Rangiora Inventory of Emissions

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Executive Summary

An inventory of emissions to air was conducted during 1997 for the urban area of Rangiora. Wintertime emissions of suspended particulate (PM_{10}), carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOCs) and carbon dioxide (CO_2) from domestic heating, transport and industry were examined. Surveying of households and industry, traffic modelling, resource consent information and the application of emission factors were used to derive emissions.

From the domestic heating survey approximately 51% of Rangiora households use electricity, 13% use gas and 66% use solid fuel to heat their main living area on a typical winter's night. Wood burners are used by 62% of Rangiora households and open fires are used by ~6% of the households. Many households use more than one method of domestic heating in their main living area.

Wood burners are responsible for over 70% of the PM_{10} emissions from domestic heating with the remainder coming from open fires (18%) and multi-fuel burners (9%). Over 80% of the PM_{10} emissions come from the burning of wood with the remainder (13%) coming from coal burning. Over half of the PM_{10} emissions occur during the evening (4 p.m. to 10 p.m.) period.

Passenger cars are responsible for about 90% of the PM_{10}, CO, NOx, VOC and CO_2, and two thirds of the SOx emissions from transport. About 42% of the CO emissions from transport occur during the evening (4 p.m. – 10 p.m.) period.

Industrial and school boilers and a local foundry contribute the majority of the PM_{10} emissions from industry in Rangiora. Industrial and school boilers are responsible for the majority of CO, NOx, SOx and CO_2 emissions from industry in Rangiora, with industrial boilers contributing approximately two thirds and school boilers one third of these emissions. The majority of VOC emissions from the industrial sector come from spray painting operations.

Overall the domestic heating sector is responsible for 62% of the PM_{10} and CO, 38% of the SOx and ~75% of the VOCs and CO_2. The transport sector contributes 38% of the CO, 30% of the SOx, most (84%) of the NOx, and 24% of the VOC emissions. Industry emits 26% of the PM_{10} emissions, 32% of the SOx emissions and up to 5% of emissions of other contaminants.

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1. Introduction

1.1 Purpose and Scope

This report describes the results of an air emissions inventory for the town of Rangiora. It provides an estimate of quantities of specific contaminants released into the air from major sources within the urban area of Rangiora.

Emission inventories are an important air quality management tool for determining the relative contribution of different sources of emissions to air. Emission inventories are used in conjunction with air quality monitoring data and results of meteorological investigations to aid air quality management.

The scope of this emissions inventory was as follows:

- Contaminants include suspended particulate (PM_{10}), carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOCs), and carbon dioxide (CO_2)
- Sources include domestic home heating, transport and industry
- The area under investigation includes the urban areas of Rangiora
- Wintertime daily emissions including a breakdown for the following periods; 6am-10am, 10am-4pm, 4pm-10pm, 10pm-6 am.

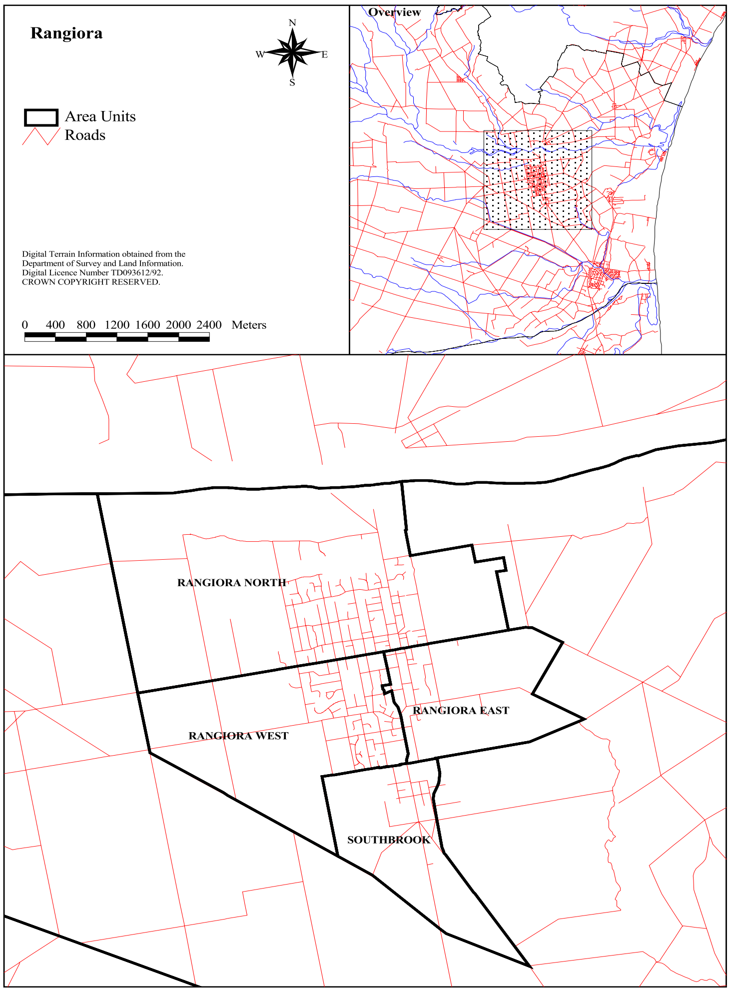


Figure 1.1 Urban areas of Rangiora

1.2 Background

Rangiora is an urban township in the Canterbury Region located approximately 20 km north via SH1 and SH72. It has a population of around 9900 and approximately 3700 dwellings.

For the purpose of this investigation the urban area of Rangiora was defined as the areas of: Rangiora East, Rangiora West, Rangiora North and Southbrook (figure 1.1).

Domestic home heating, transport and industrial discharges are likely to be the main sources of air contaminants discharging into the Rangiora area during the winter months. Backyard rubbish burning is also a potential source of air contaminants. There are currently no restrictions on backyard rubbish burning in Rangiora. Agricultural burning in nearby rural areas may contribute to emissions at some times of the year.

A small number of industrial activities that discharge to air are located in Rangiora. These tend to be a mix of fairly minor activities including automotive and joinery spray painting, and industrial boilers. Emissions from industrial processes classified as Part A or Part B under the Clean Air Act 1972 are currently discretionary activities requiring resource consents under the Resource Management Act (1991). Emissions from 6 Part A or B industries were included in the investigation as well as emissions from 11 industrial or trade premises not meeting these classifications.

Some areas of Rangiora were deemed Clean Air Zones under the Clean Air Zones (Canterbury Region) Order (1984). These are the areas that were zoned residential at the time of the introduction of that Order. The installation of solid fuel domestic home heating appliances in these areas is limited to appliances authorised for use in Clean Air Zones. This excludes open fires and wood burners not meeting an emission criteria applying at the time of installation. Further regulations prohibit the use of wood with moisture content of more than 25% (wet weight) and coal with a sulphur content of less than 1% on any appliance.

Air quality monitoring in Rangiora in recent years has been limited to smoke measurements conducted during the winter of 1993. These indicated maximum 24-hour average smoke concentrations of 70-80 μgm^{-3}. Further investigations into air quality in Rangiora are scheduled for the year 2000. This is likely to include monitoring for sulphur dioxide (SO_2), suspended particulate (PM_{10}) and carbon monoxide (CO).

