Climate Change
The New Zealand Response

New Zealand's first national communication under the Framework Convention on Climate Change

SEPTEMBER 1994

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1 Foreword

Climate change has emerged in recent times as an environmental issue which could have dramatic and permanent impacts on the planet. Tackling climate change presents unique challenges, given our dependence on fossil fuels for economic activity and the need for governments to seek to maintain and improve the quality of life for present populations while taking account of the needs of future generations.

A vital first step towards addressing this issue if the Framework Convention on Climate Change. Supported by over 160 countries, its early entry into force was proof that the international community is taking climate change seriously.

One of the many countries to sign the convention at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, New Zealand was also the 34th nation to ratify the treaty. Our actions underline the Government commitment to address climate change on a multilateral basis and to facilitate the 'prompt start' called for at Rio. Concerted international action, with each country making an equitable contribution, is critical for achieving the aims of the FCCC.

At the domestic level, successive New Zealand governments have identified targets and timetables to reduce emissions of the most significant greenhouse gas, carbon dioxide. The present aim is to stabilise net emissions of carbon dioxide by 2000 at 1990 levels through a mix of policies and measures. The Government is committed to reviewing its approach and to shaping policies for limiting emissions of other greenhouse gases in the years ahead.

Detailed background on New Zealand's current emissions, policies and measures in place, and projections of their impact, is provided in this first national communication. It shows that New Zealand takes its FCCC commitments seriously and has taken steps to curb its overall contribution to the problem.

Governments need to show joint leadership on the issue of climate change, but it has become such a fundamental question for the world community that all sectors and interests must play their part. Business, environment groups and individuals must all contribute in their own way to the global effort. An increasingly interdependent world means that partnerships are essential, especially to meet such critical environmental challenges as climate change.

Rt Hon Don McKinnon
Minister of Foreign Affairs and Trade

Hon Simon Upton
Minister for the Environment

2 Executive Summary

UNITED
NATIONS

Framework Convention on
Climate Change

Distr.
GENERAL

FCCC/NC/2
12 June 1995

Original: ENGLISH

EXECUTIVE SUMMARY OF THE
NATIONAL COMMUNICATION OF

NEW ZEALAND

submitted under Articles 4 and 12 of the
United Nations Framework Convention on Climate Change

In accordance with decision 9/2 of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC), the interim secretariat is to make available, in the official languages of the United Nations, the executive summaries of the national communications submitted by Annex I Parties.

Note: Executive summaries of national communications issued prior to the first session of the Conference of the Parties bear the symbol A/AC.237/NC/___.

Copies of the national communication of New Zealand can be obtained from:

Ministry for the Environment
P.O. Box 10362
Wellington
Fax No. (64 4) 471 0195

1. Global climate change is regarded as a serious concern by the New Zealand Government. New Zealand began its response to climate change in 1988 with the establishment of the New Zealand Climate Change Programme. The Government's policy responses have since been brought together under the Comprehensive Strategy on Climate Change which aims to address sources and sinks of all greenhouse gases. The Government's current domestic target, consistent with the Framework Convention on Climate Change (FCCC), is to return net anthropogenic emissions of carbon dioxide (CO_2) to their 1990 level by 2000, and to maintain them at that level beyond the turn of the century. New Zealand retains its ultimate objective of reducing net carbon dioxide emissions to 20 per cent below their 1990 levels, subject to certain conditions, including cost-effectiveness, not reducing our competitive advantage in international trade, and having a net benefit to New Zealand society.

2. This first Framework Convention on Climate Change (FCCC) communication indicates that New Zealand is already well on track to achieve both these objectives. It also demonstrates that we expect to achieve a reduction in methane (CH_4) emissions of up to 8 per cent and stabilisation at least of perfluorocarbon (PFC) emissions. Given uncertainties in estimates of nitrous oxide (N_2O), we are unable at present to calculate trends in emissions of that gas. Our efforts are therefore fully consistent with FCCC provisions and goals, including those for Annex 1 Parties. New Zealand is also fully meeting its obligations as an Annex II Party in respect to finance.

Emissions and sinks

3. Overall, New Zealand's net emissions of greenhouse gases are declining **(see figure 2.1, page 7 of New Zealand's first national communication)**. Net emissions of carbon dioxide will be 50-59 per cent below 1990 levels in 2000. Methane emissions will also be below 1990 levels by 2000 and emissions of perfluorocarbons (PFCs) will be stable. Although there is considerable uncertainty concerning nitrous oxide emissions these are not expected to rise over the decade.

4. In 1990 New Zealand emitted 25 530 gigagrams (Gg) (or 25.5 million tonnes) of carbon dioxide. The combustion and transformation of fossil fuels accounted for 90 per cent of these emissions (22 769 Gg). The remainder was made up of carbon dioxide emissions from industrial processes.

5. The largest source of carbon dioxide emissions in New Zealand is the transport sector which accounted for 34 per cent of the total carbon dioxide emissions in 1990. (This estimate uses IPCC methodology; transport accounts for over 40 per cent using Ministry of Commerce methodology). Electricity generation and other transformation activities (including gas used in the petrochemicals industry) accounted for 27 per cent of the total. Carbon dioxide emissions from industrial processes contributed 10 per cent of the total, with fuel combustion in the industrial, commercial/industrial and agriculture/forestry sectors accounting for 17 per

cent, 5 per cent, and 4 per cent of the total respectively. The remaining emissions (less than 4 per cent) came from the residential sector, fugitive fuel, and other sources.

6. Oil contributed around 52 per cent of total energy sector carbon dioxide emissions, with the main source, the transport sector, accounting for 72 per cent of the emissions. Gas and coal accounted for 34 per cent and 14 per cent respectively.

7. Forestry absorption of carbon dioxide was estimated to be 16716 Gg in 1990. This figure takes account of an estimated 1255 Gg of carbon dioxide that was emitted through forest clearing and fires.

8. Agriculture is New Zealand's main source of methane. Ruminants themselves accounted for around 71 per cent of total methane emissions of 2112 Gg. Landfills, other waste management systems, and fossil fuel sources (mainly from leakages and fuel combustion) made up the remainder.

9. The agricultural sector was also the main source of nitrous oxide emissions. Between 1 and 37 Gg of nitrous oxide was estimated to have been emitted from agricultural soils. Fossil fuel combustion was responsible for a further 7 Gg. Total emissions of nitrogen oxides (NO_x) are estimated to have been around 145 Gg in 1990, with the major source being the transport sector. Practically all emissions of nitrogen oxides were related to fuel combustion activities. It is estimated that New Zealand also emitted 0.1 Gg of perfluorocarbons (PFCs) in 1990. In the same year New Zealand imported less than 20 kg of HFC-134a and approximately 120 tonnes of HFC-152a.

10. Table 2.1 below summarises emissions and absorption of the main greenhouse gases in New Zealand in 1990.

Greenhouse Gas Source and Sink Categories	**CO_2**	**CH_4**	**N_2O**	**NOx**
Total (Net) National Emission	*(All figures in Gg)*			
1. All energy (Fuel Combustion + Fugitive)	23 040	61	7.5	145
2. Industrial Processes	2 490			
3. Agriculture		1 618	1-37	
4. Land Use Change and Forestry	-16 716			1
5. Waste		433	1	

Table 2.1 Summary of 1990 New Zealand greenhouse gas emissions and absorptions. Source: Ministry for the Environment

Policy measures and their effect on future emissions

11. It is expected that in the absence of policy measures New Zealand's carbon dioxide emissions would have risen by around 18-22 per cent and 35-40 per cent over 1990 levels by 2000 and 2005 respectively under the modelling assumptions detailed in Chapter 7 **(see figure 2.2, page 9 of New Zealand's first national communication)**. Within these "business-as-usual" (BAU) assumptions it is projected that the share of emissions among sectors would have remained fairly static over the outlook period.

12. Although New Zealand's gross emissions of carbon dioxide are expected to grow, it is important to recognise that the current emission profile is relatively low because of the significant contribution of renewables to the energy mix. Renewable energy contributes about 75 per cent of the country's electricity needs. While there is scope to develop further renewable energy capacity, particularly wind power, predicted future energy requirements mean some increase in power generation from fossil fuels is necessary. Nuclear power is not an option.

13. The New Zealand Government has introduced a number of policy measures which are expected to limit carbon dioxide emissions. These include:

- Use of the Resource Management Act 1991 (RMA) to consider carbon dioxide emissions in plans, policy statements, and resource use consents;

- Legislative and regulatory reform in the energy sector encouraging more competitive gas and electricity markets;

- The Energy Efficiency Strategy -- a range of measures to facilitate the uptake of cost-effective energy efficient practices and technologies, and to help overcome barriers to the development of economically viable renewable energy resources;

- Cooperative energy efficiency programmes between the Energy Efficiency and Conservation Authority (EECA) and industrial and commercial firms, and between EECA and public sector organisations such as schools, hospitals, and departments, to improve energy use in these sectors;

- Renewable energy measures and the removal of barriers to encourage greater uptake of renewable sources of energy, particularly wind and biomass;

- Voluntary agreements with industry to reduce carbon dioxide emissions;

- Specific transport sector measures including taking carbon dioxide into account in regional transport strategies and road funding, speed limit enforcement, and driver education.

In total the measures described above are expected to reduce growth in carbon dioxide emissions by around 20 per cent of the "business-as-usual" growth by 2000. In addition, the Government has announced a further measure:

- The introduction of a low-level carbon charge in 1997 if at mid-1997 it is assessed that the reduction in emissions is not on track to achieve the specified target level by 2000.

14. The Government has decided that the emission reduction target which will determine whether or not a carbon charge is to be introduced is, for any gross domestic product (GDP) growth rate, that level which results in emission reductions contributing 20 per cent, and sink absorption contributing 80 per cent, towards stabilisation of emissions at 1990 levels.

15. The target reduction corresponds to emissions growth of 14.2 per cent above 1990 carbon dioxide emission levels should GDP growth average 2 per cent; and if GDP growth averages 3 per cent, a target of emissions growth of no more than 17.3 per cent above 1990 levels.

Measures to increase carbon dioxide sinks

16. In 2000, New Zealand's planted forests are projected to remove 25 519 Gg of carbon dioxide from the atmosphere. Carbon stored in natural and planted forests in New Zealand is at least 100 times greater than the net annual carbon absorption level. The forests are therefore a substantial carbon reservoir as well as a significant carbon sink. In 1994, the new forest planting could reach 135 000 hectares. It is expected that on average 100 000 hectares of new forest will be planted each year at least until 2005. The projections estimate (using methodology similar to that of the Intergovernmental Panel on Climate Change (IPCC)) the net amount of sequestration which will take place 2000.

Measures to limit methane emissions

17. In addition the Government also expects to limit methane emissions. It is not yet possible to quantify the outcome of a research programme investigating the potential for lowering ruminant methane emissions through manipulation of enteric bacteria. Methane emissions from livestock in 2000 are expected to be 1425 Gg, about 8 per cent below 1990 levels, and methane emissions from landfills are expected to be at or below 1990 levels in 2000.

Adaptation

18. Most adaptation measures are being taken by local authorities. At present these have concentrated on coastal policy and natural hazard mitigation.

Finance and technology

19. New Zealand has agreed to contribute NZ$10.4 million (SDR 4 million) for the 1994-1996 replenishment to the Global Environment Facility (GEF). Roughly half of this amount is an assessed share. The remainder is a supplementary contribution.
New Zealand is also making an ongoing contribution to mitigation and adaptation work through its Official Development Assistance (ODA) programme. In 1993-1994, ODA expenditure on such activities through bilateral, regional, and other multilateral channels was in excess of NZ$ 8.5 million.

Research

20. New Zealand takes its responsibilities for research and monitoring related to climate change very seriously. A National Science Strategy Committee on Climate Change (NSSCCC) has been appointed by government to provide advice and coordination on climate change science issues. Climate change research also has priority research theme status for funding from the Public Good Science Fund. National expenditure on climate change research within Crown Research Institutes (CRIs) and universities in the 1993-1994 financial year is estimated as NZ$14,100,000 (US$8,200,000).

Education, training, and public participation

21. The Government has produced material on climate change for the general public, schools, and specialised audiences. There have been opportunities for public participation in the development of policy and during resource consent processes.

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3 Introduction

The Earth is surrounded by a thin film of gases forming the atmosphere. It is the composition of this atmosphere that distinguishes the Earth from the other planets in our solar system and creates the conditions necessary for the diversity of life on the Earth's surface and in the oceans.

The composition of the atmosphere has changed over geological time (see Figure 3.1). Such changes usually take place over thousands of years. Human activity over the last two hundred years has measurably changed the composition of the atmosphere through the emission of greenhouse gases. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) and chlorofluorocarbons (CFCs).

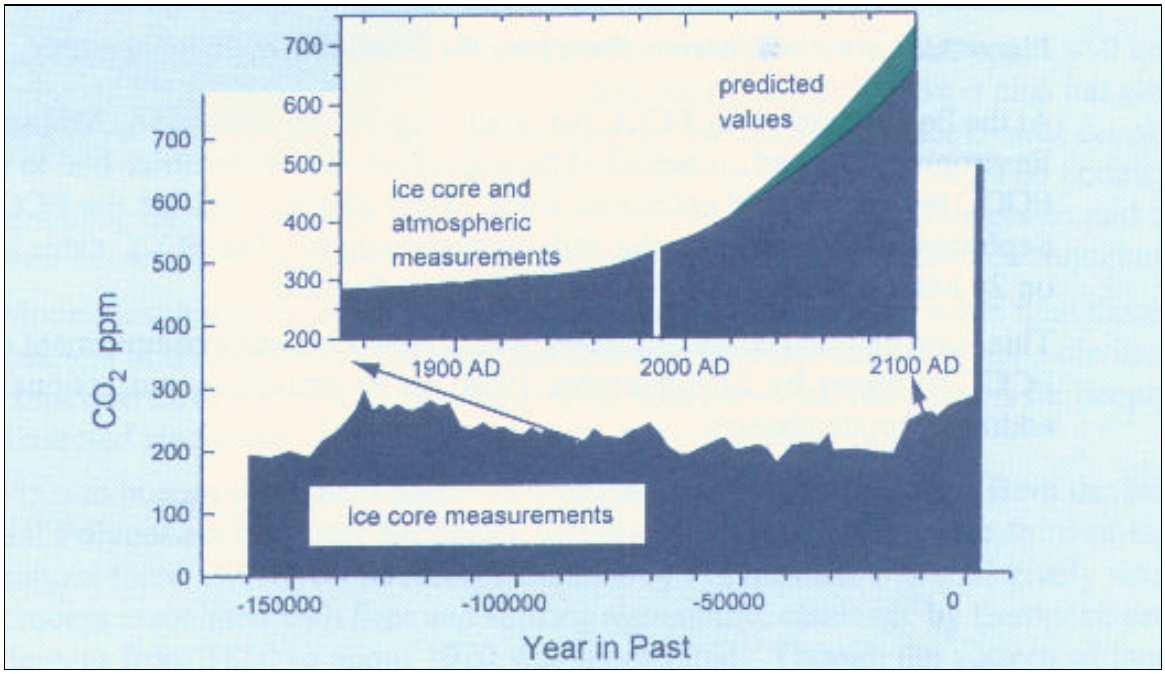


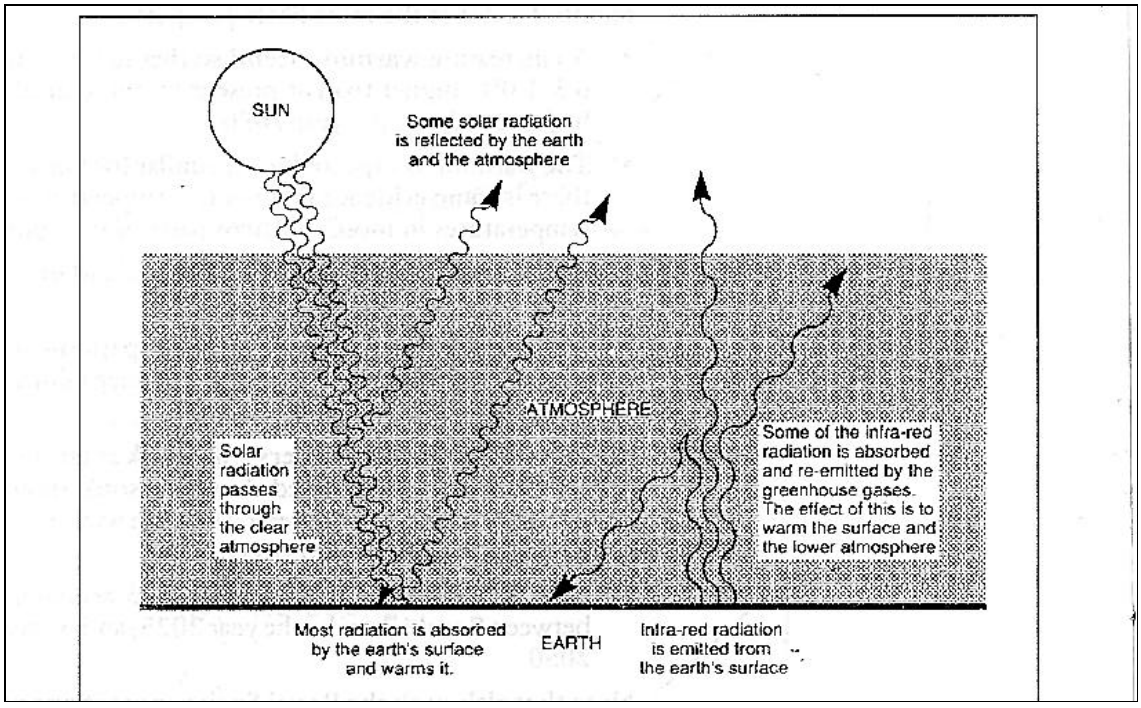
Figure 3.1: Carbon dioxide concentrations past, present, and future. Source: M. Manning, NIWA, 1994

Greenhouse gases have the potential to increase the Earth's average temperature by trapping some of the heat the Earth radiates back into space (see Figure 3.2). The greater the concentration of greenhouse gases in the atmosphere, the greater the potential for a warmer planet and changes to the climate.

In 1988 the United Nations General Assembly resolved to protect the global climate for present and future generations. At the General Assembly's instruction, the UN Environment Programme (UNEP) and the World Meteorological Organisation (WMO) established the Intergovernmental Panel on Climate Change (IPCC). The IPCC reported in 1990, concluding that human-induced climate change is a real threat. The IPCC report and peer review process involved hundreds of scientists from many countries.

In 1990 the United Nations General Assembly, reflecting growing international concern about the potential problem of climate change, established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC). Negotiators from over 150 countries met during five sessions between February 1991 and May 1992. The FCCC was finalised and adopted in New York on 9 May 1992. It was opened for signature soon afterwards in June 1992 at the United Nations Conference on Environment and Development (often referred to as the 'Earth Summit', or UNCED), held in Rio de Janeiro.

Figure 3.2: A simplified diagram illustrating the greenhouse effect. Source: IPCC, 1990



At the Earth Summit the FCCC was signed by 155 countries. The Minister for the Environment signed on behalf of New Zealand. Fifty countries had to ratify the FCCC before it could enter into force. New Zealand ratified the FCCC on 16 September, 1993, and was the 34th country to do so. The FCCC came into force on 21 March 1994, 90 days after the 50th ratification.

This 'first national communication' meets New Zealand's commitments under the FCCC to report by 21 September 1994, on its emissions and actions taken to address climate change.

4 New Zealand National Circumstances

4.1 Geography

New Zealand consists of two large, and a number of smaller, islands located in the southwest Pacific Ocean between 33° and 55° south latitude. It has a combined land area of 270 500 square kilometres, which makes it similar in size to Japan or the British Isles. New Zealand is isolated, relatively uncrowded, and endowed with natural resources such as water, coal, and natural gas/petroleum.

New Zealand is 1600 km long and spans 450 km at its widest point. At 11 500 km it also has one of the longest, and, in some places, most deeply indented coastlines in the world. The country straddles the boundary of the Pacific and Indo-Australian tectonic plates and is well known for its active volcanoes, geothermal areas, and frequent earthquakes.

