Environmental, 2002). The uncertainty reported for all wastewater figures 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<sub>4</sub> emissions have an accuracy of -40 percent to +60 percent (SCS Wetherill Environmental, 2002).

#### **Methane from industrial wastewater**

The method used in estimating CH<sub>4</sub> emissions limits a statistical analysis of uncertainty.

Total CH<sub>4</sub> production from industrial wastewater has an estimated accuracy of ± 40 percent based on assessed levels of uncertainty in the input data (SCS Wetherill Environmental, 2002).

#### **Nitrous oxide from wastewater**

There are very large uncertainties associated with N<sub>2</sub>O emissions and no attempt has been made to quantify this uncertainty. The IPCC default emissions factor, EF<sub>6</sub>, has an uncertainty of -80 percent to +1,200 percent (IPCC, 1996) meaning that the estimates have only an order of magnitude accuracy.

### **8.3.4 Source-specific QA/QC and verification**

In preparation of the 2004 inventory, the data for the wastewater handling category (CH<sub>4</sub>) underwent Tier 1 QC checks.

### **8.3.5 Source-specific recalculations**

There have been no recalculations in the 2004 inventory.

The Ministry for the Environment is developing a comprehensive database of industrial / commercial and municipal wastewater treatment plants in use in New Zealand. It is anticipated data from this database (which is expected to be completed by July 2006) will help improve estimates from this source.

## **8.4 Waste incineration (CRF 6C)**

### **8.4.1 Description**

New Zealand has not estimated emissions from waste incineration as they are considered to be negligible. There is no incineration of municipal waste in New Zealand. The only incineration is for small specific waste streams including medical, quarantine and hazardous wastes. Resource consents control certain non-greenhouse gas emissions from these incinerators. As the quantity of material being disposed through these incinerators is not required to be measured under resource consents, it is not possible to estimate the quantity of greenhouse gas emissions being released.

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

## **Chapter 9: Other (UNFCCC Sector 7)**

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 GHG inventory since the submission of the 2003 inventory. It summarises material that has already been described in greater detail in chapters 3–8.

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

Updating the New Zealand inventory involves revision of last year’s activity data for the agriculture sector and LULUCF category “forest land”. This is because New Zealand uses three-year averages of activity data in these sectors. The updating process replaces the provisional numbers used in last year’s average with actual numbers. For example, the 2004 inventory uses an average of the 2003, 2004 and 2005 years numbers. The 2003 and 2004 years are actual data, but only provisional data is available for the 2005 year. In the 2005 inventory, the provisional 2005 figures will be replaced by actual figures and the 1990–2004 inventory will be recalculated.

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 of a given year can differ from emissions reported in the previous inventory.

## 10.1 Explanations and justifications for recalculations

### 10.1.1 Energy sector

No major recalculations have occurred between the 2003 and 2004 inventories. The Ministry of Economic Development advises the small differences that have occurred in the various categories are due to some minor rounding errors and updates to data in their energy greenhouse gas emissions report (MED, 2005).

### 10.1.2 Industrial processes sector

#### Mineral products

The inclusion of CO<sub>2</sub> from soda ash has been included for the first time in the 2004 inventory. Estimates have been included for all years from 1990 and this category has been recalculated for the entire time-series.

## **Chemical industry**

Methane emissions from urea production have been removed from the industrial processes sector as industry experts consider all methane emissions from this process to be attributed to fuel combustion (CRL Energy Ltd, 2006). This has resulted in a slight reduction (1.5 Gg CO<sub>2</sub> equivalent) in methane emissions for the “chemical industry” category.

The 2004 inventory has reallocated CO<sub>2</sub> emissions from urea production from a previous country-specific “urea” category to the “ammonia” source category as recommended by the international review team in the 2005 review report (UNFCCC, 2006).

## **Consumption of halocarbons and SF6**

The 2005 survey for industrial processes was redesigned to capture more importers of HFCs and PFCs and to better identify the refrigerants associated with imported and exported factory charged refrigeration and air conditioning units. This has resulted in increased HFC and PFC emissions compared with the 2003 inventory.

### **10.1.3 Solvents and other products**

No recalculations were made for this sector.

### **10.1.4 Agriculture sector**

*Animal statistics:* Every year of inventory there is a recalculation for the previous year as the provisional animal population is updated with the actual population.

*Manure management:* The methodology for this source was upgraded to a Tier 2 approach. Emissions were recalculated for the entire time-series (further details can be found in section 6.3.5).

*Agricultural soils:* The EF<sub>1</sub> emission factor has been upgraded to a country-specific emission factor of 1 percent. This has resulted in a reduction in N<sub>2</sub>O emissions from agricultural soils for the entire time-series (a 3.4 percent reduction for this category when compared to the 2003 inventory).

### **10.1.5 LULUCF**

The carbon yield tables have been updated to better reflect the diversity represented in the National Exotic Forest Description (NEFD) data. Regimes were modelled based on averages from permanent soil plot data, rather than as notional NEFD regimes. This had the effect of smoothing fluctuations during the period of silvicultural activity and also a minor effect on predicted root/shoot biomass ratios. In addition, dead fine roots were removed from the yield table to avoid double counting with soil carbon estimates. Further explanation on these recalculations can be found in section 7.2.5.

## 10.1.6 Waste

Methane emissions from solid waste disposal have been recalculated for the entire time-series. This was due to a survey completed in 2005 which showed methane recovery rates were not as high as initially calculated in the early to mid 1990s.

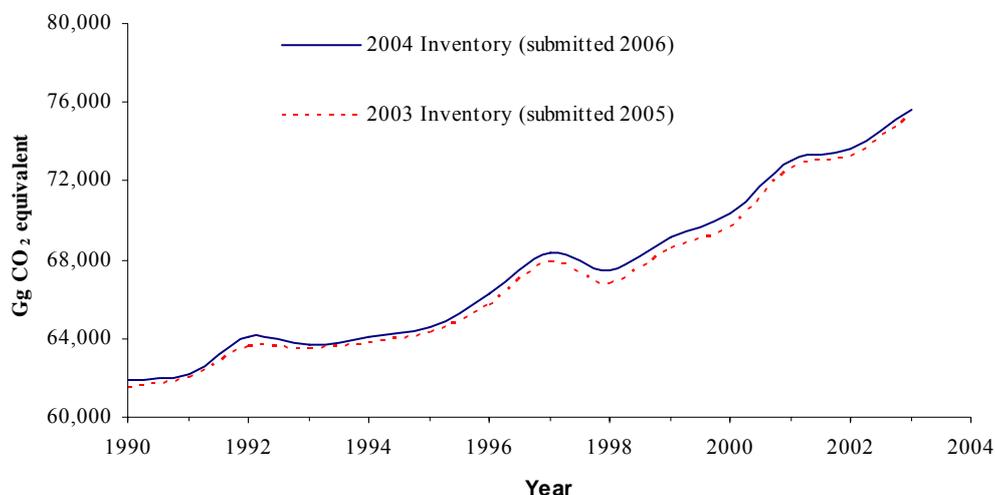
## 10.2 Implications for emission levels

The overall effect of all recalculations is shown in Figure 10.3.1. There is a 0.4 percent increase in emissions for the 2003 year and a 0.6 percent increase in emissions for the base year, 1990.

## 10.3 Implications for emission trends

In New Zealand's 2003 inventory, emissions were 22.5 percent over the level reported in 1990. In the 2004 inventory, New Zealand's total emissions for 2004 are 21.4 percent over the level in 1990. As a result of the recalculations, total emissions for 2003 were recalculated as being 22.2 percent over 1990 (Figure 10.3.1). Changes in trends for individual sectors are discussed in the following sections. Solvents are not included because of the very low level of emissions throughout the time-series.

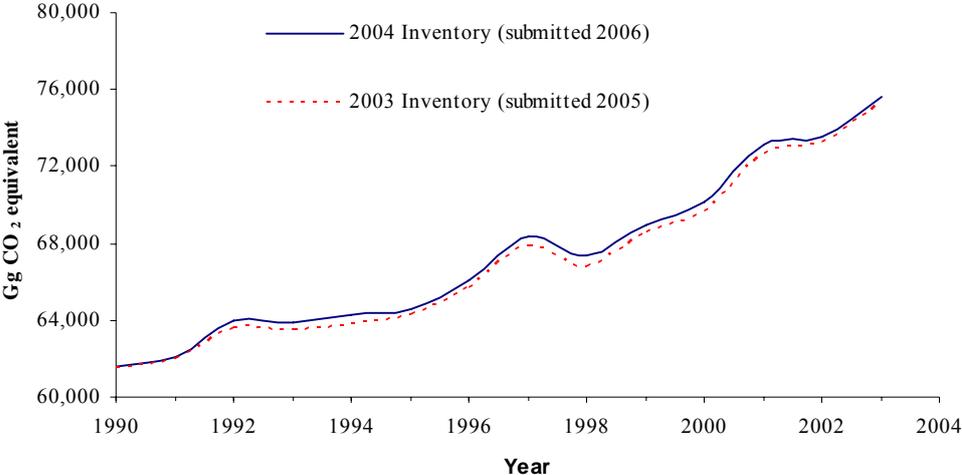
**Figure 10.3.1 The effect of recalculation on total greenhouse gas emissions**



### Energy sector

The Ministry of Economic Development advises the small differences that have occurred in the various categories are due to some minor rounding errors and updates to data in their energy greenhouse gas emissions report (MED, 2005).

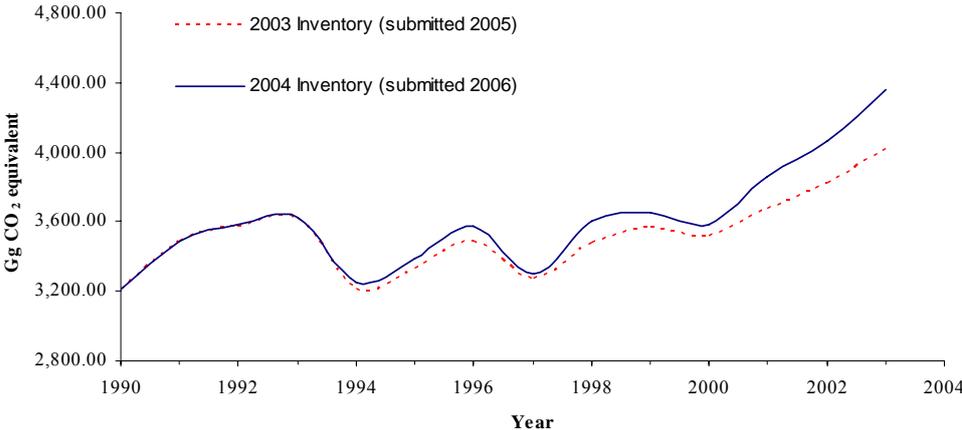
**Figure 10.3.2 The effect of recalculation on the energy sector**



**Industrial processes**

The largest recalculation for industrial processes was from the updated data on HFC and PFC use from the 2005 industrial processes survey (CRL Energy Ltd, 2006a). This resulted in an increase in emissions for the “consumption of halocarbons and SF<sub>6</sub>” category of 324.67 Gg CO<sub>2</sub> equivalent in 2003. This increased total greenhouse gas emissions by 0.4 percent for 2003. This data represents an upper limit for HFC/PFC emissions from commercial refrigeration and air conditioning but is the most accurate and complete data currently available.

**Figure 10.3.3 The effect of recalculation on the industrial processes sector**

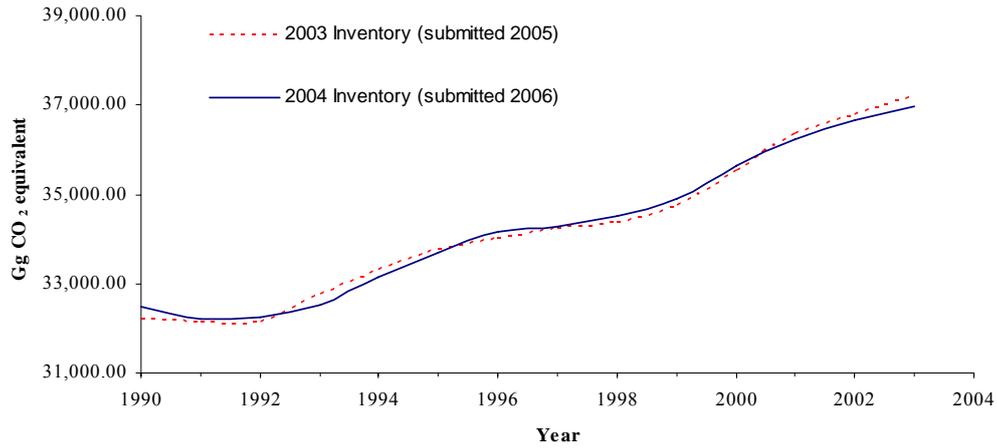


**Agriculture**

There are two prominent recalculations in the agriculture sector for the 2004 inventory. The first is the upgrade of manure management methodology from a Tier 1 to a Tier 2 approach. This

resulted in an increase in emissions for the “manure management” category of 176.50 Gg CO<sub>2</sub> equivalent in 2003. This increased total greenhouse gas emissions by 0.2 percent for 2003. The second recalculation resulted from a change in the EF<sub>1</sub> emission factor. This reduced emissions in the “agricultural soils” category by 437.36 Gg CO<sub>2</sub> equivalent in 2003. This reduced total greenhouse gas emissions by 0.6 percent for 2003.

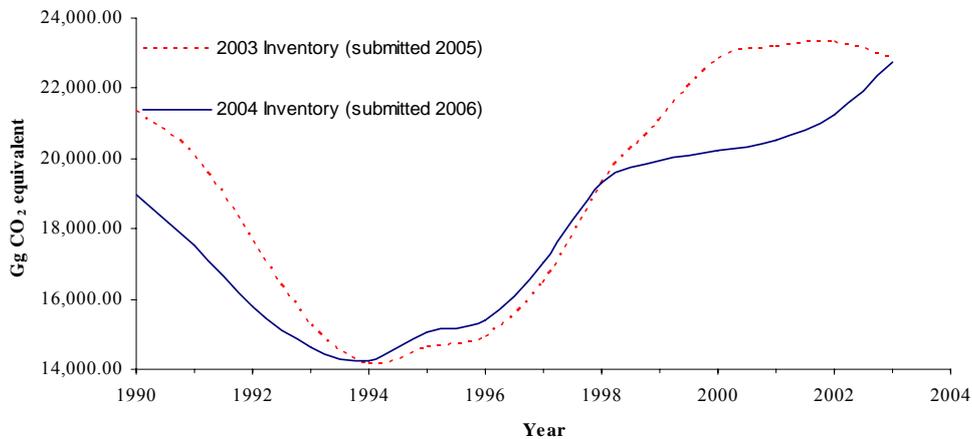
**Figure 10.3.4 The effect of recalculation on the agriculture sector**



## LULUCF

Recalculations within the LULUCF sector are explained in section 10.1.5. Differences between the carbon yield tables are not constant across age classes, so there is an interaction with forest areas (which are also not constant across age classes) which explains the differences in net removals in the LULUCF sector between the 2003 and 2004 inventories (Figure 9.3.5).

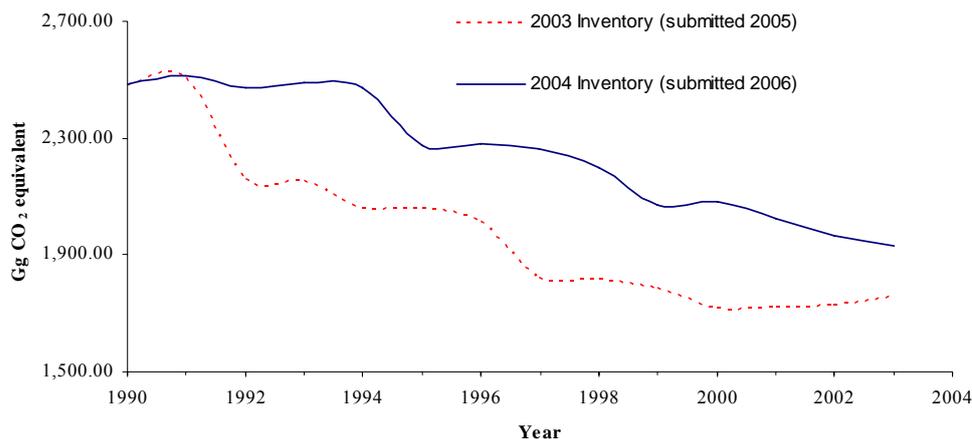
**Figure 10.3.5 The effect of recalculation on LULUCF net removals**



## Waste

Methane emissions for 1990-2003 from solid waste were recalculated as a result of methane recovery data being updated due to commissioned work undertaken in 2005. This resulted in a slower recovery of methane than previously estimated as shown in Figure 10.3.6. The recalculation resulted in an increase of 174.64 Gg CO<sub>2</sub> equivalent in 2003.

**Figure 10.3.6 The effect of recalculation on the waste sector**



## 10.4 Recalculations in response to the review process and planned improvements

### 10.4.1 Response to the review process

The UNFCCC secretariat facilitated a centralised review of New Zealand's 2003 inventory submission (UNFCCC, 2006).

A number of recommendations have not yet been addressed due to the very short amount of time between the review report being published (end of March 2006) and the submission of this inventory (15 April 2006). During 2006 the recommendations of the review team will be incorporated into New Zealand's improvement plan and addressed as time and resources allow.

### 10.4.2 Planned improvements

Improvements to methodology/emission factors are discussed under each sector as appropriate.

For this inventory submission (2006) the emphasis has been on ensuring completeness and transparency across all source categories in line with good practice. Priorities for inventory development are guided by analysis of key sources (level and trend) and uncertainty surrounding existing emissions estimates and recommendations received from previous international reviews of New Zealand's inventory. The inventory improvement plan and the quality control and assurance plan are updated regularly to reflect current and future

development. New Zealand will endeavour to undertake Tier 2 quality checks of key categories as resources permit.

The Ministry for the Environment will work towards the development of an inventory database system during 2006 to improve the inventory generation process.

## **10.5 Summary of recent improvements to the inventory**

### **10.5.1 Improvements to the 2004 inventory**

The focus of the 2004 inventory was on completeness, ensuring all estimates were calculated in accordance with good practice and increased transparency. The inclusion of data using a Tier 1 analysis for all LULUCF categories from 1990 is a significant improvement from the 2003 inventory (where data from 1997 was provided).

The other major improvements to the 2004 inventory include:

- Upgrading the methodology for CH<sub>4</sub> from manure management to a Tier 2 approach.
- Changing the EF<sub>1</sub> emission factor for nitrous oxide emissions from direct nitrogen application to a country-specific emission factor of 1 percent.
- Including estimates of CO<sub>2</sub> emissions from soda ash use.
- Including a national energy balance for 2004.
- Improving the coverage of data collection for halocarbons, especially HFCs from air conditioning units.
- Implementing a number of recommendations from the quality management review (see Annex 6). This has led to a more structured QA/QC plan and programme.

### **10.5.2 Improvements in the 2003 inventory**

The overall focus of the 2003 inventory was an improvement in the accuracy of the inventory. This is shown in the number of recalculations that were applied across all sectors.

The major improvements to the 2003 inventory include:

- Separating sectoral coal consumption into three key ranks of coal and using specific emission factors for each.
- Reporting emissions from a Tier 2 approach for mobile combustion from road transport. This was developed from a vehicle fleet model at the Ministry of Transport.
- Continuing development of the QA/QC system and extension of Tier 1 QC checks to include a selection of non-key sources and a Tier 2 QC check on the solid waste disposal key source category (refer to Annex 6).
- Reporting CH<sub>4</sub> emissions from methanol production for the entire time-series due to activity data becoming available prior to 1997.

- Increasing explanatory text in the NIR to help understanding of the methodologies and address questions raised by UNFCCC expert review teams, especially in the energy, industrial processes and agricultural sectors.
- Revising the allocation of dairy excreta between lagoons and pasture.
- Including N<sub>2</sub>O emissions from horse excreta.
- Adding emissions and removals for all LULUCF categories where activity data was available.
- Using the UNFCCC CRF reporter tool to improve the quality of data entered into the CRF.

### **10.5.3 Improvements in the 2002 inventory**

In the 2004 submission for the 2002 inventory, the focus was provide a complete series of common reporting format tables for the period 1990-2002. Other improvements included:

- The development of a preliminary QA/QC plan and the trial of Tier 1 QC checksheets.
- The trial of a Tier 3 questionnaire to calculate emissions of SF<sub>6</sub> from electrical equipment.
- Reporting N<sub>2</sub>O use in anaesthesia for the solvent sector.
- Reporting CH<sub>4</sub> from methanol production back to 1997.
- Increasing explanatory text in the NIR to help understanding of the methodologies and address questions raised by the UNFCCC expert review teams, especially in the energy and industrial processes sector.

### **10.5.4 Improvements in the 2001 inventory**

In the 2003 submission, the methodology used to estimate CH<sub>4</sub> emissions from ruminants was upgraded from Tier 1 to a Tier 2 approach consistent with good practice.

As part of the ongoing improvement to estimates of N<sub>2</sub>O from agricultural sources, a complete recalculation of the time-series was carried out using revised emission factors from IPCC (2000), some revised country-specific emission factors and new annual nitrogen excretion rates for the most significant animal classes.

### **10.5.5 Improvements in the 2000 inventory and prior inventories**

In the 2002 submission for the year 2000, emissions from solid waste disposal were upgraded to Tier 2 and emissions from small sources previously unreported (lime and dolomite) were included.

In the 2001 submission for the year 1999, estimates of emissions of the fluorinated gases (HFCs, PFCs and SF<sub>6</sub>) gases were upgraded to IPCC (2000) Tier 2 methodology.

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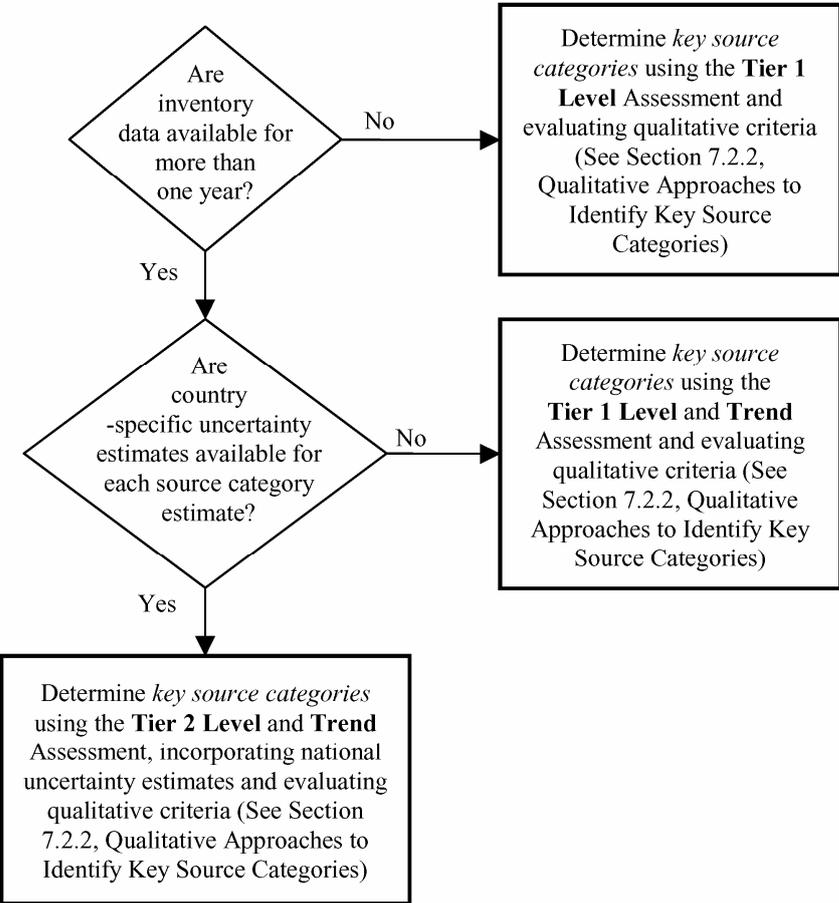
# **Annexes to New Zealand's National Inventory Report for 2004**

# 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 (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 from Good Practice)**



For the 2004 inventory the Tier 1 Level and Trend assessment were applied including the LULUCF sector and excluding the LULUCF sector as per GPG LULUCF. 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 (IPCC, 2000). Key categories are defined as those categories whose cumulative percentages, when summed in decreasing order of magnitude, contributed 95 percent of the total level or trend. Categories occurring between 95 percent and 97 percent of the cumulative total were qualitatively assessed whether they are should be regarded as key categories.

## **A1.2 Disaggregation**

The classification of categories follows the classification outlined in Table 7.1 of “Good Practice” (IPCC, 2000). The category classification follows good practice by:

- identifying categories at the level of IPCC categories using CO<sub>2</sub> equivalent emissions and considering each greenhouse gas from each category separately
- aggregating categories that use the same emission factors
- including LULUCF categories at the level shown in GPG LULUCF Table 5.4.1.

There was one modification to the suggested categories to reflect New Zealand’s national circumstances. The fugitive emissions from oil and gas operations 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 (Table 7.A1 of Good Practice) showing the results of the key category level analysis for 99 percent of the total emissions and removals in 2004. Key categories are those that comprise 95 percent of the total.**

| <b>(a) Tier 1 Category Level Assessment - including LULUCF</b> |                  |                      |                         |                         |
|--|------------------|----------------------|-------------------------|-------------------------|
| <b>IPCC Categories</b>   | <b>Gas</b>       | <b>2004 estimate</b> | <b>Level assessment</b> | <b>Cumulative total</b> |
| <b>Gg</b>  |                  |                      |                         |                         |
| Forest land remaining forest land                              | CO <sub>2</sub>  | 26254.43             | 25.3                    | 25.3                    |
| Emissions from enteric fermentation in domestic livestock      | CH <sub>4</sub>  | 23823.54             | 23.0                    | 48.3                    |
| Mobile combustion - road vehicles                              | CO <sub>2</sub>  | 12416.93             | 12.0                    | 60.2                    |
| Emissions from agricultural soils - animal production          | N <sub>2</sub> O | 7530.74              | 7.3                     | 67.5                    |
| Emissions from stationary combustion - gas                     | CO <sub>2</sub>  | 7031.32              | 6.8                     | 74.3                    |
| Emissions from stationary combustion - solid                   | CO <sub>2</sub>  | 5808.96              | 5.6                     | 79.9                    |
| Indirect emissions from Nitrogen used in agriculture           | N <sub>2</sub> O | 3376.65              | 3.3                     | 83.1                    |
| Emissions from stationary combustion - liquid                  | CO <sub>2</sub>  | 2755.47              | 2.7                     | 85.8                    |
| Direct emissions from agricultural soils                       | N <sub>2</sub> O | 1805.26              | 1.7                     | 87.5                    |
| Emissions from the iron and steel industry                     | CO <sub>2</sub>  | 1731.51              | 1.7                     | 89.2                    |
| Emissions from solid waste disposal sites                      | CH <sub>4</sub>  | 1509.12              | 1.5                     | 90.6                    |
| Mobile combustion - aviation                                   | CO <sub>2</sub>  | 1192.23              | 1.1                     | 91.8                    |
| Conversion to forest land                                      | CO <sub>2</sub>  | 747.94               | 0.7                     | 92.5                    |
| Emissions from manure management                               | CH <sub>4</sub>  | 734.08               | 0.7                     | 93.2                    |
| Conversion to grassland  | CO <sub>2</sub>  | 666.44               | 0.6                     | 93.9                    |
| Cropland remaining cropland                                    | CO <sub>2</sub>  | 662.29               | 0.6                     | 94.5                    |
| Fugitive emissions from oil and gas operations                 | CO <sub>2</sub>  | 602.86               | 0.6                     | 95.1                    |
| Emissions from substitutes for Ozone depleting substances      | HFCs             | 597.36               | 0.6                     | 95.7                    |
| Emissions from Aluminium production                            | CO <sub>2</sub>  | 552.29               | 0.5                     | 96.2                    |
| Emissions from cement production                               | CO <sub>2</sub>  | 484.77               | 0.5                     | 96.7                    |
| Emissions from ammonia/urea production                         | CO <sub>2</sub>  | 378.27               | 0.4                     | 97.0                    |
| Fugitive emissions from Oil and Gas operations                 | CH <sub>4</sub>  | 336.55               | 0.3                     | 97.3                    |
| Mobile combustion - Marine                                     | CO <sub>2</sub>  | 332.11               | 0.3                     | 97.7                    |
| Fugitive emissions from coal mining and handling               | CH <sub>4</sub>  | 311.88               | 0.3                     | 98.0                    |
| Fugitive emissions from Geothermal operations                  | CO <sub>2</sub>  | 279.67               | 0.3                     | 98.2                    |
| Emissions from Hydrogen production                             | CO <sub>2</sub>  | 175.43               | 0.2                     | 98.4                    |
| Mobile combustion - Rail                                       | CO <sub>2</sub>  | 169.05               | 0.2                     | 98.6                    |
| Emissions from wastewater handling                             | CH <sub>4</sub>  | 166.95               | 0.2                     | 98.7                    |
| Emissions from wastewater handling                             | N <sub>2</sub> O | 163.92               | 0.2                     | 98.9                    |
| Mobile combustion - Road vehicles                              | N <sub>2</sub> O | 133.42               | 0.1                     | 99.0                    |

**Table A1.2 (Table 7.A1 of Good Practice) showing the results of the key category level analysis for 99 percent of the total emissions and removals in 1990. Key categories are those that comprise 95 percent of the total**

| <b>(b) Tier 1 Category Level Assessment - excluding LULUCF</b> |                  |                 |                   |                   |
|--|------------------|-----------------|-------------------|-------------------|
| <b>IPCC Categories</b>   | <b>Gas</b>       | <b>2004</b>     | <b>Level</b>      | <b>Cumulative</b> |
|  |                  | <b>estimate</b> | <b>assessment</b> | <b>total</b>      |
| <b>Gg</b>  |                  |                 |                   |                   |
| Emissions from enteric fermentation in domestic livestock      | CH <sub>4</sub>  | 23823.54        | 31.7              | 31.7              |
| Mobile combustion - road vehicles                              | CO <sub>2</sub>  | 12416.93        | 16.5              | 48.3              |
| Emissions from agricultural soils - animal production          | N <sub>2</sub> O | 7530.74         | 10.0              | 58.3              |
| Emissions from stationary combustion - gas                     | CO <sub>2</sub>  | 7031.32         | 9.4               | 67.7              |
| Emissions from stationary combustion - solid                   | CO <sub>2</sub>  | 5808.96         | 7.7               | 75.4              |
| Indirect emissions from nitrogen used in Agriculture           | N <sub>2</sub> O | 3376.65         | 4.5               | 79.9              |
| Emissions from stationary combustion - liquid                  | CO <sub>2</sub>  | 2755.47         | 3.7               | 83.6              |
| Direct emissions from agricultural soils                       | N <sub>2</sub> O | 1805.26         | 2.4               | 86.0              |
| Emissions from the iron and steel industry                     | CO <sub>2</sub>  | 1731.51         | 2.3               | 88.3              |
| Emissions from solid waste disposal sites                      | CH <sub>4</sub>  | 1509.12         | 2.0               | 90.3              |
| Mobile combustion - aviation                                   | CO <sub>2</sub>  | 1192.23         | 1.6               | 91.9              |
| Emissions from manure management                               | CH <sub>4</sub>  | 734.08          | 1.0               | 92.8              |
| Fugitive emissions from oil and gas operations                 | CO <sub>2</sub>  | 602.86          | 0.8               | 93.6              |
| Emissions from substitutes for ozone depleting substances      | HFCs             | 597.36          | 0.8               | 94.4              |
| Emissions from aluminium production                            | CO <sub>2</sub>  | 552.29          | 0.7               | 95.2              |
| Emissions from cement production                               | CO <sub>2</sub>  | 484.77          | 0.6               | 95.8              |
| Emissions from ammonia/urea production                         | CO <sub>2</sub>  | 378.27          | 0.5               | 96.3              |
| Fugitive emissions from Oil and Gas operations                 | CH <sub>4</sub>  | 336.55          | 0.4               | 96.8              |
| Mobile combustion - Marine                                     | CO <sub>2</sub>  | 332.11          | 0.4               | 97.2              |
| Fugitive emissions from coal mining and handling               | CH <sub>4</sub>  | 311.88          | 0.4               | 97.6              |
| Fugitive emissions from Geothermal operations                  | CO <sub>2</sub>  | 279.67          | 0.4               | 98.0              |
| Emissions from Hydrogen production                             | CO <sub>2</sub>  | 175.43          | 0.2               | 98.2              |
| Mobile combustion - Rail                                       | CO <sub>2</sub>  | 169.05          | 0.2               | 98.5              |
| Emissions from wastewater handling                             | CH <sub>4</sub>  | 166.95          | 0.2               | 98.7              |
| Emissions from wastewater handling                             | N <sub>2</sub> O | 163.92          | 0.2               | 98.9              |
| Mobile combustion - Road vehicles                              | N <sub>2</sub> O | 133.42          | 0.2               | 99.1              |

**Table A1.3 (Table 7.A2 of Good Practice) showing the results of the key category trend analysis for 99 percent of the total emissions and removals in 2004. Key categories are those that comprise 95 percent of the total**

| Tier 1 Category Trend Assessment - including LULUCF       |                  |           |             |               |                 |            |
|---|------------------|-----------|-------------|---------------|-----------------|------------|
| IPCC Categories   | Gas              | Base year | 2004        | trend         | Contribution to | Cumulative |
|   |                  | estimate  | Gg estimate | Gg assessment | trend           | total      |
| Mobile combustion - Road vehicles                         | CO <sub>2</sub>  | 7534.65   | 12416.93    | 0.036         | 18.4            | 18.4       |
| Emissions from enteric fermentation in domestic livestock | CH <sub>4</sub>  | 21806.54  | 23823.54    | 0.029         | 14.8            | 33.2       |
| Emissions from Stationary combustion - gas                | CO <sub>2</sub>  | 7679.40   | 7031.32     | 0.025         | 12.8            | 46.0       |
| Emissions from Stationary combustion - solid              | CO <sub>2</sub>  | 3227.01   | 5808.96     | 0.021         | 10.6            | 56.6       |
| Direct emissions from Agricultural soils                  | N <sub>2</sub> O | 475.17    | 1805.26     | 0.013         | 6.9             | 63.5       |
| Emissions from solid waste disposal sites                 | CH <sub>4</sub>  | 2179.23   | 1509.12     | 0.012         | 6.4             | 69.9       |
| Forest land remaining forest land                         | CO <sub>2</sub>  | 20624.90  | 26254.43    | 0.014         | 6.9             | 76.8       |
| Emissions from agricultural soils - animal production     | N <sub>2</sub> O | 6858.34   | 7530.74     | 0.009         | 4.4             | 81.2       |
| Emissions from substitutes for Ozone depleting substances | HFCs             | 0.00      | 597.36      | 0.007         | 3.4             | 84.6       |
| PFC's from Aluminium production                           | PFC              | 515.60    | 80.70       | 0.006         | 3.1             | 87.6       |
| Emissions from Stationary combustion - liquid             | CO <sub>2</sub>  | 2546.55   | 2755.47     | 0.004         | 1.9             | 89.5       |
| Conversion to forest land                                 | CO <sub>2</sub>  | 870.01    | 747.94      | 0.003         | 1.7             | 91.2       |
| Fugitive emissions from Oil and Gas operations            | CO <sub>2</sub>  | 263.75    | 602.86      | 0.003         | 1.6             | 92.8       |
| Mobile combustion - Aviation                              | CO <sub>2</sub>  | 772.83    | 1192.23     | 0.003         | 1.4             | 94.2       |
| Fugitive emissions from Geothermal operations             | CO <sub>2</sub>  | 357.34    | 279.67      | 0.002         | 0.9             | 95.1       |
| Mobile combustion - Road vehicles                         | CH <sub>4</sub>  | 148.20    | 51.94       | 0.001         | 0.7             | 95.8       |
| Emissions from the iron and steel industry                | CO <sub>2</sub>  | 1329.40   | 1731.51     | 0.001         | 0.7             | 96.5       |
| Mobile combustion - Rail                                  | CO <sub>2</sub>  | 77.50     | 169.05      | 0.001         | 0.4             | 96.9       |
| Mobile combustion - Road vehicles                         | N <sub>2</sub> O | 64.41     | 133.42      | 0.001         | 0.3             | 97.2       |
| Emissions from ammonia/urea production                    | CO <sub>2</sub>  | 272.92    | 378.27      | 0.001         | 0.3             | 97.5       |
| Emissions from cement production                          | CO <sub>2</sub>  | 366.66    | 484.77      | 0.000         | 0.2             | 97.7       |
| Emissions from Manure Management                          | CH <sub>4</sub>  | 590.47    | 734.08      | 0.000         | 0.1             | 97.8       |
| Non-CO <sub>2</sub> emissions from Stationary combustion  | CH <sub>4</sub>  | 60.35     | 41.55       | 0.000         | 0.2             | 98.0       |
| Mobile combustion - Marine                                | CO <sub>2</sub>  | 247.82    | 332.11      | 0.000         | 0.2             | 98.2       |
| Grassland remaining grassland                             | CH <sub>4</sub>  | 57.36     | 43.66       | 0.000         | 0.1             | 98.3       |
| Emissions from wastewater handling                        | CH <sub>4</sub>  | 156.66    | 166.95      | 0.000         | 0.1             | 98.4       |
| Emissions from lime production                            | CO <sub>2</sub>  | 81.62     | 122.08      | 0.000         | 0.1             | 98.6       |
| Non-CO <sub>2</sub> emissions from Stationary combustion  | N <sub>2</sub> O | 76.75     | 115.66      | 0.000         | 0.1             | 98.7       |
| Indirect emissions from Nitrogen used in Agriculture      | N <sub>2</sub> O | 2701.86   | 3376.65     | 0.001         | 0.6             | 99.2       |

# Annex 2: Methodology and data collection for estimating emissions from fossil fuel combustion

New Zealand emission factors are based on GCV (gross calorific value) since energy use in NZ is conventionally reported in gross terms, with some minor exceptions. The convention adopted by New Zealand to convert GCV to NCV (net calorific value) is to follow the OECD/IEA assumptions that:

- $NCV = 0.95 * GCV$  for coal and liquid fuels
- $NCV = 0.90 * GCV$  for gas.

## A2.1 Emissions from liquid fuels

### **Activity data:**

Statistics New Zealand conducts the *Delivery of Petroleum Fuels* collection and is New Zealand's national statistical office and administers the Statistics Act 1975.

The *Delivery of Petroleum Fuels* collection is 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. It is assumed there is a 5 percent uncertainty associated with the sectoral energy allocation although the annual totals are likely to be more certain (MED, 2003).

This is a census which means there is no sampling error. The main sources of non-sample error are:

- Respondent error: Statistics New Zealand makes every effort to confirm figures supplied by the respondents, and given assurances of accuracy, Statistics New Zealand are bound to accept them. If a discrepancy is discovered at a later date, revised figures are supplied at the earliest possible opportunity.
- Processing error: there is always the possibility of error, however, Statistics New Zealand has thorough checking procedures to ensure that the risk of processing errors is minimised.

### **Emission factors:**

CO<sub>2</sub> emission factors are described in Table A2.1. The CO<sub>2</sub> emission factors for oil products are from the New Zealand Refining Company (NZRC) data, import data from industry and from a New Zealand source (Baines, 1993<sup>3</sup>). The same values are used for each year of inventory. There is a direct relationship between fuels' carbon content and the corresponding CO<sub>2</sub>

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<sup>3</sup> The LPG CO<sub>2</sub> emissions factor was confirmed by checks of 2002 gas data.

emissions during combustion. However, the carbon composition of oil products is not closely monitored and there will be variation over time, depending on the crude oil used in production. The NZRC estimates the uncertainty in emission factors to be within 5 percent (MED, 2003).

New Zealand's review of emission factors (Hale and Twomey, 2003) identified a number of non-CO<sub>2</sub> emission factors (Tables A2.2 and A2.3) where the supporting information (Bone *et al*, 1993; Waring *et al*, 1991) was assessed to be insufficient to retain the country-specific emission factors used in previous inventories. The changes mainly affected the mobile combustion category. Where a country-specific value was not available, the emission factor used by New Zealand is either the IPCC value that was closest match to New Zealand's conditions or the mid-point value from the IPCC range.

Many of the sources in the stationary combustion category already used the IPCC (1996) emission factors, however there were minor changes to the 2002 inventory related to the re-interpretation of the IPCC tables resulting from the Hale and Twomey review. The changes were made to obtain the closest match to New Zealand conditions. The decision to change from the country-specific emission factors to IPCC values was confirmed by an expert review panel prior to including the emission factors in the inventory. There was no further review of emission factors for the subsequent inventory reports. All emission factors from the IPCC guidelines are converted from NCV to GCV.

**Table A2.1 CO<sub>2</sub> emission factors used in the energy sector category**

|  | Emission factor<br>(t CO <sub>2</sub> /TJ) | Emission factor<br>(t C/TJ) |
|--|--|-----------------------------|
| <b>Gas</b>                             |  |                             |
| Maui                                   | 51.8 (2004)                                | 14.1 (2004)                 |
| Treated                                | 53.7 (2004)                                | 14.6 (2004)                 |
| Kapuni LTS                             | 84.1                                       | 22.9                        |
| Methanol – mixed feed (1990-1994)      | 62.4                                       | 17.0                        |
| Methanol – LTS (1990-1994)             | 84.0                                       | 22.9                        |
| Kaimiro                                | 65.2                                       | 17.8                        |
| Ngatoro                                | 46.3                                       | 12.6                        |
| Rimu                                   | 53.7                                       | 14.6                        |
| Waihapa/Ngaere + Tariki/Ahuroa (1990)* | 56.2                                       | 15.3                        |
| Waihapa/Ngaere + Tariki/Ahuroa (2002)  | 54.2                                       | 14.8                        |
| McKee                                  | 54.2                                       | 14.8                        |
| Mangahewa                              | 52.3                                       | 14.3                        |
| <b>Liquid fuels</b>                    |  |                             |
| Regular petrol (all petrol 1990-1995)  | 66.2                                       | 18.1                        |
| Petrol – premium (1996 and onwards)    | 67.0                                       | 18.3                        |
| Diesel                                 | 69.5                                       | 19.0                        |
| Aviation fuels                         | 68.1                                       | 18.6                        |
| Av gas                                 | 65.0                                       | 17.7                        |
| Other                                  | 72.9                                       | 19.9                        |
| Fugitive – flared                      | 65.1                                       | 17.8                        |
| LPG                                    | 60.4                                       | 16.5                        |
| Heavy fuel oil                         | 73.5                                       | 20.0                        |
| Light fuel oil                         | 72.0                                       | 19.6                        |
| Averaged fuel oil                      | 73.0                                       | 19.9                        |
| Bitumen (asphalt)                      | 76.1                                       | 20.8                        |
| <b>Biomass</b>                         |  |                             |
| Biogas                                 | 101.0                                      | 27.5                        |
| Wood (industrial)                      | 104.2                                      | 28.4                        |
| Wood (residential)                     | 104.2                                      | 28.4                        |
| <b>Coal</b>                            |  |                             |
| All sectors (sub bit)                  | 91.2                                       | 24.9                        |
| All sectors (bit)                      | 88.8                                       | 24.2                        |
| All sectors (lignite)                  | 95.2                                       | 26.0                        |

\* For the years 1991–2001, the emissions factors for these gas streams are interpolated between the 1990 and 2002 figures.

**Table A2.2 CH<sub>4</sub> emission factors used in the energy sector category**

|  | <b>Emission factor</b><br><b>t CH<sub>4</sub>/PJ</b> | <b>Source</b>  |
|--|--|--|
| <b>Natural gas</b>                             |  |  |
| 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   |
| <b>Liquid fuels</b>                            |  |  |
| <b>Stationary sources</b>                      |  |  |
| Electricity – residual oil                     | 0.855  | IPCC Tier 2 (table 1–15) residual oil boilers – normal firing                                |
| Electricity – distillate oil                   | 0.855  | IPCC Tier 2 (table 1–15) distillate oil boilers – normal firing                              |
| Industrial (including refining) – residual oil | 2.85   | IPCC Tier 2 (table 1–16) residual oil boilers  |
| Industrial – distillate oil                    | 0.19   | IPCC Tier 2 (table 1–16) distillate oil boilers  |
| Industrial – LPG                               | 1.045  | IPCC Tier 2 (table 1–18) propane/butane furnaces   |
| Commercial – residual oil                      | 1.33   | IPCC Tier 2 (table 1–19) residual oil boilers  |
| Commercial – distillate oil                    | 0.665  | IPCC Tier 2 (table 1–19) distillate oil boilers  |
| Commercial – LPG                               | 1.045  | IPCC Tier 2 (table 1–18) propane/butane furnaces   |
| Residential – distillate oil                   | 0.665  | IPCC Tier 2 (table 1–18) distillate oil furnaces   |
| Residential – LPG                              | 1.045  | IPCC Tier 2 (table 1–18) propane/butane furnaces   |
| Agriculture – stationary                       | 3.8  | IPCC Tier 2 (table 1–49) diesel engines (agriculture)  |
| <b>Mobile sources</b>                          |  |  |
| LPG  | 28.5   | IPCC Tier 2 (table 1–44) passenger cars (uncontrolled)                                       |
| Petrol – 1990–1993*                            | 60   | Bone, Hunt and Spring (1993)   |
| Petrol – 2003 onwards*                         | 18.525   | IPCC Tier 2 (table 1–27) passenger cars (uncontrolled – midpoint of average g/MJ)            |
| Diesel – 1990–1993*                            | 13   | Bone, Hunt and Spring (1993)   |
| Diesel – 2003 onwards*                         | 3.8  | IPCC Tier 2 (table 1–32) passenger cars (uncontrolled – g/MJ)                                |
| Navigation (fuel oil and diesel)               | 6.65   | IPCC Tier 2 (table 1–48) ocean going ships   |
| Aviation fuel/kerosene                         | 1.9  | IPCC Tier 2 (table 1–48) jet and turboprop aircraft  |
| <b>Coal</b>                                    |  |  |
| 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                   |
| <b>Biomass</b>      |       |  |
| 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                         |

\* For the years 1994–2002, emission factors are interpolated between the NZ specific emission factors (Bone, Hunt and Spring) and the IPCC defaults.

**Table A2.2 N<sub>2</sub>O emission factors used in the energy sector category**

|  | Emission factor       |   |
|--|-----------------------|---|
|  | t N <sub>2</sub> O/PJ | Source  |
| <b>Natural Gas</b>                             |                       |   |
| 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  |
| <b>Liquid fuels</b>                            |                       |   |
| <b>Stationary Sources</b>                      |                       |   |
| Electricity – residual oil                     | 0.285                 | IPCC Tier 2 (table 1–15) residual oil boilers – normal firing                               |
| Electricity – distillate oil                   | 0.38                  | IPCC Tier 2 (table 1–15) distillate oil boilers – normal firing                             |
| Industrial (including refining) – residual oil | 0.285                 | IPCC Tier 2 (table 1–16) residual oil boilers   |
| Industrial – distillate oil                    | 0.38                  | IPCC Tier 2 (table 1–16) distillate oil boilers   |
| Commercial – residual oil                      | 0.285                 | IPCC Tier 2 (table 1–19) residual oil boilers   |
| Commercial – distillate oil                    | 0.38                  | IPCC Tier 2 (table 1–19) distillate oil boilers   |
| Residential (all oil)                          | 0.19                  | IPCC Tier 2 (table 1–18) furnaces   |
| LPG (all uses)                                 | 0.57                  | IPCC Tier 1 (table 1–8) oil – all sources except aviation                                   |
| Agriculture – stationary                       | 28.5                  | IPCC Tier 2 (table 1–49) Diesel Engines – Agriculture                                       |
| <b>Mobile sources</b>                          |                       |   |
| LPG  | 0.57                  | IPCC Tier 1 (table 1–8) oil – all sources except aviation                                   |
| Petrol   | 1.425                 | IPCC Tier 2 (table 2.7 in “Good practice...” (2000))<br>US gasoline vehicles (uncontrolled) |
| Diesel   | 3.705                 | IPCC Tier 2 (table 2.7 in “Good practice...” (2000))<br>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  |

| <b>Coal</b>            |      |  |
|------------------------|------|--|
| 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                                       |

## A2.2 Emissions from solid fuels

### **Activity data:**

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

The survey is a full coverage of the sector and therefore there are no sampling errors. Non-sampling errors in the survey data may result from errors in the sample frame (ie, units with the wrong New Zealand Standard Industrial Classification), respondent error (ie, wrong values supplied), mistakes made during processing survey results or non-response imputation. Statistics New Zealand adopts procedures to detect and minimise these types of errors but they may still occur and they are not quantifiable.

The three ranks of coal measured are bituminous, sub-bituminous and lignite coal. From 1988 onwards the coal sales questionnaire broke coal sales into seven end use sectors, however these do not match the IPCC sectors. The sectoral shares of coal use that can be used for the UNFCCC inventory are based on Coal Research Limited’s (CRL) survey of sectoral coal use for 1990 and 1995. Data is interpolated between 1990 and 1995 and extrapolated for all years beyond 1995. The exceptions are for the coal used for steel manufacture, electricity production and the residential household sector where the MED use figures from Statistics New Zealand’s “Coal Sales” survey. Sectoral shares are calculated by:

- summing the four calendar year quarters of coal sales data from Statistics New Zealand’s “Coal Sales” survey
- subtracting coal exports and coal used by the Residential sector (from Statistics New Zealand’s “Coal Sales” survey) and coal used for steel and electricity (both known accurately) dividing CRL annual coal tonnage for each sector by the total (excluding exports, steel, electricity and residential coal use) to give sectoral shares of coal use for 1990 and 1995
- interpolating sectoral shares between 1990 and 1995 and extrapolating for beyond 1995
- applying the sectoral share estimates to the “Coal Sales” survey’s total coal sold (excluding exports, electricity, steel and residential coal use).

The process of dividing coal use between different sectors will introduce uncertainty larger than the uncertainty in total coal sales. Uncertainty is also introduced from the assumption that coal used by sector is an average of the different ranks. An uncertainty of  $\pm 5$  percent is assumed to cover these issues (MED, 2003).

The sectoral partitioning used for coal was examined in 2003 by the Ministry for the Environment officials. There was concern in extrapolating sectoral allocations from 1995 to 2002 given some probable changes in sectoral coal usage. However, coal industry experts (Hennessy, *Personal Communication*) did not consider a survey could be justified because of the difficulty and expense in collating and verifying data from a number of sectors. Furthermore the major categories of coal exports, coal used by the residential sector and coal used for steel and electricity are all known accurately and are not affected by the sectoral partitioning.

**Emission factors:**

The value for sub-bituminous coal (91.2 kt CO<sub>2</sub>/PJ) is used to calculate New Zealand's emissions from coal burning (Table A2.1). Using only the sub-bituminous value for all ranks of coal is a reasonable assumption for New Zealand as the bulk of the high-quality bituminous coal is exported and all coal used in public electricity generation is of sub-bituminous rank (MED, 2003). The range in emission factors across all grades of coal is 5.5 percent. Therefore the estimated uncertainty in coal emission factors is taken as  $\pm 3$  percent (MED, 2003). An uncertainty of  $\pm 2$  percent is used for the sub-bituminous coal used in public electricity generation. All New Zealand values are within 2 percent of the IPCC defaults (1996). The non-CO<sub>2</sub> emission factors are shown in Tables A2.2 and A2.3.

