09

2008 Calendar Year Edition

The *New Zealand Energy Greenhouse Gas Emissions* is a report that presents statistics on greenhouse gas emissions arising from the production and combustion of fuel for energy.

New Zealand Energy Greenhouse Gas Emissions

Ministry of Economic Development
Manatū Ōhanga

New Zealand Energy Greenhouse Gas Emissions

2009

Prepared by:

Energy Information and Modelling Group

Energy and Communications Branch
Ministry of Economic Development
PO Box 1473, Wellington 6140
New Zealand

Email: energyinfo@med.govt.nz

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Important

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Authorship

This publication was prepared by the Energy Information and Modelling Group of the Ministry of Economic Development. Principal contributors were Darin Godber, Kent Hammond, Simon Lawrence and Kennie Tsui.

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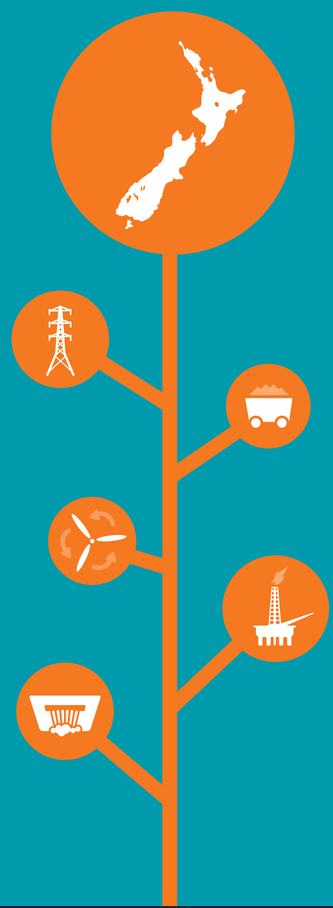
Availability

This publication is available in both electronic and paperback form. A free, electronic version of this publication can be downloaded from the Ministry of Economic Development website: www.med.govt.nz/energy/ghg. To purchase a paperback copy of this publication ($40 excluding Goods and Services Tax (GST) and postage), email energyinfo@med.govt.nz.

The *New Zealand Energy Greenhouse Gas Emissions* provides a picture of direct greenhouse gas emissions from energy and industrial processes for the calendar years 1990–2008.



Contents

Preface

What's New...

This edition reflects improvements to methodologies and access to more accurate information. In particular:

- the introduction of emissions from gas combustion at New Zealand Steel;
- historical data on emissions from coal cogeneration are now included;
- gas emissions from other sectors is now further split out between commercial, residential and primary industry;
- more accurate emissions from gas cogeneration are now available;
- more accurate information on gas emission factors;
- improved information on fugitive emissions from geothermal electricity generation (including the introduction of the Kawerau KGL geothermal plant);
- improved information on emissions from aluminium and cement production; and
- updated information on emissions from biomass.

Methodologies and data quality will continue to be refined. Suggestions and comments are welcomed and should be submitted to energyinfo@med.govt.nz.

Introduction

Greenhouse gas emissions from the New Zealand energy sector are of particular interest to policy-makers and the wider public. This publication provides a picture of direct greenhouse gas emissions from energy and industrial processes for the calendar years 1990–2008. Emissions from non-energy sources including land use, land use change and forestry, agriculture and waste are also presented at a summary level.

Energy emissions are presented as carbon dioxide equivalent (CO_2-e) emissions from the direct greenhouse gases – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – based on their global warming potential. Carbon dioxide emissions from industrial processes and biomass are also presented. This information is also available at www.med.govt.nz/energy/ghg along with estimates of indirect greenhouse gases from the energy sector. The indirect greenhouse gases covered on the website include oxides of nitrogen (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2).

This publication updates the annual series and includes revised estimates for the years 1990–2008 where improved data or methods have been applied. The base year of 1990 is that generally used for greenhouse gas emissions inventories by parties to the United Nations Framework Convention on Climate Change (UNFCCC). This convention, ratified by New Zealand in 1993, is at the centre of international efforts to mitigate and adapt to climate change.

This publication contributes to the national inventory report prepared annually by the Ministry for the Environment, which covers emissions and removals of greenhouse gases as part of New Zealand's obligations under the UNFCCC and the Kyoto Protocol.

1. New Zealand Greenhouse Gas Emissions Overview

Introduction

Like many countries, New Zealand is concerned about the potential adverse effects of climate change. Long-term risks of climate change to New Zealand's national interests include rising sea levels affecting the coastal environment and infrastructure, reduced agricultural production and adverse effects on native ecosystems and natural resources (Ministry for the Environment, 2005). New Zealand also recognises that climate change is a global challenge and that inaction would risk its international credibility.

It was in this broad context that, in 1993, New Zealand ratified the United Nations Framework Convention on Climate Change (UNFCCC). This step was followed by ratification of the Kyoto Protocol in 2002. As a party to the Kyoto Protocol, New Zealand has committed to reducing its emissions of greenhouse gases over 2008–2012 (the first commitment period) to 1990 levels or take responsibility for any emissions above this level if it cannot meet this target. This means the 2008 data in this report are part of the first commitment period for the Kyoto Protocol. This heightens the need for robust and accurate data.

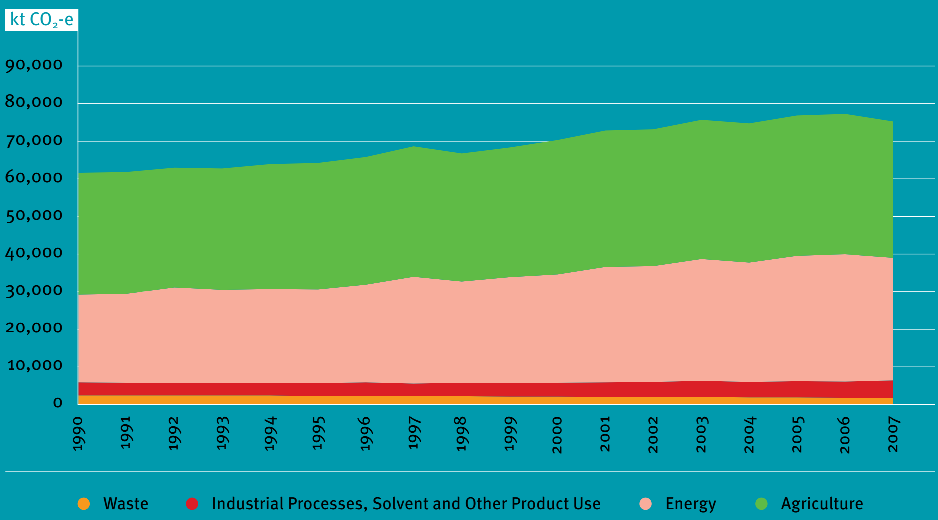
1.1 New Zealand's Greenhouse Gas Emissions

The information on energy sector emissions in this publication will feed into the 2010 edition of *New Zealand's Greenhouse Gas Inventory*, published by the Ministry for the Environment as part of New Zealand's obligations under the UNFCCC and the Kyoto Protocol.

The national inventory of greenhouse gas emissions includes emissions from industrial processes, solvent and other product use, agriculture, land use change and forestry and waste sectors. Table 1.1 shows gross carbon dioxide equivalent emissions and removals by each sector, as published in the 2009 inventory report (Ministry for the Environment, 2009).

In 2007, it was estimated that New Zealand emitted around 75.5 million tonnes of carbon dioxide equivalent greenhouse gases into the atmosphere (see Figure 1.1). However, through carbon sinks such as forested land, almost 24 million tonnes were removed. This resulted in New Zealand's estimated 'net' emissions of carbon dioxide equivalent greenhouse gases for 2007 totalling almost 52 million tonnes (see Table 1.1).

Figure 1.1: New Zealand Total Greenhouse Gas Emissions by Sector 1990–2007 (kt CO_2-e)[1]



Note: [1] This excludes carbon sinks. A carbon sink is a reservoir that accumulates and stores carbon dioxide (in New Zealand, this refers to forestry).

1.1 New Zealand's Greenhouse Gas Emissions continued

Table 1.1: New Zealand Total Greenhouse Gas Emissions and Removals 1990–2007 (kt CO_2-e)[1, 2]

CO_2 Equivalent (kt)	1990	1995	2000	2005	2006	2007	% Change 1990–2007	% Change 2006–2007
All Gases (net)	**43,714**	**48,574**	**50,626**	**51,901**	**53,722**	**51,714**	**+18.3%**	**-3.7%**
All Energy	23,453	25,043	28,987	33,479	34,011	32,653	+39.2%	-4.0%
Industrial Processes	3,409	3,390	3,648	4,267	4,234	4,602	+35.0%	+8.7%
Solvent and Other Product Use	42	45	47	44	40	43	+4.5%	+7.7%
Agriculture	32,511	33,729	35,836	37,519	37,491	36,430	+12.1%	-2.8%
Land Use Change and Forestry	-18,138	-15,893	-19,971	-25,274	-23,877	-23,836	+31.4%	-0.2%
Waste	2,438	2,260	2,079	1,865	1,823	1,822	-25.3%	-0.1%
CO_2 (net)	**7,144**	**11,251**	**11,062**	**10,514**	**12,304**	**11,316**	**+58.4%**	**-8.0%**
All Energy	22,593	24,181	27,908	32,350	32,744	31,560	+39.7%	-3.6%
Industrial Processes	2,732	3,016	3,174	3,499	3,498	3,671	+34.4%	+4.9%
Solvent and Other Product Use	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Agriculture	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Land Use Change and Forestry	-18,194	-15,958	-20,026	-25,338	-23,940	-23,915	+31.4%	-0.1%
Waste	13	13	6	4	2	1	-92.8%	-61.4%
CH_4	**25,478**	**25,769**	**27,079**	**27,281**	**27,454**	**26,622**	**+4.5%**	**-3.0%**
All Energy	716	682	862	861	998	832	+16.1%	-16.6%
Industrial Processes	20	58	101	14	17	18	-9.4%	+7.5%
Solvent and Other Product Use	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Agriculture	22,422	22,889	24,164	24,673	24,749	24,070	+7.3%	-2.7%
Land Use Change and Forestry	50	56	44	50	48	62	+24.5%	+29.5%
Waste	2,270	2,085	1,907	1,684	1,641	1,640	-27.7%	-0.1%
N_2O	**10,435**	**11,237**	**12,113**	**13,352**	**13,246**	**12,863**	**+23.3%**	**-2.9%**
All Energy	143	180	217	268	269	261	+82.2%	-2.9%
Industrial Processes	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Solvent and Other Product Use	42	45	47	44	40	43	+4.5%	+7.7%
Agriculture	10,089	10,840	11,672	12,846	12,742	12,360	+22.5%	-3.0%
Land Use Change and Forestry	6	9	11	15	15	17	+200.8%	+13.6%
Waste	155	162	166	178	179	180	+16.3%	+0.5%
HFCs (Industrial Processes)	**n.a.**	**148**	**304**	**675**	**612**	**857**	**n.a.**	**+39.9%**
PFCs (Industrial Processes)	**642**	**150**	**58**	**59**	**91**	**42**	**-93.5%**	**-54.0%**
SF_6 (Industrial Processes)	**15**	**18**	**11**	**19**	**15**	**15**	**-3.3%**	**-4.5%**

Notes: [1] Source: Ministry for the Environment (2009).

[2] The time series for the Energy and Industrial Processes sectors presented in this table may differ from those reported in this publication. This is because the updated information from this publication has not yet been incorporated into *New Zealand's Greenhouse Gas Inventory 1990–2007.*

1.2 New Zealand's Energy Greenhouse Gas Emissions

The key focus of this publication is to present annual statistics on emissions from the production and combustion of fuel in New Zealand's energy sector since 1990. For completeness, this publication also presents statistics on emissions arising from the use of energy products (e.g. coal and gas) in industrial processes such as steel making and emissions from the use of biomass. Figure 1.2 shows a summary of the energy emissions categories (this also forms the general structure of this publication).

Chapter 2 presents New Zealand's energy sector emissions on both a fuel type and sub-sector basis. The energy sector is split into five different fuel types:

- Gas
- Liquid fuels
- Coal
- Biomass
- Fugitive.

The energy sector can also be split into six different sub-sectors:

- National transport
- Electricity generation
- Transformation industries
- Manufacturing industries
- Other sectors
- Fugitive.