Mountains dominate much of the New Zealand landscape and more than three-quarters of the land area is higher than 200 metres above sea level. One obvious consequence of the intense mountain building in New Zealand's past is the deeply dissected landscape carved by numerous steep, fast-flowing rivers.

Prior to human settlement about 75% of the country was forested. Both the initial Polynesian, and later European, settlers each cleared about one-third of the natural forest cover. While forest clearance by Polynesians was a relatively slow process associated with fires and shifting agriculture, clearance by European settlement from 1850 to about 1920 was more rapid. Though the pattern of land clearance was essentially established by 1920, further controversial clearance of natural forest continued until the mid 1980s when the combined effects of conservation initiatives and the removal of land development subsidies largely stopped the activity. About 80% of natural forest resource is state owned with the remainder being privately owned, half by Maori. Almost all the state owned natural forest is in national parks, forest parks, and other reserves, with only about 2% being managed for wood production. About 90% of the private natural forests serve protective functions with the remainder being considered to be commercially viable for sustainable wood production under current market conditions. Introduced animals, particularly Australian possums, and deer, have caused significant damage to quality of the native forest.

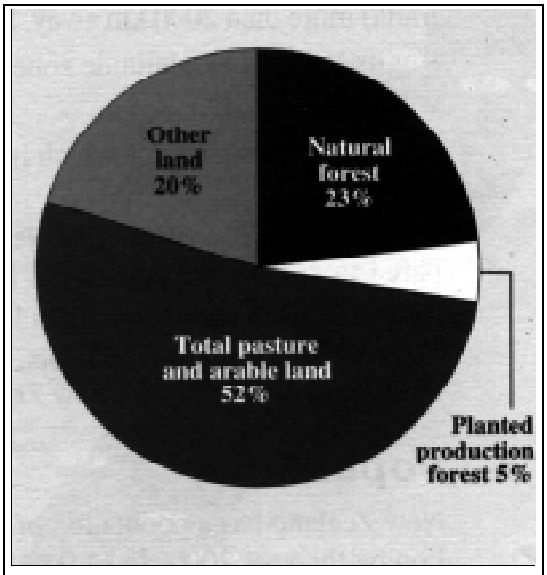


Figure* 4.1 *Land use in New Zealand
***Source: Department of Survey and Land Information,* 1993**

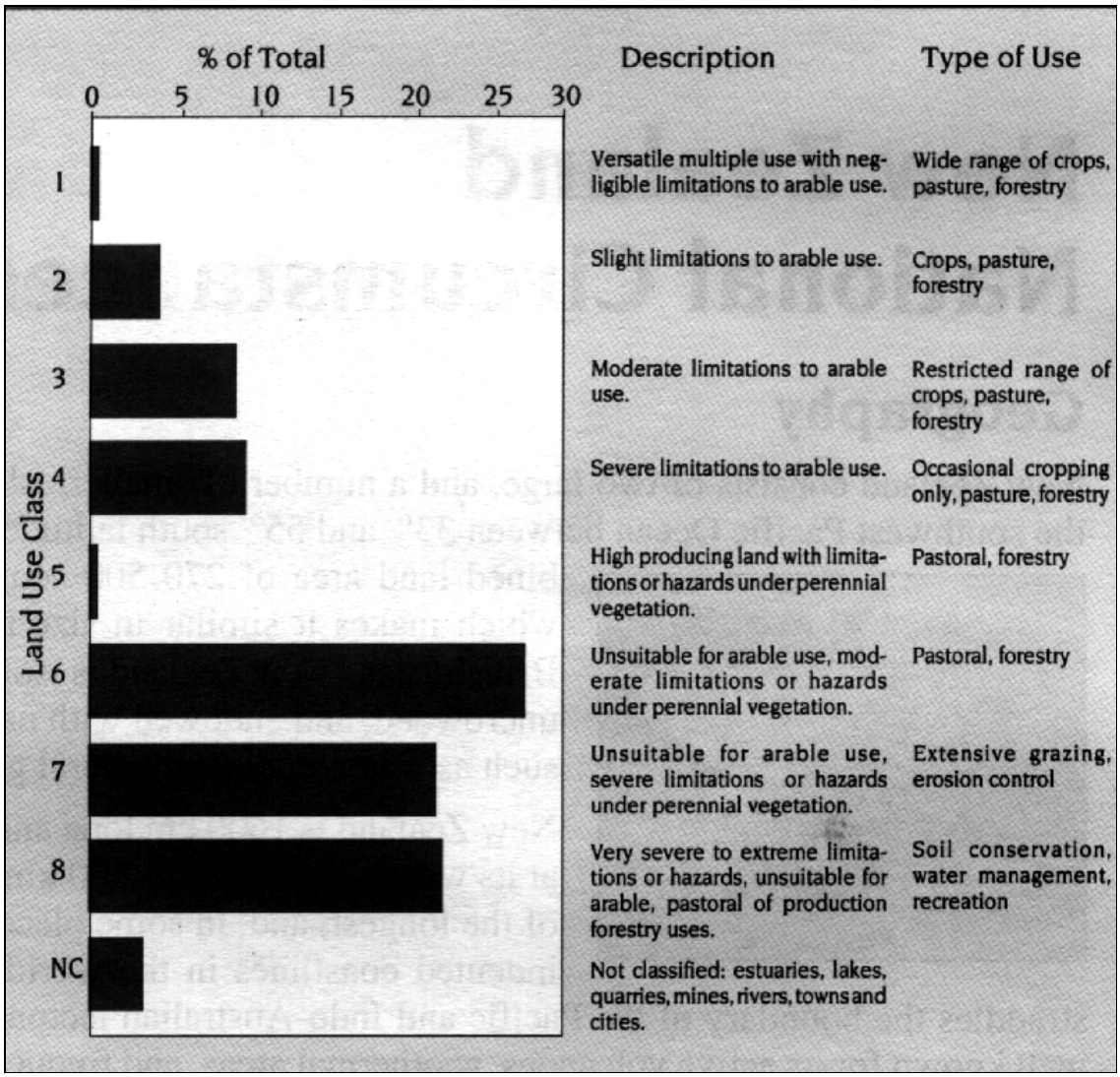


***Figure* 4.2 *Land use capability in New Zealand. Source:* DSIR *Land Resources,* 1991**

Much of the country supports managed ecosystems: pasture, production forests, and crop-land (see Figures 4.1 and 4.2). The total area of farmland is about 178 000 square kilometres or 66% of the national land area. The 1.4 million hectares (as assessed in March, 1994) of sustainably managed planted forest provides almost 99% of New Zealand's wood production. The predominant non-indigenous species is *Pinus radiata*.

4.2 Climate

As a long, narrow, mountainous country with the nearest large land mass (Australia) more than 2000 km away, New Zealand's climate is largely influenced by:

- its location in a latitude zone with prevailing westerly winds;
- the surrounding ocean;
- the mountain chains which modify the weather systems as they sweep eastward.

All these factors contribute to New Zealand having more variable weather compared to continental countries. Many parts of the country are affected by extremes of wind and rain, which, from time to time, cause considerable damage.

Figure 4.3 shows sunshine hours, rainfall, and maximum and minimum temperatures across the whole of New Zealand.

4.3 Population

New Zealand has a population of 3.5 million. This is expected to reach 3.7 million by the year 2000, and 4.0 million by 2010.

North Islanders outnumber South Islanders by 3 to 1 and there is a steady drift of people from the south to the north. Despite New Zealand's continued reliance on agricultural exports, more people are moving from the countryside into urban communities. 85% of New Zealanders live in towns and cities, and almost one-third of New Zealand's entire population lives in the greater Auckland area.

As in most other western countries the percentage of older people in the community is increasing; 16% of the population is over 60 years of age. At the same time the size of the average family has shrunk to less than half of what it was in 1960. In 1991 the average birth rate was 2.16 births per woman, a number barely sufficient to maintain a stable level of population without migration.

New Zealand is a multiracial society. While 74.5% is classified as being New Zealand European there are people of Maori (12.7%), Pacific Island Polynesian (3.8%), Indian (0.8%), Chinese (1.1%), and of other European origin (4.6%) present. New Zealand has strong links with the peoples of the South Pacific island nations. There is considerable movement of people between these island nations (e.g. the Cook Islands, Niue, Western Samoa, and Tokelau) and New Zealand.

Current projections (based on 1991 figures) indicate that New Zealand's population will grow slowly and age steadily over the next four decades to about 4.3 million people in 2030. There will be no profound changes to New Zealand's age structure with the two child family/minimal immigration scenario resulting in the median age of the population rising from 31.3 years (1991) to 39.7 years (2031).

***Figure* 4.3 *New Zealand weather. Source: Department of Statistics,* 1993**

4.4 Social Framework

The New Zealand population is predominantly urban. The bulk of the population live within a few kilometres of the coast, with estuarine systems playing an important part in the location of population centres. There are five cities with populations in excess of 100 000, and another 15 with populations between 20 000 and 100 000. About one million people in total live in towns of under 20 000 and in the rural sector.

Single, detached houses dominate the housing stock, with almost 75% of households owning their own home. The typical New Zealand house is single-storeyed and built from timber. In 1991 the average number of occupants per private dwelling was 2.8 as compared with 2.9 in 1986 and 3.2 in 1981 (see Table 4.1).

Type	1986 Census Aggregate	1986 Census Average	1991 Census Aggregate	1991 Census Average
Permanent private dwellings—				
Separate house	2 682 729	3.1	2 828 004	3.0
Two houses or flats joined together	215 418	2.1	220 434	2.0
Three or more flats/houses joined together	165 183	1.8	162 291	1.8
Flat/house attached to business or shop	22 446	2.7	24 225	2.6
Bach, crib, hut (not in a work camp)	12 285	2.1	14 073	2.0
Not specified	18 051	2.5	6 528	2.7
Total, permanent private dwellings	**3 116 112**	**2.9**	**3 255 558**	**2.8**
Temporary private dwellings	22 893	2.2	13 314	1.9
Total, private dwellings	**3 139 005**	**2.9**	**3 268 872**	**2.8**
Non-private dwellings	168 081	23.5	166 080	21.5
Total occupied dwellings	**3 307 083**	**3.0**	**3 434 949**	**2.9**

***Table* 4.1 *Number of occupants in occupied dwellings in new Zealand in* 1991 *compared with* 1986 *census data. Source: Department of Statistics,* 1993**

Housing densities are low, with the result that New Zealand cities and towns are unusually extensive with low population densities. The income distribution of households in New Zealand is shown in Table 4.2.

Annual income $	Approximate equivalent weekly income $	Number of households (000)	Average weekly income per household $
Under 12,000†	Under 230	119.8	137.10
12,000–15,999	230 and under 307	89.5	262.80
16,000–19,999	307 and under 384	124.1	345.70
20,000–24,999	384 and under 479	99.7	426.50
25,000–31,999	479 and under 614	113.3	544.00
32,000–39,999	614 and under 767	116.8	688.80
40,000–47,999	767 and under 921	111.9	839.70
48,000–57,999	921 and under 1,112	105.0	1,008.20
58,000–75,999	1,112 and under 1,458	113.4	1,268.40
76,000 or over	1,458 or over	109.3	2,063.80
Total	...	**1 102.9**	**758.70**

**As estimated from Household Expenditure and Income Survey.* *†Including nil and loss.*

***Table* 4.2 *Income distribution of New Zealand households,* 1991-1992.**
***Source: Department of Statisitics,* 1993**

4.5 Political and Decision Making Structure

New Zealand is a parliamentary democracy. There is one elected House of Representatives. The principal functions of Parliament are to enact laws, supervise the Government's administration, allocate tax income, provide a government, and redress grievances by way of petition.

New Zealand has a system of local government that is largely independent of, but subordinate to the central executive government. Local authorities fall into two main categories, namely regional and territorial authorities. They have their own sources of income independent of central government, the basic source being taxes on landed property.

Local authorities derive their functions and powers from a range of legislation, in particular the Resource Management Act 1991 (RMA). The RMA integrated the provisions of more than 75 earlier laws and is founded upon the principle of sustainable management of natural and physical resources. The use of the RMA to address climate change issues is covered in Section 6.3.

4.6 The Economy

New Zealand's economy is heavily dependent on its natural resources. Although direct employment in primary industries is low (10.6%) and declining, agriculture, fishing, and forestry provide the basis for the processing and manufacturing industries.

New Zealand's leading export classes are dominated by agricultural and forestry products (see Figure 4.4). These account for almost 70% of what is earned from the export of goods and services, although exports from horticulture, fishing, and manufacturing industries have also become significant. Livestock farming is integral to the New Zealand economy with around 70 million farm animals, mainly sheep and cattle (see Figure 4.5). In 1993 dairy exports were worth NZ$3,300,000,000 ($3.3 billion), wool exports exceeded $1 billion, as did fish exports, while forest products came to $2.4 billion. Meat exports, meanwhile, were worth $3.5 billion.

Australia, the European Union, Japan, and the United States, are New Zealand's main export markets.

Although generally regarded as an agricultural nation, New Zealand does have some heavy industry including one steel mill, an aluminium smelter, a synthetic petrol plant, cement works, and pulp and paper mills. There are also dairy factories and meat processing works throughout the country.

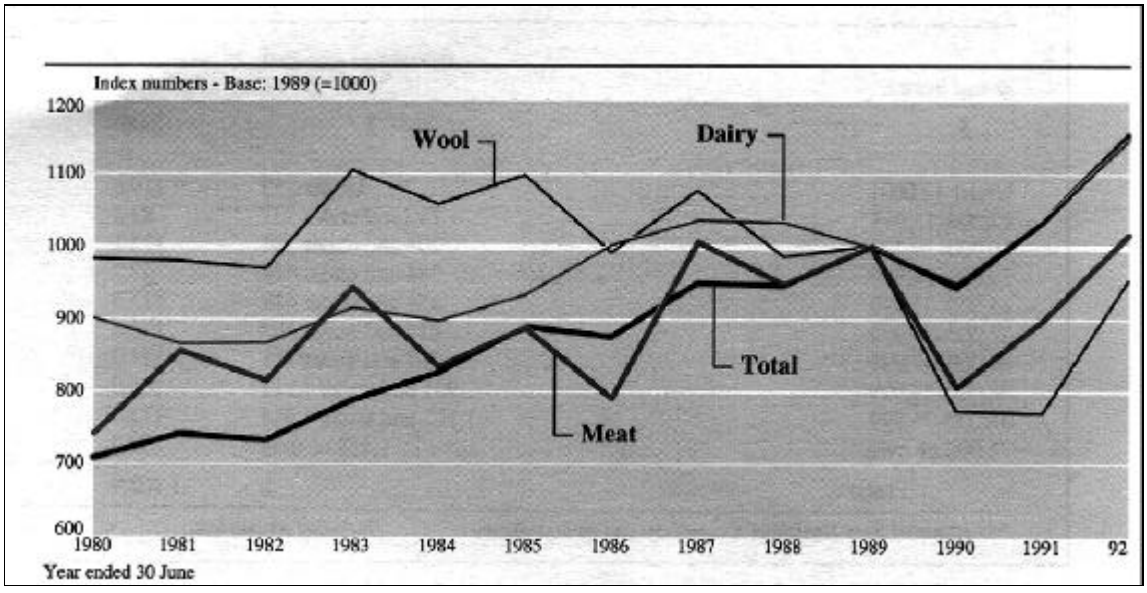


***Figure* 4.4 *New Zealand export volume index,* 1980 *to* 1992.**
***Source: Department of Statistics,* 1993**

The New Zealand economy has undergone major restructuring during the last decade, designed to foster the development of an open, competitive, and resilient economy. An extensive agenda of macro- and microeconomic reforms has allowed the price system to emerge as the dominant signal for investment, production, and consumption decisions.

The major changes implemented include removal of controls on prices, interest rates, and wages; introducing a flexible exchange rate regime; giving the central bank (the Reserve Bank) independence to maintain price stability; achievement of fiscal surplus; extensive taxation reform aimed at reducing marginal rates and broadening the base; removal of agricultural subsidies and price supports; removal of quantitative import controls and ongoing tariff reductions; deregulation of oil, banking, and transport markets; reform of labour market regulation; privatisation of State-Owned Enterprises (SOEs); and wide-ranging public sector financial management reforms.

A number of these reforms have a limited, but not quantified, impact on carbon dioxide emissions. Examples include the application of the consumption tax (Goods and Services Tax or GST) on all domestic and industrial fuels, removal of incentives and subsidies on the mining of coal and gas, and the reform of the energy sector.

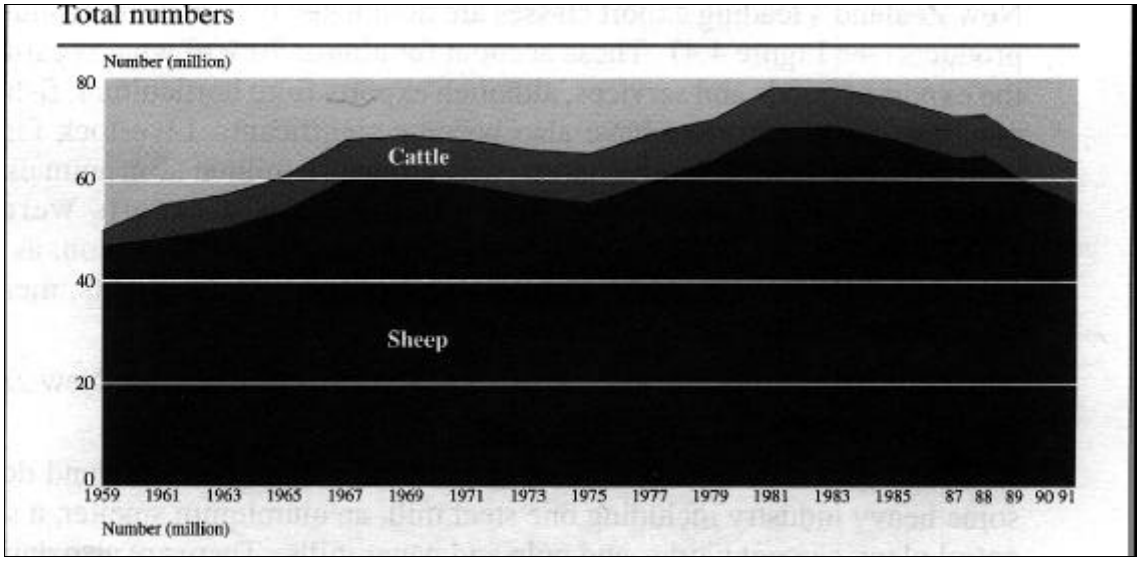


***Figure* 4.5 *Total numbers of livestock on New Zealand farms,* 1959 *to* 1991.**
***Source: Department of Statistics* 1993**

4.7 Energy

New Zealand is self-sufficient in all but liquid fuels, importing around half of its oil supplies. Figure 4.6 shows the trends in New Zealand's primary energy sources since 1974. The consumption of energy by end use type is given in Figure 4.7.

New Zealand's electricity generation is dominated by renewable energy sources, with hydroelectric power (see Figure 4.8) producing around 70-75% of annual electricity needs, depending on rainfall. Geothermal power contributes another 7%. The balance is made up by fossil fuel generation, using mostly natural gas, (but occasionally some coal).

At present New Zealand has adequate generating capacity to meet its electricity requirements. If demand continues to grow as it has been in recent years (up to 2.5% per annum) additional generating capacity will be required around the turn of the century. The initial capacity expansion is expected to be met by efficiency improvements to the existing hydroelectric network, new co-generation, geothermal, and gas combined cycle generation. Wind power is a possibility with several wind farms proposed recently. As yet, however, wind is untried commercially in New Zealand's demanding conditions. While some expansion of the current hydroelectric capacity is likely over the next decade, additional developments are likely to be affected by broader environmental considerations.