2. Domestic Home Heating

2.1 Home heating survey

During July 1997 Business Improvements Ltd conducted a telephone survey of householders to determine domestic home heating methods and fuels. This determined the methods of home heating i.e.; open fires, electricity, gas, log burners, multi-fuel burners and oil fired heating systems; the quantity of fuel, wood or coal, used over a 24 hour period, and the times of the day the method of home heating was used. A total of 187 households were surveyed giving a margin of error of approximately 7%. Because of the higher emissions during the winter months, surveys targeted use on a typical winter's day (i.e. 24-hour period) with the area of interest being the main living area only. If multiple methods e.g., electricity and a wood burner, were both used on a typical winter's night, details relating to both methods were included.

The quantity of gas used was derived from an assessment of the frequency with which gas bottles were refilled. Respondents using gas were also asked whether or not their gas appliances were flued.

Those respondents who had either log burners or multi-fuel burners were required to give an indication of the age of their appliance, and in the case of multi-fuel burners, the type (brand or model) of appliance they were using.

A copy of the questionnaire is included as appendix 1. The survey was based on 1991 census data. All tables and emission calculations in this report include an extrapolation of the initial survey to reflect household numbers indicated in the 1996 census. Further details of the home heating survey based on 1991 census data are contained in CRC report no. U97/80 (Lamb, 1997).

Details of the survey area and sampling are contained in table 2.1.

Home heating methods and fuels

Table 2.2 outlines the percentage of households using the different home heating methods in Rangiora. Table 2.3 describes the percentage use of different methods in more detail including the age of burners, the use of multi-fuel versus wood burners and open fires and the percentage of gas appliances that are flued.

Table 2.3 indicates that 51% of households use electricity and 13% of households use gas. From table 2.2 we see that 59% of households use electricity, gas or both. This indicates that 5% of households use both electricity and gas.

Solid fuel burners are considered in terms of the type of burner and the age of the burner because these factors influence the amount of contaminants emitted from the appliance. For the purpose of this assessment solid fuel burners have been classified as follows:

- A log burner is a burner of any age which does not burn coal;
- An enclosed coal burner is an older model coal burner designed during or before the 1980s;
- A modern multi-fuel burner is a more recent burner in which either wood and coal or coal can be burnt.

Table 2.1 Survey area for Rangiora

Survey area for Rangiora (based on census areas)	Area (ha)	Total number of households	Housing density (houses/ha)	Total houses surveyed	Error Level %
Rangiora North, Rangiora East, Rangiora West and Southbrook	2342.8	3692	1.6	187	7%

Table 2.2: Home heating methods in Rangiora

Home heating method	% of households*	Number of households
Electricity or gas (or both)	59	2178
Solid fuel burners	66	2437
Oil fired heating	0.5	185

*Note: The percentage of households is greater than 100% because of households using multiple methods of home heating e.g., gas and solid fuel burning, on a typical winter's night.

The following are the models or brands from the survey responses[1] included as either enclosed coal burners, modern multi-fuel burners, pot-bellies and incinerators:

1. <u>Enclosed coal burners:</u> McKay space heater, Gilles Juno, Bosca, Bellmac, Schooner, Warmaire, Rayburn, Glowburn, Wellstood, New Wonder, Speedway, Dougherty Boiler.
2. <u>Modern multi-fuel burners:</u> Masport, Jayline, Stack, Contessa, Magnum, Lady Kitchener, Kent, Fisher, Yunca, Siesta.
3. <u>Incinerator:</u> Atlas, Shacklock, Orion
4. <u>Potbelly:</u> Potbelly

Included in the list of makes and models for 2 above (multi-fuels) are wood burners that are designed to burn wood only e.g., Lady Kitchener, Magnum, Fisher. The inclusion of these models in 2 above indicates that in some instances these wood burners are being used (inappropriately) to burn coal.

Table 2.3: Breakdown of home heating methods in Rangiora

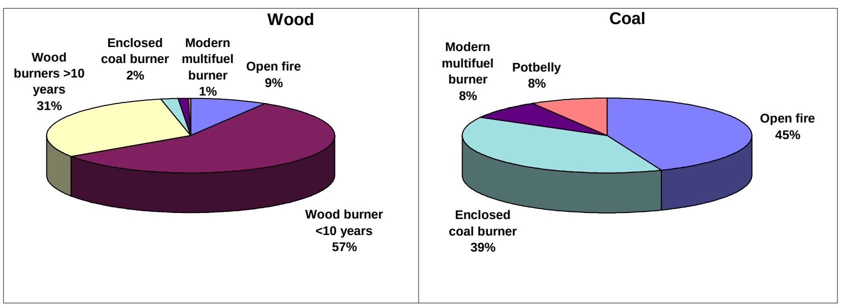
	Percentage*	Number of house holds
Electricity	51.3	1894
Total Gas	13.4	495
-flued gas	1.1	41
-unflued gas	12.3	454
Oil	0.5	185
Open fire/ visor	5.9	218
Log burner	62	2289
-10 years and older	22.5	831
-less than 10 years	39	1440
Enclosed coal burner	2.1	78
Modern multi-fuel burner	1.1	41
Pot belly	1.1	41

* The total percentage is greater than 100% because some households use more than one method of home heating.

Table 2.4: Fuel consumption across appliances

	Wood		Coal	
	% hh	kg	% hh	kg
Open fire	5.8	4407	2.6	1015
Wood burner 10yrs or older	22.5	28860		-
Wood burner <10 yrs old	38.8	15777		-
Enclosed coal burner	1.0	939	1.6	900
Modern multi-fuel burner	1.0	626	0.5	196
Potbelly	0.5	125	0.5	196
Total	**69.6**	**50734**	**5.2**	**2307**

Figures 2.1 and 2.2 illustrate the distribution of wood (kg) and coal (kg) burnt on different appliances. The greatest amount of wood is burnt on the older model wood burners.



Figures 2.1 & 2.2: Wood use and coal use across appliances

Open fires and enclosed coal burners are the appliances in which the greatest quantity of coal is burnt.

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[1] Four areas were surveyed for home heating methods during July 1997. In addition to Rangiora, Ashburton, Kaiapoi and Waimate were surveyed. Model and brand classifications were based on responses from all four areas.

The relative weight of each fuel used for domestic home heating in Rangiora on a typical winter's day is illustrated in figure 2.3.

Of the wood burnt on open fires and on wood burners approximately 40% is self collected and 60% is purchased from a wood merchant[2]. Of the wood burnt on multi-fuel burners, approximately 25% is self collected and 75% is purchased from a wood merchant.

Wood burners and multi-fuels are the most common method used to heat the home during the 10pm to 6am period (table 2.5). Open fires are rarely used during this period, probably due to the inability to get the overnight burn that can be achieved with wood burners by stoking them up and shutting down the air supply.

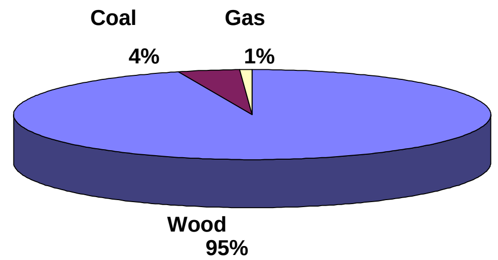


Figure 2.3: Proportion of fuel (kg) burnt in Rangiora on a typical winter's night

Home heating methods in Rangiora compared to other urban centres

The use of wood burners as a method of home heating in Rangiora is more common than in Christchurch, Timaru, Ashburton, Waimate (99% CI) and Kaiapoi (95% CI) with 62% of households choosing this method (table 2.6). The use of gas in Rangiora is significantly less than in Kaiapoi (99% CI). Open fires are least common in Rangiora and Kaiapoi compared with other urban areas. This may be due to the Clean Air Zone Canterbury Order (1984) which prohibited the installation of open fires in the then zoned residential areas of Rangiora.