## **A2.3 Emissions from gaseous fuels**

**Activity data:**

The Natural Gas Corporation (NGC) has contracts with large users that allow metering errors of  $\pm 2$  percent. Whenever the error between the meter reading and actual gas supplied exceeds 2 percent, adjustments are made to the reported quantities of gas supplied. The uncertainty is therefore assumed to have an upper limit of  $\pm 2$  percent (MED, 2003).

**Emission factors:**

The emission factors for natural gas used in distribution and sold to large users are shown in Table A2.1. The values are calculated by averaging daily gas composition data supplied by industry. The composition, hence the emissions factor varies slightly between daily measurements. Taking annual bounds, it is estimated that the uncertainty in the natural gas emission factors is less than 1.7 percent (MED, 2003).

It has been assumed that half of the gas in the system is from the Maui gas field with an average CO<sub>2</sub> emissions factor of 51.9 kt CO<sub>2</sub>/PJ for this 2004 inventory and the other half is treated gas (53.7 kt CO<sub>2</sub>/PJ). The average value of 52.8 kt CO<sub>2</sub>/PJ is used for this 2004 inventory (Table A2.4).

**Table A2.4 Variation in CO<sub>2</sub> emission factors for natural gas**

| <b>Year</b> | <b>Maui<br/>(kt CO<sub>2</sub> / PJ)</b> | <b>Treated<br/>(kt CO<sub>2</sub> / PJ)</b> | <b>Average<br/>(kt CO<sub>2</sub> / PJ)</b> |
|-------------|--|---|---|
| 1990        | 53.2                                     | 52.4  | 52.8  |
| 1991        | 52.9                                     | 52.8  | 52.8  |
| 1992        | 52.9                                     | 52.7  | 52.8  |
| 1993        | 52.6                                     | 52.5  | 52.5  |
| 1994        | 52.4                                     | 52.2  | 52.3  |
| 1995        | 52.1                                     | 52.9  | 52.5  |
| 1996        | 52.2                                     | 52.9  | 52.6  |
| 1997        | 52.3                                     | 52.4  | 52.4  |
| 1998        | 52.1                                     | 52.2  | 52.1  |
| 1999        | 51.8                                     | 52.4  | 52.1  |
| 2000        | 52.1                                     | 52.1  | 52.1  |
| 2001        | 51.9                                     | 52.6  | 52.3  |
| 2002        | 52.3                                     | 52.5  | 52.4  |
| 2003        | 52.0                                     | 52.6  | 52.3  |
| 2004        | 51.9                                     | 53.7  | 52.8  |

# A2.4 Energy balance for year ended December 2004

Table A2.5 New Zealand energy balance for year ended December 2004

Energy Supply and Demand Balance December Year 2004

| Converted into Petajoules using<br>Gross Calorific Values |                                     | COAL       |       |            |                           |         | OIL           |         |                       |             |                   |        |             | GAS               |        | RENEWABLES |                |        |                 |        |       |        | ELEC-<br>TRICITY | TOTAL   |        |         |        |
|---|-------------------------------------|------------|-------|------------|---------------------------|---------|---------------|---------|-----------------------|-------------|-------------------|--------|-------------|-------------------|--------|------------|----------------|--------|-----------------|--------|-------|--------|------------------|---------|--------|---------|--------|
|   |                                     | Bituminous |       | Sub-bitum. | Bituminous&<br>Sub-bitum. | Lignite | Peat/<br>Coke | Total   | Crudes/<br>Feedstocks | LPG/<br>NGL | Motor<br>Gasoline | Diesel | Fuel<br>Oil | Av. Fuel/<br>Kero | Others | Total      | Natural<br>Gas | Hydro  | Geo-<br>thermal | Solar  | Wind  | Biogas |                  |         | Wastes | Wood    | Total  |
|   |                                     | Coking     | Other |            |                           |         |               |         |                       |             |                   |        |             |                   |        |            |                |        |                 |        |       |        |                  |         |        |         |        |
| S<br>U<br>P<br>P<br>L<br>Y                                | Indigenous Production               | 77.58      | 1.75  | 48.89      | 128.22                    | 3.79    | 132.01        | 42.53   | 9.20                  |             |                   |        |             |                   |        | 51.74      | 160.63         | 97.28  | 84.95           | 0.20   | 1.288 | 1.47   | 17.17            | 35.00   | 237.36 |         | 581.74 |
|   | + Imports                           |            | 1.61  | 18.43      | 20.04                     | 0.00    | 20.25         | 217.01  | 0.39                  | 41.03       | 36.22             | 0.00   | 13.80       | 7.30              | 315.76 |            |                |        |                 |        |       |        |                  |         |        |         | 336.01 |
|   | - Exports                           | 59.98      |       |            | 59.98                     | 0.00    | 0.06          | 60.04   | 33.45                 | 0.75        | 0.00              | 0.24   | 2.62        | 0.00              | 37.06  |            |                |        |                 |        |       |        |                  |         |        |         | 97.10  |
|   | - Stock Change                      |            |       |            |                           |         |               |         | -1.42                 | 0.23        | 5.00              | 0.98   | 0.20        | 1.93              | 6.59   | 0.10       |                |        |                 |        |       |        |                  |         |        |         | 6.69   |
|   | - International Transport           |            |       |            |                           |         |               |         | 0.00                  | 1.53        | 8.80              | 38.04  | 0.00        |                   | 48.37  |            |                |        |                 |        |       |        |                  |         |        |         | 48.37  |
|   | <b>TOTAL PRIMARY ENERGY</b>         | 17.59      | 3.36  | 67.33      | 88.28                     | 3.79    | 92.22         | 227.51  | 8.62                  | 36.02       | 33.47             | -11.62 | -26.18      | 7.64              | 275.47 | 160.53     | 97.28          | 84.95  | 0.20            | 1.288  | 1.47  | 17.17  | 35.00            | 237.36  |        | 765.59  |        |
| U<br>S<br>E   | <b>ENERGY TRANSFORMATION</b>        |            |       |            | -45.37                    |         | -45.37        | -227.51 | -0.80                 | 76.02       | 72.20             | 23.35  | 42.62       | 5.18              | -8.95  | -67.42     | -97.28         | -70.31 |                 | -1.288 | -1.36 | -16.80 | -5.88            | -192.93 | 142.57 | -172.10 |        |
|   | Electricity Generation              |            |       |            | -42.56                    |         | -42.56        |         |                       |             |                   |        |             |                   |        | -39.80     | -97.28         | -63.71 |                 | -1.288 | -1.06 |        |                  | -163.33 | 142.56 | -103.13 |        |
|   | Cogeneration                        |            |       |            | -0.81                     |         | -0.81         |         |                       |             |                   |        |             |                   |        | -20.59     |                | -0.61  |                 |        |       | -0.30  | -16.80           | -5.88   | -23.59 | 10.85   | -34.15 |
|   | Oil Production                      |            |       |            |                           |         |               | -227.51 | 76.47                 | 74.90       | 21.30             | 43.26  | 12.28       | 0.69              |        |            |                |        |                 |        |       |        |                  |         |        | 0.69    |        |
|   | Losses and Own Use                  |            |       |            | -2.00                     |         | -2.00         |         | -0.80                 | -0.45       | -2.70             | 2.05   | -0.64       | -7.10             | -9.64  | -7.03      |                | -6.00  |                 |        |       |        |                  |         | -6.00  | -10.84  | -35.51 |
|   | <b>Non-energy Use</b>               |            |       |            |                           |         |               |         |                       |             |                   |        |             | -12.82            | -12.82 | -50.59     |                |        |                 |        |       |        |                  |         |        | -63.40  |        |
|   | <b>CONSUMER ENERGY (calculated)</b> |            | 3.36  | 67.33      | 42.90                     | 3.79    | 46.85         |         | 7.82                  | 112.04      | 105.67            | 11.73  | 16.44       | 0.00              | 253.71 | 42.53      |                | 14.64  | 0.20            | 0.000  | 0.11  | 0.37   | 29.12            | 44.43   | 142.57 | 530.09  |        |
| D<br>E<br>M<br>A<br>N<br>D                                | <b>Agriculture</b>                  |            |       |            | 0.52                      | 0.01    | 0.53          |         | 1.18                  | 9.74        | 1.48              | 0.20   |             | 12.60             |        |            |                |        |                 |        |       |        |                  |         | 5.61   | 18.74   |        |
|   | Agriculture and Hunting             |            |       |            | 0.52                      | 0.01    | 0.53          |         | 1.15                  | 6.27        | 0.01              | 0.19   |             | 7.63              |        |            |                |        |                 |        |       |        |                  |         |        | 5.40    | 13.56  |
|   | Fishing                             |            |       |            |                           |         |               |         | 0.03                  | 3.47        | 1.46              | 0.01   |             | 4.97              |        |            |                |        |                 |        |       |        |                  |         | 0.21   | 5.18    |        |
|   | <b>Industrial</b>                   |            |       |            | 28.41                     | 3.47    | 31.88         |         | 2.97                  | 0.39        | 12.20             | 1.14   | 0.17        | 16.88             | 26.85  |            | 12.32          |        |                 |        |       | 0.37   | 26.58            | 39.26   | 57.23  | 172.11  |        |
|   | Other Primary Industry              |            |       |            |                           |         |               |         |                       | 0.01        | 2.95              | 0.34   | 0.01        | 3.31              |        |            |                |        |                 |        |       |        |                  |         |        | 1.20    | *      |
|   | Food Processing                     |            |       |            |                           |         |               |         |                       | 0.00        | 0.06              | 0.13   | 0.00        | 0.19              |        |            |                |        |                 |        |       |        |                  |         |        | 7.85    | *      |
|   | Textiles                            |            |       |            |                           |         |               |         |                       |             |                   |        |             |                   |        |            |                |        |                 |        |       |        |                  |         |        | 0.61    | *      |
|   | Wood, Pulp, Paper and Printing      |            |       |            |                           |         |               |         |                       |             |                   |        |             |                   |        |            |                |        |                 |        |       |        |                  |         |        | 14.96   | *      |
|   | Chemicals                           |            |       |            |                           |         |               |         |                       |             |                   |        |             |                   |        |            |                |        |                 |        |       |        |                  |         |        | 2.60    | *      |
|   | Non-metallic Minerals               |            |       |            |                           |         |               |         |                       |             |                   |        |             |                   |        |            |                |        |                 |        |       |        |                  |         |        | 0.96    | *      |
|   | Basic Metals                        |            |       |            | 18.10                     |         | 18.10         |         |                       |             |                   | 0.00   |             |                   |        |            |                |        |                 |        |       |        |                  |         |        | 24.36   | *      |
|   | Mechanical/Electrical Equipment     |            |       |            |                           |         |               |         |                       |             |                   |        |             |                   |        |            |                |        |                 |        |       |        |                  |         |        | 1.32    | *      |
|   | Building and Construction           |            |       |            |                           |         |               |         |                       |             | 0.01              | 2.60   | 0.01        | 0.10              | 2.72   |            |                |        |                 |        |       |        |                  |         |        | 1.14    | *      |
| Unallocated   |                                     |            |       | 10.32      | 3.47                      | 13.79   |               | 2.97    | 0.36                  | 6.60        | 0.66              | 0.06   | 10.65       | 26.85             |        | 12.32      |                |        |                 |        | 0.37  | 26.58  | 39.26            | 2.23    | 2.23   | *       |        |
| <b>Commercial</b>   |                                     |            |       | 5.97       | 0.60                      | 6.57    |               | 1.40    | 0.47                  | 3.41        | 0.63              | 0.66   | 6.57        | 8.75              |        |            |                |        |                 |        | 0.11  |        |                  | 0.11    | 26.61  | 48.61   |        |
| <b>Residential</b>  |                                     |            |       | 0.45       | 0.40                      | 0.86    |               | 2.23    | 0.00                  | 0.00        | 0.00              | 0.00   | 2.23        | 6.71              |        | 2.32       | 0.20           |        |                 |        |       |        | 2.54             | 5.06    | 47.68  | 62.54   |        |
| <b>Domestic Transport</b>                                 |                                     |            |       | 0.08       |                           | 0.08    |               | 1.22    | 110.96                | 75.76       | 4.61              | 17.71  | 210.25      | 0.22              |        |            |                |        |                 |        |       |        |                  |         | 2.14   | 212.69  |        |
|   | <b>CONSUMER ENERGY (observed)</b>   |            |       |            | 35.44                     | 4.49    | 39.93         |         | 7.82                  | 113.00      | 101.11            | 7.85   | 18.75       | 0.00              | 248.52 | 42.53      |                | 14.64  | 0.20            |        | 0.11  | 0.37   | 29.12            | 44.43   | 139.28 | 514.69  |        |
|   | Statistical Differences             |            |       |            | 7.46                      | -0.70   | 0.15          | 6.92    |                       | 0.00        | -0.95             | 4.56   | 3.88        | -2.30             | 0.00   | 5.18       | 0.00           |        | 0.00            | 0.00   |       | 0.00   | 0.00             | 0.00    | 0.00   | 3.29    | 15.39  |

\* Unknown or confidential.  
Electricity end use excludes electricity generated and consumed by cogeneration plants.

# Annex 3. Detailed methodological information for other sectors

## A3.1 The agriculture sector

New Zealand's methodology 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<sub>4</sub> emitted is calculated using CH<sub>4</sub> emissions per unit of feed intake. A schematic overview of the model is presented in the agriculture sector.

### A3.1.1 Enteric methane emissions

#### *Livestock populations*

The New Zealand ruminant population can be separated into four main categories: dairy cattle, beef cattle, sheep and deer. For each livestock category, population models that further subdivided the principle categories were developed. These models reflect New Zealand farming systems with regard to the timing of births, timing of slaughter of growing animals and the transfer of younger animals into the breeding population.

Animal numbers are provided by Statistics New Zealand from census and survey data conducted in June each year. As shown in the agricultural worksheets in Annex 8, population numbers are reported as three-year rolling averages of the June 30<sup>th</sup> figure.

For sheep, dairy cattle, non-dairy cattle and deer the populations within a year are adjusted on a monthly basis to take account of births, deaths and transfers between age groups. This is necessary because the numbers present at one point in time may not accurately reflect the numbers present at other times of the year. Goats are also included in the analysis, but a separate model has not been developed and IPCC default values have been used. This is because goats represent only a very small proportion of the total animal population and numbers have dropped significantly in recent years.

#### *Livestock productivity data*

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

Obtaining data on the productivity of ruminant livestock in New Zealand, and how it has changed over time, is a difficult task. Some of the information collected is robust ie, the slaughter weight of all livestock exported from New Zealand are collected by the MAF on a census basis. This information is used as a surrogate for changes in animal liveweight. Other information is collected at irregular intervals or from small survey populations.

Livestock productivity and performance data are summarised in the time-series tables detailed in the Annex 8 worksheets. The data includes average liveweights, milk yields and milk composition of dairy cows, average liveweights of beef cattle (beef cows, heifers, bulls and

steers), average liveweights of sheep (ewes and lambs), average liveweights of deer (breeding and growing hinds and stags).

*Dairy cattle:* Data on milk production are provided by Livestock Improvement Corporation (2005). These data include the amount of milk processed through New Zealand dairy factories plus an allowance for town milk supply. Annual milk yields per animal are obtained by dividing the total milk produced by the total number of milking dairy cows and heifers. Milk composition data are taken from the Livestock Improvement Corporation (LIC) national statistics. For all years, lactation length was assumed to be 280 days.

Average liveweight data for dairy cows are obtained by taking into account the proportion of each breed in the national herd and its age structure based on data about breed and age structure from the LIC. Dairy cow live-weights are only available from 1996 onwards. For earlier years in the time-series, liveweights are estimated using the trend in liveweights from 1996 to 2003 together with data on the breed composition of the national herd. Growing dairy replacements at birth are assumed to be 9 percent of the weight of the average cow and 90 percent 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 values apply between birth and weaning when animals receive milk as part of their diet. Within each period the same daily growth rate is applied for the entire length of the period.

No data are available on the liveweights and performance of breeding bulls and an assumption was made that their average weight was 500 kg and that they are growing at 0.5 kg per day. This was based on expert opinion from industry data. For example, dairy bulls range from small Jerseys through to larger-framed European beef breeds. The assumed weight of 500 kg and growth rate of 0.5 kg/day provide an average weight (at the mid point of the year) of 592kg. This is almost 25 percent higher than the average weight of a breeding dairy cow but it is realistic given that some of the bulls will be of a heavier breed/strain (eg, Friesian and some beef breeds). Because these categories of animal make only small contributions to total emissions eg, breeding dairy bulls contribute 0.089 percent of emissions from the dairy sector, total emissions are not highly sensitive to the assumed values.

*Beef Cattle:* The principle source of information for estimating productivity was livestock slaughter statistics provided by the MAF. All growing beef animals are assumed to be slaughtered at two years of age and the average weight at slaughter for the three subcategories (heifers, steers and bulls) was estimated from the carcass weight at slaughter. Liveweights at birth are assumed to be 9 percent of an adult cow weight for heifers and 10 percent of the adult cow weight for steers and bulls. Growth rates of all growing animals is divided into two periods as higher growth rates apply prior to 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.

Weights in slaughter statistics from the MAF do not separate carcass weights of adult dairy cows and adult beef cows. Thus a number of assumptions<sup>4</sup> are made in order to estimate the liveweights of beef breeding cows. A total milk yield of 800 litres per breeding beef cow was assumed.

*Sheep:* Livestock slaughter statistics from the MAF are used to estimate the liveweight of adult sheep and lambs, assuming killing out percentages of 43 percent for ewes and 45 percent for lambs. Lamb birth liveweights are assumed to be 9 percent of the adult ewe weight with all lambs assumed to be born on 1<sup>st</sup> September. Growing breeding and non-breeding ewe hoggets are assumed to reach full adult size at the time of mating when aged 20 months. Adult wethers are assumed to be the same weight as adult breeding females.

No within year pattern of liveweight change was assumed for either adult wethers or adult ewes. All ewes rearing a lamb are assumed to have a total milk yield of 100 litres. Breeding rams are assumed to weigh 40 percent more than adult ewes. Wool growth (greasy fleece growth) was assumed to be 5kg/annum in mature sheep (ewes, rams and wethers) and 2.5kg/annum in growing sheep and lambs.

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

*Goats:* Enteric CH<sub>4</sub> from goats is not a key category. There is no published data on which to attempt a detailed categorisation of the performance characteristics in the same way as has been done for the major livestock categories. New Zealand uses the IPCC CH<sub>4</sub> emission factor for goats (9 kg CH<sub>4</sub>/head/yr).

### **Dry matter intake calculation**

Dry matter intake (DMI) for the classes (dairy cattle, beef cattle, sheep and deer) and subclasses of animals (breeding and growing) was estimated by calculating the energy required to meet the levels of performance assumed 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 (Standard Australian Livestock Tables, CSIRO, 1990). These are chosen as they specifically include methods to estimate the energy requirements of grazing animals. The method estimates a maintenance requirement (a function of liveweight and the amount of energy expended on the grazing process) and a production energy requirement – influenced by the level of productivity (eg, milk yield and liveweight gain), physiological state (eg, pregnant or lactating) and the stage of maturity of the animal. All calculations are performed on a monthly basis.

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<sup>4</sup> Number of beef breeding cows assumed to be 25% of the total beef breeding cow herd; other adult cows slaughtered assumed to be dairy cows. Carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing out percentage of 40. Total weight of dairy cattle slaughtered was then deducted from the national total carcass weight of slaughtered adult cows. This figure was then divided by the number of beef cows slaughtered to obtain an estimate of the carcass weight of adult beef cows; liveweights are then obtained assuming a killing out percentage of 50.

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

### **Monthly energy concentrations**

A single set of monthly energy concentrations of the diets consumed by beef cattle, dairy cattle, sheep and deer was used for all years in the time-series. This is because there is no comprehensive published data available that allows the estimation of a time-series dating back to 1990.

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

There are a number of published algorithms and models<sup>5</sup> of ruminant digestion for estimating CH<sub>4</sub> 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 dissimilar to those consumed by New Zealand's grazed ruminants.

Since 1996, New Zealand scientists have been measuring CH<sub>4</sub> emissions from grazing cattle and sheep using the SF<sub>6</sub> 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<sub>4</sub> emissions determined using the SF<sub>6</sub> technique on grazing ruminants. A database has been constructed and is being systematically examined to obtain generalised relationships between feed and animal characteristics and CH<sub>4</sub> emissions. As an interim measure, published and unpublished data on CH<sub>4</sub> emissions from New Zealand were collated and average values for CH<sub>4</sub> emissions from different categories of livestock obtained. Sufficient data were available to obtain values for adult dairy cattle, sheep more than one year old and growing sheep (less than one year old). These data are presented in Table A3.1.1 together with IPCC (2000) default values for percent gross energy used to produce CH<sub>4</sub>. The New Zealand values fall within the IPCC range and are adopted for use in this inventory calculation. Table A3.1.2 shows a time-series of CH<sub>4</sub> implied emission factors for dairy cattle, beef cattle, sheep and deer.

Not all classes of animals are covered in the New Zealand data set and assumptions had to be made for these additional classes. The adult dairy cattle value was assumed to apply to all dairy and beef cattle irrespective of age and the adult ewe value was applied to all sheep greater than one year old. A mean of the adult cow and adult ewe value (21.25g CH<sub>4</sub>/kg DMI) was assumed to apply to all deer. In very young animals receiving a milk diet, no CH<sub>4</sub> was assumed to arise from the milk proportion of the diet.

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<sup>5</sup> 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 A3.1.1 Methane emissions from New Zealand measurements and IPCC defaults**

|  | Adult dairy cattle | Adult sheep | Adult sheep < 1 year |
|--|--------------------|-------------|----------------------|
| New Zealand data (g CH <sub>4</sub> /kg DMI) | 21.6               | 20.9        | 16.8                 |
| New Zealand data (%GE)                       | 6.5                | 6.3         | 5.1                  |
| IPCC (2000) defaults (%GE)                   | 6 ± 0.5            | 6 ± 0.5     | 5 ± 0.5              |

**Table A3.1.2 Time-series of implied emission factors for enteric fermentation (kg methane per animal per annum)**

| Year              | Dairy cattle | Beef cattle | Sheep | Deer |
|-------------------|--------------|-------------|-------|------|
| 1990              | 70.8         | 51.0        | 8.9   | 21.0 |
| 1991              | 71.4         | 51.7        | 9.1   | 20.7 |
| 1992              | 73.3         | 52.7        | 9.2   | 20.6 |
| 1993              | 73.7         | 54.2        | 9.3   | 20.5 |
| 1994              | 73.9         | 53.6        | 9.4   | 20.6 |
| 1995              | 73.6         | 53.3        | 9.5   | 20.9 |
| 1996              | 74.4         | 52.6        | 9.6   | 21.3 |
| 1997              | 74.3         | 54.5        | 9.9   | 21.9 |
| 1998              | 75.1         | 54.5        | 10.0  | 22.2 |
| 1999              | 76.5         | 55.3        | 10.1  | 22.3 |
| 2000              | 78.7         | 55.1        | 10.2  | 22.4 |
| 2001              | 78.8         | 56.4        | 10.5  | 22.3 |
| 2002              | 79.0         | 56.1        | 10.5  | 22.3 |
| 2003              | 79.1         | 56.3        | 10.6  | 22.1 |
| Previous fixed EF | 76.8         | 67.5        | 15.1  | 30.6 |

### A.3.1.2 Manure management emissions

Methane emissions from ruminant animal wastes in New Zealand have been recalculated using an IPCC Tier 2 approach. This replaces the Tier 1 approach used in previous national communications. The methodology adopted is based on the methods recommended by Sagar *et al* (2003) in a review commissioned by the Ministry of Agriculture and Forestry.

The general approach relies on (1) an estimation of the total quantity of faecal material produced, (2) the partitioning of this faecal material between that deposited directly onto pastures and that stored in anaerobic lagoons and (3) the development of specific New Zealand emission factors for the quantity of methane produced per unit of faecal dry matter produced.

## 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 estimates and dry matter digestibilities are those used in the current enteric methane and nitrous oxide inventories. In line with the current nitrous oxide inventory 95 percent of faecal material arising from dairy cows is assumed to be deposited directly onto pastures. The quantity of methane produced per unit of faecal dry matter is 0.98g CH<sub>4</sub>/kg. This value is obtained from New Zealand studies on dairy cows (Saggar *et al*, 2003 and Sherlock *et al*, 2003).

### *Faecal material stored in anaerobic lagoons*

In line with the current nitrous oxide inventory 5 percent of faecal (dung and urine) material arising from dairy cows is assumed to be deposited directly onto pastures. The method adopted here is to assume that all faeces deposited in lagoons are diluted with 90 litres of water per kg dung dry matter (Heatley, 2001). This gives a total volume of effluent stored. Annual CH<sub>4</sub> emissions are estimated using the data of McGrath and Mason (2002) on the average depth of an anaerobic lagoon and an average emission of 3.27 CH<sub>4</sub>/M<sup>2</sup>/year.

## Beef 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 estimates and dry matter digestibilities are those used in the current enteric methane and nitrous oxide inventories. Beef cattle are not housed in New Zealand and all faecal material is deposited directly onto pastures. No specific studies have been conducted in New Zealand on CH<sub>4</sub> emissions from beef cattle faeces and values obtained from dairy cattle studies (0.98g CH<sub>4</sub>/kg) are used (Saggar *et al*, 2003, Sherlock *et al*, 2003).

### *Faecal material stored in anaerobic lagoons*

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

## Sheep

### *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 estimates and dry matter digestibilities are those used in the current enteric methane and nitrous oxide inventories. Sheep are not housed in New Zealand and all faecal material is deposited directly onto pastures. The quantity of methane produced per unit of faecal dry matter is 0.69g CH<sub>4</sub>/kg. This value is obtained from New Zealand studies on sheep (Carran *et al*, 2003).

#### *Faecal material stored in anaerobic lagoons*

Sheep are not housed in New Zealand and all faecal material is deposited directly onto pastures.

### **Deer**

#### *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 estimates and dry matter digestibilities are those used in the current enteric methane and nitrous oxide inventories. Deer are not housed in New Zealand and all faecal material is deposited directly onto pastures. There are no New Zealand studies on methane emissions from deer manure. The quantity of methane produced per unit of faecal dry matter is 0.92g CH<sub>4</sub>/kg. This value is obtained from New Zealand studies on sheep (Carran *et al*, 2003) and dairy cattle (Saggar *et al*, 2003, Sherlock *et al*, 2003).

#### *Faecal material stored in anaerobic lagoons*

Deer are not housed in New Zealand and all faecal material is deposited directly onto pastures.

### **A3.1.3 Uncertainty of animal population data**

Details of the most recent surveys and census are included to provide an understanding of the livestock statistics process and uncertainty figures. The information documented is from Statistics New Zealand. Full details of the surveys are available from Statistics New Zealand's website <http://www.stats.govt.nz/datasets/primary-production/agriculture-production.htm>.

### **2003/4 Agricultural Production Surveys**

The target population for the Agricultural Production Surveys is all businesses engaged in agricultural production activity (including livestock, cropping, horticulture and forestry) with the intention of selling that production and/or which owned land that was intended for agricultural activity during the year ended 30 June. The estimated proportion of eligible businesses responding to the 2003 Agricultural Production Survey was 85 percent. These businesses contributed 87 percent of the total agricultural output. The sample error and percentage imputed for 2003 are shown in Table A3.2.1. For the 2004 survey, 30,715 forms were distributed. The survey response rate was 87 percent or 91 percent of the estimated value of production. Final livestock population data from the 2004 survey for sheep, cattle (dairy and non-dairy) and deer have been used for the 2005 submission. This was available due to the ability to resubmit this inventory in September 2006. Usually provisional data would be used as final data is not available in time for the 15 April inventory deadline. The 2003 animal numbers have been updated with final animal number estimates, as final numbers are not available until after submission of the inventory.

## **2002 Agricultural Production Census**

The target population for the 2002 Agricultural Production Census was all units that were engaged in agricultural production activity (including livestock, cropping, horticulture and forestry) with the intention of selling that production and/or which owned land that was intended for agricultural activity during the year ended 30 June 2002. The target population also includes businesses and persons commonly referred to as 'lifestylers' engaged in agricultural production activity. The response rate was 81 percent. Statistics New Zealand imputes using a random 'hot deck' procedure for values for farmers and growers who did not return a completed questionnaire.

## **The 1999 livestock survey**

The frame for the 1999 Agricultural Production Survey was based on a national database of farms called AgriBase which is maintained by AgriQuality New Zealand Ltd (formerly MAF Quality Management). A sample survey was conducted to obtain estimates of livestock on farms and area sown in grain and arable crops for the 30 June 1999 year. Questionnaires were sent to approximately 35,000 farms. The overall response rate for the survey was 85.7 percent. The remaining units were given imputed values based on either previous data or on the mean value of similar farms. Table A3.2.2 gives the sample errors based on a 95 percent confidence level for the survey data collected in 1999.

**Table A3.2.1 Provisional sampling error and imputation levels for the 2003 Agricultural Production Survey**

| <b>Statistic</b>                                 | <b>Sample errors at 95% confidence interval (%)</b> | <b>Percentage of total estimate imputed</b> |
|--|---|---|
| Ewe hoggets put to ram                           | 4   | 12  |
| Breeding ewes 2 tooth and over                   | 2   | 12  |
| Total number of sheep                            | 2   | 11  |
| Total lambs marked or tailed                     | 2   | 11  |
| Beef cows and heifers (in calf) 2 years and over | 2   | 12  |
| Beef cows and heifers (in calf) 1–2 years        | 5   | 11  |
| Total number of beef cattle                      | 2   | 12  |
| Calves born alive to beef heifers/cows           | 3   | 12  |
| Dairy cows and heifers, in milk or calf          | 2   | 14  |
| Total number of dairy cattle                     | 2   | 14  |
| Calves born alive to dairy heifers/cows          | 3   | 13  |
| Female deer mated                                | 4   | 9   |
| Total number of deer                             | 4   | 9   |
| Fawns or calves weaned on the farm               | 4   | 9   |
| Area of potatoes harvested                       | 1   | 12  |
| Area of wheat harvested                          | 4   | 11  |
| Area of barley harvested                         | 4   | 13  |

**Table A3.2.2 Agricultural sector sample errors based on 95 percent confidence level**

| <b>Variable (total population)</b> | <b>Survey design error (%)</b> | <b>Achieved sample error (%)</b> |
|------------------------------------|--------------------------------|----------------------------------|
| Dairy cattle                       | 1                              | 1.0                              |
| Beef cattle                        | 1                              | 0.9                              |
| Sheep                              | 1                              | 0.7                              |
| Goats                              | 1                              | 1.5                              |
| Deer                               | 1                              | 1.4                              |
| Pigs                               | 1                              | 0.9                              |

## **A3.2 Additional information for the LULUCF sector: the Carbon Monitoring System plots and the New Zealand Carbon Accounting System**

Major ongoing work in the LULUCF sector includes research and implementing a monitoring system for the carbon stocks and fluxes in soils, shrublands and natural forests. This research was initiated by the MfE in 1996 and is being performed by two of New Zealand's Crown Research Institutes – Landcare Research and Forest Research. This five-year research project had the following objectives:

- the estimation of carbon storage in soils, shrublands and natural forests in 1990
- the development of a national system to determine soil carbon changes associated with land-use change
- the development of an effective information system to manage the above information.

Provisional results are available from the work under the first objective. Hall *et al.* (1998) have estimated that in 1990 carbon stored in natural forests was 933 MtC, while 527 Mt C was stored in shrublands and other woody mixed-vegetation. Forest floor litter carbon is estimated separately, based on Hall *et al.* (1998), as containing 570 Mt C for all natural vegetation (ie, both forest and scrub areas). These estimates are highly sensitive to both the accuracy of mapped areas and heterogeneity within mapped classes. Current (very provisional) estimates for soil carbon at soil depth intervals of 0-0.1, 0.1-0.3 and 0.3-1m are  $1300 \pm 20$ ,  $1590 \pm 30$  and  $1750 \pm 70$  Tg C respectively (Tate *et al.*, 2003a). Some soil cells are still poorly represented in the database and additional field work is being undertaken. Further information on this project and initial estimates of carbon stocks at 1990 are found in Coomes *et al.* (2002), Lawton and Barton (2002), Lawton and Calman (1999) and Hall *et al.* (1998).

In 1999, the soil and vegetation carbon monitoring systems (CMS) developed during the first three years of the project were reviewed by an international panel of forestry and soil experts. The panel's report concluded that the systems being developed for New Zealand's natural forests are consistent with current forest inventory practices in other countries. Furthermore, the soils that the system represented are measured through a significantly advanced methodology compared with the IPCC default method (Theron *et al.*, 1999). The international review of the system was held in time for the key recommendations of the review to be undertaken before the development phase was concluded.

The statistical design of the vegetation CMS provides for the establishment of 1400 permanent field plots on an 8x8 km grid across natural forest and shrublands for territorial New Zealand (Coomes *et al.*, 2002). This includes the North and South Islands, Stewart Island, the Chatham Islands and other offshore islands. To provide continuity, and to build on previously collected data, about one-third of the plots are existing ones matched to nearby grid intersection points, and the rest are new plots established at unmatched grid intersections specifically for monitoring forest carbon pools. The plot measurements use the 20m by 20m quadrat method (Allen 1993) which has been used at various sites of interest in New Zealand but never on a statistically representative basis across all of the nation's natural forests and shrublands. Measurements are taken of above ground biomass, such as tree heights and diameters, understorey vegetation, litter, and coarse woody debris. These measurements will have utility for other international forestry reporting obligations such as those required under the Montreal Process, the FAO Global Forest Resource Assessment, and the Convention on Biological Diversity.

The soil CMS analyses soil samples to a depth of 0.3m for carbon content. One in every three of the vegetation plots is sampled for soils to reduce the uncertainty in some soil cells.

The CMSs for soil and vegetation are currently moving from design to implementation. The first year's fieldwork for the operational vegetation CMS commenced in January 2002 and was completed in early 2003. The second year's fieldwork began in March 2003. Fieldwork over at least three more years will be required to install the complete network of field plots. Following this, another five-year round of sampling will be required to validate the implementation and begin monitoring of any changes. The current intention is then to repeat these measurements every ten years.

For the soil CMS, 40 soil-paired plots sites will be established to monitor key changes in soil carbon when land-use changes, ie, scrub to grassland, grassland to Kyoto forest and vice versa. The first four paired plots sites were established in 2003.

The New Zealand Carbon Accounting System (NZCAS) is being developed. This system will account for human-induced carbon sources and sinks from New Zealand's land use, land-use change and forestry (LULUCF) activities which (a) is appropriate for annual UNFCCC greenhouse gas emission LULUCF sector reporting; (b) enables accounting and reporting under the Kyoto Protocol; and (c) underpins scenario development and modelling capabilities that support New Zealand's Climate Change Policy development.

The most developed module of the NZCAS is for natural forests and shrublands (Coomes et al., 2002; Payton et al., 2004). This is based on the CMS plots. These unique natural forests cover 6.4 million hectares, and have been either too remote or inaccessible for timber extraction and are now largely protected, often as national parks. New Zealand has not, until now, needed to establish a national forest inventory to cover its protected forests. This is in sharp contrast to the advanced system used for monitoring and forecasting future wood supply from its 1.8 million hectares of plantation forests.

A monitoring and modelling module is currently being designed for those areas where afforestation and reforestation activities have occurred since 1990 – the so-called Kyoto forests. This will involve inventory measurements from permanent plots coupled with the use of existing allometric equations and/or forest volume and carbon models (Beets *et al*, 1999).

### **A3.3 Additional methodology for the LULUCF sector: the Land Cover Database**

The Land Cover Database (LCDB1) was completed in 2000 using SPOT 2 and SPOT 3 satellite imagery acquired over the summer of 1996/97. A 1 ha minimum mapping unit (MMU) was used and this was retained for LCDB2. LCDB2 used the Landsat 7 ETM+ sensor, with the imagery pan-sharpened to a 15 m spatial resolution. All imagery for LCDB2 was acquired during summer 2001/02. Development of the final database involved several Government Crown Research Institutes, Ministries and companies. LCDB2 was released July 2004.

A description of the process to create LCDB2 is shown in figure A3c.1. A single set of polygon boundaries is used for both the attributes from LCDB1 and LCDB2. This removes the need for GIS overlay analysis to detect changes in land cover between databases. As part of the process of developing LCDB2, any errors identified in the LCDB1 were corrected and areas of apparent change confirmed.

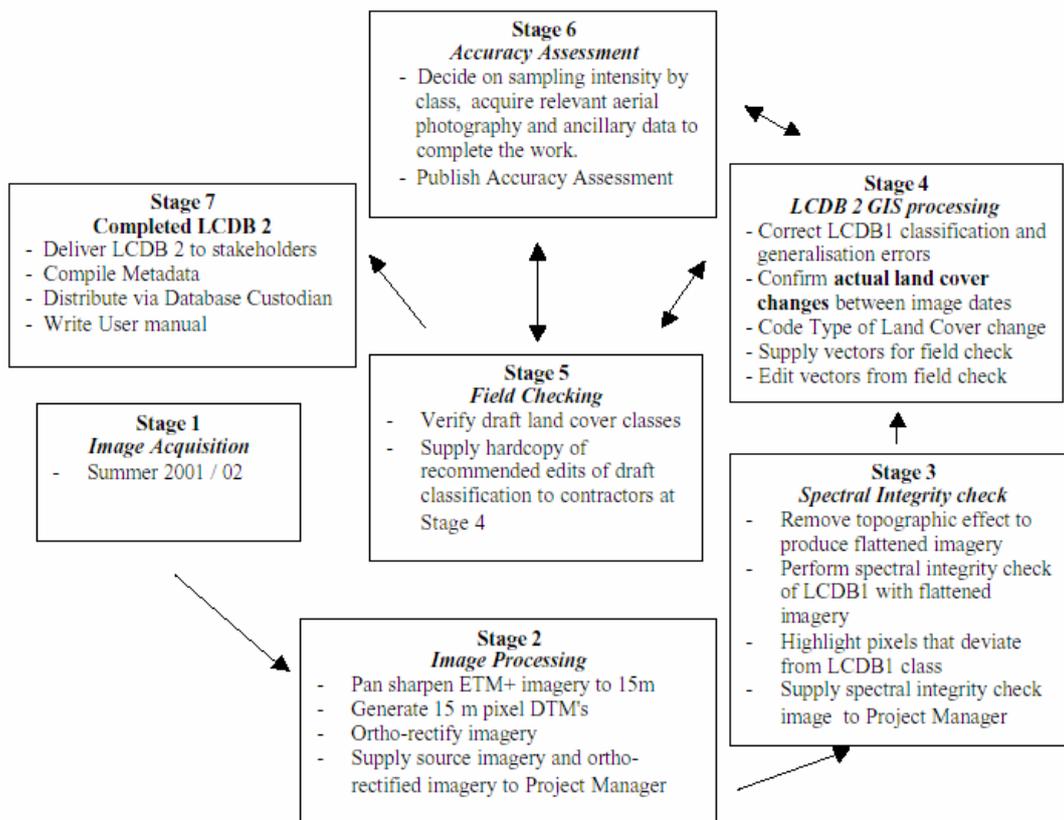
The target classes used for LCDB1 and 2 are hierarchical (and derived from eight first order classes at the highest level, with an increasing number of more detailed classes at lower levels. The first order classes are based on the physiognomy of the land cover (ie, grassland, shrubland, forest etc). The following divisions are based on other characteristics, such as phenology (evergreen/deciduous) and floristic composition (broadleaved/needle leaved).

LCDB2 was developed from image processing supplemented by ancillary data such as vegetation surveys, plot data and aerial photography. The database was also subjected to intensive field checking to determine the following:

- whether the land-cover types identified in the draft vectors are present on the ground
- whether land-cover types observed on the ground are captured and correctly labelled in the draft map
- identify land-cover classes with unknown or questionable spectral signatures
- identify characteristic signatures of the target land-cover classes to be used to train the classification in areas that cannot be field checked. Extrapolation of ground data was restricted to one New Zealand 260 map sheet (30 km x 40 km), as the spectral signatures of target classes can vary across a Landsat 7 ETM+ scene (185 km wide).

In assigning land cover to a specific class, the dominant cover rule was used. For example, a shrubland polygon with three or more main species (where further subdivision of the patch based on the 1 ha MMU is not possible), is classified according to the dominant species in the matrix. This procedure was maintained throughout the LCDB2 mapping project.

For LCDB1, overall user accuracy was assessed at 93.9 percent. A classification accuracy has not been established for LCDB2. The database was released to ensure that users have access to the updated national dataset for planning and monitoring purposes. However users can be confident that the accuracy of LCDB2 will be equal to or higher than the user accuracies for LCDB1, namely, bare ground (81 percent), natural forest (95 percent), mangrove (97 percent), planted forest (90 percent), horticultural (95 percent), pastoral (98 percent), scrubland (89 percent), tussock (95 percent), and wetlands (87 percent).



**Table A3.3.1 Mapping of LCDB classification to the IPCC land-use categories**

| IPCC category      | LCDB class  |
|--------------------|---|
| <b>Cropland</b>    |   |
| CM (perennial)     | Orchard and other perennial crops, vineyard   |
| CM (annual)        | Short-rotation cropland   |
| <b>Forest land</b> |   |
| 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   |
| <b>Grassland</b>   |   |
| GM (low prod)      | Alpine grass/herbfield, depleted tussock grassland, fernland, gorse and broom, grey scrub, low producing grassland, major shelterbelts, matagouri, mixed exotic shrubland, sub-alpine shrubland, tall tussock grassland, flaxland, herbaceous freshwater vegetation, herbaceous saline vegetation, mangrove |
| GM (high prod)     | High-producing exotic grassland   |
| <b>Other land</b>  |   |
| O                  | Alpine gravel and rock coastal sand and gravel landslide permanent snow and ice river and lakeshore gravel and rock   |
| <b>Settlement</b>  |   |
| S                  | Built-up area, dump, surface mine, transport infrastructure, urban parkland/open space  |
| <b>Wetland</b>     |   |
| W (unmanaged)      | Estuarine open water, lake and pond, river  |

# **Annex 4: CO<sub>2</sub> reference approach and comparison with sectoral approach, and relevant information on the national energy balance**

Information on the CO<sub>2</sub> reference approach and a comparison with sectoral approach is provided in Section 3.4.1. The section also includes a comparison with the IEA reference and sectoral approach for New Zealand.

# **Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded**

An assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in section 1.8 of Chapter 1.

# Annex 6: Quality assurance and quality control

During preparation of the New Zealand 2004 national greenhouse gas inventory, work continued on the implementation of the “New Zealand National Greenhouse Gas Inventory Quality Control and Quality Assurance Plan”. Specific checks have been completed as time and resources have allowed.

## A6.1 QC procedures implemented in preparation of the 2004 inventory

Tier 1 quality control (QC) checks for key sources (as identified in the level and trend analysis of the 2003 national inventory) and a selection of non key sources were completed on the 2004 data. Two of these checklists with the results are included as examples in this Annex. The checks incorporated in the CRF reporter (time-series consistency, recalculation and completeness checks) were undertaken to identify any outliers and inconsistencies in the trends from 1990-2004.

Some specific findings of the 2004 quality control process included:

- CO<sub>2</sub> emissions were found to be included for liquid fuels for iron and steel for this submission whereas the 2005 submission did not include emissions at this level. This error was corrected after consultation with the data providers Ministry of Economic Development.
- LULUCF net removals data was found to be too high and on re-checking discovered the inclusion of soil carbon information in forest land was effectively causing double counting. This was corrected.
- An error in activity data for road paving with asphalt was found for the years 2000-2003. Only activity data for cut-back was included in the CRF in the 2003 inventory. This has been corrected to include activity data for all bitumen use for roading in the 2004 inventory.

## A6.2 QA procedures implemented

A checklist of recent reviews of specific sectors (including emission factors) undertaken as part of the quality assurance of the New Zealand national inventory is included in this Annex.

During 2005 a number of recommendations from the quality management report produced in late 2004 were addressed.

- The improvement plan was updated with the objective of the greenhouse gas inventory to be consistent with IPCC Good Practice Guidance by September 2006.
- A post-inventory evaluation will be undertaken after inventory submission on 15 April to review lessons learned and how to improve processes for the next inventory compilation. This is documented in the schedule of activities in the QA/QC plan.

- The QA/QC coordinator and responsibilities for this position have been clearly defined in the QA/QC plan.
- Objectives of the QA/QC programme have been formally documented in the QA/QC plan and performance against these objectives will be regularly reviewed.
- The QA/QC plan now contains more specific information as cited in the IPCC Good Practice Guidance including a scheduled time frame that follows inventory preparation from its' initial development to final reporting in any given year. It also includes a schedule to review all source categories over a four year period.

### **A6.3 Methods of QA/QC used by external agencies**

Statistics New Zealand: To minimise error, all questionnaires are carefully designed and tested to make them easy for respondents to understand and complete correctly. During the processing of statistics, checks are carried out to ensure the data appears consistent. Checks are also undertaken to ensure responses have been recorded correctly.

Statistics New Zealand aims to ensure all farms and forests are represented in the agriculture surveys. The survey frame is updated with feedback from survey/census respondents. The questionnaire is designed with a view to making it easy for survey respondents to give the information which Statistics New Zealand requires. Questionnaires are tested prior to use in surveys. Statistics New Zealand provides an enquiry service for respondents who need to help completing questionnaires and they follow up respondents to ensure high response rates are achieved. Statistical methodology (sample design, estimation techniques etc) follows international best practice. Data editing and consistency checks are carried out on all data.

### **A6.4 Future development of the QA/QC system**

New Zealand will continue to address the recommendations from the quality management report during 2006. These include:

- documenting a plan for Tier 2 quality checks
- investigating ways of performing verification of emissions data
- continuing to plan and implement a document/records register to improve management of inventory documentation. (The new document management system implemented at the Ministry of the Environment during 2005 is assisting in achieving this improvement.)