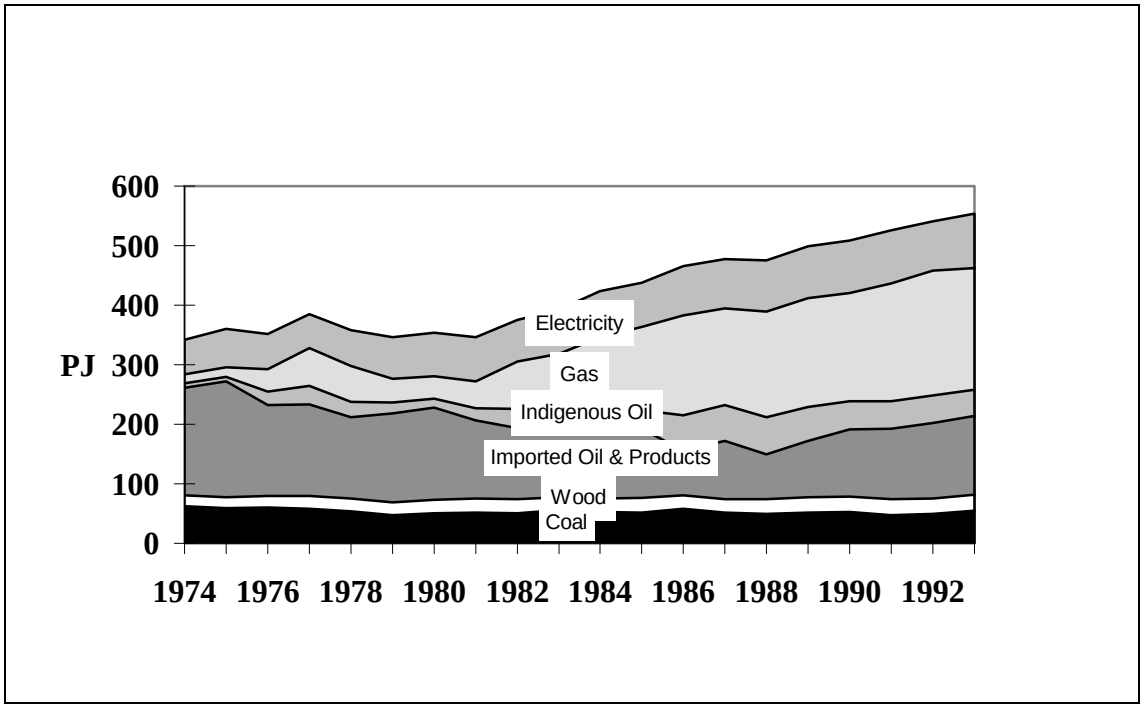


***Figure 4.6 Primary energy supply in New Zealand,* 1974 *to* 1993.**
***Source: Ministry of Commerce,* 1994**

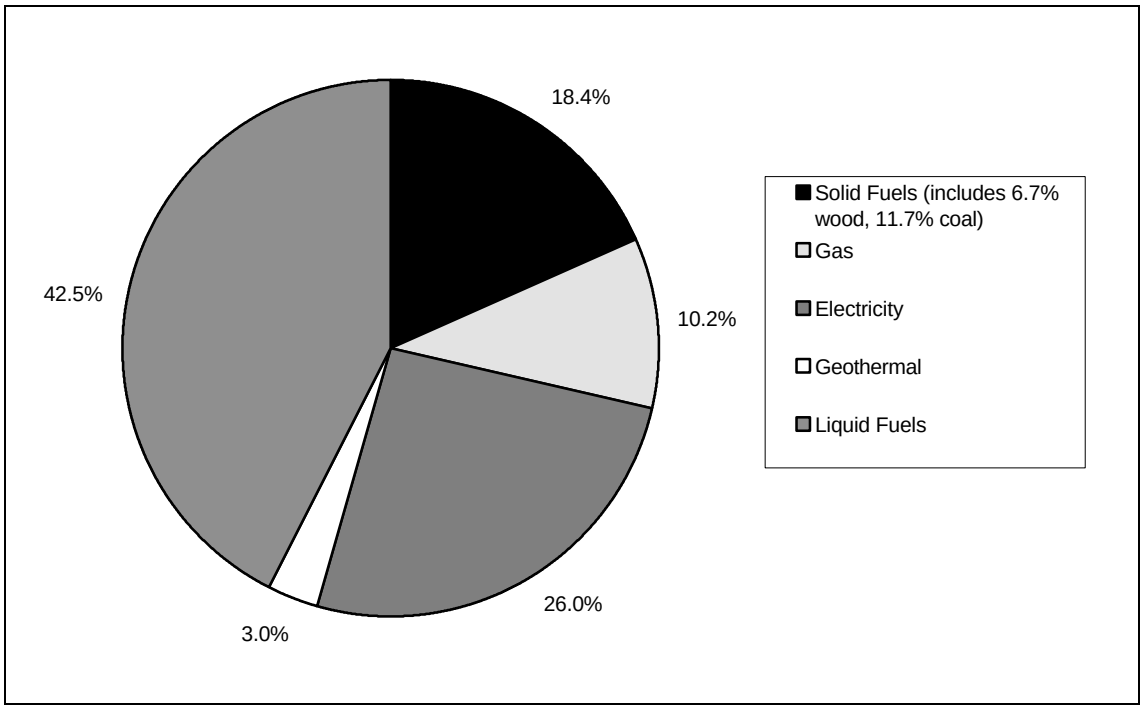


***Figure* 4.7 *Consumption of energy in New Zealand by end use type,* 1990.**
***Source: Ministry of Commerce,* 1994**

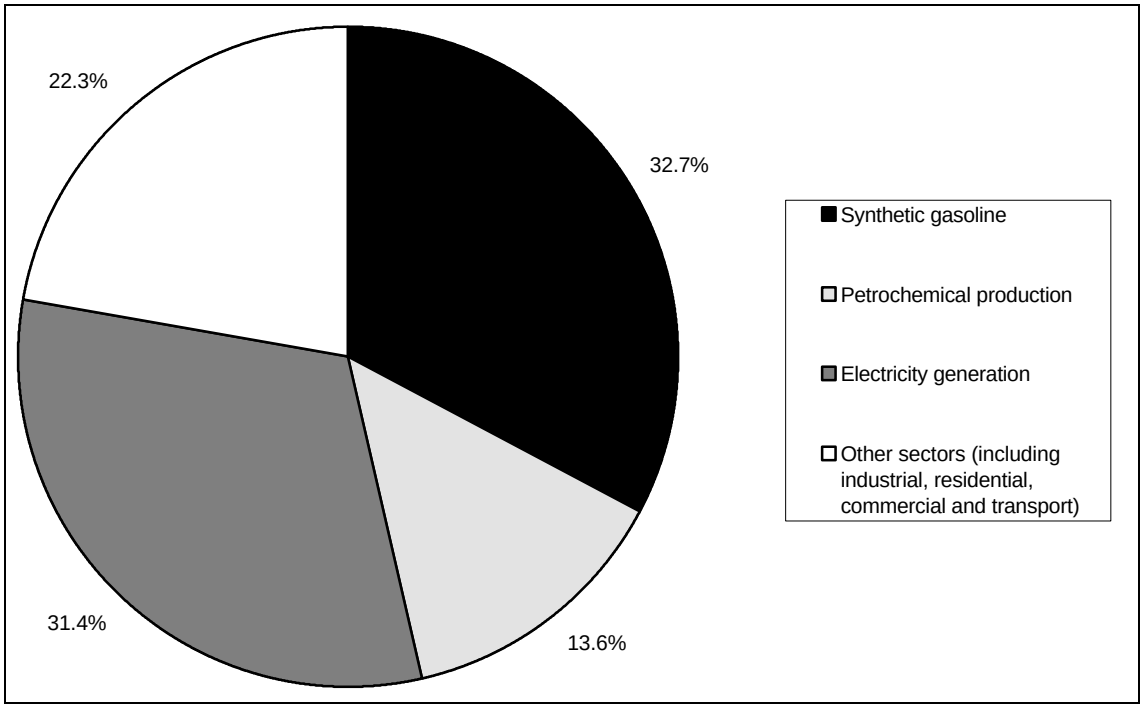


Figure* 4.9 1990 *natural gas by end use in New Zealand.
***Source: Ministry of Commerce,* 1994**

Crude oil and condensate production in 1992 was 79.7 Petajoules (PJ). Total crude oil and condensate production in 1992 represented about 44% of total refinery intake. Known recoverable reserves are estimated to last another 11 years at current rates of extraction.

New Zealand is self-sufficient in natural gas. Modelling suggests that if no new discoveries of natural gas are made, current reserves will last around 23 years in a greatly reduced market. This compares to around 16 years of supply at current levels of use if no new discoveries are made.

The New Zealand natural gas market is dominated by feedstock users (see Figure 4.9).

Coal production in 1992 was 3 million tonnes. Around 22% was exported. Of the 58 mines in operation during 1993, 39 were opencast mines and were responsible for 84% of total production. The major end users of coal are basic metal manufacturing, electricity generation, other manufacturing, and households. New Zealand has recoverable reserves of coal amounting to 8.6 billion tonnes (one billion = 10^9).

4.8 Transport

The nature of New Zealand's transport system has been influenced by the spread of the small population over two islands with a combined length of 2000 kilometres. There are 94 000 km of road and 4000 km of railway track. New Zealand's remoteness from many of its trading partners has required extensive use of shipping and, more recently, air transport.

The low density and dispersed nature of the New Zealand population has created a significant dependence on private passenger vehicles as a mode of daily travel. Approximately 1.8 million passenger cars are registered to individuals in New Zealand. The number of motor vehicles per household is shown in Table 4.3. The average age of the vehicle stock is currently about 10 years and the expected life of a vehicle is 15-20 years. Many fleet vehicles, including most taxis, together with some private vehicles, operate on compressed natural gas (CNG) or liquid petroleum gas (LPG) which emit less carbon dioxide per kilometre travelled than petrol-fuelled vehicles.

*Number of motor vehicles**	*1986 Census*		*1991 Census*		*Intercensal percentage change*
	Households‡	*Percentage of total†*	*Households*	*Percentage of total†*	
0	142 593	13.4	143 232	12.4	0.4
1	525 048	49.4	538 227	46.7	2.5
2	302 415	28.4	356 814	31.0	18.0
3	69 525	6.5	84 537	7.3	21.6
4	17 334	1.6	21 411	1.9	23.5
5 or more	6 177	0.6	8 097	0.7	31.1
Not specified	25 509	...	25 347	...	−0.6
Total	**1 088 598**	**100.0**	**1 177 665**	**100.0**	**8.2**

**Includes cars, station-wagons, vans, trucks, and other vehicles used on public roads (excludes motorcycles and scooters). Business vehicles if available for private use are also included. †Calculated on specified cases only.*

Table 4.3 Household transport in New Zealand,* 1991 *compared with* 1986 *census data.
Source: Department of Statistics

The large urban centres generally have public transport systems carrying commuters to and from work, and children to and from school. In most places public transport carries a low proportion of total commuters because the majority live in dispersed suburbs. Overall New Zealand's low population density makes it difficult to provide a comprehensive public transport system with frequent services in smaller centres throughout the country.

In the 1980s and 1990s, much of New Zealand's transport sector was deregulated and state ownership was relinquished. This restructuring and change in ownership allows the transport sector to respond to change in market demand or technology more efficiently than previously.

5 Inventory

New Zealand has developed an inventory of its 1990 emissions and sinks for the most significant greenhouse gases (see Table 5.1). The inventory is updated yearly in order to monitor trends in emissions and sinks, evaluate the effectiveness of policy measures, and to provide a base with which to exploit future actions. The inventory focuses on carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other nitrogen oxides (NO_x).

National data is provided for emissions of the above gases from all energy sources, industrial processes, agriculture, land use change and forestry, and waste. These figures are then further disaggregated into sub-sectors to provide a more detailed picture of emission trends.

Some limited information is also available for the emissions of perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). In keeping with the IPCC guidelines emissions from international bunkers are treated separately.

In 1990 New Zealand emitted 25 530 gigagrams (Gg) of carbon dioxide. Over 90% of total carbon dioxide emissions came from the energy sector. The remainder was made up primarily of carbon dioxide emissions from industrial processes.

Figure 5.1 shows 1990 emissions of carbon dioxide from all sectors. The largest source of carbon dioxide emissions in New Zealand is the transport sector which accounted for 34% of total carbon dioxide emissions in 1990. Electricity generation and other transformation activities (including gas used in the petrochemicals industry) accounted for 27% of the total. Carbon dioxide emissions from industrial processes contributed 10% of the total, with fuel combustion in the industrial, commercial/industrial and agriculture/forestry sectors accounting for 17%, 5%, and 4% of the total respectively. The remaining emissions (less than 4%) came from the residential sector, fugitive fuel, and other sources.

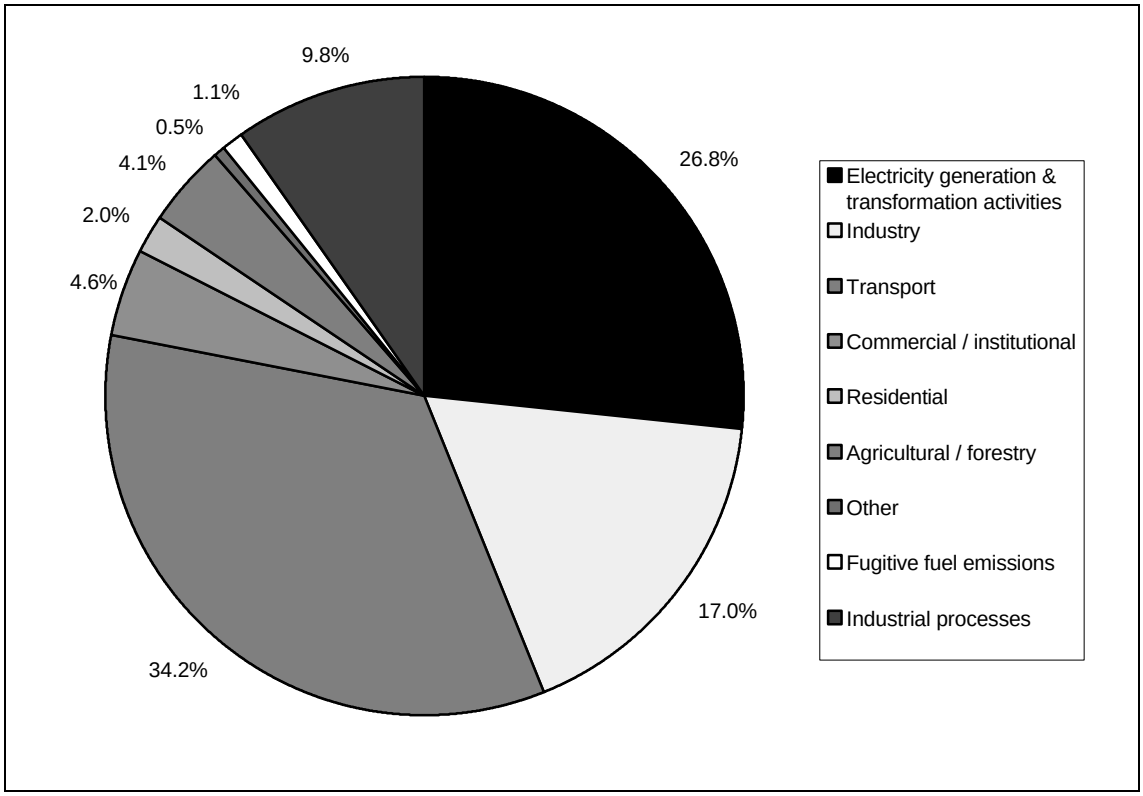


Figure* 5.1 1990 *emissions of carbon dioxide from all sectors in New Zealand.
***Source: Ministry for the Environment,* 1994**

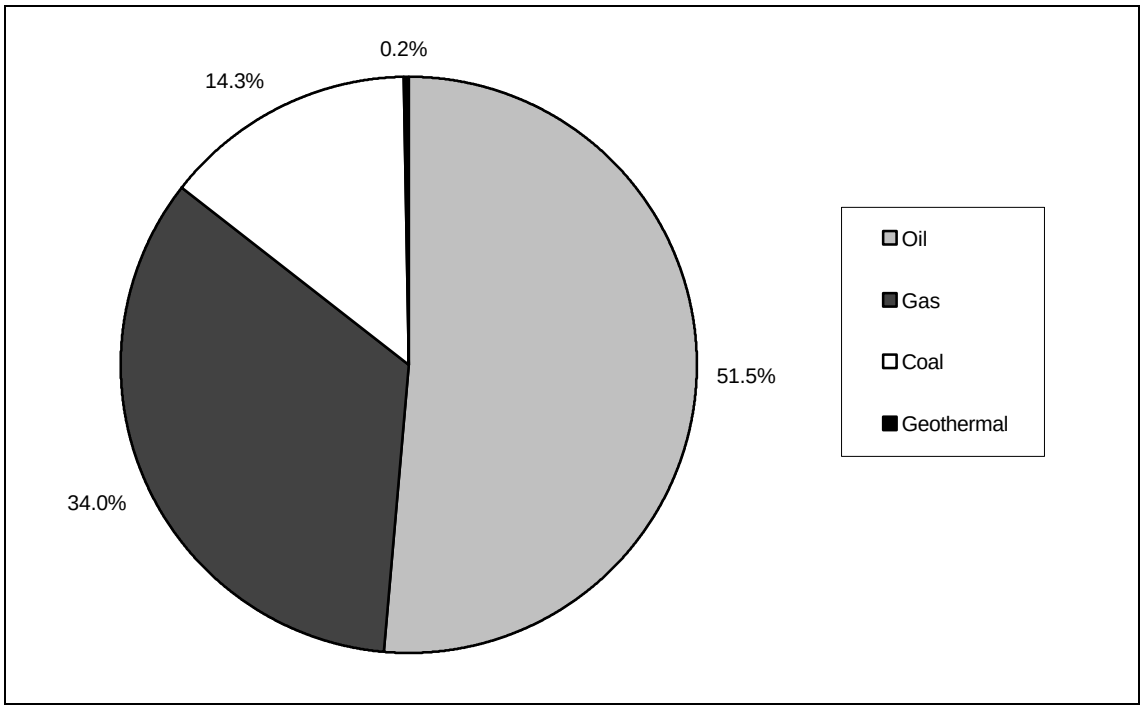


Figure* 5.2 1990 *carbon dioxide emissions by fuel in New Zealand.
***Source: Ministry for the Environment,* 1994**

Figure 5.2 shows 1990 energy sector carbon dioxide emissions by fuel. Oil contributed 52% of total energy sector carbon dioxide, with the main source being the transport sector which accounted for around 72% of all oil emissions. Gas and coal accounted for 34% and 14% respectively. Less than 1% of carbon dioxide emissions was derived from geothermal.

Forestry absorption of carbon dioxide was estimated to be 16 716 Gg in 1990. This takes into account an estimated 1255 Gg of carbon dioxide that was emitted through forest clearing and fires.

Agriculture is New Zealand's main source of methane (CH_4). Ruminants themselves accounted for around 71% of total methane emissions of 2112 Gg. Landfills, other waste management systems, and fossil fuel sources (mainly from leakages and fuel combustion) made up the remainder.

The agricultural sector was also the main source of nitrous oxide (N_2O) emissions. Between 1 and 37 Gg of nitrous oxide was estimated to have been emitted from agricultural soils. Fossil fuel combustion was responsible for a further 7 Gg.

Total emissions of nitrogen oxides (NO_x) are estimated to have been around 145 Gg in 1990, with the main source being the transport sector (over 70% of total NO_x emissions). Practically all emissions of nitrogen oxides resulted from fuel combustion activities.

The inventory also includes estimates of other greenhouse gases. Perfluorocarbons (PFCs) were estimated to emit 0.1 Gg in 1990. Hydrofluorocarbons (HFCs) are imported into New Zealand. In 1990 New Zealand imported less than 20 kg of HFC-134a and approximately 120 tonnes of HFC-152a.

5.1 Energy Sector Emissions

Energy sector emissions are based on energy use data from the Ministry of Commerce's Energy Data File and estimates of coal use by sector by the Coal Research Association of New Zealand (CRANZ). The methodology developed by Waring and Richards in "Greenhouse Gas Emissions from New Zealand Energy 1990-92" is followed, together with IPCC guidelines, in order to derive carbon dioxide, methane, and nitrous oxide emission estimates for the sector.

1990 carbon dioxide emissions by sector and by fuel are shown in Figures 5.1 and 5.2 respectively.