2.2 Home heating emissions

Emissions from domestic home heating were calculated by multiplying the amount of fuel used per day/night by an emission factor which takes into account the appliance on which the fuel is burnt i.e.,

$$CE\ (g/day) = EF\ (g/kg) * FB\ (kg/day) \qquad \textbf{(1)}$$

where CE = contaminant emission
EF = emission factor
FB = fuel burnt

An assessment of emissions from domestic home heating for different periods of the day was also conducted. This breakdown was based on a survey question regarding the time of day, for a typical winter's day, the main living area of a house was heated. Times of the day were specified as follows:

- Morning (between 6am and 10am)
- Day time (between 10am and 4pm)
- Evening (between 4pm and 10pm)
- Overnight (between 10pm and 6am)

Emissions for each period were assessed as follows:

$$CE\ (g/time\ period) = EF\ (g/kg) * FB\ (kg/time\ period) \qquad \textbf{(2)}$$

where

[2] Based on the proportions of households that do each. Therefore assumes an equal fuel useage across households that collect versus households that purchase wood.

*FB (kg/time period) = no. of hours in time period * total fuel use/day*
no. of hours in all time periods

For example, the amount of fuel burnt from 4pm to 10pm for a household that heats the main living area from 4pm to 10pm and from 10am to 4pm and burns a total of 20 kg wood per day is as follows:

*FB(kg/4pm-10pm) = 6 hrs * 20kg = 10kg*

Table 2.5: Home heating methods used at different times of the day (as a proportion of the total number of households using that method of home heating)

Time of day	Electricity %	Gas %	Oil %	Wood burner %	Open fire %	Multi -fuel %
6am - 10am	65	56	-	55	8	63
10am - 4pm	21	36	-	47	8	63
4pm - 10pm	50	76	100	98	98	100
10pm - 6am	48	12	-	37	8	49
Average over 4 time periods	46	45	25	59	31	69

Table 2.6: Home heating methods in Rangiora compared to other urban centres

	% for Rangiora	% for Ashburton	% for Kaiapoi	% for Waimate	% for Timaru[1]	% for Chch[1]
Electricity	51.3	44.2	40.6	41.5	63	68
Total Gas	13.4	13.2	32.6	14	24	17
-flued gas	1.1	1.1	3.2	-		
-unflued gas	12.3	12.1	29.4	14		
Oil	0.5	2.6	-	0.6	3	5
Open fire/ visor	5.9	10.5	5.9	9.4	10	14
Log burner	62.0	33.2	50.8	43.9	43	28
-10 yrs and older	22.5	13.7	16.6	13.5	23[2]	14[2]
-less than 10 yrs	39.0	19.5	34.2	28.7	20[3]	14[3]
Enclosed coal burner	2.1	6.8	0.5	8.8	2	3
Modern multi-fuel burner	1.1	11.1	3.2	5.8	n/a	
Pot-belly	1.1	1.6	2	1.2	1	0.3
Incinerator	-	-	4	3.5	-	1

(1) Emission inventories for Christchurch and Timaru were conducted differently due to the effect of different regulations in the Christchurch Clean Air Zones. This work was conducted by a different organisation using an alternative questionnaire. With the exception of the classifications of appliances, which isn't specified in the Christchurch/Timaru inventories, interpretation of the results is likely to be similar.

(2) Appliances recorded in the <1989 category for the Christchurch and Timaru emission inventories.

(3) Appliances recorded in the 1989-1992 and post 1993 categories for the Christchurch and Timaru emission inventories.

	12 hrs	***(3)***

Emission factors

Actual emissions of air contaminants for a given appliance are dependent on a number of factors including: properties of the fuel (e.g., wetness, chemical composition, density) the amount of oxygen supporting the combustion process (e.g., high, medium or low setting on a wood burner), and the temperature of the fire and fire box (higher emissions are expected during the initial stages of the

Table 2.7: Emission factors for domestic home heating appliances

Appliance	PM_{10}	CO	NOx	SOx	VOC	CO_2
	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg
Gas burner	0.1	0.4	2	0.01	0.2	2500
Oil burner	1.3	0.6	2.2	3.8	0.25	3200
Open fire - wood	15	120	1.6	0.2	30	1700
Open fire - coal	33	60	1.5	18	15	2800
Old (10yr +) burner - wood	12.8	104	1.4	0.2	26	1700
Newer (< 10 yr) burner - wood	6.4	51	0.7	0.2	13	1700
Enclosed coal burner - wood	14.3	114	1.6	0.2	29	1700
Enclosed coal burner - coal	31	57	1.4	18	14	2800
Multi-fuel burner - wood	6.4	51	0.7	0.2	13	1700
Multi-fuel burner - coal	14.3	26	0.6	18	6	2800
Potbelly - wood	14.3	114	1.6	0.2	31	1700
Potbelly - coal	31.5	57	1.4	18	14	2800

Table 2.8: Home heating emissions by appliance type

	Daily fuel quantity (kg/day)	PM_{10} kg	CO kg	Nox kg	Sox kg	VOC kg	CO_2 kg
Gas	377	0	0	0	0	0	123
Oil	39	0	0	0	0	0	942
Open fire - wood	4407	66	529	7	1	132	7491
Open fire - coal	1015	34	61	2	18	15	2842
Woodburner (10yr+)	28861	202	1616	22	3	404	26821
Woodburner (<10yr)	15777	185	1478	20	6	369	49063
Enclosed coal burner -wood	939	13	107	2	0	27	1597
Enclosed coal burner - coal	900	28	52	1	16	13	2520
Modern multi-fuel - wood	626	4	32	0	0	8	1065
Modern multi-fuel -coal	196	3	5	0	4	1	548
Potbelly - wood	125	2	14	0	0	4	213
Potbelly - coal	196	6	11	0	0	3	548
Total	53458	543	3905	54	48	976	93773

fire). Because it is not possible to quantify actual emissions from all appliances in an area average emissions based on appliance and fuel type are used. These are referred to as emission factors and are based on the amount of contaminant in grams e.g., PM_{10}, CO, emitted per kg of fuel burnt. Emission factors are summarised in table 2.7.

The home heating emission factors used in the emission inventory were those derived by NIWA (CRC, 1997) for the Clean Air Zones of Christchurch. These were developed from a literature survey including: United States Environmental Protection Agency (1994) and take into account the nature of the fuels and appliances in use in Christchurch. Although clean air zones do not apply to the whole of Rangiora there are unlikely to be significant differences in appliance emissions across the township.

Daily home heating emissions by appliance type

The approximate amount of fuel burnt on a typical winter's day for different appliances and the resulting emissions are shown in table 2.8. Emissions of each contaminant by appliance type are also illustrated in figures 2.4 to 2.9.

Wood burners are responsible for over 70% of the PM_{10} emissions with the remainder coming from open fires (18%) and enclosed coal burners (9%). Wood burners are also responsible for the majority of CO, NOx, VOC, and CO_2 emissions.

