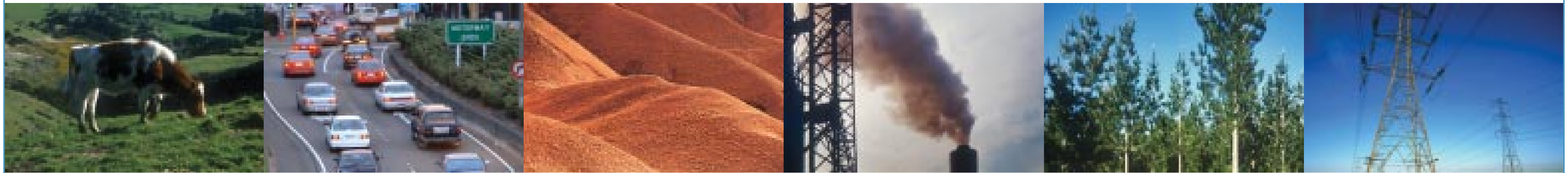
New Zealand Climate Change Office
Te Hōtaka Rerekētanga Āhuarangi ō Aotearoa

Climate Change



National Inventory Report
New Zealand

Greenhouse Gas Inventory 1990-2001

(including the Common Reporting Format (CRF) for 2001)

April 2003

Ministry for the Environment
Manatū Mō Te Taiao

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Many others were involved in the field work and analysis, and in the peer review of these reports.

Executive summary of greenhouse gas emissions

Emissions by gas

Greenhouse gas emissions	Gg CO_2 equivalents 1990	2001	Difference %
Net CO_2 emissions/removals	3,497.88	8,278.76	**136.66**
CO_2 emissions (without LUCF)*	25,266.88	32,430.19	**28.35**
CH_4	25,600.37	27,065.36	**5.72**
N_2O	10,281.46	12,576.17	**22.32**
HFCs	0	231.65	**231.65**
PFCs	602.53	58.90	**-90.22**
SF_6	2.87	16.86	**487.46**
Total (with net CO_2 from LUCF)	**39,985.11**	**48,520.33**	**21.34**
Total (without CO_2 from LUCF)	**61,754.10**	**72,379.13**	**17.21**

* Land-use change and forestry

Emissions by sector

Greenhouse gas source and sink categories	Gg CO_2 equivalents 1990	2001	Difference %
Energy	23,850.05	30,932.22	**29.69**
Industrial processes	2,994.27	3,185.26	**6.38**
Solvent and other product use	0	0	**0**
Agriculture	31,907.64	35,846.63	**12.34**
Land-use change and forestry	-21,671.11	-23,762.95	**9.65**
Waste	2,904.26	2,319.16	**-20.15**

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Chapter 1

Overview

1.1 Introduction

New Zealand has been continuing the development of its greenhouse gas inventories and this submission is the sixth National Inventory Report submitted to the United Nations Framework Convention on Climate Change (UNFCCC). The document is provided to support the Common Reporting Format (CRF) for all years 1990 through to 2001.

This report is structured by sector (energy, industrial processes, solvents and other product use, agriculture, land-use change and forestry (LUCF) and waste). A list of references is provided at the end of each chapter.

1.2 Major changes since last submission

The most significant change in this year's submission is in data reported in the agricultural sector. A re-evaluation of animal productivity and feed intakes has been used in both the ruminant methane and nitrous oxide emissions estimates. The entire time series has been recalculated for both methane emissions from enteric fermentation and manure management, and also for nitrous oxide emissions from agricultural soils. Introduction of Good Practice to the estimation of emissions from this sector has resulted in the calculation of methane emissions from enteric fermentation using a higher tier method, and to a complete review of nitrous oxide emissions from soils. These changes are described in more detail in the following section on Good Practice and in the chapter covering the agricultural sector.

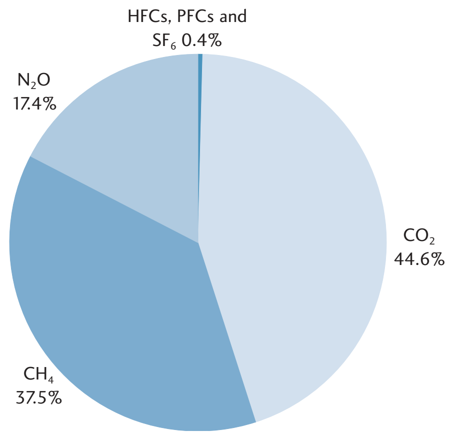
1.3 Institutional arrangements

The Climate Change Response Act (2002), which enabled New Zealand's ratification of the Kyoto Protocol, names the Ministry for the Environment as New Zealand's Inventory Agency. The New Zealand Climate Change Office, located within the Ministry for the Environment, is the Inventory Agency and it coordinates the compilation and submission of the annual inventory to the UNFCCC. The Ministry of Economic Development collects and collates the energy sector emissions and the CO_2 emissions from the industrial processes sector. The non-CO_2 gases from the industrial processes sector and the waste sector were collected and collated by environmental consultants contracted by the Ministry for the Environment. The agricultural and LUCF sectors of the national greenhouse gas inventory are managed by the Ministry of Agriculture and Forestry and the New Zealand Climate Change Office, and are underpinned by work undertaken by researchers at Crown Research Institutes and universities.

1.4 Emissions trends

Figure 1: Emissions by gas and by sector 2001

Emissions by gas in 2001



Emissions by sector in 2001

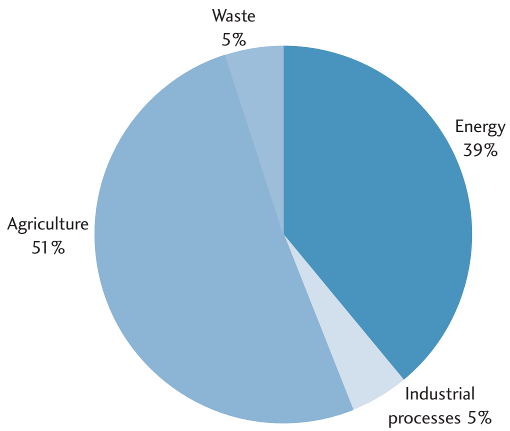
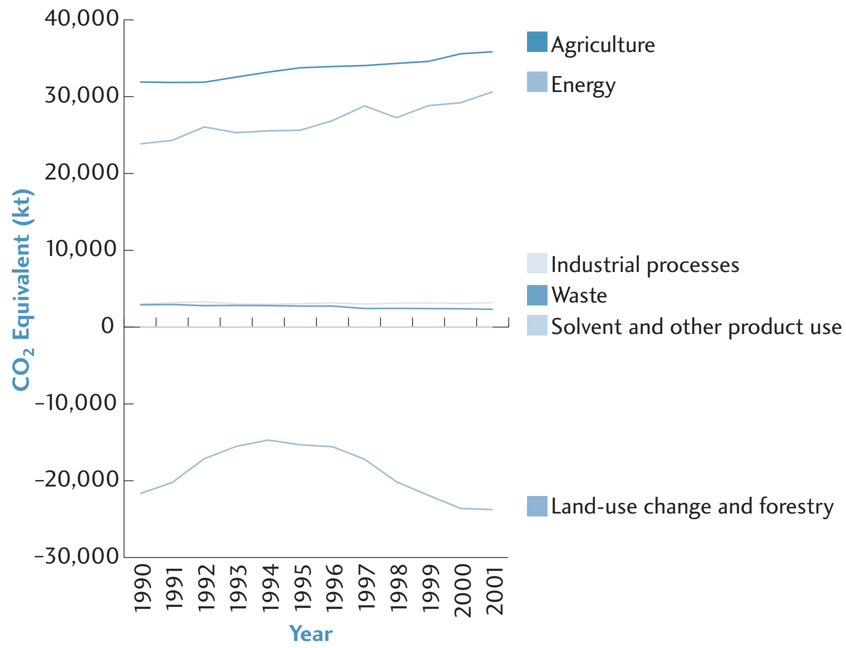


Figure 2: Emissions by sector from 1990 to 2001



Overall emissions in New Zealand have increased 2.8% since 2000 and by 17.2% since 1990. Increases since 2000 have occurred primarily in the energy sector with public electricity and heat production increasing by 29%. Emissions from agriculture and industrial processes have increased by 10% and 6% respectively, whilst waste emissions have decreased by 2.9% since 2000. Since 2000, CO_2 has increased by 5.8%, CH_4 has decreased by 0.3%, N_2O has increased by 2.2%, HFCs have increased by 35.1%, PFCs have increased by 3.6% and SF_6 has increased by 2.7%.

1.5 Good Practice

The revised 1996 Intergovernmental Panel on Climate Change (IPCC) methodology is used in the preparation of the inventory and the *IPCC Good Practice Guidance* is being implemented in stages, according to priorities and national circumstances.

In the 2001 submission for the year 1999, estimates of emissions of the fluorinated gases (HFCs, PFCs and SF_6) were upgraded to IPCC (2000) Tier 2 methodology, and in the 2002 submission for the year 2000, emissions from solid waste disposal were upgraded to Tier 2 as part of this development process.

In this year's submission the following elements of Good Practice have been introduced:

1. The methodology used to estimate methane emissions from ruminants has been upgraded from Tier 1 to a Tier 2 approach consistent with IPCC (2000). The Tier 2 approach has been applied across the whole time series from 1990.
2. As part of the ongoing improvement for estimates of nitrous oxide from agricultural sources, a complete recalculation of the time series has been 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.
3. Quality Assurance/Quality Control (QA/QC) introduced throughout the entire inventory with scientific peer review has been carried out on the reports that underpin improvements to the agricultural sector emissions (1 and 2 above).

More detail of the above elements of inventory improvement are covered in the specific chapters of the report.

1.6 Key source analysis

The key sources in the New Zealand inventory have been assessed according to the IPCC Good Practice Guidance methodologies. Following are tables showing the level assessment and the trend assessment. The trend assessment has been done using 1990 and 2001 data.

Table 1: Key source analysis – level assessment

CRF category	IPCC source categories	Gas	Current year estimate[1]	Level assessment	Cumulative total
4A	Enteric fermentation - domestic livestock	CH_4	23,126.46	0.32	0.32
1A3b	Mobile combustion (road vehicles)	CO_2	11,102.53	0.15	0.47
4D2	Animal production N_2O from agricultural soils	N_2O	7,123.80	0.10	0.57
1A2	Manufacturing industries and construction	CO_2	6,249.31	0.09	0.66
1A1a	Stationary combustion electricity (gas)	CO_2	5,172.34	0.07	0.73
4D3	Indirect N_2O from agricultural soils	N_2O	3,134.10	0.04	0.77
6A	CH_4 from solid waste disposal sites	CH_4	1,993.95	0.03	0.80
4D1	Direct N_2O from agricultural soils	N_2O	1,807.30	0.02	0.82
2C1	Iron and steel industry	CO_2	1,560.68	0.02	0.85
1A1a	Stationary combustion electricity (coal)	CO_2	1,283.50	0.02	0.86
1A4c	Stationary combustion agriculture/forestry/fisheries	CO_2	1,217.17	0.02	0.88
1A4a	Stationary combustion commercial/institutional	CO_2	1,142.62	0.02	0.90
1A3a	Mobile combustion (aviation)	CO_2	725.91	0.01	0.91
1A1b	Stationary combustion petroleum refining (gas)	CO_2	653.17	0.01	0.92
4B	CH_4 from manure management	CH_4	550.83	0.01	0.92
1B1a	Fugitive emissions from coal mining and handling	CH_4	525.84	0.01	0.93
2A1	Cement production	CO_2	523.98	0.01	0.94
2C3	Aluminium production	CO_2	504.34	0.01	0.94
1A4b	Stationary combustion residential	CO_2	482.67	0.01	0.95

[1]Units are Gigagrams of CO_2 equivalent

Table 2: Key source analysis – trend assessment

CRF category	IPCC source categories	Gas	% contribution to trend	Cumulative total
1A3b	Mobile combustion (road vehicles)	CO_2	18.07	18.07
4A	Enteric fermentation - domestic livestock	CH_4	15.44	33.51
1A1a	Stationary combustion electricity (gas)	CO_2	13.18	46.69
6A	CH_4 from solid waste disposal sites	CH_4	8.46	55.15
4D1	Direct N_2O from agricultural soils	N_2O	7.64	62.79
1A1a	Stationary combustion electricity (coal)	CO_2	5.67	68.46
2C3	Aluminium production	PFCs	5.11	73.57
1A2	Manufacturing industries and construction	CO_2	4.88	78.45
4D2	Animal production N_2O from agricultural soils	N_2O	4.43	82.88
1A4a	Stationary combustion commercial/institutional	CO_2	2.20	85.08
1B1a	Fugitive emissions from coal mining and handling	CH_4	1.89	86.97
2F1 - 5	Emissions from ODS* substitutes	HFCs	1.86	88.83
1A3a	Mobile combustion (aviation)	CO_2	1.52	90.35
1B2d	Fugitive emissions from geothermal	CO_2	1.21	91.55
1A4b	Stationary combustion residential	CO_2	1.01	92.56
4B	CH_4 from manure management	CH_4	0.97	93.53
1A3a	Mobile combustion (rail)	CO_2	0.78	94.31
1A4c	Stationary combustion agriculture/forestry/fisheries	N_2O	0.78	95.09

*Ozone Depleting Substances

1.7 UNFCCC reviews in 2001

The greenhouse gas inventory was reviewed in 2001 by the UNFCCC as part of a pilot study of the technical review process. A separate review was also carried out by an energy sector expert from New Zealand. Several of the recommendations of these reviews appeared in last year's inventory (Tier 2 approach applied for methane emissions from solid waste disposal sites, and emissions from small sources previously unreported (lime and dolomite) included), some appear for the first time in this inventory (Tier 2 approach applied for methane emissions from ruminants), whilst others are being incorporated into a longer-term work plan. The longer-term work programme includes a review of the country-specific emission factors for fuels in the energy sector, and ongoing research has been funded to improve the nitrous oxide emissions estimation. Overall, a process of cross-verification between the different government departments responsible for the inventory has been implemented and additional work is planned to formalise the verification process further.

1.8 Planned and ongoing work

The following work is continuing or is planned for ongoing inventory improvement:

1. Further revision of country-specific emission factors for nitrous oxide emissions from soil.
2. Energy sector emission factors review (commenced February 2003).
3. Development of transport emissions model (VTEC).
4. Review of the industrial processes sector.
5. Further methodological development of forestry models for the LUCF sector.
6. Establishment of a process to approve changes to emission factors.

1.9 Uncertainty

The current level of uncertainty in the inventory is very high because of the large contribution of non-CO_2 emissions from the agricultural sector to total emissions. A numerical value of total inventory uncertainty has not yet been estimated. However, included in this submission are uncertainty analyses for both CH_4 from enteric fermentation and N_2O from agricultural soils using the Monte Carlo approach. This is described in more detail in the agriculture chapter.

Chapter 2

Energy

2.1 Introduction

New Zealand's energy sector represented approximately 42% of all greenhouse gas emissions in 2001 and there was an increase of 5.9% from 2000. Emissions are now 30% above the 1990 baseline in this sector. The sources contributing most to this increase are CO_2 emissions from manufacturing industries and construction (increase of 31.4%), transport (increase of 42%), the energy industries (increase of 25.7%) and fugitive emissions from fuels (60.4% for CH_4 although a decrease of 6.7% for CO_2).

Greenhouse gas emissions from the energy sector have been estimated using both the reference and sectoral approaches. The reference approach used the prescribed worksheets from the IPCC revised 1996 guidelines and incorporated IPCC Good Practice Guidance (where currently appropriate). The sectoral approach used worksheets which have been consolidated in places by combining sheets used and by only showing relevant categories.

2.2 Changes since the last inventory submission

1. The source of the energy sector data is updated in *New Zealand Energy Greenhouse Gas Emissions 1990-2001* (Ministry of Economic Development, June 2002).
2. Continued development of a work programme to introduce Tier 2 methodology to all key source categories in the energy sector.

2.3 Country-specific approaches different from the IPCC methodology

There are very few areas of divergence from the IPCC methodology. The main differences occur in the *sectoral approach worksheets*. These were consolidated by combining sheets and excluding some IPCC source categories where they are not relevant to New Zealand. This has been done in the interest of providing concise and transparent tables that provide the complete set of data required by the guidelines. The other differences are listed below:

1 New Zealand-specific emission factors have been used where possible.
2. A detailed breakdown of the source category "*Manufacturing and construction*", as requested by the IPCC reporting tables, is currently not available due to a lack of consistent data on consumption from the source.
3. Some gas usage data by large industrial consumers in New Zealand and some emission factors for gas have been withheld for confidentiality reasons.

4. Some of the coal production in the reference approach activity data is used in steel production. The CO_2 emissions from this coal are accounted for under the industrial processes sector and have been netted out of the energy reference approach using the *Estimating the carbon stored in products* table (Worksheet 1.1).
5. The activity data shown in the CO_2 worksheets (Worksheet 1.2) under the sectoral approach exclude energy sources containing carbon that is later stored in manufactured products (rather than emitted during combustion), specifically methanol and urea. 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.
6. The worksheet for fugitive CH_4 emissions from oil and gas activities (Worksheet 1.7) is incomplete due to insufficient data availability. The worksheet does include some of the fugitive CO_2 emissions from these activities.
7. An additional worksheet is included to cover fugitive emissions of CO_2 and CH_4 from geothermal fields where electricity or heat generation plants are in operation.

2.4 Emissions calculation methodologies

Emissions from the energy sector are compiled from the Ministry of Economic Development's energy database. Generally, greenhouse gas emissions have been calculated by multiplying the emission factors of specific fuels by the energy activity data. There are only a few instances where emission factors are unavailable due to confidentiality constraints, and instances where natural gas was used as a feedstock. For those sources the calculation procedure was reversed and the emission factors were calculated from the activity and emissions data.

2.5 Reference approach

CO_2 emissions from fuel combustion

The majority of the emission factors for the reference approach are New Zealand specific (see Table 3).

Natural gas emission factors are estimated from the sectoral approach data. The aggregated CO_2 emissions, including carbon later stored, were divided by aggregate energy use.

Table 3: Emission factors used in the reference approach

	Emission factor (tC/TJ)	Emission factor (tCO_2/TJ)	Source
Liquid fuel type			
Crude oil	17.8	65.3	Baines, 1993
Gasoline (petrol)	18.2	66.6	Baines, 1993
Jet kerosene	18.8	69.0	Baines, 1993
Aviation fuels	18.8	69.0	Baines, 1993
Gas/Diesel oil	18.7	68.7	Baines, 1993
Residual fuel oil	20.0	73.4	Baines, 1993
Fuel oil	20.1	73.7	Baines, 1993
Asphalt	20.8	76.1	NZ Refining Company
LPG	16.5	60.4	Baines, 1993
Bitumen	20.9	76.7	IPCC default value
Refinery feedstocks	19.0	69.7	IPCC default value
Solid fuels			
Coking coal	24.2	88.8	Baines, 1993
Other bituminous coal	24.2	88.8	Baines, 1993
Sub-bituminous coal	24.9	91.2	Baines, 1993
Lignite	26.0	95.2	Baines, 1993
Coke	27.9	102.3	Baines, 1993
Wood	29.9	104.2	IPCC default

Note: IPCC default (converted from net to gross values)

2.6 Sectoral approach

CO_2 emissions from fuel combustion

As with the reference approach, the majority of the CO_2 emission factors are New Zealand specific.

Natural gas

Natural gas CO_2 emission factors vary greatly between gas streams (see Table 4). An average annual factor was calculated for all reticulated gas, based on Maui and 'Treated' gas field data. This emission factor is based on the CO_2 content of the contributing gas streams and the daily gas consumption data ranges from 52.8 to 52.1 tCO_2/TJ over the period 1990 to 2001. The CNG calculations also use this annual average factor.

Table 4: Natural gas CO_2 emission factors

Gas stream	Emission factor (tCO_2/TJ)
Maui	51.9 (2001 yr data)
'Treated'	52.6 (2001 yr data)
Kapuni LTS	84.1 (no variation assumed)
Waihapa/Ngaere	56.2 (no variation assumed)
Kaimiro	65.2 (no variation assumed)
McKee	54.2 (no variation assumed)
Ngatoro	46.3 (no variation assumed)

Emission factors for major gas users were calculated from the specific gas mix of the gas supplied and are slightly higher than the average distributed gas. In this group are: electricity generation providers, the oil refinery, the methanol and synthetic petrol producer and the ammonia and urea plants. Data confidentiality means that some of the gas quantities are not detailed and the carbon in the final products is excluded from the CO_2 emissions from fuel combustion.

Coal

The CO_2 emissions from coal use in electricity generation are provided each year by the sole electricity generator that uses coal. CO_2 emissions from coal use in the other sectors are extrapolated using actual sectoral data (provided by Coal Research Limited) of coal use for the years 1990 and 1995. Each sector's allocation of total coal sales is multiplied by the emission factor for sub-bituminous coal (91.2tCO_2/TJ).

Wood

The IPCC emission factor was used for CO_2 emissions from wood combustion as in Table 1.

Non-CO_2 emissions from fuel combustion

The methodology used is similar to that used for the sectoral CO_2 calculations and the New Zealand-specific emission factors used are listed below and all occur from the transport sector (see Table 5). All other emission factors not listed are IPCC default factors.

Table 5: Emission factors used to estimate transport emissions

Fuel type(s)	Emission factor	Units	Source
Petrol	60	tCH_4/PJ	Bone et al., 1993
Diesel	13	tCH_4/PJ	Bone et al., 1993
Fuel oil	14	tCH_4/PJ	Bone et al., 1993
Aviation fuels	1.5	tCH_4/PJ	Bone et al., 1993
LPG	40	tCH_4/PJ	Bone et al, 1993
Petrol, diesel	3	tN_2O/PJ	Waring et al., 1991
Fuel oil	1.8	tN_2O/PJ	Bone et al., 1993
Aviation fuels	1.1	tN_2O/PJ	Bone et al., 1993
LPG	2.8	tN_2O/PJ	Bone et al., 1993
Petrol	0.467	ktNO_x/PJ	Waring et al., 1991
Diesel	0.718	ktNO_x/PJ	Waring et al., 1991
CNG	2.8	tN_2O/PJ	Bone et al., 1993

Note: For all other non-CO_2 combustion emission factors for liquid fuels, gas, and coal that are not mentioned above, IPCC default emission factors are used.

Fugitive CO_2 and non-CO_2 emissions

Emission factors for fugitive emissions come from a variety of sources or are derived from activity and emissions data supplied by the oil, gas and coal industries.