# A6.5 Example worksheets for QC procedures in 2004

| TIER 1: INDIVIDUAL SOURCE CATEGORY CHECKLIST  |   |  |   | Ver 1.0  |  |   |
|---|---|--|---|--|--|---|
| Inventory Checked:  |   | 2004   |   | CH4  |  |   |
| Source Category:  |   | 4A Enteric fermentation-CH4  |   |  |  |   |
| Estimates prepared by:  |   | Ministry of Agriculture and Forestry with data from Statistics New Zealand and Agresearch  |   |  |  |   |
| Working spreadsheet(s)  |   |  |   |  |  |   |
| Tier 1 QC Activity & Procedures   |   |  |   |  |  |   |
| QC Activity   | Procedures  | Procedures adopted for 2006 NIR (2004 data)  | Organisation/Person responsible for quality check | Brief description of check applied (include date/person & reference if required)   | Results of check (include reference if required)   | Corrective Actions Taken  |
| Check that assumptions and criteria for the selection of activity data and emission factors are documented.     | Check descriptions of activity data and emission factors and ensure that these are properly recorded and archived.                              | Check activity data and emission factors are described in the NIR report and any changes from previous years are adequately documented.  | MIE-SP  | S. Petrie : Checked description of activity data, emission factors and methodology in NIR  | Well documented in chapter 6 and Annex 3a of the NIR   | none  |
| Check for transcription errors in data input and reference  | Confirm that bibliographical data references are properly cited in the internal documentation.  | 1. Undertake visual checks of module names for consistency in NIR worksheets.<br>2. Check all references cited in the appropriate source sector chapter in the NIR report and make sure they are correctly referenced at the end of the chapter. | MIE-TW  | TW 5/4/06: 1. Checked module names in worksheets for consistency<br>2. Check references cited in text are correctly referenced in the reference chapter.                       | 1. 1990 module names incorrectly labelled as 2004 in worksheets; 1 submodule wrongly named. Need to streamline module names<br>2. Some references cited in text missing in reference chapter and several references no longer cited in main text | corrected to 1990; submodule name amended; module names updated |
|   | Cross-check a sample of input data from each source category (either measurements or parameters used in calculations) for transcription errors. | 1. Cross check activity data from NIR worksheets with that in the CRF for transcription errors.  | MIE-TW  | TW 5/4/06: 1. visual check by comparing animal numbers for all classes for 1990 used in enteric fermentation figures from NIR worksheet with that in the CRF reporter          | 1. All livestock numbers in NIR worksheets are the same as those in the CRF reporter.  | none  |
| Check that emissions are calculated correctly.  | Reproduce a representative sample of emissions calculations.  | Using the figures in the NIR worksheets, calculate representative sample of emissions manually and compare to emissions value in CRF.  | MIE-TW  | TW 5/4/06:<br>1. Calculated dairy cattle CH4 enteric fermentation emissions using figures from worksheet 4.1 (1990)<br>2. calculate methane emissions using activity data-1990 | 1.Value calculated was 240.08Gg (NIR) compared with 240 Gg (CRF). Test passed.<br>2. Final emissions of methane: Value in NIR worksheet for 1990 is 1025.27Gg compared with 1026.38Gg in the CRF reporter. Within 1% -test passed.               | none  |
|   | Selectively mimic complex model calculations with abbreviated calculations to judge relative accuracy.  | Use Tier 1 approach to calculate a sub source of data (eg CH4 emissions from dairy cattle ) to judge relative accuracy.  | MIE   | limited time meant this check was not undertaken   |  |   |
| Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used | Check that units are properly labelled in calculation sheets  | Check the units are correctly labelled in the NIR worksheets   | MIE-TW  | TW 5/4/06: visual inspection of units labeled in agricultural worksheets   | units correctly labelled   | none  |
|   | Check that units are correctly carried through from beginning to end of calculations.   | check appropriate units are used throughout calculations   | MIE-TW  | TW 5/4/06:checked units are appropriate  | correct SI units are used in tables  | none  |
|   | Check that conversion factors are correct   | Check that the correct conversion factors have been used to calculate the emissions in the NIR worksheets-particularly conversion from tonnes to Gg and from C to CH4.   | MIE-TW  | TW 5/4/06: checked conversion from kg (as kg/head/yr) to Gg of CH4 for enteric fermentation and manure management occurred in NIR worksheet 4.1                                | conversion factors are correct and accounted for properly  | none  |

|   |  |   |        |  |   |      |
|---|--|---|--------|--|---|------|
| Check the integrity of database and/or spreadsheet files.                                 | Confirm that the appropriate data processing steps are correctly represented in the database.  | confirm data processing steps within model for enteric fermentation are appropriate   | MIE    |  |   |      |
|   | Ensure that data fields are properly labelled and have the correct design specifications.  | Ensure the addition or deletion of datalines are adequately explained   | MIE-TW | TW 5/4/06: check worksheet tables for obvious gaps in the data-series  | none found  | none |
|   | Ensure that adequate documentation of database and model structure and operation are archived.   | Ensure there is adequate documentation of the model structure and that it is archived.  | MIE    | S. Petrie 13/04/05: check adequate documentation of enteric fermentation model   | paper written by Clark et al (2003) describing the model is archived on the Mfe computer network and copies are also held at MAF  | none |
| Check for consistency in data between source categories                                   | Identify parameters (e.g. activity data, constants) that are common to multiple source categories and confirm that there is consistency in the values used for these parameters in the emissions calculations.     | Check for consistency in animal number dataset.   | MIE-TW | TW 6/4/06: Checked for consistency in animal numbers within CRF for dairy cattle and sheep in 1990 and 2004 (for enteric fermentation and manure management) | Dairy numbers consistent for dairy cattle in 1990 (3390.87) and 2004 (5118.8) and sheep in 1990 (57860.83) and 2004 (39572.43) across manure management and enteric fermentation                | none |
| Check that the movement of inventory data among processing steps is correct.              | Check that emissions data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries.  | 1. Manually sum CH4 emissions from dairy cattle & non dairy cattle sources for enteric fermentation & compare with values in cattle node in CRF reporter.               | MIE-TW | TW 5/4/06: 1. sum CH4 emissions from dairy cattle and non-dairy cattle and compare with total in CRF reporter  | 1. The summed value is 481.81 Gg from dairy and non-dairy cattle in 1990 compared with 474.62 Gg (total for cattle in CRF). Minor difference due to rounding.                                   | none |
|   | Check that emissions data are correctly transcribed between different intermediate products  | QA/QC procedures used that show correct transcription between intermediate worksheets and final entry of data into CRF reporter   | MIE    | on-going and done informally by double checking all entries in model input sheets, output sheets and CRF excel sheets  |   | none |
| Check that uncertainties in emissions and removals are estimated or calculated correctly. | Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate.   |   |        |  |   |      |
|   | Check that qualifications, assumptions and expert judgements are recorded. Check that calculated uncertainties are complete and calculated correctly.  | Check appropriate qualifications, assumptions and judgements for uncertainty analysis are recorded & archived. Check calculated uncertainties are completed and correct |        |  |   |      |
|   | If necessary, duplicate error calculations or a small sample of the probability distributions used by Monte Carlo analyses.  |   |        |  |   |      |
| Undertake review of internal documentation.   | Check that there is detailed internal documentation to support the estimates and enable duplication of the emission and uncertainty estimates.   | Review internal documentation-ensure there is adequate documentation to support the estimates and uncertainty analysis.   | MIE-SP |  |   |      |
|   | Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review.   | Check to ensure copies of reports of sector reviews and methodologies are archived.   | MIE-SP | S.Petrie: Ensure spreadsheets and information on the enteric fermentation model are stored in an accessible and secure location                              | All data and methodologies associated with estimating enteric fermentation (and all agricultural emissions) are stored on the Mfe Silent One documentation system which is regularly backed up. | none |
|   | Check integrity of any data archiving arrangements of outside organisations involved in inventory preparation.   | NA-data compilation done in house   | MIE    | N/A  | N/A   |      |
| Check methodological and data changes resulting in recalculations.                        | Check for temporal consistency in time series input data for each source category.   | record result from time series consistency check in CRF reporter software   | MIE-SP | informal check by looking at all graphs  | no inconsistencies in time-series notes   | none |
|   | Check for consistency in the algorithm/method used for calculations throughout the time series.  | Confirm the method used for estimating CH4 from enteric fermentation is consistent throughout the time series   | MIE-SP | S. Petrie : confirm consistent methodology   | Methodology is consistent-reading model description and training on how the model runs confirms this  | none |
| Undertake completeness checks.  | Confirm that estimates are reported for all source categories and for all years from the appropriate base year to the period of the current inventory.   | record result of completeness check in CRF reporter software  | MIE-SP | S.Petrie : run completeness checks.  | all passed  | none |
|   | Check that known data gaps that result in incomplete source category emissions estimates are documented.   | ensure any known data gaps are documented   | MIE-SP | N/A  | N/A   | N/A  |
| Compare estimates to previous estimates.  | For each source category, current inventory estimates should be compared to previous estimates. If there are significant changes or departures from expected trends, recheck estimates and explain any difference. | Check 1990 and 2003 value in CRF Reporter - If figures in black is consistent with previous estimates; if in blue explain differences                                   | MIE-TW | TW 5/4/06: Check for inconsistencies with previous estimates for 1990 and 2003   | Figures for 1990 and 2003 are different. These differences are due to updates in stock population numbers   | none |

## A6.6 QA summary worksheet

| QUALITY ASSURANCE CHECKLIST   |   |                |   |  |  |   |   |   |
|---|---|----------------|---|--|--|---|---|---|
| Includes all reviews up to and including the 2003 Inventory Report: |   |                |   |  |  |   |   |   |
| QA Activity & Procedures  |   |                |   |  |  |   |   |   |
| QA Activity   | Description of QA procedure   | Date of review | Reviewer  | Expert qualifications assessed                           | Brief description of review scope (include a reference to the review contract)   | Major conclusions from the review (include a reference to the review)   | Action taken  | Place where it is filed   |
| Review of complete inventory  | Not possible to do as an external review due to lack of time. Chapter 7 (LUCF) put out to review within MfE.  |                |   |  |  |   |   |   |
| Expert review of Energy Sector                                      | Review by T.S Clarkson of NIWA on the Energy Sector GHG emissions on the NIR/CRF submitted in 2001 (1999 inventory)   | Aug 2001       | T.S Clarkson of NIWA  | NIWA report internally reviewed by K.R.Lassey            | Peer review of energy sector as a quality control check, identify errors, make comments on GP and provide recommendations.<br>NIWA Report WLG2001/50   | 1. The inventory is generally well presented and complete.<br>2. A QA/QC plan should be developed and adhered to when preparing the inventory to remove inconsistencies in CRF tables.<br>3. Need a review of all emission factors to ensure they are up to date.<br>4. The documentation is insufficiently reported - statistics need explanation, and include supplementary documentation.  | 2. QA/QC plan is being continually updated. It was implemented in the 2004 inventory report and formal QC checks have been implemented for all subsequent inventories. The energy sector has a number of quality checks applied to various sources during the inventory compilation process.<br>3. Review of emission factors occurred in 2003.<br>4. Addressed in 2004 inventory report. | Document number 61671 in Silent One   |
|   | Review by T.S Clarkson of NIWA on the Energy Sector GHG emission reporting prior to submitting the 2002 NIR (2000 inventory)  | April 2002     | T.S Clarkson of NIWA  | NIWA report internally reviewed by K.R.Lassey            | Peer review of energy sector as a quality control check, identify errors, make comments on GP, provide recommendations, and comment on uptake of recommendations provided in 2001.<br>NIWA Report WLG2002/30   | 1. The inventory is generally well presented and complete.<br>2. The CRF appears more robust than 2001 with fewer errors and inconsistencies<br>3. There is still a need to ensure a QA/QC plan is developed and adhered to when preparing the inventory.<br>4. Provide more evidence of QA/QC in NIR.<br>5. Bring documentation up to that mentioned in GP, QA/QC.<br>6. Optimise T1 methods and bring in GP (including uncertainty estimates).<br>7. Note in NIR where GP applied.<br>8. Develop longer plan for adopting a T2 or bottom up approach.<br>9. Need a review of all emission factors to ensure they are up to date.<br>10. More work on differences between reference and sectoral approaches. | 3. QA/QC plan-see comment above.<br>4. This is to be addressed in 2004 NIR.<br>5. Is being addressed.<br>6. Addressed.<br>7. This is addressed in 2003 and 2004 inventory reports.<br>8. T2 approach is being developed as time and resources allow.<br>9. This has now been addressed (see report details below).<br>10.   | Hard copy kept in Sonia's tambour   |
|   | Review of Energy Sector Greenhouse Gas Emissions Factors. A report to the Energy Modelling and Statistics Unit of the Ministry of Economic Development.<br><br>(as a response to the previous reviews by T.S. Clarkson) | March 2003     | Hale & Twomey Limited<br>Level 4, Gleneagles building<br>69-71 The Terrace<br>POBox 10444<br>Wellington<br>New Zealand. | <b>Not documented (prior to QA procedures developed)</b> | To undertake a review of the energy sector emissions factors used in NZ's GHG inventory and to recommend what emissions factors should be used for each GHG and what further work the Ministry should arrange. | 1. Changes recommended for the vast majority of emissions factors, including reverting to IPCC recommended factor.<br>2. Methodology could also be improved eg by splitting petrol to premium and regular.<br>3. Further work includes - review of coal CO2 emissions factors, review of coal CH4 fugitive emissions, routine updating of gas emissions moving to tier 3 calculation for Transport (MOT's Vehicle Fleet emissions model).<br>4. NZ standardise on kt/PJ as standard unit<br>5. Show emission factors to sufficient significant digits to indicate where grossing down has occurred.   | 1. Addressed-new recommended factors being used in 2004 inventory report.<br>2. Addressed-this has been implemented in 2004 inventory report.<br>3. This will depend on the time and resources of MED.<br>4. Consensus has not been reached on this issue.<br>5. This is addressed in the 2004 inventory report.  | Hard copy kept in Sonia's tambour and draft report kept on the MfE network. |
| Expert review of Industrial Processes Sector                        | Review of Industrial Processes Sector of National Greenhouse Gases Inventory submitted on 15 April 2003   | June 2003      | Dr Doug Sheppard<br>Geochemical Solutions<br>PO Box 33 224<br>Petone<br>New Zealand                                     | <b>Not documented (prior to QA procedures developed)</b> | To review the industrial processes sector with an aim to identify gaps in reporting. Coverage does not include emissions of PFC's, HFC's and SF6   | 1. Clarify differences between tables, worksheets, the CRF and consultant reports.<br>2. Review why CO2 from methanol production is not reported.<br>3. Check confusion over quantities of bitumen, ethanol and ammonia.<br>4. Check production quantities of wooden panel products.<br>5. Provide more explanation and documentation of underlying assumptions.<br>6. Review and restructure content of questionnaire used to gather information from industry.  | 1. Energy sector?<br>2. This information is in the energy sector<br>3. Has been cleared up through CRL report (2004).<br>4. Very small part of inventory-not considered high priority at this stage.<br>5. This is being addressed in the 2004 inventory report.<br>6. A new consultant has been found for this section of work who is more quality conscious.                            | document number 61978 in Silent One   |
|   | Review of synthetic greenhouse gases in industrial processes sector   | August 2004    | Iain McClinchy contractor to Ministry for the Environment   |  |  | 1. NZCCO to establish formal relationship with Customs to ensure provision of data on a more regular basis.<br>2. NZCCO consider development of regulations under the Climate Change Response Act to clarify its powers to request data from importers and end users.<br>3. NZCCO work with Customs and the MED to develop a more useful set of tariff codes.<br>4. That potential emissions data be calculated and presented for future inventories in accordance with IPCC guidelines.  |   | Doc number 61986 in SilentOne   |

|  |   |      |  |   |   |  |   |  |
|--|---|------|--|---|---|--|---|--|
| Expert review of Solvent Sector                      |   |      |  |   |   |  |   |  |
| Expert review of Agriculture Sector                  | Peer review of nitrous oxide work through scientific papers: de Klein C A M, Barton L, Sherlock R R, Li Z, Littlejohn R P (2003). Estimating a Nitrous Oxide Emission Factor for Animal Urine from Some New Zealand Pastoral Soils. Australian Journal of Soil Research, 41(3): 381-399 | 2003 |  | Not documented (prior to QA procedures developed) |   |  |   |  |
|  | Report to MAF: Revised nitrous oxide emissions from New Zealand agricultural soils 1990-2001  | 2003 | F.M. Kallher, S.F. Ledgard, H. Clark, A.S. Walcroft, M. Buchan & R.R. Sherlock | Not documented (prior to QA procedures developed) | Revision of nitrous oxide emissions from agricultural soils 1990-2001-including recommendations for inventory improvement   | 1. N2O emissions from grazing animal's urine & dung excreta should be estimated using separate emission factors (these to be determined from available & future measurements of NzOnet).<br>2. Grazing animal feed intake should be determined by the model by Clark et.al. to connect N2O and CH4 emissions inventories.<br>3. Nitrogen excretion by grazing animals should be determined using model OVERSEER<br>4. Sales records should be used to determine N fertiliser use.  | 1. Not able to be done at present-explanation in NIR. Research ongoing.<br>2. Has been addressed-model used.<br>3. Has been addressed-model used<br>4. Has been addressed-sales records now used. | Document number 61504 in Silent One                        |
|  | Review of "Enteric methane emissions from New Zealand ruminants 1990-2001 calculated using an IPCC Tier 2 approach by Harry Clark, Ian Brookes and Adrian Walcroft"   |      | K. R. Lassey of NIWA   | Not documented (prior to QA procedures developed) |   |  |   | Report kept in Ag sector filemaster box in Sonia's tambour |
|  | Review of Agricultural sector GHG program to ascertain whether program is meeting objectives  | 2004 | Marc Uilyatt   |   | The research projects contracted by MAF over the period 2001-2004 to improve the methane inventory are reviewed within a framework that allows consideration of first the progress in developing an overall inventory model and second research into the components of the model.                           | The reviewer recommended the following areas need to be addressed, in the following order:<br>1. Evaluation of the soil sink for methane under plantation forests.<br>2. Continuation of the work determining enteric methane emission factors.<br>3. Determination of the proportion of methane emitted via the flatus.<br>4. Continued evaluation of satellite imagery in determining nutritive value on a national scale.<br>5. An independent evaluation of the methodology used in uncertainty analysis.<br>6. Measurements to determine an emission factor for waste management via anaerobic lagoons.<br>7. Annual upgrading of the model (this should probably be listed as an overhead outside research priorities because of the UNFCCC requirement for annual inventory reporting). |   | Doc no 61522 in Silent One                                 |
|  | Review of NZ Official 1990 Animal Statistics  | 2004 | Meat and Wool New Economic Service<br>Rob Davison                              | Organised by MAF                                  | Review sheep livestock numbers and provide an assessment for base livestock from 1989-1991.   | 1. Sheep numbers from the 1991 census are probably to low and should be revised in the inventory. They would likely increase by 2% from 55,162 to 56,300. Lambs tailed would increase 7% from 38,716 to 41,398.  | Follow up with MAF to ensure consistency  | Doc no 61511 in Silent One                                 |
| Expert review of Land use change and forestry Sector |   |      |  |   |   |  |   |  |
| Expert review of Waste Sector                        |   |      |  |   |   |  |   |  |
| Review of QA/QC procedures and plan                  | Review of current QA/QC procedures and plans in the national inventory  | 2004 | Mr Wayne Gillies<br>Claws consulting Ltd                                       | CV assessed and in records                        | Report detailing how the current Quality Assurance and Quality Control (QA/QC) procedures and plan used in the Inventory compare to the QA/QC guidance in GPG.<br><br>Provide a prioritised list of recommendations to be implemented for the New Zealand inventory QA/QC system to be consistent with GPG. | Key short term recommendation is to document a plan to achieve consistency with GPG by 30/9/06 and ensure this plan is understood & agreed with all necessary parties.   | Many of the recommendations in this report have been addressed this during 2005 calendar year with the remaining to be addressed during 2006.   | Doc no 60650 in Silent One                                 |

# 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 (GPG, 2000). Good practice also notes that inventories prepared following the IPCC Guidelines and Good Practice Guidance 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<sub>2</sub>O fluxes from soils and waterways.

New Zealand has included a Tier 1 uncertainty analysis as required by the inventory guidelines (FCCC/SBSTA/2004/8) and good practice. 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. The New Zealand methodology follows the Tier 1 calculation procedure as specified in good practice. LULUCF categories have been included using the absolute value of any removals of CO<sub>2</sub> (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 percent confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95 percent confidence interval is that the value corresponds to the familiar plus or minus value when uncertainties are loosely quoted as ‘plus or minus x percent’. Where uncertainty is highly asymmetrical, the larger percentage difference between the mean and the confidence limit is entered. Where only the total uncertainty is known for a category then:

- if uncertainty is correlated across years, the uncertainty is entered as emission or removal factor uncertainty and 0 in activity data uncertainty
- if uncertainty is not correlated across years, the uncertainty is entered as uncertainty in activity data and 0 in emission or removal factor uncertainty.

In tables A7.1 and A7.2, the figure labelled “uncertainty in the year” is an estimate of the percentage uncertainty in total national emissions and removals in the current year. This figure is calculated from the entries for individual categories combined by summing the squares of all the entries in column H and taking the square root.

In the Tier 1 methodology, uncertainties in the trend are estimated using two sensitivities:

- Type A sensitivity: the change in the difference in the national total between the base year and the current year, expressed as a percentage, resulting from a 1 percent increase in emissions of a given source category and gas in both the base year and the current year.

- Type B sensitivity: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1 percent increase in emissions of a given source category and gas in the current year only.

Uncertainties that are fully correlated between years will be associated with Type A sensitivities, and uncertainties that are not correlated between years will be associated with Type B sensitivities.

In tables A7.1 and A7.2, the figure labelled “uncertainty in the trend” is an estimate of the total uncertainty in the trend, calculated from the entries above by summing the squares of all the entries and taking the square root. The values for the individual categories are an estimate of the uncertainty introduced into the trend by the category in question.

**Table A7.1 Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990–2004 including LULUCF removals (following IPCC Tier 1)**

| IPCC Source category                    | Gas              | Base year emissions or absolute value of removals | Year t emissions or absolute value of removals | activity data uncertainty | emission or removal factor uncertainty | combined uncertainty | combined uncertainty as a % of the national total in year t | type A sensitivity | type b sensitivity | Uncertainty in the trend in national totals introduced by emission or removal factor uncertainty | Uncertainty in trend in national total introduced by activity data uncertainty | Uncertainty introduced into the trend in the national total | Emission /removal factor quality indicator | Activity data quality indicator |
|---|------------------|---|--|---------------------------|--|----------------------|---|--------------------|--------------------|--|--|---|--|---------------------------------|
| Energy sector                           | CO <sub>2</sub>  | 22706.86  | 30590.19                                       | 5                         | 0                                      | 5                    | 1.49  | 0.0327             | 0.3643             | 0.0000   | 2.5757   | 2.58  | M  | R                               |
| Industrial processes sector             | CO <sub>2</sub>  | 2,666.52  | 3450.30  | 5                         | 0                                      | 5                    | 0.17  | 0.0022             | 0.0411             | 0.0000   | 0.2905   | 0.29  | M  | R                               |
| LULUCF sector - forest land             | CO <sub>2</sub>  | 20624.90  | 26254.43                                       | 5                         | 25                                     | 25                   | 6.50  | 0.0115             | 0.3126             | 0.2877   | 2.2106   | 2.23  | M  | R                               |
| LULUCF sector other land use categories | CO <sub>2</sub>  | 1404.86   | 1577.33  | 15                        | 184                                    | 185                  | 2.83  |                    |                    |  |  |   | M  | R                               |
| Energy sector                           | CH <sub>4</sub>  | 797.03  | 794.25   | 5                         | 50                                     | 50                   | 0.39  | -0.0022            | 0.0095             | -0.1089  | 0.0669   | 0.13  | D  | R                               |
| CRF2A - mineral products                | CH <sub>4</sub>  | NO  | NO   |                           |  |                      |   |                    |                    |  |  |   |  |                                 |
| CRF2B - chemical industry               | CH <sub>4</sub>  | 20.16   | 45.69  | 0                         | 80                                     | 80                   | 0.04  | 0.0002             | 0.0005             | 0.0200   | 0.0000   | 0.02  | D  | R                               |
| CRF4A - enteric fermentation            | CH <sub>4</sub>  | 21806.54  | 23823.54                                       | 2                         | 53                                     | 53                   | 12.27   | -0.0346            | 0.2837             | -1.8323  | 0.8024   | 2.00  | M  | M                               |
| CRF4B - manure management               | CH <sub>4</sub>  | 590.47  | 734.08   | 2                         | 100                                    | 100                  | 0.71  | 0.0001             | 0.0087             | 0.0121   | 0.0247   | 0.03  | M  | M                               |
| CRF4E- prescribed burning               | CH <sub>4</sub>  | 2.82  | 0.70   | 20                        | 60                                     | 63                   | 0.00  | 0.0000             | 0.0000             | -0.0020  | 0.0002   | 0.00  | D  | R                               |
| CRF4F - burning of residues             | CH <sub>4</sub>  | 18.78   | 18.88  | 50                        | 40                                     | 64                   | 0.01  | 0.0000             | 0.0002             | -0.0020  | 0.0159   | 0.02  | D  | R                               |
| LULUCF sector                           | CH <sub>4</sub>  | 93.54   | 75.15  | 10                        | 35                                     | 36                   | 0.03  | -0.0005            | 0.0009             | -0.0165  | 0.0127   | 0.02  |  |                                 |
| CRF 6A - Solid waste disposal           | CH <sub>4</sub>  | 2177.70   | 1507.49  | 0                         | 20                                     | 20                   | 0.29  | -0.0138            | 0.0180             | -0.2767  | 0.0000   | 0.28  | M  | R                               |
| CRF 6B - wastewater handling            | CH <sub>4</sub>  | 156.66  | 166.95   | 0                         | 20                                     | 20                   | 0.03  | -0.0003            | 0.0020             | -0.0060  | 0.0000   | 0.01  | D  | R                               |
| Energy sector                           | N <sub>2</sub> O | 151.26  | 265.05   | 5                         | 50                                     | 50                   | 0.13  | 0.0009             | 0.0032             | 0.0474   | 0.0223   | 0.05  | D  | R                               |
| CRF4D -Agricultural soils               | N <sub>2</sub> O | 10035.37  | 12712.65                                       | 5                         | 73                                     | 73                   | 9.03  | 0.0049             | 0.1514             | 0.3555   | 1.0704   | 1.13  | M  | M                               |
| CRF4B - manure management               | N <sub>2</sub> O | 37.93   | 63.50  | 5                         | 100                                    | 100                  | 0.06  | 0.0002             | 0.0008             | 0.0202   | 0.0053   | 0.02  |  |                                 |
| CRF4E- prescribed burning               | N <sub>2</sub> O | 0.51  | 0.13   | 20                        | 60                                     | 63                   | 0.00  | 0.0000             | 0.0000             | -0.0004  | 0.0000   | 0.00  | D  | R                               |
| CRF4F - burning of residues             | N <sub>2</sub> O | 6.46  | 6.20   | 50                        | 40                                     | 64                   | 0.00  | 0.0000             | 0.0001             | -0.0008  | 0.0052   | 0.01  | D  | R                               |
| LULUCF sector                           | N <sub>2</sub> O | 9.49  | 7.63   | 10                        | 35                                     | 36                   | 0.00  | 0.0000             | 0.0001             | -0.0017  | 0.0013   | 0.00  |  |                                 |
| CRF6B - wastewater handling             | N <sub>2</sub> O | 146.92  | 163.92   | 0                         | 1200                                   | 1200                 | 1.91  | -0.0002            | 0.0020             | -0.2315  | 0.0000   | 0.23  | D  | R                               |
| CRF2F                                   | HFCs             | 0.00  | 597.36   | 120                       | 50                                     | 130                  | 0.75  | 0.0071             | 0.0071             | 0.3557   | 1.2071   | 1.26  | D  | R                               |
| CRF2C                                   | PFCs             | 515.60  | 80.70  | 0                         | 30                                     | 30                   | 0.02  | -0.0066            | 0.0010             | -0.1970  | 0.0000   | 0.20  | M  | M                               |
| CRF2F                                   | SF <sub>6</sub>  | 9.46  | 21.49  | 5                         | 20                                     | 21                   | 0.00  | 0.0001             | 0.0003             | 0.0024   | 0.0018   | 0.00  |  |                                 |
| <b>Total emissions/removals</b>         |                  | <b>83979.85</b>                                   | <b>102957.58</b>                               |                           |  |                      | <b>Uncertainty in the year</b>                              | <b>17.0%</b>       |                    | <b>Uncertainty in the trend</b>  |  | <b>4.3%</b>   |  |                                 |

assumptions as per IPCC GPG

1. where only total uncertainty is known for a source category then the following rules have been used.

- a) if uncertainty is assumed to be correlated across years, then total uncertainty is entered as emission factor uncertainty
- b) if uncertainty is assumed not to be correlated across years, then the total uncertainty is entered as activity data uncertainty

2. Column K: The same emission factor is used in both years and the emission factors are fully correlated.

3. Column L: The activity data in both years is assumed independent (not correlated).

Note that the total shown will not equal the gross or net totals reported in the CRF/NIR as not every source is specified in the uncertainty analysis

**Table A7.2 Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990–2004 excluding LULUCF removals (following IPCC Tier 1)**

| IPCC Source category            | Gas                | Base year emissions | Year t emissions | activity data uncertainty | emission factor uncertainty | combined uncertainty | combined uncertainty as a % of the total emissions in year t | type A sensitivity | type b sensitivity | Uncertainty in the trend in national totals introduced by emission factor uncertainty | Uncertainty in trend in national total introduced by activity data uncertainty | Uncertainty introduced into the trend in total emissions | Emission /removal factor quality indicator | Activity data quality indicator |
|---------------------------------|--------------------|---------------------|------------------|---------------------------|-----------------------------|----------------------|--|--------------------|--------------------|---|--|--|--|---------------------------------|
| Energy sector                   | CO <sub>2</sub>    | 22721.55            | 30590.19         | 5                         | 0                           | 5                    | 2.04   | 0.0492             | 0.4937             | 0.0000  | 3.4908   | 3.49   | M  | R                               |
| Industrial processes sector     | CO <sub>2</sub>    | 2,666.52            | 3450.30          | 5                         | 0                           | 5                    | 0.23   | 0.0035             | 0.0557             | 0.0000  | 0.3937   | 0.39   | M  | R                               |
| Energy sector                   | CH <sub>4</sub>    | 797.03              | 794.25           | 5                         | 50                          | 50                   | 0.53   | -0.0028            | 0.0128             | -0.1384   | 0.0906   | 0.17   | D  | R                               |
| CRF2A - mineral products        | CH <sub>4</sub> NO | NO                  | NO               |                           |                             |                      |  |                    |                    |   |  |  |  |                                 |
| CRF2B - chemical industry       | CH <sub>4</sub>    | 20.16               | 45.69            | 0                         | 80                          | 80                   | 0.05   | 0.0003             | 0.0007             | 0.0274  | 0.0000   | 0.03   | D  | R                               |
| CRF4A - enteric fermentation    | CH <sub>4</sub>    | 21806.54            | 23714.98         | 2                         | 53                          | 53                   | 16.75  | -0.0436            | 0.3827             | -2.3087   | 1.0825   | 2.55   | M  | M                               |
| CRF4B - manure management       | CH <sub>4</sub>    | 590.47              | 745.88           | 2                         | 100                         | 100                  | 0.99   | 0.0005             | 0.0120             | 0.0490  | 0.0340   | 0.06   | M  | M                               |
| CRF4E- prescribed burning       | CH <sub>4</sub>    | 2.82                | 0.70             | 20                        | 60                          | 63                   | 0.00   | 0.0000             | 0.0000             | -0.0026   | 0.0003   | 0.00   | D  | R                               |
| CRF4F - burning of residues     | CH <sub>4</sub>    | 18.78               | 18.88            | 50                        | 40                          | 64                   | 0.02   | -0.0001            | 0.0003             | -0.0025   | 0.0215   | 0.02   | D  | R                               |
| LULUCF sector                   | CH <sub>4</sub>    | 93.54               | 75.15            | 10                        | 35                          | 36                   | 0.04   | -0.0006            | 0.0012             | -0.0216   | 0.0172   | 0.03   |  |                                 |
| CRF 6A - Solid waste disposal   | CH <sub>4</sub>    | 2177.70             | 1507.49          | 0                         | 20                          | 20                   | 0.40   | -0.0183            | 0.0243             | -0.3650   | 0.0000   | 0.37   | M  | R                               |
| CRF 6B - wastewater handling    | CH <sub>4</sub>    | 156.66              | 166.95           | 0                         | 20                          | 20                   | 0.04   | -0.0004            | 0.0027             | -0.0074   | 0.0000   | 0.01   | D  | R                               |
| Energy sector                   | N <sub>2</sub> O   | 151.26              | 265.05           | 5                         | 50                          | 50                   | 0.18   | 0.0013             | 0.0043             | 0.0660  | 0.0302   | 0.07   | D  | R                               |
| CRF4D -Agricultural soils       | N <sub>2</sub> O   | 10035.37            | 12768.17         | 5                         | 73                          | 73                   | 12.44  | 0.0098             | 0.2061             | 0.7151  | 1.4570   | 1.62   | M  | M                               |
| CRF4B - manure management       | N <sub>2</sub> O   | 37.93               | 63.50            | 5                         | 100                         | 100                  | 0.08   | 0.0003             | 0.0010             | 0.0283  | 0.0072   | 0.03   |  |                                 |
| CRF4E- prescribed burning       | N <sub>2</sub> O   | 0.51                | 0.13             | 20                        | 60                          | 63                   | 0.00   | 0.0000             | 0.0000             | -0.0005   | 0.0001   | 0.00   | D  | R                               |
| CRF4F - burning of residues     | N <sub>2</sub> O   | 6.46                | 6.20             | 50                        | 40                          | 64                   | 0.01   | 0.0000             | 0.0001             | -0.0010   | 0.0071   | 0.01   | D  | R                               |
| LULUCF sector                   | N <sub>2</sub> O   | 9.49                | 7.63             | 10                        | 35                          | 36                   | 0.00   | -0.0001            | 0.0001             | -0.0022   | 0.0017   | 0.00   |  |                                 |
| CRF6B - wastewater handling     | N <sub>2</sub> O   | 146.92              | 163.92           | 0                         | 1200                        | 1200                 | 2.62   | -0.0002            | 0.0026             | -0.2732   | 0.0000   | 0.27   | D  | R                               |
| CRF2F                           | HFCs               | 0.00                | 597.36           | 120                       | 50                          | 130                  | 1.03   | 0.0096             | 0.0096             | 0.4820  | 1.6360   | 1.71   | D  | R                               |
| CRF2C                           | PFCs               | 515.60              | 80.70            | 0                         | 30                          | 30                   | 0.03   | -0.0088            | 0.0013             | -0.2634   | 0.0000   | 0.26   | M  | M                               |
| CRF2F                           | SF <sub>6</sub>    | 9.46                | 21.49            | 5                         | 20                          | 21                   | 0.01   | 0.0002             | 0.0003             | 0.0032  | 0.0025   | 0.00   |  |                                 |
| <b>Total emissions/removals</b> |                    | <b>61964.78</b>     | <b>75084.58</b>  |                           |                             |                      | <b>Uncertainty in the year</b>                               | <b>21.2%</b>       |                    | <b>Uncertainty in the trend</b>   |  | <b>5.0%</b>  |  |                                 |

assumptions as per IPCC GPG

- where only total uncertainty is known for a source category then the following rules have been used.
  - if uncertainty is assumed to be correlated across years, then total uncertainty is entered as emission factor uncertainty
  - if uncertainty is assumed not to be correlated across years, then the total uncertainty is entered as activity data uncertainty
- Column K: The same emission factor is used in both years and the emission factors are fully correlated.
- Column L: The activity data in both years is assumed independent (not correlated).

Note that the total emissions shown will not equal the total reported in the CRF/NIR as not every source is specified in the uncertainty analysis

# Annex 8: Worksheets for all sectors

## A8.1 Worksheets for the energy sector

Module 2004 Energy (New Zealand)  
 Submodule CO2 emissions from energy sources (reference approach)  
 Worksheet 1.1 (1-3 of 5)  
 Sheet Emissions from domestic fuel combustion

| Fuel type                         | Production                  | Imports             | Exports           | Inter-national bunkers | Stock change | Apparent consumption | Conversion factor (TJ/unit) | Apparent consumption (TJ) | Carbon emis fact (t C/TJ) | Carbon content (t C) | Carbon content (Gg) | Carbon stored (Gg) | Net C emissions (Gg) | Fraction of carbon oxidised | Actual C emissions (Gg) | Actual CO2 emissions (Gg) |
|-----------------------------------|-----------------------------|---------------------|-------------------|------------------------|--------------|----------------------|-----------------------------|---------------------------|---------------------------|----------------------|---------------------|--------------------|----------------------|-----------------------------|-------------------------|---------------------------|
| Liquid fossil fuels - primary     | Crude oil                   | 42.53               | 200.89            | 33.45                  | -3.58        | 213.56               | 1,000                       | 213,558.53                | 17.80                     | 3,801,341.83         | 3,801.34            |                    | 3,801.34             | 0.99                        | 3,763.33                | 13,798.87                 |
|                                   | Orimulsion                  | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Natural gas liquids         | 9.52                | 0.39              | 0.75                   | 0.23         | 8.94                 | 1,000                       | 8,937.82                  | 16.47                     | 147,230.27           | 147.23              |                    | 147.23               | 0.99                        | 145.76                  | 534.45                    |
| Liquid fossil fuels - secondary   | Gasoline - Regular Unleaded | 29.72               | 0.00              | 0                      | 0.93         | 28.79                | 1,000                       | 28,789.44                 | 18.05                     | 519,780.31           | 519.78              |                    | 519.78               | 0.99                        | 514.58                  | 1,886.80                  |
|                                   | Gasoline - Premium Unleaded | 11.31               | 0.00              | 0                      | 4.08         | 7.24                 | 1,000                       | 7,235.36                  | 18.27                     | 132,209.70           | 132.21              |                    | 132.21               | 0.99                        | 130.89                  | 479.92                    |
|                                   | Jet kerosene                | 13.10               | 0.00              | 38.04                  | 1.87         | -26.81               | 1,000                       | -26,812.20                | 18.57                     | -497,975.60          | -497.98             |                    | -497.98              | 0.99                        | -493.00                 | -1,807.65                 |
|                                   | Av Gas                      | 0.70                | 0.00              | 0.00                   | 0.06         | 0.63                 | 1,000                       | 634.95                    | 17.73                     | 11,255.93            | 11.26               |                    | 11.26                | 0.99                        | 11.14                   | 40.86                     |
|                                   | Other kerosene              | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Shale oil                   | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Gas/diesel oil              | 36.22               | 0.24              | 1.53                   | 0.98         | 33.47                | 1,000                       | 33,472.03                 | 18.95                     | 634,447.10           | 634.45              |                    | 634.45               | 0.99                        | 628.10                  | 2,303.04                  |
|                                   | Residual fuel oil           | 0.00                | 2.62              | 8.80                   | 0.20         | -11.62               | 1,000                       | -11,620.21                | 19.91                     | -231,347.80          | -231.35             |                    | -231.35              | 0.99                        | -229.03                 | -839.79                   |
|                                   | LPG                         | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Ethane                      | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Naphtha                     | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Bitumen                     | 7.30                | 0.00              | 0.00                   | -0.34        | 7.64                 | 1,000                       | 7,639.74                  | 20.76                     | 158,601.08           | 158.60              | 261.93             | -103.33              | 0.99                        | -102.30                 | -375.10                   |
|                                   | Lubricants                  | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Petroleum coke              | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Refinery feedstocks         | 16.12               | 0.00              | 2.17                   | 13.95        | 13.95                | 1,000                       | 13,953.45                 | 17.80                     | 248,371.32           | 248.37              |                    | 248.37               | 0.99                        | 245.89                  | 901.59                    |
|                                   | Other oil                   | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
| <b>Total liquid fossil fuels</b>  |                             | <b>52.05</b>        | <b>315.76</b>     | <b>37.06</b>           | <b>48.37</b> | <b>6.59</b>          |                             | <b>275.79</b>             |                           | <b>4,923,914.15</b>  | <b>4,923.91</b>     | <b>261.93</b>      | <b>4,661.98</b>      |                             | <b>4,615.36</b>         | <b>16,922.99</b>          |
| Solid fossil fuels - primary      | Anthracite                  | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             | 0.00                      |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Coking coal                 | 2,467,897.00        | 0.00              | 1,908,418.22           |              | 559,478.78           | 0.03                        | 0.00                      | 24.22                     | -                    | 0.00                | 0.00               | -                    | 0.98                        | 0.00                    | 0.00                      |
|                                   | Other bituminous coal       | 58,716.00           | 53,976.92         | 0.00                   | 0.00         | 112,692.92           | 0.03                        | 3,617.44                  | 24.22                     | 87,607.88            | 87.61               |                    | 87.61                | 0.98                        | 85.86                   | 314.80                    |
|                                   | Sub-bituminous coal         | 2,389,353.00        | 822,156.04        | 0.00                   | 0.00         | 3,211,509.04         | 0.02                        | 72,580.10                 | 24.87                     | 1,805,265.14         | 1,805.27            | 450.70             | 1,354.57             | 0.98                        | 1,327.48                | 4,867.42                  |
|                                   | Lignite                     | 239,428.00          | 3.45              | 0.00                   | 0.00         | 239,431.45           | 0.02                        | 3,591.47                  | 25.96                     | 93,247.67            | 93.25               |                    | 93.25                | 0.98                        | 91.38                   | 335.07                    |
|                                   | Peat                        | -                   | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
| Solid fossil fuels - secondary    | BKB & patent fuel           | 0.00                | 0.00              | 0.00                   | 0.00         | 0.00                 |                             |                           |                           |                      |                     |                    |                      |                             |                         |                           |
|                                   | Coke                        | 13,653.02           | 0.00              | 0.00                   | 0.00         | 13,653.02            | 0.03                        | 380.92                    | 27.90                     | 10,627.65            | 10.63               |                    | 10.63                | 0.98                        | 10.42                   | 38.19                     |
| <b>Total solid fossil fuels</b>   |                             | <b>5,155,394.00</b> | <b>889,789.43</b> | <b>1,908,418.22</b>    | <b>0.00</b>  | <b>559,478.78</b>    |                             | <b>3,577,286.43</b>       |                           | <b>1,996,748.34</b>  | <b>1,996.75</b>     | <b>450.70</b>      | <b>1,546.05</b>      |                             | <b>1,515.13</b>         | <b>5,555.48</b>           |
| <b>Total gaseous fossil fuels</b> |                             | <b>160.64</b>       | <b>0.00</b>       | <b>0.00</b>            |              | <b>160.54</b>        | <b>1,000</b>                | <b>160,540.44</b>         | <b>16.13</b>              | <b>2,588,816.06</b>  | <b>2,588.82</b>     | <b>511.09</b>      | <b>2,077.72</b>      | <b>1.00</b>                 | <b>2,067.33</b>         | <b>7,580.22</b>           |
| <b>Total fossil fuels</b>         |                             |                     |                   |                        |              |                      |                             | <b>516,499.29</b>         |                           | <b>9,509,478.55</b>  | <b>9,509.48</b>     | <b>1,223.72</b>    | <b>8,285.75</b>      |                             | <b>8,197.82</b>         | <b>30,058.69</b>          |
| <b>Total biomass fuels</b>        |                             |                     |                   |                        |              | <b>36.47</b>         |                             | <b>36,466.00</b>          |                           | <b>1,034,548.64</b>  | <b>1,034.55</b>     |                    | <b>1,034.55</b>      |                             | <b>984.64</b>           | <b>3,610.34</b>           |
|                                   | Solid biomass               | 35.00               |                   |                        |              | 35.00                | 1,000                       | 35,000.00                 | 28.41                     | 994,175.00           | 994.18              |                    | 994.18               | 0.95                        | 944.47                  | 3,463.04                  |
|                                   | Liquid biomass              |                     |                   |                        |              |                      |                             | ne                        |                           |                      |                     |                    |                      |                             | ne                      |                           |
|                                   | Gas biomass                 | 1.47                |                   |                        |              | 1.47                 | 1,000                       | 1,466.00                  | 27.54                     | 40,373.64            | 40.37               |                    | 40.37                | 1.00                        | 40.17                   | 147.30                    |

Liquid and gaseous fossil fuel data are shown initially in petajoules. Solid fossil fuel data are shown initially in tonnes.

**Module** 2004 Energy (New Zealand)  
**Submodule** CO2 emissions from energy sources (reference approach)  
**Worksheet** 1.1 (4-5 of 5)  
**Sheet** Emissions from international bunkers

| Fuel type           | Quantities delivered  | Conversion factor (TJ/unit) | Quantities delivered (TJ) | Carbon emis fact (t C/TJ) | Carbon content (t C) | Carbon content (Gg) | Fraction of carbon stored | Carbon stored (Gg) | Net C emissions (Gg) | Fraction of carbon oxidised | Actual C emissions (Gg) |
|---------------------|-----------------------|-----------------------------|---------------------------|---------------------------|----------------------|---------------------|---------------------------|--------------------|----------------------|-----------------------------|-------------------------|
| Solid fossil fuels  | Other bituminous coal |                             | 0.00                      |                           |                      |                     |                           |                    |                      |                             |                         |
|                     | Sub-bituminous coal   |                             | 0.00                      |                           |                      |                     |                           |                    |                      |                             |                         |
| Liquid fossil fuels | Gasoline              |                             | 0.00                      |                           |                      |                     |                           |                    |                      |                             |                         |
|                     | Jet kerosene          | 1,000                       | 38040.91                  | 18.57                     | 706,523.48           | 706.52              | 0.00                      | 0.00               | 706.52               | 0.99                        | 699.46                  |
|                     | Gas/diesel oil        | 1,000                       | 1529.29                   | 18.95                     | 28,987.08            | 28.99               | 0.00                      | 0.00               | 28.99                | 0.99                        | 28.70                   |
|                     | Residual fuel oil     | 1,000                       | 8799.80                   | 19.91                     | 175,196.08           | 175.20              | 0.00                      | 0.00               | 175.20               | 0.99                        | 173.44                  |
|                     | Lubricants            |                             | 0.00                      |                           |                      |                     |                           |                    |                      |                             |                         |
|                     | Bitumen               | 1,000                       | 0.00                      | 20.76                     | 0.00                 | 0.00                | 0.00                      | 0.00               | 0.00                 | 0.99                        | 0                       |
| Total fossil fuels  |                       |                             | 48,370.01                 |                           |                      |                     |                           |                    |                      |                             | 901.60                  |

Liquid fossil fuel data are shown initially in petajoules.

**Module** 2004 Energy (New Zealand)  
**Submodule** CO2 emissions from energy sources (reference approach)  
**Worksheet** 1.1 (supplemental)  
**Sheet** Estimating the carbon stored in products

| Fuel type          | Estimated fuel quantities | Conversion factor (TJ/unit) | Estimated quantities (TJ) | Carbon emis fact (t C/TJ) | Carbon content (t C) | Carbon content (Gg) | Fraction of carbon stored | Carbon stored (Gg) |
|--------------------|---------------------------|-----------------------------|---------------------------|---------------------------|----------------------|---------------------|---------------------------|--------------------|
| Naphtha            | 0.00                      |                             |                           |                           |                      |                     |                           | no                 |
| Lubricants         | 0.00                      |                             |                           |                           |                      |                     |                           | no                 |
| Bitumen            | 12.62                     | 1,000                       | 12,617.24                 | 20.76                     | 261,933.94           | 261.93              | 1.00                      | 261.93             |
| Coal oils and tars | 0.00                      | 0.03                        | 0.00                      | 24.24                     | 0.00                 | 0.00                | 0.75                      | 0.00               |
| Coal1              | 17.6366650                | 1,000                       | 17,636.67                 | 25.55                     | 450,696.96           | 450.70              | 1.00                      | 450.70             |
| Natural gas2       | conf                      | 1,000                       | conf                      | conf                      | conf                 | conf                | conf                      | 511.09             |
| Gas/diesel oil     | 0.00                      |                             |                           |                           |                      |                     |                           | no                 |
| LPG                | 0.00                      |                             |                           |                           |                      |                     |                           | no                 |
| Ethane             | 0.00                      |                             |                           |                           |                      |                     |                           | no                 |
| Other fuels        | 0.00                      |                             |                           |                           |                      |                     |                           | no                 |
| Total              |                           |                             |                           |                           |                      |                     |                           | 1,223.72           |

All data are shown initially in petajoules, except coal oils and tars, which is shown in tonnes.

1 Refers to coal used in the production of iron and steel. This carbon is emitted but is reported in the industrial processes sector.

2 Refers to gas used in the production of methanol, synthetic petrol and urea. Some natural gas data are confidential.

Module  
Sub-module  
Worksheets

**2004 Energy (New Zealand)**  
CO<sub>2</sub> emissions from fuel combustion by source categories (tier 1)  
1.2 (part I)

| Source and sink categories                                    | Energy consumption (TJ) | Carbon emis fact (t C/TJ) | Carbon content (t C) | Carbon content (Gg) | Fraction of carbon stored <sup>1</sup> | Carbon stored <sup>1</sup> (t C) | Net C emissions (Gg) | Fraction of carbon oxidised | Actual C emissions (Gg) | Actual CO <sub>2</sub> emissions (Gg) |
|---|-------------------------|---------------------------|----------------------|---------------------|--|----------------------------------|----------------------|-----------------------------|-------------------------|---------------------------------------|
| <b>Total energy (parts I and II of worksheet)<sup>2</sup></b> | <b>432,922.89</b>       |                           | <b>8,190,074.52</b>  | <b>8,190.07</b>     |  |                                  | <b>8,190.07</b>      |                             | <b>8,101.66</b>         | <b>29,706.08</b>                      |
| <b>Total Liquid Fuels</b>                                     | <b>251,044.90</b>       |                           | <b>4,643,535.66</b>  | <b>4,643.54</b>     |  |                                  | <b>4,643.54</b>      | <b>0.99</b>                 | <b>4,597.10</b>         | <b>16,856.03</b>                      |
| <b>Total Coal</b>   | <b>63,691.73</b>        |                           | <b>1,616,593.00</b>  | <b>1,616.59</b>     |  |                                  | <b>1,616.59</b>      | <b>0.98</b>                 | <b>1,584.26</b>         | <b>5,808.96</b>                       |
| <b>Total Gaseous Fuels</b>                                    | <b>118,186.27</b>       |                           | <b>1,929,945.85</b>  | <b>1,929.95</b>     |  |                                  | <b>1,929.95</b>      | <b>1.00</b>                 | <b>1,920.30</b>         | <b>7,041.09</b>                       |
| <b>1 Energy industries<sup>2</sup></b>                        | <b>104,434.76</b>       |                           | <b>1,978,142.40</b>  | <b>1,978.14</b>     |  |                                  | <b>1,978.14</b>      |                             | <b>1,952.37</b>         | <b>7,158.68</b>                       |
| <b>a Public electricity and heat</b>                          | <b>85,169.41</b>        |                           | <b>1,671,602.04</b>  | <b>1,671.60</b>     |  |                                  | <b>1,671.60</b>      | <b>8.91</b>                 | <b>1,647.61</b>         | <b>6,041.22</b>                       |
| <b>Total Liquid Fuels</b>                                     | <b>23.11</b>            |                           | <b>436.88</b>        | <b>0.44</b>         |  |                                  | <b>0.44</b>          | <b>6.93</b>                 | <b>0.43</b>             | <b>1.59</b>                           |
| Petrol Regular  | 1.22                    | 18.05                     | 22.03                | 0.02                |  |                                  | 0.02                 | 0.99                        | 0.02                    | 0.08                                  |
| Petrol Premium  | 0.00                    | 18.27                     | 0.00                 | 0.00                |  |                                  | 0.00                 | 0.99                        | 0.00                    | 0.00                                  |
| Diesel  | 21.89                   | 18.95                     | 414.85               | 0.41                |  |                                  | 0.41                 | 0.99                        | 0.41                    | 1.51                                  |
| Heavy Fuel oil  | 0.00                    | 20.05                     | 0.00                 | 0.00                |  |                                  | 0.00                 | 0.99                        | 0.00                    | 0.00                                  |
| Light Fuel oil  | 0.00                    | 19.64                     | 0.00                 | 0.00                |  |                                  | 0.00                 | 0.99                        | 0.00                    | 0.00                                  |
| Jet Kerosene  | 0.00                    | 18.57                     | 0.00                 | 0.00                |  |                                  | 0.00                 | 0.99                        | 0.00                    | 0.00                                  |
| Av Gas  | 0.00                    | 17.73                     | 0.00                 | 0.00                |  |                                  | 0.00                 | 0.99                        | 0.00                    | 0.00                                  |
| Coal  | 41,126.00               | 25.35                     | 1,042,454.09         | 1,042.45            |  |                                  | 1,042.45             | 0.98                        | 1,021.61                | 3,745.89                              |
| Natural gas   | 44,020.31               | 14.28                     | 628,711.07           | 628.71              |  |                                  | 628.71               | 1.00                        | 625.57                  | 2,293.75                              |
| Biogas (memo item) <sup>3</sup>                               | 1,059.00                | 28.41                     | 30,080.90            | 30.08               |  |                                  | 30.08                | 1.00                        | 29.93                   | 109.75                                |
| <b>b Petroleum refining</b>                                   | <b>13,522.42</b>        |                           | <b>225,943.36</b>    | <b>225.94</b>       |  |                                  | <b>225.94</b>        | <b>3.97</b>                 | <b>224.57</b>           | <b>823.42</b>                         |
| <b>Total Liquid Fuels</b>                                     | <b>2,495.79</b>         |                           | <b>48,911.18</b>     | <b>48.91</b>        |  |                                  | <b>48.91</b>         | <b>1.98</b>                 | <b>48.42</b>            | <b>177.55</b>                         |
| Fuel oil  | 653.07                  | 18.96                     | 12,383.18            | 12.38               |  |                                  | 12.38                | 0.99                        | 12.26                   | 44.95                                 |
| Asphalt   | 1,842.72                | 19.82                     | 36,528.00            | 36.53               |  |                                  | 36.53                | 0.99                        | 36.16                   | 132.60                                |
| <b>Total Natural Gas</b>                                      | <b>11,026.63</b>        |                           | <b>177,032.18</b>    | <b>177.03</b>       |  |                                  | <b>177.03</b>        | <b>1.99</b>                 | <b>176.15</b>           | <b>645.87</b>                         |
| Refinery gas  | 10,948.41               | 16.06                     | 175,867.36           | 175.87              |  |                                  | 175.87               | 1.00                        | 174.99                  | 641.62                                |
| Natural gas   | 78.22                   | 14.89                     | 1,164.82             | 1.16                |  |                                  | 1.16                 | 1.00                        | 1.16                    | 4.25                                  |
| <b>c Solid fuels and other energy</b>                         | <b>5,742.92</b>         |                           | <b>80,596.99</b>     | <b>80.60</b>        |  |                                  | <b>80.60</b>         | <b>1.99</b>                 | <b>80.19</b>            | <b>294.04</b>                         |
| <b>Total Natural Gas</b>                                      | <b>5,742.92</b>         |                           | <b>80,596.99</b>     | <b>80.60</b>        |  |                                  | <b>80.60</b>         | <b>1.99</b>                 | <b>80.19</b>            | <b>294.04</b>                         |
| Natural gas in synthetic petrol production                    | 0.00                    | 0.00                      | 0.00                 | 0.00                |  |                                  | 0.00                 | 1.00                        | 0.00                    | 0.00                                  |
| Natural gas in oil and gas extraction                         | 5,742.92                | 14.03                     | 80,596.99            | 80.60               |  |                                  | 80.60                | 1.00                        | 80.19                   | 294.04                                |