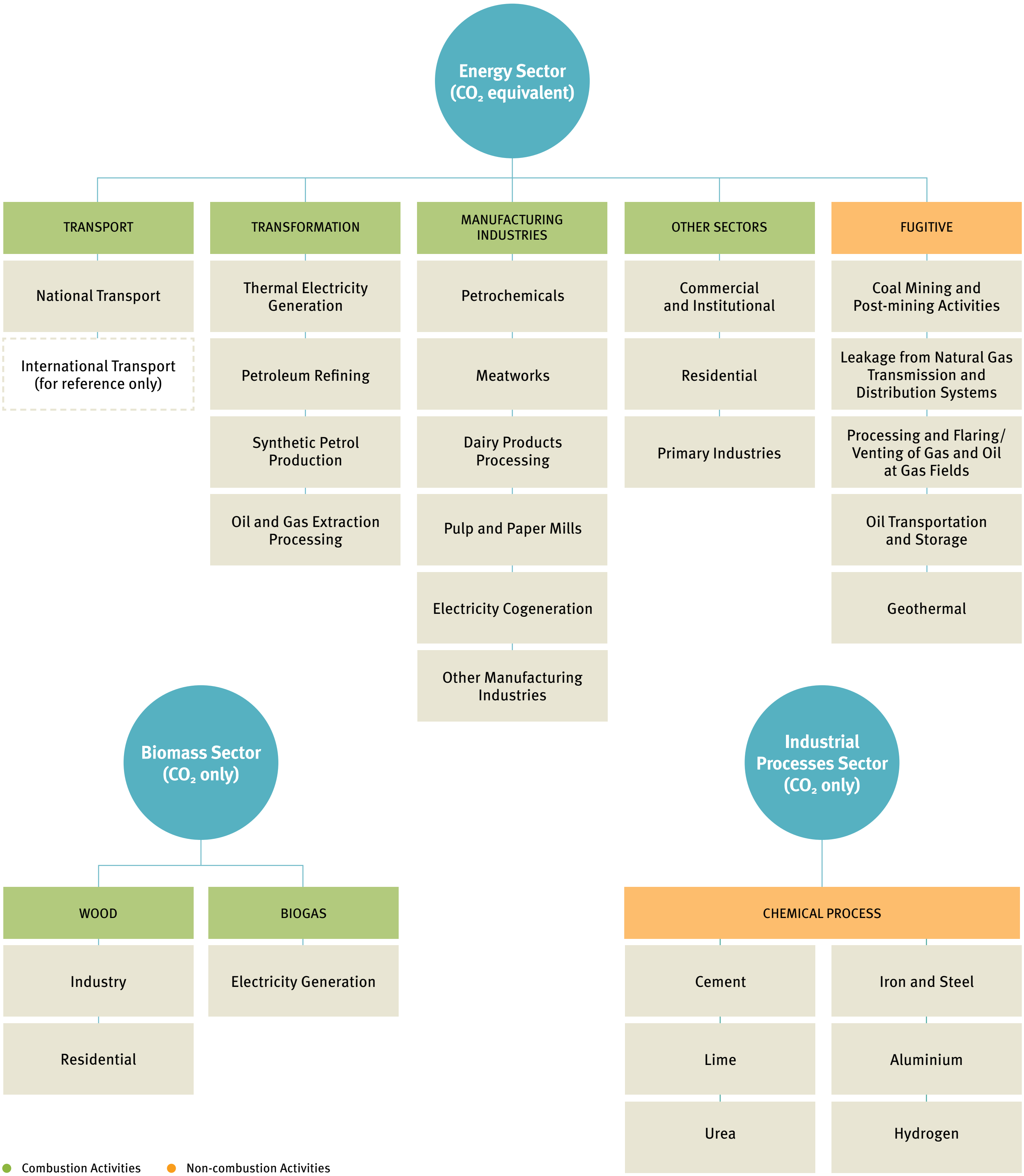
Chapter 3 presents emissions from industrial processes both as a national carbon dioxide total and by the specific processes of iron and steel, aluminium, hydrogen, cement, lime and urea production. This chapter also includes a summary of carbon dioxide emissions for biomass.

Chapter 4 presents a summary of the emission factors and methods used to calculate the emissions in this publication.

Finally, Chapter 5 looks at international comparisons of carbon dioxide emissions from fuel combustion.

1.2 New Zealand's Energy Greenhouse Gas Emissions continued

Figure 1.2: Breakdown of Categories for Energy, Industrial Processes and Biomass Sectors



2. Energy Carbon Dioxide Equivalent Emissions

Introduction

This chapter covers carbon dioxide equivalent (CO_2-e) emissions from the New Zealand energy sector. There are two types of emissions that are produced by the energy sector: combustion emissions and fugitive emissions.

Combustion emissions occur when fuel is burnt to produce useful energy. Examples of combustion emissions covered in this publication include emissions from transport, emissions from the provision of heat to industry and emissions from thermal electricity generation.

Fugitive emissions are much smaller in quantity than combustion emissions and arise as a result of processing or transforming fuels. Examples of fugitive emissions include the venting of carbon dioxide at the Kapuni Gas Treatment Plant and emissions from geothermal fields for electricity generation.

In this chapter, energy emissions are broken down by fuel type and sector. See Figure 1.2 for a summary of the energy emissions categories. An explanation of how emission factors are used to calculate emissions for the various fuel types by sector is included in Chapter 4.

2.1 Emissions by Fuel Type

At a total sector level, New Zealand's energy sector emissions have increased by 44% since 1990, or around 2% per annum. In 2008, New Zealand's energy sector emissions totalled 34,262 kt CO_2-e. This significant increase reflects increases in New Zealand's energy consumption since 1990 (particularly oil), which in turn was driven largely by the country's economic and population growth of 68% and 22% respectively since 1990.

Figure 2.2 shows that, of the energy sector emissions, liquid fuels accounted for the largest share in 2008 at 51%, or 17,431 kt CO_2-e.

Emissions from natural gas accounted for the second largest share of the total emissions in 2008 at 25%, followed by coal 18%, fugitive 6% and biomass less than 1%.

Coal emissions have almost doubled since 1990. Coal increased by 37% in 2008 from 4,532 kt CO_2-e to 6,192 kt CO_2-e, mainly because of a large increase in coal used at the Huntly power station. Some of the units at Huntly can use either coal or gas, and in 2008, coal was preferred over gas. This level of coal emissions, however, is below the 2006 level of 6,791 kt CO_2-e.

Figure 2.1: Energy Emissions by Fuel Type (kt CO_2-e)

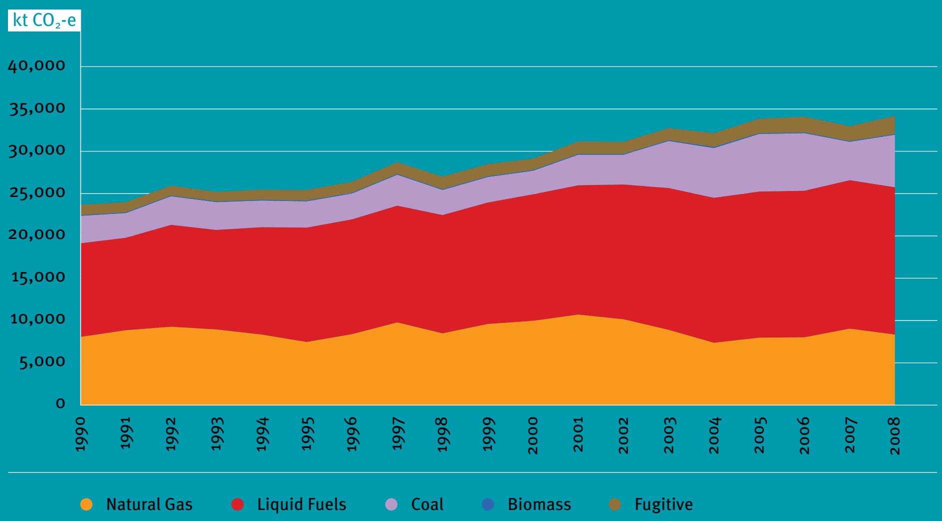


Figure 2.2: Energy Emissions by Fuel Type for 2008 (kt CO_2-e)

2.1 Emissions by Fuel Type continued

Table 2.1: Energy Emissions by Fuel Type (kt CO_2-e)

Calendar Year	Natural Gas	Liquid Fuels	Coal	Biomass	**Subtotal Combustion**	Fugitive	**Total**
1990	8,118	11,087	3,236	93	**22,535**	1,201	**23,736**
1991	8,890	10,931	2,956	93	**22,870**	1,180	**24,050**
1992	9,336	12,024	3,371	94	**24,825**	1,161	**25,985**
1993	8,972	11,779	3,294	94	**24,140**	1,130	**25,270**
1994	8,379	12,689	3,153	93	**24,314**	1,229	**25,543**
1995	7,504	13,524	3,116	94	**24,238**	1,257	**25,495**
1996	8,424	13,575	3,098	94	**25,191**	1,282	**26,473**
1997	9,829	13,811	3,659	93	**27,392**	1,403	**28,796**
1998	8,529	14,011	2,956	98	**25,594**	1,471	**27,065**
1999	9,659	14,342	3,015	99	**27,115**	1,433	**28,548**
2000	9,999	14,983	2,765	100	**27,847**	1,369	**29,216**
2001	10,761	15,276	3,632	100	**29,768**	1,459	**31,227**
2002	10,207	15,918	3,534	98	**29,757**	1,437	**31,194**
2003	8,959	16,753	5,573	99	**31,385**	1,438	**32,823**
2004	7,403	17,143	5,923	103	**30,572**	1,646	**32,218**
2005	8,011	17,283	6,821	104	**32,219**	1,703	**33,922**
2006	8,075	17,337	6,791	104	**32,307**	1,877	**34,184**
2007	9,090	17,557	4,532	105	**31,284**	1,772	**33,056**
2008	8,412	17,431	6,192	106	**32,141**	2,121	**34,262**
Δ1990/2008	3.6%	57.2%	91.3%	13.2%	**42.6%**	76.6%	**44.3%**
Δ1990/2008 p.a.	0.2%	2.5%	3.7%	0.7%	**2.0%**	3.2%	**2.1%**
Δ2007/2008	-7.5%	-0.7%	36.6%	0.5%	**2.7%**	19.7%	**3.6%**
% of total 2008 CO_2-e emissions	**24.6%**	**50.9%**	**18.1%**	**0.3%**	**93.8%**	**6.2%**	**100.0%**

2.2 Emissions by Sector

It should be noted that sector splits are not as precise as fuel type splits due in large part to difficulties in allocating liquid fuels use. For some sectors (such as electricity generation), these splits are very accurate, but in other sectors, they need to be interpreted with some caution and clear acknowledgement that they are at best indicative.

Table 2.2 and Figure 2.3 show energy carbon dioxide equivalent emissions by sector between 1990 and 2008. Over this period, total energy (including fugitive) emissions grew by 44%. Total energy emissions in 2008 were almost 4% higher than in 2007 predominantly due to a large increase in emissions from electricity generation.

Figure 2.3: Energy Emissions by Sector (kt CO_2-e)

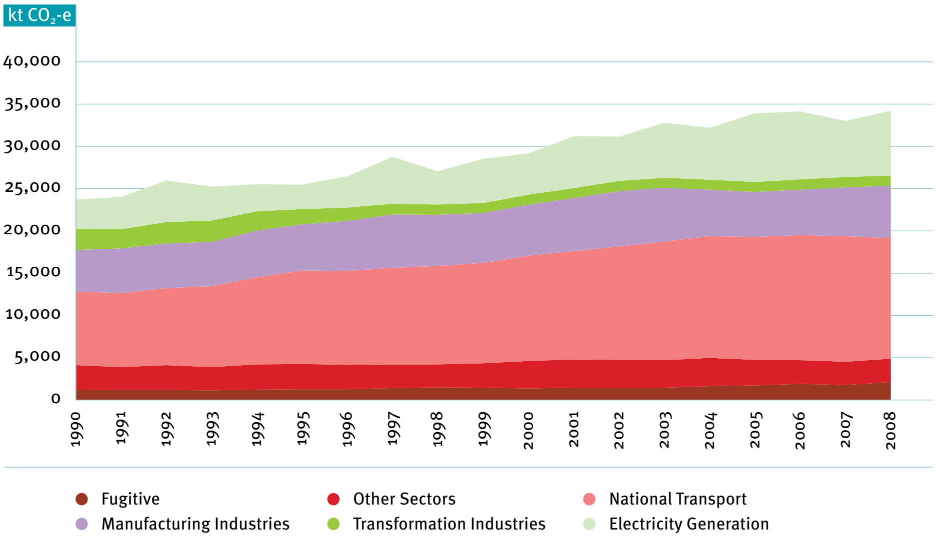
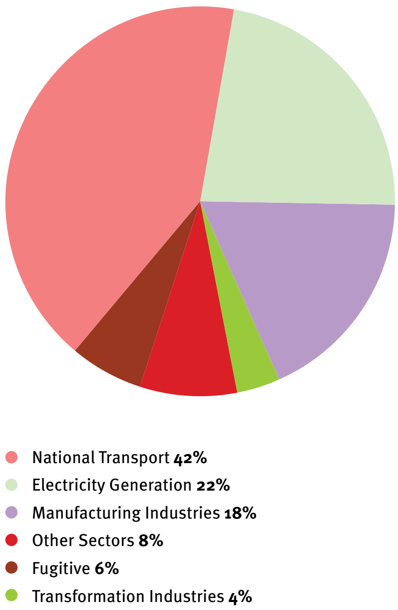


Figure 2.4: Energy Emissions by Sector for 2008 (kt CO_2-e)



2.2 Emissions by Sector continued

Table 2.2: Energy Emissions by Sector (kt CO_2-e)

Calendar Year	National Transport	Electricity Generation	Manufacturing Industries	Transformation Industries	Other Sectors	**Subtotal Combustion**	Fugitive	**Total**
1990	8,749	3,449	4,899	2,533	2,905	**22,535**	1,201	**23,736**
1991	8,772	3,869	5,279	2,241	2,710	**22,870**	1,180	**24,050**
1992	9,164	4,903	5,250	2,572	2,936	**24,825**	1,161	**25,985**
1993	9,602	4,039	5,236	2,521	2,743	**24,140**	1,130	**25,270**
1994	10,308	3,217	5,562	2,247	2,980	**24,314**	1,229	**25,543**
1995	11,051	2,913	5,470	1,795	3,008	**24,238**	1,257	**25,495**
1996	11,132	3,695	5,926	1,573	2,865	**25,191**	1,282	**26,473**
1997	11,434	5,571	6,341	1,261	2,784	**27,392**	1,403	**28,796**
1998	11,633	3,939	6,051	1,216	2,755	**25,594**	1,471	**27,065**
1999	11,892	5,212	5,929	1,167	2,915	**27,115**	1,433	**28,548**
2000	12,485	4,906	6,047	1,169	3,241	**27,847**	1,369	**29,216**
2001	12,847	6,137	6,288	1,179	3,316	**29,768**	1,459	**31,227**
2002	13,431	5,256	6,566	1,214	3,289	**29,757**	1,437	**31,194**
2003	14,060	6,496	6,361	1,220	3,249	**31,385**	1,438	**32,823**
2004	14,436	6,135	5,521	1,159	3,321	**30,572**	1,646	**32,218**
2005	14,558	8,114	5,345	1,161	3,043	**32,219**	1,703	**33,922**
2006	14,785	8,070	5,386	1,224	2,843	**32,307**	1,877	**34,184**
2007	14,903	6,675	5,772	1,205	2,730	**31,284**	1,772	**33,056**
2008	14,302	7,686	6,171	1,239	2,742	**32,141**	2,121	**34,262**
Δ1990/2008	63.5%	122.9%	26.0%	-51.1%	-5.6%	**42.6%**	76.6%	**44.3%**
Δ1990/2008 p.a.	2.8%	4.6%	1.3%	-3.9%	-0.3%	**2.0%**	3.2%	**2.1%**
Δ2007/2008	-4.0%	15.2%	6.9%	2.8%	0.4%	**2.7%**	19.7%	**3.6%**
% of total 2008 CO_2-e emissions	**41.8%**	**22.4%**	**18.0%**	**3.6%**	**8.0%**	**93.8%**	**6.2%**	**100.0%**

2.2 Emissions by Sector continued

2.2.1 Transport

This section reports emissions from the combustion and evaporation of fuel used for transport activities.