Coal mining and handling

The values from the middle of the IPCC default emission factors are used for surface mining, handling of surface-mined coal and handling of underground-mined coal. These were first converted to tCH_4/kt coal values. The average factors for underground coal mining reported here in Table 6 are based on the New Zealand-specific values established by Beamish and Vance, 1992.

Table 6: Methane release factors for New Zealand coal

Rank of underground coal	Release factor (tCH_4/kt coal)
Bituminous	35.3
Sub-bituminous	12.1

Oil transport

The fuel quantity is the total for New Zealand production of crude oil whilst the CH_4 emission factor is the midpoint of the IPCC default value range (Table 1.7).

Oil refining and storage

The fuel quantity is the oil intake at New Zealand's single oil refinery. The CH_4 emission factor is the sum of the IPCC default range midpoints for oil refining and storage (Worksheet 1.7).

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 from transmission pipelines are about 10 tonnes of CO_2 and 100 tonnes of CH_4 (Worksheet 1.7). Therefore, the gas quantity shown in the worksheets excludes the gas used in electricity generation and by others taking their gas directly from the transmission network.

The Natural Gas Corporation estimates that around 3.5% of the gas entering the distribution system is unaccounted for. It further estimates that around half of this (1.75%) is actually lost through leakage whilst the other half is unaccounted for due to metering errors and theft. The split between fugitive CO_2 and CH_4 is based on gas consumption data. These data are then used to calculate fugitive emission factors for the two gases.

Venting and flaring from oil and gas production

The CO_2 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 supplies estimates of CO_2 released during processing. These values are aggregated to derive aggregate annual emissions.

Geothermal activities

The geothermal field operators supply the emission estimates of CO_2 and CH_4 from their geothermal plants used to generate electricity and heat. These estimates are used in conjunction with geothermal energy data to derive emission factors. The proportion of these emissions that would have normally occurred in the absence of the geothermal plant has not been accounted for in the estimate. However, sites with naturally occurring emissions where no human activity is present are excluded from the inventory.

Ozone precursors and SO_2 from oil refining

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

Feedstocks

Feedstocks are accounted for in the inventory. 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_2. The non-CO_2 emissions are calculated using the IPCC default emission factors.

International bunker fuels

The data on fuel use by international transportation come from the *New Zealand Energy Data File* (a Ministry of Economic Development publication). This sources information from oil company returns to the Ministry of Economic Development. Data on fuel use by domestic transport are sourced from the *Deliveries of Petroleum Fuels by Industry* survey undertaken by Statistics New Zealand. The distinction between domestic and international transport is made easier because New Zealand is an island nation.

2.7 Issues of transparency (QA/QC)

The CRF was internally reviewed by the Climate Change Office.

2.8 Uncertainty

Estimates of CO_2 emissions from the energy sector are considered to be relatively accurate and within ±5%. This is due to the direct relationship between fuels' carbon content and the corresponding CO_2 emissions during combustion. Much of the data on fuel composition already exists in New Zealand.

The emissions of the non-CO_2 gases are much less certain as these emissions vary with the combustion conditions and fuel consumption. The majority of the emission factors in use are from the IPCC Guidelines. The combinations of uncertainty in the activity data and in the emission factors are considered to be approximately as shown in Table 7.

2.9 Future improvements

Emission factors used for the energy sector estimates are currently undergoing an extensive review. The results of this review will be incorporated in the inventory submission in 2004.

Table 7: Uncertainty ranges for emission estimates in the energy sector

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

2.10 References

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Appendix to Chapter 2:
Energy sector calculation tables 2001

Module	2001 Energy (New Zealand)
Submodule	**CO_2 emissions from energy sources (reference approach)**
Worksheet	**1.1 (1-3 of 5)**
Sheet	**Emissions from domestic fuel combustion**

Fuel type		Production	Imports	Exports	International 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 CO_2 emissions (Gg)
Liquid fossil fuels - primary	Crude oil	69.46	191.43	56.29		-6.82	211.42	1000	211420	17.80000	3763276	3763.276		3763.276	0.99	3725.64324	13660.69188
	Orimulsion	0	0	0		0	0										
	Natural gas liquids	12.44	0	4.19		0.16	8.09	1000	8090	16.47273	133264.364	133.264364		133.264364	0.99	131.93172	483.74964
Liquid fossil fuels - secondary	Gasoline		36.51	0	0.02	3.19	33.3	1000	33300	18.16364	604849.091	604.849091		604.849091	0.99	598.8006	2195.6022
	Jet kerosene		6.2	0	27.88	0.13	-21.81	1000	-21810	18.81818	-410424.55	-410.42455		-410.42455	0.99	-406.3203	-1489.8411
	Other kerosene		0	0	0	0	0										
	Shale oil		0	0	0	0	0										
	Gas/diesel oil		10.95	0	2.25	-0.43	9.13	1000	9130	18.73636	171063	171.063		171.063	0.99	169.35237	620.95869
	Residual fuel oil		0	2.38	8.75	1.76	-12.89	1000	-12890	20.10000	-259089	-259.089		-259.089	0.99	-256.49811	-940.49307
	LPG		0	0		0	0										
	Ethane		0	0		0	0										
	Naphtha		0	0		0	0										
	Bitumen		5.83	0	0	0.62	5.21	1000	5210	20.76228	108171.497	108.171497	219.042091	-110.87059	0.99	-109.76189	-402.460256
	Lubricants		0	0	0	0	0										
	Petroleum coke		0	0		0	0										
	Refinery feedstocks		19.68	0		-0.64	20.32	1000	20320	19.33065	392798.78	392.79878		392.79878	0.99	388.870792	1425.859571
	Other oil		0	0		0	0										
Total liquid fossil fuels		**81.9**	**270.6**	**62.86**	**38.9**	**-2.03**	**252.77**		**252770**		**4503909.19**	**4503.90919**	**219.042091**	**4284.8671**		**4242.01842**	**15554.06756**
Solid fossil fuels - primary	Anthracite	0	0	0		0	0										
	Coking coal	1433548	0	1792382		-358834	0	0.0321	0	24.20000	0	0	0	0	0.98	0	0
	Other bituminous coal	463223	0	0	0	0	463223	0.0321	14869.4583	24.20000	359840.891	359.840891		359.840891	0.98	352.644073	1293.028268
	Sub-bituminous coal	1811681	0	0	0	0	1811681	0.0226	40943.9906	24.90000	1019505.37	1019.50537	403.89575	615.609616	0.98	603.297424	2212.090555
	Lignite	202944	0	0		0	202944	0.015	3044.16	26.00000	79148.16	79.14816		79.14816	0.98	77.5651968	284.4057216
	Peat	0	0	0		0	0										
Solid fossil fuels - secondary	BKB & patent fuel		0	0		0	0										
	Coke		20341.18	0		0	20341.18	0.0279	567.518922	27.90000	15833.7779	15.8337779		15.8337779	0.98	15.5171024	56.89604201
Total solid fossil fuels		**3911396**	**20341.18**	**1792382**	**0**	**-358834**	**2498189.18**		**59425.1278**		**1474328.19**	**1474.32819**	**403.89575**	**1070.43245**		**1049.0238**	**3846.420586**
Total gaseous fossil fuels		247.44	**0**	**0**		0.45	**246.99**	**1000**	**246990**	14.32100	**3537143.79**	**3537.14379**	**0**	**3537.14379**	0.995	**3519.45807**	**12904.67959**
Total fossil fuels									**559185.128**		**9515381.17**	**9515.38117**	**622.937841**	**8892.44333**		**8810.50029**	**32305.16774**
Total biomass fuels									**29130**		**870987**	**870.987**		**870.987**		**827.43765**	**3118.3607**
	Solid biomass								29130	29.90000	870987	870.987		870.987	0.95	827.43765	3033.93805
	Liquid biomass								ne								ne
	Gas biomass								conf								84.42265005

Liquid and gaseous fossil fuel data are shown initially in petajoules. Solid fossil fuel data are shown initially in tonnes.

Module	2000 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)	Actual CO_2 emissions (Gg)
Solid fossil fuels	Other bituminous coal	0											no
	Sub-bituminous coal	0											no
Liquid fossil fuels	Gasoline	0.02											
	Jet kerosene	27.88	1000	27880	18.8181818	524650.909	524.650909	0	0	524.650909	0.99	519.4044	1904.4828
	Gas/diesel oil	2.25	1000	2250	18.7363636	42156.8182	42.1568182	0	0	42.1568182	0.99	41.73525	153.02925
	Residual fuel oil	8.75	1000	8750	20.1	175875	175.875	0	0	175.875	0.99	174.11625	638.42625
	Lubricants	0											no
Total fossil fuels				38880								735.2559	2695.9383

Liquid fossil fuel data are shown initially in petajoules.

Module 2000 Energy (New Zealand)
Submodule CO_2 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							no
Lubricants	0							no
Bitumen	10.55	1000	10550	20.76228	219042.091	219.042091	1	219.042091
Coal oils and tars	0	0.0325	0	24.24	0	0	0.75	0
Coal[1]	15.805241	1000	15805.241	25.5545455	403895.75	403.89575	1	403.89575
Natural gas[2]	conf	1000	conf	conf	conf	conf	conf	0
Gas/diesel oil	0							no
LPG	0							no
Ethane	0							no
Other fuels	0							no
Total								622.937841

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	2001 Energy (New Zealand)
Submodule	**CO_2 emissions from fuel combustion by source categories (tier 1)**
Worksheets	**1.2 (part I)**

Source and sink catergories	**Energy consumption (TJ)**	**Carbon emis fact (t C/TJ)**	**Carbon content (t C)**	**Carbon content (Gg)**	**Fraction of carbon stored[1]**	**Carbon stored[1] (t C)**	**Net C emissions (Gg)**	**Fraction of carbon oxidised**	**Actual C emissions (Gg)**	**Actual CO_2 emissions (Gg)**
Total energy (parts I and II of worksheet)	**515,989**		**7,955,117**	**7,955**			**7,955**		**7,880**	**28,980.38336**
1 Energy industries	**133,804**		**2,083,685**	**2,084**			**2,084**		**2,068**	**7,581.42**
a Public electricity and heat	**114,056**		**1,775,071**	**1,775**			**1,775**		**1,761**	**6,456.40**
Motor gasoline	2	18.2	33	0			0	0.99	0	0.12
Diesel	6	18.7	121	0			0	0.99	0	0.44
Fuel oil	0	20.1	0	0			0	0.99	0	0.00
Sub-bituminous coal	14,345	24.9	357,191	357			357	0.98	350	1,283.50
Natural gas	99,703	14.21954465	1,417,726	1,418			1,418	0.995	1,411	5,172.34
b Petroleum refining	**13,531**		**228,546**	**229**			**229**		**227**	**832.91**
Fuel oil	349	19.33	6,756	7			7	0.99	7	24.52
Asphalt	2,059	20.76	42,757	43			43	0.99	42	155.21
Refinery gas	10,912	16.12	175,909	176			176	0.995	175	641.77
Natural gas	210	14.89176532	3,125	3			3	0.995	3	11.40
c Solid fuels and other energy[2]	6,217		**80,068**	**80**			**80**		**80**	**292.11**
Natural gas in synthetic petrol prodn	conf	conf	0	0			0	0.995	0	0.00
Natural gas in oil and gas extraction	conf	conf	80,068	80			80	0.995	80	292.11
2 Manufacturing and construction	**154,105**		**1,721,538**	**1,722**			**1,722**		**1,704**	**6,249.31**
Total natural gas[2]	123,884		1,029,526	1,030			1,030		1,024	3,756.06
Natural gas in methanol production	conf	conf	490,864	491			491	0.995	488	1,790.84
Natural gas in urea production	conf	conf	44,890	45			45	0.995	45	163.77
Other natural gas	conf	conf	493,772	494			494	0.995	491	1,801.44
Petrol	142	18.2	2,588	3			3	0.99	3	9.39
Diesel	6,299	18.7	118,015	118			118	0.99	117	428.39
Fuel oil	1,723	20.1	34,636	35			35	0.99	34	125.73
Aviation fuels	173	18.8	3,248	3			3	0.99	3	11.79
LPG	1,350	16.5	22,238	22			22	0.99	22	80.72
Other liquid	0	19.9	0	0			0	0.99	0	0.00
Coal	20,534	24.9	511,286	511			511	0.98	501	1,837.22
Wood (memo item)[3]	22,826	28.4	648,362	648			648	1	648	2,377.33
3 Transport	**184,012**		**3,390,407**	**3,390**			**3,390**		**3,357**	**12,307.19**
a Civil aviation	10,627	**18.8**	**199,976**	**200**			**200**	**0.99**	**198**	**725.91**
b Road transport	**166,638**		**3,058,545**	**3,059**			**3,059**		**3,028**	**11,102.53**
Petrol	100,764	18.2	1,830,249	1,830			1,830	0.99	1,812	6,643.81
Diesel	63,313	18.7	1,186,259	1,186			1,186	0.99	1,174	4,306.12
LPG	2,500	16.5	41,182	41			41	0.99	41	149.49
CNG	60	14.251409423	855	1			1	0.995	1	3.12
c Rail transport (diesel)	2,736	**18.7**	**51,272**	**51**			**51**	**0.99**	**51**	**186.12**
d National navigation (fuel oil and diesel)	4,011	20.1	**80,613**	**81**			**81**	**0.99**	**80**	**292.63**
Aviation bunkers (memo item)[3]	27,885	**18.8**	**524,745**	**525**			**525**	**0.99**	**519**	**1,904.82**
Marine bunkers (memo item)[3]	**10,928**		**216,675**	**217**			**217**		**215**	**786.53**
Diesel	2,184	18.7	40,920	41			41	0.99	41	148.54
Fuel oil	8,744	20.1	175,754	176			176	0.99	174	637.99

Module 2001 Energy (New Zealand)
Submodule CO_2 emissions from fuel combustion by source categories (tier 1)
Worksheets 1.2 (part II)

Source and sink catergories	Energy Consumption (TJ)	Carbon emis fact (t C/TJ)	Carbon content (t C)	Carbon content (Gg)	Fraction of carbon stored[1]	Carbon stored[1] (t C)	Net C emissions (Gg)	Fraction of carbon oxidised	Actual C emissions (Gg)	Actual CO_2 emissions (Gg)
4 Other sectors	**44,070**		**759,486**	**759**			**759**		**752**	**2,842.46**
a Commercial/institutional	**18,105**		**314,950**	**315**			**315**		**312**	**1,142.62**
Petrol	113	18.2	2,053	2			2	0.99	2	7.45
Diesel	2,154	18.7	40,358	40			40	0.99	40	146.50
Fuel oil	426	20.1	8,561	9			9	0.99	8	31.08
Aviation fuels	940	18.8	17,681	18			18	0.99	18	64.18
LPG	850	16.5	14,002	14			14	0.99	14	50.83
Coal	3,583	24.9	89,211	89			89	0.98	87	320.57
Natural gas	10,040	14.251409423	143,084	143			143	0.995	142	522.02
b Residential	**8,486**		**132,721**	**133**			**133**		**132**	**482.67**
Petrol	4	18.2	71	0			0	0.99	0	0.26
Diesel	10	18.7	179	0			0	0.99	0	0.65
Fuel oil	0	20.1	0	0			0	0.99	0	0.00
Aviation fuels	2	18.8	32	0			0	0.99	0	0.11
LPG	1,820	16.5	29,980	30			30	0.99	30	108.83
Coal	721	24.9	17,949	18			18	0.98	18	64.50
Natural gas	5,930	14.3	84,511	85			85	0.995	84	308.32
Wood (memo item)[3]	6,304	28.4	179,062	179			179	1	179	656.56
c Agriculture/forestry/fishing	**17,478**		**311,815**	**312**			**312**		**309**	**1,217.17**
Petrol	1,207	18.2	21,916	22			22	0.99	22	79.56
Diesel	13,044	18.7	244,394	244			244	0.99	242	887.15
Fuel oil	2,104	20.1	42,281	42			42	0.99	42	153.48
Aviation fuels	171	18.8	3,224	3			3	0.99	3	11.70
Coal	953	24.9	23,732	24			24	0.98	23	85.28

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 Some natural gas data are confidential.
3 Data are included only as memo items and do not contribute to the data totals.

Module 2001 Energy (New Zealand)
Submodule CO_2 from fuel combustion by source category (tier 1)
Worksheet 1.2 overview (totals)

		Total liquid fossil TJ	Total solid fossil	Total gaseous fossil	Total other fuels[1]	Total all fuels
Total energy consumption		**218,899**	**40,135**	**256,955**	**29,130**	**515,989**
Energy industries		2,417	14,345	117,041	ne	133,804
Manufacturing industries and construction		9,687	20,534	123,884	22,826	154,105
Transport	Domestic aviation	10,627				10,627
	Road	166,578		60	no	166,638
	Railways	2,736	ne			2,736
	Navigation	4,011	ne			4,011
Other sectors	Commercial/institutional	4,482	3,583	10,040	ne	18,105
	Residential	1,835	721	5,930	6,304	8,486
	Ag/forest/fish	16,525	953	ne	ne	17,478
International marine bunkers (memo item)		10,928	ne			10,928
International aviation bunkers (memo item)		27,885				27,885
Total CO_2 emissions		**14,682**	**3,591**	**10,707**	**3,034**	**28,980**
Energy industries		180	1,284	6,118	ne	7,581
Manufacturing industries and construction		656	1,837	3,756	2,377	6,249
Transport	Domestic aviation	726				726
	Road	11,099		3	no	11,103
	Railways	186	ne			186
	Navigation	293	ne			293
Other sectors	Commercial/institutional	300	321	522	ne	1,143
	Residential	110	64	308	657	483
	Ag/forest/fish	1,132	85	ne	ne	1,217
International marine bunkers (memo item)		787	ne			787
International aviation bunkers (memo item)		1,905				1,905

1 All data shown refer to wood. Emissions from wood are included as memo items only and are not included in totals.

Module 2001 Energy (New Zealand)
Submodule Non-CO2 from fuel combustion by source category (tier 1)
Worksheet 1.3 (1 of 3)
Sheet Energy consumption by fuel

Activity			Coal quantity (TJ)	Gas quantity (TJ)	Oil quantity (TJ)	Oil quantity (road diesel) (TJ)	Wood quantity (TJ)	Charcoal quantity (TJ)	Other biomass (TJ)	Total energy (TJ)
Energy industries			14,345	117,041	2,417		0	0	750	134,554
Manufacturing industries and construction			20,534	123,884	9,687		22,826	0	ne	176,931
Transport	Domestic aviation				10,627					10,627
	Road			60	100,764	63,313				164,138
	Railways		ne		2,736					2,736
	Navigation		ne		4,011					4,011
Other sectors	Commercial/institutional		3,583	10,040	4,482		ne	0	ne	18,105
	Residential		721	5,930	1,835		6,304	ne	ne	14,790
	Ag/forest/fish	Stationary	953	ne	1,282		ne	0	ne	2,235
		Mobile		ne	15,244					15,244
Other[1]			0	0	2,500		0	0	0	2,500
Total			**40,135**	**256,955**	**218,899**		**29,130**	**0**	**750**	**545,869**
International marine bunkers (memo item)			ne		10,928					10,928
International aviation bunkers (memo item)					27,885					27,885

1 Oil quantity is LPG used in *road* transport.

Module 2001 Energy (New Zealand)
Submodule Non-CO2 from fuel combustion by source category (tier 1)
Worksheet 1.3 (2-3 of 3)
Sheet Methane emissions

Activity			Coal emis fact (kg/TJ)	Gas emis fact (kg/TJ)	Oil emis fact (kg/TJ)	Oil factor (road diesel) (kg/TJ)	Wood emis fact (kg/TJ)	Charcoal emis fact (kg/TJ)	Other bio. emis fact (kg/TJ)	Coal emissions (kg)	Gas emissions (kg)	Oil emissions (kg)	Oil emis. (road diesel) (kg)	Wood emissions (kg)	Charcoal emissions (kg)	Other biomass emis (kg)	Total emissions (Gg)
Energy industries			0.700	2.531	2.893				1.100	10,042	296,224	6,993		0	0	825	0.31
Manufacturing industries and construction			0.765	1.352	2.900		14.000			15,717	167,460	28,092		319,564	0	ne	0.53
Transport	Domestic aviation				1.500							15,940					0.02
	Road			567.000	60.000	13.000					34,020	6,045,869	823,071				6.90
	Railways				13.000					ne		35,574					0.04
	Navigation				14.000					ne		56,149					0.06
Other sectors	Commercial/institutional		12.027	1.100	2.589					43,091	11,044	11,607		ne	0	ne	0.07
	Residential		285.000	0.900	0.998		285.000			205,435	5,337	1,831		1,796,640	ne	ne	2.01
	Ag/forest/fish	Stationary	9.500		2.900					9,055	ne	3,717		ne	0	ne	0.01
		Mobile			16.525						ne	251,905					0.25
Other			0.700		40.000					0	0	100,000		0	0	0	0.10
Total										**283,340**	**514,085**	**7,380,749**		**2,116,204**	**0**	**825**	**10.30**
International marine bunkers (memo item)					7.000					ne		76,496					0.08
International aviation bunkers (memo item)					1.500							41,828					0.04

Module 2001 Energy (New Zealand)
Submodule Non-CO2 from fuel combustion by source category (tier 1)
Worksheet 1.3 (2-3 of 3)
Sheet Nitrous oxide emissions (N_2O)

Activity			Coal emis fact (kg/TJ)	Gas emis fact (kg/TJ)	Oil emis fact (kg/TJ)	Oil factor (road diesel) (kg/TJ)	Wood emis fact (kg/TJ)	Charcoal emis fact (kg/TJ)	Other bio. emis fact (kg/TJ)	Coal emissions (kg)	Gas emissions (kg)	Oil emissions (kg)	Oil emis. (road diesel) (kg)	Wood emissions (kg)	Charcoal emissions (kg)	Other biomass emis (kg)	Total emissions (Gg)
Energy industries			1.500	0.246	0.300				2.100	21,518	28,736	726		0	0	1,575	0.05
Manufacturing industries and construction			1.500	0.100	0.300		4.000			30,800	12,388	2,906		91,304	0	ne	0.14
Transport	Domestic aviation				1.100							11,689					0.01
	Road			2.800	3.000	3.000					168	302,293	189,940				0.49
	Railways				3.000					ne		8,209					0.01
	Navigation				1.800					ne		7,219					0.01
Other sectors	Commercial/institutional		1.300	2.100	0.407					4,658	21,084	1,826		ne	0	ne	0.03
	Residential		1.300	0.100	0.600		3.800			937	593	1,101		23,955	ne	ne	0.03
	Ag/forest/fish	Stationary	1.300		0.300					1,239	ne	385		ne	0	ne	0.00
		Mobile			2.859						ne	43,581					0.04
Other			1.500		2.800					0	0	7,000		0	0	0	0.01
Total										**59,152**	**62,969**	**576,876**		**115,259**	**0**	**1,575**	**0.82**
International marine bunkers (memo item)					2.000					ne		21,856					0.02
International aviation bunkers (memo item)					1.080							30,116					0.03