Module 2004 Energy (New Zealand)  
Sub-module CO2 emissions from fuel combustion by source categories (tier 1)  
Worksheets 1.2 (part II)

| Source and sink categories                          | Energy consumption (TJ) | Carbon emis fact (t C/TJ) | Carbon content (t C) | Carbon content (Gg) | Fraction of carbon stored <sup>1</sup> | Carbon stored <sup>1</sup> (t C) | Net C emissions (Gg) | Fraction of carbon oxidised | Actual C emissions (Gg) | Actual CO2 emissions (Gg) |
|---|-------------------------|---------------------------|----------------------|---------------------|--|----------------------------------|----------------------|-----------------------------|-------------------------|---------------------------|
| <b>2 Manufacturing and construction<sup>2</sup></b> | <b>66,032.19</b>        |                           | <b>1,384,534.62</b>  | <b>1,384.53</b>     |  |                                  | <b>1,384.53</b>      | <b>1.00</b>                 | <b>1,370.77</b>         | <b>5,026.17</b>           |
| <b>a Iron and Steel</b>                             | <b>1,832.61</b>         |                           | <b>26,373.99</b>     | <b>26.37</b>        |  |                                  | <b>26.37</b>         |                             | <b>26.24</b>            | <b>96.22</b>              |
| Natural gas   | 1,832.61                | 14.39                     | 26,373.99            | 26.37               |  |                                  | 26.37                | 1.00                        | 26.24                   | 96.22                     |
| <b>c Chemicals (methanol production)</b>            | <b>conf</b>             | <b>conf</b>               | <b>221,370.84</b>    | <b>221.37</b>       |  |                                  | <b>221.37</b>        | <b>1.00</b>                 | <b>220.26</b>           | <b>807.63</b>             |
| Natural gas in methanol production <sup>4</sup>     | conf                    | conf                      | 221,370.84           | 221.37              |  |                                  | 221.37               | 1.00                        | 220.26                  | 807.63                    |
| <b>f Other</b>                                      | <b>64,199.57</b>        |                           | <b>1,136,789.79</b>  | <b>1,136.79</b>     |  |                                  | <b>1,136.79</b>      |                             | <b>1,124.27</b>         | <b>4,122.31</b>           |
| <b>Total Liquid Fuels</b>                           | <b>13,728.10</b>        |                           | <b>252,639.98</b>    | <b>252.64</b>       |  |                                  | <b>252.64</b>        |                             | <b>250.11</b>           | <b>917.08</b>             |
| Petrol Regular                                      | 256.05                  | 18.05                     | 4,622.87             | 4.62                |  |                                  | 4.62                 | 0.99                        | 4.58                    | 16.78                     |
| Petrol Premium                                      | 123.66                  | 18.27                     | 2,259.68             | 2.26                |  |                                  | 2.26                 | 0.99                        | 2.24                    | 8.20                      |
| Diesel  | 9,252.46                | 18.95                     | 175,376.24           | 175.38              |  |                                  | 175.38               | 0.99                        | 173.62                  | 636.62                    |
| Heavy Fuel oil                                      | 107.64                  | 20.05                     | 2,157.66             | 2.16                |  |                                  | 2.16                 | 0.99                        | 2.14                    | 7.83                      |
| Light Fuel oil                                      | 696.51                  | 19.64                     | 13,676.93            | 13.68               |  |                                  | 13.68                | 0.99                        | 13.54                   | 49.65                     |
| Jet Kerosene  | 146.70                  | 18.57                     | 2,724.70             | 2.72                |  |                                  | 2.72                 | 0.99                        | 2.70                    | 9.89                      |
| Av Gas  | 11.21                   | 17.73                     | 198.72               | 0.20                |  |                                  | 0.20                 | 0.99                        | 0.20                    | 0.72                      |
| LPG   | 3,133.86                | 16.47                     | 51,623.17            | 51.62               |  |                                  | 51.62                | 0.99                        | 51.11                   | 187.39                    |
| Other liquid  | 0.00                    | 19.88                     | 0.00                 | 0.00                |  |                                  | 0.00                 | 0.99                        | 0.00                    | 0.00                      |
| Coal  | 14,602.28               | 25.46                     | 371,723.07           | 371.72              |  |                                  | 371.72               | 0.98                        | 364.29                  | 1,335.72                  |
| <b>Total Natural Gas</b>                            | <b>35,869.20</b>        |                           | <b>512,426.74</b>    | <b>512.43</b>       |  |                                  | <b>512.43</b>        | <b>1.99</b>                 | <b>509.86</b>           | <b>1,869.50</b>           |
| Autoproduction                                      | 14,951.09               | 14.14                     | 211,384.44           | 211.38              |  |                                  | 211.38               | 1.00                        | 210.33                  | 771.20                    |
| Other natural gas                                   | 20,918.11               | 14.39                     | 301,042.30           | 301.04              |  |                                  | 301.04               | 1.00                        | 299.54                  | 1,098.30                  |
| <b>Total Biomass</b>                                | <b>32,763.16</b>        |                           | <b>930,376.31</b>    | <b>930.38</b>       |  |                                  | <b>930.38</b>        | <b>2.00</b>                 | <b>930.33</b>           | <b>3,411.23</b>           |
| Wood (memo item) <sup>3</sup>                       | 32,461.16               | 28.41                     | 922,059.23           | 922.06              |  |                                  | 922.06               | 1.00                        | 922.06                  | 3,380.88                  |
| Biogas - Autoproduction (memo item) <sup>3</sup>    | 302.00                  | 27.54                     | 8,317.08             | 8.32                |  |                                  | 8.32                 | 1.00                        | 8.28                    | 30.34                     |

| Source and sink categories                         | Energy Consumption (TJ) | Carbon emis fact (t C/TJ) | Carbon content (t C) | Carbon content (Gg) | Fraction of carbon stored <sup>1</sup> | Carbon stored <sup>1</sup> (t C) | Net C emissions (Gg) | Fraction of carbon oxidised | Actual C emissions (Gg) | Actual CO2 emissions (Gg) |
|--|-------------------------|---------------------------|----------------------|---------------------|--|----------------------------------|----------------------|-----------------------------|-------------------------|---------------------------|
| <b>3 Transport</b>                                 | <b>210,412.73</b>       |                           | <b>3,887,129.06</b>  | <b>3,887.13</b>     |  |                                  | <b>3,887.13</b>      | <b>10.90</b>                | <b>3,848.27</b>         | <b>14,110.33</b>          |
| <b>a Civil aviation</b>                            | <b>17,711.43</b>        |                           | <b>328,437.25</b>    | <b>328.44</b>       |  |                                  | <b>328.44</b>        | <b>1.98</b>                 | <b>325.15</b>           | <b>1,192.23</b>           |
| Jet Kerosene                                       | 17,105.42               | 18.57                     | 317,694.39           | 317.69              |  |                                  | 317.69               | 0.99                        | 314.52                  | 1,153.23                  |
| Av Gas   | 606.01                  | 17.73                     | 10,742.86            | 10.74               |  |                                  | 10.74                | 0.99                        | 10.64                   | 39.00                     |
| <b>b Road transport</b>                            | <b>185,636.56</b>       |                           | <b>3,420,629.24</b>  | <b>3,420.63</b>     |  |                                  | <b>3,420.63</b>      | <b>4.96</b>                 | <b>3,386.44</b>         | <b>12,416.93</b>          |
| <b>Total Liquid Fuels</b>                          | <b>185,450.56</b>       |                           | <b>3,417,952.42</b>  | <b>3,417.95</b>     |  |                                  | <b>3,417.95</b>      |                             | <b>3,383.77</b>         | <b>12,407.17</b>          |
| Petrol Regular                                     | 85,078.13               | 18.05                     | 1,536,046.96         | 1,536.05            |  |                                  | 1,536.05             | 0.99                        | 1,520.69                | 5,575.85                  |
| Petrol Premium                                     | 25,879.62               | 18.27                     | 472,891.21           | 472.89              |  |                                  | 472.89               | 0.99                        | 468.16                  | 1,716.60                  |
| Diesel   | 73,298.87               | 18.95                     | 1,389,346.69         | 1,389.35            |  |                                  | 1,389.35             | 0.99                        | 1,375.45                | 5,043.33                  |
| LPG  | 1,193.95                | 16.47                     | 19,667.56            | 19.67               |  |                                  | 19.67                | 0.99                        | 19.47                   | 71.39                     |
| CNG  | 186.00                  | 14.39                     | 2,676.81             | 2.68                |  |                                  | 2.68                 | 1.00                        | 2.66                    | 9.77                      |
| <b>c Rail transport (diesel)</b>                   | <b>2,457.00</b>         | <b>18.95</b>              | <b>46,571.32</b>     | <b>46.57</b>        |  |                                  | <b>46.57</b>         | <b>0.99</b>                 | <b>46.11</b>            | <b>169.05</b>             |
| <b>d National navigation (fuel oil and diesel)</b> | <b>4,607.74</b>         |                           | <b>91,491.25</b>     | <b>91.49</b>        |  |                                  | <b>91.49</b>         | <b>2.97</b>                 | <b>90.58</b>            | <b>332.11</b>             |
| Diesel   | 0.00                    | 18.95                     | 0.00                 | 0.00                |  |                                  | 0.00                 | 0.99                        | 0.00                    | 0.00                      |
| Heavy Fuel oil                                     | 2,473.79                | 20.05                     | 49,588.30            | 49.59               |  |                                  | 49.59                | 0.99                        | 49.09                   | 180.01                    |
| Light Fuel oil                                     | 2,133.95                | 19.64                     | 41,902.95            | 41.90               |  |                                  | 41.90                | 0.99                        | 41.48                   | 152.11                    |
| Marine bunkers (memo item) <sup>3</sup>            | 10,244.31               |                           | 203,559.38           | 203.56              |  |                                  | 203.56               |                             | 201.52                  | 738.92                    |
| Diesel   | 1,536.33                | 18.95                     | 29,120.42            | 29.12               |  |                                  | 29.12                | 0.99                        | 28.83                   | 105.71                    |
| Heavy Fuel oil                                     | 8,423.21                | 20.05                     | 168,847.11           | 168.85              |  |                                  | 168.85               | 0.99                        | 167.16                  | 612.92                    |
| Light Fuel oil                                     | 284.77                  | 19.64                     | 5,591.85             | 5.59                |  |                                  | 5.59                 | 0.99                        | 5.54                    | 20.30                     |
| Aviation bunkers (memo item) <sup>3</sup>          | 38,040.98               | 0.00                      | 706,524.68           | 706.52              |  |                                  | 706.52               | 0.99                        | 699.46                  | 2,564.68                  |
| Av Fuels   | 38,040.98               | 18.57                     | 706,524.68           | 706.52              |  |                                  | 706.52               | 0.99                        | 699.46                  | 2,564.68                  |

Module  
Sub-module  
Worksheets

2004 Energy (New Zealand)  
CO2 emissions from fuel combustion by source categories (tier 1)  
1.2 (part IV)

| Source and sink categories            | Energy Consumption (TJ) | Carbon emis fact (t C/TJ) | Carbon content (t C) | Carbon content (Gg) | Fraction of carbon stored1 | Carbon stored1 (t C) | Net C emissions (Gg) | Fraction of carbon oxidised | Actual C emissions (Gg) | Actual CO2 emissions (Gg) |
|---------------------------------------|-------------------------|---------------------------|----------------------|---------------------|----------------------------|----------------------|----------------------|-----------------------------|-------------------------|---------------------------|
| <b>4 Other sectors</b>                | <b>52,043.22</b>        |                           | <b>940,268.45</b>    | <b>940.27</b>       |                            |                      | <b>940.27</b>        |                             | <b>930.25</b>           | <b>3,410.90</b>           |
| <b>a Commercial/institutional</b>     | <b>25,606.31</b>        |                           | <b>466,864.02</b>    | <b>466.86</b>       |                            |                      | <b>466.86</b>        | <b>9.90</b>                 | <b>461.43</b>           | <b>1,691.92</b>           |
| <b>Total Liquid Fuels</b>             | <b>6,449.40</b>         |                           | <b>119,031.44</b>    | <b>119.03</b>       |                            |                      | <b>119.03</b>        | <b>7.92</b>                 | <b>117.84</b>           | <b>432.08</b>             |
| Petrol Regular                        | 102.40                  | 18.05                     | 1,848.81             | 1.85                |                            |                      | 1.85                 | 0.99                        | 1.83                    | 6.71                      |
| Petrol Premium                        | 371.89                  | 18.27                     | 6,795.42             | 6.80                |                            |                      | 6.80                 | 0.99                        | 6.73                    | 24.67                     |
| Diesel                                | 3,409.51                | 18.95                     | 64,625.69            | 64.63               |                            |                      | 64.63                | 0.99                        | 63.98                   | 234.59                    |
| Heavy Fuel oil                        | 349.13                  | 20.05                     | 6,998.50             | 7.00                |                            |                      | 7.00                 | 0.99                        | 6.93                    | 25.40                     |
| Light Fuel oil                        | 276.94                  | 19.64                     | 5,438.12             | 5.44                |                            |                      | 5.44                 | 0.99                        | 5.38                    | 19.74                     |
| Jet Kerosene                          | 644.92                  | 18.57                     | 11,977.88            | 11.98               |                            |                      | 11.98                | 0.99                        | 11.86                   | 43.48                     |
| Av Gas                                | 16.89                   | 17.73                     | 299.34               | 0.30                |                            |                      | 0.30                 | 0.99                        | 0.30                    | 1.09                      |
| LPG                                   | 1,277.73                | 16.47                     | 21,047.68            | 21.05               |                            |                      | 21.05                | 0.99                        | 20.84                   | 76.40                     |
| Coal                                  | 6,571.77                | 25.37                     | 166,713.96           | 166.71              |                            |                      | 166.71               | 0.98                        | 163.38                  | 599.06                    |
| Natural gas                           | 12,585.14               | 14.39                     | 181,118.62           | 181.12              |                            |                      | 181.12               | 1.00                        | 180.21                  | 660.78                    |
| Biogas (memo item) <sup>3</sup>       | 105.21                  | 27.54                     | 2,897.53             | 2.90                |                            |                      | 2.90                 | 1.00                        | 2.88                    | 10.57                     |
| <b>b Residential</b>                  | <b>9,996.03</b>         |                           | <b>158,337.12</b>    | <b>158.34</b>       |                            |                      | <b>158.34</b>        | <b>9.90</b>                 | <b>157.03</b>           | <b>575.78</b>             |
| <b>Total Liquid Fuels</b>             | <b>2,213.64</b>         |                           | <b>36,468.67</b>     | <b>36.47</b>        |                            |                      | <b>36.47</b>         | <b>7.92</b>                 | <b>36.10</b>            | <b>132.38</b>             |
| Petrol Regular                        | 1.45                    | 18.05                     | 26.27                | 0.03                |                            |                      | 0.03                 | 0.99                        | 0.03                    | 0.10                      |
| Petrol Premium                        | 0.00                    | 18.27                     | 0.00                 | 0.00                |                            |                      | 0.00                 | 0.99                        | 0.00                    | 0.00                      |
| Diesel                                | 0.37                    | 18.95                     | 6.97                 | 0.01                |                            |                      | 0.01                 | 0.99                        | 0.01                    | 0.03                      |
| Heavy Fuel oil                        | 0.00                    | 20.05                     | 0.00                 | 0.00                |                            |                      | 0.00                 | 0.99                        | 0.00                    | 0.00                      |
| Light Fuel oil                        | 0.00                    | 19.64                     | 0.00                 | 0.00                |                            |                      | 0.00                 | 0.99                        | 0.00                    | 0.00                      |
| Jet Kerosene                          | 0.14                    | 18.57                     | 2.59                 | 0.00                |                            |                      | 0.00                 | 0.99                        | 0.00                    | 0.01                      |
| Av Gas                                | 0.43                    | 17.73                     | 7.55                 | 0.01                |                            |                      | 0.01                 | 0.99                        | 0.01                    | 0.03                      |
| LPG                                   | 2,211.25                | 16.47                     | 36,425.30            | 36.43               |                            |                      | 36.43                | 0.99                        | 36.06                   | 132.22                    |
| Coal                                  | 858.95                  | 25.88                     | 22,229.84            | 22.23               |                            |                      | 22.23                | 0.98                        | 21.79                   | 79.88                     |
| Natural gas                           | 6,923.45                | 14.39                     | 99,638.61            | 99.64               |                            |                      | 99.64                | 1.00                        | 99.14                   | 363.51                    |
| Wood (memo item) <sup>3</sup>         | 2,538.71                | 28.41                     | 72,112.05            | 72.11               |                            |                      | 72.11                | 1.00                        | 72.11                   | 264.41                    |
| <b>c Agriculture/forestry/fishing</b> | <b>16,440.87</b>        |                           | <b>315,067.31</b>    | <b>315.07</b>       |                            |                      | <b>315.07</b>        | <b>7.91</b>                 | <b>311.78</b>           | <b>1,143.20</b>           |
| <b>Total Liquid Fuels</b>             | <b>15,908.14</b>        |                           | <b>301,595.27</b>    | <b>301.60</b>       |                            |                      | <b>301.60</b>        | <b>6.93</b>                 | <b>298.58</b>           | <b>1,094.79</b>           |
| Petrol Regular                        | 1,088.78                | 18.05                     | 19,657.36            | 19.66               |                            |                      | 19.66                | 0.99                        | 19.46                   | 71.36                     |
| Petrol Premium                        | 97.66                   | 18.27                     | 1,784.46             | 1.78                |                            |                      | 1.78                 | 0.99                        | 1.77                    | 6.48                      |
| Diesel                                | 12,691.68               | 18.95                     | 240,564.94           | 240.56              |                            |                      | 240.56               | 0.99                        | 238.16                  | 873.25                    |
| Heavy Fuel oil                        | 0.00                    | 20.05                     | 0.00                 | 0.00                |                            |                      | 0.00                 | 0.99                        | 0.00                    | 0.00                      |
| Light Fuel oil                        | 1,816.19                | 19.64                     | 35,663.39            | 35.66               |                            |                      | 35.66                | 0.99                        | 35.31                   | 129.46                    |
| Jet Kerosene                          | 158.97                  | 18.57                     | 2,952.47             | 2.95                |                            |                      | 2.95                 | 0.99                        | 2.92                    | 10.72                     |
| Av Gas                                | 54.87                   | 17.73                     | 972.66               | 0.97                |                            |                      | 0.97                 | 0.99                        | 0.96                    | 3.53                      |
| Coal                                  | 532.74                  | 25.29                     | 13,472.04            | 13.47               |                            |                      | 13.47                | 0.98                        | 13.20                   | 48.41                     |

Sheets 1-16 of worksheet 1-2 have been combined. Only New Zealand relevant source and sink categories have been included.

1 Energy containing carbon which is later stored is not included in the energy consumption reported here.

2 Does not include energy use for methanol production.

3 Data are included only as memo items and do not contribute to the data totals

4 Natural gas consumption data for methanol production is confidential.

Module **2004 Energy (New Zealand)**  
Submodule **CO2 from fuel combustion by source category (tier 1)**  
Worksheet **1.2 overview (totals)**

|  | Total<br>liquid<br>fossil<br>TJ | Total<br>solid<br>fossil | Total<br>gaseous<br>fossil <sup>1</sup> | Total<br>biomass<br>fuels <sup>2</sup> | Total<br>all<br>fuels |
|--|---------------------------------|--------------------------|---|--|-----------------------|
| <b>Total energy consumption</b>            | <b>251,044.90</b>               | <b>63,691.73</b>         | <b>118,186.27</b>                       | <b>36,466.08</b>                       | <b>432,922.89</b>     |
| Energy industries                          | 2,518.89                        | 41,126.00                | 60,789.86                               | 1,059.00                               | 104,434.76            |
| Manufacturing industries and construction  | 13,728.10                       | 14,602.28                | 37,701.81                               | 32,763.16                              | 66,032.19             |
| Transport                                  | 17,711.43                       |                          |   |  | 17,711.43             |
| Civil aviation                             |                                 |                          |   |  |                       |
| Road                                       | 185,450.56                      |                          | 186.00                                  | no                                     | 185,636.56            |
| Railways                                   | 2,457.00                        | ne                       |   |  | 2,457.00              |
| Navigation                                 | 4,607.74                        | ne                       |   |  | 4,607.74              |
| Other sectors                              | 6,449.40                        | 6,571.77                 | 12,585.14                               | 105.21                                 | 25,606.31             |
| Commercial/institutional                   | 2,213.64                        | 858.95                   | 6,923.45                                | 2,538.71                               | 9,996.03              |
| Residential                                | 15,908.14                       | 532.74                   | ne                                      | ne                                     | 16,440.87             |
| Ag/forest/fish                             | 10,244.31                       | ne                       |   |  | 10,244.31             |
| International marine bunkers (memo item)   | 38,040.98                       |                          |   |  | 38,040.98             |
| International aviation bunkers (memo item) |                                 |                          |   |  |                       |
| <b>Total CO2 emissions</b>                 | <b>16,856.03</b>                | <b>5,808.96</b>          | <b>7,041.09</b>                         | <b>3,795.95</b>                        | <b>29,706.08</b>      |
| Energy industries                          | 179.13                          | 3,745.89                 | 3,233.66                                | 109.75                                 | 7,158.68              |
| Manufacturing industries and construction  | 917.08                          | 1,335.72                 | 2,773.36                                | 3,411.23                               | 5,026.17              |
| Transport                                  | 1,192.23                        |                          |   |  | 1,192.23              |
| Civil aviation                             |                                 |                          |   |  |                       |
| Road                                       | 12,407.17                       |                          | 9.77                                    | no                                     | 12,416.93             |
| Railways                                   | 169.05                          | ne                       |   |  | 169.05                |
| Navigation                                 | 332.11                          | ne                       |   |  | 332.11                |
| Other sectors                              | 432.08                          | 599.06                   | 660.78                                  | 10.57                                  | 1,691.92              |
| Commercial/institutional                   | 132.38                          | 79.88                    | 363.51                                  | 264.41                                 | 575.78                |
| Residential                                | 1,094.79                        | 48.41                    | ne                                      | ne                                     | 1,143.20              |
| Ag/forest/fish                             |                                 |                          |   |  |                       |
| International marine bunkers (memo item)   | 738.92                          | ne                       |   |  | 738.92                |
| International aviation bunkers (memo item) | 2,564.68                        |                          |   |  | 2,564.68              |

1 The figures for "Manufacturing industries and construction" and total gaseous fuels do not include gas used for methanol production, which is confidential.

2 Emissions from biomass (wood and biogas) are included as memo items only and are not included in totals.

| Source and sink categories                                    | Energy consumption (TJ) | CH4                        | N2O                        | NOX                        | CO                        | NM VOC                       | CH4             | N2O             | NOX               | CO                | NM VOC            |
|---|-------------------------|----------------------------|----------------------------|----------------------------|---------------------------|------------------------------|-----------------|-----------------|-------------------|-------------------|-------------------|
|   |                         | Emission Factor (t CH4/TJ) | Emission Factor (t N2O/TJ) | Emission Factor (t NOX/TJ) | Emission Factor (t CO/TJ) | Emission Factor (t NMVOC/TJ) | Emissions t CH4 | Emissions t N2O | Emissions t NOX   | Emissions t CO    | Emissions t NMVOC |
| <b>Total energy (parts I and II of worksheet)<sup>1</sup></b> | <b>451,972.35</b>       |                            |                            |                            |                           |                              | <b>4,525.65</b> | <b>855.02</b>   | <b>155,558.63</b> | <b>601,846.88</b> | <b>115,624.63</b> |
| <b>1 Energy industries</b>                                    | <b>105,493.76</b>       |                            |                            |                            |                           |                              | <b>177.59</b>   | <b>70.89</b>    | <b>27,786.45</b>  | <b>1,935.95</b>   | <b>485.63</b>     |
| <b>a Public electricity and heat</b>                          | <b>86,228.41</b>        |                            |                            |                            |                           |                              | <b>149.35</b>   | <b>68.67</b>    | <b>23,610.23</b>  | <b>1,628.72</b>   | <b>398.32</b>     |
| <b>Total Liquid Fuels</b>                                     | <b>23.11</b>            |                            |                            |                            |                           |                              | <b>0.02</b>     | <b>0.01</b>     | <b>4.83</b>       | <b>0.35</b>       | <b>0.11</b>       |
| Distillate  | 23.11                   | 0.00086                    | 0.00038                    | 0.20900                    | 0.01520                   | 0.00475                      | 0.02            | 0.01            | 4.83              | 0.35              | 0.11              |
| Residual  | 0.00                    | 0.00086                    | 0.00029                    | 0.19000                    | 0.01425                   | 0.00475                      | 0.00            | 0.00            | 0.00              | 0.00              | 0.00              |
| Coal  | 41,126.00               | 0.00067                    | 0.00152                    | 0.36100                    | 0.00855                   | 0.00475                      | 27.35           | 62.51           | 14,846.49         | 351.63            | 195.35            |
| Natural Gas   | 44,020.31               | 0.00275                    | 0.00009                    | 0.19800                    | 0.02880                   | 0.00450                      | 120.84          | 3.96            | 8,716.02          | 1,267.78          | 198.09            |
| Bio Gas   | 1,059.00                | 0.00108                    | 0.00207                    | 0.04050                    | 0.00846                   | 0.00450                      | 1.14            | 2.19            | 42.89             | 8.96              | 4.77              |
| <b>b Petroleum refining</b>                                   | <b>13,522.42</b>        |                            |                            |                            |                           |                              | <b>21.01</b>    | <b>1.70</b>     | <b>2,884.06</b>   | <b>214.20</b>     | <b>61.47</b>      |
| Oil   | 2,495.79                | 0.00285                    | 0.00029                    | 0.16150                    | 0.01425                   | 0.00475                      | 7.11            | 0.71            | 403.07            | 35.56             | 11.85             |
| Gas   | 11,026.63               |                            |                            |                            |                           |                              | 13.89           | 0.99            | 2,480.99          | 178.63            | 49.62             |
| Natural Gas   | 78.22                   | 0.00126                    | 0.00009                    | 0.22500                    | 0.01620                   | 0.00450                      | 0.10            | 0.01            | 17.60             | 1.27              | 0.35              |
| Refinery Gas  | 10,948.41               | 0.00126                    | 0.00009                    | 0.22500                    | 0.01620                   | 0.00450                      | 13.79           | 0.99            | 2,463.39          | 177.36            | 49.27             |
| <b>c Solid fuels and other energy</b>                         | <b>5,742.92</b>         |                            |                            |                            |                           |                              | <b>7.24</b>     | <b>0.52</b>     | <b>1,292.16</b>   | <b>93.04</b>      | <b>25.84</b>      |
| Natural Gas in synthetic petrol prodn                         | 0.00                    | 0.00126                    | 0.00009                    | 0.22500                    | 0.01620                   | 0.00450                      | 0.00            | 0.00            | 0.00              | 0.00              | 0.00              |
| Natural Gas in oil and Gas extraction                         | 5,742.92                | 0.00126                    | 0.00009                    | 0.22500                    | 0.01620                   | 0.00450                      | 7.24            | 0.52            | 1,292.16          | 93.04             | 25.84             |
| <b>2 Manufacturing and construction<sup>1</sup></b>           | <b>81,378.72</b>        |                            |                            |                            |                           |                              | <b>656.36</b>   | <b>171.46</b>   | <b>27,162.61</b>  | <b>22,361.70</b>  | <b>2,417.39</b>   |
| <b>a Iron and Steel</b>                                       | <b>1,832.61</b>         |                            |                            |                            |                           |                              | <b>2.31</b>     | <b>0.16</b>     | <b>412.34</b>     | <b>29.69</b>      | <b>8.25</b>       |
| Natural Gas   | 1,832.61                | 0.00126                    | 0.00009                    | 0.22500                    | 0.01620                   | 0.00450                      | 2.31            | 0.16            | 412.34            | 29.69             | 8.25              |
| <b>c Chemicals (methanol production)<sup>2</sup></b>          | <b>conf</b>             |                            |                            |                            |                           |                              | <b>54.74</b>    | <b>3.91</b>     | <b>9,774.99</b>   | <b>703.80</b>     | <b>195.50</b>     |
| Natural Gas   | conf                    | conf                       | conf                       | conf                       | conf                      | conf                         | 54.74           | 3.91            | 9,774.99          | 703.80            | 195.50            |
| <b>f Other</b>  | <b>79,546.11</b>        |                            |                            |                            |                           |                              | <b>599.31</b>   | <b>167.38</b>   | <b>16,975.28</b>  | <b>21,628.22</b>  | <b>2,213.65</b>   |
| <b>Total Liquid Fuels</b>                                     | <b>13,728.10</b>        |                            |                            |                            |                           |                              | <b>7.85</b>     | <b>5.72</b>     | <b>1,037.46</b>   | <b>209.24</b>     | <b>65.21</b>      |
| Distillate  | 9,632.18                | 0.00019                    | 0.00038                    | 0.06175                    | 0.01520                   | 0.00475                      | 1.83            | 3.66            | 594.79            | 146.41            | 45.75             |
| Residual  | 962.06                  | 0.00285                    | 0.00029                    | 0.16150                    | 0.01425                   | 0.00475                      | 2.74            | 0.27            | 155.37            | 13.71             | 4.57              |
| LPG   | 3,133.86                | 0.00105                    | 0.00057                    | 0.09168                    | 0.01568                   | 0.00475                      | 3.27            | 1.79            | 287.30            | 49.12             | 14.89             |
| <b>Total Coal</b>   | <b>14,602.28</b>        |                            |                            |                            |                           |                              | <b>11.27</b>    | <b>21.15</b>    | <b>6,038.01</b>   | <b>489.89</b>     | <b>277.44</b>     |
| Lime and Cement   | 5,489.36                | 0.00095                    | 0.00133                    | 0.50065                    | 0.07505                   | 0.01900                      | 5.21            | 7.30            | 2,748.25          | 411.98            | 104.30            |
| Other   | 9,112.92                | 0.00067                    | 0.00152                    | 0.36100                    | 0.00855                   | 0.01900                      | 6.06            | 13.85           | 3,289.76          | 77.92             | 173.15            |
| <b>Total Natural Gas</b>                                      |                         |                            |                            |                            |                           |                              | <b>67.40</b>    | <b>3.23</b>     | <b>7,666.89</b>   | <b>769.46</b>     | <b>161.41</b>     |
| Autoproduction  | 14,951.09               | 0.00275                    | 0.00009                    | 0.19800                    | 0.02880                   | 0.00450                      | 41.04           | 1.35            | 2,960.32          | 430.59            | 67.28             |
| Other   | 20,918.11               | 0.00126                    | 0.00009                    | 0.22500                    | 0.01620                   | 0.00450                      | 26.36           | 1.88            | 4,706.57          | 338.87            | 94.13             |
| <b>Total Biomass</b>  | <b>36,264.65</b>        |                            |                            |                            |                           |                              | <b>512.79</b>   | <b>137.28</b>   | <b>2,232.92</b>   | <b>20,159.62</b>  | <b>1,709.58</b>   |
| Wood  | 35,962.65               | 0.01425                    | 0.00380                    | 0.06175                    | 0.56050                   | 0.04750                      | 512.47          | 136.66          | 2,220.69          | 20,157.06         | 1,708.23          |
| Biogas  | 302.00                  | 0.00108                    | 0.00207                    | 0.04050                    | 0.00846                   | 0.00450                      | 0.33            | 0.63            | 12.23             | 2.55              | 1.36              |

Module  
Submodule  
Worksheets

2004 Energy (New Zealand)  
Non-CO2 emissions from fuel combustion by source categories (tier 1)  
1.3 (part II)

| Source and sink categories                         | Energy consumption (TJ) | CH4                        | N2O                        | NOX                        | CO                        | NMVOG                        | CH4             | N2O             | NOX              | CO                | NMVOG             |
|--|-------------------------|----------------------------|----------------------------|----------------------------|---------------------------|------------------------------|-----------------|-----------------|------------------|-------------------|-------------------|
|  |                         | Emission Factor (t CH4/TJ) | Emission Factor (t N2O/TJ) | Emission Factor (t NOX/TJ) | Emission Factor (t CO/TJ) | Emission Factor (t NMVOG/TJ) | Emissions t CH4 | Emissions t N2O | Emissions t NOX  | Emissions t CO    | Emissions t NMVOG |
| <b>3 Transport</b>                                 | <b>210,412.73</b>       |                            |                            |                            |                           |                              | <b>2,547.15</b> | <b>481.89</b>   | <b>85,376.74</b> | <b>536,975.89</b> | <b>107,161.34</b> |
| <b>a Civil aviation</b>                            | <b>17,711.43</b>        |                            |                            |                            |                           |                              | <b>33.65</b>    | <b>33.65</b>    | <b>4,879.50</b>  | <b>2,019.10</b>   | <b>302.87</b>     |
| Jet Kerosene                                       | 17,105.42               | 0.00190                    | 0.00190                    | 0.27550                    | 0.11400                   | 0.01710                      | 32.50           | 32.50           | 4,712.54         | 1,950.02          | 292.50            |
| Av Gas   | 606.01                  | 0.00190                    | 0.00190                    | 0.27550                    | 0.11400                   | 0.01710                      | 1.15            | 1.15            | 166.96           | 69.08             | 10.36             |
| <b>b Road transport</b>                            | <b>185,636.56</b>       |                            |                            |                            |                           |                              | <b>2,473.52</b> | <b>430.38</b>   | <b>71,037.78</b> | <b>533,424.27</b> | <b>106,381.10</b> |
| Total Liquid Fuels                                 | 185,450.56              |                            |                            |                            |                           |                              | 2,368.06        | 430.37          | 70,974.17        | 533,303.74        | 106,366.03        |
| Petrol   | 110,957.75              | 0.01853                    | 0.00143                    | 0.21090                    | 4.59135                   | 0.88493                      | 2,055.49        | 158.11          | 23,400.99        | 509,445.86        | 98,189.29         |
| Diesel   | 73,298.87               | 0.00380                    | 0.00371                    | 0.64315                    | 0.30305                   | 0.10165                      | 278.54          | 271.57          | 47,142.17        | 22,213.22         | 7,450.83          |
| LPG  | 1,193.95                | 0.02850                    | 0.00057                    | 0.36100                    | 1.37750                   | 0.60800                      | 34.03           | 0.68            | 431.01           | 1,644.66          | 725.92            |
| CNG  | 186.00                  | 0.56700                    | 0.00009                    | 0.34200                    | 0.64800                   | 0.08100                      | 105.46          | 0.02            | 63.61            | 120.53            | 15.07             |
| <b>c Rail transport (diesel)</b>                   | <b>2,457.00</b>         | <b>0.00380</b>             | <b>0.00371</b>             | <b>0.64315</b>             | <b>0.30305</b>            | <b>0.10165</b>               | <b>9.34</b>     | <b>9.10</b>     | <b>1,580.22</b>  | <b>744.59</b>     | <b>249.75</b>     |
| <b>d National navigation (fuel oil and diesel)</b> | <b>4,607.74</b>         |                            |                            |                            |                           |                              | <b>30.64</b>    | <b>8.75</b>     | <b>7,879.23</b>  | <b>787.92</b>     | <b>227.62</b>     |
| Diesel   | 0.00                    | 0.00665                    | 0.00190                    | 1.71000                    | 0.17100                   | 0.04940                      | 0.00            | 0.00            | 0.00             | 0.00              | 0.00              |
| Fuel oil   | 4,607.74                | 0.00665                    | 0.00190                    | 1.71000                    | 0.17100                   | 0.04940                      | 30.64           | 8.75            | 7,879.23         | 787.92            | 227.62            |
| Aviation bunkers                                   | 38,040.96               | 0.00190                    | 0.00190                    | 0.27550                    | 0.11400                   | 0.01710                      | 72.28           | 72.28           | 10,480.28        | 4,336.67          | 650.50            |
| Marine bunkers                                     | 10,329.10               |                            |                            |                            |                           |                              | 68.69           | 19.63           | 17,662.76        | 1,766.28          | 510.26            |
| Diesel   | 1,529.29                | 0.00665                    | 0.00190                    | 1.71000                    | 0.17100                   | 0.04940                      | 10.17           | 2.91            | 2,615.09         | 261.51            | 75.55             |
| Fuel Oil   | 8,799.80                | 0.00665                    | 0.00190                    | 1.71000                    | 0.17100                   | 0.04940                      | 58.52           | 16.72           | 15,047.66        | 1,504.77          | 434.71            |
| <b>4 Other sectors</b>                             | <b>54,687.14</b>        |                            |                            |                            |                           |                              | <b>1,144.55</b> | <b>130.77</b>   | <b>15,232.84</b> | <b>40,573.33</b>  | <b>5,560.26</b>   |
| <b>a Commercial/institutional</b>                  | <b>25,711.52</b>        |                            |                            |                            |                           |                              | <b>81.77</b>    | <b>37.58</b>    | <b>2,545.72</b>  | <b>1,445.76</b>   | <b>1,336.38</b>   |
| Total Liquid Fuels                                 | 6,449.40                |                            |                            |                            |                           |                              | 5.63            | 2.57            | 533.39           | 89.77             | 30.63             |
| Distillate Fuel oil                                | 3,883.80                | 0.00067                    | 0.00038                    | 0.06175                    | 0.01520                   | 0.00475                      | 2.58            | 1.48            | 239.82           | 59.03             | 18.45             |
| Residual Fuel oil                                  | 1,287.88                | 0.00133                    | 0.00029                    | 0.16150                    | 0.01425                   | 0.00475                      | 1.71            | 0.37            | 207.99           | 18.35             | 6.12              |
| LPG  | 1,277.73                | 0.00105                    | 0.00057                    | 0.06698                    | 0.00969                   | 0.00475                      | 1.34            | 0.73            | 85.58            | 12.38             | 6.07              |
| Coal   | 6,571.77                | 0.00950                    | 0.00133                    | 0.22800                    | 0.19000                   | 0.19000                      | 62.43           | 8.74            | 1,498.36         | 1,248.64          | 1,248.64          |
| Natural Gas  | 12,585.14               | 0.00108                    | 0.00207                    | 0.04050                    | 0.00846                   | 0.00450                      | 13.59           | 26.05           | 509.70           | 106.47            | 56.63             |
| Biogas   | 105.21                  | 0.00108                    | 0.00207                    | 0.04050                    | 0.00846                   | 0.00450                      | 0.11            | 0.22            | 4.26             | 0.89              | 0.47              |
| <b>b Residential</b>                               | <b>12,534.74</b>        |                            |                            |                            |                           |                              | <b>976.88</b>   | <b>12.67</b>    | <b>803.97</b>    | <b>29,550.47</b>  | <b>1,651.93</b>   |
| Total Liquid Fuels                                 | 2,213.64                |                            |                            |                            |                           |                              | 2.31            | 1.26            | 98.94            | 21.04             | 10.51             |
| Distillate Fuel oil                                | 1.82                    | 0.00067                    | 0.00019                    | 0.06175                    | 0.01520                   | 0.00475                      | 0.00            | 0.00            | 0.11             | 0.03              | 0.01              |
| Residual Fuel oil                                  | 0.56                    | 0.00133                    | 0.00019                    | 0.16150                    | 0.01425                   | 0.00475                      | 0.00            | 0.00            | 0.09             | 0.01              | 0.00              |
| LPG  | 2,211.25                | 0.00105                    | 0.00057                    | 0.04465                    | 0.00950                   | 0.00475                      | 2.31            | 1.26            | 98.73            | 21.01             | 10.50             |
| Coal   | 858.95                  | 0.28500                    | 0.00133                    | 0.17100                    | 3.42000                   | 0.19000                      | 244.80          | 1.14            | 146.88           | 2,937.60          | 163.20            |
| Natural Gas  | 6,923.45                | 0.00090                    | 0.00009                    | 0.04230                    | 0.00900                   | 0.00450                      | 6.23            | 0.62            | 292.86           | 62.31             | 31.16             |
| Wood   | 2,538.71                | 0.28500                    | 0.00380                    | 0.10450                    | 10.45000                  | 0.57000                      | 723.53          | 9.65            | 265.30           | 26,529.52         | 1,447.06          |
| <b>c Agriculture/forestry/fishing</b>              | <b>16,440.87</b>        |                            |                            |                            |                           |                              | <b>85.90</b>    | <b>80.51</b>    | <b>11,883.16</b> | <b>9,577.10</b>   | <b>2,571.95</b>   |
| Total Liquid Fuels                                 | 15,908.14               |                            |                            |                            |                           |                              | 80.84           | 79.80           | 11,761.69        | 9,475.88          | 2,470.73          |
| Distillate Fuel oil - Stationary                   | 693.91                  | 0.00380                    | 0.02850                    | 1.14000                    | 0.35150                   | 0.16150                      | 2.64            | 19.78           | 791.05           | 243.91            | 112.07            |
| Residual Fuel oil - Stationary                     | 371.95                  | 0.00380                    | 0.02850                    | 1.14000                    | 0.35150                   | 0.16150                      | 1.41            | 10.60           | 424.02           | 130.74            | 60.07             |
| Petrol - Mobile                                    | 1,127.11                | 0.01853                    | 0.00143                    | 0.21090                    | 4.59135                   | 0.88493                      | 20.88           | 1.61            | 237.71           | 5,174.96          | 997.41            |
| Diesel - Mobile                                    | 12,067.09               | 0.00380                    | 0.00371                    | 0.64315                    | 0.30305                   | 0.10165                      | 45.82           | 44.67           | 7,754.52         | 3,653.90          | 1,225.60          |
| Fuel Oil - Mobile                                  | 1,462.24                | 0.00665                    | 0.00190                    | 1.71000                    | 0.17100                   | 0.04940                      | 9.72            | 2.78            | 2,500.44         | 250.04            | 72.23             |
| Aviation fuels - Mobile                            | 195.83                  | 0.00190                    | 0.00190                    | 0.27550                    | 0.11400                   | 0.01710                      | 0.37            | 0.37            | 53.95            | 22.32             | 3.35              |
| Coal   | 532.74                  | 0.00950                    | 0.00133                    | 0.22800                    | 0.19000                   | 0.19000                      | 5.06            | 0.71            | 121.46           | 101.22            | 101.22            |

Only New Zealand relevant source and sink categories have been included.  
1 Does not include energy use for methanol production.  
2 Natural gas consumption data for methanol production is confidential.

**Module** 2004 Energy (New Zealand)  
**Submodule** Fugitive emissions from geothermal activities (tier 1)  
**Worksheet** NZ 1.6 (additional)

| Category                  | Fuel quantity (TJ) | CO2 emis fact (kg/GJ) | CH4 emis fact (kg/GJ) | CO2 emissions (Gg) | CH4 emissions (Gg) |
|---------------------------|--------------------|-----------------------|-----------------------|--------------------|--------------------|
| Elec. generation and heat | 70,312.00          | 3.98                  | 0.03                  | 279.67             | 2.42               |

**Module** 2004 Energy (New Zealand)  
**Submodule** Fugitive emissions from coal mining and handling (tier 1)  
**Worksheet** 1.4 (adapted)

| Category          | Coal production (Mt) | CH4 emis fact (Gg/Mt) | CH4 emissions (Gg) |
|-------------------|----------------------|-----------------------|--------------------|
| <b>Total</b>      |                      | <b>5.16</b>           | <b>14.85</b>       |
| Underground mines | Mining               | 0.73                  | 9.98               |
|                   | Bituminous           | 0.26                  | 16.75              |
|                   | Sub-bituminous       | 0.47                  | 12.10              |
|                   | Post-mining          |                       | 1.60               |
| Surface mines     | Mining               | 4.43                  | 0.77               |
|                   | Post-mining          |                       | 0.07               |

**Module** 2004 Energy (New Zealand)  
**Submodule** Fugitive emissions from oil  
**Worksheet** 1.5 (adapted)

| Category                                   | Fuel quantity (TJ)           |
|--|------------------------------|
| <b>Total</b>                               |                              |
| Oil  | Exploration                  |
|  | Production of crude oil      |
|  | Transport of crude oil       |
|  | Refining/storage             |
|  | Distribution of oil products |
| Gas  | Production/processing        |
|  | Transmission / Distribution  |
|  | Other leakage                |
| Venting and flaring from oil and gas prod. |                              |

**Module** 2004 Energy (New Zealand)  
**Submodule** Ozone precursors and SO2 from oil refining  
**Worksheet** 1.8-1 (additional)  
**Sheet** NMVOC emissions from oil refining (tier 1)

| Crude oil<br>Throughput<br>(m3) | Emission<br>factor<br>(kg/m3) | Emissions<br>(t) | Emissions<br>(Gg) |
|---------------------------------|-------------------------------|------------------|-------------------|
| 5,487,717.95                    | 0.53                          | 2,908.49         | 2.91              |

**Module** 2004 Energy (New Zealand)  
**Submodule** Ozone precursors and SO2 from oil refining  
**Worksheet** 1.8-2  
**Sheet** SO2 from sulphur recovery plants (tier 2)

| Quantity<br>of sulphur<br>recovered (t) | Emission<br>factor<br>(kg/t) | Emissions<br>(kg) | Emissions<br>(Gg) |
|---|------------------------------|-------------------|-------------------|
| 21,423.00                               | 139.00                       | 2,977,797.00      | 2.98              |

**Module** 2004 Energy (New Zealand)  
**Submodule** Ozone precursors and SO2 from oil refining  
**Worksheet** 1.8-3  
**Sheet** NMVOC emissions from storage and handling (tier 2)

| Storage type                  | Crude oil<br>throughput<br>(kt) | Emission<br>factor<br>(kg/t) | Emissions<br>(t) | Emissions<br>(Gg) |
|-------------------------------|---------------------------------|------------------------------|------------------|-------------------|
| Floating roof (primary seals) | 4,704.05                        | 0.70                         | 3,292.84         | 3.29              |

## A8.2 Worksheets for the industrial processes sector

Module           2004 Industrial Processes (New Zealand)  
 Worksheet       NZ 2a  
 Sheet            CO2 emissions

| Source category                   | Production<br>Quantity<br>(t) | CO2<br>emissions<br>(Gg) | CO2<br>emis factor<br>(t/t) |
|-----------------------------------|-------------------------------|--------------------------|-----------------------------|
| <b>Total industrial processes</b> |                               | <b>3,444.36</b>          |                             |
| Cement <sup>1</sup>               | 1,216,191.00                  | 484.77                   | 0.40                        |
| Lime <sup>1</sup>                 | 167,407.34                    | 122.08                   | 0.73                        |
| Hydrogen <sup>1</sup>             | 27,185.07                     | 175.43                   | 6.45                        |
| Urea <sup>1</sup>                 | 262,274.00                    | 378.27                   | 1.44                        |
| Iron and steel <sup>1</sup>       | 890,352.00                    | 1,731.51                 | 1.94                        |
| Aluminium <sup>1</sup>            | 350,299.00                    | 552.29                   | 1.58                        |

1 Production and emissions data provided by industry and reported in Ministry of Economic Development (2005)

Module  
Worksheet  
Sheet

2004 Industrial process (New Zealand)  
NZ 2b  
Non-CO<sub>2</sub> emissions

| Source Categories                                    | ACTIVITY DATA                       |                         | Emission Estimates |        |        |        |   | Aggregate Emission Factor |         |        |          |         |          |
|--|-------------------------------------|-------------------------|--------------------|--------|--------|--------|---|---------------------------|---------|--------|----------|---------|----------|
|  | A<br>Production<br>Quantity<br>(kt) | B                       |                    |        |        |        | C                                       |                           |         |        |          |         |          |
|  |                                     | Full Mass of Pollutants |                    |        |        |        | Tonne of pollutant per tonne of product |                           |         |        |          |         |          |
|  |                                     | (Gg) Tonnes x 1000      |                    |        |        |        | (t/t)                                   |                           |         |        |          |         |          |
|  |                                     | CO                      | CH4                | N2O    | NOx    | NMVOc  | SO2                                     | CO                        | CH4     | N2O    | NOx      | NMVOc   | SO2      |
| <b>A Iron and Steel</b>                              |                                     |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| Steel  | C                                   | 0.9779                  |                    |        | 0.9615 |        |   | C                         |         |        | C        |         | C        |
| <b>B Non-Ferrous Metals</b>                          |                                     |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| NZ Aluminium Smelters                                | 347.0                               | 38.2                    |                    |        | 0.7    |        | 6.9                                     | 0.11000                   |         |        | 0.00215  |         | 0.02000  |
| <b>C Inorganic Chemicals (excepting solvent use)</b> |                                     |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| Sulphuric Acid (Ballance and Ravensdown)             | 500.7                               |                         |                    |        |        |        | 1.74                                    |                           |         |        |          |         | 0.00348  |
| Superphosphate (Ballance and Ravensdown)             | 1584.3                              |                         |                    |        |        |        | 0.81                                    |                           |         |        |          |         | 0.00084  |
| Urea (Ballance)                                      | 263.0                               |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| Ammonia (Ballance)                                   | 151.2                               |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| <b>D Organic Chemicals</b>                           |                                     |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| Formaldehyde (Orica Adhesives and Dynea)             | 56.61                               | 0.0000                  | 0.0000             |        |        | 0.0849 |   | 0.00000                   | 0.00000 |        |          | 0.00150 |          |
| Methanol (Methanex)                                  | 1087.8                              | 0.1088                  | 2.1756             |        | 0.9790 | 5.4390 |   | 0.00010                   | 0.00200 |        | 0.00090  | 0.00500 |          |
| <b>E Non-Metallic Mineral Products</b>               |                                     |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| Cement   | 985.6                               |                         | 0.0000             |        | 0.0000 |        | 0.6415                                  | 0.0000                    |         |        | 0.0000   |         | 0.00065  |
| Lime   | 165.3                               |                         |                    |        |        |        | 0.0797                                  |                           |         |        |          |         | 0.00048  |
| Asphalt Roofing                                      | 0.3                                 | 0.0000                  |                    |        |        | 0.0007 |   | 0.000010                  |         |        |          | 0.00240 |          |
| Road Paving  | 156.6                               | 0.0055                  |                    |        | 0.0132 | 2.8188 | 0.0188                                  | 0.000035                  |         |        | 0.000084 | 0.01800 | 0.000120 |
| Glass  | C                                   |                         |                    |        |        | 0.6313 | 0.1705                                  |                           |         |        |          | C       | C        |
| <b>F Other (ISIC)</b>                                |                                     |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| Paper and Pulp (chemical processes)                  | 724.0                               | 0.0000                  |                    |        | 0.0000 | 0.3982 | 0.0746                                  | 0.00000                   |         |        | 0.00000  | 0.00055 | 0.00010  |
| Paper and Pulp (mechanical processes)                | 844.8                               |                         |                    |        |        | 0.4647 |   |                           |         |        |          | 0.00055 |          |
| Panel Products (particleboard)                       | 175.5                               |                         |                    |        |        | 0.1492 |   |                           |         |        |          | 0.00085 |          |
| Panel Products (fibreboard)                          | 640.5                               |                         |                    |        |        | 1.3451 |   |                           |         |        |          | 0.00210 |          |
| Nitrous oxide use                                    | 0.16                                |                         |                    | 0.1560 |        |        |   |                           |         | 1.0000 |          |         |          |
| <b>Food and drink production</b>                     |                                     |                         |                    |        |        |        |   |                           |         |        |          |         |          |
| Wine (million litres)                                | 110.5                               |                         |                    |        |        | 0.0884 |   |                           |         |        |          | 0.00083 |          |
| Beer (million litres)                                | 312.9                               |                         |                    |        |        | 0.1095 |   |                           |         |        |          | 0.00035 |          |
| Spirits (million litres)                             | 8.3                                 |                         |                    |        |        | 0.0167 |   |                           |         |        |          | 0.00215 |          |
| Meat   | 1269.0                              |                         |                    |        |        | 0.3807 |   |                           |         |        |          | 0.00030 |          |
| Fish   | 334.8                               |                         |                    |        |        | 0.1004 |   |                           |         |        |          | 0.00030 |          |
| Poultry  | 147.3                               |                         |                    |        |        | 0.0442 |   |                           |         |        |          | 0.00030 |          |
| Sugar  | 227.8                               |                         |                    |        |        | 2.2779 |   |                           |         |        |          | 0.01000 |          |
| Margarine and solid cooking fats                     | 66.4                                |                         |                    |        |        | 0.3986 |   |                           |         |        |          | 0.00600 |          |
| Cakes, biscuits and breakfast cereals                | 76.1                                |                         |                    |        |        | 0.0761 |   |                           |         |        |          | 0.00100 |          |
| Bread  | 241.8                               |                         |                    |        |        | 1.9344 |   |                           |         |        |          | 0.00800 |          |
| Animal feed  | 848.5                               |                         |                    |        |        | 0.8485 |   |                           |         |        |          | 0.00100 |          |
| Coffee roasting                                      | 6.2                                 |                         |                    |        |        | 0.0034 |   |                           |         |        |          | 0.00055 |          |
|  | 3649.68                             |                         |                    |        |        | 6.2788 |   |                           |         |        |          |         |          |

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
Worksheet Supplementary 2.F. Aerosol 1 of 2  
Sheet HFCs from aerosols (based on equation 3.3)

| Year | Quantity HFC-134a contained in aerosol products sold in year t (tonnes) | Emission factor | Quantity HFC-134a contained in aerosol products sold in year t-1 (tonnes) | Emission of HFC-134a (tonnes) |
|------|---|-----------------|---|-------------------------------|
| 1992 | 0.0   | 0.5             | 0.0   | 0.0                           |
| 1993 | 0.0   | 0.5             | 0.0   | 0.0                           |
| 1994 | 0.0   | 0.5             | 0.0   | 0.0                           |
| 1995 | 0.0   | 0.5             | 0.0   | 0.0                           |
| 1996 | 2.5   | 0.5             | 0.0   | 1.3                           |
| 1997 | 5.9   | 0.5             | 2.5   | 4.2                           |
| 1998 | 9.1   | 0.5             | 5.9   | 7.5                           |
| 1999 | 12.1  | 0.5             | 9.1   | 10.6                          |
| 2000 | 16.1  | 0.5             | 12.1  | 14.1                          |
| 2001 | 16.9  | 0.5             | 16.1  | 16.5                          |
| 2002 | 17.1  | 0.5             | 16.9  | 17.0                          |
| 2003 | 17.1  | 0.5             | 17.1  | 17.1                          |
| 2004 | 17.3  | 0.5             | 17.1  | 17.2                          |

- IPCC (2001) Equation 3.35
- Only HFC used in aerosols is HFC-134a

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
Worksheet Supplementary 2.F. Aerosols 2 of 2  
Sheet Imports and domestic production of aerosols

| Year of import | Aerosol imports |                           | Domestic Aerosol exports |                           | Total HFC contained in products in NZ (tonnes) |
|----------------|-----------------|---------------------------|--------------------------|---------------------------|--|
|                | Number of Units | HFC <sup>a</sup> (tonnes) | loading HFC (tonnes)     | HFC <sup>b</sup> (tonnes) |  |
| 1992           | 3,300,000       | 0.0                       | 0.0                      | 0.0                       | 0.0  |
| 1993           | 4,000,000       | 0.0                       | 0.0                      | 0.0                       | 0.0  |
| 1994           | 5,400,000       | 0.0                       | 0.0                      | 0.0                       | 0.0  |
| 1995           | 8,700,000       | 0.0                       | 0.0                      | 0.0                       | 0.0  |
| 1996           | 13,100,000      | 2.2                       | 3.0                      | 2.7                       | 2.5  |
| 1997           | 16,800,000      | 5.6                       | 3.0                      | 2.7                       | 5.9  |
| 1998           | 17,400,000      | 8.8                       | 3.0                      | 2.7                       | 9.1  |
| 1999           | 17,500,000      | 11.8                      | 3.0                      | 2.7                       | 12.1   |
| 2000           | 18,848,536      | 15.8                      | 3.0                      | 2.7                       | 16.1   |
| 2001           | 19,773,731      | 16.6                      | 3.0                      | 2.7                       | 16.9   |
| 2002           | 20,000,000      | 16.8                      | 3.0                      | 2.7                       | 17.1   |
| 2003           | 20,000,000      | 16.8                      | 3.0                      | 2.7                       | 17.1   |
| 2004           | 20,000,000      | 16.8                      | 4.5                      | 4.1                       | 17.3   |

- Assumes average propellant charge = 84 grams, and 0.5% of all imported aerosols contain HFCs from 2000 with a gradual phase-in from 1996-2000.
- Based on the statement that 90% of this product is exported.