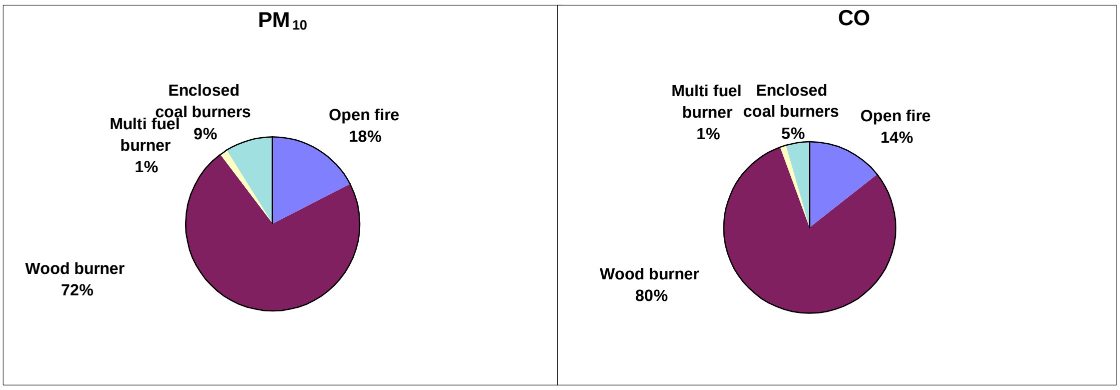


Figure 2.4 & Figure 2.5: PM_{10} & CO home heating emissions by appliance type

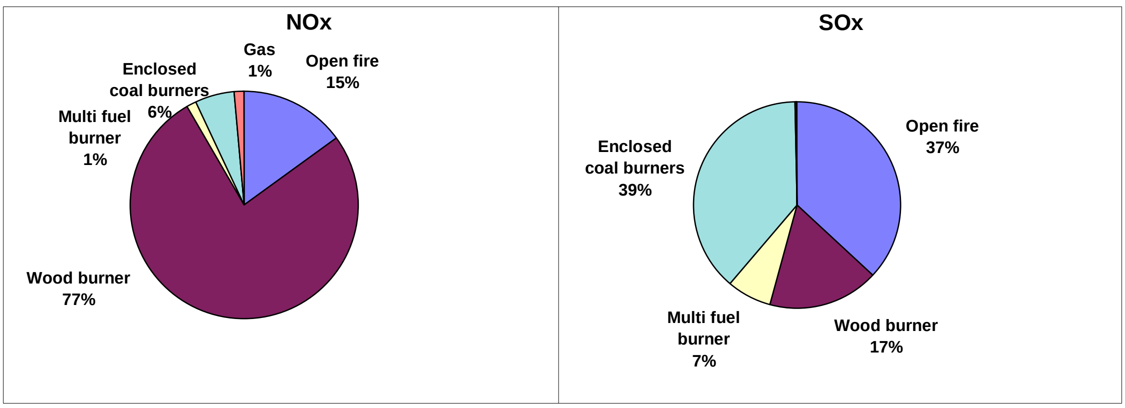


Figure 2.6 & 2.7: NOx and SOx home heating emissions by appliance type

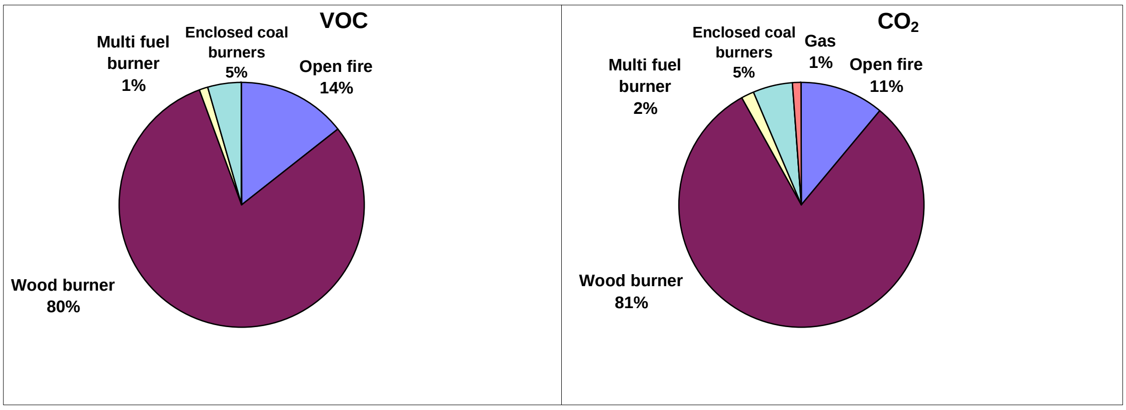


Figure 2.8 & 2.9: VOC and CO_2 home heating emissions by appliance type

Home heating emissions by fuel type

Figures 2.10 to 2.15 illustrate the contributions of the fuels wood, coal, oil and gas to the total emissions of each contaminant from domestic home heating. The burning of wood results in over 80% of the PM_{10} emissions and over 90% of the CO, NOx, VOC and CO_2 emissions. Coal burning results in 80% of the SOx emissions and 13% of the PM_{10}. Gas contributes 1% of the NOx and 1% of the CO_2 emissions.