Emissions from national transport continue to account for the largest share of total energy emissions. National transport emissions have grown by 64% since 1990 at an average growth rate of 2.8% per annum, although this has slowed in recent years.

Emissions from road transport account for the largest share of national transport emissions at 90%. This represents 38% of the total energy carbon dioxide equivalent emissions for New Zealand. Road transport emissions, however, dropped in 2008 for the first time since the energy greenhouse gas emissions series began. This is likely to be due to high petrol and diesel prices in 2008 and the beginning of the global recession.

National Transport

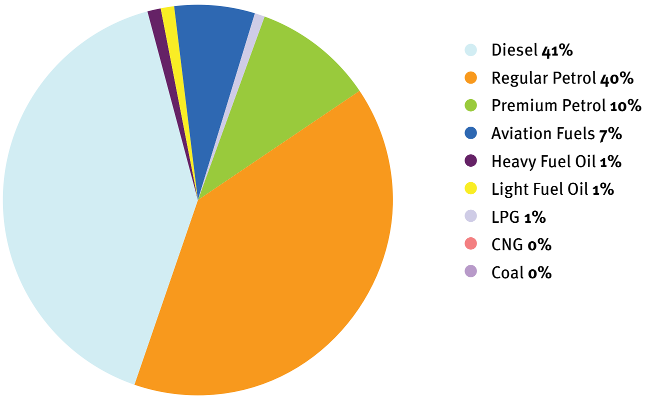
The IPCC (1996) state that emissions from the transport sector should represent combustion emissions for all domestic transport activities (both on- and off-road). This means emissions from national road, rail (including both liquid and solid fuels), aviation and marine transport are all incorporated. In practice, the ability to report emissions on this basis in New Zealand is limited by data availability.

Emissions from fuel sold for use in international transport (e.g. international bunker fuels) are reported separately and for reference only, as recommended by the IPCC (1996). The following categories are used when reporting emissions from transport: compressed natural gas (CNG), premium and regular petrol, diesel, fuel oil (heavy and light), aviation fuels, liquefied petroleum gas (LPG) and coal.

In this publication, emissions from the transport sector are calculated as those from the transport industry (i.e. commercial enterprises engaged in providing transport services) plus those from petroleum fuels sold via resellers (e.g. service stations). This is likely to result in an overstatement of emissions attributed to transport, as resellers also on-sell petroleum fuels for non-transport uses (e.g. diesel sold for powering stationary farm machinery), but there is a lack of information available to estimate and reallocate the fuel on-sold for non-transport uses. It should also be noted that emissions attributed to other sectors will also include some transport-related emissions (e.g. emissions from the operation of a commercial vehicle fleet). The Ministry of Economic Development has started work on an annual survey of independent distributor companies to correctly allocate their petroleum sales to the appropriate sectors.

Estimates of fuel consumption from transport are mainly derived from the Deliveries of Petroleum Fuels by Industry (DPFI) series collected by the Ministry of Economic Development (formerly by Statistics New Zealand). These are then supplemented by LPG and CNG consumption figures from the *New Zealand Energy Data File* (Ministry of Economic Development, 2009).

Figure 2.5: National Transport Emissions by Fuel Type for 2008 (kt CO_2-e)



2.2 Emissions by Sector continued

Table 2.3: Transport Emissions by Mode (kt CO_2-e)

	National					International			
Calendar Year	Road	Rail	Aviation	Marine	**Total**	Aviation	Marine	**Total**	**Total**
1990	7,647	86	779	237	**8,749**	1,351	1,045	**2,395**	**11,144**
1991	7,766	110	660	236	**8,772**	1,290	927	**2,216**	**10,989**
1992	8,158	136	635	234	**9,164**	1,318	878	**2,196**	**11,360**
1993	8,544	145	682	231	**9,602**	1,339	928	**2,267**	**11,869**
1994	9,033	151	837	287	**10,308**	1,452	1,370	**2,823**	**13,130**
1995	9,729	163	860	299	**11,051**	1,586	1,149	**2,735**	**13,786**
1996	9,883	161	830	257	**11,132**	1,656	1,093	**2,748**	**13,881**
1997	10,292	168	810	165	**11,434**	1,727	1,133	**2,859**	**14,294**
1998	10,499	162	841	131	**11,633**	1,722	1,089	**2,811**	**14,444**
1999	10,751	186	757	198	**11,892**	1,864	927	**2,791**	**14,683**
2000	11,011	254	842	378	**12,485**	1,749	756	**2,506**	**14,990**
2001	11,202	202	1,116	328	**12,847**	1,815	821	**2,636**	**15,483**
2002	11,852	170	1,044	365	**13,431**	1,878	1,065	**2,943**	**16,374**
2003	12,332	177	1,174	376	**14,060**	2,417	865	**3,281**	**17,341**
2004	12,708	183	1,209	336	**14,436**	2,635	736	**3,372**	**17,807**
2005	12,888	161	1,111	398	**14,558**	2,654	994	**3,648**	**18,206**
2006	13,163	165	1,132	325	**14,785**	2,665	991	**3,656**	**18,441**
2007	13,451	168	926	358	**14,903**	2,636	989	**3,626**	**18,529**
2008	12,864	163	977	298	**14,302**	2,556	1,087	**3,643**	**17,945**
Δ1990/2008	68.2%	89.2%	25.5%	25.8%	**63.5%**	89.3%	4.0%	**52.1%**	**61.0%**
Δ1990/2008 p.a.	2.9%	3.6%	1.3%	1.3%	**2.8%**	3.6%	0.2%	**2.4%**	**2.7%**
Δ2007/2008	-4.4%	-2.8%	5.5%	-16.7%	**-4.0%**	-3.0%	9.8%	**0.5%**	**-3.1%**
% of total 2008 CO_2-e emissions	**37.6%**	**0.5%**	**2.9%**	**0.9%**	**41.8%**	**n.a.**	**n.a.**	**n.a.**	**n.a.**

2.2 Emissions by Sector continued

International Transport

International transport comprises emissions from fuel used by all civil aviation and seagoing vessels engaged in international transport. IPCC (1996) rules require that emissions from this source are reported separately and so are not included in the aggregations elsewhere in this publication.

The fuels used for international transport are:

- diesel;
- fuel oil; and
- aviation fuel.

Data on fuel used for international transport are from the *New Zealand Energy Data File* (Ministry of Economic Development, 2009), which sources information from oil company returns provided to the Ministry of Economic Development.

2.2.2 Electricity Generation

New Zealand's electricity generation system can be described as a mixed renewable-thermal system, where renewable generation dominates and is supported by thermal generation. This section covers emissions from fossil-fuelled plants whose primary business activity is electricity generation. These plants produce around one-third of the electricity generated in New Zealand. Plants that generate electricity in support of another primary business activity (typically cogeneration plants that supply both heat and power) are included in the manufacturing industries section in accordance with the IPCC (1996). Emissions resulting from geothermal electricity generation are covered under fugitive emissions, as these are the result of the extraction process.

Mighty River Power, Contact Energy and Genesis Power are currently the main thermal electricity generators in New Zealand. In 2008, the major thermal stations and their main fuel types were:

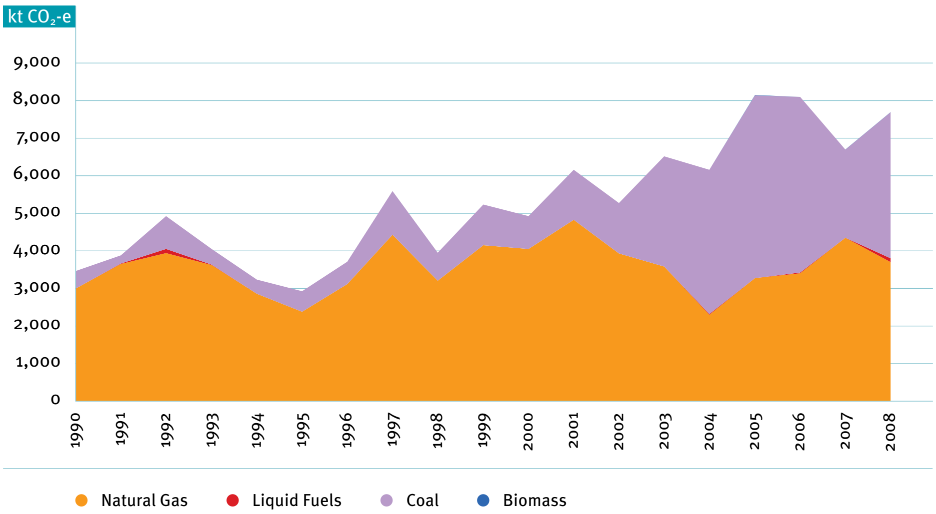
- Huntly Units 1–4 (coal and natural gas);
- Huntly Unit 5 – e3p Combined Cycle (natural gas);
- Huntly Unit 6 – P40 (natural gas);
- New Plymouth (natural gas);
- Otahuhu B Combined Cycle (natural gas);
- Southdown (natural gas);
- Taranaki Combined Cycle (natural gas); and
- Whirinaki (diesel).

Emissions from electricity generation in 2008 were 15% higher than in 2007. This is due to the fact that there were lower hydro inflows for 2008 (i.e. 2008 was a dry year), leading to an increased reliance on thermal electricity generation, in particular, coal and diesel.

Emissions from thermal electricity generation have increased significantly since 1990. However, within this general increasing trend, there are large annual variations, reflecting the cost and availability of hydro generation for that year. This variability is evident in the 2007 and 2008 years.

Further information on quarterly emissions from electricity generation can be found at www.med.govt.nz/energy/nzeq.

Figure 2.6: Electricity Generation Emissions by Fuel Type (kt CO_2-e)



2.2 Emissions by Sector continued

Table 2.4: Electricity Generation Emissions by Fuel Type (kt CO_2-e)

Calendar Year	Natural Gas	Liquid Fuels	Coal	Biomass	**Total**
1990	2,979	1.8	468	0.0	**3,449**
1991	3,638	12.6	218	0.0	**3,869**
1992	3,926	107.4	870	0.0	**4,903**
1993	3,613	1.6	425	0.0	**4,039**
1994	2,845	1.4	370	0.4	**3,217**
1995	2,367	2.1	543	0.5	**2,913**
1996	3,099	0.0	595	0.6	**3,695**
1997	4,411	0.0	1,159	0.7	**5,571**
1998	3,195	0.9	742	0.6	**3,939**
1999	4,132	0.0	1,079	0.6	**5,212**
2000	4,035	0.0	870	0.6	**4,906**
2001	4,804	0.0	1,333	0.6	**6,137**
2002	3,920	0.0	1,336	0.7	**5,256**
2003	3,572	0.0	2,923	0.9	**6,496**
2004	2,286	22.1	3,826	1.1	**6,135**
2005	3,262	3.3	4,847	1.1	**8,114**
2006	3,389	20.0	4,659	1.2	**8,070**
2007	4,330	0.6	2,342	1.2	**6,675**
2008	3,690	122.5	3,872	1.2	**7,686**
Δ1990/2008	23.9%	6,624.1%	727.8%	n.a.	**122.9%**
Δ1990/2008 p.a.	1.2%	26.3%	12.5%	n.a.	**4.6%**
Δ2007/2008	-14.8%	19,576.8%	65.3%	-2.5%	**15.2%**
% of total 2008 CO_2-e emissions	**10.8%**	**0.4%**	**11.3%**	**0.0%**	**22.4%**

2.2 Emissions by Sector continued

2.2.3 Transformation Industries

This section comprises emissions from fuel combustion by energy-producing industries during conversion processes (i.e. the transformation of energy). The sources of transformation emissions in New Zealand are the combustion of fuel during:

- petroleum refining;
- synthetic petrol production; and
- oil and gas extraction and processing.

Emissions from transformation industries have halved since 1990. This is primarily due to the cessation of synthetic petrol production in New Zealand.

Petroleum Refining

In New Zealand, there is only one oil refinery. It is situated at Marsden Point (near Whangarei) and is owned by the New Zealand Refining Company (NZRC).

The NZRC is 73% owned by the four major oil companies (Shell, BP, Chevron (Caltex) and Exxon Mobil), with the remainder held by institutional and individual investors.

The Marsden Point Oil Refinery takes crude oil (which is usually imported) and condensate (from the Maui and Kapuni fields) and treats them to make various fuels (along with sulphur and bitumen). Crude oil from the Tui field has also been used in recent times. This refining produces carbon dioxide emissions from the burning of refinery gas (gas obtained during the refining process), fuel oil, bitumen and natural gas.

Synthetic Petrol Production

Methanex New Zealand Ltd produced a large amount of synthetic petrol until 1997 at the Motunui plant in Taranaki. In 1997, though, synthetic petrol production in New Zealand ceased.

Synthetic petrol is produced from crude methanol (which is manufactured from natural gas – see section 2.2.4). The synthetic petrol production process involves three stages: petrol synthesis, distillation, and heavy petrol treating. Carbon dioxide emissions arise mainly from the petrol synthesis process where the crude methanol is initially preheated, vaporised and then superheated.

Oil and Gas Extraction and Processing

New Zealand oil and gas fields use natural gas for gas processing. Natural gas is used as a fuel to compress and heat gas that flows through the gas pipelines. New Zealand oil and gas fields also vent and flare natural gas. The resulting emissions are included under fugitive emissions.