Greenhouse Gas Source and Sink Categories	CO2	CH4	N2O	NOx
Total (Net) National Emission				
1. All Energy (Fuel Combustion + Fugutive)				
A Fuel Combustion				
Energy & Transformation Industries	6832	4	0.5	10.3
Industry	4334		0.7	14.5
Transport	8731	7.7	5.2	103.6
Commercial/Institutional	1184		0.2	2.9
Residential	515			0.7
Agricultural/Forestry	1058		0.7	13
Other				
Biomass Burned for Energy	115	16	0.4	
B Fugutive Fuel Emission				
Oil and Natural Gas Systems	271	21		
Coal Mining		12		
2 Industrial Processes				
A Iron and Steel	1300			
B Aluminium	510			
C Cement and Limestone	680			
3 Agriculture				
A Enteric Fermentation		1500		
B Animal Wastes		<118.0		
C Agricultural Soils			1-37	
4 Land Use Change & Forestry				
A Forest Clearing & On Site Burning of Cleared Forests	1255	0.4		0.4
D Managed Forests	-17971			
5 Waste				
A Landfills (1991)		137.3		
B Wastewater				
C Other (Primary, Production Processing)		<296.0	0.6	

5.2 Industrial Processes

The carbon dioxide emissions associated with cement and limestone production (Ministry of Commerce, 1994), steel manufacture (BHP NZ Steel, pers. comm. 1994) and aluminium smelting (NZAS, 1993) are listed. These emissions amount to a total of 2490 Gg of carbon dioxide. The carbon dioxide emissions from fuel combustion for energy are included in the energy sector emissions. The PFC emissions from aluminium smelting are discussed separately.

5.3 Agriculture

5.3.1 Enteric Fermentation

Compared to its human population, New Zealand has large numbers of farm animals. For 1990, the Ministry of Agriculture and Fisheries report animal numbers at an estimated 57.8 million sheep, 4.6 million beef cattle, 3.4 million dairy cattle, 1.0 million deer, and 1.1 million goats.

Methane production by ruminants in New Zealand (sheep, beef cattle, dairy cattle, goats, and deer) has been estimated at 1500 Gg. This was done using a mathematical model of rumen digestion interfaced with estimates of livestock numbers (Ulyatt *et al*., 1991). The estimates of livestock numbers took into account the fluctuations in herd sizes over the year and is more representative of the true situation than a single year-end statistic. The model required input of diet composition and feed intake. The IPCC default methodology was not used to calculate methane production by New Zealand ruminants as it is considered that a model which more closely reflects the New Zealand situation provides a more accurate assessment.

To do the calculation:

- New Zealand was divided into climatic regions that contained similar pasture species, growth patterns, and thus pasture composition.
- Each region was classified into improved, unimproved, and tussock grasslands, and livestock was allocated to these in line with acceptable stocking rates.
- Models of livestock movements within a year were developed for each animal and land class.
- Food dry matter intake for each class of livestock was calculated from estimates of feed requirements and diet digestibility.

5.3.2 Animal Wastes

Estimates have been made for the maximum methane emissions from animal wastes (<118 Gg). Included in this total are emission maxima from ruminant faecal deposits on pasture (Joblin and Waghorn, 1994) and in feedlots, plus emissions from pig and poultry farming (Campbell, 1994). The actual emissions from this source are expected to be substantially lower than the maximum presented here.

5.3.3 Agricultural Soils

Soil Carbon

The inventory table does not contain an estimate of carbon loss/gain in New Zealand soils. These soils are estimated to contain large amounts of carbon. Soils under pasture do not tend to be disturbed by normal New Zealand pastoral agriculture practice (i.e. soils used for pasture are generally not ploughed). Land used for cropping and horticulture is, however, cultivated annually, and there are large tracts of severely eroded land. Extensive soil disturbance associated with forest harvest is discouraged under the Resource Management Act (see Section 6.2).

The estimation of changes in soil carbon is difficult. Results from recent New Zealand studies indicate that changes to soil carbon (except under intensive cropping) take place slowly (decades to centuries) in response to land use changes. Process based predictive models which will assist in addressing the issue of soil carbon changes are under development. (See Annex 1 for details.)

Nitrous Oxide

Between 1 and 37 Gg of nitrous oxide are estimated to have been emitted from New Zealand soils in 1990 (Carran *et al*., 1993). Nitrous oxide emissions from agricultural soils in New Zealand generally do not come from the application of nitrogenous fertilizer. The predominant use of legume-based pastures makes fertilizer nitrogen a relatively small consideration for nitrous oxide emissions compared to the complex interaction between soil type and climatological factors such as rainfall and temperature. Grazing animals can locally enhance nitrous oxide emissions via urine deposited on the soil, and through hoof traffic causing surface damage and poor aeration in wet soils.

Nitrous oxide emissions from agricultural soils are represented as a range. A partial inventory of nitrous oxide emissions has been made using an approach based on classifying soils according to drainage class, rainfall, and temperature. Emissions data from sites of known class have been used to make broader estimates of nitrous oxide emissions.

The range is large because extensive areas of the South Island show negative (i.e. sink) to low emission ranges, and in the North Island high emission ranges make a significant contribution from a small proportion of the total land area.

5.4 Land Use Change and Forestry

Major planting of exotic forests began in the 1920s. The amount of planting has fluctuated widely since then. As most exotic planting was, until recently, mainly by the State, New Zealand has very good records of commercial planting. Planting is basically (90%) of one species (*Pinus radiata*). Research in forestry (particularly by the government body, the Forest Research Institute (FRI)) has been well developed, over many years. This combination of factors means that New Zealand has been able to develop very reliable carbon sequestration models and data.

New Zealand has developed a method (Hollinger *et al*., 1993) to quantify carbon sequestration by managed forests based on calculating a 'carbon inventory' at two points in time and identifying the difference. This difference represents the net sequestration or emission of carbon for this period. Carbon dioxide sequestered by New Zealand forests in the year 1990 is estimated at 16 714 Gg. This figure represents the sequestration which took place in one year (i.e. from 1 April 1990 to 31 March 1991). The methodology is described in more detail in Annex 2.

The estimation of the total amount of carbon dioxide sequestered by New Zealand forests in any one year takes into account:

- the amount of carbon sequestered by planted forests;
- the amount of carbon lost through the harvesting of planted forests;
- carbon lost through the logging of native forests;
- carbon lost through the clearance of shrublands for forest planting; and
- carbon loss through forest and shrubland fires. (Ministry of Forestry pers. comm., 1994; Maclaren *et al*., 1994).

No estimates are available of the net level of vegetation clearance for land uses other than forest. Reversion to shrubland of marginally economic hill pastures, mainly in the North Island has been particularly evident since the restructuring of the New Zealand economy saw agricultural assistance to farmers fall from an average 25% of the value of agricultural production in the period 1979-86, to 3% in 1992. Thus it is probable that more land is reverting to shrubland cover than is being cleared of such vegetation.

Soil carbon changes as a result of grassland conversion and the abandonment of managed lands are discussed in Annex 1.

5.5 Waste

5.5.1 Landfills

Total emissions for 1991 are estimated at 137.3 Gg (Royds Consulting Ltd, 1994). Population density and distribution, waste volume estimates, and waste stream composition were used, together with the IPCC draft methodology, to calculate methane emissions from New Zealand municipal landfills.

5.5.2 Primary Production Processing

A maximum potential figure for methane emissions is estimated at 296 Gg (Campbell, 1994). This total includes meat, dairy, chicken, fish, vegetable and fruit processing, wool scouring, and on-farm vegetable and fruit waste. Potential emissions come from waste water streams and landfilled waste. The actual amount of methane produced is likely to be a small fraction of the maximum methane potential.

Nitrous oxide emissions from the meat processing industry are estimated at 0.6 Gg (Brown and Cooper, 1992). As other primary production processing industries have nitrous oxide emission potential, total emissions are likely to be higher.

5.6 Other Gases

Emissions of perfluorocarbons and hydrofluorocarbons are summarised in Table 5.2.

PFCs (total smelter and others)	0.1 g
HFCs	
HFC-134a	negligible
HFC-152a	negligible

5.6.1 Perfluorocarbons

The main source of PFCs in New Zealand is from aluminium smelting. Small quantities are also imported for industrial purposes. The total amount from both sources is estimated to be 0.1 Gg in 1990 (NZAS, 1993).

5.6.2 Hydrofluorocarbons

Emissions of HFCs in New Zealand are thought to be negligible although there is no precise data.

In 1990 HFC-134a imported into New Zealand was in research quantities only (i.e. less than 20 kg).

Approximately 120 tonnes of HFC-152a are imported into New Zealand every year. Its main use is in New Zealand's only oil refinery at Marsden Point. The fluorine in the chemical is used as a catalyst regenerator and the HFC-152a breaks down in the process.

5.7 International Bunkers

Emissions from bunker fuels (2398 Gg CO_2, 1.06 Gg CH_4, 2.2 Gg N_2O) reflect New Zealand's geographic location, the long sea and air routes to destinations for passengers and freight, and the country's reliance on export trade (see Table 5.3).

International Bunkers-gas	CO2	CH4	N2O	NOx
	2398	1.1	2.2	44.1

5.8 Solvent Use

New Zealand does not at present collect data on Non Methane Volatile Organic Compounds (NMVOC). Historically New Zealand has not collected much data on national air quality. New Zealand, in our mid-oceanic position, with a small population, limited industrialisation and use of coal, and isolated from overseas pollutant sources, tends to have very high quality air over much of the country. So far, New Zealand has not incurred major smog problems in its cities.

The Clean Air Act 1972 provided no general direction as to broad-scale environmental issues, but was a statute for licensing individual discharges. The Clean Air Act has been now replaced by the Resource Management Act, and under this statute, several regional councils are preparing air plans. As part of this, some will develop inventories of pollution sources. As NMVOCs are precursors to tropospheric ozone formation, they may be included in these inventories.

The recently completed Ambient Air Quality Guidelines (Ministry for the Environment, 1994) lists a set of hazardous air pollutants, which includes many Volatile Organic Compounds (VOCs). Upcoming work within the Ministry for the Environment will involve assessment of these hazardous air pollutants with the aim of finding out what is being emitted (and by whom), and at what levels, to determine if further rules are needed. Future New Zealand greenhouse gas inventories will incorporate this data as appropriate.

6 Policies and Measures to Limit Emissions and Enhance Sinks

New Zealand began its response to climate change in 1988 with the establishment of the New Zealand Climate Change Programme. The Government's policy responses have since been brought together under the Comprehensive Strategy on Climate Change which aims to address sources and sinks of all greenhouse gases.

6.1 Before the Earth Summit

The New Zealand Climate Change Programme initially included three working groups – on climate change science, climate change impacts, and policy responses – to bring together the many government departments and other groups interested in New Zealand's climate change policies. A fourth working group was also established to ensure that policy recommendations were in accord with the Treaty of Waitangi. These working groups undertook substantial research and public consultation in their areas. Several reports were published by the working groups, including a discussion document on the policy options open to New Zealand.

In 1990, recognising the need for countries to make an early start in addressing climate change, the Government established a target for reducing net emissions of carbon dioxide and began implementing initial policy measures. The target was to aim to reduce net carbon dioxide emissions to 20% below their 1990 levels by 2000 conditional on the measures to achieve this objective being the most cost-effective, providing the greatest range of benefits regardless of climate change, not reducing New Zealand's competitive advantage in international trade, and having a net benefit for New Zealand society. The initial policies adopted were limited to those that reduced carbon dioxide emissions or enhanced sinks while also being justified on grounds other than climate change. The Government recognised, however, that the international community was likely to adopt a stronger approach to limiting emissions and enhancing sinks in the longer term.

6.2 Framework Convention on Climate Change

New Zealand was an active participant in the negotiation of the Framework Convention on Climate Change (FCCC). It was among the countries that signed the convention at the Earth Summit in June 1992. New Zealand ratified the FCCC on 18 September 1993, becoming the 34th Party to the Convention. It was therefore one of the 50 ratifications necessary to bring the FCCC into force. As a developed country Party, New Zealand accepts the particular obligations this involves, including:

(a) the need to adopt policies and measures to limit emissions of greenhouse gases and to protect and enhance its greenhouse gas sinks and reservoirs;

(b) a responsibility to report detailed information on its policies and measures, as well as projected emissions by sources and removals by sinks, in keeping with the timeframes identified in the FCCC;

(c) the commitment to provide new and additional financial resources to assist developing countries to fulfil their commitments on the basis outlined in the FCCC;

(d) the need to support research into climate change; and

(e) the requirement to promote public awareness and education.

6.3 The Comprehensive Strategy on Climate Change

Following on from the establishment of New Zealand's domestic target in 1990, the contribution which policies and measures would make toward achieving the target was a significant factor in relevant government decisions. The first package of measures specifically aimed at reducing carbon dioxide emissions was announced in June 1992. The issue achieved even greater prominence once the Government had signed the FCCC.

Expecting to ratify the FCCC later in 1993, the Government announced in May 1993 it would develop the Comprehensive Strategy on Climate Change. This strategy will, in time, incorporate a range of policies and measures to address sources and sinks of all greenhouse gases (apart from those covered by the Montreal Protocol) and to help New Zealand adapt to the impacts of climate change. A number of policies and measures have already been agreed to and are being implemented. Further measures will be added incrementally. This will be done in step with scientific and technological developments and the developments of appropriate policy measures, including those which are the product of the international process. The further development of commitments under the FCCC will also be an important factor.

Most of the policy measures currently being implemented are to address carbon dioxide emission sources and carbon sinks. This follows priorities identified in the negotiations leading to the FCCC.

The Government, in deciding to develop the Comprehensive Strategy, also established a clear domestic carbon dioxide target which is line with New Zealand's obligations under the FCCC. New Zealand's primary carbon dioxide objective is to return net carbon dioxide emissions to their 1990 level by 2000 and to maintain them at that level thereafter. New Zealand has also expressed a wish to reduce net carbon dioxide emissions by up to 20% below their 1990 levels by 2000 if this is possible in a cost-effective fashion without reducing New Zealand's competitive advantage in international trade.

The combination of measures which the Government has decided to put in place will see New Zealand's net carbon dioxide emissions at least 20% below the 1990 level by 2000.

Measures to address emissions of methane, New Zealand's other primary greenhouse gas, are at an earlier stage of development, though several are being implemented already. Methane emissions will also be below the 1990 level by 2000.

6.4 Policy measures being implemented to limit sources of carbon dioxide

The Government has decided to put in place a range of policy measures to reduce carbon dioxide emissions in 2000. This complements the significant increase in carbon absorption in sinks (see Section 6.5) that will see New Zealand's net emissions fall well below their 1990 level by 2000 (see Section 7).

6.4.1 Use of the Resource Management Act

The Resource Management Act 1991 provides the basis for local and regional governments' response to climate change through granting resource consents and developing plans and policies. The Act integrated provisions of more than 75 earlier laws and is founded on the concept of "sustainable management" of natural and physical resources.

'Sustainable management' under the Resource Management Act is defined as "managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while–

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment."

Greenhouse gases are regarded as contaminants under the Resource Management Act. Local authorities in New Zealand are currently being encouraged to:

- deal with resource consents with significant carbon dioxide implications by undertaking early consultation with applicants, encouraging the use of the best means practicable to reduce proposed

carbon dioxide emissions, and ensuring that emissions are monitored and that any voluntary offsets are recorded;

- base decisions as to emission reductions on a 'no regrets' approach and decisions as to mitigating the potential impacts of climate change on a 'precautionary' approach; and
- consider greenhouse gas emissions and sinks in the preparation of their regional policies and plans.

The Government has participated in several Air Discharge Permit applications where significant carbon dioxide and other greenhouse gas emissions have been involved. The Resource Management Act (RMA) has provided opportunities, prior to the consent application being made, for applicants to be encouraged to consider alternatives and adopt the best means practicable to reduce greenhouse gas emissions.

The Minister for the Environment has also made submissions with respect to greenhouse gas emissions to several consent hearings. These include the renewal of existing consents for a power station, a synthetic gasoline plant, an aluminium smelter, and the expansion of a dairy factory. In each case the conditions attached to the consents reflected the Minister's concern about greenhouse gas emissions.

Local authorities are required under the RMA to develop policy statements and plans for their areas. These policies and plans address the issue of how emissions of greenhouse gases are to be dealt with. Regional policy statements have covered:

- the promotion of renewable energy, especially planning for the environmental effects of renewable sources of energy, including wind, solar, micro-hydro, and biogas;
- the promotion of efficient energy use and energy conservation;
- the availability of water for future hydro power production;
- setting air quality standards; and
- the promotion of energy efficiency through appropriate urban design, subdivision pattern and lot orientation, and promotion of public transport systems.

The Act also allows for resource consent applications involving matters of 'national significance' to be 'called in'. Such consent applications include any relating to proposals that would affect the country's ability to achieve its policies on carbon dioxide emissions. Decisions on such consent applications are made by central government rather than the local authority. The procedure involves a board of inquiry reporting to the Minister for the Environment, with the Minister's decision being subject to appeal.

In December 1993 the Minister for the Environment called in the application for an air discharge permit for a proposed 400 MW power station. It was decided to deal with the application at a national rather than a regional level. The power station would discharge up to 1.5 million tonnes of carbon dioxide a year running at full capacity (around 5% of total 1993 carbon dioxide emissions, or 4% of projected total carbon dioxide emissions for 2000), although some of this would be initially offset by limiting the use of less efficient thermal generation elsewhere. The application for an air discharge permit is therefore of national significance with implications for the Government's climate change policy and New Zealand's international obligations.

6.4.2 Legislative and regulatory reform in the energy sector

Three new pieces of legislation were enacted in 1992 as a key part of the Government's energy sector reforms: the Electricity Act, the Gas Act, and the Energy Companies Act. This legislation provides a regulatory framework to facilitate the development of competitive gas and electricity markets.

The main objective of the reforms has been to improve the sector's efficiency, in both the production and use of energy, for the overall benefit of the economy. A key factor behind the reforms has been increased recognition of the role played by clear market incentives in the adoption of energy efficient practices.

These legislative changes do not in themselves ensure that energy efficiency will be promoted but, instead, set the scene for this to happen where commercially viable prospects exist. Overall, the energy sector reforms are expected to provide a significant boost to improving the economy's efficiency of energy use.

The significant changes enacted in the new legislation include:

- the corporatisation of electricity and gas power boards and of municipal electricity departments;
- a requirement for separate accounting of energy distribution and energy retailing functions (the 'line' and 'energy' functions) of the resulting energy companies;
- a requirement for energy companies to disclose specified information relating to line and energy costs and charges;
- the removal of franchise areas for electricity and gas retailers; and
- also price controls on gas have been removed.

The removal of franchise areas, together with the separation of line and energy charges, is intended to promote competition in electricity and gas markets including facilitating the entry of new firms. This is already encouraging the marketing of packages of energy services, including assistance with energy efficiency improvements, as companies seek to maintain and increase their share of the energy market. The reform has thus led to a shift in focus from simply supplying energy to striving to meet the needs of customers in terms of the energy services they require.

6.4.3 Energy efficiency measures

In 1992, as part of its climate change programme, the Government commissioned a study into the barriers to energy efficiency. At the same time, the Government established the Energy Efficiency and Conservation Authority (EECA) as an independent agency. EECA is charged with determining and implementing practical measures for achieving greater energy efficiency in New Zealand.

EECA is active in several areas, including:

- the development and implementation of the Energy Efficiency Strategy to address the barriers to energy efficiency identified in the barriers study;
- the development and implementation of the 'Energy-Wise Companies' programme in the private sector;
- the development and implementation of the 'Government Leadership' programme in the public sector, incorporating a number of energy efficiency requirements into the performance agreements of departmental chief executives;
- a comprehensive communications programme aimed at decision makers and all classes of energy users;
- the provision of energy management advice and services across all sectors of the economy; and
- monitoring changes in energy efficiency.

The Energy Efficiency Strategy

The Government's Energy Efficiency Strategy (EES) is a long-term strategic approach to enhancing New Zealand's energy performance. It incorporates a range of measures to facilitate the uptake of cost-effective energy efficient practices and technologies and to help overcome barriers to the development of economically viable renewable energy resources.

The measures, which span energy use in the industrial, commercial, residential, and transport sectors, are targeted at realising the most cost-effective opportunities for improving efficiency. Measures to encourage renewable energy use are also included in the strategy but are discussed in the next section.