Figure 2.10 & 2.11: PM_{10} and CO home heating emissions by fuel type

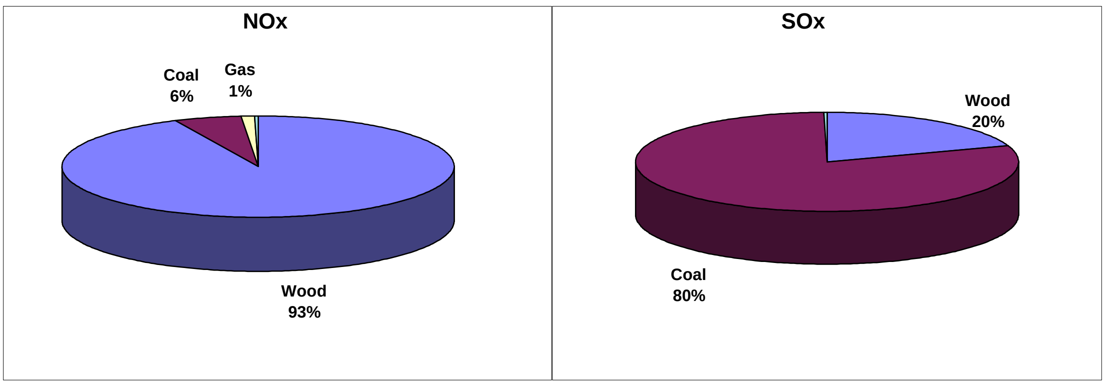


Figure 2.12 & 2.13: NOx and SOx emissions by fuel type

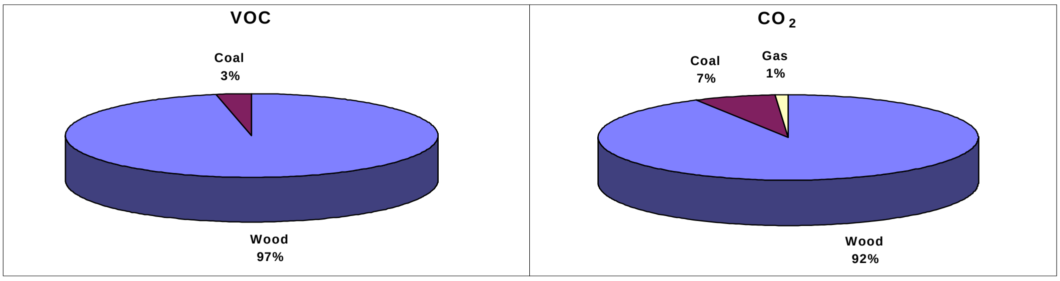
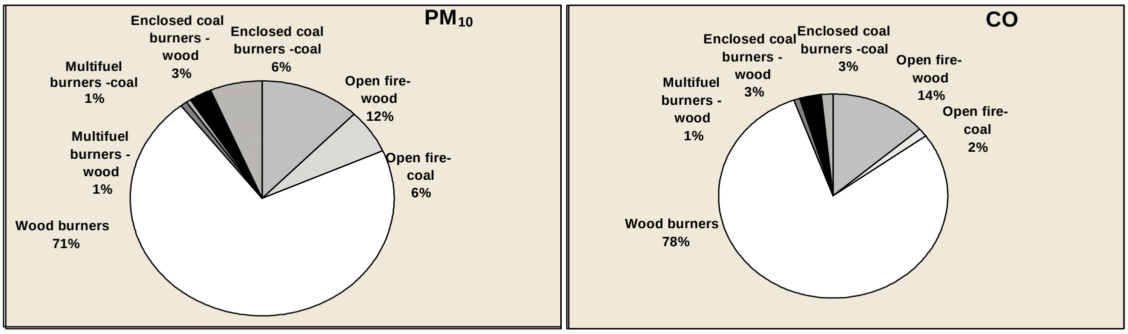


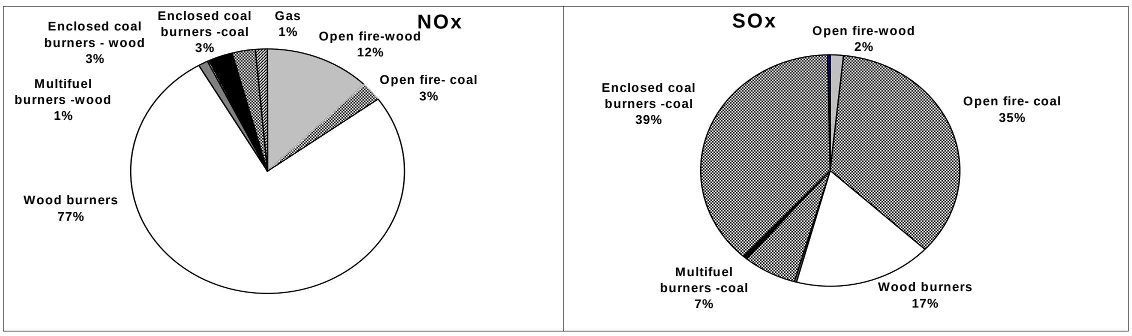
Figure 2.14 & 2.15: VOC and CO_2 home heating emissions by fuel type

Home heating emissions by fuel and appliance type

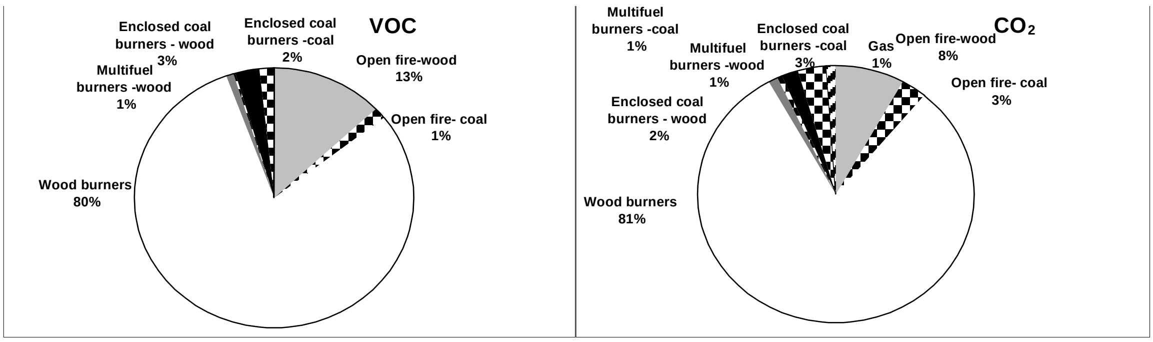
Home heating emissions by fuel and appliance type are illustrated in figures 2.16 to 2.21. A greater proportion of PM_{10} emissions from open fires comes from the burning of wood rather than coal. In contrast PM_{10} emissions from enclosed coal burners are mostly due to coal burning. Overall more emissions come from the burning of wood because of the large proportion of wood burners.



Figures 2.16 & 2.17: PM_{10} and CO emissions by fuel and appliance type



Figures 2.18 & 2.19 SOx and NOx emissions by fuel and appliance type



Figures 2.20 & 2.21 VOC and CO2 emissions by fuel and appliance type

Home heating emissions by time of day and emission density

For the purpose of allowing comparisons of emissions in Rangiora to those of other areas of the region the total weight of emissions was divided by the number of hectares in the study area. This allows a comparison of weight of emission per area volume. The Rangiora area comprises of 2342.8 ha. Emissions of contaminants from the domestic heating sector on a g/kg basis are illustrated in table 2.9.

Emissions were also examined in terms of the time of day during which they occur for a typical winter's day. This allows for an assessment of emissions relative to times in which there may be variations in meteorological conditions. For example, if meteorological measurements indicated that the wind was much stronger during the daytime, emissions that occurred at this time may have little effect on the 24-hour average concentration.

Table 2.10 shows the variations in emissions over a 24-hour period. The distribution of PM_{10} emissions over the period is also illustrated in figure 2.22. The division of the day into these four time periods is not an even distribution, with the morning period being represented by four hours, the daytime and evening by six hours and the night-time by eight hours. Variations on this distribution are minimal for other contaminants.

Table 2.9: Grams of home heating emissions per hectare

No. of Ha	Daily fuel quantity (kg/ha)	PM_{10} g/ha	CO g/ha	NOx g/ha	SOx g/ha	VOC g/ha	CO_2 g/ha
2343	23	232	1667	24	22	417	40026

Table 2.10: Variations in home heating emissions with time of day

	PM_{10}		CO		NOx		SOx		VOC		CO_2	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
6am-10am	73	31	552	236	8	3	5	2	138	59	13682	5840
10am-4pm	89	38	636	271	9	4	9	4	159	68	15694	6699
4pm-10pm	313	134	2214	945	32	14	33	14	554	236	51278	21887
10pm-6am	68	29	502	214	7	3	5	2	126	54	13120	5600
Total	543	232	3904	1666	56	24	52	22	977	417	93774	40026

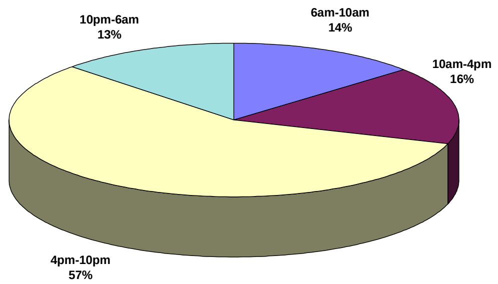


Figure 2.22: PM_{10} emissions by time of day

Assessment of the effect of emissions on the 24-hour average contaminant concentrations requires a characterisation of the meteorological conditions. Such an analysis is not yet available for Rangiora. The collection of the data presented in this report via the emission inventory allows for this assessment to be made once the appropriate meteorological model is available.

3. Transport

Air pollution from motor vehicles results from the oxidation of components of the fuel and air used in the internal combustion engines that power them. The incidence of particular forms of pollution depend on the amount of fuel consumed, the concentration of the elements in the fuel which define the pollution, and to a lesser extent the operational characteristics of the engine at the time of their formation.