Module 2001 Energy (New Zealand)
Submodule Non-CO2 from fuel combustion by source category (tier 1)
Worksheet 1.3 (2-3 of 3)
Sheet Other oxides of Nitrogen emissions (NOx)

Activity			Coal emis fact (kg/TJ)	Gas emis fact (kg/TJ)	Oil emis fact (kg/TJ)	Oil factor (road diesel) (kg/TJ)	Wood emis fact (kg/TJ)	Charcoal emis fact (kg/TJ)	Other bio. emis fact (kg/TJ)	Coal emissions (kg)	Gas emissions (kg)	Oil emissions (kg)	Oil emis. (road diesel) (kg)	Wood emissions (kg)	Charcoal emissions (kg)	Other biomass emis (kg)	Total emissions (Gg)
Energy industries			361.000	193.236	162.162				41.000	5,178,545	22,616,604	391,971		0	0	30,750	28.22
Manufacturing industries and construction			391.541	250.433	162.000		62.000			8,039,742	31,024,610	1,569,298		1,415,212	0	ne	42.05
Transport	Domestic aviation				276.000							2,932,988					2.93
	Road			342.000	467.000	718.000					20,520	47,057,012	45,458,860				92.54
	Railways				718.000					ne		1,964,805					1.96
	Navigation				1,994.956					ne		8,001,010					8.00
Other sectors	Commercial/institutional		228.000	41.000	93.411					816,874	411,640	418,712		ne	0	ne	1.65
	Residential		219.000	42.000	62.000		105.000			157,861	249,060	113,778		661,920	ne	ne	1.18
	Ag/forest/fish	Stationary	228.000		162.000					217,309	ne	207,631		ne	0	ne	0.42
		Mobile			825.397						ne	12,582,042					12.58
Other			361.000		361.000					0	0	902,500		0	0	0	0.90
Total										**14,410,331**	**54,322,434**	**121,600,606**		**2,077,132**	**0**	**30,750**	**192.44**
International marine bunkers (memo item)					1,710.000					ne		18,686,880					18.69
International aviation bunkers (memo item)					280.000							7,807,800					7.81

Module 2001 Energy (New Zealand)
Submodule Non-CO2 from fuel combustion by source category (tier 1)
Worksheet 1.3 (2-3 of 3)
Sheet Carbon monoxide emissions

Activity			Coal emis fact (kg/TJ)	Gas emis fact (kg/TJ)	Oil emis fact (kg/TJ)	Oil factor (road diesel) (kg/TJ)	Wood emis fact (kg/TJ)	Charcoal emis fact (kg/TJ)	Other bio. emis fact (kg/TJ)	Coal emissions (kg)	Gas emissions (kg)	Oil emissions (kg)	Oil emis. (road diesel) (kg)	Wood emissions (kg)	Charcoal emissions (kg)	Other biomass emis (kg)	Total emissions (Gg)
Energy industries			8.600	26.851	14.004				8.500	123,367	3,142,640	33,850		0	0	6,375	3.31
Manufacturing industries and construction			23.398	16.458	14.000		561.000			480,445	2,038,932	135,618		12,805,386	0	ne	15.46
Transport	Domestic aviation				114.000							1,211,452					1.21
	Road			648.000	6,960.000	485.000					38,880	701,320,772	30,706,890				732.07
	Railways				485.000					ne		1,327,201					1.33
	Navigation				44.015					ne		176,529					0.18
Other sectors	Commercial/institutional		190.000	8.500	15.454					680,729	85,340	69,272		ne	0	ne	0.84
	Residential		456.000	9.000	15.000		10,450.000			328,697	53,370	27,527		65,876,800	ne	ne	66.29
	Ag/forest/fish	Stationary	190.000		14.000					181,091	ne	17,943		ne	0	ne	0.20
		Mobile			923.231						ne	14,073,379					14.07
Other			9.000		1,380.000					0	0	3,450,000		0	0	0	3.45
Total										**1,794,328**	**5,359,162**	**752,550,433**		**78,682,186**	**0**	**6,375**	**838.39**
International marine bunkers (memo item)					171.000					ne		1,868,688					1.87
International aviation bunkers (memo item)					110.000							3,067,350					3.07

Module 2001 Energy (New Zealand)
Submodule Non-CO2 from fuel combustion by source category (tier 1)
Worksheet 1.3 (2-3 of 3)
Sheet NMVOC emissions

Activity			Coal emis fact (kg/TJ)	Gas emis fact (kg/TJ)	Oil emis fact (kg/TJ)	Oil factor (road diesel) (kg/TJ)	Wood emis fact (kg/TJ)	Charcoal emis fact (kg/TJ)	Other bio. emis fact (kg/TJ)	Coal emissions (kg)	Gas emissions (kg)	Oil emissions (kg)	Oil emis. (road diesel) (kg)	Wood emissions (kg)	Charcoal emissions (kg)	Other biomass emis (kg)	Total emissions (Gg)
Energy industries			4.750	4.500	4.750				4.500	68,139	526,687	11,482		0	0	3,375	0.61
Manufacturing industries and construction			19.000	4.508	4.750		47.500			390,138	558,483	46,013		1,084,235	0	ne	2.08
Transport	Domestic aviation				17.000							180,655					0.18
	Road			81.000	1,080.000	171.000					4,860	108,825,637	10,826,553				119.66
	Railways				171.000					ne		467,941					0.47
	Navigation				105.002					ne		421,124					0.42
Other sectors	Commercial/institutional		190.000	4.500	4.750					680,729	45,180	21,292		ne	0	ne	0.75
	Residential		190.000	4.500	4.750		570.000			136,957	26,685	8,717		3,593,280	ne	ne	3.77
	Ag/forest/fish	Stationary	190.000		4.750					181,091	ne	6,088		ne	0	ne	0.19
		Mobile			231.118						ne	3,523,076					3.52
Other			19.000		608.000					0	0	1,520,000		0	0	0	1.52
Total										**1,457,053**	**1,161,895**	**125,858,578**		**4,677,515**	**0**	**3,375**	**133.16**
International marine bunkers (memo item)					49.000					ne		535,472					0.54
International aviation bunkers (memo item)					17.000							474,045					0.47

Module 2001 Energy (New Zealand)
Submodule SO_2 emissions from fuel combustion by source categories (tier 1)
Worksheet 1.4

Fuel type		Fuel consumption (TJ)	Sulphur content (%)	Sulphur retention in ash (%)	Abatement efficiency (%)	Gross cal. value (TJ/kt)	SO_2 emis fact (kg/TJ)	SO_2 emissions (t)	SO_2 emissions (Gg)
Total		544,423						49,534	49.534
Coal	Low[1]	3,998	0.30%	12.50%	0.00%	15.0	350.0	1,399	1.399
	Medium[2]	24,701	0.50%	12.50%	0.00%	22.6	387.2	9,563	9.563
	High[3]	10,483	1.10%	2.50%	0.00%	32.1	668.2	7,005	7.005
Heavy fuel oil	Low							no	no
	Medium[4]	4,305	2.30%	0.00%	0.00%	44.06	1,044.0	4,494	4.494
	High							no	no
Light fuel oil	Low[5]	4,564	1.75%	0.00%	0.00%	44.46	787.2	3,593	3.593
	High							no	no
Diesel		87,562	0.24%	0.00%	0.00%	45.98	104.4	9,141	9.141
Petrol		102,232	0.01%	0.00%	0.00%	46.93	2.1	218	0.218
Jet kerosene		11,912	0.01%	0.00%	0.00%	46.4	4.3	51	0.051
Asphalt[6]		2,059	4.50%	0.00%	0.00%	41.9	2,148.0	4,423	4.423
LPG		6,520	0.00%					0	0.000
Natural gas[7]		256,955	0.00%					0	0.000
Municipal Waste								ne	ne
Industrial Waste								ne	ne
Black Liquor								ne	ne
Fuelwood		29,130	0.20%	0.00%	0.00%	12.1	331.1	9,646	9.646
Other Biomass								ne	ne
Marine bunkers (memo item)	HFO	8,354	2.30%	0.00%	0.00%	44.06	1,044.0	8,721	8.721
	LFO	390	1.75%	0.00%	0.00%	44.46	787.2	307	0.307
	Diesel	2,184	0.24%	0.00%	0.00%	45.98	104.4	228	0.228
Aviation bunkers (memo item)	Jet kero	27,885	0.01%	0.00%	0.00%	46.4	4.3	120	0.120

1 Lignite coal.
2 Sub-bituminious coal.
3 Bituminous coal.
4 All HFO assumed to be medium sulphur.
5 All LFO assumed to be low sulphur.
6 Includes *other liquids* in *manufacturing and construction*.
7 Includes refinery gas and CNG.

Module	**2001 Energy (New Zealand)**
Submodule	**Fugitive emissions from coal mining and handling (tier 1)**
Worksheet	**1.6 (adapted)**

Category		Coal production (Mt)	CH_4 emis fact (Gg/Mt)	CH_4 emissions (Gg)
Total		3.91		24.661
Underground mines	Mining	0.92	22.604	20.689
	Post-mining		1.600	1.464
Surface mines	Mining	3.00	0.770	2.307
	Post-mining		0.067	0.201

Module	**2001 Energy (New Zealand)**
Submodule	**Fugitive emissions from geothermal activities (tier 1)**
Worksheet	**NZ 1a (additional)**

Category	Fuel quantity (TJ)	CO_2 emis fact (kg/GJ)	CH_4 emis fact (kg/GJ)	CO_2 emissions (Gg)	CH_4 emissions (Gg)
Elec. generation and heat	73,370	3.657	0.034	268.290	2.474

Module	**2001 Energy (New Zealand)**
Submodule	**Fugitive emissions from oil and gas handling (tier 1)**
Worksheet	**1.7 (adapted)**

Category		Fuel quantity (TJ)	CO_2 emis fact (kg/TJ)	CH_4 emis fact (kg/TJ)	CO_2 emissions (Gg)	CH_4 emissions (Gg)
Total					305.969	15.468
Oil	Exploration	ne			ne	ne
	Production of crude oil	ne			ne	ne
	Transport of crude oil	68,836		0.745	ne	0.051
	Refining/storage	208,918		0.745	ne	0.156
	Distribution of oil products	ne			ne	ne
Gas	Production/processing	ne			ne	ne
	Transmission and distributior	70,222	19.9	206.7	1.400	14.513
	Other leakage	ne			ne	ne
Venting and flaring from oil and gas prod.		8,589	35,462.4	87.1	304.569	0.748

Module 2001 Energy (New Zealand)
Submodule Ozone precursors and SO_2 from oil refining
Worksheet 1.8 (additional)
Sheet NMVOC emissions from oil refining (tier 1)

Crude oil Throughput (m3)	Emission factor (kg/m3)	Emissions (t)	Emissions (Gg)
5,356,872	0.53	2,839	2.839

Module 2001 Energy (New Zealand)
Submodule Ozone precursors and SO_2 from oil refining
Worksheet 1.8 (3 of 4)
Sheet SO_2 from sulphur recovery plants (tier 2)

Quantity of sulphur recovered (t)	Emission factor (kg/t)	Emissions (kg)	Emissions (Gg)
25,827	139	3,589,953	3.590

Module 2001 Energy (New Zealand)
Submodule Ozone precursors and SO_2 from oil refining
Worksheet 1.8 (4 of 4)
Sheet NMVOC emissions from storage and handling (tier 2)

Storage type	Crude oil throughput (kt)	Emission factor (kg/t)	Emissions (t)	Emissions (Gg)
Floating roof (primary seals)	4,575.3	0.70	3,202.7	3.203

Chapter 3

Industrial Processes

3.1 Introduction

New Zealand's industrial processes sector represented approximately 5% of all greenhouse gas emissions in 2001 and there was an increase of 4% from 2000. Emissions are now 6.4% above the 1990 baseline in this sector.

Emissions included under industrial processes arise from the chemical transformation of materials from one substance to another. Although fuel is also often combusted in the course of these processes, emissions arising from this combustion are included in the energy sector emissions.

Process emissions related to energy production are also considered within the energy sector. These include, for example, refining crude oil and producing synthetic petrol from natural gas.

3.2 Country-specific approaches different from the IPCC methodology

Estimates of emissions from industrial processes are mostly based on industry-supplied information. Many of the emission factors are New Zealand specific and supplied by industry.

3.3 Emissions calculation methodologies

New Zealand has a relatively small number of plants emitting non-energy-related greenhouse gases from industrial processes. This allows us to use a high level of New Zealand-specific information.

Emissions of CO_2 from industrial processes were compiled by the Ministry of Economic Development and reported in *New Zealand Energy Greenhouse Gas Emissions 1990-2001* (Ministry of Economic Development, 2002). Production and emissions data are provided by industry and emission factors are derived from these.

Data on non-CO_2 emissions was primarily gathered through a questionnaire distributed directly to companies by consultants. It requested information on emissions and production, as well as on any relationship the companies had established between the two. This was supplemented by information from a variety of industry groups and other statistical sources. IPCC default emission factors were applied to supplied production data where no local information on emissions was available.

Estimates of actual emissions of HFCs and PFCs are included in the inventory, using the methodology provided in *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). Emissions of two PFCs from the production of aluminium, CF_4 and C_2F_6, are supplied by Comalco New Zealand (the operator of New Zealand's sole aluminium smelter). These emissions from aluminium smelting are calculated using the IPCC (2000) Tier 2 method and the default coefficients for Centre Worked Pre Bake technology.

Actual and potential emissions of SF_6 resulting primarily from the use of SF_6 in electrical switchgear are reported using the IPCC (2000) Tier 2b methodology.

Montgomery Watson (2002) contains information on the estimates of non-CO_2 emissions, including descriptions of the industrial processes found in New Zealand and the information sources used.

Worksheets are included at the end of the chapter showing activity data and emission factors for the industrial processes sector. A full-time series of activity data and emissions is provided for HFCs, PFCs and SF_6.

3.4 Changes since the last inventory submission

New Zealand Energy Greenhouse Gas Emissions 1990-2001 (Ministry of Economic Development, 2002), the source document for CO_2 emissions from industrial processing, has been added to the references for this section.

3.5 Uncertainty

The number of companies in New Zealand producing CO_2 from industrial processes is small. The emission estimates they have supplied are considered to be accurate to within ±5%.

The uncertainty surrounding estimates of non-CO_2 emissions is greater. The combination of uncertainty in the activity data and in the emission factors are considered to be approximately as shown in Table 8. Montgomery Watson (2002) provides further information on this.

Table 8: Uncertainty ranges for industrial process emissions

Gas	Uncertainty
CO_2	±5%
CH_4	±80%
HFCs	see below
PFCs[1]	±27%
SF_6	±10%
SO_2	±9%
NO_x	±30%
CO	±33%
NMVOC	±53%

1. From aluminium smelting only.

Discussion of the uncertainties surrounding estimates of actual emissions from the use of HFCs and PFCs is included in Montgomery Watson, 2002. The level of uncertainty varies with each application. For example, for aerosols, emission data could be over- or under-estimated by a factor between one third and three times; for mobile air conditioning, the top-down approach provides an upper bound so it is unlikely that the true emissions value will exceed the calculated top-down approach; and for fire protection, only one company is involved in the administration of the installed chemical and therefore the uncertainty associated with its emissions is considered to be low.

3.6 References

Intergovernmental Panel on Climate Change, 2000, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, IPCC National Greenhouse Gas Inventories Programme.

Ministry of Economic Development, 2002, *New Zealand Energy Greenhouse Gas Emissions 1990-2001*, Wellington, New Zealand.

Montgomery Watson, 2002, *Inventory of Non-CO_2 Greenhouse Gas Emissions from Industrial Sources and Solvent and Other Product Use, HFCs and PFCs and SF_6*, report to the Ministry for the Environment, New Zealand, April 2002.

Appendix to Chapter 3:
Industrial Process calculation tables 2001
HFC, PFC and SF_6 calculation tables 1990 to 2001

Module 2001 Industrial process (New Zealand)
Worksheet NZ 2a
Sheet CO_2 emissions

Source category	Production Quantity (t)	CO_2 emissions (Gg)	CO_2 emis factor (t/t)
Total industrial processes		**2,875.54**	
Cement[1]	1,088,130	523.98	0.48
Lime[1]	144,200	103.66	0.72
Hydrogen[1]	29,950	182.89	6.11
Iron and steel[1]	800,790	1,560.68	1.95
Aluminium[1]	324,110	504.34	1.56

1 Production and emissions data provided by industry and reported in Ministry of Economic Development (2002):

Module 1990 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. Aerosol 1 of 2
Sheet HFCs from aerosols (based on equation 3.35[1])

Year	Quantity HFC 134a contained in aerosol products sold in year t (tonnes)[2]	Emission factor	Quantity HFC 134a contained in aerosol products sold in year t-1 (tonnes)	Emission of HFC 134a (tonnes)
1992	5.5	0.5	6.7	6.1
1993	6.7	0.5	9.9	8.3
1994	9.9	0.5	20.3	15.1
1995	20.3	0.5	28.5	24.4
1996	28.5	0.5	34.7	31.6
1997	34.7	0.5	34.7	34.7
1998	34.7	0.5	33.8	34.3
1999	33.8	0.5	37.0	35.4
2000	37.0	0.5	38.6	37.8
2001	38.6	0.5	40.3	39.5

1. IPCC (2001) Equation 3.35
2. Only HFCs used in aerosols is HFC 134a

Module 1990 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. MDIs 1 of 1
Sheet HFCs from metered dose inhalers

Year[1]	Estimated no. of doses (millions)	Weighted average propellant/dose (g/dose)	Total propellant (tonnes)	HFC doses	Emission of HFC 134a (tonnes)[2]
1995	350.0	0.032	11.2	1%	0.1
1996	350.0	0.032	11.2	5%	0.6
1997	350.0	0.032	11.2	10%	1.1
1998	361.9	0.032	11.6	10%	1.2
1999	360.7	0.032	11.5	10%	1.2
2000	397.2	0.032	12.7	13%	1.7
2001	457.7	0.032	14.6	70%	10.3

1. HFC 134a not used in MDIs before 1995
2. Only HFC used in MDIs is HFC 134a

Module 1990 - 2001 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 (all)		Domestic loading HFC (tonnes)	Total HFC contained in products (tonnes)
	Number of Units	HFC[1] (tonnes)		
1992	3,300,000	5.54	0.0	5.5
1993	4,000,000	6.72	0.0	6.7
1994	5,400,000	9.07	0.8	9.9
1995	8,700,000	14.62	5.7	20.3
1996	13,100,000	22.01	6.5	28.5
1997	16,800,000	28.22	6.5	34.7
1998	17,400,000	29.23	5.5	34.7
1999	17,500,000	29.40	4.4	33.8
2000	18,848,536	31.67	5.3	37.0
2001	19,773,731	33.22	5.4	38.6

1. Assumes average propellant charge =84 grams, 2% of all imported aerosols contain HFCs

Module 1990 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. Fire protection 1 of 1
Sheet Annual emissions from the fire protection industry

Year[1]	Total HFC 227a installed (tonnes)		Emission rate	Emissions of HFC 227a (tonnes)
	Streaming	Portable		
1994	1.6	_	0.0133	0.02
1995	3.2	_	0.0133	0.04
1996	4.8	_	0.0133	0.06
1997	6.4	_	0.0133	0.09
1998	8.0	_	0.0133	0.11
1999	10.0	_	0.0133	0.13
2000	11.0	_	0.0133	0.15
2001	12.0	_	0.0133	0.16

1. Use of HFC 227a in fire protection industry not ocurring before 1994

Module 1990 - 2001 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 equation 3.4[1])

Year	Domestically manufactured chemical	Imported bulk chemical	Exported bulk chemical	Chemical in imported equipment	Chemical in exported equipment	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	0.0	0	3.9	0.3	3.6
1993	0	6.0	0	6.4	2.0	10.4
1994	0	53.0	0	6.8	10.5	49.3
1995	0	105.4	0	8.4	16.6	97.2
1996	0	152.3	0	10.6	15.9	147.0
1997	0	88.5	0	10.5	14.9	84.1
1998	0	192.9	0	9.9	16.8	186.0
1999	0	170.1	0	12.6	17.8	165.0
2000	0	134.0	0	11.9	19.0	126.9
2001	0	184.9	0	11.5	18.9	177.5

1. IPCC (2001) Equation 3.4

Module 1990 - 2001 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 equation 3.4[1])

Year	Chemical to charge domestically maunfactured equipment	Chemical to charge imported equipment	Chemical contained in factory charged imported equipment	Chemical contained in factory charged exported equip	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	0.2	0	3.9	0.3	3.8
1993	4.9	0	6.4	2.0	9.3
1994	38.4	0	6.8	10.5	34.7
1995	74.3	0	8.4	16.6	66.1
1996	102.1	0	10.6	15.9	96.8
1997	63.6	0	10.5	14.9	59.2
1998	127.1	0	9.9	16.8	120.2
1999	112.3	0	12.6	17.8	107.1
2000	94.1	0	11.9	19.0	87.0
2001	140.4	0	11.5	18.9	133.1

1. IPCC (2001) Equation 3.4
2. Chemical to charge imported equipment that is not factory charged

Module 1990 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. RAC 3 of 4
Sheet All HFC and PFC emissions from stationary refrigeration Equation 3.4[1]

Year	Annual sales of new refrigerant	Total charge of new eqipment	Original charge of retiring equipment	Amount of intentional destruction	Emissions[2] (tonnes)
1990	0.0	0.0	0	0	0.0
1991	0.0	0.0	0	0	0.0
1992	3.6	3.8	0	0	0.0
1993	10.4	9.3	0	0	1.1
1994	49.3	34.7	0	0	14.6
1995	97.2	66.1	0	0	31.1
1996	147.0	96.8	0	0	50.1
1997	84.1	59.2	0	0	24.8
1998	186.0	120.2	0	0	65.8
1999	165.0	107.1	0	0	57.8
2000	126.9	87.0	0	0	39.9
2001	177.5	133.1	0	0	44.5

1. IPCC (2001) Equation 3.4
2. The methodology produces a negative number for 1992, thus 0 has been entered for this year.