Various studies show that there is substantial cost-effective potential for increased energy efficiency in New Zealand. Savings could amount to hundreds of millions of dollars and could make an important contribution to reducing greenhouse gas emissions.

Implementation of the Energy Efficiency Strategy began in 1993 with an initial package of measures to lay the groundwork for the rest of the Strategy. This initial package included increased monitoring and analysis of energy end uses to enable robust policies and well-directed operational activities to continue. It also included a significant increase in the already established Crown Loan Scheme. This is facilitating additional energy efficiency improvements in the public sector.

In 1994, after further energy sector research and evaluation of possible initiatives, the Energy Efficiency Strategy was considerably expanded into a 10-point plan to be implemented over the next three years. The effectiveness of the strategy in reducing carbon dioxide emissions is to be assessed in March 1995 with a view to possible enhancements that could be made to the strategy if this is seen as necessary.

The strategy is designed to inform and motivate energy consumers about what they can do to improve energy efficiency. Other key elements include the development of minimum standards relating to energy use in commercial and residential buildings, domestic appliances, and commercial and industrial equipment; assistance with commercial development of energy efficient technologies; and the evaluation of data on opportunities to make savings and how well these are being achieved. Box 6.1 gives further detail on these measures.

The Government's initiatives inform, educate, and motivate energy consumers about how best to improve their use of energy. They also reinforce and enhance activities being undertaken by a number of parties, such as energy suppliers.

Box 6.1 New Zealand's Energy Efficiency Strategy –the 10-Point Plan

1 Enhancement of work being done to improve energy efficiency standards in the Building Code. Improvements in energy use in buildings will lead to significant savings over time. These are best achieved by ensuring they are 'designed in' during construction.

2 Extension of a programme to improve the energy efficiency of residential appliances. This programme aims to improve energy efficiency in appliances through energy rating and endorsement labelling schemes.

3 Development of minimum energy performance standards for a range of appliances and equipment in the residential and industrial sectors, including hot water cylinders and electric motors. The objective is to raise the base level of energy efficiency in key technologies. This level may be raised further over time to keep pace with technological developments. Information programmes will be developed to complement the standards by helping to drive consumer demand for more energy efficient products.

4 Programmes to improve energy use in existing applications, including hot water use, commercial lighting, industrial motors and variable speed drives:

- the water heating programme focuses on encouraging and facilitating consumer action, such as installing cylinder wraps and low-flow shower heads;
- the lighting programme focuses on retrofitting a variety of technologies through providing information and promoting technologies and potential savings; and
- the electric motors programme focuses on identifying and testing means for

5 Cooperative partnerships between EECA and industrial and commercial firms and between EECA and public sector organisations, such as schools, hospitals, and departments, to improve energy use in these sectors. Box 6.2 contains detail on these cooperative programmes.

6 A programme to determine how vehicle fuel efficiency and urban air quality could be improved through an appropriate vehicle emissions testing scheme.

7 Implementation of a 'Best Practice' programme to improve energy management techniques. This programme will help provide information, motivation, guidance, and energy management solutions geared to the needs of industrial energy consumers.

8 Demonstration of efficiency technologies and increased provision of information to industry, architects, engineers, and local authorities, on the means of achieving energy efficiency. The objective is to assist the commercialisation and wider use of energy efficiency technologies.

9 Assessment of New Zealand's overall research and development needs for new forms of renewable energy such as wind, biomass, and solar power. New renewable energy resources could make an increasing contribution to sustainable energy use in New Zealand. A research and development strategy is being developed to assist innovation and the application of new technologies to New Zealand conditions.

10 A programme to improve the collection and evaluation of data about energy use and the potential for saving energy. Data collection, evaluation, and monitoring will assist in measuring trends in energy savings, and will identify how future strategies should be best developed. It also ties in with an increased emphasis on energy efficiency and non-traditional renewable energy research in the new strategy for energy research developed by the Foundation for Research Science and Technology (the body which allocates public good science research funding).

The cooperative programmes being implemented by EECA as part of the Energy Efficiency Strategy reinforce the other components of the strategy by raising the profile of energy efficiency among those making decisions regarding energy use. These programmes are the 'Energy-Wise Companies Campaign' in the private sector and the "Government Energy Efficiency Leadership" programme in the public sector. They are illustrated in Boxes 6.2 and 6.3.

Box 6.2 The Energy-Wise Companies Campaign

The Energy-Wise Companies Campaign aims to promote commitment to energy efficiency at the top management level of companies. It was launched in August 1994. An effective partnership is sought between the Government and the private sector to direct management attention to the identification and implementation of cost effective energy efficient practices and technologies. The Campaign is expected to enhance the effect of measures in the strategy targeted at the industrial and commercial sectors. The main features of the campaign are:

- a public commitment to energy management by company chief executives and managing directors through endorsement of a common charter of key principles;
- endorsement of the campaign by the Ministers of Energy, Commerce, and Environment;
- support from and participation of energy suppliers;
- support from major business, consumer, and environmental organisations;
- practical information, advisory, and secretariat support from EECA;
- an annual award to the company making the most creative and significant improvement in energy efficiency.

Box 6.3 The Government Energy Efficiency Leadership Programme

The Government Leadership Programme encourages improvements in energy efficiency within public sector agencies and institutions, demonstrating the Government's commitments to effective energy management and lowering emissions of carbon dioxide.

The programme was established in 1993 with the following key elements:

- The inclusion of energy efficiency objectives in chief executives' performance contracts. To date, these have placed formal accountability on chief executives to develop five-year plans covering energy auditing, data collection, energy management planning, the setting of targets, monitoring of progress, and public reporting.
- Funding of capital investments to improve energy efficiency through the dedicated Crown Energy Efficiency Loans Scheme. This scheme has been operating since 1989 and loans from it have totalled $3.9 million to March 1994, with cumulative savings in costs estimated at around $6.7 million. On going savings are estimated at $2.1 million per annum.
- Activity by EECA to market the Crown Energy Efficiency Loans Scheme by identifying suitable energy efficiency projects, providing technical and economic assessments, and monitoring projects to ensure savings targets are met.
- Provision of training and advice by EECA, in conjunction with other agencies, to ensure that the appropriate expertise is available to provide advice and training in support of energy efficiency programmes.

6.4.4 Renewable energy measures

New Zealand already makes extensive use of renewable energy. Some 80% of New Zealand's electricity needs are met through electricity generated from hydro and geothermal energy sources (with most of the remainder being generated from natural gas). Wood is used extensively in residential heating and some industrial uses, particularly in forest processing industries. Some geothermal energy is also used directly in industrial and commercial uses, and small hydro and wind turbines are being used increasingly to supply electricity in remote areas.

Research on non-traditional renewable energy sources

Research in the early 1990s indicated that wind-powered electricity generation is New Zealand's most promising means of utilising non-traditional renewable energy resources. In May 1993, as part of a

Government programme to research and promote renewable energy sources, a report was published identifying the technical feasibility, resource potential, and costs of a wide range of potential renewable energy sources in New Zealand.

The Foundation for Research Science and Technology (FRST) developed a strategy in 1993 for energy research over the next five years. Funding for energy related research was increased by 25% to $5.4 million with an additional $400,000 in 1995-96 and possible further increases in 1996-97. Within these amounts over the five year period, the research funding into non-traditional renewable energy is to be increased from $50,000 in 1992-93 to $1.3 million in 1997-98. Funding for research on non-renewable energy sources and traditional renewable energy will decrease from $4.1 million to $2.9 million.

EECA is also preparing a research strategy targeted specifically at non-traditional renewable energy sources. This will build on the Foundation's priority-setting exercise to further assist funders and research providers.

Measures to increase renewable energy use

The Government produced a policy statement on renewable energy in June 1993 to demonstrate its support for renewable energy. The statement sets out the Government's objective of facilitating the development of renewable energy.

The legislative and regulatory reforms in the energy sector have stressed open access to transmission facilities, improved pricing signals and competitive incentives in the electricity and gas markets. This provides improved access to markets by new electricity generators using renewable sources and new gas suppliers drawing gas from renewable or landfill sources.

Possible changes to the wholesale electricity market (see Section 6.5) would also be expected to assist non-traditional renewable energy sources in gaining access to energy markets.

A study examining possible barriers to renewable energy was undertaken in 1993. This led to the Standards Association being asked to develop a noise standard as a measure to assist in wind-power development. It also led to EECA examining additional measures that might be needed to assist in the development of renewable energy. As a result, EECA is now preparing guidelines to assist local authorities with consent applications under the Resource Management Act that relate to the use of non-traditional renewable energy resources. Import duties on large wind turbines are being reviewed with a view to removing any tariff impediments to imported turbines.

EECA will be assisting in a programme of demonstrations and information provision to help non-traditional renewable energy technologies reach maturity. Other information programmes include New Zealand's recently established membership of the IEA/OECD Information Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) renewable energy programme. New Zealand is also a party to three other IEA implementing agreements for research and development of renewable energy technologies (for wind energy conversion, bio-energy, and solar heating, and cooling systems).

6.4.5 Voluntary agreements with industry

The Government is encouraging a broad range of business sector groups to enter into voluntary agreements to reduce their emissions of carbon dioxide. These agreements are a means of building partnerships to lower New Zealand's emissions over time through the more efficient use of energy and the greater use of renewable energy.

The use of voluntary agreements recognises the critical role of business in reducing New Zealand's emissions of greenhouse gases. They provide a means of encouraging industry to consider carbon dioxide emissions when making decisions as to their type and level of energy use and, in this way, they attempt to fulfil the role of price signals that build in the environmental costs of carbon dioxide emissions.

Large companies are currently the focus of the Government as they are responsible for around 35% of New Zealand's total carbon dioxide emissions (assuming all thermally-generated electricity is used by this sector). The cement industry, for example, has recently entered such an agreement and this is outlined in Box 6.4. But efforts will be made to engage the broadest possible range of business interests in the voluntary agreements programme.

Box 6.4 The Cement Industry Energy Management Association (CIEMA)

CIEMA was formed in May 1994 as a voluntary partnership between companies in the cement industry and EECA. It aims to "continually improve energy efficiencies in the cement industry by 'best practice' and demonstrate commitment to New Zealand's international climate change obligations".

Energy use improvements of around 20% per tonne of cement are thought to be feasible within this decade and a series of energy audits is being undertaken to identify specific areas where savings can be made. Specific initiatives include the use of alternative kiln fuels (such as used oil and tyres), the use of secondary materials (such as fly-ash and blast furnace slag), product development (such as reduced 'clinker' content in concrete) and energy efficiency improvement made through the recapturing of heat and cogeneration of electricity.

The Ministry of Commerce is coordinating the development of the voluntary agreement initiative, and will be reporting to the Government in November 1994 on implementation and monitoring details, and any legislative requirements in respect of voluntary agreements to reduce carbon dioxide emissions. The agreements will be developed over the next 12 to 18 months, beginning with an examination of the potential for all major emitters to reduce emissions. Agreements may take the form of an exchange of letters, particularly in the early stages, and may progress to more formal documents later in the process.

The voluntary agreements will be designed to complement and build on the work of the Energy Efficiency and Conservation Authority (EECA) which is fully involved in developing the approach. New Zealand is also looking to draw on the experience of other developed countries, such as the Netherlands, the United States, and Canada, who are further down the track in developing voluntary agreements.

It is intended that the agreements will take carbon dioxide emissions in a base year as a starting point and will seek significant reductions in emissions below this level. These reductions are likely to be specified in terms of reduced carbon dioxide emissions per unit of output. It is not envisaged that industry parties will be given target reductions to achieve, except perhaps in a general or indicative sense. However, how the burden of reducing emissions is distributed across large industrial emitters will be considered in developing the voluntary agreements.

The agreements will seek to maximise self-policing and minimise compliance and transaction costs while, at the same time, ensuring that sufficient information is available to make the agreements verifiable and transparent. In particular, it is considered important to establish robust monitoring procedures to measure and verify reductions in carbon dioxide emissions.

The Government wishes that substantial reductions in carbon dioxide emissions be made through the voluntary agreements with industry in order to add to the overall level of emission reductions from its policy measures. The level of carbon dioxide emission reduction likely to be made under the agreements has yet to be ascertained. The Government will be actively monitoring progress on the effectiveness of these voluntary reduction initiatives.

6.4.6 Specific transport sector measures

The following transport sector measures were adopted as part of the Carbon Dioxide Reduction Action Programme in May 1992.

- **Regional Transport Strategies.** Regional Land Transport Strategies, introduced in 1992, are required to take environmental issues into account. Research is underway on how best to incorporate carbon dioxide emissions into this process.

- **Road Funding Decisions.** Transit New Zealand, the agency which allocates most roading funds, is developing procedures for incorporating carbon dioxide emissions into its cost benefit analysis. Trials are likely to begin in 1995.

- **Regional petrol levies**. Regional petrol levies to fund part of public transport costs were introduced in 1992 for a three year trial period. They transferred some of the costs of public transport from national to local agencies.

- **Speed limit education and improved enforcement.** Major reductions in open road speeds have occurred in the first half of 1994, following the introduction of speed cameras.

Vehicle fleet strategy

The Ministry of Transport is currently developing a national vehicle fleet strategy. Its intention is to manage the impacts and structure of New Zealand's vehicle fleet. The draft strategy will be presented to the Government in mid-1995, then released for public consultation. The objectives of the strategy include reducing vehicle emissions and improving the fuel efficiency of the vehicle fleet, thus reducing carbon dioxide emissions.

Actions by local authorities

Transport management has also been targeted by local government as a means of reducing liquid fuel use. Regional Councils have land transport planning responsibilities under the Transit New Zealand Act. These include the preparation of an integrated land transport strategy which takes into account regional transport needs, safety, cost and environmental considerations. As part of the strategy, regional councils determine the passenger transport needs of the region and manage the provision of passenger transport services. Also, since Transit New Zealand must incorporate carbon dioxide considerations into its funding decisions. This assists local authorities decide what emphasis they should place on this aspect.

Most local authorities are currently working on a range of approaches in developing their land transport strategies, within the scope of their powers and responsibilities. Wellington Regional Council, for example, has an integrated strategy which has been evaluated on a number of points, including likely carbon dioxide emissions.

Most local authorities are aware of the need to consider carbon dioxide emissions in evaluating new roading proposals and traffic management mechanisms.

6.4.7 Introduction of a low-level carbon charge

The Government will be actively monitoring progress on emission reductions under the measures outlined above.

If, by 30 June 1997, it is assessed that these measures are not on track to achieving a target level of emission reductions by the year 2000, then the Government will introduce a low-level carbon charge to be implemented by December 1997.

The Government has decided that the emission reduction target which will determine whether or not a carbon charge is to be introduced is, for any GDP growth rate, that level which results in emission reductions contributing 20%, and sink absorption contributing 80%, towards stabilisation of emissions at 1990 levels.

6.5 Further measures that could reduce carbon dioxide emissions

6.5.1 Wholesale electricity market development

Further reforms in the energy sector could involve changes to the wholesale electricity market. The Government will shortly be considering recommendations of the Wholesale Electricity Market Development Group (WEMDG) set up to explore alternative market structures. This group is broadly based, comprising representatives of suppliers and users, both industrial and residential.

WEMDG's draft proposal is for electricity producers and consumers to buy and sell through a pool under the proposed market structure. Thus, prices would be determined by supply and demand, rather than being set by the dominant producer, and would follow the costs of generation more accurately. There are also features that could be included in a new market structure which would assist in reducing carbon dioxide emissions. These include an energy efficiency levy for residential consumers to fund investments in their sector, and a loan fund for financing energy efficiency investments in the industrial and commercial sectors.

6.5.2 Further enhancements to the Energy Efficiency Strategy

In March 1995 the Government will assess the effectiveness of the Energy Efficiency Strategy in reducing carbon dioxide emissions with a view to possible enhancements that may be made at that stage.

The possible enhancements could include general awareness programmes, programmes for commercial and domestic energy use, heating, ventilation and air- conditioning programmes, mandatory fuel efficiency labelling, mandatory disclosure of energy use in commercial buildings, a forum on heavy road transport fuel efficiency, a driver education programme, and improved infrastructure for non-traditional energy sources.

6.5.3 The Land Transport Pricing Study

Reductions in carbon dioxide emissions are expected from the recommendation made by the Land Transport Pricing Study (LTPS). The broad goal of the LTPS is to identify the full costs of the roading system (including infrastructure, safety, and environmental externality costs) as part of the total transport system; to identify the costs that should fall on individual road users; and to make appropriate policy proposals to the Government.

There are three main components to the LTPS. The most significant of these is a study of the National Roading Account which is a set of business accounts for the New Zealand roading infrastructure as if it were owned by a single agency. Other components are the Safety Externality Study and the Environmental Externalities Study. Consultants' reports on all three projects (the National Roading Account, Safety, and Environmental Externalities Reports) are nearly complete with final policy recommendations expected early in 1995, following public consultation and peer review.

Any significant increase in road user charges and/or transport fuel prices would probably reduce the volume of petrol and/or diesel consumed in New Zealand. Any decrease in the volume of motor vehicle fuel sold can be assumed to result in a corresponding decrease in emissions.

6.6 Policy measures to enhance carbon sinks

In 2000, New Zealand's planted forests are projected to remove 25 519 Gg of carbon dioxide from the atmosphere. This annual carbon absorption level arises from new forest planting and also because the biomass of existing planted forests is increasing (caused by skewed age-class distribution). Carbon stored in natural and planted forests in New Zealand is at least 100 times greater than the net annual carbon absorption level. The forests are therefore a substantial carbon reservoir as well as a significant carbon sink. This assumes that on average 100 000 ha of new forest is planted each year.

6.6.1 Commercial planted forests

New Zealand recognises the important role that forests can play as sinks and reservoirs of greenhouse gases. In March 1994, there were 1.4 million hectares of sustainably managed planted forest. The predominant non-indigenous species is *Pinus radiata*. Since 1990 the Government has taken this consideration into account in the development of forestry policies. It has adopted a number of policies which have promoted forest expansion including:

- a return to tax deductibility in the year of expenditure for forest growing costs (which has enhanced profitability by around 7%) with the aim of establishing a taxation regime which adequately reflects the long-term nature of forestry investment;
- introduction of a 'qualifying company' regime which gives investors limited liability while being treated as individuals for tax purposes. By forming a partnership of qualifying companies, up to 125 individuals can invest in a project under the regime (earlier legislation which treated investors as individuals for tax purposes did not provide limited liability and restricted the number of individuals to 25 per partnership);
- abolition of lease duty on forestry rights (planting rights granted by a landowner to a forestry investor);
- amendment to the forestry rights legislation to allow forestry rights to be granted over land which has no Certificate of Title, thereby improving opportunities for forestry, particularly on Maori-owned land; and
- the introduction of the Resource Management Act which has the potential to reduce planning controls on sustainable forestry as a land use.

New Zealand has a sustainable forest resource which is a crop rather than a product of a natural ecosystem. This provides flexibility to manipulate the crop through management. Productivity and quality gains have also resulted from our strongly developed forestry research and development capability.

Since 1990, annual forest planting levels have been increasing and the planting level could reach 135 000 hectares in 1994, eight times the 1990 level.

Strong investment in forestry is based on many factors working in combination to make it an attractive investment. The most important factors are strong long-term market prospects, the current taxation regime, and the Government's commitment to removing unreasonable impediments to forestry and wood processing. Although there are some potential constraints on new planting investment, the balance is in favour of continued high levels of new planting.

Until land availability constraints begin to apply, possibly around 2020, new land planting is expected to continue at an average annual rate of 100 000 ha provided there is no change to the forestry investment environment.

In 2000, New Zealand's planted forests are projected to remove 25 520 Gg carbon dioxide from the atmosphere (Maclaren *et al*., 1994). This figure is based on an average 100 000 ha per year new land planting, and employs a five year rolling average to even out annual peaks and troughs. An allowance has been made for carbon lost through forest fires and shrubland clearance. In 2010 the corresponding figure is 37 890 Gg of carbon dioxide.

6.6.2 East Coast forestry project

In 1992 the Government established the East Coast Forestry Project which aims to facilitate the planting of 200 000 hectares of commercially productive forest over the next 28 years on eroding and erodible land in the East Coast region of the North Island. Government funding is available on a contestable basis to those proposing to establish and manage forest on land meeting the scheme's criteria.