This means that the quantities of pollution produced in a selected area will depend on the number of vehicle kilometres run within the area over a defined period of time, and to a lesser extent the amount of delay to vehicle movement produced by vehicle interaction and intersection control.

The air pollutants discharged are principally oxides of carbon, nitrogen, and sulphur as gases; carbon and hydrocarbons as particulate material; and other hydrocarbons as fumes. While all these pollutants result from the combustion of hydrocarbon fuels such as petrol and diesel, higher concentrations of carbon monoxide are associated with petrol combustion, whereas higher concentration of particulate is characteristic of diesel combustion.

Emissions relate to the amount of vehicle travel in a road network. However the quantities of the various emissions are notably non-linear with respect to vehicle speed. High emissions generally occur at low vehicle speeds, but also at very high speeds. Typically emissions reduce as speeds increase and are generally at a minimum at relatively high cruising speeds. Carbon dioxide, carbon monoxide, volatile organic compounds, and sulphur oxides all fit this pattern. For vehicles with reasonably tuned motors, nitrogen oxides emissions can differ slightly, with emissions decreasing at speeds less than about 35 kilometres per hour, and then increase as speeds increase.

A further complication is that some of the pollutants are particularly associated with one fuel, whereas others are more associated with the particular engine configuration at the time the pollutants are being produced. Sulphur oxides and black smoke are particularly characteristic of the use of diesel fuels and as stated above, carbon monoxide is characteristic of petrol burning engines. In the case of black smoke (diesel) and carbon monoxide (petrol) the amount of pollutant produced is maximised during short periods of high acceleration.

As a result of the different fuels and the engine configurations that burn them, the emission types are split by fuel type to reflect the different reactions.

Those splits between petrol and diesel are for CO 5:1, for NOx 1:2, for SOx 1:10, VOCs 2:1, and PM_{10} 1:30. In the case of PM_{10} the lopsided nature of the ratio and the size of the amounts involved, means no value for PM_{10} from petrol engines has been assessed.

In the road network of Rangiora almost all of the motor vehicle running is on the flat. Therefore emissions are related primarily to vehicle kilometres run and secondly to the degree of congestion in the road network. In modern road vehicles powered by normally aspirated engines (90% of the current fleet), oxides of carbon and sulphur will be minimised at a constant speed of between 70-80 km/h but increase slightly for speeds above that. When the speed is highly variable and slower than the stated speed, the discharges of carbon oxides, sulphur oxides, etc. will be significantly greater. For the purposes of this work the variability of the speeds increases as the mean speed value falls below 45 km/h.

The quantities of the various emissions are assessed from the amount of travel within the specified network over a particular period of time, estimated using urban transport models. In Rangiora these models were the ones developed by the Canterbury Regional Council, for the greater Christchurch area, during 1993-94 and since reviewed by Christchurch City Council in the subsequent two years. They form the principal parts of a 3-step urban transportation model, where the steps are trip generation, trip distribution and trip assignment.

Table 3.1: Rangiora Motor Vehicle Emissions (kg) by Emission Type and Time of Day and Fuel Used

Rangiora Road Network Motor Vehicle Emissions Based on Modelled Traffic Flows for 1996											
Emissions	CO_2		CO		NOx		SOx		VOCs		PM_{10}
Period	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel
6am-10am	6012	7336	699	18	64	17	6	8	90	6	2
10am-4pm	4607	325	535	8	49	8	5	4	69	3	2
4pm-10pm	8517	515	989	13	91	0.4	9	6	127	4	3
10pm-6am	1468	119	170	3	16	3	2	1	22	1	0.6
Total by Fuel	20600	16924	2394	43	219	28	21	19	308	14	
Total	22296		2437		247		40		322		8

Table 3.2: Rangiora Motor Vehicle Emissions (kg) by Emission Type and Vehicle Class and Fuel Used

Rangiora Road Network Motor Vehicle Emissions Based on Modelled Traffic Flows for 1996											
Emissions	CO_2		CO		NOx		SOx		VOCs		PM_{10}
Vehicle Type	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel
Pass. Car	19300	653	2233	15	204	8	20	7	870	5	7
Light Goods	992	367	115	8	11	6	1	4	15	3	0.5
Heavy Goods	275	602	32	14	3	10	0.3	6	4	4	0.3
Buses	370	706	14	6	1	4	0.1	2	2	2	0.04
Total by Fuel	20600	16924	2394	43	219	28	21	019	308	14	
Total	22296		2437		247		40		322		8

Assessment of Fuel Use and Emissions

As the road networks in Kaiapoi and Rangiora are on level ground and are relatively uncongested there is little reason to differentiate between street geometry and street function. With the exception of the section of Northern Motorway through Kaiapoi, each of the networks has been assumed to be homogenous and subjected to traffic travelling at a range of speeds represented by a single speed value.

The TRACKS utility NETBEN has been used to provide estimates of vehicle kilometres travelled in Rangiora.

Petrol or diesel internal combustion engines power almost the entire road vehicle fleet, with diesel being favoured for larger light goods and heavy goods vehicles.

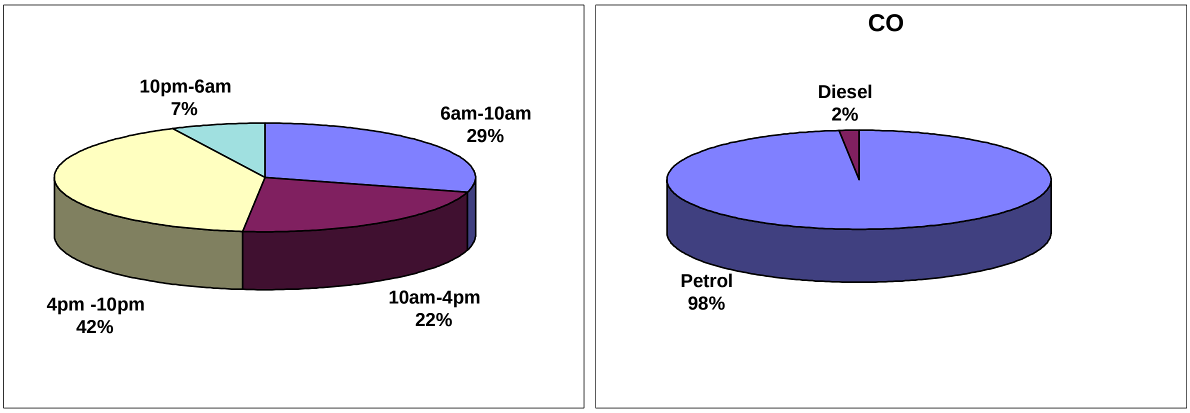
Tables 3.1 and 3.2 show emissions in tonnes per day by period of the day and fuel type, and vehicle type and fuel type.