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
Worksheet Supplementary 2.F. MDIs 1 of 1  
Sheet HFCs from metered dose inhalers

| Year | Estimated no. of doses (millions) | Proportion of HFC-134a doses | Emission of HFC-134a (tonnes) |
|------|-----------------------------------|------------------------------|-------------------------------|
| 1995 | 500.0                             | 1%                           | 0.4                           |
| 1996 | 500.0                             | 5%                           | 1.9                           |
| 1997 | 500.0                             | 5%                           | 1.9                           |
| 1998 | 500.0                             | 5%                           | 1.9                           |
| 1999 | 497.2                             | 8%                           | 2.8                           |
| 2000 | 477.4                             | 9%                           | 3.3                           |
| 2001 | 485.2                             | 39%                          | 14.0                          |
| 2002 | 486.3                             | 68%                          | 25.0                          |
| 2003 | 474.8                             | 73%                          | 26.1                          |
| 2004 | 469.4                             | 76%                          | 26.7                          |

- HFC-134a not used in MDIs before 1995
- Only HFC used in MDIs is HFC-134a; average 0.075 gram per dose

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
Worksheet Supplementary 2.F. Fire protection 1 of 1  
Sheet Annual emissions from the fire protection industry

| Year | Total HFC-227a installed |                   | Emission rate | Emissions of HFC-227a (tonnes) |
|------|--------------------------|-------------------|---------------|--------------------------------|
|      | Streaming (tonnes)       | Portable (tonnes) |               |                                |
| 1994 | 1.6                      | 0                 | 0.015         | 0.02                           |
| 1995 | 3.2                      | 0                 | 0.015         | 0.05                           |
| 1996 | 4.8                      | 0                 | 0.015         | 0.07                           |
| 1997 | 6.4                      | 0                 | 0.015         | 0.10                           |
| 1998 | 8.0                      | 0                 | 0.015         | 0.12                           |
| 1999 | 10.2                     | 0                 | 0.015         | 0.15                           |
| 2000 | 11.4                     | 0                 | 0.015         | 0.17                           |
| 2001 | 12.6                     | 0                 | 0.015         | 0.19                           |
| 2002 | 17.0                     | 0                 | 0.015         | 0.26                           |
| 2003 | 19.4                     | 0                 | 0.015         | 0.29                           |
| 2004 | 21.2                     | 0                 | 0.015         | 0.32                           |

- No evidence for use of HFC-227a in fire protection industry before 1994

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
Worksheet Supplementary 2.F. Foam blowing 1 of 1  
Sheet Annual emissions from the foam blowing industry

| Year | HFC usage <sup>a</sup> (tonnes) | Emission rate first year | Emission rate later years | Emissions of HFC (tonnes) |
|------|---------------------------------|--------------------------|---------------------------|---------------------------|
|      |                                 |                          |                           |                           |
| 2001 | 0.5                             | 0.100                    | 0.045                     | 0.07                      |
| 2002 | 0.5                             | 0.100                    | 0.045                     | 0.10                      |
| 2003 | 0.5                             | 0.100                    | 0.045                     | 0.12                      |
| 2004 | 1.5                             | 0.100                    | 0.045                     | 0.24                      |

- Assumed no use of HFC in foam blowing industry before 2000
- HFC-134a from 2000-2003 and HFC-245fa/365mfc from 2004-2005.

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
 Worksheet Supplementary 2.F. RAC 1 of 4  
 Sheet Stationary Refrigeration and Air Conditioning - annual sales of refrigerant (input to Box 3.4 equation)

| Year | Domestically manufactured chemical (tonnes) | Imported bulk chemical (tonnes) | Exported bulk chemical (tonnes) | Chemical in imported equipment (tonnes) | Chemical in exported equipment (tonnes) | Annual sales (tonnes) |
|------|---|---------------------------------|---------------------------------|---|---|-----------------------|
| 1990 | 0   | 0.0                             | 0                               | 0                                       | 0.0                                     | 0.0                   |
| 1991 | 0   | 0.0                             | 0                               | 0                                       | 0.0                                     | 0.0                   |
| 1992 | 0   | 2.0                             | 0                               | 0.1                                     | 0.8                                     | 1.3                   |
| 1993 | 0   | 6.0                             | 0                               | 0.2                                     | 3.0                                     | 3.2                   |
| 1994 | 0   | 51.2                            | 0                               | 2.3                                     | 7.2                                     | 46.3                  |
| 1995 | 0   | 111.2                           | 0                               | 7.8                                     | 18.6                                    | 100.4                 |
| 1996 | 0   | 159.8                           | 0                               | 9.3                                     | 19.8                                    | 149.3                 |
| 1997 | 0   | 61.4                            | 0                               | 10.3                                    | 20.5                                    | 51.2                  |
| 1998 | 0   | 197.5                           | 0                               | 9.4                                     | 21.2                                    | 185.6                 |
| 1999 | 0   | 145.5                           | 0                               | 12.5                                    | 22.4                                    | 135.6                 |
| 2000 | 0   | 124.1                           | 0                               | 11.1                                    | 24.3                                    | 110.9                 |
| 2001 | 0   | 186.9                           | 0                               | 12.1                                    | 25.5                                    | 173.4                 |
| 2002 | 0   | 231.7                           | 0                               | 14.4                                    | 25.6                                    | 220.5                 |
| 2003 | 0   | 298.0                           | 0                               | 20.7                                    | 27.5                                    | 291.1                 |
| 2004 | 0   | 222.3                           | 0                               | 35.7                                    | 30.8                                    | 227.2                 |

1. IPCC (2001) Box 3.4 equation

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
 Worksheet Supplementary 2.F. RAC 2 of 4  
 Sheet Stationary Refrigeration and Air Conditioning - total charge of new equipment (input to Box 3.4 equation)

| Year | Chemical to charge domestically manufactured + imported equipment (tonnes) 2 | Chemical contained in factory charged imported equipment (tonnes) | Chemical contained in factory charged exported eqmmt (tonnes) | Total charge of new equipment (tonnes) |
|------|--|---|---|--|
| 1990 | 0.0  | 0.0   | 0.0   | 0.0                                    |
| 1991 | 0.0  | 0.0   | 0.0   | 0.0                                    |
| 1992 | 1.2  | 0.1   | 0.8   | 0.5                                    |
| 1993 | 2.4  | 0.2   | 3.0   | -0.4                                   |
| 1994 | 8.6  | 2.3   | 7.2   | 3.7                                    |
| 1995 | 20.0   | 7.8   | 18.6  | 9.2                                    |
| 1996 | 25.0   | 9.3   | 19.8  | 14.5                                   |
| 1997 | 30.0   | 10.3  | 20.5  | 19.8                                   |
| 1998 | 28.1   | 9.4   | 21.2  | 16.2                                   |
| 1999 | 37.0   | 12.5  | 22.4  | 27.1                                   |
| 2000 | 31.3   | 11.1  | 24.3  | 18.1                                   |
| 2001 | 28.7   | 12.1  | 25.5  | 15.2                                   |
| 2002 | 28.0   | 14.4  | 25.6  | 16.8                                   |
| 2003 | 36.5   | 20.7  | 27.5  | 29.7                                   |
| 2004 | 45.4   | 35.7  | 30.8  | 50.2                                   |

1. IPCC (2001) Box 3.4 equation

2. Can not distinguish chemical to charge domestically manufactured and imported non-factory charged equipment.

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
 Worksheet Supplementary 2.F. RAC 3 of 4  
 Sheet All HFC and PFC emissions from stationary refrigeration

| Year | Annual sales of new refrigerant (tonnes) | Total charge of new equipment (tonnes) | Emissions from retiring NZ eqpt. (tonnes) | Amount of intentional destruction (tonnes) | Emissions* (tonnes) |
|------|--|--|---|--|---------------------|
| 1990 | 0.0                                      | 0.0                                    | 0.0                                       | 0  | 0.0                 |
| 1991 | 0.0                                      | 0.0                                    | 0.0                                       | 0  | 0.0                 |
| 1992 | 1.3                                      | 0.5                                    | 0.0                                       | 0  | 0.8                 |
| 1993 | 3.2                                      | -0.4                                   | 0.0                                       | 0  | 3.6                 |
| 1994 | 46.3                                     | 3.7                                    | 0.0                                       | 0  | 42.6                |
| 1995 | 100.4                                    | 9.2                                    | 0.0                                       | 0  | 91.2                |
| 1996 | 149.3                                    | 14.5                                   | 0.0                                       | 0  | 134.8               |
| 1997 | 51.2                                     | 19.8                                   | 0.0                                       | 0  | 31.4                |
| 1998 | 185.6                                    | 16.2                                   | 0.0                                       | 0  | 169.4               |
| 1999 | 135.6                                    | 27.1                                   | 0.0                                       | 0  | 108.5               |
| 2000 | 110.9                                    | 18.1                                   | 0.0                                       | 0.1  | 92.6                |
| 2001 | 173.4                                    | 15.2                                   | 0.0                                       | 0.3  | 157.9               |
| 2002 | 220.5                                    | 16.8                                   | 0.1                                       | 0.4  | 203.4               |
| 2003 | 291.1                                    | 29.7                                   | 0.3                                       | 0.7  | 261.0               |
| 2004 | 227.2                                    | 50.2                                   | 1.1                                       | 1.1  | 177.0               |

1. IPCC (2001) equation 3.40

2. The methodology produces a negative number for 1992, thus 0 has been entered for this year.

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
 Worksheet Supplementary 2.F. MAC 1 of 4  
 Sheet Mobile air conditioning Equation 3.45 <sup>1</sup>(input to equation 3.44 <sup>1</sup>)

| Year <sup>2</sup> | Total virgin HFC-134a <sup>3</sup><br>in first-fill MAC<br>systems<br><br>(tonnes) | Emission<br>factor | First-fill emissions<br>HFC-134a<br><br>(tonnes) |
|-------------------|--|--------------------|--|
| 1994              | 2.9  | 0.005              | 0.015  |
| 1995              | 10.8   | 0.005              | 0.054  |
| 1996              | 15.8   | 0.005              | 0.079  |
| 1997              | 11.0   | 0.005              | 0.055  |
| 1998              | 8.2  | 0.005              | 0.041  |
| 1999              | 6.9  | 0.005              | 0.035  |
| 2000              | 5.5  | 0.005              | 0.028  |
| 2001              | 4.6  | 0.005              | 0.023  |
| 2002              | 2.9  | 0.005              | 0.014  |
| 2003              | 3.3  | 0.005              | 0.017  |
| 2004              | 1.9  | 0.005              | 0.009  |

1. IPCC (2001) Equations 3.44 and 3.45
2. No use recorded before 1994
3. HFC-134a the only HFC used in MAC

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
 Worksheet Supplementary 2.F. MAC 2 of 4  
 Sheet Mobile air conditioning Equation 3.46 <sup>1</sup>(input to equation 3.44 <sup>1</sup>)

| Year <sup>2</sup> | Total virgin<br>HFC-134a <sup>3</sup><br><br>(tonnes) | HFC in first-fill MAC systems |                    |                       |                                | Total<br>(tonnes) | Operation<br>emissions<br>HFC-134a<br><br>(tonnes) |
|-------------------|---|-------------------------------|--------------------|-----------------------|--------------------------------|-------------------|--|
|                   |   | Buses<br>(tonnes)             | Trucks<br>(tonnes) | Cars/vans<br>(tonnes) | Cars/vans<br>(new)<br>(tonnes) |                   |  |
| 1994              | 5.0   | 0.2                           | 1.0                | 1.7                   | 0.0                            | 2.9               | 2.1  |
| 1995              | 15.0  | 0.2                           | 3.3                | 6.9                   | 0.3                            | 10.8              | 4.2  |
| 1996              | 30.0  | 0.3                           | 3.3                | 10.2                  | 2.0                            | 15.8              | 14.2   |
| 1997              | 40.0  | 0.3                           | 2.8                | 6.5                   | 1.4                            | 11.0              | 29.0   |
| 1998              | 50.0  | 0.2                           | 2.3                | 5.0                   | 0.8                            | 8.2               | 41.8   |
| 1999              | 52.0  | 0.3                           | 2.5                | 3.9                   | 0.2                            | 6.9               | 45.1   |
| 2000              | 54.0  | 0.3                           | 2.6                | 2.4                   | 0.2                            | 5.5               | 48.5   |
| 2001              | 56.0  | 0.3                           | 2.7                | 1.3                   | 0.3                            | 4.6               | 51.4   |
| 2002              | 58.0  | 0.4                           | 1.9                | 0.4                   | 0.2                            | 2.9               | 55.1   |
| 2003              | 60.0  | 0.4                           | 1.9                | 0.4                   | 0.6                            | 3.3               | 56.7   |
| 2004              | 62.0  | 0.3                           | 1.1                | 0.4                   | 0.1                            | 1.9               | 60.1   |

1. IPCC (2001) Equations 3.44 and 3.45
2. No use recorded before 1994
3. This model of MAC refrigerant use approximately follows the highly variable quantities provided by suppliers.

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
 Worksheet Supplementary 2.F. MAC 3 of 4 (IPCC (2001) equation 3.47)  
 Sheet HFC-134a emissions from mobile air conditioning (equation 3.44) <sup>1</sup>

| Year | Annual scrap<br>rate of vehicles<br>with MAC using<br>HFC-134a | Number of<br>vehicles<br>with MAC<br>using<br>HFC-134a | Average<br>HFC-134a<br>charge per<br>vehicle<br>(kg) | Destruction<br><br>(tonnes) | Disposal<br>emissions<br><br>(tonnes) |
|------|--|--|--|-----------------------------|---------------------------------------|
| 1994 | 0.000  | 90,780   | 0.86   | 0                           | 0.04                                  |
| 1995 | 0.012  | 200,564  | 0.81   | 0                           | 1.98                                  |
| 1996 | 0.017  | 318,586  | 0.80   | 0                           | 4.38                                  |
| 1997 | 0.032  | 446,168  | 0.81   | 0                           | 11.40                                 |
| 1998 | 0.022  | 580,065  | 0.79   | 0                           | 9.98                                  |
| 1999 | 0.017  | 755,133  | 0.78   | 0                           | 9.77                                  |
| 2000 | 0.020  | 925,705  | 0.77   | 0                           | 14.00                                 |
| 2001 | 0.023  | 1,101,395  | 0.77   | 0                           | 19.34                                 |
| 2002 | 0.024  | 1,290,412  | 0.77   | 0                           | 23.76                                 |
| 2003 | 0.022  | 1,506,253  | 0.76   | 0                           | 25.14                                 |
| 2004 | 0.024  | 1,722,148  | 0.76   | 0                           | 30.94                                 |

1. IPCC (2001) Equations 3.44 and 3.47

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
 Worksheet Supplementary 2.F. MAC 4 of 4  
 Sheet HFC-134a emissions from mobile air conditioning (equation 3.44) <sup>1</sup>

| Year <sup>2</sup> | First-fill<br>emissions<br><br>(tonnes) | Operation<br>emissions<br><br>(tonnes) | Disposal<br>emissions <sup>3</sup><br><br>(tonnes) | Intentional<br>destruction<br><br>(tonnes) | Annual<br>emissions<br>of HFC-134a<br><br>(tonnes) |
|-------------------|---|--|--|--|--|
| 1994              | 0.015                                   | 2.1                                    | 0.04   | 0  | 2.1  |
| 1995              | 0.054                                   | 4.2                                    | 1.98   | 0  | 6.3  |
| 1996              | 0.079                                   | 14.2                                   | 4.38   | 0  | 18.7   |
| 1997              | 0.055                                   | 29.0                                   | 11.40  | 0  | 40.5   |
| 1998              | 0.041                                   | 41.8                                   | 9.98   | 0  | 51.8   |
| 1999              | 0.035                                   | 45.1                                   | 9.77   | 0  | 54.9   |
| 2000              | 0.028                                   | 48.5                                   | 14.00  | 0  | 62.5   |
| 2001              | 0.023                                   | 51.4                                   | 19.34  | 0  | 70.8   |
| 2002              | 0.014                                   | 55.1                                   | 23.76  | 0  | 78.9   |
| 2003              | 0.017                                   | 56.7                                   | 25.14  | 0  | 81.8   |
| 2004              | 0.009                                   | 60.1                                   | 30.94  | 0  | 91.1   |

1. IPCC (2001) Equation 3.44
2. No use recorded before 1994
3. Calculated using IPCC (2001) equation 3.47

Module 1990 - 2004 Consumption of halocarbons (New Zealand)  
Worksheet Supplementary 2.F. RAC 4 of 4  
Sheet All HFC and PFC emissions from stationary refrigeration<sup>1</sup>

| Year | Bulk emissions (tonnes) | HFC-32 (tonnes) | HFC-125 (tonnes) | HFC-134a <sup>2</sup> (tonnes) | HFC-143a (tonnes) | HFC-152a (tonnes) | PFC-218 (tonnes) |
|------|-------------------------|-----------------|------------------|--------------------------------|-------------------|-------------------|------------------|
| 1990 | 0.0                     | 0.0             | 0.0              | 0.0                            | 0.0               | 0.0               | 0.0              |
| 1991 | 0.0                     | 0.0             | 0.0              | 0.0                            | 0.0               | 0.0               | 0.0              |
| 1992 | 0.8                     | 0.0             | 0.0              | 0.8                            | 0.0               | 0.0               | 0.0              |
| 1993 | 3.6                     | 0.0             | 0.0              | 3.6                            | 0.0               | 0.0               | 0.0              |
| 1994 | 42.6                    | 0.0             | 1.2              | 40.7                           | 0.4               | 0.4               | 0.0              |
| 1995 | 91.2                    | 0.4             | 0.5              | 80.5                           | 7.9               | 1.2               | 0.8              |
| 1996 | 134.8                   | 0.0             | 6.7              | 115.8                          | 7.1               | 0.4               | 4.8              |
| 1997 | 31.4                    | 0.0             | 10.5             | 11.0                           | 9.3               | 0.2               | 0.3              |
| 1998 | 169.4                   | 0.0             | 9.5              | 142.1                          | 9.4               | 0.4               | 8.0              |
| 1999 | 108.5                   | 7.4             | 10.4             | 77.9                           | 11.0              | 1.7               | 0.0              |
| 2000 | 92.6                    | 0.0             | 4.1              | 82.1                           | 6.4               | 0.0               | 0.0              |
| 2001 | 157.9                   | 3.4             | 27.6             | 99.9                           | 26.1              | 0.9               | 0.0              |
| 2002 | 203.4                   | 3.0             | 47.6             | 99.8                           | 51.8              | 0.0               | 1.1              |
| 2003 | 261.0                   | 5.0             | 53.9             | 140.1                          | 60.2              | 0.0               | 1.8              |
| 2004 | 177.0                   | 6.2             | 49.5             | 71.6                           | 48.7              | 0.0               | 1.0              |

1. Calculated as bulk imports - exported in eqpt - charge for new NZ eqpt - destruction + eqpt retirement

2. HFC-134a calculated by difference after detailed consideration of other gases.

Module 1990 - 2004 Emissions of Sulphur Hexafluoride (New Zealand)

Worksheet

Sheet SF<sub>6</sub> from Electrical Equipment and Other Sources (based on equations 3.13, 3.17, 3.18 and 3.22)

| Year | Potential SF <sub>6</sub><br>Emissions<br>(kg) <sup>1</sup> | Emissions from<br>Electrical Equipment<br>(kg) <sup>2</sup> | Emissions from<br>Other Sources <sup>4</sup><br>(kg) <sup>3</sup> | Actual SF <sub>6</sub><br>Emissions<br>(kg) |
|------|---|---|---|---|
| 1990 | 2030  | 396   | 120   | 516   |
| 1991 | 2256  | 409   | 131   | 540   |
| 1992 | 1393  | 423   | 147   | 570   |
| 1993 | 2026  | 435   | 153   | 588   |
| 1994 | 1842  | 448   | 155   | 603   |
| 1995 | 1566  | 466   | 162   | 628   |
| 1996 | 2240  | 485   | 134   | 619   |
| 1997 | 2354  | 505   | 135   | 640   |
| 1998 | 1952  | 439   | 148   | 587   |
| 1999 | 1851  | 414   | 138   | 552   |
| 2000 | 1753  | 499   | 11  | 510   |
| 2001 | 1535  | 501   | 14  | 514   |
| 2002 | 2523  | 536   | 14  | 550   |
| 2003 | 1939  | 722   | 11  | 733   |
| 2004 | 1901  | 888   | 11  | 899   |

1. IPCC (2001) Equation 3.18

2. IPCC (2001) Equation 3.13 (Tier 3c) for the few utilities with detailed data and Equation 3.17 (Tier 2b) for others.

3. IPCC (2001) Equation 3.22

4. SF<sub>6</sub> use in magnesium casting ceased in 1998

## A8.3 Worksheets for the solvents sector

Module  
Worksheet  
Sheet

2004 Solvent and other product use (New Zealand)  
NZ 3a  
Non-CO<sub>2</sub> emissions

| Source Categories                               | ACTIVITY DATA<br>Quantity Consumed<br>tonnes | NMVOC<br>fraction | Emission Estimates |  | Emission Factors |  |
|---|--|-------------------|--------------------|--|------------------|--|
|   |  |                   | (Gg)               |  | kg/year/person   |  |
|   |  |                   | NMVOC              |  | NMVOC            |  |
| <b>TOTAL SOLVENT EMISSIONS</b>                  |  |                   |                    |  |                  |  |
| <b>A Surface Coatings</b>                       | <b>60584</b>                                 |                   | <b>16.48</b>       |  |                  |  |
| <b>Architectural/ Decorative</b>                |  |                   |                    |  |                  |  |
| <b>Organic Base</b>                             | <b>4500</b>                                  |                   | <b>1.4969</b>      |  |                  |  |
| Primers and Undercoats                          | 1691   | 0.27              | 0.4566             |  | 0.1118           |  |
| Finishing Coats - Gloss                         | 1348   | 0.34              | 0.4584             |  | 0.1122           |  |
| Finishing Coats - Semi Gloss                    | 352  | 0.26              | 0.0915             |  | 0.0224           |  |
| Finishing Coats - Flat                          | 266  | 0.26              | 0.0691             |  | 0.0169           |  |
| Clears and Satins                               | 843  | 0.50              | 0.4213             |  | 0.1032           |  |
| <b>Water Base</b>                               | <b>33086</b>                                 |                   | <b>2.1237</b>      |  |                  |  |
| Primers and Undercoats                          | 2762   | 0.07              | 0.1934             |  | 0.0473           |  |
| Finishing Coats - Gloss                         | 12997  | 0.07              | 0.9098             |  | 0.2228           |  |
| Finishing Coats - Semi Gloss                    | 7382   | 0.07              | 0.5167             |  | 0.1265           |  |
| Finishing Coats - Flat                          | 9288   | 0.05              | 0.4644             |  | 0.1137           |  |
| Clears and Satins                               | 657  | 0.06              | 0.0394             |  | 0.0097           |  |
| <b>Industrial</b>                               |  |                   |                    |  |                  |  |
| <b>Organic Base</b>                             | <b>17448</b>                                 |                   | <b>8.6458</b>      |  |                  |  |
| Primers and Undercoats                          | 6678   | 0.34              | 2.2707             |  | 0.5560           |  |
| Finishing Coats                                 | 9902   | 0.60              | 5.9413             |  | 1.4548           |  |
| Clears  | 868  | 0.50              | 0.4338             |  | 0.1062           |  |
| <b>Water Base</b>                               | <b>1442</b>                                  |                   | <b>0.1009</b>      |  |                  |  |
| Primers and Undercoats                          | 1296   | 0.07              | 0.0907             |  | 0.0222           |  |
| Finishing Coats                                 | 146  | 0.07              | 0.0102             |  | 0.0025           |  |
| <b>Thinners</b>                                 |  |                   | <b>4.1080</b>      |  |                  |  |
| Solvents/Thinners                               | 4108   | 1.00              | 4.1080             |  | 1.0059           |  |
| <b>B Degreasing and Drycleaning<sup>2</sup></b> | <b>990</b>                                   |                   | <b>0.9900</b>      |  |                  |  |
| <b>C Chemical Products</b>                      |  |                   | <b>0.0868</b>      |  |                  |  |
| Ethanol <sup>1</sup>                            | 10000  |                   | 0.0480             |  |                  |  |
| Hydrogen Peroxide <sup>1</sup>                  | 16310  |                   | 0.0388             |  |                  |  |
| <b>D Other</b>                                  |  |                   | <b>14.3815</b>     |  |                  |  |
| Printing <sup>2</sup>                           | 3220   |                   | 2.0930             |  |                  |  |
| Aerosols <sup>2</sup>                           |  |                   | 1.915              |  |                  |  |
| Domestic and Commercial Use                     |  |                   | 10.373             |  | 2.5400           |  |

31.93

Emission factors derived on a kg/person/year basis (EPAV and USEPA)

1. Emissions calculated on production not consumption data
2. Emissions calculated from import not consumption data

## A8.4 Worksheets for the agriculture sector

Animal numbers in New Zealand Revised 2004

Agricultural sector calculations: emissions from domestic livestock and agricultural soils

|      | Dairy<br>cattle <sup>1</sup><br>(1000s) | Dairy<br>cattle<br>(3 yr av)<br>(1000s) | Non-dairy<br>cattle <sup>1</sup><br>(1000s) | Non-dairy<br>cattle<br>(3 yr av)<br>(1000s) | Sheep<br>numbers <sup>1</sup><br>(1000s) | Sheep<br>numbers<br>(3 yr av)<br>(1000s) | Goat<br>numbers <sup>1</sup><br>(jun yr)<br>(1000s) | Goat<br>numbers<br>(3 yr av)<br>(1000s) | Deer<br>numbers <sup>1</sup><br>(1000s) | Deer<br>numbers<br>(3 yr av)<br>(1000s) | Swine<br>numbers <sup>1</sup><br>(jun yr)<br>(1000s) | Swine<br>numbers<br>(3 yr av)<br>(1000s) |
|------|---|---|---|---|--|--|---|---|---|---|--|--|
| 1989 | 3,302                                   |   | 4,526                                       |   | 60,569                                   |  | 1,222   |   | 780                                     |   | 411  |  |
| 1990 | 3,441                                   | 3,391                                   | 4,593                                       | 4,597                                       | 57,852                                   | 57,861                                   | 1,063   | 1,026                                   | 976                                     | 962                                     | 395  | 404                                      |
| 1991 | 3,429                                   | 3,446                                   | 4,671                                       | 4,647                                       | 55,162                                   | 55,194                                   | 793   | 796                                     | 1,130                                   | 1,080                                   | 407  | 404                                      |
| 1992 | 3,468                                   | 3,482                                   | 4,676                                       | 4,702                                       | 52,568                                   | 52,676                                   | 533   | 559                                     | 1,135                                   | 1,114                                   | 411  | 405                                      |
| 1993 | 3,550                                   | 3,619                                   | 4,758                                       | 4,827                                       | 50,298                                   | 50,778                                   | 353   | 390                                     | 1,078                                   | 1,148                                   | 395  | 410                                      |
| 1994 | 3,839                                   | 3,826                                   | 5,048                                       | 4,996                                       | 49,466                                   | 49,527                                   | 284   | 324                                     | 1,231                                   | 1,163                                   | 423  | 416                                      |
| 1995 | 4,090                                   | 4,031                                   | 5,183                                       | 5,028                                       | 48,816                                   | 48,559                                   | 337   | 283                                     | 1,179                                   | 1,201                                   | 431  | 426                                      |
| 1996 | 4,165                                   | 4,170                                   | 4,852                                       | 4,947                                       | 47,394                                   | 47,681                                   | 228   | 264                                     | 1,192                                   | 1,242                                   | 424  | 424                                      |
| 1997 | 4,256                                   | 4,255                                   | 4,806                                       | 4,697                                       | 46,834                                   | 46,728                                   | 228   | 228                                     | 1,354                                   | 1,354                                   | 417  | 418                                      |
| 1998 | 4,344                                   | 4,305                                   | 4,432                                       | 4,627                                       | 45,956                                   | 46,157                                   | 228   | 214                                     | 1,515                                   | 1,515                                   | 412  | 399                                      |
| 1999 | 4,316                                   | 4,420                                   | 4,644                                       | 4,557                                       | 45,680                                   | 45,093                                   | 186   | 197                                     | 1,677                                   | 1,620                                   | 369  | 383                                      |
| 2000 | 4,598                                   | 4,598                                   | 4,594                                       | 4,594                                       | 43,644                                   | 43,644                                   | 175   | 175                                     | 1,667                                   | 1,667                                   | 369  | 364                                      |
| 2001 | 4,880                                   | 4,880                                   | 4,544                                       | 4,543                                       | 41,608                                   | 41,608                                   | 164   | 164                                     | 1,658                                   | 1,658                                   | 354  | 355                                      |
| 2002 | 5,162                                   | 5,048                                   | 4,491                                       | 4,554                                       | 39,572                                   | 40,244                                   | 153   | 153                                     | 1,648                                   | 1,665                                   | 342  | 358                                      |
| 2003 | 5,102                                   | 5,139                                   | 4,627                                       | 4,522                                       | 39,552                                   | 39,460                                   | 142   | 142                                     | 1,689                                   | 1,699                                   | 377  | 369                                      |
| 2004 | 5,154                                   | 5,119                                   | 4,448                                       | 4,532                                       | 39,255                                   | 39,572                                   | 131   | 137                                     | 1,759                                   | 1,720                                   | 389  | 369                                      |
| 2005 | 5,101                                   |   | 4,522                                       |   | 39,911                                   |  |   |   | 1,711                                   |   | 341  |  |

<sup>1</sup> 1994, 1995, 1996, 1999 and 2002 data from Statistics New Zealand. Other estimates provided by MAF based on a combination of official livestock survey data, information from the Meat and Wool Board Economic Service, and CES Forecast estimates.

**Animal numbers in New Zealand (thousands) Revised 2004 Continued**  
**Agricultural sector calculations: emissions from domestic livestock and agricultural soils**

|      | Poultry<br>numbers<br>layers <sup>1,4</sup><br>(jun yr) | Poultry<br>others and<br>broilers <sup>2,4</sup><br>(jun yr) | Poultry<br>numbers<br>total<br>(jun yr) | Poultry<br>numbers<br>(3 yr av)<br>(jun yr) | Horse<br>numbers <sup>3</sup><br>(jun yr) | Horse<br>numbers<br>(3 yr av)<br>(jun yr) |
|------|---|--|---|---|---|---|
| 1989 | 3,324   | 4,925  | 8,249                                   |   | 98.0                                      |   |
| 1990 | 2,996   | 6,089  | 9,085                                   | 8,670                                       | 94.0                                      | 94.0                                      |
| 1991 | 2,908   | 5,770  | 8,677                                   | 8,677                                       | 90.0                                      | 90.6                                      |
| 1992 | 2,819   | 5,450  | 8,270                                   | 8,988                                       | 87.9                                      | 88.4                                      |
| 1993 | 2,862   | 7,154  | 10,016                                  | 10,016                                      | 87.2                                      | 81.0                                      |
| 1994 | 2,905   | 8,858  | 11,762                                  | 11,762                                      | 67.8                                      | 74.5                                      |
| 1995 | 2,947   | 10,561   | 13,509                                  | 12,914                                      | 68.6                                      | 68.0                                      |
| 1996 | 3,210   | 10,262   | 13,472                                  | 13,953                                      | 67.7                                      | 68.5                                      |
| 1997 | 3,211   | 11,667   | 14,878                                  | 14,878                                      | 69.1                                      | 69.1                                      |
| 1998 | 3,212   | 13,072   | 16,284                                  | 16,284                                      | 70.4                                      | 70.4                                      |
| 1999 | 3,213   | 14,476   | 17,690                                  | 17,690                                      | 71.8                                      | 71.8                                      |
| 2000 | 3,215   | 15,881   | 19,096                                  | 19,096                                      | 73.1                                      | 73.1                                      |
| 2001 | 3,216   | 17,286   | 20,502                                  | 20,502                                      | 74.5                                      | 74.5                                      |
| 2002 | 3,217   | 18,691   | 21,908                                  | 21,499                                      | 75.9                                      | 76.9                                      |
| 2003 | 3,218   | 18,868   | 22,086                                  | 22,389                                      | 80.4                                      | 77.7                                      |
| 2004 | 3,219   | 19,954   | 23,173                                  | 23,183                                      | 76.9                                      | 78.1                                      |
| 2005 | 3,220   | 21,069   | 24,289                                  |   | 76.9                                      |   |

<sup>1</sup> 1995, 1996 and 2002 (provisional) data from Statistics New Zealand. 1989, 1990 and 1992 from MAF survey data.

Other estimates provided by MAF February 2003.

<sup>2</sup> 2002 data from Statistics New Zealand. 1989, 1990, 1992, 1995 and 1996 from MAF survey data.

2003-2005 data not available from Statistics New Zealand and are extrapolated.

<sup>3</sup> 1994, 1995, 1996 and 2002 data from Statistics New Zealand. 1990, 1992 and 1993 from MAF survey data.

2003-2005 data not available from Statistics New Zealand and are extrapolated.

<sup>4</sup> Poultry numbers for 2005 extrapolated

**Livestock productivity data for New Zealand 2004**

Agricultural sector calculations: CH<sub>4</sub> emissions from domestic livestock

**Table 1: Average weights, average annual milk yields and average milk composition of dairy cattle in New Zealand 1990-2004. All data are three year averages.**

|      | Dairy cow weights | Milk yields (litres/year) | Milk fat (percent) | Milk protein (percent) | Milk yield (kg/day) <sup>1</sup> |
|------|-------------------|---------------------------|--------------------|------------------------|----------------------------------|
| 1990 | 446               | 2714                      | 4.80               | 3.58                   | 9.69                             |
| 1991 | 447               | 2801                      | 4.85               | 3.58                   | 10.01                            |
| 1992 | 449               | 2858                      | 4.88               | 3.61                   | 10.21                            |
| 1993 | 450               | 3011                      | 4.90               | 3.63                   | 10.75                            |
| 1994 | 451               | 3029                      | 4.90               | 3.62                   | 10.82                            |
| 1995 | 452               | 3076                      | 4.89               | 3.61                   | 10.98                            |
| 1996 | 453               | 3121                      | 4.88               | 3.61                   | 11.15                            |
| 1997 | 447               | 3227                      | 4.85               | 3.59                   | 11.52                            |
| 1998 | 455               | 3247                      | 4.82               | 3.58                   | 11.60                            |
| 1999 | 444               | 3303                      | 4.80               | 3.58                   | 11.80                            |
| 2000 | 455               | 3430                      | 4.81               | 3.61                   | 12.25                            |
| 2001 | 460               | 3625                      | 4.83               | 3.63                   | 12.95                            |
| 2002 | 455               | 3670                      | 4.84               | 3.66                   | 13.11                            |
| 2003 | 458               | 3680                      | 4.86               | 3.67                   | 13.14                            |
| 2004 | 457               | 3628                      | 4.89               | 3.69                   | 12.96                            |

<sup>1</sup> Lactation period = 280 days

**Livestock productivity data for New Zealand 2004**

Agricultural sector calculations: CH<sub>4</sub> emissions from domestic livestock

**Table 2: Average weights of beef cattle in New Zealand 1990-2004. All data are three year averages.**

|      | Beef cow weights (kg) | Heifer weights at slaughter (kg) | Bull weights at slaughter (kg) | Steer weights at slaughter (kg) |
|------|-----------------------|----------------------------------|--------------------------------|---------------------------------|
| 1990 | 387                   | 413                              | 553                            | 568                             |
| 1991 | 379                   | 417                              | 562                            | 577                             |
| 1992 | 381                   | 422                              | 566                            | 584                             |
| 1993 | 389                   | 427                              | 574                            | 593                             |
| 1994 | 403                   | 432                              | 581                            | 598                             |
| 1995 | 406                   | 436                              | 585                            | 601                             |
| 1996 | 412                   | 438                              | 593                            | 601                             |
| 1997 | 418                   | 438                              | 600                            | 601                             |
| 1998 | 430                   | 438                              | 603                            | 599                             |
| 1999 | 426                   | 437                              | 599                            | 602                             |
| 2000 | 423                   | 437                              | 599                            | 607                             |
| 2001 | 423                   | 441                              | 603                            | 614                             |
| 2002 | 432                   | 446                              | 605                            | 615                             |
| 2003 | 433                   | 453                              | 608                            | 617                             |
| 2004 | 430                   | 457                              | 615                            | 620                             |

**Livestock productivity data for New Zealand 2004**

Agricultural sector calculations: CH<sub>4</sub> emissions from domestic livestock

**Table 3: Weights of ewes and lambs in New Zealand 1990-2004. All data are three year averages.**

|      | Ewe weights (kg) | Lamb weights at slaughter (kg) |
|------|------------------|--------------------------------|
| 1990 | 48.4             | 31.2                           |
| 1991 | 49.0             | 32.1                           |
| 1992 | 49.1             | 33.0                           |
| 1993 | 49.6             | 33.6                           |
| 1994 | 49.4             | 33.5                           |
| 1995 | 49.7             | 33.4                           |
| 1996 | 50.0             | 33.7                           |
| 1997 | 51.1             | 34.4                           |
| 1998 | 52.0             | 34.7                           |
| 1999 | 53.0             | 35.4                           |
| 2000 | 54.1             | 36.2                           |
| 2001 | 54.7             | 37.0                           |
| 2002 | 54.8             | 37.1                           |
| 2003 | 55.1             | 37.6                           |
| 2004 | 56.2             | 38.1                           |

**Livestock productivity data for New Zealand 2004**

Agricultural sector calculations: CH<sub>4</sub> emissions from domestic livestock

**Table 4: Weights of deer in New Zealand 1990-2004. All data are three year averages.**

|      | Breeding hind live weight (kg) | Breeding stag live weight (kg) | Growing stag live weight at slaughter (kg) | Growing hind live weight at slaughter (kg) |
|------|--------------------------------|--------------------------------|--|--|
| 1990 | 110.0                          | 150.0                          | 95.0                                       | 78.0                                       |
| 1991 | 110.1                          | 144.2                          | 95.6                                       | 79.0                                       |
| 1992 | 113.5                          | 144.4                          | 98.3                                       | 80.8                                       |
| 1993 | 114.2                          | 153.1                          | 101.2                                      | 80.5                                       |
| 1994 | 117.9                          | 156.3                          | 103.4                                      | 81.0                                       |
| 1995 | 112.2                          | 157.9                          | 103.6                                      | 80.4                                       |
| 1996 | 116.2                          | 163.5                          | 103.8                                      | 82.0                                       |
| 1997 | 115.4                          | 157.1                          | 106.1                                      | 82.7                                       |
| 1998 | 119.0                          | 158.8                          | 110.3                                      | 85.5                                       |
| 1999 | 119.3                          | 174.1                          | 113.0                                      | 87.2                                       |
| 2000 | 127.5                          | 176.3                          | 109.8                                      | 89.6                                       |
| 2001 | 126.4                          | 171.4                          | 106.5                                      | 90.4                                       |
| 2002 | 129.2                          | 159.4                          | 104.9                                      | 91.2                                       |
| 2003 | 131.1                          | 161.1                          | 104.6                                      | 91.4                                       |
| 2004 | 129.7                          | 164.1                          | 105.4                                      | 90.9                                       |

**Livestock productivity data for New Zealand 2004**

Agriculture sector calculations: emissions from domestic livestock and soils

**Table 5: Nitrogen excretion (Nex) for grazing animals**

|      | Sheep (kg/head/yr) | Non-dairy cattle (kg/head/yr) | Dairy cattle (kg/head/yr) | Deer (kg/head/yr) |
|------|--------------------|-------------------------------|---------------------------|-------------------|
| 1990 | 12.60              | 66.16                         | 104.90                    | 25.10             |
| 1991 | 12.75              | 66.67                         | 106.13                    | 25.83             |
| 1992 | 12.85              | 67.96                         | 108.12                    | 26.50             |
| 1993 | 12.90              | 69.12                         | 108.02                    | 26.68             |
| 1994 | 12.91              | 69.46                         | 107.64                    | 26.82             |
| 1995 | 13.05              | 69.92                         | 107.75                    | 26.83             |
| 1996 | 13.34              | 70.29                         | 108.95                    | 27.10             |
| 1997 | 13.71              | 71.20                         | 109.58                    | 27.36             |
| 1998 | 13.93              | 71.03                         | 110.30                    | 27.80             |
| 1999 | 14.18              | 71.46                         | 111.33                    | 28.34             |
| 2000 | 14.43              | 72.07                         | 113.15                    | 28.61             |
| 2001 | 14.67              | 72.98                         | 113.49                    | 28.80             |
| 2002 | 14.68              | 72.78                         | 114.89                    | 28.77             |
| 2003 | 14.81              | 72.93                         | 115.51                    | 28.67             |
| 2004 | 14.98              | 73.11                         | 116.94                    | 28.69             |

**Table 6: Enteric fermentation (Gg CH<sub>4</sub>)**

|      | Dairy  | Non-dairy cattle | Sheep  | Deer  |
|------|--------|------------------|--------|-------|
| 1990 | 237.72 | 235.48           | 535.17 | 18.50 |
| 1991 | 244.65 | 239.88           | 515.05 | 21.35 |
| 1992 | 252.59 | 247.24           | 495.58 | 22.60 |
| 1993 | 262.61 | 258.01           | 480.19 | 23.44 |
| 1994 | 276.93 | 268.20           | 470.60 | 23.88 |
| 1995 | 292.36 | 271.42           | 466.51 | 24.66 |
| 1996 | 306.45 | 268.18           | 467.82 | 25.78 |
| 1997 | 314.86 | 257.71           | 470.48 | 28.41 |
| 1998 | 321.10 | 253.43           | 470.75 | 32.31 |
| 1999 | 333.37 | 251.32           | 467.15 | 35.17 |
| 2000 | 353.60 | 255.79           | 459.38 | 36.51 |
| 2001 | 376.66 | 256.39           | 445.25 | 36.53 |
| 2002 | 394.37 | 256.57           | 430.58 | 36.65 |
| 2003 | 403.28 | 255.44           | 425.58 | 37.27 |
| 2004 | 406.88 | 256.66           | 429.97 | 37.76 |

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Domestic livestock emissions from enteric fermentation and manure management  
**Worksheet** 4.1 (1 of 2)  
**Sheet** Methane emissions

| Livestock type   | Number of animals (3 yr av) (1000s) | Emission factor for enteric fermentation <sup>1</sup> (kg CH <sub>4</sub> /head/yr) | Emissions from enteric fermentation (Gg) | Emission factor for manure management <sup>2</sup> (kg CH <sub>4</sub> /head/yr) | Emissions from manure management (Gg) | Total CH <sub>4</sub> emissions from dom livestock (Gg) |
|------------------|-------------------------------------|---|--|--|---------------------------------------|---|
| Dairy cattle     | 5,119                               | 79.5  | 406.88                                   | 3.312  | 16.954                                | 423.83  |
| Non-dairy cattle | 4,532                               | 56.6  | 256.66                                   | 0.691  | 3.134                                 | 259.80  |
| Sheep            | 39,572                              | 10.9  | 429.97                                   | 0.107  | 4.245                                 | 434.22  |
| Goats            | 137                                 | 9.0   | 1.23                                     | 0.180  | 0.025                                 | 1.25  |
| Deer             | 1,720                               | 22.0  | 37.76                                    | 0.198  | 0.341                                 | 38.10   |
| Horses           | 78                                  | 18.0  | 1.41                                     | 2.080  | 0.162                                 | 1.57  |
| Swine            | 369                                 | 1.5   | 0.55                                     | 20.000   | 7.382                                 | 7.94  |
| Poultry          | 23,183                              | NE  | NE                                       | 0.117  | 2.712                                 | 2.71  |
| <b>Total</b>     |                                     |   | <b>1,134.45</b>                          |  | <b>34.956</b>                         | <b>1,169.41</b>   |

<sup>1</sup> Horses and swine use IPCC default emission factors. Other emission factors are implied.

<sup>1</sup> Enteric emission factors for dairy, non-dairy, sheep and deer are implied emission factors

<sup>2</sup> Manure management: Horses, goats, swine and poultry use IPCC default emission factors from IPCC Reference Manual B-7 & B-6

<sup>2</sup> Manure management: Dairy, non-dairy, sheep and deer implied emission factors derived from Ag model.

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Domestic livestock emissions from enteric fermentation and manure management  
**Worksheet** 4.1 (2 of 2)  
**Sheet** Nitrous oxide emissions from manure management

| Animal waste management system (AWMS) | N excretion for each AWMS (Nex <sub>(AWMS)</sub> ) (kg N) | Emission factor for each AWMS (EF <sub>3</sub> ) (kg N <sub>2</sub> O-N/kg N) | Emissions from domestic livestock (Gg N <sub>2</sub> O) |
|---------------------------------------|---|---|---|
| Anaerobic lagoons                     | 33,177,948  | 0.001   | 0.052   |
| Liquid Systems                        |   |   | NO  |
| Daily spread                          |   |   | IE  |
| Solid storage and drylot              | 1,004,001   | 0.02  | 0.032   |
| Pasture range and paddock             |   |   | IE  |
| Other                                 | 15,145,870  | 0.005   | 0.119   |
| <b>Total</b>                          |   |   | <b>0.203</b>  |

N<sub>2</sub>O emissions from daily spread and pasture range and paddock are reported under agricultural soils.

**2004 Agriculture (New Zealand)**

**Table 4.17 (IPCC Workbook, adapted)**

**Parameter values for agricultural emissions of nitrous oxide**

| Parameter             | Value | Fraction of ...  | Additional sources                                    |
|-----------------------|-------|--|---|
| Frac <sub>BURN</sub>  | 0.5   | ... crop residue burned in fields  | Ministry of Agriculture and Forestry (expert opinion) |
| Frac <sub>BURNL</sub> | 0     | ... Legume crop residue burned in fields                                     | Ministry of Agriculture and Forestry (expert opinion) |
| Frac <sub>FUEL</sub>  | 0     | ... livestock nitrogen excretion in excrements burned for fuel               | Practice does not occur in New Zealand                |
| Frac <sub>GASF</sub>  | 0.1   | ... total synthetic fertiliser emitted as NO <sub>x</sub> or NH <sub>3</sub> | IPCC Reference manual Table 4.19                      |
| Frac <sub>GASM</sub>  | 0.2   | ... total nitrogen excretion emitted as NO <sub>x</sub> or NH <sub>3</sub>   | IPCC Reference manual Table 4.19                      |
| Frac <sub>GRAZ</sub>  |       | ... livestock nitrogen excreted and deposited onto soil during grazing       | Refer worksheet 4.1 Supplemental                      |
| Frac <sub>LEACH</sub> | 0.07  | ... nitrogen input to soils that is lost through leaching and run-off        | Thomas et al (2002)                                   |
| Frac <sub>NCRBF</sub> | 0.03  | ... nitrogen in N-fixing crops   | IPCC Reference manual Table 4.19                      |
| Frac <sub>NCR0</sub>  | 0.015 | ... nitrogen in non-N-fixing crops   | IPCC Reference manual Table 4.19                      |
| Frac <sub>R</sub>     | 0.45  | ... crop residue removed from the field as crop                              | IPCC Reference manual Table 4.19                      |

**2004 Agriculture (New Zealand)**

**Table 4.18 (IPCC Workbook, adapted)**

**Emission factors for agricultural emissions of nitrous oxide**

| Emission factor         | Value | Emission factor for ...  | Additional sources   |
|-------------------------|-------|--|--|
| EF <sub>1</sub>         | 0.01  | ... direct emissions from N input to soil                                    | IPCC GPG Table 4.17  |
| EF <sub>2</sub>         | 8     | ... direct emissions from organic soil mineralisation due to cultivation     | IPCC GPG Table 4.17  |
| EF <sub>3</sub> (AL)    | 0.001 | ... direct emissions from waste in the <i>anaerobic lagoons</i> AWMS         | IPCC GPG Table 4.12  |
| EF <sub>3</sub> (SS&D)  | 0.02  | ... direct emissions from waste in the <i>solid waste and drylot</i> AWMS    | IPCC GPG Table 4.12  |
| EF <sub>3</sub> (PR&P)  | 0.01  | ... direct emissions from waste in the <i>pasture range and paddock</i> AWMS | Carran et al (1995), Sherlock et al (1995), Kelliher et al.(2003)                    |
| EF <sub>3</sub> (OTHER) | 0.005 | ... direct emissions from waste in other AWMSs                               | IPCC GPG Table 4.13 (poultry manure without bedding) and swine deep litter < 1 month |
| EF <sub>4</sub>         | 0.01  | ... indirect emissions from volatilising nitrogen                            | IPCC GPG Table 4.18  |
| EF <sub>5</sub>         | 0.025 | ... indirect emissions from leaching nitrogen                                | IPCC GPG Table 4.18  |

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Domestic livestock emissions  
**Worksheet** 4.1 (supplemental) for worksheet 4.1 (2 of 2)  
**Sheet** Nitrogen excretion from anaerobic lagoons (AWMS=AL)

| Livestock type             | Number<br>of animals<br>(3 yr av)<br>(1000s) | Nitrogen<br>excretion <sup>1</sup><br>(Nex)<br>(kg/head/yr) | Percentage<br>of nitrogen<br>excretion in<br>AWMS=AL <sup>2</sup> | Nitrogen<br>excretion<br>from AL<br>(kg N) |
|----------------------------|--|---|---|--|
| Non-dairy cattle           | 4,532  |   |   | no   |
| Dairy cattle               | 5,119  | 116.9   | 5%  | 29,929,710                                 |
| Poultry                    | 23,183                                       |   |   | no   |
| Sheep                      | 39,572                                       |   |   | no   |
| Swine                      | 369  | 16.0  | 55%   | 3,248,238                                  |
| Goats                      | 137  |   |   | no   |
| Deer                       | 1,720  |   |   | no   |
| Horses                     | 78   |   |   | no   |
| Total (Nex <sub>AL</sub> ) |  |   |   | 33,177,948                                 |

<sup>1</sup> Nex value for dairy cattle based on Ledgard, AgResearch (2003)

<sup>2</sup> Value for dairy cattle from Ledgard and Brier (2004).