Carbon sink attributes were an important consideration leading to the introduction of the project. It was estimated at the time that planting under the project would absorb, in 2000, an amount equal to around 3% of New Zealand's carbon dioxide emissions in 1990.

The planting rate has been below the target of 7000 ha per annum in the first two years of the project but it is expected to reach this level by 1995. This is included in the expected new plantings of 100 000 ha/year from 1994.

6.6.3 Indigenous forests

New Zealand indigenous forests represent a considerable reservoir of carbon, but it is not known whether this reservoir is expanding or shrinking, i.e. whether it is a sink or a source. In order to protect this reservoir, steps have been taken to discourage unsustainable management practices and to counteract injurious influences.

Indigenous forests occupy 6.2 million ha. Some 4.9 million ha are owned by the State. The vast bulk of the State resource is managed for its conservation values. It is comprised of a network of 13 national parks, 19 forest parks, and a network of other reserves. Only 164 000 hectares are managed for wood production. A further 1.3 million ha of natural forest is privately owned, half by Maori, with 124 000 hectares of this considered to be commercially viable for wood production under current market conditions. Only about 1% of New Zealand's total commercial wood production is from indigenous forests.

In recent years there have been a number of Government measures aimed at protecting and conserving New Zealand's indigenous forests. In 1990 the Government introduced the Forest Heritage Fund and Nga Whenua Rahui. These provide financial assistance to landowners to enter into voluntary forest protection agreements with the Government. Over 60 000 ha of forest have been protected under the programmes.

In 1993 the Government introduced a major amendment to the Forests Act with the purpose of promoting sustainable indigenous forest management. The amendment introduced indigenous timber milling and exporting controls with a requirement for sustainable forest management plans for private and Crown forests. The amendment should see an end to the currently low level of unsustainable indigenous forest harvesting by July 1996 - the date when transitional arrangements expire.

The Government, through the Animal Health Board and the Department of Conservation, has greatly increased the effort and expenditure on controlling the country's major mammal pest, the Australian brush-tailed possum (*Trichosurus vulpecula*). The objectives of this programme are to minimise the risk to domestic stock of any diseases for which possums are believed to be responsible, and to improve the health and regenerative capacity of important indigenous plant communities, particularly forests.

The control of possums in 700 000 ha of indigenous forest is expected to preserve or enhance these natural reservoirs of carbon and prevent them from becoming a carbon source. Longer-term possum control, and control of other pest animals such as deer and goats over the whole country is likely to depend heavily on the development of new methods of sustainable control.

6.6.4 Forest risk management

New Zealand is concerned to ensure that a 'risk averse' approach is taken to management of the national forest estate. Fire is a potential hazard, but the New Zealand Fire Service records only 1006 ha of forest as having been burnt between 1986 and 1993. This was likely to have been a mix of indigenous and planted forest. If it was all exotic forest area, it would account for approximately 0.08% of the national planted forest estate.

Insect pests and pathogens have been recognised as a threat to New Zealand's forests for many years. Well developed quarantine and forest health surveillance systems are in place to minimise the risk. Tested emergency procedures are also in place to enable eradication or containment of pest introductions which occur at a rate of about four per year. Few have significant impacts on forest health. Genetic tree improvement is offsetting growth rate losses from disease. Any decline in forest vigour that might occur as a result of pest introductions would be reflected in calculations of carbon sequestration by forests.

6.7 Policy measures to limit sources of methane

Overall, methane emissions in New Zealand are dropping. Additional measures for reducing ruminant methane are limited at present, but there is further potential for reducing methane emissions from landfills and primary production processing waste.

6.7.1 Livestock Methane

Methane emissions from livestock in 2000 are expected to be about 8% below 1990 levels (i.e. 1425 Gg).

During the restructuring that has taken place in New Zealand agriculture over recent years livestock numbers on many farms have been reduced. In part this is due to a switch to cattle from sheep. Of greater influence, however, has been the removal of subsidies and the decline in livestock commodity prices worldwide in real terms.

Changes have also been made to the taxation system, resulting in more indirect taxation and a widening of the tax base. Total government assistance to agriculture fell from 30% of output in 1984 to 3% in 1990.

As a consequence of the above factors, New Zealand farms are being run at much lower stocking rates than less than a decade ago. A continuation of this trend would lead to methane emissions from livestock in 2000 being about 5% below 1990 levels.

Forest planting could also have important implications for methane emissions for livestock. Significantly increased levels of forestry planting are being undertaken in New Zealand as a result of increases in the price of timber and amendments in 1991 to the income tax laws. If these planting rates are sustained, as expected, livestock will be displaced by the trees being planted on pasture land.

Based on Ministry of Forestry estimates of an average of 100 000 ha of new planting per annum between 1994 and 2000, methane emissions from livestock by the year 2000 can be expected to be around 3.0% lower than would otherwise have been the case. Together with the already established trend in methane emissions, it is expected that methane emissions from livestock in 2000 will be about 8% below 1990 levels.

The Ministry of Agriculture and Fisheries estimates of livestock numbers are based on anticipated developments in price, overseas markets and trading conditions, and seasonal variation. The Ministry of Agriculture and Fisheries has not made estimates for livestock numbers beyond 2000. This could be done but would only yield a continuation of the trend currently anticipated. The risk associated with such projections, however, means this exercise would have little or no value.

The current projections reflect what the Ministry of Agriculture and Fisheries considers to be the most likely outcome to 2000. As with any projections involving a number of variables, there is potential for considerable variation in these figures.

Options for further reducing methane emissions from livestock in New Zealand other than by reducing livestock numbers are limited.

Improvements to animal husbandry emphasise reducing methane emissions per unit of product, rather than emissions per animal, as the most cost effective means of reducing overall methane production. This relies on a reduced herd size while maintaining the same level of output and is more suited to developing countries, or semi-arid regions of developed countries.

Modifying enteric ecology through feed additives and/or supplements is also unsuited to New Zealand where 75% of the livestock derive nourishment from fresh pasture without individual management on a daily or even weekly basis.

The Ministry of Agriculture and Fisheries has undertaken an investigation of the management of dairy shed effluent ponds with the long-term objective of reducing the impact of effluent discharge. Such improvements may also reduce the output of methane although the reduction is expected to be small in comparison to the levels of methane emitted by ruminants.

Other possibilities for reducing methane exist in terms of altered management practices in dealing with waste from industry, breeding stock identified as low emitters, and altering the microbiology of the rumen.

The Government has commenced a research programme to investige the potential for lowering methane emissions from grazing farm ruminants by changing the natural balance of enteric bacteria that produce methane in the rumen. Funding for this programme is to double from the 1994-95 to 1995-96 financial years.

6.7.2 Landfill Methane

Methane emissions from landfills are expected to be at or below 1990 levels in 2000.

The Government has adopted a Waste Management Policy which encourages a ‘waste-generator-pays’ approach and use of the Waste Management Hierarchy. The effect of this is likely to be a gradual minimisation of waste requiring residual disposal. This, in turn, will have an effect on the amount of greenhouse gases produced from disposal processes.

Cleaner production initiatives and waste audits should also see a minimisation of waste and change in waste streams affecting the final production of greenhouse gases.

Landfill Guidelines have been produced which recommend the use of a ‘bioreactor’ design (wet) landfill which aims to treat waste to make it stable. Over the short-term more methane may be produced, but this methane will be more accessible to capture or flaring.

Composting of green wastes is also becoming more prevalent and composting facilities are likely to be set up in many areas. The intention is to divert waste from landfills.

However, other changes, including the greater use of landfills for treatment of sewage sludges, could offset some of the gains from waste minimisation and composting activities.

If all the methane from municipal landfills were to be emitted to the atmosphere, there would be a projected increase of between 5 and 12% over 1990 levels by 2000. However, between 1990 and 2000 there will be an increase in the recovery of landfill methane for the production of energy. In 2000, between 40 and 65 Gg of landfill methane is expected to be utilized for the production of energy. Some sewage ‘biogas’ will continue to be used as a fuel.

The Government will continue to promote cleaner production and waste minimisation initiatives and improved landfill management which will reduce greenhouse gas emissions. This is likely to balance

the changes in the waste stream composition and any increase in waste generation associated with an increase in economic activity and population.

6.7.3 Methane from Primary Production Processing

Considerable potential exists in the primary production processing sector to use waste to generate methane for fuel. There is increasing uptake of technology to make use of this methane potential. As the actual methane emissions from this sector have yet to be well quantified, an estimate of emissions in 2000 would be extremely uncertain, and so none is provided.

6.8 Policy measures to limit sources of other greenhouse gases

Perfluorocarbons (PFCs)

New Zealand Aluminium Smelters Ltd (NZAS) have, through changes in process control procedures, significantly reduced PFC emissions from its aluminium smelter since 1987. Through the air discharge consent process under the Resource Management Act, conditions have been put in place with respect to the discharge of both PFCs and carbon dioxide from the smelter. These conditions ensure monitoring of emissions, minimising emissions, and minimising the adverse effects of these emissions on the environment. The conditions also allow the consent authority to review conditions at specified intervals to ensure that the best practicable technical option is being used to minimise emissions and their adverse effects.

It is expected that these air discharge consent conditions will keep PFC emissions from the aluminium smelter at or below 1990 levels.

7 Emission Projections and the Effects of Policy Measures

To assist in deciding on and measuring the effect of policies related to carbon dioxide emissions, a 'business-as-usual' (BAU) projection of carbon dioxide emissions has been developed. This BAU scenario attempts to project the path which emissions would take if there had been no government policies put in place since 1990 to address the growth in carbon dioxide emissions. Estimates have also been made as to the effects of policy measures in reducing sources of carbon dioxide emissions and the effects of sink enhancements on final net carbon dioxide emissions.

The chapter also presents projections of methane emissions. These projections take account of the policy measures implemented to reduce methane emissions.

7.1 Summary of projections for source carbon dioxide emissions, carbon sinks, and methane

Carbon dioxide emissions are expected to rise by 17.8% between 1990 and 2000 if GDP growth averages 2%, and by 21.6% if GDP growth averages 3%. (This projection is shown in Figure 7.1.) Most of the increase originates in the energy sector. Further description of energy sector trends for carbon dioxide emissions is given in Section 7.2.

The effects of policy measures to reduce source carbon dioxide emissions and enhance sinks are shown in Figure 7.2. Overall, policy measures are expected to reduce the growth in source carbon dioxide emissions by 20% below the 'business-as-usual' growth by 2000.

In addition, policies to increase new forest planting are expected to remove significant quantities of carbon from the atmosphere.

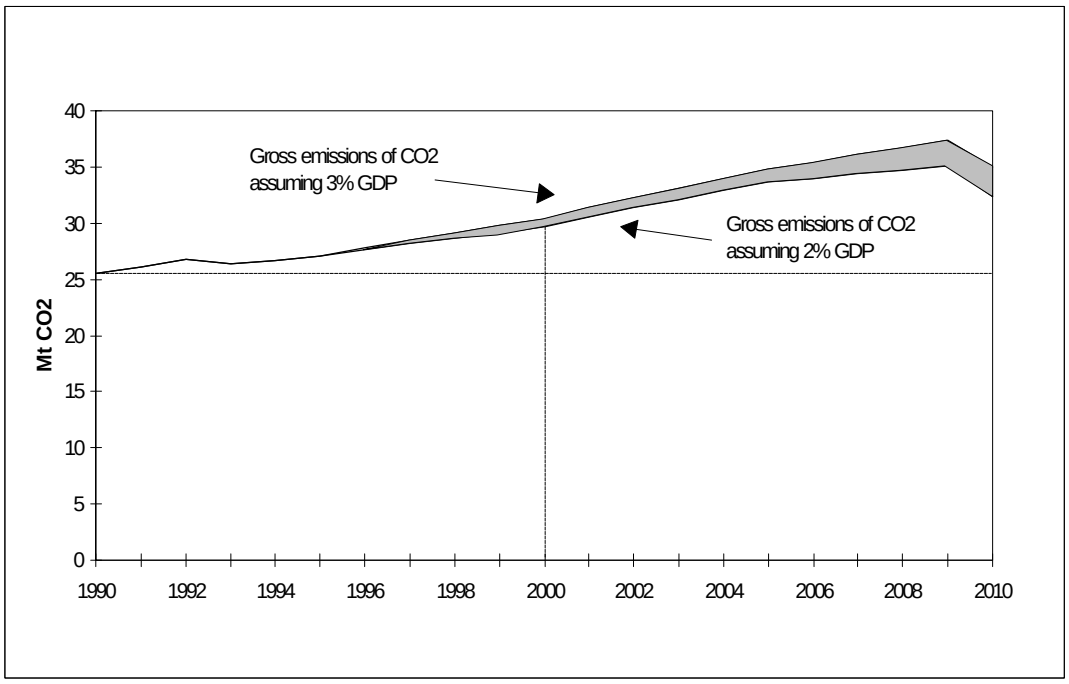


***Figure* 7.1 *Gross carbon dioxide emissions in New Zealand assuming* 2% *and* 3% GDP *growth. Source: Ministry of Commerce,* 1994.**

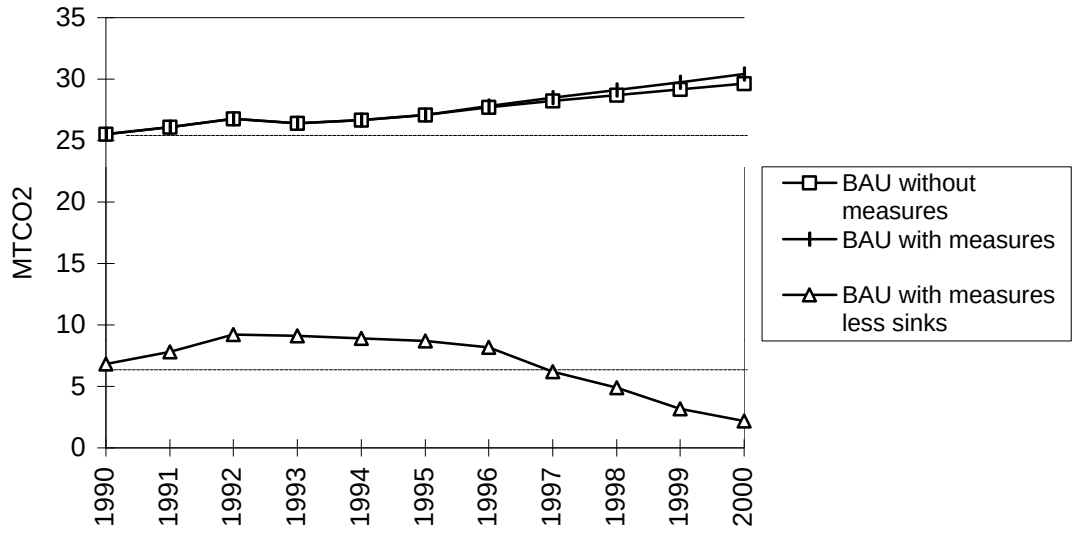


Figure* 7.2 *'Business-as-usual'* (BAU) *emissions of carbon dioxide in New Zealand and the effects of: 9a) policy measures and (b) carbon absorption. (Mid points assumed:* 19.7% *emissions growth,* 3.3% *emission reduction,* 100 000 *hectares per year forest planting with no account taken for clearance of vegetation other than forest harvest or loss due to fires).
Source: ministry for the Environment

In fact, allowing for the full effects of sink enhancement net emissions of carbon dioxide are expected to decline to between 50% and 59% below 1990 levels in 2000. The BAU projections of source carbon dioxide emissions, carbon absorption and the effects of policy measures are summarised in Table 7.1.

Methane emissions are also projected to decline between 1990 and 2000. These projections are summarised in Table 7.2.

	BAU without measures (Gg)	BAU with measures (Gg)	Sinks only(Gg)	Total Measures and Sinks (Gg)
1990	25 530	25 530	-16 716	8814
2000	30 068 to 31 042	29 160 to 29 940	-25 519	3641 to 4421

***Table* 7.1 *Summary of the effects of policy measures on carbon dioxide emissions and carbon absorption by planted forests in New Zealand. (The clearance of vegetation other than forest harvest, and loss of forest due to fire, have been taken into account). Source: Ministry for the Environment,* 1994**

	1990	2000
	(Gg)	(Gg)
Ruminants	1500	1380
Animal wastes	<118	<118
Landfills	137	<137
Primary	<296	<296

Production		
TOTAL	2051	<1931

***Table* 7.2 *Summary of New Zealand methane emissions in* 1990*, and projected effects of policy measures on methane emissions in* 2000*. Source: Ministry for the Environment,* 1994**

7.2 Carbon dioxide emission projections in the absence of policy measures

On the basis of the assumptions outlined in this section, New Zealand's carbon dioxide emissions are expected in 'business-as-usual' projections to rise by around 18-22% and 35-40% over 1990 levels by 2000 and 2005 respectively (from 25 530 Gg in 1990 to 30 068 – 31 042 in 2000, and to 34 360 – 35 708 in 2005). The main source of carbon dioxide emissions is forecast to come from the energy sector, with emissions from industrial processes making up the remainder.

Carbon dioxide emissions from all fuels are expected to increase over the period from 1990 to 2000. Emissions from electricity generation are forecast to rise by 4.8% per annum up to 2000, with emissions from coal, oil, and gas rising 1.3%, 1.4%, and 1.2% per annum respectively.

Oil will continue to be the largest single source of energy sector emissions. Gas and coal emissions also experience slight falls over the projection period. The share of total emissions from electricity generation is projected to rise from 13% to 18% over the same period.

The projections are drawn from energy production and consumption scenario work by the Ministry of Commerce. Additional information concerning emissions from industrial processes was provided by industry representatives.

These projections are based on key determinants of energy demand and supply. These include energy prices, economic and physical variables, autonomous energy efficiency improvements, and government policy.

The key assumptions over the projection period are those for GDP. Different assumptions about economic growth rates are used to provide a view of the possible range that emissions may reasonably fall within.

7.2.1 Modelling methodology and assumptions used in the carbon dioxide emission projection

Carbon dioxide emission projections to 2005 are derived from the modelling work of the Energy and Resources Division of the Ministry of Commerce. This work focuses primarily on energy production and consumption for the period 1990 to 2020 and adopts a market equilibrium approach. The model examines energy demand and fossil fuel emissions by fuel and sector.

Energy prices are the main mechanism through which the interaction between energy demand and supply occurs. The future availability of indigenous energy resources and the associated costs with bringing these, and internationally sourced fuels, to consumers, will greatly influence future patterns of energy pricing, and, as a consequence, energy consumption.

Beyond energy prices, the key determinants of energy demand and supply include economic and physical variables, economic efficiency, and government policy. Changes in the baseline assumptions concerning the key determinants of energy use have important implications for emissions growth. For example, higher economic growth is expected to lead to increases in emissions levels. Alternatively, real energy price increases may lead to reductions in energy use and improvements in energy efficiency.

Some influences on energy demand and supply cannot be predicted with much certainty. These influences include government policy, accelerated technological advancement, accelerated uptake of

technology, environmental awareness, and consumer preferences in the use of energy. Where appropriate, however, the possible effects of these factors have been taken into account.

Even if 'business-as-usual' projections for carbon dioxide emissions vary from current assumptions, e.g. if GDP growth were below 2% or above 3%, the Government will preserve its commitment to a reduction target which represents a balance between 20% emission reduction and 80% sink enhancement in achieving stabilisation of carbon dioxide emissions at 1990 levels.

7.2.2 Energy prices

Crude oil and coal prices are exogenous variables in the modelling. They are assumed to be determined by international markets. Gas and electricity prices are, however, determined by allowing for the interaction of demand and supply on a national level.

Crude oil prices

Crude oil price assumptions have been adopted from the International Energy Agency (IEA) forecasts published in the 1993 "World Energy Outlook". This outlook assumes that crude oil prices will rise slightly to $US22 per barrel by 1995. Prices will then rise slowly to $US27 and $US30 per barrel in real terms by 2000 and 2005 respectively and remain constant thereafter.

Coal prices

The price of internationally traded coal is expected to experience little growth in the period up to 2000.