3.1 Transport emissions

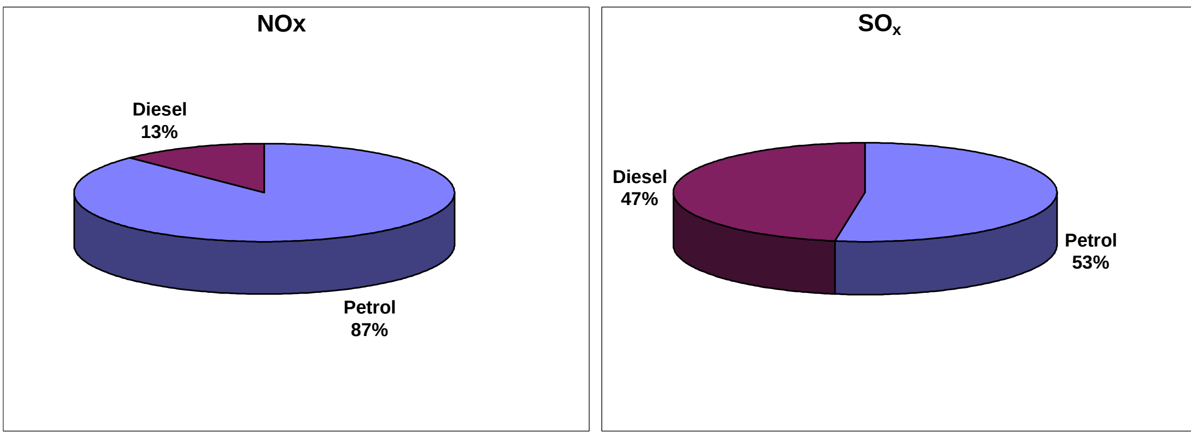
Table 3.1 shows the daily transport emissions (tonnes) of PM_{10}, CO, NOx, SOx, VOC and CO_2 and a breakdown of the time of day in which they occur. Emissions by vehicle type are detailed in table 3.2.

Figures 3.1 to 3.12 show that petrol vehicles are responsible for the majority of CO, NOx, VOC and CO_2 emissions. Diesel vehicles contribute over 50% of the SO_2 and PM_{10} emissions. No illustration of the latter is provided as only PM_{10} emissions from diesel fuel were considered.

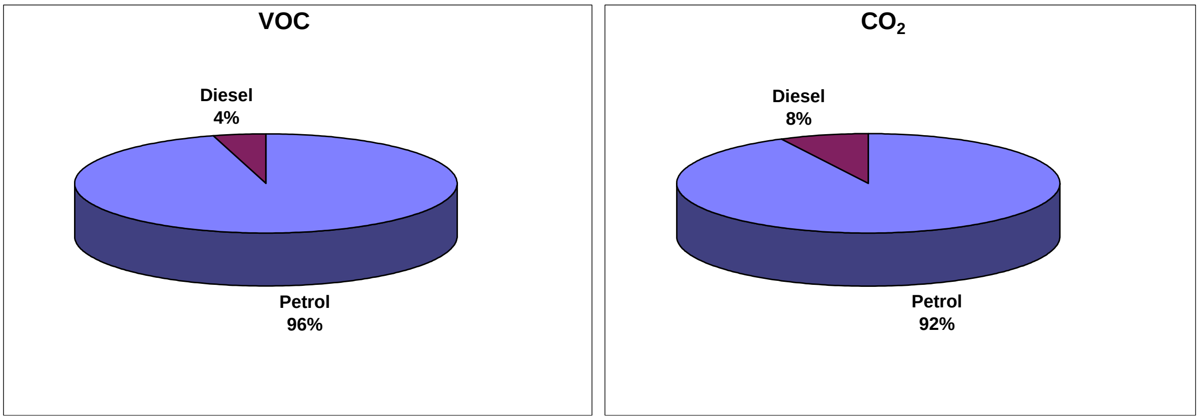
Passenger car emissions were found to contribute to over 80% of the CO, VOC, and CO_2 emissions and over 50% of the SOx and NOx from the transport sector. Heavy goods vehicles produced one third of the SOx emissions.



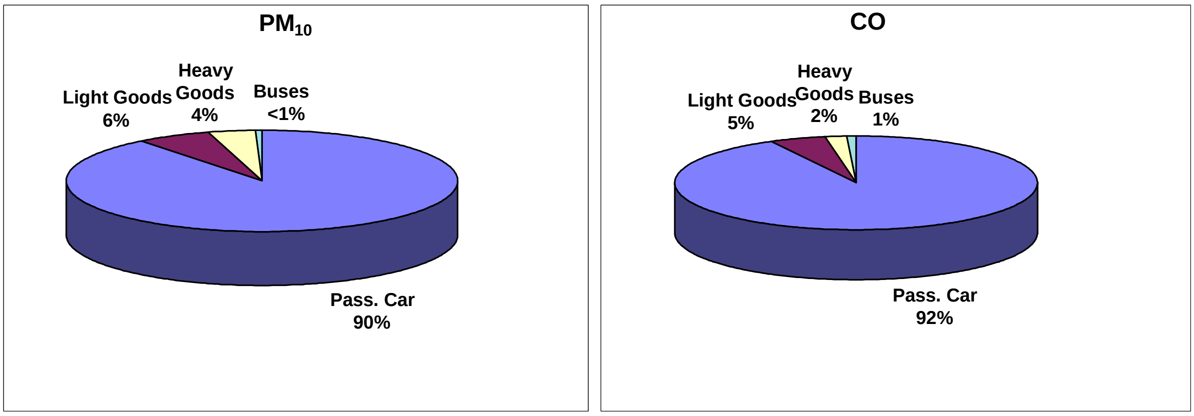
Figures 3.1 & 3.2: CO transport emissions by time of day and by fuel type



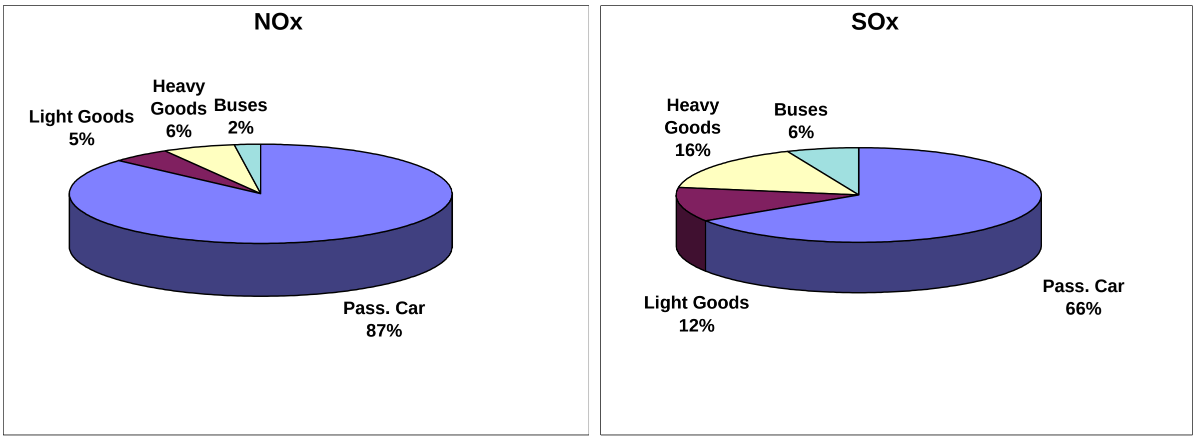
Figures 3.3 & 3.4: NOx and SOx transport emissions by fuel type