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Agricultural soils  
**Worksheet** 4.1 (supplemental) for worksheet 4.5 (3 of 5)  
**Sheet** Nitrogen excretion from pasture range and paddock (AWMS=PR&P)

| Livestock type                   | Number<br>of animals<br>(3 yr av)<br>(1000s) | Nitrogen<br>excretion <sup>1</sup><br>(Nex)<br>(kg/head/yr) | Percentage<br>of nitrogen<br>excretion in<br>AWMS=PR&P <sup>2,3</sup> | Nitrogen<br>excretion<br>from PR&P<br>(kg N) |
|----------------------------------|--|---|---|--|
| Non-dairy cattle                 | 4,532  | 73.1  | 100%  | 331,352,442                                  |
| Dairy cattle                     | 5,119  | 116.9   | 95%   | 568,664,489                                  |
| Poultry                          | 23,183                                       | 0.6   | 3%  | 417,285                                      |
| Sheep                            | 39,572                                       | 14.98   | 100%  | 592,877,128                                  |
| Swine                            | 369  |   |   | no   |
| Goats                            | 137  | 9.5   | 100%  | 1,296,750                                    |
| Deer                             | 1,720  | 28.7  | 100%  | 49,349,211                                   |
| Horses                           | 78   | 25.0  | 100%  | 1,951,792                                    |
| Total (Nex <sub>PR&amp;P</sub> ) |  |   |   | 1,545,909,097                                |

<sup>1</sup> Values for sheep, non-dairy and dairy cattle, and deer from Ledgard, AgResearch (2003)  
 Values from goats from Ulyatt (pers comm).

<sup>2</sup> Value for dairy cattle from Ledgard and Brier (2004).

<sup>3</sup> Values for goats and deer from the Ministry of Agriculture and Forestry.

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Domestic livestock emissions  
**Worksheet** 4.1 (supplemental) for worksheet 4.1 (2 of 2)  
**Sheet** Nitrogen excretion from solid storage and drylot (AWMS=SS&D)

| Livestock type                   | Number<br>of animals<br>(3 yr av)<br>(1000s) | Nitrogen<br>excretion<br>(Nex)<br>(kg/head/yr) | Percentage<br>of nitrogen<br>excretion in<br>AWMS=SS&D | Nitrogen<br>excretion<br>from SS&D<br>(kg N) |
|----------------------------------|--|--|--|--|
| Non-dairy cattle                 | 4,532  |  |  | no   |
| Dairy cattle                     | 5,119  |  |  | no   |
| Poultry                          | 23,183                                       |  |  | no   |
| Sheep                            | 39,572                                       |  |  | no   |
| Swine                            | 369  | 16.0   | 17%  | 1,004,001                                    |
| Goats                            | 137  |  |  | no   |
| Deer                             | 1,720  |  |  | no   |
| Horses                           | 78   |  |  | no   |
| Total (Nex <sub>SS&amp;D</sub> ) |  |  |  | 1,004,001                                    |

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Domestic livestock emissions  
**Worksheet** 4.1 (supplemental) for worksheet 4.1 (2 of 2)  
**Sheet** Nitrogen excretion from other management systems (AWMS=OTHER)

| Livestock type                | Number<br>of animals<br>(3 yr av)<br>(1000s) | Nitrogen<br>excretion<br>(Nex)<br>(kg/head/yr) | Percentage<br>of nitrogen<br>excretion in<br>AWMS=OTHER | Nitrogen<br>excretion<br>from OTHER<br>(kg N) |
|-------------------------------|--|--|---|---|
| Non-dairy cattle              | 4,532  |  |   | no  |
| Dairy cattle                  | 5,119  |  |   | no  |
| Poultry                       | 23,183                                       | 0.6  | 97%   | 13,492,221                                    |
| Sheep                         | 39,572                                       |  |   | no  |
| Swine                         | 369  | 16.0   | 28%   | 1,653,649                                     |
| Goats                         | 137  |  |   | no  |
| Deer                          | 1,720  |  |   | no  |
| Horses                        | 0  |  |   | no  |
| Total (Nex <sub>OTHER</sub> ) |  |  |   | 15,145,870                                    |

**2004 Agriculture (New Zealand)**

**F<sub>AW</sub> calculation for worksheet 4.5 (1 of 5)**

**Nitrogen input to agricultural soils from animal waste (supplemental worksheet 4.5A)**

| N excretion spread from all AWMSs (kg N) <sup>1</sup> | Fraction of N excretion burned for fuel | Fraction of N excretion deposited onto soil during grazing | Fraction of N excretion emitted as NO <sub>x</sub> or NH <sub>3</sub> | Nitrogen input from animal waste (kg N) |
|---|---|--|---|---|
| N <sub>spread</sub>                                   | x (1-(Frac <sub>FUEL</sub>              | + Frac <sub>GRAZ</sub>                                     | + Frac <sub>GASM</sub> ))   | = F <sub>AW</sub>                       |
| 49,327,819  | 0                                       |  | 0.2   | 39,462,255                              |

<sup>1</sup> Animal waste in all AWMS except pasture range and paddock.

<sup>2</sup> Frac<sub>GRAZ</sub> is not required as waste from grazing livestock is already excluded.

**2004 Agriculture (New Zealand)**

**F<sub>BN</sub> calculation for worksheet 4.5 (1 of 5)**

**Nitrogen input to agricultural soils from N-fixing crops**

| Production of pulses and soyabeans (kg dry biomass) | Fraction of nitrogen in N-fixing crops | Nitrogen input from N-fixing crops (kg N) |
|---|--|---|
| Crop <sub>BF</sub>                                  | x Frac <sub>NCRBF</sub>                | x 2 = F <sub>BN</sub>                     |
| 61,800,000  | 0.03                                   | 3,708,000                                 |

**2004 Agriculture (New Zealand)**

**F<sub>SN</sub> calculation for worksheet 4.5 (1 of 5)**

**Nitrogen input to agricultural soils from synthetic fertiliser use**

| Synthetic fertiliser use (kg N) | One minus the fraction of syn. fertiliser emitted as NO <sub>x</sub> or NH <sub>3</sub> | Nitrogen input from synthetic fertiliser use (kg N) |
|---------------------------------|---|---|
| N <sub>FERT</sub>               | x (1-Frac <sub>GASF</sub> )   | = F <sub>SN</sub>                                   |
| 345,240,000                     | 0.9   | 310,716,000   |

**2004 Agriculture (New Zealand)**

**F<sub>CR</sub> calculation for worksheet 4.5 (1 of 5)**

**Nitrogen input to agricultural soils from crop residues (supplemental worksheet 4.5B)**

| Production of non-N-fixing crops (kg dry biomass) | Fraction of nitrogen in non-N-fixing crops | Production of pulses and soyabeans (kg dry biomass) | Fraction of nitrogen in N-fixing crops | One minus the fraction of crop residue removed from field as crop | One minus the fraction of crop residue burned in the field | Nitrogen input from crop residues (F <sub>CR</sub> ) (kg N) |
|---|--|---|--|---|--|---|
| (Crop <sub>0</sub>                                | x Frac <sub>NCR0</sub>                     | + Crop <sub>BF</sub>                                | x Frac <sub>NCRBF</sub> )              | x (1 - Frac <sub>R</sub> )  | x (1 - Frac <sub>BURN</sub> )                              | x 2 = F <sub>CR</sub>                                       |
|   |  | 61,800,000  | 0.03                                   | 0.55  | 1  | 2,039,400   |
| 796,073,478                                       | 0.015                                      |   |  | 0.55  | 0.50   | 6,567,606   |
|   |  |   |  |   |  | 8,607,006   |

Module 2004 Agriculture (New Zealand)  
 Submodule Agricultural soils  
 Worksheet 4.5 (1 of 5)  
 Sheet Direct nitrous oxide emissions from agricultural soils (excluding histosols)

| Type of N input to soil                      | Amount of N input to soil (kg N) | Emission factor for direct emissions (EF <sub>1</sub> ) (kg N <sub>2</sub> O-N/kg N) | Direct soil emissions (excl. histosols) (Gg N <sub>2</sub> O-N) | Direct soil emissions (excl. histosols) (Gg N <sub>2</sub> O) |
|--|----------------------------------|--|---|---|
| Synthetic fertiliser (F <sub>SN</sub> )      | 310,716,000                      | 0.01   | 3.107   | 4.883   |
| Animal Waste (F <sub>AW</sub> ) <sup>1</sup> | 39,462,255                       | 0.01   | 0.395   | 0.620   |
| N-Fixing crops (F <sub>BN</sub> )            | 3,708,000                        | 0.01   | 0.037   | 0.058   |
| Crop residue (F <sub>CR</sub> )              | 8,607,006                        | 0.01   | 0.086   | 0.135   |
| Total  |                                  |  | 3.625   | 5.696   |

<sup>1</sup> Based on animal waste in all AWMS except pasture range and paddock.

Module 2004 Agriculture (New Zealand)  
 Submodule Agricultural soils  
 Worksheet 4.5 (2 of 5)  
 Sheet Direct nitrous oxide emissions from agricultural soils (histosols)

| Area of cultivated organic soils <sup>1</sup> (ha) (FOS) | Emission factor for direct soil emissions (EF <sub>2</sub> ) (kg N <sub>2</sub> O-N/ha/yr) | Direct soil emissions from histosols (Gg N <sub>2</sub> O-N) | Direct soil emissions from histosols (Gg N <sub>2</sub> O) |
|--|--|--|--|
| 10,109   | 8  | 0.081  | 0.127  |

<sup>1</sup> MAF estimate

Module 2004 Agriculture (New Zealand)  
 Submodule Agricultural soils  
 Worksheet 4.5 (3 of 5)  
 Sheet Direct nitrous oxide emissions from animal production (grazing animals)

| Pasture, range and paddock AWMS | N excretion for AWMS PRP (kg N) | Emission factor for AWMS (EF <sub>3 PRP</sub> ) <sup>1</sup> (kg N <sub>2</sub> O-N/kg N) | Total direct animal prodn. emissions of N <sub>2</sub> O-N (Gg) | Total direct animal prodn. emissions of N <sub>2</sub> O (Gg) |
|---------------------------------|---------------------------------|---|---|---|
| PRP                             | 1,545,909,097                   | 0.01  | 15.459  | 24.293  |

<sup>1</sup> Value based on Carran et al (1995) and Sherlock et al (1995).

Module 2004 Agriculture (New Zealand)  
 Submodule Agricultural soils  
 Worksheet 4.5 (4 of 5)  
 Sheet Indirect nitrous oxide emissions from nitrogen used in agriculture (atmospheric deposition of NH<sub>3</sub> and NO<sub>x</sub>)

| Synthetic fertiliser applied to soil (N <sub>FERT</sub> ) (kg N) | Fraction of syn. fertiliser N that volatilises (Frac <sub>GASF</sub> ) | Amount of syn. N applied to soil that volatilises (kg N) | Total nitrogen excreted by livestock (kg N) | Fraction of N excretion that volatilises (Frac <sub>GASM</sub> ) | Amount of N excretion that volatilises (kg N) | Emission factor (EF <sub>4</sub> ) (kg N <sub>2</sub> O-N/kg volatilised N) | Indirect N <sub>2</sub> O emissions from atmos. deposition (Gg N <sub>2</sub> O-N) | Indirect N <sub>2</sub> O emissions from atmos. deposition (Gg N <sub>2</sub> O) |
|--|--|--|---|--|---|---|--|--|
| 345,240,000  | 0.1  | 34,524,000   | 1,595,236,916                               | 0.2  | 319,047,383                                   | 0.01  | 3.536  | 5.556  |

Module 2004 Agriculture (New Zealand)  
 Submodule Agricultural soils  
 Worksheet 4.5 (5 of 5)  
 Sheet Indirect nitrous oxide emissions from nitrogen used in agriculture (leaching) and total nitrous oxide emissions from agricultural soils

| Synthetic fertiliser applied to soil (N <sub>FERT</sub> ) (kg N) | Total nitrogen excreted by livestock (kg N) | Fraction of nitrogen that leaches (Frac <sub>LEACH</sub> ) | Emission factor (EF <sub>5</sub> ) (kg N <sub>2</sub> O-N/kg leached N) | Indirect N <sub>2</sub> O emissions from leaching (Gg N <sub>2</sub> O-N) | Indirect N <sub>2</sub> O emissions from leaching (Gg N <sub>2</sub> O) |
|--|---|--|---|---|---|
| 345,240,000  | 1,595,236,916                               | 0.07   | 0.025   | 3.396   | 5.336   |

Module 2004 Agriculture (New Zealand)  
 Submodule Agricultural soils  
 Worksheet 4.5 (4 of 5)  
 Sheet Total nitrous oxide emissions agricultural soils

| Total indirect N <sub>2</sub> O emissions from N used in agric. (Gg N <sub>2</sub> O) | Total direct N <sub>2</sub> O emissions (Gg N <sub>2</sub> O) | Total nitrous oxide emissions from agricultural soils (Gg N <sub>2</sub> O) |
|---|---|---|
| 10.892  | 30.116  | 41.009  |

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Prescribed burning of savanna

| Year | Otago consented area (ha) | Canterbury consented area (ha) | Southland consented area (ha) | Total consented area (ha) | 3 yr average consented area (ha) | assume 20% consented area (ha) burnt | above ground biomass density <sup>1</sup> (t/ha) ground biomass density | fraction burned | biomass burnt (t) |
|------|---------------------------|--------------------------------|-------------------------------|---------------------------|----------------------------------|--------------------------------------|---|-----------------|-------------------|
| 1989 | 11310.0                   | 15425.7                        | 5445.0                        | 32180.7                   |                                  |                                      |   |                 |                   |
| 1990 | 14332.0                   | 15425.7                        | 5634.0                        | 35391.7                   | 36471.2                          | 7294.2                               | 28.0  | 0.32            | 65254.9           |
| 1991 | 22020.0                   | 15241.2                        | 4580.0                        | 41841.2                   | 36108.1                          | 7221.6                               | 28.0  | 0.32            | 64605.3           |
| 1992 | 10740.0                   | 15531.5                        | 4820.0                        | 31091.5                   | 34571.7                          | 6914.3                               | 28.0  | 0.32            | 61856.4           |
| 1993 | 15229.0                   | 10953.5                        | 4600.0                        | 30782.5                   | 27819.7                          | 5563.9                               | 28.0  | 0.32            | 49775.5           |
| 1994 | 7875.0                    | 9900.0                         | 3810.0                        | 21585.0                   | 22006.2                          | 4401.2                               | 28.0  | 0.32            | 39373.9           |
| 1995 | 7485.0                    | 1626.0                         | 4540.0                        | 13651.0                   | 17770.7                          | 3554.1                               | 28.0  | 0.32            | 31795.6           |
| 1996 | 4790.0                    | 9061.0                         | 4225.0                        | 18076.0                   | 16109.0                          | 3221.8                               | 28.0  | 0.32            | 28822.5           |
| 1997 | 5895.0                    | 6955.0                         | 3750.0                        | 16600.0                   | 14466.7                          | 2893.3                               | 28.0  | 0.32            | 25884.0           |
| 1998 | 1810.0                    | 5314.0                         | 1600.0                        | 8724.0                    | 10919.3                          | 2183.9                               | 28.0  | 0.32            | 19537.1           |
| 1999 | 1.0                       | 4963.0                         | 2470.0                        | 7434.0                    | 9921.3                           | 1984.3                               | 28.0  | 0.32            | 17751.4           |
| 2000 | 2425.0                    | 9491.0                         | 1690.0                        | 13606.0                   | 10424.3                          | 2084.9                               | 28.0  | 0.32            | 18651.4           |
| 2001 | 3770.0                    | 4303.0                         | 2160.0                        | 10233.0                   | 11943.7                          | 2388.7                               | 28.0  | 0.32            | 21369.8           |
| 2002 | 350.0                     | 8792.0                         | 2850.0                        | 11992.0                   | 10972.0                          | 2194.4                               | 28.0  | 0.32            | 19631.3           |
| 2003 | 4670.0                    | 3721.0                         | 2300.0                        | 10691.0                   | 10901.7                          | 2180.3                               | 28.0  | 0.32            | 19505.5           |
| 2004 | 1125.0                    | 2714.0                         | 6183.0                        | 10022.0                   | 8986.0                           | 1797.2                               | 28.0  | 0.3             | 16102.9           |
| 2005 | 0.0                       | 200.0                          | 6045.0                        | 6245.0                    |                                  |                                      |   |                 |                   |

Notes

<sup>1</sup> from Ian J. Payton & Grant Pearce (2001) Does fire deplete the physical and biological resources of tall-tussock (Chionochloa) grasslands? The latest attempt at some answers . Pp. 243-249 in proceedings: Bushfire 2001. Australasian Bushfire Conference. 3-6 July 2001, Christchurch, New Zealand  
<sup>2</sup> from Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Prescribed burning of savanna  
**Worksheet** 4.3 (3 of 3)  
**Sheet** Non-CO<sub>2</sub> released from savanna burning

| Year | CH <sub>4</sub> emission ratio <sup>2</sup> | CO emission ratio <sup>2</sup> | N <sub>2</sub> O emission ratio <sup>2</sup> | NO <sub>x</sub> emission ratio <sup>2</sup> | N/C ratio <sup>2</sup> | CH <sub>4</sub> emissions (Gg) | CO emissions (Gg) | N <sub>2</sub> O emissions (Gg) | NO <sub>x</sub> emissions (Gg) | Total CH <sub>4</sub> and N <sub>2</sub> O in CO <sub>2</sub> equivalent (Gg) |
|------|---|--------------------------------|--|---|------------------------|--------------------------------|-------------------|---------------------------------|--------------------------------|---|
| 2004 | 0.00  | 0.06                           | 0.01   | 0.12  | 0.01                   | 0.033                          | 0.869             | 0.000                           | 0.015                          | 0.822   |

<sup>1</sup> from Ian J. Payton & Grant Pearce (2001) Does fire deplete the physical and biological resources of tall-tussock (Chionochloa) grasslands? The latest attempt at some answers . Pp. 243-249 in proceedings: Bushfire 2001. Australasian Bushfire Conference. 3-6 July 2001, Christchurch, New Zealand  
<sup>2</sup> from Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Prescribed burning of savanna  
**Worksheet** 4.3 (2 of 3)  
**Sheet** Total carbon released from burning

| Year | biomass burned (t) | fraction of live material <sup>1</sup> | fraction of dead material <sup>1</sup> | fraction live material oxidised <sup>2</sup> | fraction dead material oxidised <sup>2</sup> | C content of live biomass (living) <sup>2</sup> | C content dead biomass <sup>2</sup> | carbon released from live biomass (t) | carbon released from dead biomass (t) | total carbon released (t) |
|------|--------------------|--|--|--|--|---|-------------------------------------|---------------------------------------|---------------------------------------|---------------------------|
| 2004 | 16103              | 0.36                                   | 0.64                                   | 0.8  | 1  | 0.45  | 0.4                                 | 2090                                  | 4119                                  | 6209                      |

**Non-N-fixing crop yields in New Zealand Revised 2004**

**Agricultural sector calculations: emissions from field burning and agricultural soils**

|      | Barley<br>prodn<br>(jun yr)<br>(tonnes) | Barley<br>prodn<br>(3 yr av)<br>(Gg) | Wheat<br>prodn<br>(jun yr)<br>(tonnes) | Wheat<br>prodn<br>(3 yr av)<br>(Gg) | Maize<br>prodn<br>(jun yr)<br>(tonnes) | Maize<br>prodn<br>(3 yr av)<br>(Gg) | Oats<br>prodn<br>(jun yr)<br>(tonnes) | Oats<br>prodn<br>(3 yr av)<br>(Gg) | Non-N-<br>fixing crops<br>(3 yr av)<br>(kg) |
|------|---|--------------------------------------|--|-------------------------------------|--|-------------------------------------|---------------------------------------|------------------------------------|---|
| 1989 | 326,850                                 |                                      | 134,994                                |                                     | 138,694                                |                                     | 65,892                                |                                    |   |
| 1990 | 434,856                                 | 381.2                                | 188,042                                | 167.9                               | 161,651                                | 161.2                               | 78,877                                | 67.3                               |   |
| 1991 | 382,043                                 | 378.6                                | 180,690                                | 186.6                               | 183,388                                | 169.6                               | 57,187                                | 64.6                               |   |
| 1992 | 318,787                                 | 363.5                                | 191,039                                | 197.0                               | 163,842                                | 160.1                               | 57,625                                | 57.2                               |   |
| 1993 | 389,523                                 | 367.9                                | 219,414                                | 217.5                               | 133,069                                | 146.6                               | 56,793                                | 57.4                               |   |
| 1994 | 395,500                                 | 362.6                                | 241,900                                | 235.5                               | 142,768                                | 145.5                               | 57,718                                | 51.1                               |   |
| 1995 | 302,800                                 | 355.2                                | 245,200                                | 254.7                               | 160,797                                | 171.1                               | 38,735                                | 45.9                               |   |
| 1996 | 367,200                                 | 360.3                                | 277,000                                | 279.9                               | 209,710                                | 188.1                               | 41,217                                | 43.0                               |   |
| 1997 | 411,000                                 | 372.7                                | 317,379                                | 298.8                               | 193,806                                | 193.2                               | 49,065                                | 44.2                               |   |
| 1998 | 340,000                                 | 351.7                                | 302,100                                | 313.2                               | 176,148                                | 189.0                               | 42,223                                | 44.3                               |   |
| 1999 | 304,000                                 | 315.3                                | 320,000                                | 316.0                               | 197,000                                | 184.7                               | 41,702                                | 39.8                               |   |
| 2000 | 302,000                                 | 300.7                                | 326,000                                | 336.7                               | 181,000                                | 185.0                               | 35,398                                | 33.2                               |   |
| 2001 | 296,000                                 | 346.3                                | 364,000                                | 330.5                               | 177,000                                | 168.9                               | 22,400                                | 30.9                               |   |
| 2002 | 440,883                                 | 371.7                                | 301,498                                | 328.5                               | 148,847                                | 174.3                               | 34,987                                | 29.1                               |   |
| 2003 | 378,340                                 | 348.4                                | 319,977                                | 292.4                               | 197,182                                | 180.7                               | 29,934                                | 30.9                               |   |
| 2004 | 226,082                                 | 290.1                                | 255,860                                | 289.6                               | 196,000                                | 187.1                               | 27,845                                | 29.3                               |   |
| 2005 | 266,000                                 |                                      | 293,000                                |                                     | 168,000                                |                                     | 30,000                                |                                    |   |

Source: Statistics New Zealand.

Estimates provided by MAF for 1998, 1999, 2000, 2001, 2004 and 2005

**N-fixing crop yields in New Zealand Revised 2004**

**Agricultural sector calculations: emissions from field burning and agricultural soils**

|      | Processed<br>peas prodn <sup>1,3</sup><br>(jun yr)<br>(tonnes dry weight) | Peas<br>prodn <sup>2,3</sup><br>(jun yr)<br>(tonnes) | Peas<br>Processed <sup>3</sup><br>and<br>(tonnes DW) | Peas<br>prodn<br>(3 yr av)<br>(Gg) | Lentils<br>prodn <sup>3</sup><br>(jun yr)<br>(tonnes) | Lentils<br>prodn<br>(3 yr av)<br>(Gg) | N-fixing<br>crops<br>(3 yr av)<br>(kg) |
|------|---|--|--|------------------------------------|---|---------------------------------------|--|
| 1989 | 24,000  | 47,308   | 71,308   |                                    | 3,386   |                                       |  |
| 1990 | 24,000  | 57,378   | 81,378   | 80.6                               | 3,386   | 3.4                                   | 83,969,333                             |
| 1991 | 24,000  | 65,064   | 89,064   | 89.9                               | 3,386   | 4.0                                   | 93,902,667                             |
| 1992 | 24,000  | 75,290   | 99,290   | 91.9                               | 5,204   | 4.5                                   | 96,410,000                             |
| 1993 | 24,000  | 63,268   | 87,268   | 90.2                               | 5,018   | 4.3                                   | 94,463,333                             |
| 1994 | 24,000  | 59,898   | 83,898   | 83.9                               | 2,712   | 2.9                                   | 86,755,667                             |
| 1995 | 24,000  | 56,448   | 80,448   | 79.6                               | 923   | 1.5                                   | 81,080,333                             |
| 1996 | 24,000  | 50,337   | 74,337   | 76.5                               | 923   | 0.9                                   | 77,397,000                             |
| 1997 | 24,300  | 50,337   | 74,637   | 82.1                               | 923   | 0.9                                   | 83,053,333                             |
| 1998 | 31,200  | 66,200   | 97,400   | 86.1                               | 940   | 0.6                                   | 86,766,667                             |
| 1999 | 34,200  | 52,200   | 86,400   | 94.6                               | 0   | 0.3                                   | 84,913,333                             |
| 2000 | 36,000  | 64,000   | 100,000  | 86.7                               | 0   | 0.0                                   | 86,700,000                             |
| 2001 | 36,000  | 37,700   | 73,700   | 79.7                               | 0   | 1.1                                   | 80,819,667                             |
| 2002 | 36,000  | 29,457   | 65,457   | 67.2                               | 3,302   | 1.8                                   | 68,953,000                             |
| 2003 | 31,200  | 31,200   | 62,400   | 61.6                               | 2,000   | 2.4340                                | 64,053,000                             |
| 2004 | 28,500  | 28,500   | 57,000   | 59.8                               | 2,000   | 2.0000                                | 61,800,000                             |
| 2005 | 28,500  | 31,500   | 60,000   |                                    | 2,000   |                                       |  |

<sup>1</sup> MAF estimate. Zero has been entered when production negligible.

<sup>2</sup> Statistics New Zealand. 1998, 1999, 2000, 2001 estimates provided by MAF.

Production pea data for 2003 calculated from area in peas.

<sup>3</sup> MAF estimates for 2004 and 2005

**Miscellaneous agricultural data Revised 2004**

**Agricultural sector calculations: emissions from agricultural soils**

|      | Cultivated<br>organic<br>soils (ha) <sup>1</sup><br>(jun yr) | Cultivated<br>organic<br>soils (ha)<br>(3 yr av) | Synthetic<br>fertiliser<br>use (kg N) <sup>2</sup><br>(jun yr) | Synthetic<br>fertiliser<br>use (kg N)<br>(3 yr av) |
|------|--|--|--|--|
| 1989 | 10,109   |  | 51,663,000   |  |
| 1990 | 10,109   | 10,109   | 59,265,000   | 57,540,667   |
| 1991 | 10,109   | 10,109   | 61,694,000   | 63,693,667   |
| 1992 | 10,109   | 10,109   | 70,122,000   | 78,637,000   |
| 1993 | 10,109   | 10,109   | 104,095,000  | 99,449,333   |
| 1994 | 10,109   | 10,109   | 124,131,000  | 126,496,333  |
| 1995 | 10,109   | 10,109   | 151,263,000  | 143,058,000  |
| 1996 | 10,109   | 10,109   | 153,780,000  | 149,446,000  |
| 1997 | 10,109   | 10,109   | 143,295,000  | 150,847,333  |
| 1998 | 10,109   | 10,109   | 155,467,000  | 155,193,667  |
| 1999 | 10,109   | 10,109   | 166,819,000  | 170,460,667  |
| 2000 | 10,109   | 10,109   | 189,096,000  | 201,305,000  |
| 2001 | 10,109   | 10,109   | 248,000,000  | 248,765,333  |
| 2002 | 10,109   | 10,109   | 309,200,000  | 298,200,000  |
| 2003 | 10,109   | 10,109   | 337,400,000  | 331,533,333  |
| 2004 | 10,109   | 10,109   | 348,000,000  | 345,240,000  |
| 2005 | 10,109   |  | 350,320,000  |  |

<sup>1</sup> MAF estimate 2003

<sup>2</sup> Best estimate from MAF and sales records obtained by FertResearch

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Field burning of agricultural residues  
**Worksheet** 4.4 (1 and 2 of 3)  
**Sheet** Calculation of carbon and nitrogen releases

| Crops    | Production<br>(3 yr av)<br>(Gg crop) | Residue<br>to crop<br>ratio | Quantity<br>of residue<br>(Gg biomass) | Dry<br>matter<br>fraction | Quantity of<br>dry residue<br>(Gg dm) | Fraction<br>burned in<br>fields <sup>1</sup> | Fraction<br>oxidised | Biomass<br>burned<br>(Gg dm) | Carbon<br>fraction<br>of residue | Carbon<br>released<br>(Gg C) | Nitrogen-<br>carbon<br>ratio | Nitrogen<br>released<br>(Gg N) |
|----------|--------------------------------------|-----------------------------|--|---------------------------|---------------------------------------|--|----------------------|------------------------------|----------------------------------|------------------------------|------------------------------|--------------------------------|
| Cereals  | 609.0                                |                             | 762.7                                  |                           | 636.5                                 |  |                      | 171.8                        |                                  | 80.895                       |                              | 1.091                          |
| a Barley | 290.1                                | 1.2                         | 348.2                                  | 0.83                      | 289.0                                 | 0.3  | 0.9                  | 78.0                         | 0.4567                           | 35.634                       | 0.015                        | 0.535                          |
| b Wheat  | 289.6                                | 1.3                         | 376.5                                  | 0.83                      | 312.5                                 | 0.3  | 0.9                  | 84.4                         | 0.4853                           | 40.946                       | 0.012                        | 0.491                          |
| c Oats   | 29.3                                 | 1.3                         | 38.0                                   | 0.92                      | 35.0                                  | 0.3  | 0.9                  | 9.4                          | 0.4567                           | 4.315                        | 0.015                        | 0.065                          |

<sup>1</sup> Ministry of Agriculture and Forestry.

Maize no longer included in calculation as no maize residue burning occurs - MAF 2003

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Field burning of agricultural residues  
**Worksheet** 4.4 (3 of 3)  
**Sheet** Total non-CO<sub>2</sub> trace gas emissions from cereals

|                  | Emission<br>ratio to C or N | Emissions<br>(Gg C or N) | Conversion<br>ratio | Emissions<br>(Gg of gas) |
|------------------|-----------------------------|--------------------------|---------------------|--------------------------|
| CH <sub>4</sub>  | 0.005                       | 0.404                    | 1.333               | 0.539                    |
| CO               | 0.060                       | 4.854                    | 2.333               | 11.325                   |
| N <sub>2</sub> O | 0.007                       | 0.008                    | 1.571               | 0.012                    |
| NO <sub>x</sub>  | 0.121                       | 0.132                    | 3.286               | 0.434                    |

**Module** 2004 Agriculture (New Zealand)  
**Submodule** Field burning of agricultural residues  
**Worksheet** 4.4 (supplementary)  
**Sheet** Calculation of carbon and nitrogen releases per crop type

| Crops    | Emissions<br>of<br>CH <sub>4</sub> (Gg) | Emissions<br>of<br>CO (Gg) | Emissions<br>of<br>N <sub>2</sub> O (Gg) | Emissions<br>of<br>NO <sub>x</sub> (Gg) |
|----------|---|----------------------------|--|---|
| Cereals  |   |                            |  |   |
| a Barley | 0.238                                   | 4.989                      | 0.006                                    | 0.213                                   |
| b Wheat  | 0.273                                   | 5.732                      | 0.005                                    | 0.195                                   |
| d Oats   | 0.029                                   | 0.604                      | 0.001                                    | 0.026                                   |

# A8.5 Worksheets for the LULUCF sector

Module Land-use change and forestry (New Zealand)  
 Submodule Changes in forest and other woody biomass stocks  
 Worksheet Equivalent to 5.1 (2 of 3)  
 Sheet Carbon release from harvesting in *Pinus radiata* plantations (temperate) and native forests

|      | Stem volume<br>in plantation<br>forest harvest <sup>1</sup><br>(merch. m <sup>3</sup> ) | Biomass<br>conversion<br>ratio <sup>2</sup><br>(t dm/m <sup>3</sup> ) | Dry matter<br>in stem <sup>1,3</sup><br>t C/t dm = 0.5<br>(t dm) | Carbon in<br>plantation<br>forest harvest <sup>1</sup><br>(t C) | Stem volume<br>in native<br>forest harvest<br>(merch. m <sup>3</sup> ) | Biomass<br>conversion<br>ratio<br>(t dm/m <sup>3</sup> ) | Biomass<br>expansion<br>ratio<br>(t dm/m <sup>3</sup> ) | Dry matter in<br>total native<br>forest harvest<br>(t dm) | Carbon in<br>native forest<br>harvest (t C)<br>t C/t dm = 0.5 | Carbon release<br>from total<br>forest harvest<br>(t C) |
|------|---|---|--|---|--|--|---|---|---|---|
| 1990 | 10,813,787  | 0.461   | 4,985,514  | 2,492,757   | 365,000  | 0.50   | 2.04  | 372,300   | 186,150   | 2,678,907   |
| 1991 | 11,797,488  | 0.461   | 5,439,033  | 2,719,516   | 307,667  | 0.50   | 2.04  | 313,820   | 156,910   | 2,876,426   |
| 1992 | 12,500,583  | 0.461   | 5,763,183  | 2,881,591   | 257,333  | 0.50   | 2.04  | 262,480   | 131,240   | 3,012,831   |
| 1993 | 13,232,522  | 0.461   | 6,100,631  | 3,050,316   | 205,000  | 0.50   | 2.04  | 209,100   | 104,550   | 3,154,866   |
| 1994 | 13,987,203  | 0.461   | 6,448,564  | 3,224,282   | 158,000  | 0.50   | 2.04  | 161,160   | 80,580  | 3,304,862   |
| 1995 | 14,700,793  | 0.461   | 6,777,553  | 3,388,776   | 107,333  | 0.50   | 2.04  | 109,480   | 54,740  | 3,443,516   |
| 1996 | 15,214,390  | 0.461   | 7,014,338  | 3,507,169   | 50,000   | 0.50   | 2.04  | 51,000  | 25,500  | 3,532,669   |
| 1997 | 15,202,118  | 0.461   | 7,008,681  | 3,504,340   | 56,667   | 0.50   | 2.04  | 57,800  | 28,900  | 3,533,240   |
| 1998 | 15,746,397  | 0.461   | 7,259,611  | 3,629,806   | 57,667   | 0.50   | 2.04  | 58,820  | 29,410  | 3,659,216   |
| 1999 | 16,672,535  | 0.461   | 7,686,591  | 3,843,296   | 57,000   | 0.50   | 2.04  | 58,140  | 29,070  | 3,872,366   |
| 2000 | 18,228,284  | 0.461   | 8,403,843  | 4,201,922   | 38,333   | 0.50   | 2.04  | 39,100  | 19,550  | 4,221,472   |
| 2001 | 19,711,404  | 0.461   | 9,087,610  | 4,543,805   | 23,000   | 0.50   | 2.04  | 23,460  | 11,730  | 4,555,535   |
| 2002 | 20,419,021  | 0.461   | 9,413,846  | 4,706,923   | 16,667   | 0.50   | 2.04  | 17,000  | 8,500   | 4,715,423   |
| 2003 | 20,106,098  | 0.461   | 9,269,577  | 4,634,789   | 9,667  | 0.50   | 2.04  | 9,860   | 4,930   | 4,639,719   |
| 2004 | 19,133,626  | 0.462   | 8,843,636  | 4,421,818   | 7,667  | 0.50   | 2.04  | 7,820   | 3,910   | 4,425,728   |

Module Land-use change and forestry (New Zealand)  
 Submodule Changes in forest and other woody biomass stocks  
 Worksheet Equivalent to 5.1 (1 of 3)  
 Sheet Carbon uptake in *Pinus radiata* plantations (temperate)

|      | Total forest<br>estate area<br>(net of harvest)<br>(ha) | Total Forest<br>estate carbon<br>(net of harvest)<br>(t C) | Forest estate<br>carbon uptake<br>(net of harvest)<br>(t C) | Forest Estate<br>Crop uptake<br>(before harvest)<br>(t C) | Forest Estate<br>Shrub uptake<br>(before harvest)<br>(t C) | Forest Estate<br>DOM* uptake<br>(before harvest)<br>(t C) | Carbon in<br>plantation<br>forest harvest<br>(t C) | Total forest<br>carbon uptake<br>(before harvest)<br>(t C) |
|------|---|--|---|---|--|---|--|--|
| 1990 | 1,184,884   | 112,041,802  | 5,811,122   | 6,498,460   | 101,754  | 1,703,666   | 2,492,757  | 8,303,880  |
| 1991 | 1,211,537   | 117,564,626  | 5,522,825   | 6,581,928   | 99,189   | 1,561,224   | 2,719,516  | 8,242,341  |
| 1992 | 1,250,219   | 122,795,595  | 5,230,968   | 6,609,125   | 96,645   | 1,406,790   | 2,881,591  | 8,112,560  |
| 1993 | 1,312,586   | 127,875,773  | 5,080,178   | 6,687,033   | 96,750   | 1,346,712   | 3,050,316  | 8,130,494  |
| 1994 | 1,388,015   | 132,923,040  | 5,047,267   | 6,791,309   | 98,162   | 1,382,078   | 3,224,282  | 8,271,549  |
| 1995 | 1,471,062   | 137,973,594  | 5,050,553   | 6,971,401   | 100,456  | 1,367,473   | 3,388,776  | 8,439,330  |
| 1996 | 1,547,997   | 143,149,902  | 5,176,308   | 7,224,150   | 104,327  | 1,355,001   | 3,507,169  | 8,683,477  |
| 1997 | 1,618,343   | 148,719,074  | 5,569,172   | 7,585,467   | 110,398  | 1,377,647   | 3,504,340  | 9,073,512  |
| 1998 | 1,675,967   | 154,599,528  | 5,880,454   | 8,054,681   | 121,234  | 1,334,344   | 3,629,806  | 9,510,260  |
| 1999 | 1,722,793   | 160,733,279  | 6,133,751   | 8,448,682   | 126,144  | 1,402,221   | 3,843,296  | 9,977,047  |
| 2000 | 1,761,242   | 166,945,582  | 6,212,302   | 8,784,702   | 127,029  | 1,502,493   | 4,201,922  | 10,414,224   |
| 2001 | 1,794,483   | 173,288,966  | 6,343,385   | 8,978,906   | 120,781  | 1,787,503   | 4,543,805  | 10,887,190   |
| 2002 | 1,823,075   | 179,708,653  | 6,419,686   | 9,146,109   | 115,437  | 1,865,062   | 4,706,923  | 11,126,609   |
| 2003 | 1,847,130   | 186,510,386  | 6,801,733   | 9,388,698   | 115,706  | 1,932,118   | 4,634,789  | 11,436,522   |
| 2004 | 1,865,374   | 193,674,595  | 7,164,209   | 9,751,426   | 126,510  | 1,708,091   | 4,421,818  | 11,586,027   |

Module Land-use change and forestry (New Zealand)  
 Submodule Changes in forest and other woody biomass stocks  
 Worksheet Equivalent of 5.1 (3 of 3)  
 Sheet Net Carbon uptake in forest

|      | Total forest<br>carbon uptake<br>(before harvest)<br>(Gg C) | Carbon release<br>from total<br>forest harvest<br>(Gg C) | Carbon uptake<br>from Crop<br>(before harvest)<br>(Gg C) | Carbon uptake<br>from shrub<br>(before harvest)<br>(Gg C) | Carbon uptake<br>dead matter<br>(before harvest)<br>(Gg C) | Net carbon<br>uptake in<br>forests<br>(Gg C) | Net CO2<br>uptake in<br>forests<br>(Gg CO2) |
|------|---|--|--|---|--|--|---|
| 1990 | 8,304   | 2,679  | 6,498  | 102   | 1,704  | 5,625  | 20,625                                      |
| 1991 | 8,242   | 2,876  | 6,582  | 99  | 1,561  | 5,366  | 19,675                                      |
| 1992 | 8,113   | 3,013  | 6,609  | 97  | 1,407  | 5,100  | 18,699                                      |
| 1993 | 8,130   | 3,155  | 6,687  | 97  | 1,347  | 4,976  | 18,244                                      |
| 1994 | 8,272   | 3,305  | 6,791  | 98  | 1,382  | 4,967  | 18,211                                      |
| 1995 | 8,439   | 3,444  | 6,971  | 100   | 1,367  | 4,996  | 18,318                                      |
| 1996 | 8,683   | 3,533  | 7,224  | 104   | 1,355  | 5,151  | 18,886                                      |
| 1997 | 9,074   | 3,533  | 7,585  | 110   | 1,378  | 5,540  | 20,314                                      |
| 1998 | 9,510   | 3,659  | 8,055  | 121   | 1,334  | 5,851  | 21,454                                      |
| 1999 | 9,977   | 3,872  | 8,449  | 126   | 1,402  | 6,105  | 22,384                                      |
| 2000 | 10,414  | 4,221  | 8,785  | 127   | 1,502  | 6,193  | 22,707                                      |
| 2001 | 10,887  | 4,556  | 8,979  | 121   | 1,788  | 6,332  | 23,216                                      |
| 2002 | 11,127  | 4,715  | 9,146  | 115   | 1,865  | 6,411  | 23,508                                      |
| 2003 | 11,437  | 4,640  | 9,389  | 116   | 1,932  | 6,797  | 24,922                                      |
| 2004 | 11,586  | 4,426  | 9,751  | 127   | 1,708  | 7,160  | 26,254                                      |

Module Land-use change and forestry (New Zealand)  
 Submodule Land converted to forest  
 Worksheet  
 Sheet Carbon release from grasland (woody vegetation) cleared for new forest planting

|      | Grassland cleared for forest planting <sup>1</sup><br>(ha) | Clearance where scrub is burned <sup>2</sup><br>(25% of total)<br>(ha) | Quantity of biomass burned<br>(t dm/ha = 136)<br>(t dm) | Oxidised biomass<br>(90% of total)<br>(t dm) | C release from burning scrub<br>(t C/t dm = 0.5)<br>(t C) | CO2 release from burning for new planting<br>(t CO2) | Clearance where scrub decays <sup>2</sup><br>(75% of total)<br>(ha) | Initial quantity of biomass to decay <sup>3</sup><br>(t dm/ha = 136)<br>(t dm) | Added biomass left to decay after fire<br>(10 %)<br>(t dm) | C release from decay over period<br>(t C/t dm = 0.5)<br>(t C) | CO2 release from decay for new planting<br>(t CO2) |
|------|--|--|---|--|---|--|---|--|--|---|--|
| 1990 | 3,885  | 971  | 132,106   | 118,895                                      | 59,448  | 217,975  | 2,914   | 396,318  | 0  | 198,159   | 726,582  |
| 1991 | 3,579  | 895  | 121,679   | 109,511                                      | 54,756  | 200,771  | 2,684   | 365,038  | 0  | 182,519   | 669,236  |
| 1992 | 5,427  | 1,357  | 184,507   | 166,056                                      | 83,028  | 304,436  | 4,070   | 553,520  | 0  | 276,760   | 1,014,787  |
| 1993 | 6,784  | 1,696  | 230,656   | 207,590                                      | 103,795   | 380,582  | 5,088   | 691,968  | 0  | 345,984   | 1,268,608  |
| 1994 | 11,200   | 2,800  | 380,800   | 342,720                                      | 171,360   | 628,320  | 8,400   | 1,142,400  | 0  | 571,200   | 2,094,400  |
| 1995 | 8,569  | 2,142  | 291,346   | 262,211                                      | 131,106   | 480,721  | 6,427   | 874,038  | 0  | 437,019   | 1,602,403  |
| 1996 | 11,933   | 2,983  | 405,711   | 365,140                                      | 182,570   | 669,423  | 8,950   | 1,217,132  | 0  | 608,566   | 2,231,409  |
| 1997 | 10,323   | 2,581  | 350,971   | 315,874                                      | 157,937   | 579,102  | 7,742   | 1,052,912  | 0  | 526,456   | 1,930,339  |
| 1998 | 5,955  | 1,489  | 202,470   | 182,223                                      | 91,112  | 334,076  | 4,466   | 607,410  | 0  | 303,705   | 1,113,585  |
| 1999 | 7,229  | 1,807  | 245,775   | 221,197                                      | 110,599   | 405,528  | 5,422   | 737,324  | 0  | 368,662   | 1,351,761  |
| 2000 | 7,072  | 1,768  | 240,448   | 216,403                                      | 108,202   | 396,739  | 5,304   | 721,344  | 0  | 360,672   | 1,322,464  |
| 2001 | 7,950  | 1,988  | 270,311   | 243,280                                      | 121,640   | 446,014  | 5,963   | 810,934  | 0  | 405,467   | 1,486,712  |
| 2002 | 5,720  | 1,430  | 194,480   | 175,032                                      | 87,516  | 320,892  | 4,290   | 583,440  | 0  | 291,720   | 1,069,640  |
| 2003 | 6,249  | 1,562  | 212,455   | 191,209                                      | 95,605  | 350,550  | 4,687   | 637,364  | 0  | 318,682   | 1,168,501  |
| 2004 | 4,559  | 1,140  | 154,995   | 139,495                                      | 69,748  | 255,741  | 3,419   | 464,984  | 0  | 232,492   | 852,471  |

Module Land-use change and forestry (New Zealand)  
 Submodule Grassland remaining grassland/forest land remaining forest land  
 Worksheet  
 Sheet Carbon release from wildfires

|      | Area of grassland burned in wildfires <sup>1</sup><br>(ha) | Quantity of biomass burned<br>(t dm/ha = 136)<br>(t dm) | Oxidised biomass<br>(90% of total)<br>(t dm) | C release from scrub wildfires<br>(t C/t dm = 0.5)<br>(t C) | Area of Forest burned in wildfires <sup>1</sup><br>(ha) | Quantity of biomass burned<br>(t dm/ha = 364)<br>(t dm) | Oxidised biomass<br>(90 % of total)<br>(t dm) | C release from forest wildfires<br>(t C/t dm = 0.5)<br>(t C) |
|------|--|---|--|---|---|---|---|--|
| 1990 | 2,564  | 348,738   | 313,864                                      | 156,932   | 323   | 117,663   | 105,897                                       | 52,948   |
| 1991 | 2,064  | 280,659   | 252,593                                      | 126,296   | 207   | 75,318  | 67,786  | 33,893   |
| 1992 | 1,954  | 265,744   | 239,170                                      | 119,585   | 165   | 60,151  | 54,136  | 27,068   |
| 1993 | 2,330  | 316,812   | 285,131                                      | 142,565   | 239   | 86,814  | 78,133  | 39,066   |
| 1994 | 2,529  | 343,978   | 309,580                                      | 154,790   | 314   | 114,266   | 102,839                                       | 51,420   |
| 1995 | 2,645  | 359,765   | 323,789                                      | 161,894   | 472   | 171,929   | 154,736                                       | 77,368   |
| 1996 | 2,532  | 344,318   | 309,886                                      | 154,943   | 727   | 264,598   | 238,138                                       | 119,069  |
| 1997 | 3,320  | 451,565   | 406,409                                      | 203,204   | 762   | 277,520   | 249,768                                       | 124,884  |
| 1998 | 3,268  | 444,391   | 399,952                                      | 199,976   | 692   | 251,949   | 226,754                                       | 113,377  |
| 1999 | 3,049  | 414,709   | 373,238                                      | 186,619   | 403   | 146,571   | 131,914                                       | 65,957   |
| 2000 | 2,119  | 288,184   | 259,366                                      | 129,683   | 334   | 121,576   | 109,418                                       | 54,709   |
| 2001 | 1,954  | 265,789   | 239,210                                      | 119,605   | 282   | 102,648   | 92,383  | 46,192   |
| 2002 | 2,165  | 294,440   | 264,996                                      | 132,498   | 283   | 102,891   | 92,602  | 46,301   |
| 2003 | 2,030  | 276,080   | 248,472                                      | 124,236   | 284   | 103,255   | 92,929  | 46,465   |
| 2004 | 1,898  | 258,098   | 232,288                                      | 116,144   | 285   | 103,740   | 93,366  | 46,683   |

**Module** Land-use change and forestry (New Zealand)  
**Submodule** Forest land remaining forest land  
**Worksheet**  
**Sheet** Non-CO2 emissions from the on-site burning of forests

|      | Carbon release by on-site burning (t C) | Nitrogen released (t N/t c = 0.01) (t C) | Carbon in CH <sub>4</sub> emissions (ratio = 0.012) (t C) | Nitrogen in N <sub>2</sub> O emissions (ratio = 0.007) (t N) | Nitrogen in NO <sub>x</sub> emissions (ratio = 0.121) (t N) | Carbon in CO emissions (ratio = 0.06) (t C) | CH <sub>4</sub> emissions from burning (ratio = 1.333) (Gg CH <sub>4</sub> ) | N <sub>2</sub> O emissions from burning (ratio = 1.571) (Gg N <sub>2</sub> O) | NO <sub>x</sub> emissions from burning (ratio = 3.286) (Gg NO <sub>x</sub> ) | CO emissions from burning (ratio = 2.333) (Gg CO) |
|------|---|--|---|--|---|---|--|---|--|---|
| 1990 | 52,948                                  | 529                                      | 635   | 4  | 64  | 3,177                                       | 0.847  | 0.006   | 0.211  | 7.412   |
| 1991 | 33,893                                  | 339                                      | 407   | 2  | 41  | 2,034                                       | 0.542  | 0.004   | 0.135  | 4.744   |
| 1992 | 27,068                                  | 271                                      | 325   | 2  | 33  | 1,624                                       | 0.433  | 0.003   | 0.108  | 3.789   |
| 1993 | 39,066                                  | 391                                      | 469   | 3  | 47  | 2,344                                       | 0.625  | 0.004   | 0.155  | 5.469   |
| 1994 | 51,420                                  | 514                                      | 617   | 4  | 62  | 3,085                                       | 0.823  | 0.006   | 0.204  | 7.198   |
| 1995 | 77,368                                  | 774                                      | 928   | 5  | 94  | 4,642                                       | 1.238  | 0.009   | 0.308  | 10.830  |
| 1996 | 119,069                                 | 1,191                                    | 1,429   | 8  | 144   | 7,144                                       | 1.905  | 0.013   | 0.473  | 16.667  |
| 1997 | 124,884                                 | 1,249                                    | 1,499   | 9  | 151   | 7,493                                       | 1.998  | 0.014   | 0.497  | 17.481  |
| 1998 | 113,377                                 | 1,134                                    | 1,361   | 8  | 137   | 6,803                                       | 1.814  | 0.012   | 0.451  | 15.870  |
| 1999 | 65,957                                  | 660                                      | 791   | 5  | 80  | 3,957                                       | 1.055  | 0.007   | 0.262  | 9.233   |
| 2000 | 54,709                                  | 547                                      | 657   | 4  | 66  | 3,283                                       | 0.875  | 0.006   | 0.218  | 7.658   |
| 2001 | 46,192                                  | 462                                      | 554   | 3  | 56  | 2,771                                       | 0.739  | 0.005   | 0.184  | 6.466   |
| 2002 | 46,301                                  | 463                                      | 556   | 3  | 56  | 2,778                                       | 0.741  | 0.005   | 0.184  | 6.481   |
| 2003 | 46,465                                  | 465                                      | 558   | 3  | 56  | 2,788                                       | 0.743  | 0.005   | 0.185  | 6.504   |
| 2004 | 46,683                                  | 467                                      | 560   | 3  | 56  | 2,801                                       | 0.747  | 0.005   | 0.186  | 6.535   |