Module 1990 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. MAC 1 of 4
Sheet Mobile air conditioning Equation 3.45[1] (input to equation 3.44[1])

Year[2]	Total vrigin HFC 134a[3] in first-fill MAC systems (tonnes)	Emission factor	First-fill emissions HFC 134a (tonnes)
1994	4.0	0.005	0.020
1995	13.4	0.005	0.067
1996	13.1	0.005	0.065
1997	11.7	0.005	0.058
1998	10.8	0.005	0.054
1999	10.8	0.005	0.054
2000	11.2	0.005	0.056
2001	9.1	0.005	0.045

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 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. MAC 2 of 4
Sheet Mobile air conditioning Equation 3.46[1] (input to equation 3.44[1])

Year[2]	Total annual virgin HFC 134a	Annual virign HFC in first-fill MAC systems					Operation emissions HFC 134a (tonnes)
		Buses	Trucks	Cars	Cars (new)	Total	
1994	3.2	0.0	0.7	2.6	0.7	4.0	-0.8
1995	20.8	0.2	3.3	7.4	2.5	13.4	7.4
1996	37.5	0.3	3.4	7.0	2.4	13.1	24.4
1997	12.9	0.3	3.2	6.8	1.4	11.7	1.2
1998	54.6	0.3	3.0	6.8	0.7	10.8	43.8
1999	27.4	0.4	3.7	6.7	0.0	10.8	16.6
2000	44.1	0.3	4.4	6.5	0.0	11.2	32.9
2001	46.3	0.2	2.9	6.0	0.0	9.1	37.2

1. IPCC (2001) Equations 3.44 and 3.45
2. No use recorded before 1994

Module 1990 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. MAC 3 of 4 (IPCC (2000) equation 3.47)
Sheet HFC 134a emissions from mobile air conditioning (equation 3.44[1])

Year	Annual scrap rate of vehicles with MACs using HFC-134a	Number of vehicles with MACs using HFC-134a	Average HFC-134a charge per vehicle (kg)	Destruction (tonnes)	Disposal emissions (tonnes)
1994	0.0108	39,805	0.81	0	0.35
1995	0.0115	91,301	0.81	0	0.85
1996	0.0069	143,987	0.81	0	0.80
1997	0.0052	199,857	0.81	0	0.84
1998	0.0037	257,314	0.81	0	0.77
1999	0.0034	331,757	0.81	0	0.91
2000					
2001					

Module 1990 - 2001 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. MAC 4 of 4
Sheet HFC 134a emissions from mobile air conditioning (equation 3.44[1])

Year[2]	First-fill emissions (tonnes)	Operation emissions	Disposal emissions[3]	Intentional destruction	Annual emissions of HFC 134a (tonnes)
1994	0.020	-0.8	0.35	0	-0.5
1995	0.067	7.4	0.85	0	8.3
1996	0.065	24.4	0.80	0	25.3
1997	0.058	1.2	0.84	0	2.1
1998	0.054	43.8	0.77	0	44.6
1999	0.054	16.6	0.91	0	17.5
2000	0.056	32.9	2.16	0	35.1
2001	0.045	37.2	2.91	0	40.2

1. IPCC (2001) Equation 3.44
2. No use recorded before 1994
3. Calculated using IPCC (2000) equation 3.47

Module 1990 - 2000 Consumption of halocarbons (New Zealand)
Worksheet Supplementary 2.F. RAC 4 of 4
Sheet All HFC and PFC emissions from stationary refrigeration

Year	Bulk emissions (tonnes)	HFC 32 (tonnes)	HFC 125 (tonnes)	HFC 134a (tonnes)	HFC 143a (tonnes)	HFC 152 (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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	1.1	0.0	0.0	1.1	0.0	0.0	0.0
1994	14.6	0.0	1.2	11.3	0.4	0.4	0.0
1995	31.1	0.4	0.5	18.2	7.9	1.2	0.8
1996	50.1	0.0	6.7	28.3	7.1	0.4	4.8
1997	24.8	0.0	10.5	3.6	9.3	0.2	0.3
1998	65.8	0.0	9.5	35.2	9.4	0.4	8.0
1999	57.8	7.4	10.4	23.0	11.0	1.7	0.0
2000	39.9	0.0	4.1	29.3	6.4	0.0	0.0
2001	44.5	0.1	12.8	16.6	14.9	0.0	0.0

Module 1990 - 2001 Emissions of Sulphur Hexafluoride (New Zealand)

Worksheet

Sheet SF_6 from Electrical Equipment and Other Sources (based on equation 3.18, 3.17 and 3.22)

Year	Potential SF_6 Emissions (kgs)[1]	Emissions from Electical Equipment (kgs)[2]	Emission from Other Sources[4] (kgs)[3]	Actual SF_6 Emissions (kgs)
1990		396.2	120.0	516.2
1991	2256.0	409.0	131.0	540.0
1992	1392.8	422.9	147.0	569.9
1993	2026.4	435.4	153.0	588.4
1994	1842.0	448.5	155.0	603.5
1995	1566.0	466.0	162.0	628.0
1996	2240.0	484.7	134.0	618.7
1997	2354.0	505.4	135.0	640.4
1998				
1999				
2000	1752.6	671.6	15.0	686.6
2001	1483.5	690.4	15.0	705.4

1. IPCC (2001) Equation 3.18
2. IPCC (2001) Equation 3.17
3. IPCC (2001) Equation 3.22
4. SF_6 use in magnesium casting ceased in 1998

Module 2001 Industrial process (New Zealand)
Worksheet NZ 2b part 1
Sheet Non-CO_2 emissions

Source Categories	ACTIVITY DATA	Emission Estimates									Aggregate Emission Factor								
	A Production Quantity (kt)	B Full Mass of Pollutants (Gg) Tonnes x 1000									C Tonne of pollutant per tonne of product (t/t)								
		CO	CH4	N20	NOx	NMVOC	HFC	PFC	SF6	SO2	CO	CH4	N20	NOx	NMVOC	HFC	PFC	SF6	SO2
A Iron and Steel	**800.79**	0.2300			0.9287														
Fletcher Challenge	189.00	0.0006			0.0110						0.000003			0.00006					
BHP Steel	611.79	0.2294			0.9177					0.7036	0.000375			0.00150					0.001150
B Non-Ferrous Metals																			
Aluminium Production	324.11							0.0087											
Other (Magnesium)																			
C Inorganic Chemicals (excepting solvent use)																			
Nitric Acid																			
Fertiliser Production	**593.87**																		
Ballance (Mount)	157.07									0.5497									0.003500
Ballance (Invercargill)	70.80									1.2036									0.017000
Ravensdowne Fertiliser	366.00									3.7332									0.010200
Other																			
Ammonia/ Urea (Ballance)	163.21		0.1142									0.000700							
D Organic Chemicals																			
Adipic Acid																			
Other																			
Orica Adhesives and resins (Formaldehyde)	20.13	0.0503	0.0503			0.1550					0.002500	0.002500			0.007700				
Methanex (Methanol)	2132.33					10.6616									0.005000				
E Non-Metallic Mineral Products																			
Cement (total)	**1063.95**				3.8302					1.1916				0.003600					0.001120
Golden Bay Cement																			
Milburn Cement	462.58																		
Lime (total)	**141.00**									0.0050									
Websters Hydrated Lime	7.00									0.0006									0.000080
McDonalds Lime	134.00									0.0044									0.000033
Other																			
Asphalt Roofing (Emoleum)	0.00																		
The New Zealand Refining Company	4700.00					0.0000									0.000500				
Road Paving (Bitumen Contractors Assoc)	105.00	0.0037			0.0088	2.5200				0.0126	0.000035			0.000084	0.024000				0.000120
						0.0000									0.023000				
Glass	57.54					0.2589									0.004500				
F Other (ISIC)																			
Paper and Pulp	**1501.00**	4.0902			1.0956	2.7024				5.1127	0.002725			0.000730	0.001800				0.003406
Winstone Pulp International	150.00																		
Pan Pac Forest Products	241.40																		
Fletcher Challenge																			
Carter Holt Harvey																			
Panel Products	**84.00**																		
Carter Holt Harvey Panels	84.00					0.0089									0.000106				
Nelson Pine Industries																			

Module 2001 Industrial process (New Zealand)
Worksheet NZ 2b part 2
Sheet Non-CO_2 emissions

Module 2001 Industrial process (New Zealand)
Worksheet NZ 2b part 2
Sheet Non-CO_2 emissions

Source Categories	ACTIVITY DATA	Emission Estimates									Aggregate Emission Factor								
	A Production Quantity (kt)	B Full Mass of Pollutants (Gg) Tonnes x 1000									C Tonne of pollutant per tonne of product (t/t)								
		CO	CH4	N20	NOx	NMVOC	HFC	PFC	SF6	SO2	CO	CH4	N20	NOx	NMVOC	HFC	PFC	SF6	SO2
Food and drink production	**3110.3469**					**4.4742**													
Wine (million litres)	53.30					0.0043									0.000080				
Beer (million litres)	307.00					0.0107									0.000035				
Spirits (million litres)	0.18					0.0027									0.015000				
Meat	1200.80					0.3602									0.000300				
Fish	283.29					0.0850									0.000300				
Poultry	115.79					0.0347									0.000300				
Sugar	223.32					2.2332									0.010000				
Margarine and solid cooking fats						0.0000									0.010000				
Cakes, biscuits and breakfast cereals	23.89					0.0239									0.001000				
Bread	117.00					0.9360									0.008000				
Animal feed	780.64					0.7806									0.001000				
Coffee roasting	5.14					0.0028									0.000550				

		CO	CH4	N20	NOx	NMVOC	HFC	PFC	SF6	SO2
TOTAL		**4.6041**	**0.1646**	**0.0000**	**6.7920**	**25.2553**		**0.0087**		**12.5170**

Note: Use of halocarbons and SF6 covered in
separate tables

Note: Total SO2 emissions from fertiliser production
is 5.4865 Gg

Chapter 4

Solvent and Other Product Use

4.1 Introduction

New Zealand's relatively small manufacturing base means that solvent use is lower than in many other countries. Ethanol and methanol are produced domestically while other solvents are imported.

4.2 Country-specific approaches different from the IPCC methodology

The IPCC has not yet provided methodologies for emissions from solvents and other product use.

4.3 Emissions calculation methodology

Estimates of Non Methane Volatile Organic Substance (NMVOC) emissions were made with a consumption-based approach. Further information is contained in Montgomery Watson (2002). Per capita emission factors have been developed and used as the basis for the calculations. Emission factors have been checked against USEPA AP-42 and other emissions references such as the World Health Organisation (WHO) *Rapid Techniques for Pollution Sources*.

The four categories of solvents and other products given in the reporting tables are used in the New Zealand inventory.

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

Data represents imports of perchlorethylene from Statistics New Zealand.

Chemical products (manufacturing and processing)

Data refers to the use of solvents in the production of hydrogen peroxide and steel. It is provided by industry.

Other

This 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. Use of these products is based on United States Environmental Protection Authority (USEPA) information on consumption rates in the United States. This rate is 2.54kg of all the above products per capita per year. Population numbers are from Statistics New Zealand.

This category also includes NMVOC emissions from printing ink. Around 50% of printing inks are liquid, of which around 60% are solvent based. It is assumed that the solvent component in these inks is emitted as NMVOCs. The remaining 50% of ink is oil-based paste ink. Emissions from these inks are minimised by their treatment in a "solvent burner" as they evaporate during heating.

4.4 Changes since the last inventory submission

Data in this sector for the 2001 calendar year were derived using the same method used for previously reported data and a new survey was carried out in 2002 of emissions in this sector. No changes have been made to the methodology or to previously reported data.

4.5 Uncertainty

As with other sections of the inventory, uncertainty arises from estimating the activity data and from estimating the emission factors. The combination of these uncertainties for NMVOC emissions from solvent and other product use is considered to be ±22% (Montgomery Watson 1998).

4.6 References

Auckland Regional Council, 1997, *Auckland Emissions Inventory*, report by the Victorian Environmental Protection Agency, New Zealand.

Montgomery Watson, 1998, *Inventory of Non-CO_2 Greenhouse Gas Emissions from Industrial Sources and Solvent and Other Product Use*, report to the Ministry of Commerce, New Zealand.

Montgomery Watson, 2002, *Inventory of Non-CO_2 Greenhouse Gas Emissions from Industrial Sources and Solvent and Other Product Use, HFCs and PFCs and SF_6*, report to the Ministry for the Environment, April 2002.

Nelson, P, 1992, Waste Control and Pollution Prevention in the Paint Industry, *Surface Coatings Australia*, July.

Appendix to Chapter 4:
Solvent amd Other Product Use calculation tables 2001

Module 2001 Solvent and other product use (New Zealand)
Worksheet NZ 3a
Sheet Non-CO_2 emissions

Source Categories	ACTIVITY DATA Quanity Consumed tonnes	Emission Estimates B (Gg)			Emission Factors C kg/year/person			
		$N_2$0	HFC	NMVOC	CO	$N_2$0	HFC	NMVOC
TOTAL SOLVENT EMISSIONS								
A Surface Coatings								
Architectural/ Decorative	**58036**			**15.7822**				
Organic Base	**4310.2848**			**1.4339**				
Primers and Undercoats	1620			0.4374				0.1118
Finishing Coats - Gloss	1292			0.4391				0.1122
Finishing Coats - Semi Gloss	337			0.0876				0.0224
Finishing Coats - Flat	255			0.0662				0.0169
Clears and Stains	807			0.4036				0.1032
Water Base	**31694.6112**			**2.0344**				
Primers and Undercoats	2646			0.1852				0.0473
Finishing Coats - Gloss	12451			0.8715				0.2228
Finishing Coats - Semi Gloss	7071			0.4950				0.1265
Finishing Coats - Flat	8897			0.4449				0.1137
Clears and Stains	630			0.0378				0.0097
Industrial								
Organic Base	**16714.1889**			**8.2821**				
Primers and Undercoats	6397			2.1751				0.5560
Finishing Coats	9486			5.6914				1.4548
Clears	831			0.4155				0.1062
Water Base	**1381.3183**			**0.0967**				
Primers and Undercoats	1242			0.0869				0.0222
Finishing Coats	140			0.0098				0.0025
Thinners	**3935.1732**			**3.9352**				
Solvents/Thinners	3935			3.9352				1.0059
B Degreasing and Drycleaning	2439			**2.4394**				
Drycleaning	991			0.9913				0.2534
Metal Degreasing	1448			1.4482				0.3702
C Chemical Products	**3912.1000**			**3.9199**				
Ethanol	3912			3.9121				1.0000
Hydrogen Peroxide				0.0078				0.0020
D Other	**21733.5032**			**15.9275**				
Total printing	**8294**			**2.4883**				
Printing	5290			1.5871				0.4057
Small Commercial	3004			0.9012				0.2304
Industrial	3502			3.5022				0.8952
Aerosols				0.0000				0.000000005
Steel production[1]	9937			9.9369				2.5400
Total commercial and domestic	**13439**			**13.4391**				
Other Solvents Use								
	86120.60			**38.07**				

Emission factors derived on a kg/person/year basis
1. Emissions calculated on production not consumption data.

POPULATION 3,912,100

Chapter 5

Agriculture

5.1 Introduction

The agricultural sector represented approximately 50% of all greenhouse gas emissions in 2001 and there was an increase of 0.7% from 2000. Emissions are now 12.3% higher than the 1990 baseline in this sector.

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 all-year-round grazing systems and a reliance on nitrogen fixation by legumes rather than the high nitrogenous fertilizer and energy inputs which are prevalent in many agricultural sectors in Europe and North America.

There has been very little government financial support for agriculture since 1984, which means that the agriculture sector needs to react rapidly to world market fluctuations. This has resulted in important benefits to the environment. There has been a reduction in sheep livestock numbers. However, this has been offset by an increase in dairy cattle and deer numbers. There have also been productivity increases across all major animal classes. The land used in horticulture has not changed significantly since 1990 although the types of produce grown have shifted with less grain and more vegetables, fruit and grapes.

In June 2002, a census of the animal population and other agricultural data took place and will occur every five years thereafter. Surveys will be undertaken in intervening years. New Zealand uses a June year for all animal statistics. A complete time series of the agriculture data used in this submission is shown in the tables at the end of this chapter. Poultry numbers have been revised in this submission as it became apparent with the new animal population census data available this year that the numbers of broilers had been overestimated.

5.2 Emissions profile

Methane and nitrous oxide resulting from animal production, particularly sheep, dairy and beef cattle, and deer, dominate this sector.

5.3 Methodological approach: Methane from enteric fermentation in domestic livestock

Overview

The methodological approach for estimating CH_4 emissions from enteric fermentation in domestic livestock has undergone a complete change for this submission, and the entire time series has undergone recalculation. New Zealand is now using a Tier 2 approach for these estimates. A full description of the methodological approach follows below under methodology.

New Zealand-specific methodology/emission factors are not currently available for CH_4 emissions from enteric fermentation in horses or swine, but using IPCC default emission factors, these CH_4 emissions are included in this submission for the first time. It is unlikely that research on New Zealand-specific factors will be done as the contributions from horses and swine are so small.

Methodology

As methane is a key source category, a Tier 2 methodology has been developed, replacing the hybrid Tier 1/Tier 2 approach used in previous national inventory reports. The new methodology closely follows the IPCC 2000 Good Practice approach, and is fully described in Clark et al. (2003). What follows is a summary of the methodology applied.

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 sub-divided the principal categories were developed. These models reflect New Zealand farming systems with regard to the timing of births, the timing of slaughter of growing animals and the transfer of younger animals into the breeding population. Goats are also included in the analysis, but a separate model has not been developed as goat numbers have dropped significantly in recent years and the numbers represent only a very small proportion of the total animal population and emissions.

Animal numbers are from Statistics New Zealand, supplemented by estimates from the Ministry of Agriculture and Forestry for those years where an annual census or survey was not undertaken. For details, see the accompanying set of tables for a complete time series of agricultural data used in the agricultural sector inventory calculations. As shown in the tables, three-year averages are used throughout the agricultural sector.

For sheep, dairy cattle, non-dairy cattle and deer the three-year average populations 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.

Livestock productivity data: Livestock productivity and performance data are summarised in the accompanying time series tables for the agriculture sector. This 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) and monthly energy concentrations of the diets consumed by beef cattle, sheep, dairy cattle and deer. Obtaining data on the productivity of ruminant livestock in New Zealand, and how it has changed over time, is a difficult task since, in general, no routine comprehensive surveys are conducted. For each livestock category the best available data was used, although this was sparse in many cases. The same data sources have been used in each year, meaning that even if there is some doubt as to the absolute values used each year, the values do provide a time series that reflects changing farming practices.

For **dairy cattle**, data on milk production was provided by the Ministry of Agriculture and Forestry. 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 were obtained by dividing the total milk produced by the total number of milking dairy cows and heifers. Milk composition data was taken from the Livestock Improvement Corporation (LIC) national statistics. For all years, lactation length was assumed to be 280 days.

Average weight data for dairy cows was obtained by taking into account the proportion of each breed in the national herd and its age structure based on data on breed and age structure from the LIC. Dairy cow liveweights are only available from 1996 onwards. For earlier years in the time series, liveweights were estimated using the trend in liveweights from 1996 to 2001 together with data on the breed composition of the national herd. Growing dairy replacements at birth were assumed to be 9% of the weight of the average cow and 90% of the weight of the average adult cow at calving. Growth between birth and calving (at two years of age) was assumed to be linear. The birth date of all calves was assumed to be mid-August.

No data are available on the liveweights and performance of breeding bulls and an assumption was made that their average weight was 500kg and that they were growing at 0.5kg per day.

For **beef cattle**, the principal source of information for estimating productivity was livestock slaughter statistics provided by the Ministry of Agriculture and Forestry. All growing beef animals were assumed to be slaughtered at two years of age, and the average weight at slaughter for the three sub-categories (heifers, steers and bulls) was estimated from the carcass weight at slaughter. Liveweights at birth were assumed to be 9% of an adult cow weight for heifers and 10% of the adult cow weight for steers and bulls. Growth between weight at birth and slaughter was assumed to be linear.

Weights at slaughter statistics from the Ministry of Agriculture and Forestry do not separate carcass weights of adult dairy cows and adult beef cows. Thus a number of assumptions[1] were made in order to estimate the liveweights of beef breeding cows. A total milk yield of 800 litres per breeding beef cow was assumed.

For **sheep**, livestock slaughter statistics from the Ministry of Agriculture and Forestry were used to estimate the liveweight of adult sheep and lambs, assuming killing out percentages of 43% for ewes and 45% for lambs. Lamb birth liveweights were assumed to be 9% of the adult ewe weight, with all lambs assumed to be born on 1 September. Growing breeding and non-breeding ewe hoggets were assumed to reach full adult size at the time of mating when aged 20 months. Adult wethers were 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 were assumed to have a total milk yield of 100 litres. Breeding rams were assumed to weigh 40% 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.

[1] Number of beef breeding cows was assumed to be 25% of the total beef breeding cow herd; other adult cows slaughtered were 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 were then obtained assuming a killing out percentage of 45%.

For **deer**, liveweights of growing hinds and stags were estimated from Ministry of Agriculture and Forestry slaughter statistics, assuming a killing out percentage of 55%. Fawn birthweight of 9% of the adult female weight and a common birth date of mid-December were assumed. Liveweights of breeding stags and hinds were 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 1989 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).

For **goats** in New Zealand, 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. Enteric methane from goats is not a "key source category". Methane emissions from goats for all years 1990-2001 were assumed to average the same per head as the average sheep in 1990 (i.e. total sheep emissions/ total sheep number).

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

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

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 as there are no comprehensive published data available that allow the estimation of a time series dating back to 1990.

There are a number of published algorithms and models[2] of ruminant digestion for estimating **methane 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 with experimental data. Additionally, the relationships in the models have been derived from animals fed indoor on diets dissimilar to those consumed by New Zealand's grazed ruminants.

Since 1996 New Zealand scientists have been measuring methane emissions from grazing cattle and sheep using the SF_6 tracer technique (Lassey et al, 1997; Ulyatt et al, 1999). New Zealand now has one of the largest data sets in the world of methane emissions from grazing ruminants. Currently a database of these data is being constructed and systematically examined to obtain generalised relationships between feed characteristics and methane emissions. As an interim measure, published and unpublished data on methane emissions from New Zealand was collated and average values for methane emissions from different categories of livestock obtained. Enough 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 9 together with IPCC (2000) default values for percent gross energy used to produce methane. The New Zealand values fall within the IPCC range and so were adopted for use in this inventory calculation.