Electricity prices

The current average wholesale electricity price charged by the dominant generator (the Electricity Corporation of New Zealand with approximately 95% of the generation market) is currently higher than the short run marginal cost of generation. Electricity prices are assumed to move towards the long-run marginal cost of supply as existing generation capacity is used up and new, more expensive, generation capacity is built. It is projected that the short-run marginal cost will surpass the average wholesale price after around 2000.

It is assumed that the transmission and distribution components of final electricity prices will fall as the largely fixed costs are spread over greater demand. The impact of tariff rebalancing will also work to reduce commercial and industrial electricity prices and increase domestic electricity prices.

Gas prices

At present New Zealand enjoys plentiful supplies of gas at relatively low prices. As currently known gas reserves near depletion, the growing scarcity will cause the gas to be traded from low value to higher value use. It has been assumed that there will continue to be new oil and gas discoveries, though new gas discoveries are not expected to be large enough or cheap enough to maintain the current level of supply.

As a result wholesale gas prices are expected to rise in the second half of the present decade to reflect the depletion of the Maui field. Post Maui, wholesale gas prices rise more slowly reflecting the availability of new gas reserves. Residential gas prices are assumed to remain constant until around 2000 then rise gradually over the rest of the outlook period. As in the electricity case, transmission and distribution unit costs are expected to fall with growth in reticulated demand.

7.2.3 Economic growth

Real GDP growth of 4.8% in 1993-94 and 3.6% in 1994-95 is assumed, with 2-3% being adopted for the remainder of the outlook period. This is consistent with the current predictions of most economic forecasters.

7.2.4 Real disposable income

The assumptions on real disposable income have been drawn from the New Zealand Institute of Economic Research (NZIER) publication "Quarterly Predictions". They assume 3.6% growth for 1994-95, 3.4% per annum for the period 1996-98, and 2% or 3% per annum thereafter.

7.2.5 Exchange rate

An exchange rate of NZ$=US$0.53 has been adopted throughout the outlook period.

7.2.6 Population

Forecasts of population growth were taken from Statistics New Zealand. Based on medium fertility and medium mortality assumptions and on annual migration inflows of 5000, New Zealand's population growth is expected to grow from 3.43 million in 1990 to 3.70 million in 2000.

7.3 Reductions in source carbon dioxide emissions from policy measures

The expected reductions in source carbon dioxide emissions, as a result of the policy measures being implemented, are presented in Table 7.3.

Cross-sectoral policy measures

Use of the Resource Management Act*	
Energy sector reforms	0-2%
Energy Efficiency Strategy and cooperative programmes	0.5-1%
Other less significant measures	*
Renewable energy measures	*

Specific sectoral policy measures to limit sources of CO_2

Voluntary agreements with industry	approx 1%
Specific transport sector measures	*
Development of a vehicle fleet strategy	*
Actions by local authorities	*

Introduction of a low-level carbon charge from 1997 if the threshold referred to in Section 6.4.7 is not reached =

* level of reduction unquantifiable or not yet reliably quantified

= level of charge yet to be determined (under current

modelling $10 per tonne carbon charge applied for 4 years

would generate a 2-3% emission reduction)

7.3.1 Effect of policy measures on future emissions

In total the measures described above are expected to reduce the growth in carbon dioxide emissions by 20% below the 'business-as-usual' growth by 2000, for any GDP growth rate.

In addition, the Government has announced the introduction of a low-level carbon charge in 1997 if policy measures including those listed above (other than the carbon charge) are at that time not on track to contain emissions growth by 20% by 2000.

This 20% target corresponds to a 3% (i.e. 3.6 percentage point) reduction if GDP growth to 2000 is projected to average 2%, and a 3.6% (i.e. 4.3 percentage point) reduction if GDP growth to 2000 is projected to average 3%. That is, for 2% GDP growth, the growth in emissions will need to be limited to 14.2% above 1990 levels if the introduction of a carbon charge in 1997 is to be avoided. And for 3% GDP growth, the growth in emissions will need to be limited to 17.3% above 1990 levels if a carbon charge is to avoided.

If economic growth should average more than 3%, any increased emissions flowing from that higher growth will require correspondingly increased emission reductions to be achieved (so as to maintain the 80%/20% balance) if a carbon charge is to be avoided.

It is not possible to say what the level of carbon dioxide emissions in 2000 would be, should it be necessary to introduce the carbon charge, since the exact level of the carbon charge has not yet been determined. However the commitment to introduce a carbon charge should emissions not be 'on track' as described earlier should ensure that overall carbon dioxide emissions will, by 2000, have increased by not more than around 14-17% (for GDP growth averaging 2-3%).

7.4 Summary

Overall, New Zealand's net emissions of greenhouse gases are declining (see Figure 2.1). Net emissions of carbon dioxide will be 50-59% below 1990 levels in 2000. Methane emissions will also be below 1990 levels by 2000 and emissions of perfluorocarbons (PFCs) will be stable. Although there is considerable uncertainty concerning nitrous oxide emissions these are not expected to rise over the decade.

8 Vulnerability and Adaptation Measures

8.1 Expected impacts of climate change

The New Zealand Climate Committee of the Royal Society of New Zealand provided two scenarios of climate and sea level in the year 2050, based on computer models and inference from geological evidence of conditions during warmer periods ten to twelve thousand years ago. These were within the range of the expected temperature and sea level rises reported by the IPCC in 1990 and 1992. The work of the New Zealand Climate Change Programme Impacts Working Group in 1989 and 1990 used these scenarios as a starting point.

The Impacts Working Group comprised 40 experts who drew on the expertise of a network of over 300 people spanning all economic sectors. A process of consultation was used which allowed the assembly of a substantial body of information and expert opinion to provide a comprehensive assessment of the possible impacts of climate change in New Zealand.

The impacts most likely for New Zealand are:

- warming is expected to be similar for both the North and South Islands but winter temperatures may rise faster than summer temperatures in more southern parts of the country;
- average westerly winds over New Zealand may decrease, particularly in the winter;
- whilst winter rainfall might decrease, summer rainfall might increase in western and northern parts of both Islands (predictions of likely changes in rainfall patterns are still quite uncertain);
- most New Zealand glaciers will shrink at a faster rate than previously;
- seasonal snow storage in the South Island will decrease, with increased flows in winter and decreased flows in summer likely for large snow-fed rivers;
- New Zealand sea levels are likely to rise by between 7 and 17 cm by the year 2025 and between 17 and 35 cm by the year 2050.

The Royal Society of New Zealand has identified the most likely prospect (based on a 'business-as-usual' scenario) as being "an accelerating warming trend so that temperatures average 0.5° C - 1.0° C higher than at present by the year 2025 and perhaps 1.0° C - 2.0° C higher by about the year 2050". While this is slightly lower than the IPCC predictions both the temperature rise, and the consequent sea level rises, are within the range predicted by the IPCC.

Overall Effects

Beyond this broad identification, the types and extent of effects is difficult to predict for New Zealand. There are, however, a number of generally agreed findings that the Impacts Working Group identified. Some of these are:

- the greatest immediate impacts could arise from changes in the severity and frequency of climatic 'extreme events' such as floods and storms;
- the costs and benefits of the effects will not be evenly spread either at national or local level. Some regions would tend to suffer particularly adverse consequences and others less adverse consequences or benefits;
- because of the complexity of the global climate system, there may be 'surprises' which cannot reasonably be predicted. Great uncertainty still exists regarding the likelihood of climatic change and its consequences and more information and monitoring is required to increase understanding and to enable well informed decisions and plans to be made;
- Maori lands and estates in coastal and estuarine areas and on floodplains, taonga (treasures) such as native forest species, and traditional sources of seafood and other resources, would be particularly affected by climatic change and sea level rise;

- the adverse effects of climatic change could be most severe for those parts of the environment and society which are least able to adjust. These include native ecosystems and species which are already under threat or at the limits of their climatic change, and groups in society who are disadvantaged and lacking in the resources needed to respond to change, such as low income people living in flood prone areas, or the elderly or infirm.

8.2 Actions taken to adapt to the impacts of climate change

8.2.1 Adaptation to possible sea level rise

After extensive public consultation the New Zealand Coastal Policy Statement (NZCPS) was prepared under the Resource Management Act (RMA) in 1994. This policy statement is to guide local authorities in their day-to-day management of the coastal environment.

The NZCPS has provided a structure for adaptive response to sea level rise as part of the national strategic planning framework. The NZCPS requires recognition of the potential impacts of likely changes in sea level, including the need to avoid development in areas prone to inundation or accelerated erosion; protecting human life, essential facilities and economic activities; and ensuring that the integrity of natural systems and their buffers is not unduly affected.

Local authorities are already taking action to respond to climate change through their response to the NZCPS. The emphasis to date has been on avoiding and mitigating the possible effects from future sea level rise. Some councils have already incorporated sea level rise considerations as policy while others are developing these policies as part of their RMA responsibilities.

8.2.2 Avoidance and Mitigation of Natural Hazards

Climate change may result in more frequent occurrence of 'unusual' climate events, and greater extremes such as high rainfall, severe winds, and periods of drought. Coastal and low-lying land is particularly vulnerable to natural hazards resulting from climate change such as sea level rise. Planning to reduce the adverse effects of natural hazards is particularly important at local government level because the hazards usually have localised effects.

Local authorities have a stake in avoiding, minimising, and mitigating the costs and effects of natural hazards because:

- they are responsible for providing services and utilities necessary for the wellbeing of communities;
- they are responsible for the avoidance and mitigation of natural hazards through plans and rules under the RMA;
- they can be liable for loss or damage to private property in specific circumstances.

9 Finance and Technology

9.1 Contributions to the financial mechanism

New Zealand has agreed to contribute a substantial amount of new and additional funding to the Global Environment Facility (GEF), which is the international entity entrusted with the operation of the financial mechanism of the FCCC on an interim basis. For the 1994-96 replenishment, New Zealand's contribution will be around NZ$10.4 million (SDR 4 million). Roughly half of this amount is an assessed share. The remainder is a supplementary contribution. On a per capita basis, this contribution is one of the largest to the first operational phase of the GEF.

New Zealand did not contribute to the pilot phase of the GEF. It had a range of concerns about the operation of the GEF in the pilot phase. These have been addressed to its satisfaction in the negotiations on the restructuring and replenishment of the GEF, in which New Zealand played an active part.

9.2 Actions to implement Article 4.3, 4.4, and 4.5

New Zealand is fulfilling its Article 4.3 commitment at this point through its contribution to the GEF.

New Zealand recognises the need to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects (Article 4.4). Although the Intergovernmental Negotiating Committee (INC) has not reached an agreed interpretation of this commitment, New Zealand has been active in the debate in trying to find an acceptable outcome.

New Zealand has a particular concern about the possible implications of climate change for the small island developing states. They make little contribution to the problem of climate change, yet stand to be among the first to suffer the consequences.

9.3 Financial resources provided through bilateral, regional, and other multilateral channels

Through its multilateral, regional, and bilateral Official Development Assistance (ODA) programme, New Zealand has supported a number of projects which are relevant to the problem of climate change. Some projects have the effect of mitigating the process of climate change through lowering net emissions of greenhouse gases (such as through increased energy efficiency, the increased use of alternative fuels, or enhancement of forest sinks), others enhance the ability of assisted countries to cope with climate change (see also Section 10.8, Capacity Building in Developing Countries).

New Zealand values regional approaches to development and environmental issues and its ODA programme has a strong regional component. New Zealand contributes to a number of regional development cooperation organisations, including the South Pacific Forum Secretariat, the South Pacific Applied Geoscience Commission, and the South Pacific Regional Environment Programme (SPREP).

9.3.1 Mitigation

Energy efficiency and alternative energy

New Zealand is providing ongoing funding of approximately NZ$250,000 annually to a project administered by the South Pacific Forum (a grouping of South Pacific independent and self-governing

countries). This project is aimed at reducing Pacific developing country dependence on petrol, in particular through the increased use of alternative fuels.

In the 1993-94 financial year New Zealand contributed NZ$200,000 to a project organised by the Association of South East Asian Nations (ASEAN) to further the use of natural gas in the transport sector. In the same financial year New Zealand also provided NZ$452,000 for an ongoing geothermal power project in Indonesia (to which it has contributed approximately NZ$1.5 million so far) and NZ$25,000 for studies into the viability of geothermal power in Vanuatu, Fiji, the Solomon Islands, and Papua New Guinea. The New Zealand ODA programme also allocates approximately $1 million annually on an ongoing basis to support study at the Geothermal Institute at Auckland University, New Zealand. The Institute teaches a diploma course in geothermal resource management.

Forestry Projects

New Zealand has allocated significant ODA resources to forest sector projects for some time and supports forest programmes in a number of Asian and Pacific countries. Assistance takes several forms: policy and technical advice, assistance in forest conservation and the creation of national parks, assistance in afforestation and planted forestry projects, and assistance in monitoring. New Zealand contributed approximately NZ$6 million to ongoing projects of this type in 1993-94.

9.3.2 Adaptation

New Zealand recognises the special difficulties climate change poses for developing island countries and supports a number of projects that will help countries deal with them. These include the development of meteorological services and coastal zone management programmes which will assist responses to the increased erosion and sea level changes that climate change could cause. The total expenditure on projects of this sort in the 1993-94 financial year was approximately NZ$1.5 million.

10 Research and Systematic Observations

New Zealand takes its responsibilities for research and monitoring related to climate change very seriously. Because New Zealand is situated in a data-sparse region of the South Pacific our national climate observations are of global importance. The country's isolated location and low population mean the atmosphere is less affected by localised pollution sources than much of the Northern Hemisphere. This has enabled New Zealand to build a strong research and monitoring programme on background levels of greenhouse gases and related atmospheric constituents.

A National Science Strategy Committee for Climate Change (NSSCCC) has been appointed by government to provide advice and coordination on climate change science issues. It has developed a strategic framework for climate research and monitoring, and reports annually to the Government. The NSSCCC report (National Science Strategy Committee for Climate Change, 1993) includes a detailed listing of climate change research projects. Climate change research also has priority research theme status for funding from the Public Good Science Fund, a fund that represents 60% of all government science funding.

An important facet of New Zealand's strategy is collaboration within international research and monitoring programmes. New Zealand research groups participate in projects within the International Geosphere Biosphere Programme (IGBP) and the World Climate Research Programme. New Zealand scientists contribute to the assessments carried out by the Intergovernmental Panel on Climate Change.

National expenditure on climate change research within Crown Research Institutes and Universities in the 1993-94 financial year is estimated as NZ$14,100,000 (US$8,200,000).

10.1 Research on the Impacts of Climate Change

New Zealand completed an initial assessment of national impacts of climate change in 1990 (Mosley, 1990). Work is continuing on important areas identified in this assessment which require more research. Specific projects focus on potential impacts on coastal and estuarine regions, agriculture and horticulture, ecosystems, water resources, alpine environments (including glaciers and seasonal snow), and Pacific Islands and their reef environments. A key component of many of these studies is determination of the sensitivity of physical and biological systems to variations in climate.

The research summarised above includes two research programmes which are components of the Global Change and Terrestrial Ecosystem Core Project (GCTE) of the IGBP. These are:

- a multidisciplinary study of the effects of elevated carbon dioxide concentrations and of variations in climate and UV-B radiation on temperate pasture ecosystems, and the implications for animal production.
- an experiment in which open-top chambers are being used to investigate the interactive effects of increased temperature and elevated carbon dioxide concentrations on indigenous red beech and exotic radiata pine forest ecosystems.

Work has begun on a computer-based framework for integrated assessment of climate and sectoral impact information to determine the sensitivity of the natural and managed environments of New Zealand to climate variability and change (CLIMPACTS).

New Zealand scientists are the convening lead authors for two chapters within the 1995 IPCC assessments. These are the chapter on changes in sea level of the Working Group I scientific assessment, and the chapter on the cryosphere in the Working Group II report on impacts and adaptation options. New Zealand scientists are contributing authors for several other chapters.

10.2 Modelling and Prediction, including Global Circulation Models

Regional modelling of climate variability, extreme events, and climate change is a priority theme within the climate change research strategy. New Zealand has not developed its own global circulation model (GCM) but collaborates with other countries which are already running such models, particularly Australia.

The main climate modelling and prediction activities in New Zealand are:

- Assessing how well various climate models simulate current atmospheric circulation systems in the Southwest Pacific/Tasman Sea/New Zealand region.
- Developing and testing techniques for simulating regional climatic variations around New Zealand given the output from global circulation models. These techniques include mesoscale meteorological models, and statistical techniques (model output statistics) which relate observed local weather to larger scale circulation features.
- Using palaeoclimate indicators to infer climates of various regions of New Zealand during unusually warm periods in the past, as a possible guide to the local influences of future global warming.

Research of this type and global predictions from the Intergovernmental Panel on Climate Change have been used to provide guidance on possible future changes in climate around New Zealand (Royal Society of New Zealand, 1990). Revised national climate change scenarios are being developed for a joint Australia/New Zealand climate change conference to be held in October 1994.

Collaboration with the Division of Atmospheric Research of CSIRO, and with the Bureau of Meteorology (both in Melbourne, Australia) are important facets of New Zealand's modelling and prediction research. These Australian groups have hosted New Zealand's modelling and prediction research and New Zealand scientists for extended periods.

New Zealand work on Southern Hemisphere validation of global circulation models contributes to the international Atmospheric Model Intercomparison Programme (AMIP) within the World Climate Research Programme. A workshop was held in Wellington in May 1994 for palaeoclimate scientists and climate modellers to discuss palaeoclimate studies in the Southwest Pacific/New Zealand/Antarctic region which could contribute to validation of global circulation models.

10.3 Climate Process and Climate System Studies

10.3.1 Trace Gases, Atmospheric Chemistry, and Aerosols

Processes governing methane and nitrous oxide concentrations are of particular interest because of New Zealand's agriculturally based economy. Changes in carbon isotope ratios in methane samples collected at the Baring Head clean air monitoring station (near Wellington) have been used to investigate reasons for recent changes in global methane concentrations. Initial work has been done on production of methane by ruminants and possibilities for reducing this. The attenuation of methane emissions from subsoil anaerobic processes by surface wetlands is also under investigation. Research is commencing on aircraft vertical profile measurements of methane concentration to estimate integrated net emissions over regions of several hundred square kilometres.

Research is under way on factors influencing nitrous oxide emissions from soils under pastures. This work is now being extended to include other important New Zealand ecosystems.

Research on terrestrial sources and sinks of carbon dioxide is a priority theme because of New Zealand's extensive indigenous forests, and rapidly extending planted forests. Research topics include carbon uptake and exchange by forest and grassland ecosystems, and the carbon budget through the life-cycle of managed plantation forests. Further topics include interpretation of fluctuations and trends in Southern Hemisphere carbon dioxide concentrations as measured at the Baring Head clean air research station, and work on greenhouse gas emissions from New Zealand vehicles.

The research on carbon dioxide and on methane fits under the umbrella of the International Global Atmospheric Chemistry Project (IGAC) of IGBP. Relevant atmospheric chemistry work also includes

studies of regional variations in the oxidative capacity of the atmosphere, using isotopic measurements on carbon monoxide.

Aerosols affect the radiative balance in the atmosphere, both directly and through their role in cloud formation. IPCC scientific assessments suggest they may be offsetting some of the warming effect of anthropogenic greenhouse gases. New Zealand has made various aircraft-based observations over the last decade of aerosol concentrations and properties over the Southwest Pacific. Because of our remoteness from large industrial aerosol sources we have developed a particular interest in natural atmospheric aerosols, and are collaborating with Australian and United States scientists on studies of naturally produced sulphur aerosols.

10.3.2 Ocean Processes and Ocean-Atmosphere Exchange

New Zealand is surrounded by a huge expanse of ocean which plays an important role in moderating our climate, in uptake and release of greenhouse gases, and in production of natural aerosols from substances such as dimethyl sulphide. During the 1993-94 year scientific cruises have been undertaken to study ocean carbon fluxes off the West Coast of New Zealand, and in part of the subtropical convergence zone to the east of the country. This work on carbon fluxes contributes to the Joint Global Ocean Flux Study (JGOFS) of IGBP.