**Module** Land-use change and forestry (New Zealand)  
**Submodule** Grassland remaining grassland  
**Worksheet**  
**Sheet** Non-CO2 emissions from the on-site burning of scrub - WILDFIRE ONLY

|      | Carbon release by on-site burning (t C) | Nitrogen released (t N/t c = 0.01) (t C) | Carbon in CH <sub>4</sub> emissions (ratio = 0.012) (t C) | Nitrogen in N <sub>2</sub> O emissions (ratio = 0.007) (t N) | Nitrogen in NO <sub>x</sub> emissions (ratio = 0.121) (t N) | Carbon in CO emissions (ratio = 0.06) (t C) | CH <sub>4</sub> emissions from burning (ratio = 1.333) (Gg CH <sub>4</sub> ) | N <sub>2</sub> O emissions from burning (ratio = 1.571) (Gg N <sub>2</sub> O) | NO <sub>x</sub> emissions from burning (ratio = 3.286) (Gg NO <sub>x</sub> ) | CO emissions from burning (ratio = 2.333) (Gg CO) |
|------|---|--|---|--|---|---|--|---|--|---|
| 1990 | 156,932                                 | 1,569                                    | 1,883   | 11   | 190   | 9,416                                       | 2,510  | 0.017   | 0.624  | 21.967  |
| 1991 | 126,296                                 | 1,263                                    | 1,516   | 9  | 153   | 7,578                                       | 2,020  | 0.014   | 0.502  | 17.679  |
| 1992 | 119,585                                 | 1,196                                    | 1,435   | 8  | 145   | 7,175                                       | 1,913  | 0.013   | 0.475  | 16.739  |
| 1993 | 142,565                                 | 1,426                                    | 1,711   | 10   | 173   | 8,554                                       | 2,280  | 0.016   | 0.567  | 19.956  |
| 1994 | 154,790                                 | 1,548                                    | 1,857   | 11   | 187   | 9,287                                       | 2,476  | 0.017   | 0.615  | 21.668  |
| 1995 | 161,894                                 | 1,619                                    | 1,943   | 11   | 196   | 9,714                                       | 2,590  | 0.018   | 0.644  | 22.662  |
| 1996 | 154,943                                 | 1,549                                    | 1,859   | 11   | 187   | 9,297                                       | 2,478  | 0.017   | 0.616  | 21.689  |
| 1997 | 203,204                                 | 2,032                                    | 2,438   | 14   | 246   | 12,192                                      | 3,250  | 0.022   | 0.808  | 28.445  |
| 1998 | 199,976                                 | 2,000                                    | 2,400   | 14   | 242   | 11,999                                      | 3,199  | 0.022   | 0.795  | 27.993  |
| 1999 | 186,619                                 | 1,866                                    | 2,239   | 13   | 226   | 11,197                                      | 2,985  | 0.021   | 0.742  | 26.123  |
| 2000 | 129,683                                 | 1,297                                    | 1,556   | 9  | 157   | 7,781                                       | 2,074  | 0.014   | 0.516  | 18.153  |
| 2001 | 119,605                                 | 1,196                                    | 1,435   | 8  | 145   | 7,176                                       | 1,913  | 0.013   | 0.476  | 16.742  |
| 2002 | 132,498                                 | 1,325                                    | 1,590   | 9  | 160   | 7,950                                       | 2,119  | 0.015   | 0.527  | 18.547  |
| 2003 | 124,236                                 | 1,242                                    | 1,491   | 9  | 150   | 7,454                                       | 1,987  | 0.014   | 0.494  | 17.391  |
| 2004 | 116,144                                 | 1,161                                    | 1,394   | 8  | 141   | 6,969                                       | 1,858  | 0.013   | 0.462  | 16.258  |

Module Land-use change and forestry (New Zealand)  
 Submodule Grassland converted to forest land  
 Worksheet  
 Sheet Non-CO2 emissions from the on-site burning of scrub - CONTROLLED BURN ONLY

|      | Carbon release by on-site burning (t C) | Nitrogen released (t N/t c = 0.01) (t C) | Carbon in CH <sub>4</sub> emissions (ratio = 0.012) (t C) | Nitrogen in N <sub>2</sub> O emissions (ratio = 0.007) (t N) | Nitrogen in NO <sub>x</sub> emissions (ratio = 0.121) (t N) | Carbon in CO emissions (ratio = 0.06) (t C) | CH <sub>4</sub> emissions from burning (ratio = 1.333) Gg CH | N <sub>2</sub> O emissions from burning (ratio = 1.571) (Gg N <sub>2</sub> O) | NO <sub>x</sub> emissions from burning (ratio = 3.286) (Gg NO <sub>x</sub> ) | CO emissions from burning (ratio = 2.333) (Gg CO) |
|------|---|--|---|--|---|---|--|---|--|---|
| 1990 | 59,448                                  | 594                                      | 713   | 4  | 72  | 3,567                                       | 0.951  | 0.007   | 0.236  | 8,321   |
| 1991 | 54,756                                  | 548                                      | 657   | 4  | 66  | 3,285                                       | 0.876  | 0.006   | 0.218  | 7,665   |
| 1992 | 83,028                                  | 830                                      | 996   | 6  | 100   | 4,982                                       | 1.328  | 0.009   | 0.330  | 11,622  |
| 1993 | 103,795                                 | 1,038                                    | 1,246   | 7  | 126   | 6,228                                       | 1.660  | 0.011   | 0.413  | 14,529  |
| 1994 | 171,360                                 | 1,714                                    | 2,056   | 12   | 207   | 10,282                                      | 2,741  | 0.019   | 0.681  | 23,987  |
| 1995 | 131,106                                 | 1,311                                    | 1,573   | 9  | 159   | 7,866                                       | 2,097  | 0.014   | 0.521  | 18,352  |
| 1996 | 182,570                                 | 1,826                                    | 2,191   | 13   | 221   | 10,954                                      | 2,920  | 0.020   | 0.726  | 25,556  |
| 1997 | 157,937                                 | 1,579                                    | 1,895   | 11   | 191   | 9,476                                       | 2,526  | 0.017   | 0.628  | 22,108  |
| 1998 | 91,112                                  | 911                                      | 1,093   | 6  | 110   | 5,467                                       | 1,457  | 0.010   | 0.362  | 12,754  |
| 1999 | 110,599                                 | 1,106                                    | 1,327   | 8  | 134   | 6,636                                       | 1,769  | 0.012   | 0.440  | 15,482  |
| 2000 | 108,202                                 | 1,082                                    | 1,298   | 8  | 131   | 6,492                                       | 1,731  | 0.012   | 0.430  | 15,146  |
| 2001 | 121,640                                 | 1,216                                    | 1,460   | 9  | 147   | 7,298                                       | 1,946  | 0.013   | 0.484  | 17,027  |
| 2002 | 87,516                                  | 875                                      | 1,050   | 6  | 106   | 5,251                                       | 1,400  | 0.010   | 0.348  | 12,250  |
| 2003 | 95,605                                  | 956                                      | 1,147   | 7  | 116   | 5,736                                       | 1,529  | 0.011   | 0.380  | 13,383  |
| 2004 | 69,748                                  | 697                                      | 837   | 5  | 84  | 4,185                                       | 1,116  | 0.008   | 0.277  | 9,763   |

Module Land-use change and forestry (New Zealand)  
 Submodule Carbon emissions from liming soils

|      | Total annual amount of limestone (Mg) | Total annual amount of limestone (3 yr average) (Mg C) | Carbon conversion factor | Carbon emissions from liming (Mg C) | Emissions of CO <sub>2</sub> (Gg CO <sub>2</sub> ) |
|------|---------------------------------------|--|--------------------------|-------------------------------------|--|
| 1989 | 662,753                               |  |                          |                                     |  |
| 1990 | 817,127                               | 787,329  | 0.12                     | 94,479                              | 346  |
| 1991 | 882,107                               | 882,107  | 0.12                     | 105,853                             | 388  |
| 1992 | 947,087                               | 951,619  | 0.12                     | 114,194                             | 419  |
| 1993 | 1,025,662                             | 1,033,210  | 0.12                     | 123,985                             | 455  |
| 1994 | 1,126,880                             | 1,126,880  | 0.12                     | 135,226                             | 496  |
| 1995 | 1,228,097                             | 1,152,047  | 0.12                     | 138,246                             | 507  |
| 1996 | 1,101,163                             | 1,180,840  | 0.12                     | 141,701                             | 520  |
| 1997 | 1,213,261                             | 1,213,261  | 0.12                     | 145,591                             | 534  |
| 1998 | 1,325,360                             | 1,325,360  | 0.12                     | 159,043                             | 583  |
| 1999 | 1,437,458                             | 1,437,458  | 0.12                     | 172,495                             | 632  |
| 2000 | 1,549,556                             | 1,549,556  | 0.12                     | 185,947                             | 682  |
| 2001 | 1,661,655                             | 1,661,655  | 0.12                     | 199,399                             | 731  |
| 2002 | 1,773,753                             | 1,666,600  | 0.12                     | 199,992                             | 733  |
| 2003 | 1,564,392                             | 1,634,179  | 0.12                     | 196,101                             | 719  |
| 2004 | 1,564,392                             | 1,564,392  | 0.12                     | 187,727                             | 688  |
| 2005 | 1,564,392                             |  |                          |                                     |  |

**Land use change matrix from 1997 to 2002 (based on the LCDB1 and LCDB2 data)**

|               |          | Land area categories from LCDB1 (1997) (kha) |          |         |          |          |          |         |         |          |           | Total    |
|---------------|----------|--|----------|---------|----------|----------|----------|---------|---------|----------|-----------|----------|
|               |          | FMp  | FMn      | CMa     | CMp      | GMh      | GMI      | WM      | WU      | S        | O         |          |
| LCDB2<br>2002 | FMp      | 1904.478                                     | 10.841   | 0.007   | 0.015    | 90.986   | 39.611   | 0.000   | 0.000   | 0.027    | 0.023     | 2045.988 |
|               | FMn      | 0.020  | 8182.228 | 0.000   | 0.000    | 0.281    | 0.005    | 0.000   | 0.000   | 0.031    | 0.033     | 8182.598 |
|               | CMa      | 0.000  | 0.003    | 333.590 | 0.000    | 0.119    | 0.000    | 0.000   | 0.000   | 0.000    | 0.006     | 333.719  |
|               | CMp      | 0.212  | 0.000    | 1.363   | 77.954   | 4.197    | 0.000    | 0.000   | 0.000   | 0.000    | 0.000     | 83.726   |
|               | GMh      | 0.132  | 0.928    | 0.000   | 0.000    | 8883.802 | 0.903    | 0.000   | 0.000   | 0.027    | 0.000     | 8885.793 |
|               | GMI      | 1.250  | 2.801    | 0.000   | 0.000    | 0.135    | 5475.786 | 0.000   | 0.000   | 0.034    | 0.213     | 5480.217 |
|               | WM       | 0.000  | 0.000    | 0.000   | 0.000    | 0.000    | 0.000    | 0.000   | 0.001   | 0.000    | 0.000     | 0.001    |
|               | WU       | 0.000  | 0.001    | 0.000   | 0.000    | 0.646    | 0.019    | 0.000   | 531.244 | 0.038    | 0.014     | 531.960  |
|               | S        | 0.544  | 0.019    | 0.000   | 0.023    | 5.006    | 0.026    | 0.000   | 0.000   | 214.844  | 0.000     | 220.462  |
|               | O        | 0.002  | 0.192    | 0.000   | 0.000    | 0.043    | 0.018    | 0.000   | 0.000   | 0.000    | 1056.841  | 1057.095 |
| Total         | 1906.638 | 8197.012                                     | 334.960  | 77.992  | 8985.215 | 5516.369 | 0.000    | 531.244 | 215.000 | 1057.129 | 26821.559 |          |
| Net           | 139.350  | -14.414                                      | -1.241   | 5.734   | -99.422  | -36.152  | 0.001    | 0.716   | 5.462   | -0.034   |           |          |

**Land use change matrix from 1997 to 1998 (an example showing interpolated annual changes)**

|       |          | Implied land use changes from 1997 to 1998 (kha) |          |         |          |          |          |         |         |          |           | Total    |
|-------|----------|--|----------|---------|----------|----------|----------|---------|---------|----------|-----------|----------|
|       |          | FMp  | FMn      | CMa     | CMp      | GMh      | GMI      | WM      | WU      | S        | O         |          |
| 1998  | FMp      | 1906.206   | 2.168    | 0.001   | 0.003    | 18.197   | 7.922    | 0.000   | 0.000   | 0.005    | 0.005     | 1934.508 |
|       | FMn      | 0.004  | 8194.055 | 0.000   | 0.000    | 0.056    | 0.001    | 0.000   | 0.000   | 0.006    | 0.007     | 8194.129 |
|       | CMa      | 0.000  | 0.001    | 334.686 | 0.000    | 0.024    | 0.000    | 0.000   | 0.000   | 0.000    | 0.001     | 334.712  |
|       | CMp      | 0.042  | 0.000    | 0.273   | 77.984   | 0.839    | 0.000    | 0.000   | 0.000   | 0.000    | 0.000     | 79.139   |
|       | GMh      | 0.026  | 0.186    | 0.000   | 0.000    | 8964.932 | 0.181    | 0.000   | 0.000   | 0.005    | 0.000     | 8965.330 |
|       | GMI      | 0.250  | 0.560    | 0.000   | 0.000    | 0.027    | 5508.252 | 0.000   | 0.000   | 0.007    | 0.043     | 5509.138 |
|       | WM       | 0.000  | 0.000    | 0.000   | 0.000    | 0.000    | 0.000    | 0.000   | 0.000   | 0.000    | 0.000     | 0.000    |
|       | WU       | 0.000  | 0.000    | 0.000   | 0.000    | 0.129    | 0.004    | 0.000   | 531.244 | 0.008    | 0.003     | 531.387  |
|       | S        | 0.109  | 0.004    | 0.000   | 0.005    | 1.001    | 0.005    | 0.000   | 0.000   | 214.969  | 0.000     | 216.093  |
|       | O        | 0.000  | 0.038    | 0.000   | 0.000    | 0.009    | 0.004    | 0.000   | 0.000   | 0.000    | 1057.071  | 1057.122 |
| total | 1906.638 | 8197.012   | 334.960  | 77.992  | 8985.215 | 5516.369 | 0.000    | 531.244 | 215.000 | 1057.129 | 26821.559 |          |
| net   | 27.870   | -2.883   | -0.248   | 1.147   | -19.884  | -7.230   | 0.000    | 0.143   | 1.092   | -0.007   |           |          |

**Land use change matrix from 2003 to 2004 (an example showing extrapolated annual changes)**

|       |          | Extrapolated land use changes from 2003 to 2004 (kha) |          |         |          |          |          |         |         |          |           | Total    |
|-------|----------|---|----------|---------|----------|----------|----------|---------|---------|----------|-----------|----------|
|       |          | FMp   | FMn      | CMa     | CMp      | GMh      | GMI      | WM      | WU      | S        | O         |          |
| 2004  | FMp      | 2073.426  | 2.168    | 0.001   | 0.003    | 18.197   | 7.922    | 0.000   | 0.000   | 0.005    | 0.005     | 2101.728 |
|       | FMn      | 0.004   | 8176.758 | 0.000   | 0.000    | 0.056    | 0.001    | 0.000   | 0.000   | 0.006    | 0.007     | 8176.832 |
|       | CMa      | 0.000   | 0.001    | 333.197 | 0.000    | 0.024    | 0.000    | 0.000   | 0.000   | 0.000    | 0.001     | 333.222  |
|       | CMp      | 0.042   | 0.000    | 0.273   | 84.865   | 0.839    | 0.000    | 0.000   | 0.000   | 0.000    | 0.000     | 86.019   |
|       | GMh      | 0.026   | 0.186    | 0.000   | 0.000    | 8845.626 | 0.181    | 0.000   | 0.000   | 0.005    | 0.000     | 8846.024 |
|       | GMI      | 0.250   | 0.560    | 0.000   | 0.000    | 0.027    | 5464.870 | 0.000   | 0.000   | 0.007    | 0.043     | 5465.756 |
|       | WM       | 0.000   | 0.000    | 0.000   | 0.000    | 0.000    | 0.000    | 0.001   | 0.000   | 0.000    | 0.000     | 0.001    |
|       | WU       | 0.000   | 0.000    | 0.000   | 0.000    | 0.129    | 0.004    | 0.000   | 532.104 | 0.008    | 0.003     | 532.247  |
|       | S        | 0.109   | 0.004    | 0.000   | 0.005    | 1.001    | 0.005    | 0.000   | 0.000   | 221.523  | 0.000     | 222.647  |
|       | O        | 0.000   | 0.038    | 0.000   | 0.000    | 0.009    | 0.004    | 0.000   | 0.000   | 0.000    | 1057.030  | 1057.081 |
| total | 2073.858 | 8179.715  | 333.471  | 84.872  | 8865.908 | 5472.987 | 0.001    | 532.104 | 221.555 | 1057.088 | 26821.559 |          |

## A8.6 Worksheets for the waste sector

Module 2004 Waste (New Zealand)  
 Submodule Methane emissions from solid waste disposal sites  
 Worksheet 6.1A (supplemental)

| Total population <sup>1</sup> | MSW generation rate <sup>2</sup><br>(kg/cap/day) | Annual MSW generated<br>(Gg/yr) | Fraction of MSW to SWDs | Total MSW to SWDSs<br>(Gg) |
|-------------------------------|--|---------------------------------|-------------------------|----------------------------|
| 4039400                       | 2.07   | 3045                            | 1.00                    | 3,045                      |

<sup>1</sup> Statistics New Zealand "100 years of population growth"

<sup>2</sup> Solid Waste Analysis Protocol (2003 results), Ministry for the Environment

Module 2004 Waste (New Zealand)  
 Submodule Methane emissions from solid waste disposal sites (tier 2)  
 Worksheet 6.1

| Year | Total annual MSW disposed to SWDs<br>(Gg MSW) | Methane generation potential<br>(L <sub>0</sub> ) | Methane Generation rate constant<br>(k) | Gross annual methane generation<br>(model output) | Total annual MSW disposed to SWDs with LFG systems<br>(Gg MSW) | Percentage of MSW with LFG systems<br>(%) | Estimated average LFG system collection efficiency<br>(%) | Recovered methane per year<br>(Gg CH <sub>4</sub> ) | Net methane generation<br>(Gg CH <sub>4</sub> ) | One minus oxidation correction factor | Net methane emissions<br>(Gg CH <sub>4</sub> ) |
|------|---|---|---|---|--|---|---|---|---|---------------------------------------|--|
| 1990 | 2,977   | 69.55   | 0.06                                    | 115.3   | 1050.1   | 35.80                                     | 0.00  | 0.00  | 115.3   | 0.9                                   | 103.8  |
| 1991 | 3,069   | 69.55   | 0.06                                    | 116.8   | 1089.3   | 35.72                                     | 0.00  | 0.00  | 116.8   | 0.9                                   | 105.1  |
| 1992 | 3,101   | 69.55   | 0.06                                    | 118.2   | 1138.9   | 36.95                                     | 0.09  | 3.53  | 114.7   | 0.9                                   | 103.2  |
| 1993 | 3,141   | 69.55   | 0.06                                    | 119.5   | 1230.6   | 39.47                                     | 0.09  | 3.95  | 115.5   | 0.9                                   | 104.0  |
| 1994 | 3,185   | 69.55   | 0.06                                    | 120.9   | 1410.2   | 44.64                                     | 0.10  | 6.59  | 114.3   | 0.9                                   | 102.9  |
| 1995 | 3,184   | 69.55   | 0.06                                    | 122.2   | 1511.1   | 47.13                                     | 0.23  | 18.46   | 103.7   | 0.9                                   | 93.4   |
| 1996 | 3,161   | 68.84   | 0.06                                    | 123.3   | 1649.3   | 50.64                                     | 0.23  | 19.16   | 104.1   | 0.9                                   | 93.7   |
| 1997 | 3,138   | 68.13   | 0.06                                    | 124.2   | 1842.5   | 55.84                                     | 0.28  | 21.11   | 103.1   | 0.9                                   | 92.8   |
| 1998 | 3,116   | 67.42   | 0.06                                    | 124.9   | 1827.1   | 54.89                                     | 0.33  | 25.32   | 99.6  | 0.9                                   | 89.7   |
| 1999 | 3,093   | 66.71   | 0.06                                    | 125.4   | 1911.2   | 57.09                                     | 0.40  | 32.88   | 92.5  | 0.9                                   | 83.3   |
| 2000 | 3,070   | 66.01   | 0.06                                    | 125.8   | 1939.2   | 59.58                                     | 0.38  | 32.56   | 93.2  | 0.9                                   | 83.9   |
| 2001 | 3,047   | 65.30   | 0.06                                    | 125.9   | 1915.3   | 60.55                                     | 0.39  | 35.87   | 90.0  | 0.9                                   | 81.0   |
| 2002 | 3,024   | 64.59   | 0.06                                    | 126.0   | 2013.9   | 65.10                                     | 0.42  | 39.13   | 86.9  | 0.9                                   | 78.2   |
| 2003 | 3,001   | 63.88   | 0.06                                    | 125.9   | 2117.1   | 69.88                                     | 0.42  | 41.21   | 84.7  | 0.9                                   | 76.2   |
| 2004 | 3,034   | 64.05   | 0.06                                    | 125.8   | 2192.9   | 71.44                                     | 0.44  | 46.00   | 79.8  | 0.9                                   | 71.9   |

Information in this table based on SCS Wetherill 2002, Solid Waste Analysis Protocol (2003 results), 2002 Landfill Review and Audit and Waste Management New Zealand 2005.

### 2004 Calculations of DOC and L<sub>0</sub>

#### New Zealand DOC Estimate Worksheet

| Waste category<br>(NZ WAP) | Waste Quantity<br>(tonnes) | Waste composition<br>(% by weight) | Fraction DOC<br>(by weight) |
|----------------------------|----------------------------|------------------------------------|-----------------------------|
| Paper                      | 386,697                    | 13                                 | 0.4                         |
| Plastic                    | 207,050                    | 7                                  | 0                           |
| Glass                      | 82,211                     | 3                                  | 0                           |
| Ferrous Metal              | 140,063                    | 5                                  | 0                           |
| Non ferr metal             | 33,493                     | 1                                  | 0                           |
| Organic                    | 752,080                    | 25                                 | 0.17                        |
| Rubble/concrete            | 496,312                    | 16                                 | 0                           |
| Timber                     | 380,607                    | 13                                 | 0.3                         |
| Rubber                     | 39,583                     | 1                                  | 0                           |
| Nappies/Sanitary           | 60,897                     | 2                                  | 0                           |
| Textiles                   | 115,705                    | 4                                  | 0                           |
| Pot Haz                    | 353,203                    | 12                                 | 0                           |
| Total                      | 3,044,857                  | 100                                |                             |

#### Methane Generation Potential Calculation by Using Waste Type Data in 2004

| Methane correction factor<br>(MCF) | Degradable organic carbon<br>(DOC) | Fraction of DOC dissimilated<br>(DOC <sub>r</sub> ) | Fraction by volume of CH <sub>4</sub> | Conversion from C to CH <sub>4</sub> | Methane Generation Potential<br>(L <sub>0</sub> ) | Methane Generation Potential<br>(L <sub>0</sub> ) |
|------------------------------------|------------------------------------|---|---------------------------------------|--------------------------------------|---|---|
| GgC/Gg waste                       |                                    |   | GgCH <sub>4</sub> /Gg waste           |                                      |   |   |
| 0.984                              | 0.1303                             | 0.50  | 0.50                                  | 1.3333                               | 0.0427  | 64.06   |

**Module** 2004 Waste (New Zealand)  
**Submodule** Methane emissions from domestic and commercial wastewater treatment  
**Worksheet** NZ 6.2  
**Sheet** Estimation of emission factor for wastewater handling systems

| Wastewater handling system <sup>1</sup> | Fraction of wastewater treated by the handling system <sup>1</sup> (percent) | Methane conversion factor for the handling system | Product | Maximum methane producing capacity (kg CH <sub>4</sub> /kg BOD B <sub>o</sub> ) | Emission factor for domestic/commercial wastewater (kg CH <sub>4</sub> /kg BOD) |
|---|--|---|---------|---|---|
| Anaerobic pond                          | 1.7  | 0.65  | 0.01105 | 0.375   | 0.00415   |
| Imhoff tank                             | 0.3  | 0.55  | 0.00186 | 0.375   | 0.00070   |
| Septic tank                             | 7.4  | 0.40  | 0.02974 | 0.375   | 0.01115   |
| Oxidation pond                          | 10.7   | 0.20  | 0.02131 | 0.375   | 0.00799   |
| Facultative aerated pd                  | 1.8  | 0.10  | 0.00181 | 0.375   | 0.00068   |
| Fully mixed aerated pd                  | 1.6  | 0   | 0       | 0.375   | 0   |
| Activated sludge                        | 31.2   | 0   | 0       | 0.375   | 0   |
| Other aerobic plant                     | 12.6   | 0   | 0       | 0.375   | 0   |
| Milliscreening <sup>2</sup>             | 24.0   | 0   | 0       | 0.375   | 0   |
| Aerobic <sup>3</sup>                    | 8.4  | 0.10  | 0.00836 | 0.375   | 0.00313   |
| Aggregate MCF                           |  |   |         |   | 0.0278  |

- 1 SCS Wetherill 2002  
2 Milliscreening or no treatment  
3 Methane from sludge

**Module** 2004 Waste (New Zealand)  
**Submodule** Methane emissions from domestic and commercial wastewater and sludge treatment  
**Worksheet** NZ 6.2  
**Sheet** Estimation of methane emissions from domestic/commercial wastewater and sludge

|                     | Total organic product <sup>1</sup> (kg BOD/yr) | Emission factor (kg CH <sub>4</sub> /kg BOD) | CH <sub>4</sub> emissions without recovery/ flaring (kg CH <sub>4</sub> /yr) | CH <sub>4</sub> recovered and/or flared <sup>2</sup> (kg CH <sub>4</sub> /yr) | Net CH <sub>4</sub> emissions (Gg CH <sub>4</sub> /yr) |
|---------------------|--|--|--|---|--|
| Wastewater          | 143,033,614                                    | 0.0278                                       | 3,976,137  | 0   | 4.0  |
| Sludge <sup>2</sup> |  |  |  |   | 0.0  |
| Total               |  |  |  |   | 4.0  |

- 1 SCS Wetherill 2002  
2 Almost all CH<sub>4</sub> generated from aerobic sludge handling is collected therefore does not contribute to methane emissions, thus emissions from sludge have not been estimated; after methane recovery net emissions of methane from sludge are zero.

**Module** 2004 Waste (New Zealand)  
**Submodule** Indirect nitrous oxide emissions from human sewage  
**Worksheet** 6.4 (adapted)

| Per capita wastewater N (kg/person/year) <sup>1</sup> | Total Population <sup>2</sup> | Emission factor (EF <sub>6</sub> ) (kg N <sub>2</sub> O-N/kg sewage-N produced) | Total N <sub>2</sub> O emissions (Gg) |
|---|-------------------------------|---|---------------------------------------|
| 4.75  | 4,083,900                     | 0.01  | <b>0.30</b>                           |

- <sup>1</sup> SCS Wetherill 2002  
<sup>2</sup> Statistics New Zealand.

**Module**            **2004 Waste (New Zealand)**  
**Submodule**       **Waste sector summary**

|                  | CH <sub>4</sub><br>(Gg/year) | N <sub>2</sub> O<br>(Gg/year) |
|------------------|------------------------------|-------------------------------|
| Solid waste      | 71.86                        |                               |
| Wastewater - dom | 3.98                         | 0.30                          |
| Wastewater - ind | 3.97                         | 0.23                          |
| Total            | 79.80                        | 0.54                          |

# Annex 9: Trend tables from the 2004 Common Reporting Format

SUMMARY 2 SUMMARY REPORT FOR CO<sub>2</sub> EQUIVALENT EMISSIONS  
(Sheet 1 of 1)

Inventory 2004  
Submission 2006 v2.1  
NEW ZEALAND

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES                        | CO <sub>2</sub> <sup>(1)</sup>   | CH <sub>4</sub>    | N <sub>2</sub> O   | HFCs <sup>(2)</sup> | PFCS <sup>(2)</sup> | SF <sub>6</sub> <sup>(2)</sup> | Total               |
|--|--|--------------------|--------------------|---------------------|---------------------|--------------------------------|---------------------|
|  | CO <sub>2</sub> equivalent (Gg)  |                    |                    |                     |                     |                                |                     |
| <b>Total (Net Emissions)<sup>(1)</sup></b>                       | <b>9,473.4954</b>  | <b>27,160.7968</b> | <b>13,264.9479</b> | <b>597.1317</b>     | <b>87.7000</b>      | <b>21.4861</b>                 | <b>50,605.5579</b>  |
| <b>1. Energy</b>   | <b>30,588.6023</b>   | <b>794.2531</b>    | <b>265.0518</b>    |                     |                     |                                | <b>31,647.9072</b>  |
| A. Fuel Combustion (Sectoral Approach)                           | 29,706.0778  | 95.0378            | 265.0518           |                     |                     |                                | 30,066.1674         |
| 1. Energy Industries   | 7,158.6831   | 3,7294             | 21,9774            |                     |                     |                                | 7,184,3000          |
| 2. Manufacturing Industries and Construction                     | 5,026.1673   | 13,9828            | 53,1494            |                     |                     |                                | 5,093,0994          |
| 3. Transport   | 14,110.5276  | 53,4901            | 149,3871           |                     |                     |                                | 14,313,5048         |
| 4. Other Sectors   | 3,410.8998   | 24,0355            | 40,5379            |                     |                     |                                | 3,475,4732          |
| 5. Other   | NA   | NA                 | NA                 |                     |                     |                                | NA                  |
| B. Fugitive Emissions from Fuels                                 | 882,5245   | 699,2153           | IE,NA,NE,NO        |                     |                     |                                | 1,581,7398          |
| 1. Solid Fuels   | NA,NE  | 311,8801           | NA,NE              |                     |                     |                                | 311,8801            |
| 2. Oil and Natural Gas   | 882,5245   | 387,3352           | IE,NE,NO           |                     |                     |                                | 1,269,8597          |
| <b>2. Industrial Processes</b>                                   | <b>3,450.2965</b>  | <b>45.6880</b>     | <b>NA,NO</b>       | <b>597.3597</b>     | <b>87.7000</b>      | <b>21.4861</b>                 | <b>4,202.5303</b>   |
| A. Mineral Products  | 612,7920   | NA                 | NA                 |                     |                     |                                | 612,7920            |
| B. Chemical Industry   | 553,7041   | 45,6880            | NA,NO              | NA                  | NA                  | NA,NO                          | 599,3921            |
| C. Metal Production  | 2,283,8003   | IE,NA,NE,NO        | NA                 | NA,NO               | 80,7000             | IE,NA,NO                       | 2,364,5003          |
| D. Other Production  | NA   |                    |                    |                     |                     |                                | NA                  |
| E. Production of Halocarbons and SF <sub>6</sub>                 |  |                    |                    | NA,NO               | NO                  | NO                             | NA,NO               |
| F. Consumption of Halocarbons and SF <sub>6</sub> <sup>(2)</sup> |  |                    |                    | 597,3597            | 7,0000              | 21,4861                        | 625,8458            |
| G. Other   | NA   | NA                 | NA                 | NA                  | NA                  | NA                             | NA                  |
| <b>3. Solvent and Other Product Use</b>                          | <b>IE,NA</b>   | <b>48.3600</b>     | <b>48.3600</b>     |                     |                     |                                | <b>48.3600</b>      |
| <b>4. Agriculture</b>  | <b>24,569.6413</b>   | <b>12,779.9929</b> | <b>37,349.6342</b> |                     |                     |                                | <b>37,349.6342</b>  |
| A. Enteric Fermentation  |  | 23,823,5375        |                    |                     |                     |                                | 23,823,5375         |
| B. Manure Management   |  | 734,0832           | 63,4982            |                     |                     |                                | 797,5813            |
| C. Rice Cultivation  |  | NO                 | NO                 |                     |                     |                                | NO                  |
| D. Agricultural Soils <sup>(3)</sup>                             |  | NE,NO              | 12,712,6488        |                     |                     |                                | 12,712,6488         |
| E. Prescribed Burning of Savannas                                |  | 0,6954             | 0,1270             |                     |                     |                                | 0,8224              |
| F. Field Burning of Agricultural Residues                        |  | 11,3253            | 3,7189             |                     |                     |                                | 15,0442             |
| G. Other   |  | NO                 | NO                 |                     |                     |                                | NO                  |
| <b>5. Land Use, Land-Use Change and Forestry<sup>(1)</sup></b>   | <b>-24,565.4034</b>  | <b>75.1492</b>     | <b>7.6266</b>      |                     |                     |                                | <b>-24,482.6277</b> |
| A. Forest Land   | -25,506,4924   | 31,4941            | 3,1962             |                     |                     |                                | -25,471,8021        |
| B. Cropland  | -549,7246  | NA,NO              | NA,NE,NO           |                     |                     |                                | -549,7246           |
| C. Grassland   | 666,4376   | 43,6550            | 4,4304             |                     |                     |                                | 714,5230            |
| D. Wetlands  | 0,7223   | NO                 | NE,NO              |                     |                     |                                | 0,7223              |
| E. Settlements   | 97,1575  | NE,NO              | NE,NO              |                     |                     |                                | 97,1575             |
| F. Other Land  | 38,1638  | NE,NO              | NE,NO              |                     |                     |                                | 38,1638             |
| G. Other   | 688,3325   | NO                 | NA,NO              |                     |                     |                                | 688,3325            |
| <b>6. Waste</b>  | <b>NA,NE,NO</b>  | <b>1,676.0653</b>  | <b>163.9166</b>    |                     |                     |                                | <b>1,839.9819</b>   |
| A. Solid Waste Disposal on Land                                  | NA,NE  | 1,509,1153         |                    |                     |                     |                                | 1,509,1153          |
| B. Waste-water Handling  |  | 166,9500           | 163,9166           |                     |                     |                                | 330,8666            |
| C. Waste Incineration  | NE   | NE                 | NE                 |                     |                     |                                | NE                  |
| D. Other   | NO   | NO                 | NO                 |                     |                     |                                | NO                  |
| <b>7. Other (as specified in Summary 1.A)</b>                    | <b>NA</b>  | <b>NA</b>          | <b>NA</b>          | <b>NA</b>           | <b>NA</b>           | <b>NA</b>                      | <b>NA</b>           |
| <b>Memo Items:<sup>(4)</sup></b>                                 |  |                    |                    |                     |                     |                                |                     |
| <b>International Bankers</b>                                     | <b>3,303.6052</b>  | <b>2,9603</b>      | <b>28,4900</b>     |                     |                     |                                | <b>3,335.0554</b>   |
| Aviation   | 2,564,6846   | 1,3178             | 22,4061            |                     |                     |                                | 2,588,6086          |
| Marine   | 738,9206   | 1,4425             | 6,0838             |                     |                     |                                | 746,4469            |
| <b>Multilateral Operations</b>                                   | <b>NE</b>  | <b>NE</b>          | <b>NE</b>          |                     |                     |                                | <b>NE</b>           |
| <b>CO<sub>2</sub> Emissions from Biomass</b>                     | <b>3,795.9545</b>  |                    |                    |                     |                     |                                | <b>3,795.9545</b>   |
|  | Total CO <sub>2</sub> Equivalent Emissions without Land Use, Land-Use Change and Forestry <sup>(5)</sup> |                    |                    |                     |                     |                                | 75,088,1855         |
|  | Total CO <sub>2</sub> Equivalent Emissions with Land Use, Land-Use Change and Forestry <sup>(5)</sup>    |                    |                    |                     |                     |                                | 50,605,5579         |

(1) For CO<sub>2</sub> from Land Use, Land-use Change and Forestry the net emissions/removals are to be reported. For the purposes of reporting, the signs for removals are always negative (-) and for emissions positive (+).

(2) Actual emissions should be included in the national totals. If no actual emissions were reported, potential emissions should be included.

(3) Parties which previously reported CO<sub>2</sub> from soils in the Agriculture sector should note this in the NIR.

(4) See footnote 8 to table Summary 1.A.

(5) These totals will differ from the totals reported in table 10, sheet 5 if Parties report non-CO<sub>2</sub> emissions from LULUCF.

**TABLE 10 EMISSIONS TRENDS (CO<sub>2</sub>)**  
(Sheet 1 of 5)  
(Part 1 of 2)

Inventory 2004  
Submission 2006 v2.1  
NEW ZEALAND

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES  | Base year ( 1990 )  | 1991                | 1992                | 1993                | 1994                | 1995                | 1996                | 1997                | 1998                | 1999                |
|--|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|  | (Gg)                |
| <b>1. Energy</b>   | <b>22,706.8638</b>  | <b>23,093.4818</b>  | <b>24,850.9794</b>  | <b>24,132.2253</b>  | <b>24,331.9909</b>  | <b>24,176.0571</b>  | <b>25,228.4128</b>  | <b>27,517.6374</b>  | <b>26,053.5464</b>  | <b>27,343.3145</b>  |
| A. Fuel Combustion (Sectoral Approach)   | 22,085.7748         | 22,385.8516         | 24,176.4239         | 23,498.1334         | 23,654.6081         | 23,540.2235         | 24,579.5691         | 26,816.3788         | 25,379.5441         | 26,713.6633         |
| 1. Energy Industries   | 6,033.0866          | 6,107.8172          | 7,556.5118          | 6,541.0043          | 5,414.0048          | 4,678.4263          | 5,254.0881          | 6,866.0079          | 5,190.1918          | 6,419.3085          |
| 2. Manufacturing Industries and Construction   | 4,568.3961          | 4,972.3336          | 4,617.6227          | 4,737.1246          | 5,159.9412          | 5,050.5596          | 5,556.9727          | 5,940.6411          | 6,015.4325          | 5,693.0523          |
| 3. Transport   | 8,632.8050          | 8,639.9631          | 9,024.7479          | 9,440.6414          | 10,143.7333         | 10,855.8742         | 10,941.5881         | 11,257.7299         | 11,448.8523         | 11,698.5632         |
| 4. Other Sectors   | 2,851.4871          | 2,665.7377          | 2,977.5416          | 2,779.3630          | 2,936.9287          | 2,955.3635          | 2,826.9201          | 2,752.0000          | 2,725.0675          | 2,902.7393          |
| 5. Other   | NA                  |
| B. Fugitive Emissions from Fuels   | 621.0890            | 707.6302            | 674.5555            | 634.0919            | 677.3827            | 635.8335            | 648.8436            | 701.2586            | 674.0023            | 629.6511            |
| 1. Solid Fuels   | NA,NE               |
| 2. Oil and Natural Gas   | 621.0890            | 707.6302            | 674.5555            | 634.0919            | 677.3827            | 635.8335            | 648.8436            | 701.2586            | 674.0023            | 629.6511            |
| <b>2. Industrial Processes</b>   | <b>2,666.5221</b>   | <b>2,791.5537</b>   | <b>2,897.8142</b>   | <b>3,043.7973</b>   | <b>2,948.2050</b>   | <b>3,024.9704</b>   | <b>2,993.7832</b>   | <b>2,896.5588</b>   | <b>3,053.4448</b>   | <b>3,217.3820</b>   |
| A. Mineral Products  | 453.9916            | 442.8743            | 506.2298            | 559.2469            | 572.2439            | 592.6055            | 587.8326            | 605.7003            | 581.2946            | 645.1438            |
| B. Chemical Industry   | 425.2064            | 440.0643            | 402.0251            | 423.8701            | 448.3287            | 423.2651            | 409.7422            | 434.2864            | 479.1388            | 526.0127            |
| C. Metal Production  | 1,787.3242          | 1,908.6151          | 1,989.5593          | 2,060.6803          | 1,927.6325          | 2,009.0998          | 1,996.2084          | 1,856.5722          | 1,993.0114          | 2,046.2255          |
| D. Other Production  | NA                  |
| E. Production of Halocarbons and SF <sub>6</sub>   |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| F. Consumption of Halocarbons and SF <sub>6</sub>  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| G. Other   | NA                  |
| <b>3. Solvent and Other Product Use</b>  | <b>IE,NA</b>        |
| <b>4. Agriculture</b>  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| A. Enteric Fermentation  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| B. Manure Management   |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| C. Rice Cultivation  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| D. Agricultural Soils  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| E. Prescribed Burning of Savannas  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| F. Field Burning of Agricultural Residues  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| G. Other   |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| <b>5. Land Use, Land-Use Change and Forestry<sup>(2)</sup></b>                           | <b>-19,080.9481</b> | <b>-17,645.4924</b> | <b>-15,901.9652</b> | <b>-14,755.1406</b> | <b>-14,379.2003</b> | <b>-15,231.0386</b> | <b>-15,561.8086</b> | <b>-17,238.4406</b> | <b>-19,456.1860</b> | <b>-20,056.0790</b> |
| A. Forest Land   | -19,754.8928        | -18,355.7985        | -16,637.5163        | -15,521.2508        | -15,181.1867        | -16,038.7580        | -16,376.8575        | -18,062.4138        | -20,324.1423        | -20,968.0173        |
| B. Cropland  | -501.3169           | -504.7750           | -508.2323           | -511.6903           | -515.1476           | -518.6053           | -522.0629           | -525.5202           | -528.9779           | -532.4363           |
| C. Grassland   | 704.2152            | 701.5166            | 698.8179            | 696.1196            | 693.4217            | 690.7230            | 688.0251            | 685.3260            | 682.6274            | 679.9291            |
| D. Wetlands  | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.7223              |
| E. Settlements   | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 97.1575             |
| F. Other Land  | 26.7417             | 27.5576             | 28.3734             | 29.1889             | 30.0054             | 30.8213             | 31.6371             | 32.4526             | 33.2688             | 34.0842             |
| G. Other   | 346.4248            | 388.1271            | 418.7122            | 454.6123            | 495.8271            | 506.9005            | 519.5697            | 533.8350            | 583.1583            | 632.4815            |
| <b>6. Waste</b>  | <b>NA,NE,NO</b>     |
| A. Solid Waste Disposal on Land  | NA,NE               |
| B. Waste-water Handling  |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| C. Waste Incineration  | NE                  |
| D. Other   | NO                  |
| <b>7. Other (as specified in Summary 1.A)</b>  | <b>NA</b>           |
| Total CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF <sup>(3)</sup> | 6,292.4377          | 8,239.5430          | 11,846.8284         | 12,420.8820         | 12,900.9956         | 11,969.9889         | 12,660.3873         | 13,175.7556         | 9,650.8051          | 10,504.6175         |
| Total CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF <sup>(3)</sup> | 25,373.3859         | 25,885.0355         | 27,748.7936         | 27,176.0226         | 27,280.1959         | 27,201.0275         | 28,222.1959         | 30,414.1962         | 29,106.9911         | 30,560.6965         |
| <b>Memo Items:</b>   |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| <b>International Bankers</b>   | <b>2,374.1613</b>   | <b>2,194.8700</b>   | <b>2,177.5539</b>   | <b>2,244.2893</b>   | <b>2,755.2214</b>   | <b>2,692.8896</b>   | <b>2,696.3615</b>   | <b>2,819.7338</b>   | <b>2,772.8555</b>   | <b>2,856.9977</b>   |
| Aviation   | 1,340.9830          | 1,281.6762          | 1,311.1985          | 1,329.6277          | 1,431.6214          | 1,568.6113          | 1,634.7244          | 1,708.8468          | 1,700.5404          | 1,942.0746          |
| Marine   | 1,033.1784          | 913.1938            | 866.3554            | 914.6615            | 1,323.6000          | 1,124.2783          | 1,061.6371          | 1,110.8870          | 1,072.3151          | 914.9232            |
| <b>Multilateral Operations</b>   | <b>NE</b>           |
| <b>CO<sub>2</sub> Emissions from Biomass</b>   | <b>2,600.7087</b>   | <b>2,792.9516</b>   | <b>2,662.0549</b>   | <b>2,692.7771</b>   | <b>3,170.0048</b>   | <b>3,200.5740</b>   | <b>3,145.3945</b>   | <b>2,960.7580</b>   | <b>3,091.2663</b>   | <b>3,805.4396</b>   |

Note: All footnotes for this table are given at the end of the table on sheet 5.

**TABLE 10 EMISSIONS TRENDS (CO<sub>2</sub>)**  
 (Sheet 1 of 5)  
 (Part 2 of 2)

Inventory 2004  
 Submission 2006 v2.1  
 NEW ZEALAND

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES  | 2000                | 2001                | 2002                | 2003                | 2004                | Change from base to latest reported year |
|--|---------------------|---------------------|---------------------|---------------------|---------------------|--|
|  | (Gg)                | (Gg)                | (Gg)                | (Gg)                | (Gg)                | %  |
| <b>1. Energy</b>   | <b>27,868.1551</b>  | <b>29,781.2021</b>  | <b>29,781.8879</b>  | <b>31,206.4826</b>  | <b>30,588.6023</b>  | <b>34.7108</b>                           |
| A. Fuel Combustion (Sectoral Approach)   | 27,280.8523         | 29,152.8588         | 29,178.8454         | 30,562.6502         | 29,706.0778         | 34.5032                                  |
| 1. Energy Industries   | 6,049.7275          | 7,265.5471          | 6,421.7353          | 7,518.5162          | 7,158.6831          | 18.6571                                  |
| 2. Manufacturing Industries and Construction   | 5,899.0642          | 6,007.2631          | 6,317.6916          | 5,876.3360          | 5,026.1673          | 10.0204                                  |
| 3. Transport   | 12,281.1819         | 12,657.6878         | 13,230.7051         | 13,787.2979         | 14,110.3276         | 63.4501                                  |
| 4. Other Sectors   | 3,050.8787          | 3,222.3609          | 3,208.7135          | 3,380.5001          | 3,410.8998          | 19.6183                                  |
| 5. Other   | NA                  | NA                  | NA                  | NA                  | NA                  | 0.0000                                   |
| B. Fugitive Emissions from Fuels   | 587.3028            | 628.3433            | 603.0424            | 643.8324            | 882.5245            | 42.0931                                  |
| 1. Solid Fuels   | NA,NE               | NA,NE               | NA,NE               | NA,NE               | NA,NE               | 0.0000                                   |
| 2. Oil and Natural Gas   | 587.3028            | 628.3433            | 603.0424            | 643.8324            | 882.5245            | 42.0931                                  |
| <b>2. Industrial Processes</b>   | <b>3,168.6277</b>   | <b>3,260.6654</b>   | <b>3,248.1562</b>   | <b>3,474.5673</b>   | <b>3,450.2965</b>   | <b>29.3931</b>                           |
| A. Mineral Products  | 637.2197            | 634.9222            | 659.4324            | 645.3028            | 612.7920            | 34.9787                                  |
| B. Chemical Industry   | 512.5027            | 555.3167            | 537.6845            | 570.3253            | 553.7041            | 30.2201                                  |
| C. Metal Production  | 2,018.9053          | 2,070.4264          | 2,051.0392          | 2,258.9393          | 2,283.8003          | 27.7776                                  |
| D. Other Production  | NA                  | NA                  | NA                  | NA                  | NA                  | 0.0000                                   |
| E. Production of Halocarbons and SF <sub>6</sub>   |                     |                     |                     |                     |                     |  |
| F. Consumption of Halocarbons and SF <sub>6</sub>  |                     |                     |                     |                     |                     |  |
| G. Other   | NA                  | NA                  | NA                  | NA                  | NA                  | 0.0000                                   |
| <b>3. Solvent and Other Product Use</b>  | <b>IE,NA</b>        | <b>IE,NA</b>        | <b>IE,NA</b>        | <b>IE,NA</b>        | <b>IE,NA</b>        | <b>0.0000</b>                            |
| <b>4. Agriculture</b>  |                     |                     |                     |                     |                     |  |
| A. Enteric Fermentation  |                     |                     |                     |                     |                     |  |
| B. Manure Management   |                     |                     |                     |                     |                     |  |
| C. Rice Cultivation  |                     |                     |                     |                     |                     |  |
| D. Agricultural Soils  |                     |                     |                     |                     |                     |  |
| E. Prescribed Burning of Savannas  |                     |                     |                     |                     |                     |  |
| F. Field Burning of Agricultural Residues  |                     |                     |                     |                     |                     |  |
| G. Other   |                     |                     |                     |                     |                     |  |
| <b>5. Land Use, Land-Use Change and Forestry<sup>(2)</sup></b>                               | <b>-20,322.2994</b> | <b>-20,617.0525</b> | <b>-21,342.4420</b> | <b>-22,836.2644</b> | <b>-24,565.4034</b> | <b>28.7431</b>                           |
| A. Forest Land   | -21,278.2216        | -21,616.9564        | -22,339.1821        | -23,813.3998        | -25,506.4924        | 29.1148                                  |
| B. Cropland  | -535.8936           | -539.3520           | -542.8093           | -546.2666           | -549.7246           | 9.6561                                   |
| C. Grassland   | 677.2311            | 674.5325            | 671.8354            | 669.1351            | 666.4376            | -5.3645                                  |
| D. Wetlands  | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.7223              | 0.0000                                   |
| E. Settlements   | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 97.1575             | 0.0000                                   |
| F. Other Land  | 34.9001             | 35.7155             | 36.5321             | 37.3483             | 38.1638             | 42.7124                                  |
| G. Other   | 681.8048            | 731.1281            | 733.3040            | 719.0388            | 688.3325            | 98.6961                                  |
| <b>6. Waste</b>  | <b>NA,NE,NO</b>     | <b>NA,NE,NO</b>     | <b>NA,NE,NO</b>     | <b>NA,NE,NO</b>     | <b>NA,NE,NO</b>     | <b>0.0000</b>                            |
| A. Solid Waste Disposal on Land  | NA,NE               | NA,NE               | NA,NE               | NA,NE               | NA,NE               | 0.0000                                   |
| B. Waste-water Handling  |                     |                     |                     |                     |                     |  |
| C. Waste Incineration  | NE                  | NE                  | NE                  | NE                  | NE                  | 0.0000                                   |
| D. Other   | NO                  | NO                  | NO                  | NO                  | NO                  | 0.0000                                   |
| <b>7. Other (as specified in Summary 1.A)</b>  | <b>NA</b>           | <b>NA</b>           | <b>NA</b>           | <b>NA</b>           | <b>NA</b>           | <b>0.0000</b>                            |
| <b>Total CO<sub>2</sub> emissions including net CO<sub>2</sub> from LULUCF<sup>(3)</sup></b> | <b>10,714.4834</b>  | <b>12,424.8149</b>  | <b>11,687.6020</b>  | <b>11,844.7855</b>  | <b>9,473.4954</b>   | <b>50.5537</b>                           |
| <b>Total CO<sub>2</sub> emissions excluding net CO<sub>2</sub> from LULUCF<sup>(3)</sup></b> | <b>31,036.7828</b>  | <b>33,041.8675</b>  | <b>33,030.0440</b>  | <b>34,681.0500</b>  | <b>34,038.8988</b>  | <b>34.1520</b>                           |
| <b>Memo Items:</b>   |                     |                     |                     |                     |                     |  |
| <b>International Bankers</b>   | <b>2,502.2225</b>   | <b>2,670.4168</b>   | <b>2,974.4184</b>   | <b>3,023.2488</b>   | <b>3,303.6052</b>   | <b>39.1483</b>                           |
| Aviation   | 1,756.6747          | 1,879.9517          | 1,918.7194          | 2,230.2458          | 2,564.6846          | 91.2541                                  |
| Marine   | 745.5478            | 790.4651            | 1,055.6991          | 793.0030            | 738.9206            | -28.4808                                 |
| <b>Multilateral Operations</b>   | <b>NE</b>           | <b>NE</b>           | <b>NE</b>           | <b>NE</b>           | <b>NE</b>           | <b>0.0000</b>                            |
| <b>CO<sub>2</sub> Emissions from Biomass</b>   | <b>3,887.2160</b>   | <b>3,350.0029</b>   | <b>3,514.6333</b>   | <b>3,568.4617</b>   | <b>3,795.9545</b>   | <b>45.9585</b>                           |

Note: All footnotes for this table are given at the end of the table on sheet 5.