Not all classes of animals are covered in the New Zealand data set, thus assumptions had to be made for these 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_4/kg DMI) was assumed to apply to all deer. In very young animals receiving a milk diet, no methane was assumed to arise from the milk proportion of the diet.

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

Table 9: Methane emissions from New Zealand measurements compared with IPCC default values

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

Revised time series of methane emissions from ruminants

The entire time series of methane emissions from ruminants has been recalculated using the Tier 2 approach. The data is summarised in Table 10. The time series of implied emission factors (kg CH_4/animal/year) is presented in Table 11.

Table 10: Summary of total national methane emissions per animal class ($Gg\ CH_4$)

Year	Dairy cattle	Beef cattle	Sheep	Deer	Goats	Swine	Horses	Total (this inventory)	NIR* 2002 total
1990	237.9	233.3	514.7	20.4	9.1	0.6	1.7	1,017.7	1,493.1
1991	243.7	238.5	499.5	23.4	7.1	0.6	1.6	1,014.3	1,461.8
1992	252.5	246.4	480.8	24.5	5.0	0.6	1.6	1,011.4	1,428.6
1993	263.7	259.9	474.3	24.7	3.5	0.6	1.5	1,028.1	1,417.0
1994	279.1	266.3	467.3	24.1	2.9	0.6	1.3	1,041.7	1,423.7
1995	293.2	266.9	467.1	24.4	2.5	0.6	1.2	1,056.0	1,426.8
1996	305.9	259.2	464.0	25.3	2.4	0.6	1.2	1,058.6	1,420.1
1997	310.4	254.5	466.8	27.1	2.0	0.6	1.2	1,062.8	1,397.8
1998	318.4	251.0	467.8	28.8	1.9	0.6	1.3	1,069.8	1,391.8
1999	333.2	251.4	456.8	30.0	1.8	0.6	1.3	1,075.1	1,389.9
2000	358.3	252.1	455.7	31.1	1.6	0.5	1.3	1,100.6	1,398.3
2001	372.5	254.0	438.7	32.7	1.5	0.5	1.4	1,101.3	

*National Inventory Report

The values in this inventory are considerably lower than those previously reported, and show an increase in methane emissions since 1990 rather than a decrease. Two factors are responsible for these changes. Firstly, previous inventories were calculated using methane emission factors derived from a complex model of ruminant digestion (the Baldwin model) that over-predicted methane per unit of intake by about 20% to 30% compared with New Zealand experimental data (Clark, 2001). Secondly, the revised inventory uses animal performance data that reflects the increased levels of productivity achieved by New Zealand farmers since 1990. Animals are now larger and more productive than they were in 1990 – they eat more and thus emit more methane. Previous inventories were calculated using a fixed emission factor across all years for each animal class. The implied emission factors obtained from the revised inventory (for dairy cattle, beef cattle, sheep and deer) are summarised in Table 9.

Table 11: Summary of implied emission factors obtained from this inventory compared with the previous fixed values (kg methane per animal per annum)

Year	Dairy cattle	Beef cattle	Sheep	Deer	Goats
1990	70.2	50.8	8.9	19.7	8.9
1991	70.7	51.3	9.1	19.4	8.9
1992	72.5	52.4	9.1	19.3	8.9
1993	72.9	53.8	9.3	19.2	8.9
1994	73.0	53.3	9.4	19.3	8.9
1995	72.7	53.1	9.6	19.6	8.9
1996	73.4	52.4	9.7	20.0	8.9
1997	73.0	54.2	10.0	20.5	8.9
1998	73.9	54.3	10.1	20.7	8.9
1999	75.1	55.2	10.1	20.8	8.9
2000	77.0	54.9	10.5	20.9	8.9
2001	74.7	56.0	10.6	20.9	8.9
Previous fixed EF	76.8	67.5	15.1	30.6	16.5

Note: A detailed categorisation of the performance characteristics has not been done for goats in the same way as has been done for the major livestock categories.

The most significant differences between the emission factors in this inventory and the previous fixed emission factors are for sheep, deer and goats. The downward revision for the sheep is explained by: a fall of 15% to 20% in the estimate of methane emissions per unit of intake in older sheep; an almost 30% decrease in the estimated emissions per head in younger sheep; the ewe and lamb liveweights assumed for the earlier emission factor were 10% higher than those in the revised inventory; and the model from which the previous emission factor was derived kept animal numbers constant throughout the year and had only three categories (ewes, lambs and growing sheep) whereas the revised inventory takes into account ewe and lamb mortality and has nine classes, several of which have lower intakes and consequently lower methane emissions than the growing sheep class. Technical errors were also made in the previous estimates of methane emission per head from deer and goats.

An arithmetic error was made in translating the total emissions from deer, calculated by Ulyatt et al. (1991) into the annual emission factor used in previously reported inventories. In the Ulyatt et al. (1991) study, total deer emissions included emissions from feral deer. However, the annual emission factor for deer was obtained by dividing by only the farmed population resulting in an emission factor that was too high. If only farmed deer had been used in the calculation, the emission factor would have been 22.60kg CH_4 per head per year (Clark, 2001). A similar technical error was also made when deriving the emission factor for goats. If only the farmed goats had been included, the emission factor would have been 10.5kg CH_4 per head per year.

5.4 Methodological approach: Methane emissions from manure management

Most animal waste decomposes aerobically on New Zealand pastures. The current estimates of CH_4 emissions from manure management for cattle, sheep and goats are derived from Joblin and Waghorn (1994) who used stock numbers, feed intake and digestibility data from Ulyatt et al. (1992) to estimate total faecal output from cattle, sheep, goats and deer at approximately 16 million tonnes dry weight in 1990. This is shown in Table 12. The same emission factors are used for each year of the inventory. Further research has been commissioned to reassess these values.

Table 12: Derivation of New Zealand emission factors for methane emissions from manure

Animal class	Faecal dry matter (1000t)	Estimated maximum CH_4 potential (1000t)	Emission factor (kg/animal/year)
Dairy cattle	2,683.6	3.1	0.889
Non-dairy cattle	3,647.5	4.2	0.909
Sheep	9,009.1	10.3	0.178
Goats	115.4	0.1	0.119
Deer	313.5	0.4	0.369
Total	**15,769.1**		

New Zealand-specific methodology/emission factors are not currently available for CH_4 emissions from manure management for swine, horses and poultry, but emissions estimates using IPCC default emission factors are included in this submission for the first time. These estimates are considered preliminary and will undergo change if New Zealand-specific emission factors can be derived.

5.5 Methodological approach: Nitrous oxide emissions from agricultural soils

Overview

Pastoral agriculture is the source of most N_2O emissions in New Zealand. Using the IPCC 1996 approach, N_2O emissions are determined by a combination of nitrogen inputs and emission factors that dictate the fraction of N deposited on the soils that is emitted to the atmosphere as N_2O. The two main inputs are excreta deposited during animal grazing, and nitrogen fertilizer. The entire time series of N_2O emissions from agricultural soils has been reviewed (Kelliher et al., 2003) and in line with Good Practice this has resulted in recalculations to the time series.

The revised data reported this year differ from previously reported data mainly as a result of using new methods for estimating N intake by animals and excreta deposited during grazing (to reflect productivity changes since 1990), and revised activity data for nitrogen fertilizer use.

For this report, the New Zealand Fertiliser Manufacturers' Research Association (FertResearch) obtained sales records for 1990 to 2002 to determine the annual use of N fertilizer. These data were corroborated by the Ministry of Agriculture and Forestry using urea production (by the Kapuni plant) and industrial applications (including resin manufacture for timber processing) data obtained by FertResearch, and fertilizer import and export data from Statistics New Zealand.

New Zealand continues to use the IPCC 1996 method for calculating N_2O emissions from agricultural soils. The worksheets at the end of this chapter list the emission factors and other parameters used in the calculations. These are IPCC factors and parameters unless otherwise indicated. In particular, two New Zealand-specific factors/parameters are used: $EF_{3(PR\&P)}$ and $Frac_{LEACH}$. $EF_{3(PR\&P)}$ has been extensively reviewed prior to this submission, and a new value for $Frac_{LEACH}$ is used in this submission.

Animal production (N_2O)

Six alternative regimes for treating animal manure, known as animal waste management systems (AWMS), are identified in the IPCC guidelines. With the exception of dairy cattle for which the data from Haynes and Williams (1993) was used, animals were allocated to the different AWMS according to the information provided in the IPCC 1996 guidelines for the Oceania region. Nitrous oxide emissions from four AWMS were allocated to livestock emissions:

1. Anaerobic lagoons.
2. Pasture, range and paddock.
3. Solid storage and dry-lot.
4. Other systems.

Excretion of nitrogen for each animal waste management system is calculated in the supplemental tables to Worksheet 4.1 using revised parameters for nitrogen excretion (Nex) for each livestock type. A time series of Nex values used for recalculating animal production N_2O emissions is also shown in the worksheets that follow. These parameters resulted from using the nutrient input/output model OVERSEER® to determine the annual quantities of nitrogen deposited in excreta by grazing animals, derived from feed intake from the new process-based model used to determine methane emissions (Clark et al., 2003) and a new assessment of feed nitrogen content.

Indirect N_2O from nitrogen used in agriculture

Table 4 of the worksheets shows the N_2O emitted indirectly through synthetic fertilizer and animal waste being spread on agricultural soils. Some of the nitrogen contained in these compounds is deposited to the atmosphere as ammonia (NH_3) and NO_x through volatilisation, which then returns to the ground during rainfall and is then re-emitted as N_2O. All animal waste is included. Emission factors are applied to the amounts of nitrogen that volatilise from synthetic fertilizer and waste.

Table 5 of the worksheets shows the N_2O emitted indirectly from nitrogen lost from agricultural soils through leaching and run-off. This nitrogen enters water systems and eventually the sea with quantities of N_2O being emitted along the way. The amount of nitrogen that leaches is taken as a fraction that is deposited or spread on land ($Frac_{LEACH}$).

Studies in New Zealand together with a literature review have shown lower rates of nitrogen leaching than is suggested in the IPCC guidelines. Previously a New Zealand parameter for $Frac_{LEACH}$ of 0.15 was used, based on studies involving both grazing livestock and fertilizer application. Model OVERSEER® was used to scrutinise the fraction of added nitrogen leached from grazed pastoral soils nationally (Thomas et al., 2002). The model has been calibrated for grazed dairy pastures. Following the recommendation of Thomas et al. (2002), a new value of 0.07 for $Frac_{LEACH}$ has been used in this submission and applied to all years of the time series.

Table 5 of Worksheet 4.5 also totals the N_2O emissions from all categories in the agricultural soils section.

Direct N_2O emissions from agricultural soils

Emissions from agricultural soils are calculated in the five tables of Worksheet 4.5. Table 1 shows the calculation of direct emissions with the F_{SN}, F_{AW}, F_{BW} and F_{CR} formulae that arise from the following:

1. Synthetic fertilizer use.
2. Spreading animal waste as fertilizer.
3. Nitrogen fixing in soils by crops.
4. Crop residues left on fields.

Separate tables are included for these calculations. Table 1 of Worksheet 4.5 collects all of these nitrogen inputs together. An emission factor is then applied to the inputs to calculate total direct emissions from non-organic soils.

The F_{AW} calculation for animal waste includes all manure that is spread on agricultural soils, irrespective of the AWMS in which it was initially stored. This includes all waste in New Zealand (except for emissions from the pasture range and paddock AWMS which are calculated in Table 3 of Worksheet 4.5). No animals are reported for daily spread AWMS as advised by the IPCC guidelines.

Table 2 of Worksheet 4.5 relates to direct N_2O emissions from organic soils. The area of cultivated organic soils is simply multiplied by an emission factor. In this submission, the area of cultivated organic soils has been revised (downwards from 160,000ha to 10,109ha) and the IPCC 2000 emission factor (EF_2 equal to 8) has been used for all years of the time series. The revision of the area of cultivated soils has occurred as the previous area used was based on a peat bog survey carried out in the 1970s, representing the total amount of peat soil, and did not reflect cultivation. More recent data puts New Zealand's total organic soils at 202,181 hectares, of which it is estimated that 5% (i.e. 10,109ha) is cultivated on an annual basis (Kelliher et al., 2003).

Table 3 of Worksheet 4.5 concerns the last of the AWMS – manure deposited by grazing stock on "pasture range and paddock" which is left to decompose. This AWMS is the predominant regime for animal waste in New Zealand as 100% of sheep, goats, deer and non-dairy cattle are allocated to it and 89% of dairy cattle and grazing animal excreta dominate the N input to pastoral soils. Nitrogen excretion from the pasture range and paddock AWMS is estimated in supplemental tables and an emission factor (EF_3) of 0.01 (Carren et al., 1995; Muller et al., 1995; de Klein et al., 2003; and Kelliher et al., 2003) is applied to the result in Worksheet 4.5 (3 of 5). The rates of nitrogen excretion per animal for dairy cattle, non-dairy cattle, sheep and deer are derived from model OVERSEER® as described above. The values used for goats and poultry are unchanged from previous submissions.

Previous analysis showed that EF_3 accounted for 80% of the uncertainty in agricultural nitrous oxide emissions (Sherlock et al., 2001). Considerable research effort has gone into establishing a better quantification of EF_3. Field studies have been performed as part of a collaborative research effort called N_2Onet[3]. Over the past three years, parameter EF_3 has been measured by N_2Onet researchers in the Waikato (Hamilton), Canterbury (Lincoln) and Otago (Invermay) regions for pastoral soils of different drainage classes (de Klein et al., 2003). These regional data are comparable because the same measurement methods were used at the three locations. The percentage of applied nitrogen (as urine or dung) emitted as N_2O, and environmental variables were measured in 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) have assessed all available EF_3 data and its distribution with respect to pastoral soil drainage class, to determine an appropriate national annual mean value. The complete EF_3 data set of N_2Onet 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_2O emissions using the IPCC 1996 methodology, (2) N_2O 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% well drained, 17% imperfectly drained and 9% poorly drained (Sherlock et al., 2001).

Research and analysis to date indicate that if excreta is separated into urine and dung, EF_3 for urine and dung could be set to 0.007 and 0.003 respectively. However, it is recognised that the dung EF_3 data are limited.

Combining urine and dung EF_3 values, the dairy cattle total excreta EF_3 is 0.6% which is 42% less than the New Zealand-specific value currently used for sheep, beef and dairy cattle, and deer excreta. The IPCC default value of EF_3 is 2%. Conservatively rounding the total excreta EF_3 of 0.6% provides a value of 1% for EF_3. Thus, the ongoing, seasonal studies of N_2Onet throughout New Zealand do not yet provide sufficient evidence to change EF_3 from the New Zealand-specific value of 0.01 (Kelliher et al., 2003) although the current data suggest that a reduction may be appropriate.

Trace gases from the field burning of agricultural residues

These emissions are estimated in accordance with the revised 1996 IPCC guidelines. Barley, wheat and oats are reported in this category. Previous inventories have also included maize, but this has now been excluded on advice from the Ministry of Agriculture and Forestry that maize residue is not burnt in New Zealand. Oats are included under the same emission factors as barley. The "fraction land burned" was changed from 0.05 to 0.5 in last year's submission based on a revised estimate from the Ministry of Agriculture and Forestry.

[3] The research conducted by N_2Onet is funded by the Ministry of Agriculture and Forestry. N_2Onet draws on the skills of researchers in Crown Research Institutes and universities, and includes researchers from the private sector. N_2Onet is also supported by the Climate Change Office.

Revised time series of N_2O emissions from the agriculture sector

The total emissions of nitrous oxide from the agricultural sector, estimated as described above using revised factors and parameters, for the entire time series are summarised in Table 13. These revised emissions are compared with those reported in New Zealand's 2002 inventory submission.

Table 13: Total (revised) agricultural sector emissions of N_2O for 1990 to 2001 compared with those reported in 2002. Emissions are in Gg of N_2O

Year	Revised inventory	NIR 2002
1990	31.9	37.0
1991	32.0	36.5
1992	32.3	36.2
1993	33.3	36.5
1994	34.4	37.1
1995	35.2	37.3
1996	35.6	37.3
1997	35.7	37.4
1998	36.1	37.3
1999	36.6	38.4
2000	38.1	39.0
2001	38.9	

Unlike the National Inventory Report (NIR) of 2002, the revised N_2O emissions are increasing over time above the 1990 level. For example in 2001, N_2O emissions from agricultural soils were 7.0Gg above the 1990 level. This is attributable to a factor of four increase in nitrogen fertilizer use over the 11 years (3.9 of the 7.0Gg) and an increase in N excreta from grazing animals (3.1 of the 7.0Gg).

N_2O emissions from nitrogen fertilizer use have increased from 1.3Gg in 1990 to 5.2Gg in 2001, and N_2O emissions from excreta deposited during grazing have also increased from 29.8Gg in 1990 to 32.8Gg in 2001. The N content of pasture was constant over time so the changes in N_2O emissions from excreta deposited during grazing were determined by changes in animal numbers and the animals increasing in productivity (size) and thus eating more over time.

5.6 Issues of transparency (QA/QC)

The agriculture part of the CRF was internally reviewed by the New Zealand Climate Change Office and the Ministry of Agriculture and Forestry. The models and research reported (in particular the revision of the enteric methane and nitrous oxide emissions) have been reviewed by national and international experts as part of the formal academic procedure of peer review carried out by New Zealand research organisations.

5.7 Uncertainty

Uncertainty of emissions estimates in the agricultural sector is difficult to quantify as it arises in many different areas due to the biological nature of emissions in the sector.

Animal numbers

Many of the calculations in this sector require livestock numbers. Both census and survey methods are used. Surveys occur in the intervening years between each census. Table 14 below gives the sample errors based on a 95% confidence level for survey data collected in 1999. Generally animal numbers do not contribute significantly to errors.

Table 14: Agricultural sector sample errors based on 95% confidence level

Variable (total population)	Survey design error (%)	Achieved sample error (%)
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

(Reference: www.maf.govt.nz/statistics/primaryindustries/livestock/technotes.htm)

Methane emissions from enteric fermentation

The revised inventory data for methane emissions from domestic livestock was subjected to Monte Carlo analysis using the software package @RISK to determine uncertainty. This method enables estimates of standard deviation for the calculated emissions and allows a 95% confidence interval to be placed around the methane emissions from enteric fermentation. This is shown in Table 15. Full details are presented in Clark et al., 2003. The coefficient of variation (standard deviation/mean) is approximately 23%.

Table 15: Enteric methane emissions 1990 and 2001 and the 95% confidence interval (±1.96 standard deviations from the mean) estimated using Monte Carlo simulation

Year	Enteric CH_4 emissions (Gg/annum)	95% CI min	95% CI max
1990	1,015.5	547.8	1,483.2
2001	1,099.4	593.0	1,605.8

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

The Monte Carlo simulation demonstrates that in this part of the methane inventory, the uncertainty in the total is dominated by the uncertainty in the "methane per unit of intake" factor (multiple regression coefficient 0.95). Uncertainties in the estimation of energy requirements and herbage quality play a much smaller role (+0.21 and -0.21 respectively).

Research strategy to reduce uncertainty in methane emissions from animals

A national inter-institutional ruminant methane expert group has been formed to identify the key strategic directions for research into the inventory and mitigation to maximise the benefit of the existing programmes and to develop a collaborative approach to improve the certainty of methane emissions. This is funded by the Ministry of Agriculture and Forestry.

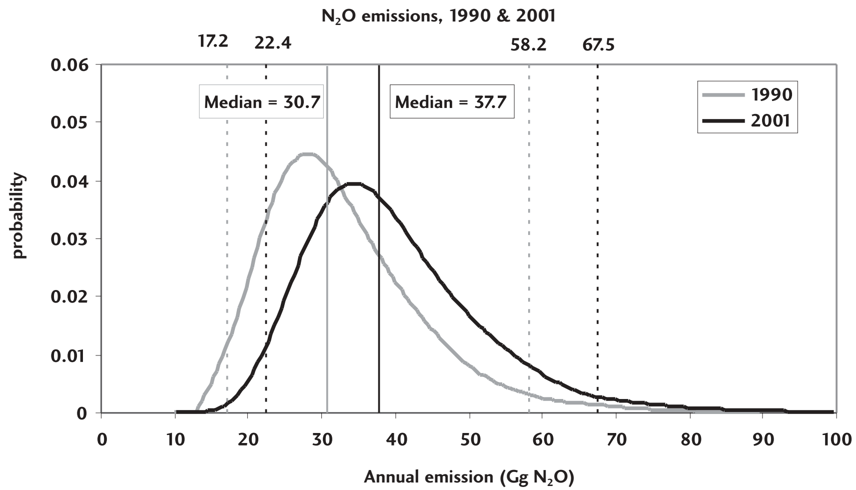
Methane emissions from manure management

Methane estimates from the anaerobic degradation of animal waste are still preliminary and are based on the maximum potential emission of methane from animal waste. Actual emissions are likely to be substantially lower in a range of 10-50% of the reported values (an uncertainty between 50% and 90%).

Nitrous oxide emissions from soils

Monte Carlo numerical assessment using the @RISK software was used to assess uncertainties in nitrous oxide emissions from agricultural soils. This analysis is fully described in Kelliher et al., 2003. From the Monte Carlo numerical simulation for 1990, as illustrated in Figure 3 below, the most probable N_2O emission was the revised value, with a 95% probability that it was between 17Gg and 58Gg with a medium of 30.7Gg.

Figure 3: Relations between nitrous oxide emissions in 1990 and 2001 and their probability of occurrence according to Monte Carlo numerical simulation. Probabilities were normalised so the area under each curve is equal to unity (Source Kelliher et al., 2003)



The Monte Carlo numerical assessment determined the effects of variability in the nine most influential parameters on the uncertainty of the calculated N_2O emissions. These parameters are shown in Table 16 together with their percentage contributions to the uncertainty. The Monte Carlo analysis confirmed that uncertainty in parameter EF_3 has the most influence on total uncertainty, accounting for 91% of the uncertainty in total N_2O emissions in 1990. This broad uncertainty reflects natural variance in EF_3 determined largely by the vagaries of the weather and soil type.