Table 2.5: Transformation Industries Emissions (kt CO_2-e)

Calendar Year	Petroleum Refining	Synthetic Petrol Production	Oil and Gas Extraction and Processing	**Total**
1990	775	1,489	269	**2,533**
1991	770	1,191	280	**2,241**
1992	771	1,489	312	**2,572**
1993	836	1,374	311	**2,521**
1994	835	1,071	341	**2,247**
1995	801	663	331	**1,795**
1996	808	403	362	**1,573**
1997	840	33	389	**1,261**
1998	864	-	353	**1,216**
1999	829	-	338	**1,167**
2000	827	-	342	**1,169**
2001	823	-	356	**1,179**
2002	860	-	354	**1,214**
2003	863	-	357	**1,220**
2004	824	-	335	**1,159**
2005	850	-	311	**1,161**
2006	921	-	302	**1,224**
2007	894	-	312	**1,205**
2008	911	-	329	**1,239**
Δ1990/2008	17.5%	-100.0%	22.0%	**-51.1%**
Δ1990/2008 p.a.	0.9%	-100.0%	1.1%	**-3.9%**
Δ2007/2008	1.9%	n.a.	5.5%	**2.8%**
% of total 2008 CO_2-e emissions	**2.7%**	**0.0%**	**1.0%**	**3.6%**

2.2 Emissions by Sector continued

2.2.4 Manufacturing Industries

This section reports emissions from the combustion of fuels by manufacturing industries. These industries are often described as plants, factories or mills and generally use power-driven machines and other materials-handling equipment. Industries within this section include:

- methanol production;
- urea production;
- cement production;
- dairy products processing;
- meatworks; and
- pulp and paper mills.

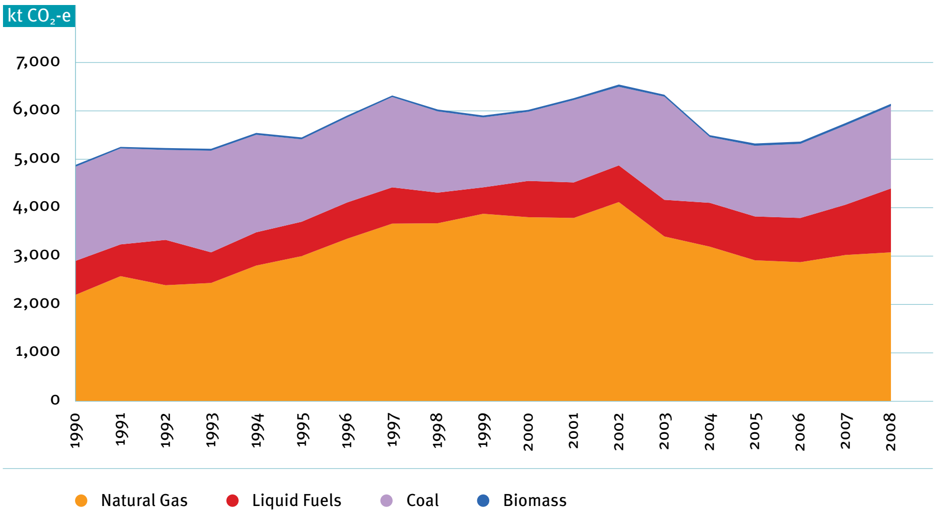
Natural gas and coal are the most commonly used fuels by manufacturing industries. The use of liquid fuels in manufacturing industries has increased substantially in recent years, with a 27% increase from 2007 to 2008.

Most of the emissions resulting from natural gas use in manufacturing industries come from the production of methanol. In New Zealand, methanol is produced by Methanex New Zealand Limited who have two methanol production facilities (Motunui and Waitara Valley). In November 2004, production at Motunui was halted, but the plant re-opened in late 2008. Methanex then exports the majority of this methanol.

Table 2.6: Manufacturing Industries Emissions by Fuel Type (kt CO_2-e)

Calendar Year	Natural Gas	Liquid Fuels	Coal	Biomass	**Total**
1990	2,200	708	1,955	36	**4,899**
1991	2,594	660	1,990	35	**5,279**
1992	2,408	936	1,871	36	**5,250**
1993	2,456	635	2,108	36	**5,236**
1994	2,817	690	2,020	35	**5,562**
1995	3,013	708	1,713	35	**5,470**
1996	3,371	753	1,767	35	**5,926**
1997	3,681	752	1,874	34	**6,341**
1998	3,690	638	1,682	40	**6,051**
1999	3,886	552	1,450	40	**5,929**
2000	3,816	758	1,432	41	**6,047**
2001	3,803	735	1,709	42	**6,288**
2002	4,128	765	1,632	41	**6,566**
2003	3,415	766	2,139	41	**6,361**
2004	3,204	908	1,365	45	**5,521**
2005	2,921	910	1,467	46	**5,345**
2006	2,884	920	1,535	46	**5,386**
2007	3,036	1,043	1,644	48	**5,772**
2008	3,085	1,325	1,713	49	**6,171**
Δ1990/2008	40.2%	87.1%	-12.4%	37.3%	**26.0%**
Δ1990/2008 p.a.	1.9%	3.5%	-0.7%	1.8%	**1.3%**
Δ2007/2008	1.6%	26.9%	4.2%	2.0%	**6.9%**
% of total 2008 CO_2-e emissions	**9.0%**	**3.9%**	**5.0%**	**0.1%**	**18.0%**

Figure 2.7: Manufacturing Industries Emissions by Fuel Type (kt CO_2-e)



2.2 Emissions by Sector continued

2.2.5 Other Sectors

Other sectors refers to emissions from fuel use in:

- commercial and institutional buildings;
- residential dwellings; and
- primary industries (the agriculture, forestry and fishing sectors).

As noted previously, emissions from other sectors are likely to include some transport-related emissions, particularly in the commercial and primary industries sectors.

Emissions from other sectors have remained relatively constant over time. In 2008, the total emissions for other sectors was only slightly below total emissions from 1990.

2.2.6 Fugitive Emissions

Fugitive emissions are those that arise from the production, processing, transmission, storage and use of fuels, and from non-productive combustion (e.g. flaring of natural gas at oil and gas production facilities).

The main sources of fugitive emissions in New Zealand are listed below, with the main greenhouse gas emitted noted in brackets:

- Coal mining and post-mining activities (CH_4).
- Leakage from natural gas transmission and distribution systems (CH_4).
- Processing and flaring/venting of gas at oil and gas fields (CO_2).
- Oil transportation, refining and storage (NMVOCs).
- Electricity generation and heat use from geothermal fields (CO_2).

Fugitive emissions have increased by 77% since 1990 and show a large increase of 20% between 2007 and 2008. This increase is mainly due to increased geothermal emissions from electricity generation in 2008.

Coal Mining and Post-mining Activities

Methane is produced during coal formation, either from a biological process as a result of microbial action, or from a thermal process resulting from higher temperature and pressure with increasing depth of burial. The methane produced is retained within the micropore structure of coal by surface adsorption and kept there by pressures that act on the coal seam at depth. Release of these pressures through natural processes or mining allows methane to escape from the coal.

Methane is hazardous to mining and is removed from underground coal faces through the mine's ventilation system, or by drainage techniques ahead of mining. The gas is then either released to the atmosphere or captured and used to generate electricity or create heat. Additional methane is released during coal preparation, particularly at the crushing stage, and during other stages of the utilisation chain such as transportation.

The amount of methane released by coal mining depends on how much methane was formed during the coal formation process, which is primarily a function of coal rank and seam depth. Methane emissions from opencast and shallow underground mines are low. Assessing emissions from deeper mines is particularly complex in New Zealand where coal rank can vary across a coal field and geological and topographical conditions that affect the retention of coal seam methane vary greatly. Ideally, site-specific data are required for calculating methane emissions.

In 2008, only around 17% of New Zealand coal production was from underground mining. Most underground mining is either of lower-rank coal or is from quite shallow mines relative to typical underground coal mines in other countries.[1]

Particularly gassy coals are confined to the Greymouth coal field. Fugitive methane emissions from coal mining only account for around 1% of New Zealand's carbon dioxide equivalent emissions from the energy sector.

Table 2.7: Other Sectors Emissions (kt CO_2-e)

Calendar Year	Commercial	Residential	Primary Industries	**Total**
1990	1,163	643	1,099	**2,905**
1991	1,194	556	960	**2,710**
1992	1,336	491	1,109	**2,936**
1993	1,164	464	1,115	**2,743**
1994	1,352	475	1,153	**2,980**
1995	1,316	467	1,225	**3,008**
1996	1,079	559	1,227	**2,865**
1997	950	578	1,256	**2,784**
1998	897	589	1,269	**2,755**
1999	1,087	572	1,256	**2,915**
2000	1,404	645	1,192	**3,241**
2001	1,478	625	1,212	**3,316**
2002	1,403	583	1,303	**3,289**
2003	1,231	614	1,403	**3,249**
2004	1,498	629	1,194	**3,321**
2005	1,092	624	1,327	**3,043**
2006	903	625	1,316	**2,843**
2007	915	573	1,243	**2,730**
2008	1,072	475	1,195	**2,742**
Δ1990/2008	-7.9%	-26.1%	8.7%	**-5.6%**
Δ1990/2008 p.a.	-0.5%	-1.7%	0.5%	**-0.3%**
Δ2007/2008	17.2%	-17.1%	-3.8%	**0.4%**
% of total 2008 CO_2-e emissions	**3.1%**	**1.4%**	**3.5%**	**8.0%**

Note: [1] The methane emissions factors for underground mining quoted by the IPCC (IPCC, 1996) are much higher than site-specific methane contents from New Zealand coal fields. The normal range of methane content for New Zealand coal mines is 2–10m³/tonne.

2.2 Emissions by Sector continued

Gas Transmission and Distribution Losses

Natural gas is transported around the main centres in the North Island in:

- high-pressure (transmission) pipelines from the gas fields and treatment plants to large purchasers including distributors and direct large end-users (such as dairy companies and pulp and paper mills); and
- low-pressure (distribution) pipelines in North Island towns and cities.

Estimating natural gas losses is inherently difficult. The level of accuracy around these data is therefore not high.

According to estimates provided by Vector Limited, losses of carbon dioxide from its high-pressure transmission system are negligible (approximately 17 tonnes in 2008). Methane losses from the same source are slightly higher at around 140 tonnes in 2008. Losses from local distribution systems are much higher, and in 2008, losses were around 16,000 tonnes of methane.

Distribution companies collect data for unaccounted for gas (UFG). UFG consists of:

- actual gas lost;
- metering errors; and
- theft.

For the purposes of this publication, an estimate of the proportion of UFG is needed. Consultation with the Gas Association of New Zealand has resulted in an estimate of UFG of 3.5% of the gas entering distribution systems. It is then assumed that half of this UFG (1.75%) is actually lost to the atmosphere, with the other half being burned, resulting in virtually no methane emissions but slightly increased carbon dioxide emissions.

Gas Processing and Flaring

The main source of emissions from production and processing of gas is at the Kapuni Gas Treatment Plant, located near the Kapuni field. Before the discovery of the Maui gas field, this plant treated all of the gas from the Kapuni field to remove carbon dioxide prior to entering the transmission system.

Until 2004, some Kapuni gas was treated for distribution while the rest was supplied directly to the petrochemical industry – Methanex and Ballance Agri-Nutrients – which values the high carbon dioxide content of the gas. This supply of Kapuni Low Temperature Separation (LTS) (the high carbon dioxide Kapuni gas) stopped in May 2004, reflecting the sharp decline in methanol production in New Zealand at that time. This resulted in a significant increase in carbon dioxide emissions vented from the Kapuni Gas Treatment Plant from 2004 and onwards.

Occasionally, natural gas is flared at the wellheads (e.g. during maintenance or field start-up). While most carbon dioxide from flaring is as a result of burning the gas, there are fugitive emissions of natural gas due to incomplete combustion. There have been large increases in emissions from processing and flaring in the last few years, largely due to the flaring at the offshore Tui field.

Figure 2.8 shows how gas processing and flaring emissions fit into the gas processing scheme.

Oil Transportation, Refining and Storage

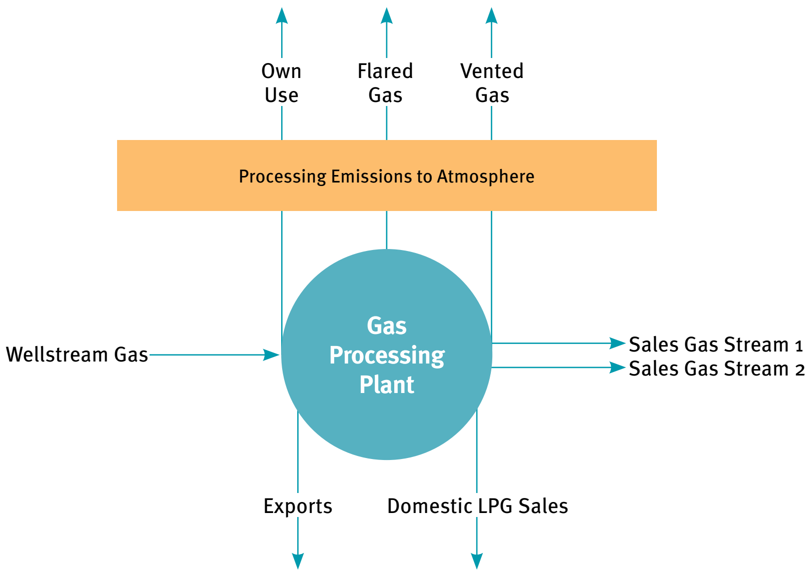
Crude oil is transported by pipelines and tankers to refining facilities, where it is stored in tanks for a period of time. An estimate of fugitive emissions of CH_4 and NMVOCs (a type of indirect greenhouse gas) released during the transportation, refining and storage of crude oil and refined products is included in this publication.

Geothermal

Production of electricity and heat from geothermal fields results in fugitive emissions as these are the result of the extraction process, rather than fuel combustion. Note that, because the UNFCCC is concerned with anthropogenic greenhouse gas emissions, natural emissions from geothermal fields are not included here.

CO_2-e emissions from fugitive geothermal increased by almost 50% in 2008. This is mainly due to an increase in geothermal electricity generation, partly due to the new Kawerau geothermal plant, which came online in late 2008.