**TABLE 10 EMISSIONS TRENDS (CH<sub>4</sub>)**  
 (Sheet 2 of 5)  
 (Part 1 of 2)

Inventory 2004  
 Submission 2006 v2.1  
 NEW ZEALAND

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES         | Base year ( 1990 ) | 1991              | 1992              | 1993              | 1994              | 1995              | 1996              | 1997              | 1998              | 1999              |
|---|--------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|   | (Gg)               | (Gg)              | (Gg)              | (Gg)              | (Gg)              | (Gg)              | (Gg)              | (Gg)              | (Gg)              | (Gg)              |
| <b>Total CH<sub>4</sub> emissions</b>             | <b>1,222.1534</b>  | <b>1,206.3640</b> | <b>1,203.4310</b> | <b>1,210.0551</b> | <b>1,227.3648</b> | <b>1,236.6433</b> | <b>1,252.3868</b> | <b>1,257.1800</b> | <b>1,261.3250</b> | <b>1,266.3166</b> |
| <b>1. Energy</b>                                  | <b>37.9536</b>     | <b>32.7691</b>    | <b>32.4263</b>    | <b>31.6342</b>    | <b>33.2924</b>    | <b>35.6644</b>    | <b>35.4820</b>    | <b>37.2103</b>    | <b>40.0391</b>    | <b>42.1062</b>    |
| A. Fuel Combustion (Sectoral Approach)            | 9.9902             | 9.7097            | 9.7144            | 9.6151            | 8.9541            | 8.4997            | 7.8650            | 7.4257            | 6.8378            | 6.2708            |
| 1. Energy Industries                              | 0.2628             | 0.2806            | 0.3179            | 0.2935            | 0.1934            | 0.2372            | 0.1934            | 0.2176            | 0.2035            | 0.2571            |
| 2. Manufacturing Industries and Construction      | 0.3815             | 0.4218            | 0.3951            | 0.4023            | 0.4877            | 0.5116            | 0.5358            | 0.5299            | 0.5532            | 0.6509            |
| 3. Transport                                      | 7.1163             | 7.1486            | 7.1800            | 7.2002            | 6.7770            | 6.3722            | 5.7388            | 5.2685            | 4.7400            | 4.0796            |
| 4. Other Sectors                                  | 2.2296             | 1.8587            | 1.8214            | 1.7191            | 1.4522            | 1.4225            | 1.3727            | 1.3562            | 1.3410            | 1.2832            |
| 5. Other  | NA                 | NA                | NA                | NA                | NA                | NA                | NA                | NA                | NA                | NA                |
| B. Fugitive Emissions from Fuels                  | 27.9635            | 23.0594           | 22.7120           | 22.0191           | 24.3383           | 27.1646           | 27.6170           | 29.7846           | 33.2013           | 35.8354           |
| 1. Solid Fuels                                    | 12.9584            | 8.7340            | 9.0388            | 8.6082            | 10.1859           | 13.4714           | 13.9432           | 13.8761           | 16.2593           | 16.8421           |
| 2. Oil and Natural Gas                            | 15.0051            | 14.3254           | 13.6732           | 13.4109           | 14.1524           | 13.6932           | 13.6738           | 15.9085           | 16.9420           | 18.9933           |
| <b>2. Industrial Processes</b>                    | <b>0.9600</b>      | <b>1.6400</b>     | <b>1.3900</b>     | <b>1.5600</b>     | <b>1.9560</b>     | <b>2.7480</b>     | <b>3.6930</b>     | <b>3.8100</b>     | <b>3.5870</b>     | <b>4.0000</b>     |
| A. Mineral Products                               | NA                 | NA                | NA                | NA                | NA                | NA                | NA                | NA                | NA                | NA                |
| B. Chemical Industry                              | 0.9600             | 1.6400            | 1.3900            | 1.5600            | 1.9560            | 2.7480            | 3.6930            | 3.8100            | 3.5870            | 4.0000            |
| C. Metal Production                               | IE,NA,NE,NO        | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       |
| D. Other Production                               |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |
| E. Production of Halocarbons and SF <sub>6</sub>  |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |
| F. Consumption of Halocarbons and SF <sub>6</sub> |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |
| G. Other  | NA                 | NA                | NA                | NA                | NA                | NA                | NA                | NA                | NA                | NA                |
| <b>3. Solvent and Other Product Use</b>           |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |
| <b>4. Agriculture</b>                             | <b>1,067.5528</b>  | <b>1,055.2010</b> | <b>1,054.2492</b> | <b>1,059.4629</b> | <b>1,075.0652</b> | <b>1,090.8886</b> | <b>1,104.6929</b> | <b>1,107.9149</b> | <b>1,113.9467</b> | <b>1,123.4838</b> |
| A. Enteric Fermentation                           | 1,038.4065         | 1,025.9336        | 1,025.2431        | 1,029.8310        | 1,044.4939        | 1,059.3734        | 1,072.4685        | 1,075.3775        | 1,081.3735        | 1,090.6494        |
| B. Manure Management                              | 28.1178            | 28.2190           | 27.9796           | 28.5918           | 29.5419           | 30.4899           | 31.1633           | 31.4337           | 31.4886           | 31.8059           |
| C. Rice Cultivation                               | NO                 | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                |
| D. Agricultural Soils                             | NE,NO              | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             |
| E. Prescribed Burning of Savannas                 | 0.1342             | 0.1329            | 0.1272            | 0.1024            | 0.0810            | 0.0654            | 0.0593            | 0.0532            | 0.0402            | 0.0365            |
| F. Field Burning of Agricultural Residues         | 0.8943             | 0.9155            | 0.8993            | 0.9377            | 0.9485            | 0.9600            | 1.0018            | 1.0504            | 1.0445            | 0.9919            |
| G. Other  | NO                 | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                |
| <b>5. Land Use, Land-Use Change and Forestry</b>  | <b>4.4541</b>      | <b>4.1115</b>     | <b>4.6422</b>     | <b>5.8674</b>     | <b>6.5699</b>     | <b>6.3428</b>     | <b>7.1304</b>     | <b>7.7362</b>     | <b>6.3707</b>     | <b>5.6865</b>     |
| A. Forest Land                                    | 1.7228             | 1.8703            | 2.5084            | 3.3660            | 3.8729            | 3.5322            | 4.4310            | 4.2647            | 2.9509            | 2.4804            |
| B. Cropland                                       | NA,NO              | NA,NO             | NA,NO             | NA,NO             | NA,NO             | NA,NO             | NA,NO             | NA,NO             | NA,NO             | NA,NO             |
| C. Grassland                                      | 2.7313             | 2.2412            | 2.1338            | 2.5014            | 2.6970            | 2.8106            | 2.6994            | 3.4714            | 3.4198            | 3.2061            |
| D. Wetlands                                       | NO                 | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                |
| E. Settlements                                    | NE,NO              | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             |
| F. Other Land                                     | NE,NO              | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             |
| G. Other  | NO                 | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                |
| <b>6. Waste</b>                                   | <b>111.2329</b>    | <b>112.6424</b>   | <b>110.7233</b>   | <b>111.5305</b>   | <b>110.4813</b>   | <b>100.9995</b>   | <b>101.3884</b>   | <b>100.5086</b>   | <b>97.3816</b>    | <b>91.0400</b>    |
| A. Solid Waste Disposal on Land                   | 103.7729           | 105.1424          | 103.1933          | 103.9705          | 102.8913          | 93.3695           | 93.7284           | 92.8186           | 89.6616           | 83.2800           |
| B. Waste-water Handling                           | 7.4600             | 7.5000            | 7.5300            | 7.5600            | 7.5900            | 7.6300            | 7.6600            | 7.6900            | 7.7200            | 7.7600            |
| C. Waste Incineration                             | NE                 | NE                | NE                | NE                | NE                | NE                | NE                | NE                | NE                | NE                |
| D. Other  | NO                 | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                | NO                |
| <b>7. Other (as specified in Summary I.A)</b>     | <b>NA</b>          | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         |
| <b>Memo Items:</b>                                |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |
| <b>International Bunkers</b>                      | <b>0.1345</b>      | <b>0.1221</b>     | <b>0.1181</b>     | <b>0.1230</b>     | <b>0.1641</b>     | <b>0.1494</b>     | <b>0.1450</b>     | <b>0.1515</b>     | <b>0.1475</b>     | <b>0.1394</b>     |
| Aviation  | 0.0378             | 0.0361            | 0.0369            | 0.0375            | 0.0403            | 0.0442            | 0.0461            | 0.0482            | 0.0479            | 0.0547            |
| Marine  | 0.0967             | 0.0860            | 0.0811            | 0.0855            | 0.1238            | 0.1052            | 0.0990            | 0.1034            | 0.0996            | 0.0847            |
| <b>Multilateral Operations</b>                    | <b>NE</b>          | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         |
| <b>CO<sub>2</sub> Emissions from Biomass</b>      |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (CH<sub>4</sub>)

(Sheet 2 of 5)

(Part 2 of 2)

Inventory 2004  
Submission 2006 v2.1  
NEW ZEALAND

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES         | 2000              | 2001              | 2002              | 2003              | 2004              | Change from base to latest reported year |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|--|
|   | (Gg)              | (Gg)              | (Gg)              | (Gg)              | (Gg)              |  |
| <b>Total CH<sub>4</sub> emissions</b>             | <b>1,283.6423</b> | <b>1,291.8072</b> | <b>1,292.3811</b> | <b>1,290.4858</b> | <b>1,293.3713</b> | <b>5.8272</b>                            |
| <b>1. Energy</b>                                  | <b>40.4280</b>    | <b>41.8136</b>    | <b>41.0562</b>    | <b>39.9839</b>    | <b>37.8216</b>    | <b>-0.3480</b>                           |
| A. Fuel Combustion (Sectoral Approach)            | 5.8039            | 5.2535            | 4.8529            | 4.4290            | 4.5256            | -54.6994                                 |
| 1. Energy Industries                              | 0.2488            | 0.2932            | 0.2477            | 0.2411            | 0.1776            | -32.4135                                 |
| 2. Manufacturing Industries and Construction      | 0.6772            | 0.5965            | 0.6312            | 0.5867            | 0.6563            | 72.0506                                  |
| 3. Transport                                      | 3.6496            | 3.2445            | 2.9055            | 2.4715            | 2.5471            | -64.2070                                 |
| 4. Other Sectors                                  | 1.2283            | 1.1193            | 1.0685            | 1.1297            | 1.1445            | -48.6661                                 |
| 5. Other  | NA                | NA                | NA                | NA                | NA                | 0.0000                                   |
| B. Fugitive Emissions from Fuels                  | 34.6241           | 36.5600           | 36.2034           | 35.5549           | 33.2960           | 19.0695                                  |
| 1. Solid Fuels                                    | 16.1922           | 16.9739           | 16.8609           | 15.8215           | 14.8514           | 14.6086                                  |
| 2. Oil and Natural Gas                            | 18.4319           | 19.5862           | 19.3425           | 19.7334           | 18.4445           | 22.9220                                  |
| <b>2. Industrial Processes</b>                    | <b>4.8213</b>     | <b>4.2600</b>     | <b>4.5628</b>     | <b>1.9354</b>     | <b>2.1756</b>     | <b>126.6269</b>                          |
| A. Mineral Products                               | NA                | NA                | NA                | NA                | NA                | 0.0000                                   |
| B. Chemical Industry                              | 4.8213            | 4.2600            | 4.5628            | 1.9354            | 2.1756            | 126.6269                                 |
| C. Metal Production                               | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | IE,NA,NE,NO       | 0.0000                                   |
| D. Other Production                               |                   |                   |                   |                   |                   |  |
| E. Production of Halocarbons and SF <sub>6</sub>  |                   |                   |                   |                   |                   |  |
| F. Consumption of Halocarbons and SF <sub>6</sub> |                   |                   |                   |                   |                   |  |
| G. Other  | NA                | NA                | NA                | NA                | NA                | 0.0000                                   |
| <b>3. Solvent and Other Product Use</b>           |                   |                   |                   |                   |                   |  |
| <b>4. Agriculture</b>                             | <b>1,142.1400</b> | <b>1,152.3867</b> | <b>1,156.4519</b> | <b>1,160.3933</b> | <b>1,169.9829</b> | <b>9.5949</b>                            |
| A. Enteric Fermentation                           | 1,108.7233        | 1,118.1751        | 1,121.4660        | 1,124.7987        | 1,134.4542        | 9.2495                                   |
| B. Manure Management                              | 32.3848           | 33.1252           | 33.8745           | 34.5690           | 34.9563           | 24.3213                                  |
| C. Rice Cultivation                               | NO                | NO                | NO                | NO                | NO                | 0.0000                                   |
| D. Agricultural Soils                             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | 0.0000                                   |
| E. Prescribed Burning of Savannas                 | 0.0384            | 0.0439            | 0.0404            | 0.0401            | 0.0331            | -75.3231                                 |
| F. Field Burning of Agricultural Residues         | 0.9935            | 1.0424            | 1.0710            | 0.9856            | 0.5393            | -39.6986                                 |
| G. Other  | NO                | NO                | NO                | NO                | NO                | 0.0000                                   |
| <b>5. Land Use, Land-Use Change and Forestry</b>  | <b>4.6087</b>     | <b>4.4829</b>     | <b>4.2616</b>     | <b>4.0672</b>     | <b>3.5785</b>     | <b>-19.6574</b>                          |
| A. Forest Land                                    | 2.3133            | 2.3488            | 1.9170            | 1.8589            | 1.4997            | -12.9503                                 |
| B. Cropland                                       | NA,NO             | NA,NO             | NA,NO             | NA,NO             | NA,NO             | 0.0000                                   |
| C. Grassland                                      | 2.2954            | 2.1342            | 2.3446            | 2.2083            | 2.0788            | -23.8881                                 |
| D. Wetlands                                       | NO                | NO                | NO                | NO                | NO                | 0.0000                                   |
| E. Settlements                                    | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | 0.0000                                   |
| F. Other Land                                     | NE,NO             | NE,NO             | NE,NO             | NE,NO             | NE,NO             | 0.0000                                   |
| G. Other  | NO                | NO                | NO                | NO                | NO                | 0.0000                                   |
| <b>6. Waste</b>                                   | <b>91.6443</b>    | <b>88.8640</b>    | <b>86.0486</b>    | <b>84.1060</b>    | <b>79.8126</b>    | <b>-28.2473</b>                          |
| A. Solid Waste Disposal on Land                   | 83.8543           | 81.0440           | 78.1886           | 76.1960           | 71.8626           | -30.7501                                 |
| B. Waste-water Handling                           | 7.7900            | 7.8200            | 7.8600            | 7.9100            | 7.9500            | 6.5684                                   |
| C. Waste Incineration                             | NE                | NE                | NE                | NE                | NE                | 0.0000                                   |
| D. Other  | NO                | NO                | NO                | NO                | NO                | 0.0000                                   |
| <b>7. Other (as specified in Summary I.A.)</b>    | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>NA</b>         | <b>0.0000</b>                            |
|   | NA                | NA                | NA                | NA                | NA                | 0.0000                                   |
| <b>Memo Items:</b>                                |                   |                   |                   |                   |                   |  |
| <b>International Bunkers</b>                      | <b>0.1184</b>     | <b>0.1261</b>     | <b>0.1517</b>     | <b>0.1399</b>     | <b>0.1410</b>     | <b>4.8217</b>                            |
| Aviation  | 0.0495            | 0.0530            | 0.0541            | 0.0643            | 0.0723            | 91.2567                                  |
| Marine  | 0.0689            | 0.0731            | 0.0977            | 0.0757            | 0.0687            | -28.9608                                 |
| <b>Multilateral Operations</b>                    | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>NE</b>         | <b>0.0000</b>                            |
| <b>CO<sub>2</sub> Emissions from Biomass</b>      |                   |                   |                   |                   |                   |  |

Note: All footnotes for this table are given at the end of the table on sheet 5.

**TABLE 10 EMISSIONS TRENDS (N<sub>2</sub>O)**  
 (Sheet 3 of 5)  
 (Part 1 of 2)

Inventory 2004  
 Submission 2006 v2.1  
 NEW ZEALAND

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES         | Base year ( 1990 ) | 1991           | 1992           | 1993           | 1994           | 1995           | 1996           | 1997           | 1998           | 1999           |
|---|--------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|   | (Gg)               | (Gg)           | (Gg)           | (Gg)           | (Gg)           | (Gg)           | (Gg)           | (Gg)           | (Gg)           | (Gg)           |
| <b>Total N<sub>2</sub>O emissions</b>             | <b>33.6435</b>     | <b>33.5878</b> | <b>33.7786</b> | <b>34.3343</b> | <b>35.3034</b> | <b>36.1390</b> | <b>36.7211</b> | <b>36.9323</b> | <b>37.2534</b> | <b>37.9144</b> |
| <b>1. Energy</b>                                  | <b>0.4879</b>      | <b>0.4858</b>  | <b>0.5244</b>  | <b>0.5442</b>  | <b>0.5875</b>  | <b>0.6229</b>  | <b>0.6320</b>  | <b>0.6542</b>  | <b>0.6575</b>  | <b>0.7054</b>  |
| A. Fuel Combustion (Sectoral Approach)            | 0.4879             | 0.4858         | 0.5244         | 0.5442         | 0.5875         | 0.6229         | 0.6320         | 0.6542         | 0.6575         | 0.7054         |
| 1. Energy Industries                              | 0.0205             | 0.0164         | 0.0298         | 0.0208         | 0.0185         | 0.0193         | 0.0209         | 0.0317         | 0.0222         | 0.0296         |
| 2. Manufacturing Industries and Construction      | 0.1185             | 0.1263         | 0.1172         | 0.1215         | 0.1423         | 0.1388         | 0.1395         | 0.1339         | 0.1388         | 0.1610         |
| 3. Transport                                      | 0.2403             | 0.2427         | 0.2603         | 0.2797         | 0.3068         | 0.3403         | 0.3498         | 0.3654         | 0.3750         | 0.3880         |
| 4. Other Sectors                                  | 0.1085             | 0.1003         | 0.1171         | 0.1223         | 0.1200         | 0.1244         | 0.1218         | 0.1232         | 0.1215         | 0.1267         |
| 5. Other  | NA                 | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             |
| B. Fugitive Emissions from Fuels                  | IE,NA,NE,NO        | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    |
| 1. Solid Fuels                                    | NA,NE              | NA,NE          | NA,NE          | NA,NE          | NA,NE          | NA,NE          | NA,NE          | NA,NE          | NA,NE          | NA,NE          |
| 2. Oil and Natural Gas                            | IE,NE,NO           | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       |
| <b>2. Industrial Processes</b>                    | <b>NA,NO</b>       | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   |
| A. Mineral Products                               | NA                 | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             |
| B. Chemical Industry                              | NA,NO              | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          |
| C. Metal Production                               | NA                 | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             |
| D. Other Production                               |                    |                |                |                |                |                |                |                |                |                |
| E. Production of Halocarbons and SF <sub>6</sub>  |                    |                |                |                |                |                |                |                |                |                |
| F. Consumption of Halocarbons and SF <sub>6</sub> |                    |                |                |                |                |                |                |                |                |                |
| G. Other  | NA                 | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             | NA             |
| <b>3. Solvent and Other Product Use</b>           | <b>0.1340</b>      | <b>0.1380</b>  | <b>0.1390</b>  | <b>0.1410</b>  | <b>0.1430</b>  | <b>0.1450</b>  | <b>0.1480</b>  | <b>0.1490</b>  | <b>0.1500</b>  | <b>0.1510</b>  |
| <b>4. Agriculture</b>                             | <b>32.5170</b>     | <b>32.4618</b> | <b>32.5994</b> | <b>33.1248</b> | <b>34.0438</b> | <b>34.8336</b> | <b>35.3981</b> | <b>35.5820</b> | <b>35.8982</b> | <b>36.5149</b> |
| A. Enteric Fermentation                           |                    |                |                |                |                |                |                |                |                |                |
| B. Manure Management                              | 0.1224             | 0.1231         | 0.1255         | 0.1322         | 0.1430         | 0.1511         | 0.1571         | 0.1611         | 0.1659         | 0.1718         |
| C. Rice Cultivation                               |                    |                |                |                |                |                |                |                |                |                |
| D. Agricultural Soils                             | 32.3722            | 32.3159        | 32.4516        | 32.9698        | 33.8781        | 34.6599        | 35.2177        | 35.3966        | 35.7084        | 36.3206        |
| E. Prescribed Burning of Savannas                 | 0.0017             | 0.0016         | 0.0016         | 0.0013         | 0.0010         | 0.0008         | 0.0007         | 0.0007         | 0.0005         | 0.0005         |
| F. Field Burning of Agricultural Residues         | 0.0208             | 0.0212         | 0.0207         | 0.0215         | 0.0216         | 0.0218         | 0.0226         | 0.0237         | 0.0234         | 0.0221         |
| G. Other  | NO                 | NO             | NO             | NO             | NO             | NO             | NO             | NO             | NO             | NO             |
| <b>5. Land Use, Land-Use Change and Forestry</b>  | <b>0.0306</b>      | <b>0.0283</b>  | <b>0.0319</b>  | <b>0.0403</b>  | <b>0.0452</b>  | <b>0.0436</b>  | <b>0.0490</b>  | <b>0.0532</b>  | <b>0.0438</b>  | <b>0.0391</b>  |
| A. Forest Land                                    | 0.0118             | 0.0129         | 0.0172         | 0.0231         | 0.0266         | 0.0243         | 0.0305         | 0.0293         | 0.0203         | 0.0171         |
| B. Cropland                                       | NA,NE,NO           | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       |
| C. Grassland                                      | 0.0188             | 0.0154         | 0.0147         | 0.0172         | 0.0185         | 0.0193         | 0.0186         | 0.0239         | 0.0235         | 0.0220         |
| D. Wetlands                                       | NE,NO              | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          |
| E. Settlements                                    | NE,NO              | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          |
| F. Other Land                                     | NE,NO              | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          |
| G. Other  | NA,NO              | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          |
| <b>6. Waste</b>                                   | <b>0.4739</b>      | <b>0.4739</b>  | <b>0.4839</b>  | <b>0.4839</b>  | <b>0.4839</b>  | <b>0.4939</b>  | <b>0.4939</b>  | <b>0.4939</b>  | <b>0.5039</b>  | <b>0.5039</b>  |
| A. Solid Waste Disposal on Land                   |                    |                |                |                |                |                |                |                |                |                |
| B. Waste-water Handling                           | 0.4739             | 0.4739         | 0.4839         | 0.4839         | 0.4839         | 0.4939         | 0.4939         | 0.4939         | 0.5039         | 0.5039         |
| C. Waste Incineration                             | NE                 | NE             | NE             | NE             | NE             | NE             | NE             | NE             | NE             | NE             |
| D. Other  | NO                 | NO             | NO             | NO             | NO             | NO             | NO             | NO             | NO             | NO             |
| <b>7. Other (as specified in Summary I.A)</b>     | <b>NA</b>          | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      |
| Memo Items:                                       |                    |                |                |                |                |                |                |                |                |                |
| <b>International Bunkers</b>                      | <b>0.0654</b>      | <b>0.0607</b>  | <b>0.0601</b>  | <b>0.0619</b>  | <b>0.0757</b>  | <b>0.0743</b>  | <b>0.0743</b>  | <b>0.0777</b>  | <b>0.0764</b>  | <b>0.0789</b>  |
| Aviation  | 0.0378             | 0.0361         | 0.0369         | 0.0375         | 0.0403         | 0.0442         | 0.0461         | 0.0482         | 0.0479         | 0.0547         |
| Marine  | 0.0276             | 0.0246         | 0.0232         | 0.0244         | 0.0354         | 0.0301         | 0.0283         | 0.0295         | 0.0284         | 0.0242         |
| <b>Multilateral Operations</b>                    | <b>NE</b>          | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      |
| <b>CO<sub>2</sub> Emissions from Biomass</b>      |                    |                |                |                |                |                |                |                |                |                |

Note: All footnotes for this table are given at the end of the table on sheet 5.

**TABLE 10 EMISSIONS TRENDS (N<sub>2</sub>O)**  
(Sheet 3 of 5)  
(Part 2 of 2)

Inventory 2004  
Submission 2006 v2.1  
NEW ZEALAND

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES         | 2000           | 2001           | 2002           | 2003           | 2004           | Change from base to latest reported year |
|---|----------------|----------------|----------------|----------------|----------------|--|
|   | (Gg)           | (Gg)           | (Gg)           | (Gg)           | (Gg)           |  |
| <b>Total N<sub>2</sub>O emissions</b>             | <b>39,0633</b> | <b>40,2774</b> | <b>41,3708</b> | <b>42,1920</b> | <b>42,7902</b> | <b>27,1870</b>                           |
| <b>1. Energy</b>                                  | <b>0,7387</b>  | <b>0,7505</b>  | <b>0,7840</b>  | <b>0,8384</b>  | <b>0,8550</b>  | <b>75,2332</b>                           |
| A. Fuel Combustion (Sectoral Approach)            | 0,7387         | 0,7505         | 0,7840         | 0,8384         | 0,8550         | 75,2332                                  |
| 1. Energy Industries                              | 0,0352         | 0,0342         | 0,0326         | 0,0592         | 0,0709         | 245,0992                                 |
| 2. Manufacturing Industries and Construction      | 0,1660         | 0,1507         | 0,1561         | 0,1645         | 0,1714         | -44,6727                                 |
| 3. Transport                                      | 0,4154         | 0,4285         | 0,4520         | 0,4713         | 0,4819         | 100,5137                                 |
| 4. Other Sectors                                  | 0,1321         | 0,1371         | 0,1433         | 0,1434         | 0,1308         | 20,4753                                  |
| 5. Other  | NA             | NA             | NA             | NA             | NA             | 0,0000                                   |
| B. Fugitive Emissions from Fuels                  | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | IE,NA,NE,NO    | 0,0000                                   |
| 1. Solid Fuels                                    | NA,NE          | NA,NE          | NA,NE          | NA,NE          | NA,NE          | 0,0000                                   |
| 2. Oil and Natural Gas                            | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | IE,NE,NO       | 0,0000                                   |
| <b>2. Industrial Processes</b>                    | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>NA,NO</b>   | <b>0,0000</b>                            |
| A. Mineral Products                               | NA             | NA             | NA             | NA             | NA             | 0,0000                                   |
| B. Chemical Industry                              | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | 0,0000                                   |
| C. Metal Production                               | NA             | NA             | NA             | NA             | NA             | 0,0000                                   |
| D. Other Production                               |                |                |                |                |                |  |
| E. Production of Halocarbons and SF <sub>6</sub>  |                |                |                |                |                |  |
| F. Consumption of Halocarbons and SF <sub>6</sub> |                |                |                |                |                |  |
| G. Other  | NA             | NA             | NA             | NA             | NA             | 0,0000                                   |
| <b>3. Solvent and Other Product Use</b>           | <b>0,1520</b>  | <b>0,1530</b>  | <b>0,1560</b>  | <b>0,1560</b>  | <b>0,1560</b>  | <b>16,4179</b>                           |
| <b>4. Agriculture</b>                             | <b>37,6369</b> | <b>38,8291</b> | <b>39,8876</b> | <b>40,6442</b> | <b>41,2258</b> | <b>26,7822</b>                           |
| A. Enteric Fermentation                           |                |                |                |                |                |  |
| B. Manure Management                              | 0,1783         | 0,1861         | 0,1917         | 0,1970         | 0,2048         | 67,4087                                  |
| C. Rice Cultivation                               |                |                |                |                |                |  |
| D. Agricultural Soils                             | 37,4363        | 38,6192        | 39,6714        | 40,4246        | 41,0083        | 26,6784                                  |
| E. Prescribed Burning of Savannas                 | 0,0005         | 0,0005         | 0,0005         | 0,0005         | 0,0004         | -75,3231                                 |
| F. Field Burning of Agricultural Residues         | 0,0220         | 0,0232         | 0,0240         | 0,0221         | 0,0120         | -42,4058                                 |
| G. Other  | NO             | NO             | NO             | NO             | NO             | 0,0000                                   |
| <b>5. Land Use, Land-Use Change and Forestry</b>  | <b>0,0317</b>  | <b>0,0308</b>  | <b>0,0293</b>  | <b>0,0280</b>  | <b>0,0246</b>  | <b>-19,6574</b>                          |
| A. Forest Land                                    | 0,0159         | 0,0161         | 0,0132         | 0,0128         | 0,0103         | -12,9503                                 |
| B. Cropland                                       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | NA,NE,NO       | 0,0000                                   |
| C. Grassland                                      | 0,0158         | 0,0147         | 0,0161         | 0,0152         | 0,0143         | -23,8881                                 |
| D. Wetlands                                       | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | 0,0000                                   |
| E. Settlements                                    | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | 0,0000                                   |
| F. Other Land                                     | NE,NO          | NE,NO          | NE,NO          | NE,NO          | NE,NO          | 0,0000                                   |
| G. Other  | NA,NO          | NA,NO          | NA,NO          | NA,NO          | NA,NO          | 0,0000                                   |
| <b>6. Waste</b>                                   | <b>0,5039</b>  | <b>0,5139</b>  | <b>0,5139</b>  | <b>0,5254</b>  | <b>0,5288</b>  | <b>11,5691</b>                           |
| A. Solid Waste Disposal on Land                   |                |                |                |                |                |  |
| B. Waste-water Handling                           | 0,5039         | 0,5139         | 0,5139         | 0,5254         | 0,5288         | 11,5691                                  |
| C. Waste Incineration                             | NE             | NE             | NE             | NE             | NE             | 0,0000                                   |
| D. Other  | NO             | NO             | NO             | NO             | NO             | 0,0000                                   |
| <b>7. Other (as specified in Summary 1.A)</b>     | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>NA</b>      | <b>0,0000</b>                            |
| A. Other  | NA             | NA             | NA             | NA             | NA             | 0,0000                                   |
| <b>Memo Items:</b>                                |                |                |                |                |                |  |
| <b>International Bankers</b>                      | <b>0,0692</b>  | <b>0,0739</b>  | <b>0,0820</b>  | <b>0,0859</b>  | <b>0,0919</b>  | <b>40,4881</b>                           |
| Aviation  | 0,0495         | 0,0530         | 0,0541         | 0,0643         | 0,0723         | 91,2567                                  |
| Marine  | 0,0197         | 0,0209         | 0,0279         | 0,0216         | 0,0196         | -28,9608                                 |
| <b>Multilateral Operations</b>                    | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>NE</b>      | <b>0,0000</b>                            |
| <b>CO<sub>2</sub> Emissions from Biomass</b>      |                |                |                |                |                |  |

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSION TRENDS ( HFCs, PFCs and SF<sub>6</sub>)  
(Sheet 4 of 5)  
(Part 1 of 2)

Inventory 2004  
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| GREENHOUSE GAS SOURCE AND SINK CATEGORIES   | Base year ( 1990 ) | 1991     | 1992     | 1993     | 1994     | 1995     | 1996     | 1997     | 1998     | 1999     |
|---|--------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|   | (Gg)               | (Gg)     | (Gg)     | (Gg)     | (Gg)     | (Gg)     | (Gg)     | (Gg)     | (Gg)     | (Gg)     |
| <b>Emissions of HFCs<sup>(4)</sup> - (Gg CO<sub>2</sub> equivalent)</b>           | IE,NA,NO           | IE,NA,NO | 1.0400   | 4.6800   | 59.1855  | 145.2672 | 224.9557 | 139.8795 | 327.0413 | 266.4695 |
| HFC-23  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| HFC-32  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | 0.0004   | NA,NO    | NA,NO    | NA,NO    | 0.0074   |
| HFC-41  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| HFC-43-10mee  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| HFC-125   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | 0.0012   | 0.0005   | 0.0067   | 0.0105   | 0.0095   | 0.0104   |
| HFC-134   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| HFC-134a  | NA,NO              | NA,NO    | 0.0008   | 0.0036   | 0.0429   | 0.0871   | 0.1377   | 0.0576   | 0.2033   | 0.1462   |
| HFC-152a  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | 0.0004   | 0.0012   | 0.0004   | 0.0002   | 0.0004   | 0.0017   |
| HFC-143   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| HFC-143a  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | 0.0079   | 0.0071   | 0.0093   | 0.0094   | 0.0110   |
| HFC-227ea   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | 0.0000   | 0.0001   | 0.0001   | 0.0001   | 0.0001   | 0.0002   |
| HFC-236fa   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| HFC-245ca   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| Unspecified mix of listed HFCs <sup>(5)</sup> - (Gg CO <sub>2</sub> equivalent)   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| <b>Emissions of PFCs<sup>(4)</sup> - (Gg CO<sub>2</sub> equivalent)</b>           | 515.6000           | 651.6400 | 638.1000 | 524.8000 | 183.6000 | 147.5000 | 265.4000 | 166.2000 | 130.2000 | 74.2000  |
| CF <sub>4</sub>   | 0.0680             | 0.0844   | 0.0826   | 0.0680   | 0.0240   | 0.0190   | 0.0300   | 0.0210   | 0.0100   | 0.0100   |
| C <sub>2</sub> F <sub>6</sub>   | 0.0080             | 0.0112   | 0.0110   | 0.0090   | 0.0030   | 0.0020   | 0.0040   | 0.0030   | 0.0010   | 0.0010   |
| C <sub>3</sub> F <sub>8</sub>   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | 0.0008   | 0.0048   | 0.0003   | 0.0080   | NA,NO    |
| C <sub>4</sub> F <sub>10</sub>  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| c-C <sub>4</sub> F <sub>8</sub>   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| C <sub>5</sub> F <sub>12</sub>  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| C <sub>6</sub> F <sub>14</sub>  | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| Unspecified mix of listed PFCs <sup>(5)</sup> - (Gg CO <sub>2</sub> equivalent)   | NA,NO              | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    | NA,NO    |
| <b>Emissions of SF<sub>6</sub><sup>(4)</sup> - (Gg CO<sub>2</sub> equivalent)</b> | 12.3324            | 12.9060  | 13.6230  | 14.0532  | 14.4117  | 15.0092  | 14.7941  | 15.2960  | 14.0293  | 13.1928  |
| SF <sub>6</sub>   | 0.0005             | 0.0005   | 0.0006   | 0.0006   | 0.0006   | 0.0006   | 0.0006   | 0.0006   | 0.0006   | 0.0006   |

Note: All footnotes for this table are given at the end of the table on sheet 5.

**TABLE 10 EMISSION TRENDS ( HFCs, PFCs and SF<sub>6</sub> )**  
 (Sheet 4 of 5)  
 (Part 2 of 2)

Inventory 2004  
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| GREENHOUSE GAS SOURCE AND SINK CATEGORIES   | 2000            | 2001            | 2002            | 2003            | 2004            | Change from base to latest reported year |
|---|-----------------|-----------------|-----------------|-----------------|-----------------|--|
|   | (Gg)            | (Gg)            | (Gg)            | (Gg)            | (Gg)            | %  |
| <b>Emissions of HFCs<sup>(4)</sup> - (Gg CO<sub>2</sub> equivalent)</b>           | <b>246.9944</b> | <b>440.9499</b> | <b>619.8302</b> | <b>728.6311</b> | <b>597.1317</b> | <b>100.0000</b>                          |
| HFC-23  | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| HFC-32  | NA,NO           | 0.0034          | 0.0030          | 0.0050          | 0.0062          | 100.0000                                 |
| HFC-41  | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| HFC-43-10mce  | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| HFC-125   | 0.0041          | 0.0276          | 0.0476          | 0.0539          | 0.0495          | 100.0000                                 |
| HFC-134   | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| HFC-134a  | 0.1621          | 0.2012          | 0.2208          | 0.2653          | 0.2065          | 100.0000                                 |
| HFC-152a  | NA,NO           | 0.0009          | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| HFC-143   | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| HFC-143a  | 0.0064          | 0.0261          | 0.0518          | 0.0602          | 0.0487          | 100.0000                                 |
| HFC-227ea   | 0.0002          | 0.0002          | 0.0003          | 0.0003          | 0.0003          | 100.0000                                 |
| HFC-236fa   | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| HFC-245ca   | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| Unspecified mix of listed HFCs <sup>(5)</sup> - (Gg CO <sub>2</sub> equivalent)   | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| <b>Emissions of PFCs<sup>(4)</sup> - (Gg CO<sub>2</sub> equivalent)</b>           | <b>59.2500</b>  | <b>59.2500</b>  | <b>88.4000</b>  | <b>93.3000</b>  | <b>87.7000</b>  | <b>-82.9907</b>                          |
| CF <sub>4</sub>   | 0.0077          | 0.0077          | 0.0110          | 0.0110          | 0.0110          | -83.8235                                 |
| C <sub>2</sub> F <sub>6</sub>   | 0.0010          | 0.0010          | 0.0010          | 0.0010          | 0.0010          | -87.5000                                 |
| C <sub>3</sub> F <sub>8</sub>   | NA,NE,NO        | NA,NO           | 0.0011          | 0.0018          | 0.0010          | 100.0000                                 |
| C <sub>4</sub> F <sub>10</sub>  | NA,NE,NO        | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| c-C <sub>4</sub> F <sub>8</sub>   | NA,NE,NO        | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| C <sub>3</sub> F <sub>12</sub>  | NA,NE,NO        | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| C <sub>6</sub> F <sub>14</sub>  | NA,NE,NO        | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| Unspecified mix of listed PFCs <sup>(5)</sup> - (Gg CO <sub>2</sub> equivalent)   | NA,NO           | NA,NO           | NA,NO           | NA,NO           | NA,NO           | 0.0000                                   |
| <b>Emissions of SF<sub>6</sub><sup>(4)</sup> - (Gg CO<sub>2</sub> equivalent)</b> | <b>12.1890</b>  | <b>12.3085</b>  | <b>13.1450</b>  | <b>17.5187</b>  | <b>21.4861</b>  | <b>74.2248</b>                           |
| SF <sub>6</sub>   | 0.0005          | 0.0005          | 0.0006          | 0.0007          | 0.0009          | 74.2248                                  |

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSION TRENDS (SUMMARY)  
(Sheet 5 of 5)  
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Inventory 2004  
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| GREENHOUSE GAS EMISSIONS   | Base year ( 1990 )              | 1991                            | 1992                            | 1993                            | 1994                            | 1995                            | 1996                            | 1997                            | 1998                            | 1999                            |
|--|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|  | CO <sub>2</sub> equivalent (Gg) |
| CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF <sup>(3)</sup> | 6,292.4377                      | 8,239.5430                      | 11,846.8284                     | 12,420.8820                     | 12,900.9956                     | 11,969.9889                     | 12,660.3873                     | 13,175.7556                     | 9,650.8051                      | 10,504.6175                     |
| CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF <sup>(3)</sup> | 25,373.3859                     | 25,885.0355                     | 27,748.7936                     | 27,176.0226                     | 27,280.1959                     | 27,201.0275                     | 28,222.1959                     | 30,414.1962                     | 29,106.9911                     | 30,560.6965                     |
| CH <sub>4</sub>  | 25,665.2224                     | 25,333.6444                     | 25,272.0513                     | 25,411.1566                     | 25,774.6609                     | 25,969.5087                     | 26,300.1223                     | 26,400.7790                     | 26,487.8251                     | 26,592.6479                     |
| N <sub>2</sub> O   | 10,429.4835                     | 10,412.2126                     | 10,471.3609                     | 10,643.6405                     | 10,944.0396                     | 11,203.0856                     | 11,383.5292                     | 11,449.0130                     | 11,548.5448                     | 11,753.4614                     |
| HFCs   | IE,NA,NO                        | IE,NA,NO                        | 1.0400                          | 4.6800                          | 59.1855                         | 145.2672                        | 224.9557                        | 139.8795                        | 327.0413                        | 266.4695                        |
| PFCs   | 515.6000                        | 651.6400                        | 638.1000                        | 524.8000                        | 183.6000                        | 147.5000                        | 265.4000                        | 166.2000                        | 130.2000                        | 74.2000                         |
| SF <sub>6</sub>  | 12.3324                         | 12.9060                         | 13.6230                         | 14.0532                         | 14.4117                         | 15.0092                         | 14.7941                         | 15.2960                         | 14.0293                         | 13.1928                         |
| <b>Total (including net CO<sub>2</sub> from LULUCF)<sup>(3)</sup></b>              | <b>42,915.0761</b>              | <b>44,649.9461</b>              | <b>48,243.0036</b>              | <b>49,019.2124</b>              | <b>49,876.8933</b>              | <b>49,450.3596</b>              | <b>50,849.1886</b>              | <b>51,346.9231</b>              | <b>48,158.4456</b>              | <b>49,204.5891</b>              |
| <b>Total (excluding net CO<sub>2</sub> from LULUCF)<sup>(3), (6)</sup></b>         | <b>61,996.0242</b>              | <b>62,295.4385</b>              | <b>64,144.9688</b>              | <b>63,774.3529</b>              | <b>64,256.0936</b>              | <b>64,681.3982</b>              | <b>66,410.9972</b>              | <b>68,585.3637</b>              | <b>67,614.6316</b>              | <b>69,260.6681</b>              |

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES                | Base year ( 1990 )              | 1991                            | 1992                            | 1993                            | 1994                            | 1995                            | 1996                            | 1997                            | 1998                            | 1999                            |
|--|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|  | CO <sub>2</sub> equivalent (Gg) |
| 1. Energy  | 23,655.1469                     | 23,932.2302                     | 25,694.4911                     | 24,965.2583                     | 25,213.2580                     | 25,118.0963                     | 26,169.4525                     | 28,501.8448                     | 27,098.1838                     | 28,446.2306                     |
| 2. Industrial Processes                                  | 3,214.6145                      | 3,490.5397                      | 3,579.7672                      | 3,620.0905                      | 3,246.4782                      | 3,390.4548                      | 3,576.4860                      | 3,297.9443                      | 3,600.0424                      | 3,655.2443                      |
| 3. Solvent and Other Product Use                         | 41.5400                         | 42.7800                         | 43.0900                         | 43.7100                         | 44.3300                         | 44.9500                         | 45.8800                         | 46.1900                         | 46.5000                         | 46.8100                         |
| 4. Agriculture   | 32,498.8838                     | 32,222.3754                     | 32,245.0321                     | 32,517.4132                     | 33,129.9313                     | 33,707.0718                     | 34,171.9672                     | 34,296.6374                     | 34,521.3122                     | 34,912.7869                     |
| 5. Land Use, Land-Use Change and Forestry <sup>(7)</sup> | -18,977.9197                    | -17,550.3891                    | -15,794.5852                    | -14,619.4199                    | -14,227.2300                    | -15,084.3219                    | -15,396.8734                    | -17,059.4938                    | -19,308.8248                    | -19,924.5426                    |
| 6. Waste   | 2,482.8106                      | 2,512.4098                      | 2,475.2084                      | 2,492.1603                      | 2,470.1258                      | 2,274.1085                      | 2,282.2763                      | 2,263.8004                      | 2,201.2321                      | 2,068.0598                      |
| 7. Other   | NA                              |
| <b>Total (including LULUCF)<sup>(7)</sup></b>            | <b>42,915.0761</b>              | <b>44,649.9461</b>              | <b>48,243.0036</b>              | <b>49,019.2124</b>              | <b>49,876.8933</b>              | <b>49,450.3596</b>              | <b>50,849.1886</b>              | <b>51,346.9231</b>              | <b>48,158.4456</b>              | <b>49,204.5891</b>              |

TABLE 10 EMISSION TRENDS (SUMMARY)  
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| GREENHOUSE GAS EMISSIONS   | 2000                            | 2001                            | 2002                            | 2003                            | 2004                            | Change from base to latest reported year (%) |
|--|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|--|
|  | CO <sub>2</sub> equivalent (Gg) |  |
| CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF <sup>(5)</sup> | 10,714.4834                     | 12,424.8149                     | 11,687.6020                     | 11,844.7855                     | 9,473.4954                      | 50.5537                                      |
| CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF <sup>(5)</sup> | 31,036.7828                     | 33,041.8675                     | 33,030.0440                     | 34,681.0500                     | 34,038.8988                     | 34.1520                                      |
| CH <sub>4</sub>  | 26,956.4881                     | 27,127.9500                     | 27,140.0033                     | 27,100.2011                     | 27,160.7968                     | 5.8272                                       |
| N <sub>2</sub> O   | 12,109.6227                     | 12,485.9853                     | 12,824.9482                     | 13,079.5315                     | 13,264.9479                     | 27.1870                                      |
| HFCs   | 246.9944                        | 440.9499                        | 619.8302                        | 728.6311                        | 597.1317                        | 100.0000                                     |
| PFCs   | 59.2500                         | 59.2500                         | 88.4000                         | 93.3000                         | 87.7000                         | -82.9907                                     |
| SF <sub>6</sub>  | 12.1890                         | 12.3085                         | 13.1450                         | 17.5187                         | 21.4861                         | 74.2248                                      |
| <b>Total (including net CO<sub>2</sub> from LULUCF)<sup>(5)</sup></b>              | <b>50,099.0276</b>              | <b>52,551.2595</b>              | <b>52,373.9288</b>              | <b>52,863.9680</b>              | <b>50,605.5579</b>              | <b>17.9202</b>                               |
| <b>Total (excluding net CO<sub>2</sub> from LULUCF)<sup>(5),(6)</sup></b>          | <b>70,421.3270</b>              | <b>73,168.3120</b>              | <b>73,716.3708</b>              | <b>75,700.2324</b>              | <b>75,170.9613</b>              | <b>21.2513</b>                               |

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES                | 2000                            | 2001                            | 2002                            | 2003                            | 2004                            | Change from base to latest reported year (%) |
|--|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|--|
|  | CO <sub>2</sub> equivalent (Gg) |  |
| 1. Energy  | 28,946.1547                     | 30,891.9390                     | 30,887.1120                     | 32,306.0540                     | 31,647.9072                     | 33.7887                                      |
| 2. Industrial Processes                                  | 3,588.3088                      | 3,862.6338                      | 4,065.3502                      | 4,354.6605                      | 4,202.5303                      | 30.7320                                      |
| 3. Solvent and Other Product Use                         | 47.1200                         | 47.4300                         | 48.3600                         | 48.3600                         | 48.3600                         | 16.4179                                      |
| 4. Agriculture   | 35,652.3893                     | 36,237.1487                     | 36,650.6318                     | 36,967.9657                     | 37,349.6342                     | 14.9259                                      |
| 5. Land Use, Land-Use Change and Forestry <sup>(7)</sup> | -20,215.6952                    | -20,513.3566                    | -21,243.8657                    | -22,742.1856                    | -24,482.6277                    | 29.0059                                      |
| 6. Waste   | 2,080.7501                      | 2,025.4637                      | 1,966.3395                      | 1,929.1134                      | 1,839.9818                      | -25.8912                                     |
| 7. Other   | NA                              | NA                              | NA                              | NA                              | NA                              | 0.0000                                       |
| <b>Total (including LULUCF)<sup>(7)</sup></b>            | <b>50,099.0276</b>              | <b>52,551.2595</b>              | <b>52,373.9288</b>              | <b>52,863.9680</b>              | <b>50,605.5579</b>              | <b>17.9202</b>                               |

<sup>(1)</sup> The column "Base year" should be filled in only by those Parties with economies in transition that use a base year different from 1990 in accordance with the relevant decisions of the COP. For those Parties, this different base year is

<sup>(2)</sup> Fill in net emissions/removals as reported in table Summary 1.A. For the purposes of reporting, the signs for removals are always negative (-) and for emissions positive (+).

<sup>(3)</sup> The information in these rows is requested to facilitate comparison of data, because Parties differ in the way they report CO<sub>2</sub> emissions and removals from LULUCF.

<sup>(4)</sup> Enter actual emissions estimates. If only potential emissions estimates are available, these should be reported in this table and an indication for this be provided in the documentation box. Only in these rows are the emissions expressed as CO<sub>2</sub> equivalent emissions.

<sup>(5)</sup> In accordance with the UNFCCC reporting guidelines, HFC and PFC emissions should be reported for each relevant chemical. However, if it is not possible to report values for each chemical (i.e. mixtures, confidential data, lack of disaggregation), this row could be used for reporting aggregate figures for HFCs and PFCs, respectively. Note that the unit used for this row is Gg of CO<sub>2</sub> equivalent and that appropriate notation keys should be entered in the cells for the individual chemicals.

<sup>(6)</sup> These totals will differ from the totals reported in table Summary 2 if Parties report non-CO<sub>2</sub> emissions from LULUCF.

<sup>(7)</sup> Includes net CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from LULUCF.

|   |
|---|
| <b>Documentation box:</b>   |
| * Parties should provide detailed explanations on emissions trends in Chapter 2. Trends in Greenhouse Gas Emissions and, as appropriate, in the corresponding Chapters 3 - 9 of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and further details are needed to understand the content of * |
| * Use the documentation box to provide explanations if potential emissions are reported.  |
| CO <sub>2</sub> /SO <sub>2</sub> emissions: These values have been updated due to new information. Emission factors supplied by industry-these vary depending on the processing technology and the input materials. An average emission factor of 0.5 kg SO <sub>2</sub> /t lime has been calculated.   |
|   |
| N <sub>2</sub> O and CO: Emissions assumed to be totally associated with fuel use rather than industrial process so are counted with other fuel combustion emissions in the energy sector. 1AA.2 "Manufacturing Industries and Construction".   |