Table 16: The percentage contribution of the nine most influential parameters on the uncertainty of total N_2O emissions inventories for 1990 and 2001

Parameter	1990 % contribution to uncertainty	2001 % contribution to uncertainty
EF_3	90.8	88.0
EF_4	2.9	3.3
Sheep N excretion	2.5	1.8
EF_5	2.2	2.8
Dairy N excretion	0.5	0.7
$Frac_{GASM}$*	0.5	0.5
EF_1	0.3	2.4
Beef N excretion	0.2	0.3
$Frac_{LEACH}$**	0.1	0.2

*Total nitrogen excretion emitted as NO_x or NH_3

**Nitrogen input to soils that is lost through leaching and run off

Research strategy to reduce uncertainty in nitrous oxide emissions from soils

As described earlier, the Ministry for the Environment and the Ministry of Agriculture and Forestry have been funding a national inter-institutional expert group called N_zOnet. This initiative comprises teams of scientists with existing research programmes encompassing the agricultural greenhouse gases and promotes a collaborative approach to meeting the challenge of refining measurement and mitigation techniques. The work of N_zOnet will continue in order to better quantify appropriate nitrous oxide emission factors for New Zealand's pastoral agriculture.

Trace gases from the field burning of agricultural residues

These calculations were made according to the 1996 revised IPCC guidelines and no numerical estimates for uncertainty are available for these emissions.

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Appendix to Chapter 5:
Time series of agricultural data 1989 to 2002
Livestock productivity data 1990 to 2001
Agriculture calculation tables 2001

Animal numbers in New Zealand Revised 2003

Agricultural sector calculations: emissions from domestic livestock and agricultural soils

	Dairy cattle[1] (jun yr)	Dairy cattle (3 yr av)	Non-dairy cattle[1] (jun yr)	Non-dairy cattle (3 yr av)	Sheep numbers[1] (jun yr)	Sheep numbers (3 yr av)	Goat numbers[1] (jun yr) (1000s)	Goat numbers (3 yr av) (1000s)	Deer numbers[2] (jun yr)	Deer numbers (3 yr av)	Swine numbers[1] (jun yr) (1000s)	Swine numbers (3 yr av) (1000s)
1989	3,302,377		4,526,056		60,568,653		1,222		835		411	
1990	3,440,815	3,390,873	4,593,160	4,596,595	57,852,192	57,860,829	1,063	1,026	1,043	1,036	395	404
1991	3,429,427	3,446,022	4,670,569	4,646,742	55,161,643	55,194,076	793	796	1,230	1,204	407	404
1992	3,467,824	3,482,464	4,676,497	4,701,676	52,568,393	52,676,132	533	559	1,340	1,270	411	405
1993	3,550,140	3,619,055	4,757,962	4,827,436	50,298,361	50,777,603	353	390	1,240	1,287	395	410
1994	3,839,200	3,826,380	5,047,848	4,996,103	49,466,054	49,526,895	284	324	1,280	1,246	423	416
1995	4,089,800	4,031,367	5,182,500	5,027,516	48,816,271	48,558,744	337	283	1,219	1,244	431	426
1996	4,165,100	4,170,300	4,852,200	4,946,933	47,393,907	47,681,393	228	264	1,232	1,264	424	424
1997	4,256,000	4,255,033	4,806,100	4,696,767	46,834,000	46,727,969	228	228	1,342	1,325	417	418
1998	4,344,000	4,305,467	4,432,000	4,627,267	45,956,000	46,156,667	228	214	1,400	1,388	412	399
1999	4,316,400	4,436,933	4,643,700	4,555,267	45,680,000	45,052,111	186	197	1,423	1,440	369	383
2000	4,650,400	4,650,400	4,590,100	4,590,100	43,520,333	43,520,333	176	176	1,496	1,491	369	364
2001	4,984,400	4,984,400	4,536,500	4,536,500	41,360,667	41,360,667	165	165	1,553	1,568	354	356
2002	5,318,400		4,482,900		39,201,000		155		1,656		345	

1. 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.
2. MAF estimates February 2003

Animal numbers in New Zealand (thousands) Revised 2003

Agricultural sector calculations: emissions from domestic livestock and agricultural soils

	Poultry numbers layers[1] (June yr)	Poultry others and broilers[2] (June yr)	Poultry numbers total (June yr)	Poultry numbers (3 yr av)	Horse numbers[3] (jun yr)	Horse numbers (3 yr av)
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	13,977	67.7	68.5
1997	3,307	11,643	14,950	14,950	69.2	69.2
1998	3,405	13,023	16,429	16,429	70.6	70.6
1999	3,503	14,404	17,907	17,907	72.1	72.1
2000	3,601	15,784	19,385	19,385	73.6	73.6
2001	3,699	17,165	20,864	20,864	75.0	75.0
2002	3,797	18,545	22,342		76.5	

1. 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.
2. 2002 (provisional) data from Statistics New Zealand. 1989, 1990, 1992, 1995 and 1996 from MAF survey data.
3. 1994, 1995, 1996 and 2002 (provisional) data from Statistics New Zealand. 1990, 1992 and 1993 from MAF survey data.
   Other estimates provided by MAF February 2003.

Non-N-fixing crop yields in New Zealand Revised 2003

Agricultural sector calculations: emissions from field burning and agricultural soils

	Barley prodn (jun yr) (tonnes)	Barley prodn (3 yr av) (Gg)	Wheat prodn (jun yr) (tonnes)	Wheat prodn (3 yr av) (Gg)	Maize prodn (jun yr) (tonnes)	Maize prodn (3 yr av) (Gg)	Oats prodn (jun yr) (tonnes)	Oats prodn (3 yr av) (Gg)	Non-N-fixing crops (3 yr av) (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	777,721,333
1991	382,043	378.6	180,690	186.6	183,388	169.6	57,187	64.6	799,342,333
1992	318,787	363.5	191,039	197.0	163,842	160.1	57,625	57.2	777,800,000
1993	389,523	367.9	219,414	217.5	133,069	146.6	56,793	57.4	789,326,000
1994	395,500	362.6	241,900	235.5	142,768	145.5	57,718	51.1	794,739,000
1995	302,800	355.2	245,200	254.7	160,797	171.1	38,735	45.9	826,848,333
1996	367,200	360.3	277,000	279.9	209,710	188.1	41,217	43.0	871,302,897
1997	411,000	372.7	317,379	298.8	193,806	193.2	49,065	44.2	908,949,449
1998	340,000	351.7	302,100	313.2	176,148	189.0	42,223	44.3	898,141,049
1999	304,000	315.3	320,000	316.0	197,000	184.7	41,702	39.8	855,857,115
2000	302,000	300.7	326,000	336.7	181,000	185.0	35,398	33.2	855,499,896
2001	296,000	340.2	364,000	329.3	177,000	173.0	22,400	26.8	869,332,630
2002	422,700		297,900		161,000		22,600		

Source: Statistics New Zealand.

Estimates provided by MAF for 1998, 1999, 2000 and 2001

N-fixing crop yields in New Zealand Revised 2003

Agricultural sector calculations: emissions from field burning and agricultural soils

	Processed peas prodn[1] (jun yr) (tonnes dry weight)	Peas prodn[2] (jun yr) (tonnes)	Peas Processed and Seed Peas (tonnes DW)	Peas prodn (3 yr av) (Gg)	Lentils prodn[3] (jun yr) (tonnes)	Lentils prodn (3 yr av) (Gg)	N-fixing crops (3 yr av) (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	94,913,333
2000	36,000	64,000	100,000	86.7	0	0.0	86,700,000
2001	36,000	37,700	73,700	78.0	0	0.0	77,966,667
2002	36,000	24,200	60,200		0		

1 MAF estimate

2 Statistics New Zealand. 1998, 1999, 2000, 2001 estimates provided by MAF.

3 Ministry of Agriculture and Forestry. Zero has been entered when production negligible.

Micsellaneous agricultural data Revised 2003

Agricultural sector calculations: emissions from agricultural soils

	Cultivated organic soils (ha)[1] (jun yr)	Cultivated organic soils (ha) (3 yr av)	Synthetic fertiliser use (kg N)[2] (jun yr)	Synthetic fertiliser use (kg N) (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	238,748,000
2002	10,109		279,148,000	

1 MAF estimate 2003

2 Best estimate from MAF and sales records obtained by FertResearch

Livestock productivity data for New Zealand 2003
Agricultural sector calculations: CH_4 emissions from domestic livestock
Table 1: Average weights, average annual milk yeilds and average milk composition of dairy cattle in New Zealand 1990-2001. All data are three year averages.

	Dairy cow weights (kg)	Milk yields (litres/year)	Milk fat (percent)	Milk protein (percent)
1990	447	2,800	4.79	3.66
1991	448	2,857	4.83	3.67
1992	449	3,013	4.81	3.68
1993	450	3,029	4.79	3.66
1994	452	3,073	4.78	3.64
1995	450	3,125	4.76	3.63
1996	451	3,228	4.72	3.59
1997	448	3,239	4.65	3.54
1998	451	3,314	4.62	3.51
1999	453	3,405	4.63	3.54
2000	455	3,564	4.69	3.59
2001	454	3,594	4.68	3.59

Livestock productivity data for New Zealand 2003
Agricultural sector calculations: CH_4 emissions from domestic livestock
Table 2: Average weights of beef cattle in New Zealand 1990-2001
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	376	413	553	568
1991	379	417	562	577
1992	387	422	567	583
1993	401	427	575	593
1994	405	432	581	597
1995	410	436	586	601
1996	415	438	593	601
1997	425	439	600	601
1998	423	438	603	600
1999	420	438	599	603
2000	423	437	599	607
2001	434	441	605	615

Livestock productivity data for New Zealand 2003
Agricultural sector calculations: CH_4 emissions from domestic livestock
Table 3: Weights of ewes and lambs in New Zealand 1990-2001
All data are three year averages

	Ewe weights (kg)	Lamb weights at slaughter (kg)
1990	47.33	30.42
1991	47.95	31.31
1992	48.02	32.22
1993	48.89	33.10
1994	49.23	33.33
1995	49.99	33.50
1996	50.34	33.88
1997	51.45	34.53
1998	52.40	34.87
1999	53.40	35.51
2000	54.53	36.35
2001	55.06	37.13

Livestock productivity data for New Zealand 2003
Agricultural sector calculations: CH_4 emissions from domestic livestock
Table 4: Weights of deer in New Zealand 1990-2001
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	102.3	153.2	95.6	79.0
1991	104.7	157.4	98.3	80.8
1992	104.3	162.1	101.2	80.5
1993	104.9	165.7	103.4	81.0
1994	104.1	166.0	103.6	80.4
1995	106.2	166.3	103.8	82.0
1996	107.1	170.0	106.1	82.7
1997	110.7	176.6	110.3	85.5
1998	113.0	181.0	113.0	87.2
1999	116.0	176.0	109.8	89.6
2000	117.1	170.6	106.5	90.4
2001	118.1	168.1	104.9	91.2

Livestock productivity data for New Zealand 2003
Agricultural sector calculations: CH_4 emissions from domestic livestock
Table 5: Assumed monthly energy concentrations of the diets consumed by beef cattle, sheep, dairy cattle and deer for all years 1990-2001

	Dairy cattle and deer MJ ME/kg dry matter	Beef cattle and sheep MJ ME/kg dry matter
July	12.6	10.8
August	11.5	10.8
September	11.7	11.4
October	12.0	11.4
November	11.6	11.4
December	10.8	9.9
January	11.1	9.9
February	10.6	9.9
March	10.7	9.6
April	11.3	9.6
May	12.0	9.6
June	11.7	10.8

Livestock productivity data for New Zealand 2003
Agriculture sector calculations: emissions from domestic livestock and soils
Table 6: 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	12.0	65.3	105.0	27.3
1991	12.2	66.0	105.7	26.9
1992	12.4	67.4	107.7	25.9
1993	12.7	69.3	108.1	26.6
1994	12.9	68.7	108.3	26.7
1995	13.1	68.5	108.0	27.1
1996	13.3	67.7	108.9	27.6
1997	13.6	70.0	108.5	27.5
1998	13.9	70.0	109.8	28.7
1999	13.9	71.1	111.2	28.8
2000	14.4	70.7	113.4	28.9
2001	14.6	71.6	109.7	28.9

Module	2001 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[1] (kg CH_4/head/yr)**	**Emissions from enteric fermentation (Gg)**	**Emission factor for manure management[2] (kg CH_4/head/yr)**	**Emissions from manure management (Gg)**	**Total CH_4 emissions from dom livestock (Gg)**
Dairy cattle	4,984	74.7	372.52	0.889	4.431	376.95
Non-dairy cattle	4,537	56.0	253.99	0.909	4.124	258.11
Sheep	41,361	10.6	438.70	0.178	7.362	446.06
Goats	165	8.9	1.47	0.119	0.020	1.49
Deer	1,568	20.9	32.70	0.369	0.579	33.28
Horses	75	18.0	1.35	2.080	0.156	1.51
Swine	356	1.5	0.53	20.000	7.120	7.65
Poultry	20,864			0.117	2.441	2.44
Total			**1,101.26**		**26.232**	**1,127.50**

1. Horses and swine use IPCC default emission factors. Other emission factors are implied.
2. Horses, swine and poultry use IPCC default emission factors. Others from Joblin and Waghorn (1994)

Module	2001 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 ($Nex_{(AWMS)}$) (kg N)**	**Emission factor for each AWMS (EF_3) (kg N_2O-N/kg N)**	**Emissions from domestic livestock (Gg N_2O)**
Anaerobic lagoons	63,279,555	0.001	0.099
Liquid Systems			no
Daily spread			ie
Solid storage and drylot	968,320	0.02	0.030
Pasture range and paddock			ie
Other	13,737,514	0.005	0.108
Total			**0.238**

N_2O emissions from *daily spread* and *pasture range and paddock* are reported under *agricultural soils.*

Module	2001 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 (3 yr av) (Gg crop)	Residue to crop ratio	Quantity of residue (Gg biomass)	Dry matter fraction	Quantity of dry residue (Gg dm)	Fraction burned in fields[1]	Fraction oxidised	Biomass burned (Gg dm)	Carbon fraction of residue	Carbon released (Gg C)	Nitrogen-carbon ratio	Nitrogen released (Gg N)
Cereals	696.3		871.2		726.2			326.8		153.826		2.075
a Barley	340.2	1.2	408.3	0.83	338.9	0.5	0.9	152.5	0.4567	69.643	0.015	1.045
b Wheat	329.3	1.3	428.1	0.83	355.3	0.5	0.9	159.9	0.4853	77.595	0.012	0.931
c Oats	26.8	1.3	34.8	0.92	32.1	0.5	0.9	14.4	0.4567	6.587	0.015	0.099

1 Ministry of Agriculture and Forestry.
Maize no longer included in calculation as no maize residue burning occurs - MAF 2003

Module	2001 Agriculture (New Zealand)
Submodule	**Field burning of agricultural residues**
Worksheet	**4.4 (3 of 3)**
Sheet	**Total non-CO_2 trace gas emissions from cereals**

	Emission ratio to C or N	Emissions (Gg C or N)	Conversion ratio	**Emissions (Gg of gas)**
CH_4	0.005	0.769	1.333	1.026
CO	0.060	9.230	2.333	21.536
N_2O	0.007	0.015	1.571	0.023
NO_x	0.121	0.251	3.286	0.825

Module	2001 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 of CH_4 (Gg)**	**Emissions of CO (Gg)**	**Emissions of N_2O (Gg)**	**Emissions of NO_x (Gg)**
Cereals				
a Barley	0.464	9.750	0.011	0.415
b Wheat	0.517	10.863	0.010	0.370
d Oats	0.044	0.922	0.001	0.039

Module	2001 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_1) (kg N_2O-N/kg N)	Direct soil emissions (excl. histosols) (Gg N_2O-N)
Synthetic fertiliser (F_{SN})	214,873,200	0.0125	2.686
Animal Waste (F_{AW})[1]	62,388,311	0.0125	0.780
N-Fixing crops (F_{BN})	4,678,000	0.0125	0.058
Crop residue (F_{CR})	8,458,444	0.0125	0.106
Total			3.630

1 Based on animal waste in all AWMS except *pasture range and paddock*.

Module	2001 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[1] (ha) (F_{OS})	Emission factor for direct soil emissions (EF_2) (kg N_2O-N/ha/yr)	Direct soil emissions from histosols (Gg N_2O-N)	**Total direct soil emissions of N_2O (Gg)**
	10,109	8	0.081	**5.831**

1 MAF estimate 2003

Module	2001 Agriculture (New Zealand)
Submodule	**Agricultural soils**
Worksheet	**4.5 (3 of 5)**
Sheet	**Direct nitrous oxide emissions from animal production (grazing animals)**

Animal waste management system (AWMS)	N excretion for AWMS (Nex_{AWMS}) (kg N)	Emission factor for AWMS (EF_3)[1] (kg N_2O-N/kg N)	**Total direct animal prodn. emissions of N_2O (Gg)**
Pasture range and paddock	1,462,589,853	0.01	**22.984**

1 Value based on Carran et al (1995) and Sherlock et al (1995).

Module 2001 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_3 and NO_x)

	Synthetic fertiliser applied to soil (N_{FERT}) (kg N)	Fraction of syn. fertiliser N that volatises ($Frac_{GASF}$)	Amount of syn. N applied to soil that volatises (kg N)	Total nitrogen excreted by livestock (kg N)	Fraction of N excretion that volatises ($Frac_{GASM}$)	Amount of N excretion that volatises (kg N)	Emission factor (EF_4) (kg N_2O-N/ kg volatised N)	Indirect N_2O emissions from atmos. deposition (Gg N_2O-N)
	238,748,000	0.1	23,874,800	1,540,575,241	0.2	308,115,048	0.01	3.320

Module 2001 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_{FERT}) (kg N)	Total nitrogen excreted by livestock (kg N)	Fraction of nitrogen that leaches ($Frac_{LEACH}$)	Emission factor (EF_5) (kg N_2O-N/ kg leached N)	Indirect N_2O emissions from leaching (Gg N_2O-N)	**Total indirect N_2O emissions from N used in agric. (Gg N_2O)**	**Total nitrous oxide emissions from agricultural soils (Gg N_2O)**
	238,748,000	1,540,575,241	0.07	0.025	3.114	**10.110**	**38.925**

2001 Agriculture (New Zealand)

Table 4.17 (IPCC Workbook, adapted)

Parameter values for agricultural emissions of nitrous oxide

Parameter	Value	Fraction of ...	Additional sources
$Frac_{BURN}$	0.5	... crop residue burned in fields	Ministry of Agriculture and Forestry
$Frac_{FUEL}$	0	... livestock nitrogen excretion in excrements burned for fuel	
$Frac_{GASF}$	0.1	... total synthetic fertiliser emitted as NO_x or NH_3	
$Frac_{GASM}$	0.2	... total nitrogen excretion emitted as NO_x or NH_3	
$Frac_{GRAZ}$		... livestock nitrogen excreted and deposited onto soil during grazing	
$Frac_{LEACH}$	0.07	... nitrogen input to soils that is lost through leaching and run-off	Thomas et al (2002)
$Frac_{NCRBF}$	0.03	... nitrogen in N-fixing crops	
$Frac_{NCR0}$	0.015	... nitrogen in non-N-fixing crops	
$Frac_{R}$	0.45	... crop residue removed from the field as crop	

2001 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_1	0.0125	... direct emissions from N input to soil	
EF_2	8	... direct emissions from organic soil mineralisation due to cultivation	IPCC GPG
EF_3 (AL)	0.001	... direct emissions from waste in the *anaerobic lagoons* AWMS	
EF_3 (SS&D)	0.02	... direct emissions from waste in the *solid waste and drylot* AWMS	
EF_3 (PR&P)	0.01	... direct emissions from waste in the *pasture range and paddock* AWMS	Based on Carran et al (1995) and Sherlock et al (1995)
EF_3 (OTHER)	0.005	... direct emissions from waste in other AWMSs	
EF_4	0.01	... indirect emissions from volatising nitrogen	
EF_5	0.025	... indirect emissions from leaching nitrogen	

Module	2001 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 of animals (3 yr av) (1000s)	Nitrogen excretion[1] (Nex) (kg/head/yr)	Percentage of nitrogen excretion in AWMS=AL[2]	Nitrogen excretion from AL (kg N)
Non-dairy cattle	4,537			no
Dairy cattle	4,984	109.7	11%	60,146,755
Poultry	20,864			no
Sheep	41,361			no
Swine	356	16.0	55%	3,132,800
Goats	165			no
Deer	1,568			no
Total (Nex_{AL})				**63,279,555**

1 Value for dairy cattle from Ledgard, AgResearch (2003)
2 Value for dairy cattle from Haynes and Williams (1993).

Module	2001 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 of animals (3 yr av) (1000s)	Nitrogen excretion[1] (Nex) (kg/head/yr)	Percentage of nitrogen excretion in AWMS=PR&P[2 3]	Nitrogen excretion from PR&P (kg N)
Non-dairy cattle	4,537	71.6	100%	324,813,400
Dairy cattle	4,984	109.7	89%	486,641,925
Poultry	20,864	0.6	3%	375,545
Sheep	41,361	14.6	100%	603,865,733
Swine	356			no
Goats	165	9.5	100%	1,568,767
Deer	1,568	28.9	100%	45,324,482
Total ($Nex_{PR\&P}$)				**1,462,589,853**

1 Values for sheep, non-dairy and dairy cattle, and deer from Ledgard, AgResearch (2003)
Values from goats from Ulyatt (pers comm).
2 Value for dairy cattle based on Haynes and Williams (1993).
3 Values for goats and deer from the Ministry of Agriculture and Forestry.

Module	2001 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 of animals (3 yr av) (1000s)	Nitrogen excretion (Nex) (kg/head/yr)	Percentage of nitrogen excretion in AWMS=SS&D	Nitrogen excretion from SS&D (kg N)
Non-dairy cattle	4,537			no
Dairy cattle	4,984			no
Poultry	20,864			no
Sheep	41,361			no
Swine	356	16.0	17%	968,320
Goats	165			no
Deer	1,568			no
Total ($Nex_{SS\&D}$)				**968,320**

Module	2001 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 of animals (3 yr av) (1000s)	Nitrogen excretion (Nex) (kg/head/yr)	Percentage of nitrogen excretion in AWMS=OTHER	Nitrogen excretion from OTHER (kg N)
Non-dairy cattle	4,537			no
Dairy cattle	4,984			no
Poultry	20,864	0.6	97%	12,142,634
Sheep	41,361			no
Swine	356	16.0	28%	1,594,880
Goats	165			no
Deer	1,568			no
Total (Nex_{OTHER})				**13,737,514**

2001 Agriculture (New Zealand)
F_{AW} 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)[1]	Fraction of N excretion burned for fuel	Fraction of N excretion deposited onto soil during grazing	Fraction of N excretion emitted as NO_x or NH_3	Nitrogen input from animal waste (kg N)
Nex_{spread}	x (1-($Frac_{FUEL}$	+ $Frac_{GRAZ}$	+ $Frac_{GASM}$))	= F_{AW}
77,985,389	0		0.2	62,388,311

1 Animal waste in all AWMS except *pasture range and paddock.*
2 FracGRAZ is not required as waste from grazing livestock is already excluded.