Figure 2.8: Schematic Diagram of Gas Processing

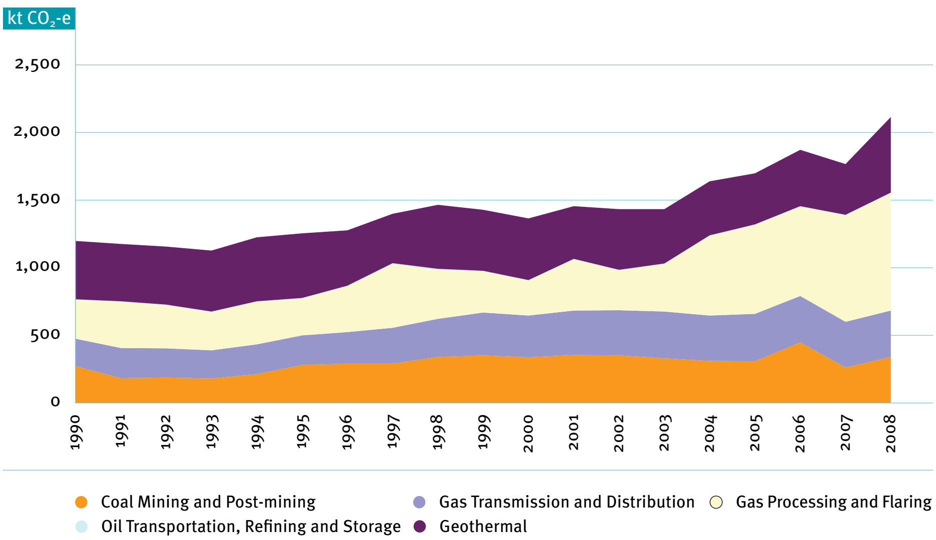


2.2 Emissions by Sector continued

Table 2.8: Fugitive Emissions (kt CO_2-e)

Calendar Year	Coal Mining and Post-mining	Gas Transmission and Distribution	Gas Processing and Flaring	Oil Transportation, Refining and Storage	Geothermal	Total
1990	272	205	287	5	432	**1,201**
1991	183	224	342	5	425	**1,180**
1992	190	215	321	5	430	**1,161**
1993	181	211	283	5	451	**1,130**
1994	214	221	314	5	476	**1,229**
1995	283	218	273	5	478	**1,257**
1996	293	232	340	5	412	**1,282**
1997	291	266	474	6	366	**1,403**
1998	341	282	366	6	476	**1,471**
1999	354	318	304	5	452	**1,433**
2000	340	309	258	5	456	**1,369**
2001	356	330	378	5	390	**1,459**
2002	354	335	294	5	449	**1,437**
2003	332	346	352	5	403	**1,438**
2004	312	336	591	5	401	**1,646**
2005	310	350	660	5	378	**1,703**
2006	450	343	662	5	417	**1,877**
2007	262	341	787	5	376	**1,772**
2008	343	344	867	6	561	**2,121**
Δ1990/2008	25.9%	68.1%	202.3%	28.5%	29.8%	**76.6%**
Δ1990/2008 p.a.	1.3%	2.9%	6.3%	1.4%	1.5%	**3.2%**
Δ2007/2008	30.9%	0.9%	10.1%	17.9%	49.2%	**19.7%**
% of total 2008 CO_2-e emissions	**1.0%**	**1.0%**	**2.5%**	**0.0%**	**1.6%**	**6.2%**

Figure 2.9: Fugitive Emissions (kt CO_2-e)



3. Industrial Processes and Biomass Carbon Dioxide Emissions

3.1 Industrial Processes

Industrial processes emissions are emissions from production processes in which carbon dioxide is a by-product of chemical reactions. They are distinct from energy sector emissions, which arise from fuel combustion, and processing and transforming fuels.

Some sectors have energy emissions and industrial processes emissions. For example, emissions from urea production are allocated between both energy and industrial processes. This ensures that emissions that arise from fuel combustion during urea production are accounted for distinctly from emissions arising from the chemical process.

There are six industrial processes in New Zealand that emit significant quantities of carbon dioxide:

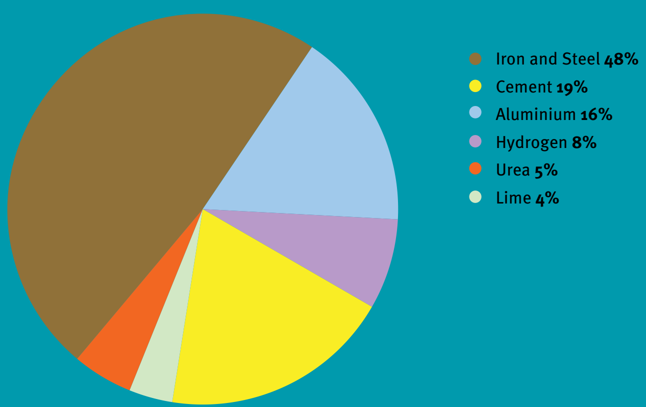
- Reduction of ironsand in steel production.
- Oxidisation of anodes in aluminium production.
- Production of hydrogen.
- Calcination of limestone in cement production.
- Manufacture of lime from limestone.
- Production of urea.

Estimates of carbon dioxide emissions from industrial processes are presented in Table 3.1.

Table 3.1: Industrial Processes Emissions (kt CO_2)

Calendar Year	Iron and Steel	Aluminium	Hydrogen	Cement	Lime	Urea	**Total**
1990	1,329	443	152	442	82	125	**2,574**
1991	1,453	437	167	431	94	125	**2,707**
1992	1,566	447	158	469	95	108	**2,843**
1993	1,594	452	161	481	92	122	**2,902**
1994	1,460	454	178	489	79	126	**2,786**
1995	1,539	435	143	530	83	125	**2,854**
1996	1,504	482	167	502	78	107	**2,838**
1997	1,353	501	158	524	95	123	**2,755**
1998	1,452	505	176	481	95	147	**2,857**
1999	1,512	530	177	523	117	172	**3,032**
2000	1,495	527	183	522	110	167	**3,004**
2001	1,566	511	187	526	104	184	**3,078**
2002	1,507	574	197	542	111	172	**3,103**
2003	1,707	561	184	526	111	198	**3,287**
2004	1,721	568	175	480	122	193	**3,259**
2005	1,669	569	213	569	129	173	**3,320**
2006	1,661	553	228	539	125	196	**3,301**
2007	1,690	579	225	688	127	173	**3,481**
2008	1,584	541	247	640	119	161	**3,292**
Δ1990/2008	19.2%	22.1%	62.0%	44.8%	45.9%	28.6%	**27.9%**
Δ1990/2008 p.a.	1.0%	1.1%	2.7%	2.1%	2.1%	1.4%	**1.4%**
Δ2007/2008	-6.2%	-6.5%	9.7%	-7.0%	-6.0%	-6.6%	**-5.4%**
% of total 2008 CO_2 emissions	**48.1%**	**16.4%**	**7.5%**	**19.4%**	**3.6%**	**4.9%**	**100.0%**

Figure 3.1: Industrial Processes Emissions for 2008 (kt CO_2)



3.1 Industrial Processes continued

Non carbon dioxide emissions are calculated separately by the Ministry for the Environment. As a rough guide, carbon dioxide equivalent emissions can be estimated by multiplying carbon dioxide emissions by 1.17.

Since 1990, emissions from industrial processes have increased by 28%, or 1.4% per annum. 2008 saw a 5% drop in industrial processes carbon dioxide emissions from 2007. This drop was driven by decreases from 2007 in iron and steel, aluminium, cement, lime and urea. It is hard to tell if this decrease is due to a decrease in production or an increase in efficiency. Table 3.2, however, shows that the carbon dioxide per unit of production for iron and steel, hydrogen and cement all improved from 2007 to 2008.

Table 3.2: Industrial Processes Emissions (CO_2 per unit of production)

Calendar Year	Iron and Steel	Aluminium	Hydrogen	Cement	Lime	Urea
1990	1.92	1.68	7.12	0.61	0.72	0.73
1991	1.93	1.67	6.99	0.64	0.72	0.73
1992	2.07	1.83	6.94	0.59	0.72	0.73
1993	1.90	1.68	6.57	0.53	0.72	0.73
1994	1.81	1.68	6.32	0.51	0.72	0.73
1995	1.82	1.60	6.13	0.54	0.72	0.73
1996	1.89	1.69	6.78	0.51	0.72	0.73
1997	1.85	1.61	6.39	0.52	0.72	0.73
1998	1.96	1.59	6.45	0.49	0.72	0.73
1999	1.99	1.62	6.48	0.49	0.72	0.73
2000	2.03	1.60	6.44	0.49	0.72	0.73
2001	1.96	1.58	6.25	0.48	0.72	0.73
2002	1.94	1.72	6.67	0.46	0.73	0.73
2003	2.02	1.68	6.51	0.42	0.73	0.73
2004	1.93	1.64	6.45	0.39	0.73	0.73
2005	2.03	1.63	5.98	0.46	0.72	0.73
2006	2.04	1.65	6.48	0.41	0.72	0.73
2007	1.94	1.64	6.29	0.50	0.72	0.73
2008	1.91	1.71	6.14	0.49	0.73	0.73
Δ1990/2008	-0.5%	1.8%	-13.7%	-20.6%	0.9%	0.0%
Δ1990/2008 p.a.	-0.0%	0.1%	-0.8%	-1.3%	0.1%	0.0%
Δ2007/2008	-1.5%	4.1%	-2.3%	-2.9%	0.3%	0.0%

Iron and Steel

Most carbon dioxide emitted by the iron and steel industry is associated with the production of iron. In the iron production process, carbon is supplied as a reducing agent to convert iron oxides to iron.

One of the main steel production plants in New Zealand is Blue Scope Steel's Glenbrook plant south of Auckland. The Glenbrook plant uses coal in a direct reduction process to remove oxygen from ironsand. These emissions are therefore included under industrial processes emissions (rather than energy sector emissions). Carbon dioxide emissions also arise from the use of limestone in the blending process.

Pacific Steel also produces carbon dioxide emissions through steel production. They do this through an electric arc furnace (EAF), which also emits small amounts of carbon dioxide.

Aluminium

New Zealand's only aluminium smelter plant is located at Tiwai Point at the bottom of the South Island. In aluminium production, graphite is mixed with aluminium oxide resulting in aluminium along with carbon dioxide emissions (a process called anode oxidisation).

Hydrogen

Most carbon dioxide emissions arising from hydrogen production in New Zealand are from the NZRC Marsden Point refinery. The NZRC has a Hydrogen Manufacturing Unit (HMU). In the HMU, methane and steam are used to produce hydrogen. As a by-product of this, carbon dioxide is vented into the atmosphere.

The other large producer of hydrogen in New Zealand is Evonik Degussa Peroxide, which produces a small amount of hydrogen as an intermediate product in the production of hydrogen peroxide (H_2O_2). Carbon dioxide is again vented into the atmosphere as a by-product.

Cement

Cement is produced by changing limestone into clinker (called the calcination of lime), which is then heated to produce cement. Emissions arise from the turning of limestone into clinker and from the heating of the clinker. Because of the large growth in the construction industry in recent years, there has been increased demand for cement. This has resulted in a large amount of clinker being imported into New Zealand to keep up with this demand. There are two major producers of cement in New Zealand: Golden Bay Cement and Holcim (New Zealand).

3. Industrial Processes and Biomass Carbon Dioxide Emissions

3.1 Industrial Processes continued

Lime

The production of lime also results in carbon dioxide emissions. Lime production uses limestone ($CaCO_3$) and converts it to lime (CaO) with carbon dioxide released as a by-product.

Urea

Ballance Agri-Nutrients (formerly Petrochem Limited) is the sole manufacturer of urea in New Zealand.

Carbon dioxide is released when urea is applied as a fertiliser. These carbon dioxide emissions are included in the industrial processes sector.

3.2 Biomass

To prevent double-counting, carbon dioxide emissions from the use of biomass are not included in energy carbon dioxide emissions because they are accounted for elsewhere in *New Zealand's Greenhouse Gas Inventory* (2009). Carbon dioxide emissions from woody biomass are captured in the land use, land use change and forestry (LULUCF) category, while carbon dioxide emissions from biogas emissions are accounted for in the waste category. This information, however, is presented for completeness and as an ongoing reconciliation across the energy and industrial processes sectors. Any non carbon dioxide emissions due to fuel combustion during the process are reported in Chapter 2.

Table 3.3 presents estimates of carbon dioxide emissions from biomass combustion – both wood and biogas (sewage gas and landfill gas). Emissions from biomass have shown steady increases since 1990. Biogas emissions especially have increased significantly since 1990.

Table 3.3: Biomass Emissions (kt CO_2)

	Wood				
Calendar Year	Industry	Residential	Subtotal	Biogas	**Total**
1990	2,504	840	3,344	174	**3,518**
1991	2,449	840	3,290	202	**3,492**
1992	2,527	840	3,368	208	**3,576**
1993	2,564	840	3,404	208	**3,612**
1994	2,429	840	3,269	217	**3,486**
1995	2,447	840	3,288	230	**3,517**
1996	2,426	840	3,266	195	**3,461**
1997	2,360	840	3,201	187	**3,388**
1998	2,756	840	3,596	184	**3,780**
1999	2,798	840	3,639	165	**3,803**
2000	2,896	840	3,737	148	**3,885**
2001	2,937	834	3,771	149	**3,920**
2002	2,836	828	3,664	189	**3,853**
2003	2,883	826	3,709	248	**3,957**
2004	3,125	824	3,950	269	**4,219**
2005	3,235	822	4,058	273	**4,330**
2006	3,231	818	4,049	305	**4,353**
2007	3,333	813	4,146	298	**4,444**
2008	3,403	807	4,210	290	**4,500**
Δ1990/2008	35.9%	-4.0%	25.9%	66.2%	**27.9%**
Δ1990/2008 p.a.	1.7%	-0.2%	1.3%	2.9%	**1.4%**
Δ2007/2008	2.1%	-0.7%	1.5%	-2.9%	**1.3%**
% of total 2008 CO_2 emissions	**75.6%**	**17.9%**	**93.6%**	**6.4%**	**100.0%**

4. Emission Factors

4.1 Carbon Dioxide Emission Factors for Combustion

Combustion emission factors are used to estimate the amount of a greenhouse gas emitted from a given quantity of fuel. These factors are expressed in terms of quantity of the greenhouse gas released per unit of energy of the fuel combusted. Details on the methodologies used to calculate the emission factors in this publication are provided in the technical notes.

Carbon dioxide emission factors for the various fuel types used in New Zealand are discussed below.

Gas Carbon Dioxide Emission Factors

Table 4.1 shows the 2008 emission factors for natural gas used in distribution and sales. Gas carbon dioxide emission factors are based on information and spot analysis provided by the gas field operators. The average emission factor for distributed gas is derived based on the gas production by each field.