Samples of sea water have been isotopically analysed by New Zealand scientists for many years to track changes in the concentration of carbon from atom bomb tests in the eastern Pacific as a guide to oceanic uptake and transport. New Zealand is also participating in ocean transect measurements under the World Ocean Circulation Experiment (WOCE) of the World Climate Research Programme (WCRP), and is undertaking work on oceanic dimethyl sulphide production.

Further understanding of interchanges of energy momentum and trace gases between the ocean and atmosphere is needed to improve coupled atmosphere-ocean circulation models, and to improve predictions of trends in greenhouse gas concentrations. New Zealand research groups participated in the TOGA-COARE (coupled atmosphere-ocean response experiment) project of the World Climate Research Programme. They are currently analysing and interpreting the data they collected on fluxes of energy, momentum, and carbon dioxide. Work has been published on the physical chemistry of air-sea gas exchange, and research undertaken on air-sea exchange of carbon dioxide across the subtropical convergence east of New Zealand.

New Zealand scientists are carrying out research on breaking waves, which influence ocean-atmosphere exchange processes. Interactions between waves and floating Antarctic ice are also being investigated.

10.3.3 Land-Atmosphere Interactions

Measurements are being made of energy and water balances over forest, grasslands, ice and snow. Experimental and theoretical research is underway to improve estimates of land/vegetation/atmospheric transfer over heterogeneous areas and at regional scales. This includes collaboration with overseas groups, and observational and numerical modelling studies of mesoscale circulations influencing local climate. Modelling studies of changes in carbon exchange between New Zealand's land systems and the atmosphere in response to changes in land use and climate are also in progress.

The processes through which mountains influence regional weather and climate (precipitation, temperature, and wind) are of particular interest to New Zealand. These are being studied within the Southern Alps Experiment (SALPEX).

10.3.4 Climate Trends and Variability

Observational data from the past 140 years from New Zealand and the Southwest Pacific have been checked and homogenised to produce comprehensive data sets for climate change research. These data sets have been analysed for trends and variability in regional temperature and rainfall. This data has also been used to study atmospheric circulation features in the South Pacific and their influence on regional climate. Information on earlier climatic features of the South Pacific, New Zealand, and Antarctica, is being obtained from tree ring measurements, pollen analyses, sediment studies, and borehole temperature measurements.

10.4 Data Collection, Monitoring and Systematic Observation, including Databanks

New Zealand's monitoring and observation activities relevant to climate change are summarised in a recent Ministry for the Environment publication (Ministry for the Environment, 1993). They include:

- **Climate monitoring:** Climate and weather observations from New Zealand and the South Pacific islands are archived in the National Institute of Water and Atmosphere Research (NIWA) climate databank. A set of 26 existing climate stations has been proposed for a reference climate station network.

- **Oceans:** NIWA is monitoring sea surface temperatures at coastal sites using *in situ* temperature recorders, and sea surface temperature over the ocean using satellites. Auckland University scientists will participate in the international Acoustic Thermometry of Ocean Climate (ATOC) experiment to monitor ocean temperatures over a ten year period.

- **Greenhouse gases and aerosols:** NIWA measures concentrations and isotope ratios in carbon dioxide, methane, and carbon monoxide, as well as aerosol properties and non-methane hydrocarbons, at the Baring Head clean air monitoring station. The carbon dioxide data are submitted to World Meteorological Organisation (WMO) databases, and information on other chemical species is maintained by NIWA.

- **Stratospheric ozone monitoring:** The NIWA research station at Lauder in Otago is the mid-latitude Southern Hemisphere site of the Network for the Detection of Stratospheric Change. Measurements include stratospheric ozone and oxides of nitrogen, stratospheric aerosols, and detailed spectral measurements of surface UV radiation. NIWA also monitors stratospheric ozone and oxides of nitrogen near Scott Base in the Antarctic, and in collaboration with France has installed monitoring equipment at Kiribati near the Equator.

- **Sea Level:** The Department of Survey and Land Information (DOSLI) maintains an open coast tide gauge offshore of Tauranga on New Zealand's North Island, and one at Scott Base in Antarctica. The ports of Auckland, Wellington, Lyttelton, and Dunedin, have 90 year sea level records. DOSLI also monitors subsidence or crustal deformation in the vicinity of key tidal gauge sites.

- **Hydrology:** NIWA operates almost 300 river flow and lake level measurements throughout New Zealand. The Institute of Geological and Nuclear Sciences (IGNS) carries out an annual survey of snowlines and the position of glacial snouts.

- **Terrestrial landscapes and ecosystems:** Landcare Research maintains five New Zealand long-term ecological research and monitoring sites, and also monitors erosion, plant species population and vegetation patterns at a number of other mainland and offshore island sites. These monitoring studies include the use of satellite remote sensing and Geographic Information Systems (GIS) techniques. National information on land resources, soils and vegetative cover is archived in databanks held by Landcare Research. The New Zealand Pastoral Agriculture Research Institute Ltd. (AgResearch) has conducted a national survey to monitor pasture composition and subtropical grass distribution, and plans future studies to detect any changes in patterns. Landcare Research monitors the presence or range of self-advective fungal and insect species.

- **Forests:** The Ministry of Forestry keeps records of carbon absorbed in new planting and lost through logging, fires, and vegetation clearance. The New Zealand Forest Research Institute (NZFRI) is conducting long-term research (including monitoring) on a central North Island radiata pine forest.

- **Antarctica:** NIWA monitors climate at Scott Base, and holds climate records from field expeditions. Databases of Antarctic environmental information are being developed at the International Centre for Antarctic Information and Research (ICAIR) in Christchurch.

10.5 Socio-economic Analysis of the Impacts of Climate Change and of Response Options

The CLIMPACTS study (already noted under impacts research) aims eventually to quantify the economic impacts on various sectors (e.g. agriculture, forestry) of climate change.

The potential impacts of carbon taxes on New Zealand's GDP and on various sectors of the economy have been investigated using economic models. The economics of energy efficiency for New Zealand have also been investigated, including possible spin-offs in reduced carbon dioxide emissions.

10.6 Technology Research and Development

The feasibility for New Zealand of extending the area under plantation forests as a "technology" for absorbing carbon dioxide has been carefully analysed, and methodology has been developed for estimating carbon sinks provided by new plantation forests.

A research and development programme seeks to reduce greenhouse gas emissions during coal combustion and to introduce new combustion technology to New Zealand. Also, the injection and containment of waste greenhouse gases in underground reservoirs (such as exhausted natural gas fields) has been mathematically modelled under contract to the Research Institute for Creative Technology, Kyoto, Japan.

New Zealand's research and development efforts in energy efficiency and renewable energy contribute to reducing greenhouse gas emissions. Our renewable energy research and development focuses on more efficient use of solar energy, and on identifying suitable sites and undertaking pilot studies for wind energy. There is also a small programme on tidal stream energy generation.

Research programmes are also addressing improved energy efficiency. These include:

- improvements to the mechanical pulping process for New Zealand's dominant planted wood resource (*Pinus radiata*), to make this more energy efficient;
- improved energy efficiency in the food industry through process controls and optimisation of freezing requirements for specific food types;
- optimising the efficiency of industrial electric drive motors;
- optimisation of energy use within buildings, life cycle analysis of the environmental effect of buildings, and development of an energy rating system for complete buildings.

10.7 International Programmes

Collaboration in international climate change research is essential for New Zealand, because of the global scale and the complexity of processes which influence climate. Collaboration on projects of the World Climate Research Programme (WCRP) and the International Geosphere Biosphere Programme (IGBP), and contributions to the work of the Intergovernmental Panel on Climate Change (IPCC) have already been covered under the individual research headings of this report.

New Zealand continues to provide climate and greenhouse gas monitoring data to international data centres under WMO/ICSU (International Council of Scientific Unions) programmes which are now being coordinated into a Global Climate Observing System (GCOS). New Zealand operates the Southern Hemisphere mid-latitude station of the Network for the Detection of Stratospheric Change (NDSC). A tripartite agreement to foster climate change research collaboration with Australia and the United Kingdom has operated for four years and is currently under review.

New Zealand is currently exploring ways of participating in IGBP START (Global Change System for Analysis, Research and Training) activities for the Antarctic and Oceania regions. We are also participating in discussions regarding the formation of an Asia-Pacific Network (APN) for Global Change research.

New Zealand has recently become a member of the OECD Megascience Forum. One of the subject areas under consideration is global change research.

10.8 Capacity Building in Developing Countries

The potential impact of sea level rise is of great concern to small Pacific Island nations to the North of New Zealand, and our capacity building efforts are concentrated in this region.

New Zealand provides financial, training, and technical support, to assist meteorological services in several of these countries. As well as providing weather forecasts these national meteorological services make climate observations and provide climate change advice to their governments. A New Zealand scientist participated in a World Meteorological Organisation (WMO) review of climate monitoring and impacts in the South-West Pacific (Brook *et al*., 1992), and New Zealand is now funding a CLICOM inventory and review project through the South Pacific Regional Environment Programme (SPREP). CLICOM is a personal computer based climate archiving system developed for small countries by WMO.

New Zealand also produces the monthly South Pacific Climate Monitor, in collaboration with Pacific Island meteorological services. Data provided by these services, together with global climate diagnostics information (such as the state of the El Nino – Southern Oscillation), are compiled into a summary and outlook bulletin for use by regional meteorological services and individuals.

11 Education, Training and Public Participation

11.1 General Public Information

In 1991 the Ministry for the Environment produced a pamphlet "Climate Change – Exhausting the Future" explaining the science, likely impacts, and responses individuals might make to reduce emissions. This was updated in 1993.

In addition the Ministry for the Environment produced posters and accompanying material on climate change in 1991 and 1994. Material produced for World Environment Day in 1989 ("So you want to save the World") and 1992 ("Take the Green Road") encouraged individuals and communities to take actions which among other things reduced greenhouse gas emissions.

The Ministry for the Environment has also produced reports and general information sheets on climate change science, monitoring and possible impacts for New Zealand. Examples are:

Climate Change: Impacts on New Zealand. Implications for the Environment, Economy and Society. (Mosley (*ed*.), 1990a).

Climate Change: A Review of Impacts on New Zealand. (Mosley, 1990b).

Climate Change: The Consensus and The Debate. (Wratt *et al*., 1991).

A Climate Change Monitoring Network. (Ministry for the Environment, 1993).

Local government also has a public education function through newsletters, community development, local publicity material, healthy cities promotions, and seeking to encourage community and individual responsibility in energy use, recycling, and driving habits. Many local authorities are active in promoting recycling, public transport use, support for local facilities and activities, and sustainable land use planning.

11.2 Material for schools

Much of the material produced for the general public has been provided to schools. Specific information for schools was produced to accompany the 1994 climate change poster.

A "green box" containing environmental information is sent to all New Zealand schools every six months. Material on climate change from many sources is included in these boxes.

11.3 Information and education material for specialist groups

The Ministry for the Environment has provided local government with advice and information on climate change. This has included the publications "Information for the Guidance of Local Authorities in Addressing Climate Change" (Allen, 1993) and "Waste and the Resource Management Act" (Ministry for the Environment, April 1994).

EECA has provided material to a number of groups.

Regional and district councils are also educating and working with sectoral interests within their areas to limit and minimise greenhouse gas emissions. For example, applicants for resource consents are being encouraged by councils to consider the following issues in the design of their proposals:

- consumer education identifying practical ways in which the burning of fossil fuels can be reduced;
- encouragement of greater efficiency in production and use of energy from fossil fuels;

- encouragement of a transfer to technologies which do not produce greenhouse gases or produce reduced levels, including types of agricultural production and agricultural technologies;
- account taken of efforts to enhance sinks and reservoirs of greenhouse gases.

11.4 Public participation

There have been opportunities for interest group input throughout the Government's policy development programme. In 1990 a discussion document on policy options was released accompanied by considerable publicity inviting any interested party to make a submission. The discussion documents were provided free of charge to any person or group who requested them. Meetings were held with industry and environmental and professional groups. In addition a three day hui (meeting) was held with Maori people to discuss climate change science, impacts, and responses.

In 1991 a scoping paper "Developing a Strategy to Reduce Carbon Dioxide Emissions" was circulated. This was produced by the Ministries for the Environment, Commerce, and Transport and circulated widely. Submissions on this contributed to the policy development leading to the Carbon Dioxide Reduction Action Plan in 1992.

A further round of consultation occurred in 1994 leading up to the Government's decision on the package of policy measures it would adopt to reduce carbon dioxide emissions. A consultation document was sent to industry, local authorities, environmental groups and any others who requested a copy. Submissions were received which contributed to the advice officials provided to ministers. Meetings were also held with a number of key organisations.

In relation to the Framework Convention on Climate Change (FCCC), the Government has maintained a dialogue with interested non-government organisations (NGOs), and individuals. Material related to the negotiations, including reports by New Zealand delegations, have been circulated. Public discussions and briefings on the progress of negotiations have also been held from time to time.

The Ministry for the Environment holds regular meetings with environment NGOs, professional bodies, and local government and industry leaders. Each group meets six times a year. Climate change is almost always on the agenda.

Local government also provides consultation opportunities on resource consents, and public input into plan preparation. Under the RMA any person has the opportunity to make a submission when a resource consent, plan, or policy statement is notified. Those making submissions can also participate at hearings and prehearing meetings.

Annex 1

Soil Carbon Changes

In New Zealand, changes in land use are usually accompanied by only small shifts in the quantity of inputs (from plant and animal residues), making difficult the estimation in soil carbon storage. In addition direct estimation of total above and below ground inputs is very difficult especially for perennial species, generally requiring the use of process-based predictive models.

Such models are under active development in New Zealand. There are few reports of the effects of different land uses on soil organic matter (the main carbon reservoir) in New Zealand, and none that permit spatial integration over large areas; most studies have been on the local effects of converting established pasture for arable use. New Zealand soils are estimated to contain 4262 ± 190 megatonnes (Mt) carbon to 1 metre depth.

Deforestation in New Zealand over the past millenium has resulted in the loss to the atmosphere of about 4 gigatonnes (Gt) vegetation carbon; the associated loss of soil carbon, either directly from the effects of burning or indirectly from subsequent soil erosion, is unknown. However, fire-induced carbon losses from litter and the upper few millimetres of mineral soil, probably would have been similar to above-ground losses.

Extensive forest removal occurred during the 19th and early part of the 20th Century for the development of pastoral farming. However, the influence of these forests on New Zealand's soil processes is still evident today, including the persistence of a considerable proportion of the forest soil carbon. Improved pastures represent 24% (approximately 6.5 million ha) of the total area of New Zealand. Despite losses of soil carbon at the time of forest clearances, the introduction of legume-based pastures has over time maintained or increased soil carbon at similar levels, in spite of accelerated carbon turnover rates. In a recent study where soil type and climate were comparable, conversion of indigenous forest to faster-growing exotic species, or pasture, gave no detectable changes in topsoil or microbial carbon after several decades.

Recent changes from pasture to arable cropping and horticulture could have contributed as much as 5 Mt carbon to the atmosphere over the last ten years. Further losses of carbon from soil erosion (wind and water) are likely, but no estimates are available.

Reversion to forest of marginally economic hill pastures, mostly in the North Island, represents the main New Zealand equivalent of land abandonment; this has occurred periodically in the past, but has been particularly evident in recent years during restructuring of the New Zealand economy. Shrublands are quite extensive, and currently cover over 1 million ha. Removal of grazing animals and cessation of fertiliser application result in only slight changes in soil carbon contents, but a general slowing down of soil carbon turnover. In addition to accumulation of carbon in woody shrubland species (unimproved pasture ca. 2 t C/ha; shrubland ca. 70 t C/ ha), the reversion process, in the absence of fire, increases carbon storage on the soil surface as litter and in the mineral soil. No quantitative estimates are available for the rate or magnitude of this increase in soil carbon, but is expected to be quite small.

The major current land use change throughout New Zealand is from shrubland and (marginal) pasture to planted forest. A planting rate of at least 100 000 ha per year is forecast to continue for the next few years. Where the new forests are planted in dune-sands or eroded land, then soil carbon will increase markedly. Forest planting in shrubland or pasture, however, will not result in rapid changes in soil carbon. The direction, rates, and ultimate magnitude of these changes are difficult to predict without reliable process-based models operating in a timeframe of years to a century.

An early indication of the direction of change in soil carbon may, however, be possible from an assessment of soil microbial processes. Recent research indicates that soil carbon can either increase or decrease under forests, and that establishment of a new steady state may take several decades. This is one reason why current research is endeavouring to improve predictive models based on an understanding of soil/plant/ atmosphere carbon exchange processes, and their regulatory controls.

Annex 2

Methodology for Carbon Sequestration in Planted Forests

The total standing volume of stemwood is used to estimate biomass which is then converted to stored carbon. This calculation is done as follows:

1 The physical make-up of the forest is determined to obtain an estimate of the area of land in each age class and 'crop-type'. A 'crop-type' is an aggregate of stands that possess similar properties, including species, site quality, management regime, and territorial location.

2 Appropriate yield tables are used for each crop-type to convert area and age class information into total stemwood volume. Such yield tables have been developed by the New Zealand Forest Research Institute (NZFRI) for a large variety of predominant crop-types within New Zealand.

On a national scale, New Zealand uses one crop-type which represents the entire national planted forest estate. The yield table used for this single national crop-type is developed from the area weighted yields of the individual crop-types held within the National Exotic Forest Description.

3 Stemwood volume is converted to oven-dry weight of stemwood by multiplying by the appropriate wood density factor for the crop-type and location. Since basic density varies with age, crop-type, and location, when calculating carbon sequestration at a national level data from each territorial location has been grouped into one of three regions based on wood density.

4 Oven-dry weight of stemwood biomass is converted to total biomass oven-dry weight since carbon is stored not only in the stemwood, but also in the bark, branches, foliage, cones, stumps, roots, forest floor litter and in understorey species. The NZFRI computer model DRYMAT has been used to estimate the oven-dry weight of non-stem biomass in *Pinus radiata* stands over a rotation. The model is based on forest biomass studies which provide data on the effects of tree age, spacing, and site fertility on stand development parameters.

5 The total biomass oven-dry weight is summed for all age classes, crop-types and growth regions, and converted to the weight of carbon. The fractional carbon content of dry woody biomass varies, but a value of 0.5 has been used in New Zealand for carbon inventory calculations to date.

In summary, as a simple approximation forest carbon uptake (or emissions) can be calculated by:

$$U = V.r.a.\ 0.5$$

where U = forest carbon uptake (tonnes C/ha)

V = change in wood volume from one specified point in time to another (m^3)

r = average wood density (oven-dry tonnes/m^3)

a = a dimensionless factor that relates oven-dry weight of stem volume to oven-dry weight of stemwood plus tree components

0.5 = the fractional carbon content of the biomass

Conversion factors will change from year to year depending on changes in age-class, regional location, crop-type etc.

Definition of Terms

Stand

In New Zealand, a "stand" is an area of standing trees that is relatively uniform in species, age, and management regime. A "forest" may consist of hundreds or thousands of individual stands.

Age class

Stands can be classified according to the age of their component trees. In New Zealand, records are usually adequate to enable stands to be aged to within one year. For example, a manager could say that a forest contains 500 ha of trees in the 31-year age class. If records are poor, or if there is a need to reduce the quantity of information, age classes can comprise intervals of several years. For example, a manager might say that the forest contains 5000 ha in the 30 to 35 year age class.

Stemwood

In addition to the trunk or bole, trees contain wood in the branches, stumps and roots, but this is not generally commercially useful. Therefore methods have been developed for the accurate volumetric calculation of the wood (including or excluding the bark) from the height of the stump (nominally 0.3 m above ground) to the tip of the main stem. This is the "total stemwood". "Merchantable stemwood" is the total stemwood less logging waste, and is often 85% of total stemwood.

Oven-dry weight

This is the weight of a piece of wood when heated to 103°C until there is no change in weight. All the "free" water is evaporated, but the water that is part of a chemical bond remains, as does most of the volatile chemicals.

Wood density

The type of wood density used in carbon calculations is called the "basic density", and this is defined as the oven-dry weight of wood divided by the volume when green (i.e. in its fresh, undried state).

Fractional carbon content

This is the weight of elemental carbon in a given quantity of wood divided by the total oven-dry weight. The non-carbon components consist mainly of hydrogen and oxygen, obtained from water through the tree roots.

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