2001 Agriculture (New Zealand)
F_{BN} 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)
$Crop_{BF}$	x $Frac_{NCRBF}$	x 2 = F_{BN}
77,966,667	0.03	4,678,000

2001 Agriculture (New Zealand)
F_{SN} 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_x or NH_3	Nitrogen input from synthetic fertiliser use (kg N)
N_{FERT}	x (1-$Frac_{GASF}$)	= F_{SN}
238,748,000	0.9	214,873,200

2001 Agriculture (New Zealand)
F_{CR} 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_{CR}) (kg N)
($Crop_0$	x $Frac_{NCR0}$	+ $Crop_{BF}$	x $Frac_{NCRBF}$)	x (1 - $Frac_R$)	x (1 - $Frac_{BURN}$)	x 2 = F_{CR}
869,332,630	0.015	77,966,667	0.03	0.55	0.50	8,458,444

Chapter 6

Land-Use Change and Forestry (LUCF)

6.1 Introduction

The LUCF sector represented the removal of approximately 33% of all greenhouse gas emissions in 2001 and there was an increase in net removals of 0.7% from 2000. Net removals in 2001 were almost 10% above net removals in 1990.

New Zealand has a substantial estate of planted forests, mainly comprising *Pinus radiata*, and has well established data on its extent and characteristics. These forests have removed and stored substantially more carbon over the period 1990 to 2001 than has been emitted through forest harvesting of both planted and natural forests together.

Some land-use change has been occurring, mostly in the form of new forest planting. Rates of new planting were high between 1992 and 1998. During this period new planting averaged 69,000ha per year. Since 1998 the planting rate has declined but is still occurring at an average annual rate of between 30,000ha and 40,000ha. However, a current lack of data on other forms of land-use change and changes in soil carbon has limited reporting in this sector. A substantial project has been funded since 1996 to remedy these gaps in New Zealand's inventory. This project is discussed at the end of this chapter.

6.2 Country-specific approaches different from the IPCC methodology

The worksheets for this section of the inventory are in a format that is consistent with the 1996 revised IPCC guidelines. However, these worksheets have been designed to match New Zealand's national methodology for estimating emissions and carbon uptake by planted forests. For transparency, these worksheets have been designed to be as equivalent as possible to the IPCC worksheets. As a modified form of the IPCC worksheets has been used, Tables 5(a)-(d) of the CRF have not been completed.

The worksheets with carbon/CO_2 emissions from "land conversion" have not been included in the "uptake from forests" in the reporting tables. LUCF therefore shows data in both the CO_2 emission and the CO_2 removals columns. This has been done to make the calculation more transparent. For completion of Table 5 and the summary tables of the CRF, the net CO_2 emissions/removals figure has been reported (as per the reporting instructions accompanying the tables).

The worksheets discussed below are included at the end of the chapter and cover emissions/removals for 1990 to 2001.

Worksheet 5.1 equivalent

Uptake has only been estimated for planted forests, as this is the major anthropogenic sink. Surveys and forest models have been used to estimate emissions and removals. Estimates include above- and below-ground biomass components (including the forest floor). The models account for both the removal of stemwood carbon through harvesting and the release of non-stemwood carbon on-site over a longer period following harvesting. The release of carbon through harvesting natural forests is also accounted for. This methodology gives significantly more accurate results than could have been achieved using the IPCC methodology. It is assumed that stemwood removed at harvest for both natural and planted forest is oxidised in the year of harvest.

Worksheet NZ 5a-d

Data on forest and grassland conversion is currently limited. Emissions from clearing land for new forest planting are reported (including carbon emissions as the carbon uptake in the subsequent planting is already accounted for in Worksheet 5.1). Non-CO_2 emissions are reported for scrub and forest wildfires (as per the IPCC default method the carbon is assumed to be absorbed during re-growth) and for land clearing.

Abandonment of managed lands

Abandonment of managed lands is not reported due to a lack of data. However, some pasture does revert to scrub in marginal farming areas.

Soil carbon

Changes in soil carbon are also not reported due to a current lack of data.

6.3 Methodological approach

The estimates derived from modelling March years are converted to calendar years, before applying a three-year average as per the IPCC approach.

The following calculations were made to estimate emissions and the uptake of carbon/non-CO_2 in the LUCF sector:

Changes in forests and other woody biomass stocks

1. Uptake of carbon by planted forests.
2. Emissions from planted forests through harvesting.
3. Emissions from natural forests from unsustainable harvesting.

Forest and grassland conversion

1. Emissions from clearing land in preparation for new forest planting.
2. Non-CO_2 emissions from scrub and forest wildfires and land clearing.

Planted forests

The total biomass in New Zealand's planted forests is relatively simple to estimate as planted forest stands are almost exclusively of a single species and single age. Annual surveys are used in conjunction with the models (C-change and FOLPI) to estimate forest biomass and carbon at one point in time. The models "time-shift" the estate forwards to represent future forest growth and forest management, including harvesting. The models then time-shift backwards to improve historical estimates.

This time-shifting of the estate is necessary to minimise errors. Changes in carbon stocks are typically very small relative to the stocks themselves, and even small inconsistencies in the stocks will lead to large errors in the stock change. As the estimation of carbon stocks is continuously being improved, it is necessary to recalculate both past and future years in each run of the model.

The process begins with the National Exotic Forest Description (NEFD) survey, which provides estimates of the forest area and merchantable stemwood volume (via yield tables). The NEFD subdivides the forest estate by crop-type and age class. A crop-type is an aggregate of forest stands that are similar in respect to species, site quality, management regime and location. Each crop-type has a yield table that provides estimated volumes of stemwood per hectare by age.

To simplify the subsequent modelling, all crop-types are then aggregated to form a single, national area-weighted crop-type (still broken down by age class) and associated area-weighted national yield table.

Both models used in this part of the inventory are managed and run by the New Zealand Forest Research Institute (Forest Research). The first is the **C-change model** (previously known as the CARBON/DRYMAT model). This estimates carbon stock per hectare, by component and age-class, from stemwood volume data. The modelling steps are as follows:

1. Stemwood volume is first converted to an oven-dry biomass weight.
2. The dry weight of non-stemwood components (bark, branches, foliage, cones, stumps, roots, floor litter and understorey) is from stemwood volume using allometric equations. Various equations built into the model take account of age, spacing and site fertility.

3. Total forest biomass is lastly converted to carbon weight. Carbon is taken as being 50% of biomass.

The forestry models

Several simplifications have been made in the C-change model. Firstly, the wood density factors for the different age classes assume that all trees grow in a medium-density region of New Zealand. Secondly, the model takes the weighted national crop-type as being wholly *Pinus radiata*, when in fact around 10% of the estate is made up of Douglas fir *(Pseudotsuga menziesii* – 5%) and other species.

The C-change model assumes four tending and thinning regimes. These scenarios are then aggregated to show the stock of biomass and carbon for the total planted forest estate at one time.

Biomass and carbon totals take into account the biomass left in the forest after harvesting. Harvesting is defined in the models as the removal only of the stemwood from the forest. Non-stemwood biomass is modelled to decay on-site over approximately 12 years.

The biomass and carbon stocks at one point in time are available for time-shifting to give carbon stocks for each modelled year and changes in carbon stocks between those years. This is done in the **FOLPI** (Forest Oriented Linear Programming Integrator) forest estate model, the second of the two models run by Forest Research. FOLPI is a linear programming model that optimises the management of the forest estate across time while maximising the discounted harvest volume. The model simulates actual rates of planting and harvesting where historic data exists.

Among the outputs of the FOLPI model are the LUCF inventory results for 1990 to 2001. These results include:

1. Stemwood volume harvested from the planted estate and, hence, carbon "emitted" in that harvest.
2. *Total stock of estate carbon* after harvesting in each year (accounting also for the decay of non-stemwood carbon left after harvesting).

From the *total stock* values we calculate the *uptake of carbon (net of harvest)*. The *gross uptake of carbon* is then calculated by adding the harvested stemwood carbon back into the net carbon uptake figures. This gives the change in carbon stock between last year's harvested forests and this year's unharvested forests.

This approach, in conformity with IPCC methodology, assumes that all carbon held in harvested stemwood is emitted at the time of harvest (the decay of non-stemwood biomass is accounted for in the models and hence in the net carbon uptake results). The difficulty with this approach is that some carbon remains stored in long-life wood products and a substantial proportion of harvested wood is exported and therefore removed from New Zealand. The emissions from harvest figures therefore refer to potential, rather than actual, emissions.

For more information regarding the NEFD surveys, the most recent publication by the Ministry of Agriculture and Forestry (2001) was used. Information regarding the modelling methodology is provided in Wakelin and Te Morenga (1995), although greater detail on certain aspects of the work can be found in Hollinger et al. (1993) and Garcia (1984). The model results used here are given in Te Morenga and Wakelin (2003) and replace those previously reported in Marshall and Wakelin (2002).

Natural forests

Estimates of the stemwood volumes removed from natural forests were provided by the Ministry of Agriculture and Forestry. These figures show a significant decrease in natural forest harvesting following the passing of new legislation in 1993 and its implementation in 1995. The Forest Act 1993 has made logging in natural forests illegal, but for several limited-life exemptions. Natural forest harvest data for 1995 onwards therefore show only logging from these exempted forests. Such logging is assumed to cease by 2005, although government policy announcements mean that unsustainable harvesting in some areas will end (and has ended) sooner than this.

Stemwood volumes are converted to oven-dry weight using a factor of 0.5 (accounting for wood moisture) and then expanded to include non-stemwood biomass using a factor of 2.04. As for harvesting in planted forests, emissions from harvesting natural forests are potential rather than actual.

Land clearance for new forest planting

Data is available from the Ministry of Agriculture and Forestry including the proportion of new forest planting that occurs on scrubland. There is data from 1993 to the present and we assume this proportion to have been around 20% prior to that time. It is assumed, for calculation purposes, that 25% of the scrub biomass is burnt on-site and that the remainder is left to decay.

Wildfire burning

Emissions from wildfires are based on fire reports collected by the National Rural Fire Authority. These reports show the areas of forest and scrub burnt. It is assumed that all forest burning occurs in natural forests. As reported in the national inventory reports submitted in 2001 and 2002, carbon released from scrub and forest burnt in wildfires is no longer reported since it is mostly re-absorbed during re-growth on the burnt land. Hence, only non-CO_2 emissions are reported here (consistent with the IPCC default method). For planted forests, fires occur relatively infrequently and fire-damaged standing trees are usually salvaged and thus appear in harvest statistics. Some areas in the Fire Authority statistics involve land clearing, however the Fire Authority does not specify whether this is for agricultural or forestry purposes. This may imply some double-counting between these figures and those allowed for in the land clearing for new forest planting calculations discussed above.

As reported previously, the quantity of on-site biomass for both scrub and forest, used in the land conversion calculations (Worksheets 5a-d), is now based on the (provisional) results of research into indigenous forest and scrub (adapted from Hall et al., 1998). The values reported (136t dm/ha for scrub and 364t dm/ha for forest) are based on a national area weighted average for biomass per hectare for a range of the principal forest and scrub vegetation classes.

The non-CO_2 emissions estimated for burning of both forest and scrub biomass are likely to be overestimated as not all biomass is typically consumed in a fire event. For forests, the typical fuel load combusted may only be 10-40% of on-site biomass. For scrub, the upper value could be somewhat higher (depending on seasonal and other factors), although combustion is again unlikely to be complete for wildfire events (Fire Researchers, pers comm.). The current assumptions reflect a lack of data on the percentage of fuel load combusted.

6.4 Changes since the last inventory submission

The incorporation of new input data has not resulted in significant overall changes to the inventory but has meant revisions to all years in the time series.

New data incorporated since the last inventory included the following:

1. The results of the latest NEFD survey as at 1 April 2001 have been incorporated in the planted forest models. This brings in new data for new planting, restocking and harvesting and also improves data for earlier years in the time series. The total forest estate area after harvest for the year ending March 2001 is based on (a) the latest area estimates provided by the 2001 NEFD; (b) an estimate of the area to be planted during the year; and (c) an estimate of the area harvested during the year, which is derived from the estimate of clearfell volume production. The total estate area for the years before 2001 has been estimated through back-calculations using this latest NEFD area data combined with historic new planting and harvesting information.
2. New proportions of area by NEFD regime have been used to weight the carbon yield. Area data and carbon yields underlying the models in this report are similar to those used previously. The difference in net "managed forest" CO_2 removals between this and the previous inventory is generally of the order of less than 2%. Further work will be undertaken to investigate whether alternative inventory and modelling approaches could be used for inventory estimates, to avoid recalculation of historic estimates either as a result of changes in future intentions or as a product of the forwards and backwards forecasting required by the current model.
3. The area of new land planting is based on Ministry of Agriculture and Forestry statistics. These estimates are revised annually (including for the previous years, as provisional estimates are replaced by confirmed actual areas).

Estimates of CO_2 emissions from the liming of agricultural soils were included in the CRF for 2000. This submission provides data on these emissions for all years from 1990 in a table at the end of this chapter and via the recalculation tables in the CRF.

The recalculation tables also show that, although the last National Inventory Report submission included tables (like the ones at the end of this chapter) showing the CO_2 released from burning on land cleared for new forest planting, due to an oversight these emissions were not included in the total CO_2 emissions from this source. This has been corrected in this submission and included in the recalculations reported for the whole of the time series.

6.5 Uncertainty

Attempts have been made to quantify the uncertainties in the carbon sequestration 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 CARBON/DRYMAT model are well characterised (Hollinger et al., 1993). These include ±3% for wood density, ±15% for carbon allocation and ±5% for carbon content. Taking the root mean squares of the uncertainties indicates that the proportional error in the carbon sequestration estimates is likely to be at least ±16%.

However, the overall level of uncertainty could be higher, depending on the errors in the NEFD area and commercial yield data. The total national planted area is thought to be accurate to within ±5% (Ministry of Agriculture and Forestry, 2001) and the yield tables are assumed to be accurate to within ±5%.

Sensitivity analysis was conducted using the above accuracy ranges for total planted area and commercial yield and a proportional uncertainty error of ±16%. The CARBON/DRYMAT model runs indicate that the precision of the carbon sequestration estimates could be of the order of ±25%.

No uncertainty estimates are currently available for emissions from unsustainable harvesting of natural forests or from forest and grassland conversion.

6.6 Future work

Both forest models held by Forest Research are regularly revised and re-run on the basis of the latest year's NEFD survey. NEFD data improves each year because more planted area is included and boundaries are defined more precisely. This will lead to future revisions and improvements in the inventory data, including revisions to historical years as a result of back calculations or new data[4].

Major new work in this sector includes research on the carbon held in soils, scrub and natural forests. This research was initiated by the Ministry for the Environment in 1996 and is being carried out jointly by Landcare Research New Zealand and Forest Research.

[4] New data in this context includes the case where the NEFD survey may detect previously unrecorded stands of trees at particular ages. In such cases, NEFD data for the previous seven years must be adjusted to account for the revised area in each age class. A similar situation arises with harvesting data and the need to adjust historical data to match the latest information on harvest by age class. Changes in the historical time series data of estate area by age class can thus affect both uptake and harvest estimates.

This research will make it possible to fill the major gaps in the current inventory, including land-use changes other than new forest planting, the abandonment of managed lands, and changes in soil carbon. The project is a five-year programme with the following objectives:

1. The estimation of carbon storage in soils, scrub and natural forests in 1990.
2. The development of a national system for monitoring changes in carbon storage.
3. The development of an effective information system to manage the above information.

The soil carbon work focuses on the major factors influencing carbon storage (the soil and vegetation research components have been separated for the purposes of this project). Data on soil type, land use and climate is currently being improved and is being used to stratify New Zealand into compartments with similar characteristics, thus revising estimates of soil carbon across the country and enabling estimates of the changes in carbon stock that accompany changes in land use and land management. Changing carbon storage will be monitored over time to establish the time profile over which it occurs.

The research on scrub and natural forest vegetation is synthesising several existing sources of information on vegetation area and composition, updating and completing this data as necessary. Other research is aimed at improving data on vegetation biomass and the carbon held in the various vegetation components. It is hoped that dead material and below-ground material will be able to be included in the resulting carbon estimates.

Provisional results are available from the work under objective 1 above. Hall et al. (1998) have estimated that in 1990 carbon stored in natural forests was 933Mt C, while 527Mt C were stored in scrub and other woody mixed-vegetation. Forest floor litter carbon is estimated separately, based on Tate et al. (1997), as containing 570Mt C for all natural vegetation (i.e. 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 1,208Mt C, 1,532Mt C, and 1944Mt C respectively. 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 stated by Lawton and Barton (2002), Lawton and Calman (1999), and Hall et al. (1998).

In 1999, the carbon monitoring systems 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 forests were consistent with current forest inventory practices in other countries. Furthermore, the soils that the system represented were measured in a significantly advanced methodology as 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 carbon monitoring system provides for the establishment of 1,400 permanent field plots on an 8x8km grid across indigenous forest and shrub across territorial New Zealand. This includes the North and South Islands, Stewart Island, the Chatham Islands and other offshore islands. A range of standard tree and other botanical measurements and site characteristics is recorded for each 20x20m plot. Soil samples to a depth of 0.3m are taken for one in three plots and are analysed for carbon content.

The carbon monitoring system is currently moving from its design phase to its implementation phase. The first year's field work for the operational carbon monitoring system commenced in January 2002 and was completed early in 2003. The second year's field work began in March 2003. Field work over 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.

In conjunction with the above field work, 40 paired soil plots will eventually be established to monitor key changes in soil carbon when land-use changes (i.e. scrub to pasture and pasture to plantation forest and vice versa). The first four paired plots are planned to be established in the second quarter of 2003.

A remote-sensing based Land Cover Database (LCDB), significantly improving the accuracy of the mapped land use and land cover, became available in 2000. The LCDB has provided a tool for improved information on the extent of all forest types (planted and natural forest, and scrub) and land conversion and abandonment. Work is underway to commission LCDB 2, which is intended to increase the number of major classes and improve the thematic depth for forest classes. It is expected that LCDB 2 will be completed in 2004. LCDB 2 is also likely to draw on ancillary land-use data from annual landowner surveys such as those involving AgriBase.

Further enhancements to the above described system are planned, including the incorporation of IPCC Good Practice once it has been agreed and adopted by the Conference of the Parties.

6.7 References

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Appendix to Chapter 6:
Land-use change and forestry calculation tables 1990 to 2001
Agricultural lime calculation table 1990 to 2001

Land Use Change and Forestry calculation tables 1990 -2001

SCENARIO	Medium New Planting
FOREST RESOURCES	All Forests

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 in plantation forest harvest[1] (merch. m^3)	Biomass conversion ratio[2] (t dm/m^3)	Dry matter in stem[1 3] t C/t dm = 0.5 (t dm)	Carbon in plantation forest harvest [1] (t C)	Stem volume in native forest harvest (merch. m3)	Biomass conversion ratio (t dm/m^3)	Biomass expansion ratio (t dm/m^3)	Dry matter in total native forest harvest (t dm)	Carbon in native forest harvest (t C) t C/t dm = 0.5	Carbon release from total forest harvest (t C)
1990	10,813,787	0.497	5,371,388	2,685,694	365,000	0.50	2.04	372,300	186,150	2,871,844
1991	11,797,488	0.482	5,691,506	2,845,753	307,667	0.50	2.04	313,820	156,910	3,002,663
1992	12,500,584	0.482	6,024,758	3,012,379	257,333	0.50	2.04	262,480	131,240	3,143,619
1993	13,232,522	0.481	6,368,363	3,184,182	205,000	0.50	2.04	209,100	104,550	3,288,732
1994	13,987,203	0.479	6,693,260	3,346,630	158,000	0.50	2.04	161,160	80,580	3,427,210
1995	14,700,793	0.471	6,927,101	3,463,550	107,333	0.50	2.04	109,480	54,740	3,518,290
1996	15,214,390	0.455	6,921,513	3,460,757	50,000	0.50	2.04	51,000	25,500	3,486,257
1997	15,202,118	0.472	7,169,323	3,584,662	56,667	0.50	2.04	57,800	28,900	3,613,562
1998	15,746,397	0.482	7,590,993	3,795,497	57,667	0.50	2.04	58,820	29,410	3,824,907
1999	16,672,535	0.499	8,321,132	4,160,566	57,000	0.50	2.04	58,140	29,070	4,189,636
2000	18,226,875	0.492	8,961,734	4,480,867	38,333	0.50	2.04	39,100	19,550	4,500,417
2001	19,576,074	0.493	9,659,696	4,829,848	23,667	0.50	2.04	24,140	12,070	4,841,918

All data are three-year straight averages.
[1] Estimated using Forest Research models.
[2] Derived from the model results contained in columns 1 and 3.
[3] No adjustment from stem volume to total biomass volume is made here as on-site decay is accounted for in the carbon uptake data.

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 estate area (net of harvest) (ha)	Total Forest estate carbon (net of harvest) (t C)	Forest estate carbon uptake (net of harvest) (t C)	Carbon in plantation forest harvest (t C)	Total forest carbon uptake (before harvest) (t C)
1990	1,243,837	118,886,179	6,454,675	2,685,694	9,140,368
1991	1,272,913	125,052,116	6,165,937	2,845,753	9,011,691
1992	1,313,737	130,742,461	5,690,344	3,012,379	8,702,723
1993	1,376,816	135,983,896	5,241,435	3,184,182	8,425,616
1994	1,452,659	141,075,779	5,091,883	3,346,630	8,438,513
1995	1,536,124	146,109,439	5,033,660	3,463,550	8,497,211
1996	1,613,397	151,250,246	5,140,807	3,460,757	8,601,563
1997	1,683,459	156,774,789	5,524,543	3,584,662	9,109,205
1998	1,740,442	162,806,387	6,031,598	3,795,497	9,827,094
1999	1,786,237	169,406,056	6,599,669	4,160,566	10,760,235
2000	1,824,130	176,470,501	7,064,445	4,480,867	11,545,311
2001	1,855,741	183,614,247	7,143,746	4,829,848	11,973,594

All data are three year straight averages.
Data were estimated using Forest Research Institute models.