Kapuni Low Temperature Separation (LTS) gas is high in carbon dioxide (around 43%) and, for this reason, is valued by the petrochemicals industry as a feedstock (see section 2.2.6).

Table 4.1: Average CO_2 Emission Factors for Distributed Gas after Oxidation (kt CO_2/PJ)

Calendar Year	Emission Factor (kt CO_2/PJ)
1990	52.77
1991	52.72
1992	52.67
1993	52.43
1994	52.26
1995	52.08
1996	52.23
1997	52.24
1998	52.20
1999	51.84
2000	52.02
2001	52.24
2002	52.39
2003	52.35
2004	52.46
2005	52.45
2006	52.49
2007	53.23
2008	53.32

Table 4.2: Average 2008 CO_2 Emission Factors for Gas Streams after Oxidation (kt CO_2/PJ)

Gas Streams	Emission Factor (kt CO_2/PJ)
Maui	52.11
Kapuni	52.77
McKee	54.03
Kaimiro	54.81
Ngatoro	52.80
TAWN	54.58
Mangahewa	57.11
Turangi	54.40
Pohokura	53.96
Rimu/Kauri	51.59
Kapuni LTS	83.68

Liquid Fuels Carbon Dioxide Emission Factors

Table 4.3 shows the 2008 emission factors for petrol, diesel, fuel oil and aviation fuels, which are based on carbon content and calorific data from the New Zealand Refining Company Limited. Although there is some annual variation, the liquid fuels carbon dioxide emission factors are fairly constant across all years.

Petrol is split into regular and premium petrol, with different emission factors for each. Fuel oil is split into heavy and light fuel oil, and aviation fuels comprise jet fuel and aviation gasoline. The emission factors for LPG and other fuels are sourced from the *New Zealand Energy Information Handbook* (Eng, Bywater & Hendtlass, 2008).

Although data on mileage and fuel consumption by vehicle type in New Zealand is under development, the current methodologies for both carbon dioxide and non carbon dioxide emissions are currently Tier 1 approaches.[1] This approach uses country-specific emission factors for carbon dioxide emissions and mainly IPCC default factors for non carbon dioxide emissions.

Note: [1] For a description of methodological tiers, please see the technical notes.

Table 4.3: Average 2008 CO_2 Emission Factors for Liquid Fuels after Oxidation (kt CO_2/PJ)

Liquid Fuel Type	Emission Factor (kt CO_2/PJ)
Petrol – Regular	65.8
Petrol – Premium	66.2
Diesel (50 ppm)	68.8
Fuel Oil – Heavy	73.2
Fuel Oil – Light	72.1
Jet/Kerosene	67.8
Aviation Gas	65.2
LPG	59.8
Other Fuels	72.2

4.1 Carbon Dioxide Emission Factors for Combustion continued

Coal Carbon Dioxide Emission Factors

Emission factors used for the three key ranks of coal (bituminous, sub-bituminous and lignite) are shown in Table 4.4. The source for these emission factors is the *New Zealand Energy Information Handbook* (Eng et al, 2008)

The emission factor for the coal used in steel making at the Glenbrook Steel Mill, which is of sub-bituminous rank, differs from the emission factor for sub-bituminous coal given in Table 4.4. This is because the sources of coal used at the mill are known with more certainty than for other coal use.

Table 4.4: Average 2008 CO_2 Emission Factors for Coal after Oxidation (kt CO_2/PJ)

Coal Rank	Emission Factor (kt CO_2/PJ)
Bituminous	87.0
Sub-bituminous	89.4
Lignite	93.3

Biomass Carbon Dioxide Emission Factors

The carbon dioxide emission factors used for wood and biogas combustion are derived from the IPCC default net emission factors (1996). It is assumed that the net emission factors are higher than the gross emission factors by 5% for wood and 10% for biogas. For biogas, it is also assumed that half the carbon is converted into methane (CH_4).

Table 4.5: Average 2008 CO_2 Emission Factors for Biomass after Oxidation (kt CO_2/PJ)

Biomass Type	Emission Factor (kt CO_2/PJ)
Wood	104.2
Biogas	101.0

4.2 Non Carbon Dioxide Emission Factors for Combustion

Almost all of the non carbon dioxide emission factors used in the inventory are default IPCC emission factors (1996). These emission factors can be split into two types: Tier 1 and Tier 2. The technical notes explain how these tiers work.

Tables 4.6 and 4.7 list the emission factors for the greenhouse gases CH_4 and N_2O, along with the source for each emission factor. For IPCC emission factors, it is noted whether the emission factor is Tier 1 or Tier 2. The middle columns of Tables 4.6 and 4.7 contain the IPCC emission factors (in net calorific terms) while the preceding column contains the derived emission factors (in gross calorific terms) that are used in the inventory.

4.2 Non Carbon Dioxide Emission Factors for Combustion continued

Table 4.6: CH_4 Emission Factors for Energy

	NZ Emission Factor[1] (Gross CV) t CH_4/PJ	IPCC Emission Factor[2] (Net CV) t CH_4/PJ	Source of Emission Factors Used (refer below)
Natural Gas			
Electricity – Boilers	0.09	0.10	a
Electricity – Large Turbines	5.40	6.00	b
Own Use	1.26	1.40	c
Industry	1.26	1.40	c
Commercial	1.08	1.20	d
Residential	0.90	1.00	e
National Transport (CNG)	567.00	630.00	f
Liquid Fuels			
Stationary Use[3]			
Electricity Generation – LPG, Petrol, Diesel and Fuel Oil	0.86	0.90	g
Agriculture – LPG, Petrol, Diesel and Fuel Oil	0.19	0.25	h
Manufacturing Industries – LPG	1.05	1.10	i
Manufacturing Industries – Petrol and Diesel	0.19	0.20	j
Manufacturing Industries – Fuel Oil	2.85	3.00	k
Commercial and Residential – LPG	1.05	1.10	i
Commercial and Residential – Petrol and Diesel	0.67	0.70	l, m
Commercial and Residential – Fuel Oil	1.33	1.40	n, o
Mobile Use			
LPG	28.50	30.00	p
Petrol	18.53	19.50	q
Diesel	3.80	4.00	r
Fuel Oil (Ships)	6.65	7.00	s
Aviation Fuel/Kerosene	1.90	2.00	t
Coal			
Combustion			
Electricity Generation	0.67	0.70	u
Cement	0.95	1.00	v
Lime	0.95	1.00	v
Industry	0.67	0.70	w
Commercial/Agriculture	9.50	10.00	x
Residential	285.00	300.00	y
Transport – Railway	10.00	10.00	z
Biomass			
Wood Stoker Boilers	14.25	15.00	aa
Wood – Fireplaces	285.00	300.00	ab
Biogas	1.08	1.20	ac

Notes: [1] New Zealand emission factors are derived on a gross calorific basis from the IPCC factors that are provided on a net calorific basis. It is assumed that the net emission factors are higher than the gross emission factors by 10% for gas and 5% for oil, coal and biomass. These are the standard OECD/IEA assumptions.

[2] IPCC (1996).

[3] Manufacturing industries include food processing, iron and steel and other manufacturing.

Natural Gas

a. IPCC Tier 2 – utility boiler performance (boilers).
b. IPCC Tier 2 – utility boiler performance (large gas fired turbines › 3MW).
c. IPCC Tier 2 – industrial boiler performance (large boilers).
d. IPCC Tier 2 – commercial source performance (gas boilers).
e. IPCC Tier 2 – residential source performance (gas heaters).
f. IPCC Tier 2 – light and heavy-duty natural gas vehicles (passenger cars, uncontrolled).

Liquid Fuels

g. IPCC Tier 2 – utility boiler performance (residual oil boilers).
h. IPCC Tier 2 – industrial boiler performance (residual oil boilers).
i. IPCC Tier 2 – industrial boiler performance (distillate oil boilers).
j. IPCC Tier 2 – residential source performance (propane/butane furnaces).
k. IPCC Tier 2 – commercial source performance (residual oil boilers).
l. IPCC Tier 2 – commercial source performance (distillate oil boilers).
m. IPCC Tier 2 – residential source performance (residual oil furnaces).
n. IPCC Tier 2 – residential source performance (distillate oil furnaces).
o. IPCC Tier 2 – European non-road mobile sources and machinery (diesel engines, agriculture).
p. IPCC Tier 2 – US light and heavy-duty LPG vehicles (passenger cars, uncontrolled).
q. IPCC Tier 2 – US gasoline passenger cars (uncontrolled – midpoint of average t/PJ).
r. IPCC Tier 2 – US heavy-duty diesel vehicles (uncontrolled – average t/PJ).
s. IPCC Tier 2 – default marine emission factors (ocean-going ships).
t. IPCC Tier 2 – US non-road mobile sources (jet and turboprop aircraft).

Coal

u. IPCC Tier 2 – utility boiler source performance (pulverised bituminous combustion – dry bottom, wall fired).
v. IPCC Tier 2 – kilns, ovens and dryers source performance (cement, lime coal kilns).
w. IPCC Tier 2 – industrial boiler performance (dry bottom, wall fired coal boilers).
x. IPCC Tier 2 – commercial source performance (coal boilers).
y. IPCC Tier 1 – residential coal use.
z. IPCC Tier 1 – railway transport.

Biomass

aa. IPCC Tier 2 – industrial boiler performance (wood stoker boilers).
ab. IPCC Tier 1 – residential wood use.
ac. IPCC Tier 2 – commercial source performance (gas boilers).

4.2 Non Carbon Dioxide Emission Factors for Combustion continued

Table 4.7: N_2O Emission Factors for Energy

	NZ Emission Factor[1] (Gross CV) t N_2O/PJ	IPCC Emission Factor[2] (Net CV) t N_2O/PJ	Source of Emission Factors Used (refer below)
Natural Gas			
Electricity Generation	0.09	0.10	a
Industry	0.09	0.10	a
Commercial	2.07	2.30	b
Residential	0.09	0.10	a
National Transport (CNG)	0.09	0.10	a
Liquid Fuels			
Stationary Use[3]			
Electricity – Petrol and Diesel	0.38	0.40	c
Electricity – Fuel Oil	0.29	0.30	d
Agriculture – Petrol, Diesel, and Fuel Oil	0.38	0.40	e
Manufacturing Industries – LPG	0.57	0.60	f
Manufacturing Industries – Petrol and Diesel	0.38	0.40	g
Manufacturing Industries – Fuel Oil	0.29	0.30	h
Commercial – LPG	0.57	0.60	f
Commercial – Petrol and Diesel	0.38	0.40	j
Commercial – Fuel Oil	0.29	0.30	i
Residential – LPG	0.57	0.60	f
Residential – Petrol, Diesel, and Fuel Oil	0.19	0.20	k
Mobile Use			
LPG	0.57	0.60	f
Petrol	1.43	1.50	l
Diesel	3.71	3.90	m
Fuel Oil (Ships)	1.90	2.00	n
Aviation Fuel/Kerosene	1.90	2.00	o
Coal			
Combustion			
Electricity	1.52	1.60	p
Cement	1.33	1.40	q
Lime	1.33	1.40	q
Industry	1.52	1.60	r
Commercial/Agriculture	1.33	1.40	q
Residential	1.33	1.40	q
Transport – Railway	1.40	1.40	q
Biomass			
Wood Stoker Boilers	3.80	4.00	s
Wood – Fireplaces	3.80	4.00	s
Biogas	2.07	2.30	t

Notes: [1] New Zealand emission factors are derived on a gross calorific basis from the IPCC factors that are provided on a net calorific basis. It is assumed that the net emission factors are higher than the gross emission factors by 10% for gas and 5% for oil, coal and biomass. These are the standard OECD/IEA assumptions.

[2] IPCC (1996).

[3] Manufacturing industries include food processing, iron and steel and other manufacturing.

Natural Gas

a. IPCC Tier 1 – natural gas (all uses).
b. IPCC Tier 2 – commercial source performance (gas boilers).

Liquid Fuels

c. IPCC Tier 2 – source performance tables for utility, industrial and commercial (residual oil boilers).
d. IPCC Tier 2 – utility boiler performance (distillate oil boilers).
e. IPCC Tier 2 – industrial source performance (residual oil boilers).
f. IPCC Tier 2 – industrial source performance (distillate oil boilers).
g. IPCC default emission factors for Tier 1 methods (converted from net to gross) – all oil use except for aviation.
h. IPCC Tier 2 – commercial source performance (residual oil boilers).
j. IPCC Tier 2 – residential source performance (furnaces).
i. IPCC Tier 2 – commercial source performance (distillate oil boilers).
k. IPCC Tier 2 – European non-road mobile sources and machinery (diesel engines, agriculture).
l. IPCC Tier 2 – US gasoline passenger cars (uncontrolled average t/PJ – updated figure from *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000).
m. IPCC Tier 2 – updated figure for all diesel vehicles regardless of control technology in *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000).
n. IPCC Tier 2 – default marine emission factors (ocean-going ships).
o. IPCC Tier 1 – oil used in aviation.

Coal

p. IPCC Tier 2 – utility boiler source performance (pulverised bituminous combustion – dry bottom, wall fired).
q. IPCC Tier 1 – coal (all uses).
r. IPCC Tier 2 – industrial boiler performance (bituminous/sub-bituminous pulverised – dry bottom, wall fired coal boilers).

Biomass

s. IPCC Tier 1 – wood/wood waste (all uses).
t. IPCC Tier 1 – commercial/institutional gas use.

5. International Comparisons of Carbon Dioxide Emissions

Emissions data used in this chapter are from the International Energy Agency (2008) and cover carbon dioxide emissions from fuel combustion for selected countries in 2006.

The IEA's method is based on the IPCC guidelines (1996), which have also been followed in this publication. However, despite using the same methodology, for a number of reasons, the IEA estimates may differ from in-country estimates:

- The IEA may not have complete and accurate data for each country.
- The IEA has used the IPCC's default carbon dioxide emission factors and does not use country-specific emission factors (which have been used where appropriate in this publication). The IPCC guidelines state that, where country-specific information is available, then this should be used instead.
- The IEA has used universal average net calorific values for different fuels, whereas this publication uses New Zealand-specific average gross calorific values. This is because New Zealand energy data are recorded in terms of gross values.

Despite these differences, the IEA's emission estimates still give a useful indication of differences among countries. In order to aid this comparison, the emissions shown in this chapter for New Zealand are those estimated by the IEA, rather than those presented in earlier chapters of this publication. This chapter only presents data for selected years in the period 1990–2006.

According to the International Energy Agency, key findings on fuel combustion emissions between 1990 and 2006 were that:

- New Zealand's carbon dioxide emissions for fuel combustion in 2006 were 0.13% of global fuel combustion emissions; and
- carbon dioxide emissions from fuel combustion in New Zealand increased by 72% since 1990, compared to the rate of increase for total global fuel combustion emissions of 33%.
- in 2006, carbon dioxide emissions from fuel combustion in New Zealand were 8.9 tonnes per capita, an increase of 40% since 1990.

Since 1990, world carbon dioxide emissions from fuel combustion have increased by 33%, from 20,988 million tonnes to 28,003 million tonnes. Of the world total (in 2006), the five largest fuel combustion carbon dioxide emitters from the selected OECD and non-OECD countries were the US, China, Russia, India and Japan, producing 20.3%, 20.2%, 5.7%, 4.5% and 4.3% respectively of the world total carbon dioxide emissions.

Figure 5.1: Percentage change in CO_2 Emissions from Fuel Combustion for OECD Countries in 2006 Relative to 1990

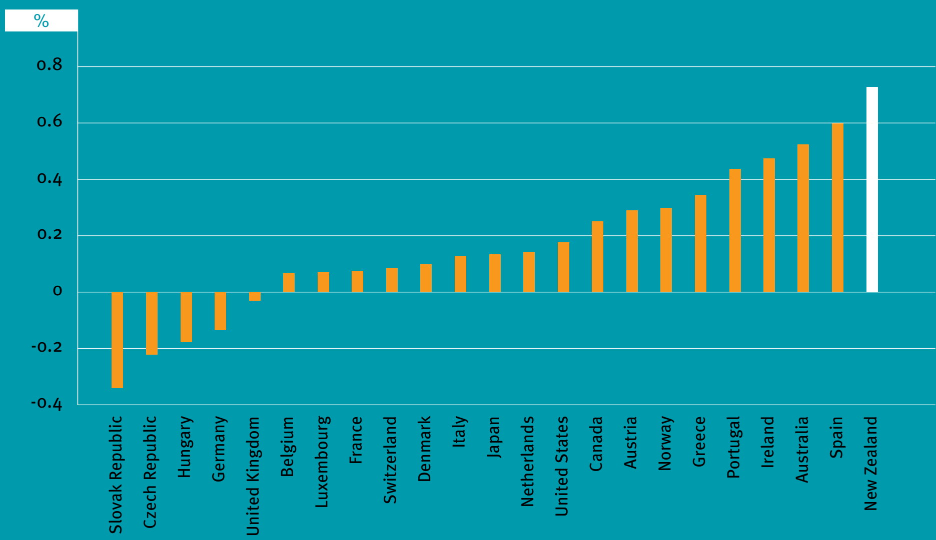
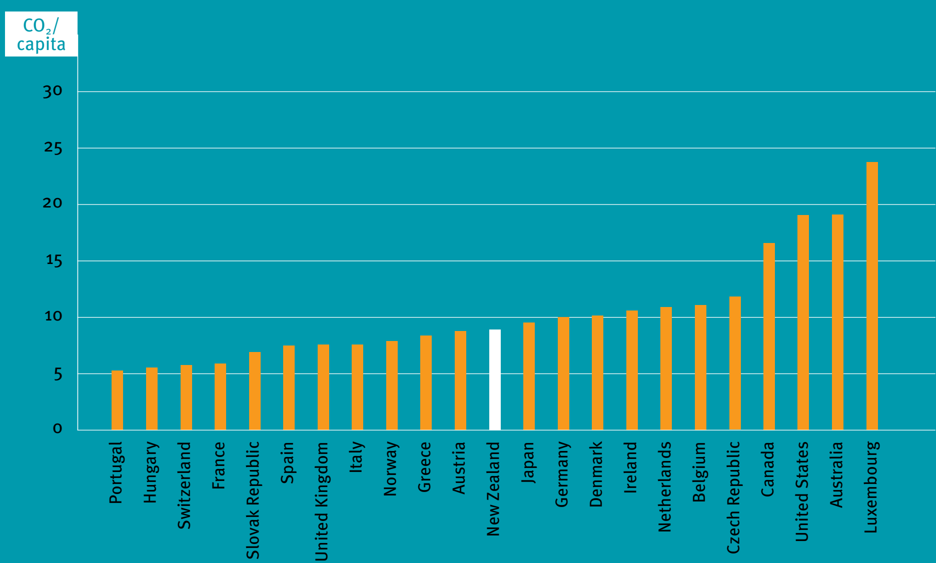


Figure 5.2: CO_2 Emissions from Fuel Combustion per Capita for OECD Countries in 2006



5. International Comparisons of Carbon Dioxide Emissions

Figure 5.1 shows the change in fuel combustion carbon dioxide emissions between 1990 and 2006 for OECD countries only. As can be seen, the Slovak Republic, the Czech Republic and Hungary saw the largest falls in emissions over this period, while New Zealand, Spain and Australia saw the largest increases.

Figure 5.2 presents a comparison of fuel combustion carbon dioxide emissions on a per capita basis for OECD countries. Those countries with the highest per capita emissions are Luxembourg, Australia and the US. New Zealand is placed in the middle of the countries listed.

Figures 5.3 and 5.4 present comparisons of fuel combustion carbon dioxide emissions per unit of gross domestic product (GDP) in US$ and on a purchasing power parity (PPP) basis. The countries with the highest per GDP (in US$) emissions are the Czech Republic, the Slovak Republic and Hungary.

On a purchasing power parity basis, the countries with the highest per GDP emissions are the Czech Republic, Australia and Canada. New Zealand's position stays at number 6 on the list of selected countries for both measures.

Table 5.1: CO_2 Emissions from Fuel Combustion 1990–2006 by Rank of Percentage Contribution (million tonnes of CO_2)[1]

Country		1990	1995	2000	2003	2004	2005	2006	2006 % of World Total	% Change 1990–2006
OECD	USA	4,863	5,133	5,693	5,689	5,772	5,785	5,697	20.34%	17.14%
	Japan	1,071	1,157	1,192	1,223	1,222	1,228	1,213	4.33%	13.19%
	Germany	950	869	827	842	843	811	824	2.94%	-13.35%
	Canada	432	465	533	554	550	556	539	1.92%	24.66%
	UK	553	519	526	536	536	535	537	1.92%	-2.98%
	Italy	398	410	425	542	450	454	448	1.60%	12.62%
	France	352	354	376	384	384	387	378	1.35%	7.21%
	Australia	260	285	339	361	370	387	394	1.41%	51.81%
	Spain	206	234	284	310	327	340	328	1.17%	59.18%
	Netherlands	157	171	173	184	185	183	178	0.64%	13.86%
	Czech Rep	155	124	122	121	122	120	121	0.43%	-21.99%
	Belgium	110	121	127	127	124	120	117	0.42%	6.26%
	Greece	70	76	87	94	93	95	94	0.34%	34.09%
	Austria	57	59	62	74	74	75	73	0.26%	28.62%
	Portugal	39	48	60	58	60	63	56	0.20%	43.26%
	Hungary	69	59	55	58	57	57	56	0.20%	-17.66%
	Denmark	50	58	50	56	51	47	55	0.20%	9.52%
	Switzerland	41	41	42	43	44	44	44	0.16%	8.35%
	Ireland	31	33	41	42	42	43	45	0.16%	46.73%
	Slovak Rep	57	41	37	38	37	38	38	0.13%	-33.86%
	Norway	28	33	34	35	36	37	37	0.13%	29.58%
	New Zealand	**21**	**24**	**32**	**36**	**36**	**36**	**37**	**0.13%**	**71.96%**
	Luxembourg	11	8	8	10	11	11	11	0.04%	6.67%
Non-OECD	China	2,244	3,022	3,078	3,871	4,587	5,101	5,649	20.17%	151.72%
	Russia	2,180	1,583	1,514	1,540	1,524	1,531	1,587	5.67%	-27.19%
	India	589	783	977	1,043	1,114	1,161	1,250	4.46%	112.07%
	Bulgaria	75	53	42	46	45	46	48	0.17%	-36.58%
	Estonia	36	16	15	16	17	16	15	0.05%	-58.29%
World Total[2]		**20,988**	**21,829**	**23,509**	**25,108**	**26,332**	**27,146**	**28,003**	**70.94%**	**33.42%**

Notes: [1] Each country is recommended to revise historical information and update results if necessary for annual submission to the IEA. Therefore, information presented in this publication may be different from previous publications.

[2] World total includes the non-OECD total and OECD total, as well as international marine bunkers and international aviation.

Figure 5.3: CO_2 Emissions from Fuel Combustion as a Ratio of GDP (US$) for OECD Countries in 2006

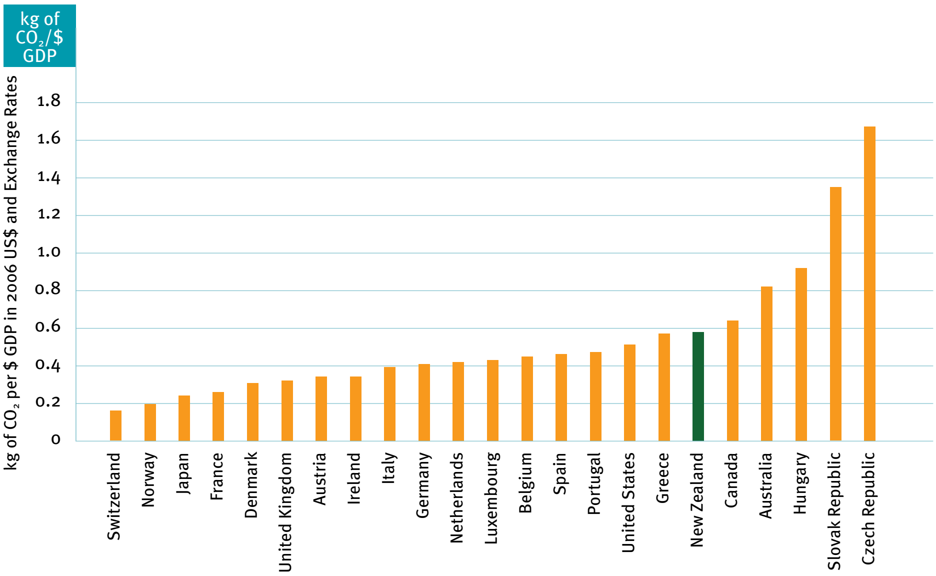
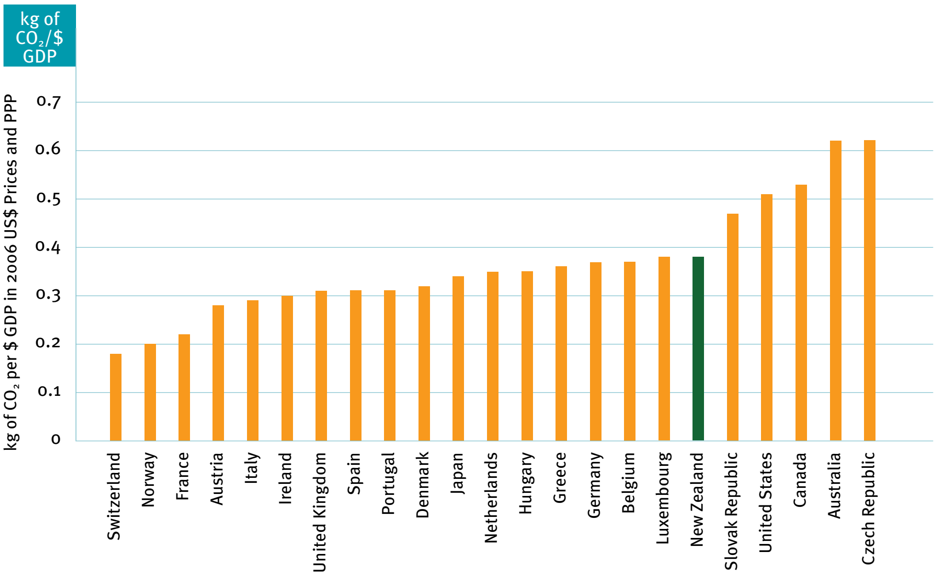


Figure 5.4: CO_2 Emissions from Fuel Combustion as a Ratio of GDP (PPP) for OECD Countries in 2006



Glossary

Agriculture	The agriculture sector includes all types of farming, hunting, forestry, logging and fishing.
Anthropogenic emissions	These are emissions that result from human activities (e.g. the emissions from the combustion of petrol in an automobile) as opposed to emissions that occur naturally (naturogenic emissions).
Aviation fuels	Avgas, Avtur, Jet-A1 and Jet-4 aviation fuels, light kerosene and premium kerosene.
Biogas	Energy produced from the anaerobic digestion of sewage and industrial waste. Includes landfill gas and sewage.
Biomass	This refers to living and recently dead biological material that can be used as a fuel. Biomass in this publication consists of biogas and wood.
Bunker fuels	Fuels used in international marine transportation.
Calorific value	The energy content or energy value of a fuel can be measured as the heat released on complete combustion. Referenced to unit quantity or mass, the energy content of a fuel is referred to as its calorific value, or specific energy. The choice of unit, however, is a matter of convention. For gas, the cubic metre is typically used. For coal, the kilogram is more usual. For liquid fuels, both volumes and masses are commonly used. Calorific values based on gas volumes are assigned to specific conditions of temperature and pressure.
Cogeneration	The simultaneous or sequential production of two or more forms of useful energy from a single primary energy source. In this publication, a cogenerator is an electricity generating facility that produces electricity and a form of useful thermal energy (such as heat or steam for industrial or commercial heating or cooling purposes).
Commercial	The commercial sector includes non-manufacturing business establishments such as hotels, motels, restaurants, wholesale businesses, retail stores and health, social and educational institutions. It also includes electricity used in public lighting, railway and urban traction.
Carbon dioxide equivalent (CO_2-e)	Measures the combined climate changing potential of emissions of multiple greenhouse gases. Emissions of each gas are converted to an amount of carbon dioxide that would cause the same climate change impact and then summed.
Direct gases	Emissions from carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have global warming potentials identified by the Intergovernmental Panel on Climate Change (IPCC) and are classified as direct greenhouse gases. Other gases are also categorised as direct gases. For further information, refer to www.ipcc.ch.
Emission factor	A unique value for scaling emissions to activity data in terms of a standard rate of emissions per unit of activity (e.g. grams of carbon dioxide emitted per barrel of fossil fuel consumed). It is used to calculate the amount of greenhouse gas emitted – the product of the emissions factor and the amount of energy used.
Energy emissions	Emissions from fuel combustion, production, storage and distribution. This does not include emissions from the combustion of biomass or emissions from bunker fuels.
Feedstock	Raw material directly used in the production of goods. This is not the same as fuel used to power the production process as this only indirectly contributes to the production of goods.
Flaring	The burning of natural gas that would otherwise be wasted and allowed to escape into the atmosphere. Combustion converts methane in natural gas and the oxygen in the air to carbon dioxide and water.