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 carbon uptake (before harvest) (Gg C)	Carbon release from total forest harvest (Gg C)	Net carbon uptake in forests (Gg C)	Net CO2 uptake in forests (Gg CO2)
1990	9,140	2,872	6,269	22,985
1991	9,012	3,003	6,009	22,033
1992	8,703	3,144	5,559	20,383
1993	8,426	3,289	5,137	18,835
1994	8,439	3,427	5,011	18,375
1995	8,497	3,518	4,979	18,256
1996	8,602	3,486	5,115	18,756
1997	9,109	3,614	5,496	20,151
1998	9,827	3,825	6,002	22,008
1999	10,760	4,190	6,571	24,092
2000	11,545	4,500	7,045	25,831
2001	11,974	4,842	7,132	26,149

All data are three year straight averages.
Data were estimated using Forest Research Institute models.

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5a
Sheet Carbon release from scrubland cleared for new forest planting

	Scrub land cleared for forest planting[1] (ha)	Clearance where scrub is burned[2] (25% of total) (t dm)	Quantity of biomass burned (t dm/ha = 136) (t dm)	Oxidised biomass (90% of total) (t dm)	C release from burning scrub (t C/t dm = 0.5) (t C)	CO2 release from burning for new planting (t CO2)	Clearance where scrub decays[2] (75% of total) (ha)	Quantity of biomass decay[3] (t dm/ha =136) (t dm)	C release from decay (t C/t dm = 0.5) (t C)	CO2 release from decay for new planting (t CO2)
1990	3,579	895	121,679	109,511	54,756	200,771	2,684	365,038	182,519	669,236
1991	5,427	1,357	184,507	166,056	83,028	304,436	4,070	553,520	276,760	1,014,787
1992	8,480	2,120	288,320	259,488	129,744	475,728	6,360	864,960	432,480	1,585,760
1993	11,200	2,800	380,800	342,720	171,360	628,320	8,400	1,142,400	571,200	2,094,400
1994	12,464	3,116	423,776	381,398	190,699	699,230	9,348	1,271,328	635,664	2,330,768
1995	9,376	2,344	318,773	286,895	143,448	525,975	7,032	956,318	478,159	1,753,250
1996	10,323	2,581	350,971	315,874	157,937	579,102	7,742	1,052,912	526,456	1,930,339
1997	9,263	2,316	314,953	283,458	141,729	519,673	6,948	944,860	472,430	1,732,243
1998	4,662	1,166	158,508	142,657	71,329	261,538	3,497	475,524	237,762	871,794
1999	5,847	1,462	198,809	178,928	89,464	328,035	4,386	596,428	298,214	1,093,451
2000	5,905	1,476	200,759	180,683	90,341	331,252	4,429	602,276	301,138	1,104,173
2001	6,373	1,593	216,671	195,004	97,502	357,507	4,780	650,012	325,006	1,191,689

All data are three year straight averages
[1] Ministry of Agriculture and Forestry
[2] Percentage assumed for calculation purposes.
[3] Biomass on the land cleared is assumed to decay over five years.

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5b
Sheet Carbon release from wildfires

	Area of scrub burned in wildfires[1] (ha)	Quantity of biomass burned (t dm/ha = 136) (t dm)	Oxidised biomass (90% of total) (t dm)	C release from scrub wildfires (t C\t dm = 0.5) (t C)	Area of Forest burned in wildfires[1] (ha)	Quantity of biomass burned (t dm/ha = 364) (t dm)	Oxidised biomass (90 % of total) (t dm)	C release from forest wildfires (t C/t dm = 0.5) (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	1,893	257,493	231,744	115,872	282	102,527	92,274	46,137

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5c (adaptation of 5.3)
Sheet Non-CO2 emissions from the on-site burning of scrub

	Carbon release by on-site burning (t C)	Nitrogen released (t N/t c = 0.01) (t C)	Carbon in CH_4 emissions (ratio = 0.012) (t C)	Nitrogen in N_2O emissions (ratio = 0.007) (t N)	Nitrogen in NO_x emissions (ratio = 0.121) (t N)	Carbon in CO emissions (ratio = 0.06) (t C)	CH_4 emissions from burning (ratio = 1.333) Gg CH	N_2O emissions from burning (ratio = 1.571) (Gg N2O)	NO_x emissions from burning (ratio = 3.286) (Gg CO)	CO emissions from burning (ratio = 2.333) (Gg CO)
1990	211,688	2,117	2,540	15	256	12,701	3.386	0.023	0.842	29.632
1991	209,324	2,093	2,512	15	253	12,559	3.348	0.023	0.832	29.301
1992	249,329	2,493	2,992	17	302	14,960	3.988	0.027	0.991	34.901
1993	313,925	3,139	3,767	22	380	18,836	5.022	0.035	1.248	43.943
1994	345,489	3,455	4,146	24	418	20,729	5.526	0.038	1.374	48.362
1995	305,342	3,053	3,664	21	369	18,321	4.884	0.034	1.214	42.742
1996	312,880	3,129	3,755	22	379	18,773	5.005	0.034	1.244	43.797
1997	344,933	3,449	4,139	24	417	20,696	5.518	0.038	1.371	48.284
1998	271,305	2,713	3,256	19	328	16,278	4.340	0.030	1.079	37.977
1999	276,083	2,761	3,313	19	334	16,565	4.416	0.030	1.098	38.646
2000	220,024	2,200	2,640	15	266	13,201	3.520	0.024	0.875	30.799
2001	213,374	2,134	2,560	15	258	12,802	3.413	0.023	0.848	29.868

Module Land-use change and forestry (New Zealand)
Submodule Forest and Grassland conversion
Worksheet NZ 5d (adaptation of 5.3)
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_4 emissions (ratio = 0.012) (t C)	Nitrogen in N_2O emissions (ratio = 0.007) (t N)	Nitrogen in NO_x emissions (ratio = 0.121) (t N)	Carbon in CO emissions (ratio = 0.06) (t C)	CH_4 emissions from burning (ratio = 1.333) Gg CH	N_2O emissions from burning (ratio = 1.571) (Gg N2O)	NO_x emissions from burning (ratio = 3.286) (Gg CO)	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	46,137	461	554	3	56	2,768	0.738	0.005	0.183	6.458

Module Land-use change and forestry (New Zealand)
Submodule Abandonment of managed lands

Not estimated due to lack of data

Module Land-use change and forestry (New Zealand)
Submodule Change in soil carbon

Not estimated due to lack of data

Module 2001 Land use change and forestry (New Zealand)
Submodule Carbon emissions from liming of agricultural soils
Worksheet 5.5
Sheet 3 of 4 (adapted)

	Total annual amount of limestone[1] (Mg)	Total annual amount of limestone (3yr average) (Mg)	Carbon conversion factor[2]	Carbon emissions from liming (MgC)	Emissions of CO_2 (Gg)
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	1,182,354	0.12	141,883	520
1997	1,217,803	1,217,803	0.12	146,136	536
1998	1,334,442	1,334,442	0.12	160,133	587
1999	1,451,082	1,451,082	0.12	174,130	638
2000	1,567,721	1,567,721	0.12	188,127	690
2001	1,684,361	1,684,361	0.12	202,123	741
2002	1,801,000				

1. Statistics New Zealand June year data for 1989, 1990, 1992, 1993, 1995, and 1996. 2002 is a MAF estimate based on provisional data from Statistics New Zealand
1991 estimate is average of 1990 and 1992
1994 estimate is average of 1993 and 1995
1997 to 2001 is interpolated between 1996 and 2002

2 IPCC default value

Chapter 7

Waste

7.1 Introduction

The waste sector represented approximately 3% of all greenhouse gas emissions in 2001 and there was a decrease of 2.9% from 2000. Emissions are now 20% below the 1990 baseline in this sector. The majority of this reduction has occurred in the solid waste disposal on land source, which has decreased by 23.4%.

In New Zealand, managing solid wastes has traditionally meant disposing of them in landfills. Based on the results of the 1995 National Landfill Census that was conducted by the Ministry for the Environment, there were 327 legally operating landfills, or solid waste disposal sites (SWDSs), in New Zealand that accepted approximately 3,180,000 tonnes of solid waste.

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, the closure and management of landfill sites, and for consent conditions for landfills under the Resource Management Act 1991. As a result of these initiatives, a number of poorly located and substandard landfills have been closed and communities increasingly rely on modern regional disposal facilities for disposal of their solid waste.

Recently, the national focus has been towards waste minimisation and resource recovery. In March 2002, the Government announced its New Zealand Waste Strategy. The strategy sets targets for a range of waste streams as well as for improving landfilling practices by the year 2010.

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 and around 50 government or privately owned treatment plants serving more than 100 people.

While most of the treatment processes are aerobic and therefore produce no methane, 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, or if anaerobic treatment is used, all the methane is collected and burned. There are however a significant number of anaerobic ponds that do not have methane collection, particularly serving the meat processing industry. These are the major sources of industrial wastewater methane.

7.2 Country-specific approaches different from the IPCC methodology

Both IPCC Tier 1 and Tier 2 methods have been applied for emissions from solid waste. A country-specific Degradable Organic Carbon factor (DOC) and methane generation potential (L_o) have been estimated. An oxidation correction factor of 0.1 is used consistent with IPCC Good Practice Guidance. A country-specific Methane Generation Rate Constant (k) has been derived based on conditions at New Zealand landfills, including a generally wet climate.

Methane emissions from domestic and industrial wastewater handling have been calculated using a refinement of the IPCC methodology. An adjusted value for Biological Oxygen Demand (BOD) has been used. The treatment of sludge is described in the methodologies section below. A modification of the IPCC methodology was used for calculations of nitrous oxide emissions from wastewater handling.

Negligible quantities of waste are incinerated and emissions from this were not estimated.

7.3 Emissions calculation methodologies

The details of both CH_4 and N_2O emissions from the waste sector, as summarised below, are reported in *National Greenhouse Gas Inventory from the Waste Sector 1990 - 2020 (*SCS Wetherill Environmental and Bruce Wallace Partners, 2002). Both Tier 1 and Tier 2 approaches have been used for solid waste emissions estimates and the results compared[5]. The data reported in the CRF is from the Tier 2 approach.

Solid waste disposal sites

Data on Municipal Solid Waste (MSW) generation rates, waste composition and the percentage of MSW disposed to SWDS was obtained from the National Waste Data Report (1997) and Waste Analysis Protocol (WAP) surveys for the period 1993 to 1995. Based on the 1995 data, each person sends approximately 1.08kg of residential waste per day. Industrial waste that is landfilled reportedly averages approximately 1.31kg per person per day. As a result, it is estimated that the total quantity of solid waste that is landfilled in New Zealand is 2.39kg per person per day[6].

[5] This was a recommendation from the technical review of New Zealand's greenhouse gas inventory conducted in May 2001.

[6] It has been noted that the results for New Zealand are higher than for other OECD nations. The residential result for New Zealand includes "bulky waste" associated with garden and home renovations. In addition, the industrial result for New Zealand includes construction and demolition waste. These two categories are counted separately by most other OECD nations.

The calculation of methane emissions from MSW entering landfills follows the IPCC methodology. The proportion of waste for each type of SWDS was obtained from the 1995 National Landfill Census. Based on a review of that information it is estimated that 90% of New Zealand's waste is disposed to managed SWDS, and 10% to "uncategorised" sites. The IPCC default methane correction factors were applied. The fraction of DOC was estimated using a knowledge of waste composition in New Zealand, and applying the default values for each fraction of the waste stream. In addition an estimate was made of the quantity of wood waste in the construction and demolition waste stream, and an allowance for this material was included in the NZ DOC Estimate Worksheet.

The fraction of DOC that actually degrades (50%) and the methane oxidation factor (10%) 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. These figures are consistent with IPCC Good Practice Guidance.

The recovered methane rate per year was estimated based on information from a previous survey of SWDSs that serve populations of over 20,000 in New Zealand. The survey information was updated based on local knowledge and experience (SCS Wetherill Environmental and Bruce Wallace Partners, 2002).

Wastewater treatment - methane

Methane emissions from domestic and industrial wastewater handling have been calculated using a refinement of the IPCC methodology. For each municipal treatment plant in New Zealand a population has been assessed. Where industrial wastewater flows to a municipal wastewater treatment plant then an equivalent population for that industry has been assessed based on a BOD loading of 70g 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 each been assigned to one of nine typical treatment processes with a characteristic emission factor. The emission factor is the proportion of incoming BOD to the plant that is anaerobically degraded multiplied by the methane conversion factor (MCF).

For industrial wastewater methane emissions, after reviewing the available information, the IPCC maximum methane-producing capacity, Bo of 0.25 for Chemical Oxygen Demand (COD) and an adjusted value of 0.375 for BOD were adopted (SCS Wetherill Environmental and Bruce Wallace Partners, 2002).

Sludge

For larger treatment plants in New Zealand where sludge is handled anaerobically the methane is almost always flared or used. Smaller plants generally use aerobic handling processes such as aerobic consolidation tanks, filter presses and drying beds.

Sludge from wastewater treatment plants is typically landfilled and so any methane produced is accounted for under solid waste disposal.

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 and with an average age of approximately ten years. It has a low biodegradable organic content and is unlikely to be a significant source of methane.

Sludge from septic tank clean-out, known as septage, is often removed to the nearest municipal treatment plant. In those cases it has been included in the inventory for that plant. Where sludge is landfilled the methane production has been 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 methane and their effect is included in the calculations.

Wastewater treatment – nitrous oxide

The IPCC does not offer a methodology for estimating of N_2O emissions from industrial wastewater handling. The BOD load from the CH_4 emission calculations was adopted, a ratio of BOD to nitrogen in the wastewater was assessed for each industry and total nitrogen loads calculated. An emission factor giving the proportion of total nitrogen in the wastewater converted to N_2O was used to calculate total N_2O emissions from industrial wastewater.

Human waste

The IPCC method calculates nitrogen production based on the average per capita protein intake. Raw sewage nitrogen data is available for many New Zealand treatment plants and it has been calculated that the per capita New Zealand domestic nitrogen production is 13g/day, and this has been used to derive a per capita wastewater N figure of 4.75kg/person/year.

7.4 Changes since the last inventory submission

There have been no changes introduced to the methodology for estimating greenhouse gas emissions from the waste sector since the last submission in 2002. That inventory (for the first time) used a Tier 2 approach for estimating methane emissions from solid waste disposal. That shift in approach also involved a change to the DOC value used (changed from 0.1582 to 0.1531) as a result of using more recent population data. The DOC value of 0.1531 is consistent with the waste statistics value of 2.39kg per person per day identified above.

As in last year's submission, the calculations for methane emissions from industrial wastewater handling are based on COD rather than BOD as was done previously, as COD is the preferred IPCC measure, and reliable COD measurements were available from the meat industry, which is the largest source of industrial wastewater methane emissions.

7.5 Uncertainty

Solid waste disposal

Tier 1: Although the IPCC model has been updated and more current data has been used in the estimates for this inventory, the primary areas of data uncertainty include waste statistics, quantity of methane generated, quantity of methane which is emitted to the atmosphere, and recovered methane rate. Due to the unknown level of uncertainty associated with the accuracy of some of the input data, it is not possible to perform a statistical analysis to determine uncertainty levels. As a result, it is estimated that the level of uncertainty remains at the level of ±35% previously reported.

Tier 2: Given that the input data for the Tier 2 method is the same as the Tier 1 method, the uncertainty value is assumed to be the same – i.e. at a level of ±35% previously reported.

Methane from domestic wastewater

The primary sources of inaccuracy in the data are biases due to collection methods, thus it is not possible to perform rigorous statistical analyses to determine uncertainty levels. The uncertainty 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. Domestic wastewater methane emissions have an estimated accuracy of -40% to +60%.

Methane from industrial wastewater

Because of the method used in estimating methane emissions a statistical analysis of uncertainty is not possible. However, based on assessed levels of uncertainty in the input data, the total methane production from industrial wastewater has an estimated accuracy of -30% to +40%.

Nitrous oxide from wastewater

Nitrous oxide emissions from anaerobic ponds are not well quantified. There may also be significant nitrous oxide emissions from downstream treatment processes in aerobic plants. There are very large uncertainties associated with nitrous oxide emissions and no attempt has been made to quantify this uncertainty. The IPCC default emission factor, EF_6, has an uncertainty of -80% to +1,200%. The estimates only have an order of magnitude accuracy.

7.6 References

Hauber G, 1995, Wastewater Treatment in New Zealand: Evaluation of 1992/93 Performance Data, *Water and Wastes in New Zealand*, Auckland, New Zealand.

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Savage, E, 1996, *Methane Emissions from Wastewater in New Zealand*, report for the Ministry for the Environment, Wellington, New Zealand.

SCS Wetherill Environmental and Bruce Wallace Partners Ltd, 1998, *New Zealand's National Greenhouse Gas Inventory from Wastes 1990 - 2020*, report for the Ministry for the Environment, Wellington, New Zealand.

SCS Wetherill Environmental and Bruce Wallace Partners Ltd, 2002, *National Greenhouse Gas Inventory from the Waste Sector 1990 – 2020*.

Appendix to Chapter 7:
Waste sector calculation table 2001

Module	2001 Waste (New Zealand)
Submodule	**Methane emissions from solid waste disposal sites**
Worksheet	**6.1A (supplemental)**

Total population[1]	MSW generation rate[1] (kg/cap/day)	Annual MSW generated (Gg/yr)	Fraction of MSW to SWDs	Total MSW to SWDSs (Gg)
3,859,000	2.39	3,363	1.00	3,363

1 SCS Wetherill 2002

Module	2001 Waste (New Zealand)
Submodule	**Methane emissions from solid waste disposal sites (tier 2)**
Worksheet	**6.1**

Total annual MSW disposed to SWDs (Gg MSW)	Methane generation potential (L_o)	Methane Generation rate constant (k)	Gross annual methane generation (model output)	Total annual MSW disposed to SWDs with LFG systems (Gg MSW)	Percentage of MSW with LFG systems (%)	Estimated average LFG system collection efficiency (%)	Recovered methane per year (Gg CH_4)	Net methane generation (Gg CH_4)	One minus oxidation correction factor	Net methane emissions (Gg CH_4)
3,363	73.43	0.06	157.5	1,708.0	50.79	0.65	51.9990	105.5	0.9	**95.0**

Information in this table based on SCS Wetherill 2002

Calculations of DOC and L_o

New Zealand DOC Estimate Worksheet

Waste category (NZ WAP)	Waste Quantity (tonnes)	Waste composition (% by weight)	Fraction DOC (by weight)
Paper	586,710	18	0.4
Plastic	222,600	7	0
Glass	60,420	2	0
Metal	208,290	7	0
Organic	1,135,260	36	0.17
C&D[1] non wood	330,720	10	0
C&D wood	197,160	6	0.3
Other	162,180	5	0
Pot Haz	276,660	9	0
Total	3,180,000		

1 Construction and demolition

Methane Generation Potential Calculation by Using Waste Type Data in 1995

Methane correction factor (MCF)	Degradable organic carbon (DOC) GgC/Gg waste	Fraction of DOC dissimilated (DOC_F)	Fraction by volume of CH_4	Conversion from C to CH_4	Methane Generation Potential (L_o) $GgCH_4$/Gg waste	Methane Generation Potential (L_o) m^3CH_4/Mg waste
0.96	0.1531	0.50	0.50	1.3333	0.0490	73.43

Module 2001 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[1]	Fraction of wastewater treated by the handling system[1] (percent)	Methane conversion factor for the handling system	Product	Maximum methane producing capacity (kg CH_4/kg BOD) B_o	Emission factor for domestic/ commercial wastewater (kg CH4/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[2]	24.0	0	0	0.375	0
Aerobic[3]	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 2001 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[1] (kg BOD/yr)	Emission factor (kg CH_4/ kg BOD	CH_4 emissions without recovery/ flaring (kg CH_4/yr)	CH_4 recovered and/or flared[2] (kg CH_4/yr)	Net CH_4 emissions (Gg CH_4/yr)
Wastewater	143,033,614	0.0278	3,976,137	0	4.0
Sludge[2]					0.0
Total					4.0

1 SCS Wetherill 2002
2 Almost all CH4 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 2001 Waste (New Zealand)
Submodule Indirect nitrous oxide emissions from human sewage
Worksheet 6.4 (adapted)

Per capita wastewater N (kg/person/ year)[1]	Total Population[2]	Emission factor (EF_6) (kg N_2O-N/kg sewage-N produced)	Total N_2O emissions (Gg)
4.75	3,975,600	0.01	**0.30**

1 SCS Wetherill 2002
2 Statistics New Zealand.

Module 2001 Waste (New Zealand)
Submodule Methane emissions from industrial wastewater and sludge handling
Worksheet NZ 6.3 (modified)

	Total industrial output (tonne product/year)	Degradable organic component (kg COD/ tonne product)	Total industrial organic wastewater (kg COD/yr) TOW_{ind}	Proportion of industry using anaerobic treatment (without CH_4 collection)	Proportion of incoming COD degraded anaerobically in anaerobic plant	Maximum CH_4 producing capacity (kg CH_4/kg COD) B_0	Emission factor (kg CH_4/ kg incoming COD)	CH_4 emissions (Gg/year)
Meat industry								
beef	571,857	50	28,592,850	43%	55%	0.25	0.059	1.69
sheep/lambs	539,014	50	26,950,700	33%	55%	0.25	0.045	1.22
pigs	48,338	50	2,416,900	40%	55%	0.25	0.055	0.13
venison	27,081	50	1,354,050	40%	55%	0.25	0.055	0.07
goats	1,285	50	64,250	40%	55%	0.25	0.055	0.00
poultry	111,000	123	13,653,000	20%	55%	0.25	0.028	0.38
Leather and skins	85,000	180	15,300,000	0%	70%	0.25	0.000	0.00
Pulp and paper			56,889,552	100%	2%	0.25	0.005	0.28
Wool scouring	183,000	22	4,026,000	9%	29%	0.25	0.007	0.03
Wine[1]								0.02
Beverages				0%			0	
Dairy processing	1,714,363	5.8	9,943,305	0%			0	
Food processing				0%			0	
Metals and minerals				0%			0	
Petrochemical				0%			0	
Plastics				0%			0	
Textiles				0%			0	
Iron and steel				0%			0	
Non-ferrous metals				0%			0	
Fertiliser				0%			0	
Total								**3.83**

1 Emissions estimate for wine from Savage 1997. All other data from SCS Wetherill 2002