Fugitive emissions	Fugitive emissions result from the leakage of gases during various human activities. In practice, this refers to emissions from natural gas flaring and processing, and to transmission and distribution leakages of gas. Also included are CH_4 emissions from coal mining and post-mining activities and emissions from geothermal fields.
Global warming potential	Global warming potentials (GWP) are calculated as the ratio of the radiative forcing of one kilogram of greenhouse gas emitted to the atmosphere to that from one kilogram of carbon dioxide over a period of time (e.g. 100 years).
Greenhouse gases	Gases in an atmosphere that absorb and emit radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. This report refers to direct greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2).
Gross emissions	For the purposes of this publication, gross emissions are greenhouse gas emissions from energy sources and industrial processes. This is in contrast to net emissions, which includes all carbon sinks, i.e. the IPCC's land use, land use change and forestry category. New Zealand reports gross and net emissions under the UNFCCC.
Indirect greenhouse gases	Emissions of carbon monoxide (CO), oxides of nitrogen (NO_x), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2) are not included in global warming potential-weighted greenhouse gas emission totals. They are reported in greenhouse gas inventories for completeness.
Industrial processes emissions	Emissions that are a by-product of industrial or chemical processes. This excludes emissions from fuel combustion used in the process, which are reported under energy. In New Zealand, industrial processes emissions come from the manufacture of iron and steel, aluminium, hydrogen, cement, lime and urea.
International transport	Includes international sea and air transport. Excludes coastal shipping, national air transport and all land transport.
Manufacturing industries	These industries are often described as plants, factories or mills and generally use power-driven machines and other materials-handling equipment.
Natural gas	Consists mainly of methane occurring naturally in underground deposits.
Naturogenic emissions	Emissions that occur naturally (e.g. the emissions from an erupting volcano or geyser).
Primary industries	The agriculture, forestry and fishing industries.
Transformation industries	Industries that convert energy. In New Zealand, this includes petroleum refining, synthetic petrol production and oil and gas extraction and processing.
Residential	This refers to each separately metered private dwelling, i.e. private houses. It excludes hotels, hostels, institutions, etc. (which are included in the commercial sector) but does include normally unoccupied holiday homes, beach houses, etc.
Thermal electricity generation	Electricity generation where the prime mover is steam driven. Thermal electricity burns fossils fuels (e.g. natural gas, coal or oil) to produce and use steam to generate electricity.
Transformation	Transformation in this publication refers to the transformation of energy from one form to another.
Transport	Refers to emissions from the combustion and evaporation of fuel used for transport activities. Emissions for fuel sold for use in international transport are not included.

Abbreviations and Units

Abbreviations

CH_4	Methane
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
GCV	Gross calorific value
GDP	Gross domestic product
GWP	Global warming potential
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
Kapuni LTS	Kapuni Low Temperature Separation
Kt	Kilotonne
LPG	Liquefied petroleum gas
LULUCF	Land use, land use change and forestry
Mt	Megatonne
NCV	Net calorific value
NMVOCs	Non-methane volatile organic compounds
NZRC	New Zealand Refining Company
N_2O	Nitrous oxide
NO_X	Other oxides of nitrogen
OECD	Organisation for Economic Cooperation and Development
PJ	Petajoule
PPP	Purchasing power parity
SO_2	Sulphur dioxide
T	Tonne
UFG	Unaccounted for gas
UNFCCC	United Nations Framework Convention on Climate Change

Common Global Warming Potentials

CO_2 = 1

CH_4 = 21

N_2O = 310

CF_4 = 6,500

C_2F_6 = 9,200

SF_6 = 23,900

HFC-32 = 650

HFC-125 = 2,800

HFC-134a = 1,300

HFC-143a = 3,800

HFC-227 ea = 2,900

Conversion Factors

From element basis to molecular mass:

$C \rightarrow CO_2$: C × 44/12 (3.67)

$C \rightarrow CH_4$: C × 16/12 (1.33)

$N \rightarrow N_2O$: N × 44/28 (1.57)

From molecular mass to element basis:

$CO_2 \rightarrow C$: CO_2 × 12/44 (0.27)

$CH_4 \rightarrow C$: CO_2 × 12/16 (0.75)

$N_2O \rightarrow N$: N_2O × 28/44 (0.64)

Units

1 t (tonne) = 1,000 kg = 1,000,000 g

1 kt (kilotonne) = 1,000 t

1 Mt (megatonne) = 1,000 kt = 1,000,000 t

1 Gg (gigagram) = 10^9 g = 1 kt

1 PJ (petajoule) = 10^{15} J

Emission Factors

Combustion emission factors are used to estimate the amount of a greenhouse gas emitted from a given quantity of fuel. These factors are expressed in terms of quantity of the greenhouse gas released per unit of energy of the fuel combusted.

Other emission factors that do not involve combustion or the use of fuel are expressed in terms of emissions per unit of production or some other kind of activity.

The methods used to calculate emission factors in this publication follow the IPCC (1996).

Carbon Dioxide Emissions

Carbon dioxide emissions from the combustion of fuel can be estimated with a high degree of certainty, as these emissions depend almost exclusively on the carbon content of the fuel, which is generally known with a high level of certainty. New Zealand carbon dioxide emission factors for combustion are based on energy content in gross calorific value (GCV) terms. The amount of carbon released as a result of combustion can be estimated by multiplying the amount of fuel combusted, expressed in units of energy, by a carbon emission factor. Carbon dioxide emissions can be derived by substituting the carbon emission factor with a carbon dioxide emission factor, calculated by multiplying the carbon emission factor by 44/12 (the ratio of the molecular weight of carbon dioxide to the molecular weight of carbon). The carbon dioxide emission factors listed in this publication are calculated in this way.

However, simply multiplying fuel consumption by a carbon dioxide emission factor, as above, does not allow for the small proportion of the carbon that remains unoxidised due to incomplete combustion. An oxidation factor is therefore applied. The oxidation factors used in this publication are the recommended default factors from the IPCC (1996). These are:

- 0.995 for gas;
- 0.990 for liquid fuels; and
- 0.980 for coal.

Carbon dioxide emissions from combustion can therefore be summarised with the following formula:

> Carbon dioxide emissions = activity x (carbon emission factor x 44/12) x oxidation factor

The following shows an example of how an emission factor is calculated. Suppose we wanted to know the carbon dioxide emissions from diesel in the transport sector in 2008:

- In 2008, the national transport sector used 83.10 PJ of diesel.
- The 2008 CO_2 emission factor for diesel is 69.53 kt CO_2/PJ (before oxidation).
- The oxidation factor for liquid fuels is 0.990.

Therefore, carbon dioxide emissions from diesel in the transport sector in 2008 are:

> 83.10 PJ x 69.53 kt CO_2/PJ × 0.99 = 5,721 kt CO_2 (with rounding differences accounted for)

The carbon dioxide emission factors used in this publication are mainly based on New Zealand-specific sources, while most of the non carbon dioxide emission factors are from the IPCC (1996).

Non Carbon Dioxide Emissions

In contrast to carbon dioxide emissions, the non carbon dioxide emissions from combustion depend on the precise nature of the activity in which the fuel is being combusted. A litre of diesel used for industrial heating produces a different level of methane emissions compared with the same amount used in road vehicles. Given that we have an imprecise knowledge of where and how fuel is being consumed and also because the emission factors used are inherently imprecise, there is a much greater level of uncertainty surrounding estimates of non carbon dioxide emissions than there is for carbon dioxide emissions.

Methodological Tiers

The IPCC (1996) provide three methodological tiers when measuring greenhouse gas emissions. Tier 1 is the simple, first order approach. It uses coarse activity data, simplified assumptions, IPCC default parameters and large uncertainties. Tier 2 is a more accurate approach to measuring greenhouse gas emissions. The Tier 2 approach uses more disaggregated activity data with country-specific parameter values and smaller uncertainties. Tier 3 is the highest order method and involves detailed modelling and/or inventory measurement systems, which are driven by data at higher resolution and much lower uncertainties.

The emission factors classed as Tier 1 apply to very broad groupings of fuel types and sectors. For instance, a single emission factor applies to all oil used in manufacturing industries and construction. The use of Tier 2 emission factors requires more detailed information about where and how fuel is being consumed with respect to both technology and fuel type. For instance, there is an emission factor for coal used in residential coal stoves. Tier 2 emission factors are used in the inventory where possible – Tier 1 emission factors are only used when an IPCC Tier 2 emission factor does not exist.

Carbon Dioxide Equivalent (CO_2-e) Emissions

Carbon dioxide equivalent emissions are calculated based on the estimated global warming potential (GWP) of each greenhouse gas, expressed as the effect of one kilogram of carbon dioxide on global warming over a given time horizon. Non carbon dioxide emissions are multiplied by the appropriate warming potential to convert to a carbon dioxide equivalent basis. The GWPs for CH_4 and N_2O applied are 21 and 310, respectively, which are for a 100-year time horizon.

Industrial Processes Carbon Dioxide Emissions

Industrial processes carbon dioxide emissions arise out of a variety of different chemical reactions, and the methodologies to measure them vary significantly according to the type of production. In some cases, emissions are primarily related to the release of carbon from a fuel or fuels. In these cases, release of carbon is not primarily the result of combustion, but like combustion, the end result is that all or almost all of the carbon in the fuel oxidises to form carbon dioxide. Therefore, emissions from these processes are broadly calculated in the same way as combustion emissions: by multiplying the amount of fuel used by the appropriate carbon dioxide emission factor. Emissions from the production of urea and the production of steel fall under this category. In other industrial processes, emissions result from the release of carbon from a raw material in the production process. For instance, carbon dioxide is emitted from the calcination of limestone in the production of cement or the oxidation of anodes in the production of aluminium.

Biomass Emissions

Carbon dioxide emissions from the use of biomass are not included in this publication, but CH_4 and N_2O emissions are. This is because any carbon dioxide emissions from woody biomass are captured in the Land Use, land use change and forestry (LULUCF) category, while carbon dioxide emissions from biogas emissions are accounted for in the waste category. The IPCC methodology assumes that carbon in the biomass is released as carbon dioxide when the forest is harvested. Including carbon dioxide emissions directly from wood combustion or from any wood waste that has been landfilled would be double counting. CH_4 and N_2O emissions from the combustion of biomass, though, are captured in the energy category and are therefore reported in this publication.

Data Sources

These include Ballance Agri-Nutrients (Kapuni) Limited, BlueScope Steel Limited, Century Drilling & Energy Services Limited, Contact Energy Limited, Evonik Degussa Peroxide Limited, Fonterra Co-operative Group Limited, Genesis Power Limited, Golden Bay Cement Limited, Holcim (New Zealand) Limited, the Interisland Line, McDonald's Lime Limited, Methanex New Zealand Limited, Mighty River Power Limited, the Ministry for the Environment, the New Zealand Army, the New Zealand Refining Company Limited, Nova Gas Limited, Pacific Steel, Perry Group Limited, Rio Tinto Limited, the Royal New Zealand Air Force, the Royal New Zealand Navy, Shell Todd Oil Services Limited, Kiwirail Limited, Top Energy Limited, Vector Limited and Websters Hydrated Lime Co. Limited.

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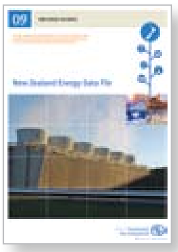
Further Reading

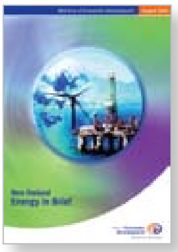
www.med.govt.nz/energy/data/info/

Other Energy Information and Modelling Group Publications

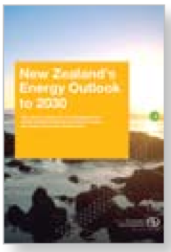
The *New Zealand Energy Quarterly* provides quarterly energy statistics and trend data on the supply of major fuel types, electricity generation and its associated greenhouse gas emissions, and liquid fuel prices.
www.med.govt.nz/energy/nzeq/



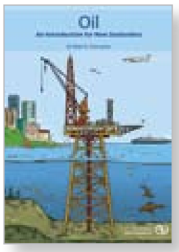
The *New Zealand Energy Data File* provides comprehensive statistics and supporting information on New Zealand's energy supply, demand and prices, mostly as national aggregates. It includes annual data from 1974, with quarterly data and annual energy balances to the end of 2007. Oil and gas reserves information is also included.
www.med.govt.nz/energy/edf/



New Zealand Energy in Brief provides a handy pocket-sized summary and concise graphical representation of key energy data. It includes an energy flow diagram showing energy flows for the calendar year 2007.
www.med.govt.nz/energy/eib/



New Zealand's Energy Outlook is designed to be a starting point for anyone who wants to be more informed about the energy choices New Zealand faces. The latest publication gives projections to 2030 of New Zealand energy supply, demand, prices and greenhouse gas emissions under a variety of assumptions. *Energy Outlook* also provides essential background on every form of commercial energy, on each category of demand, and on the relationship of energy to climate change.
www.med.govt.nz/energy/eo/



Oil: An Introduction for New Zealanders provides an easy-to-read background on oil from a New Zealand perspective. Topics include oil production and refining technologies, uncertainties around statistics on world oil reserves, the structure and regulation of New Zealand's oil industry and international efforts to promote oil security.
www.med.govt.nz/energy/oilintro/

New Zealand Energy Greenhouse Gas Emissions

2008 Calendar Year Edition

Ministry of Economic Development
Manatū Ōhanga

New Zealand Government