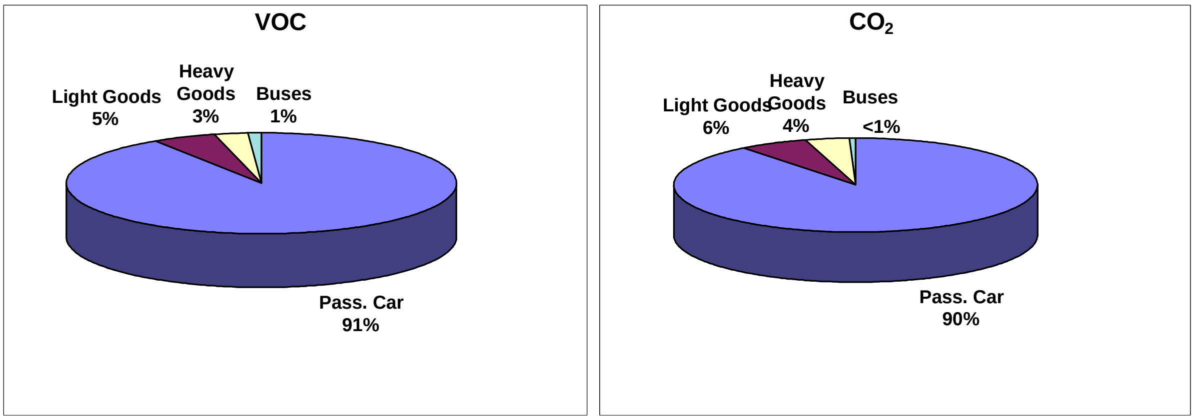
Figures 3.5 & 3.6: VOC and CO_2 transport emissions by fuel type



Figures 3.7 & 3.8: PM_{10} and CO transport emissions by vehicle type



Figures 3.9 & 3.10: NOx and SOx transport emissions by vehicle type



Figures 3.11 & 3.12: VOC and CO2 transport emissions by vehicle type

4. Industry

4.1 Industrial Processes

4.1.1 Identification of potential industrial dischargers

A search of the Canterbury Regional Council's resource consent database was conducted using GIS to identify industries with resource consents for "discharges to air" in the urban areas of Rangiora. A total of 6 consents were found. These were discharges resulting from seed cleaning, coal burning and foundry operations. Of these only one related to a process classified as "Part A" under the Clean Air Act 1972[3]. The remaining 5 came under "Part B" classification as licensing of "Part C" processes was not required in Rangiora under the Clean Air Act 1972. Although superseded by the Resource Management Act 1991, classification of processes under the Clean Air Act is relevant in terms of processes that require licensing until the preparation of a regional air quality plan.

Other potential discharges classified as "Part C" processes[4] were identified through a search of the Rangiora telephone directory and via consultation with the Waimakariri District Council.

Activities identified as potential dischargers to air were examined in terms of the contaminants PM_{10}, CO, SOx, NOx, CO_2, and VOCs, specified for the emission inventory. Activities such as landfills and processes not meeting the specifications of Part A, B or C's of the former Clean Air Act were excluded from the analysis due to relatively low emissions of the contaminants concerned.

4.1.2 Assessment of emissions from industrial processes

Discharges to air from industrial activities generally arise from either combustion processes or as a result of the use or handling of materials which can generate emissions, e.g., paint in spray painting. For the purpose of this report the latter are referred to as process emissions and include all non-combustion sources.

A number of industries use the combustion of fuels such as LPG, oil, and coal to produce energy. The following equation illustrates the chemical reaction required for complete combustion:

$$C_xH_y + O_2 = xCO_2 + yH_20 \qquad \textbf{(5)}$$

[3] In general Part A processes have greater potential for adverse effects on the environment. Historically these processes were controlled by the Department of Health while "Part B" processes were legislated by District/ Local Councils.

[4] and therefore not currently requiring consents from the CRC.

where C_xH_y represents the fuel being burnt. The reaction is exothermic, resulting in the production of heat.

The formation of air contaminants resulting from the combustion process varies depending on the chemical and physical properties of the fuels. From the above equation it is apparent that carbon dioxide (CO_2) is produced as a product of combustion while CO is produced when combustion is incomplete. Because sulphur dioxide emissions occur as a result of oxidation of sulphur in the fuel, fuels with a greater proportion of sulphur will result in higher emissions of sulphur oxides. Nitrogen oxides form as a result of nitrogen (N_2), which is present in the air we breathe, reacting with the oxygen (O_2) under high temperatures. Suspended particulate, particles in the air less than 10 microns in diameter, are also produced during the combustion process.

Emission factors for emissions from combustion processes were those used in the Christchurch emission inventory. The Christchurch emission factors were derived by National Institute of Water and Atmospheric Research from international literature (United States Environmental Protection Agency (USEPA) 1994; Economopoulos, 1993; International Panel on Climate Change, 1995; Air Pollution Engineering Manual, 1992). The emission factors are based on typical operation for an average boiler and do not account for variations in technology or age of the boilers. Emission factors used for the Christchurch inventory for the different fuels are contained in table 4.1.

Contaminants from the domestic sector, as a result of domestic home heating, primarily occur during the winter months. As domestic home heating emissions are likely to be significant during the winter, the daily emissions across all sectors were examined in terms of wintertime loading.

Emissions were also examined on a time of day basis. This allows for an assessment of the effect of any variations in meteorological conditions over a 24-hour period that may impact on contaminant concentrations.

A small number of industries had adequate information contained on the resource consent to ascertain the daily fuel use and time of day variations. However, most data was obtained via a telephone survey of all industries in the area.

Daily and annual emissions were calculated as follows:

*Contaminant emission (kg/day) = fuel use (tonnes/day) * contaminant emission factor (kg/tonne)* **(6)**

For example, calculations for PM_{10} emissions from an industry using 1.5 tonnes of coal per day are shown in equation 7.

*PM_{10} emission = 1.5 tonnes/day * 5 kg/tonne = 7.5 kg PM_{10} per day* **(7)**

The most common non-combustion processes from which discharges to air occur in the Rangiora area are spraypainting and seed cleaning/handling. Emission factors for these and other non-combustion sources were obtained from emission inventories prepared by NIWA for Christchurch and the USEPA emission factors (USEPA, 1996). These are shown in table 4.2.

Processes emissions were calculated as follows:

Emissions (kg/day) = quantity of product used (units/day) x emission factor (kg/unit) **(8)**

The unit of material will be dependent on the process but could include for example,

Table 4.1: Emission factors used for industrial combustion processes (from Christchurch emission inventory)

Fuel	Boiler size	PM_{10} kg/tonne	CO kg/tonne	NOx kg/tonne	SOx kg/tonne	VOC kg/tonne	CO2 kg/tonne
LPG	5 MW	0.06	0.71	2.6	0.007	0.12	2885
	50 MW	0.06	0.71	2.6	0.007	0.12	2885
Oil	40 kW	0.28	0.64	2.8	4.0	0.18	3010
	10 MW	0.28	0.64	2.8	4.0	0.18	3010
Coal	40kW	5.00	2.3	8.2	17.5	0.06	2355
	10MW	5.00	2.5	9.0	17.5	0.06	2355
Wood	40kW	1.3	2.0	0.33	0.037	0.15	1100
	10 MW	1.3	13.0	1.15	0.037	0.15	1100

Table 4.2: Process emission factors

	PM_{10}	CO	NOx	SOx	VOC	CO_2
Bitumin Plants -per tonne produced	0.34 kg[(1)]					
Spray-painting - per tonne paint used					560 kg[(2)]	
Seed cleaning -per tonne of product	0.0094 kg[(3)]					
Grain loading and handling	0.0039 kg[(4)]					

(1) Assuming a dryer drum hot mix process with a cyclone (from Christchurch emission inventory 1997)
(2) Assuming the density of paint = 1 kg/l for conversion to tonnes (from Christchurch emission inventory 1997)
(3) (From AP42 (USEPA, 1996))
(4) (From AP42 (USEPA, 1996))

litres of paint sprayed, tonnes of seed handled, tonnes of asphalt produced, etc.

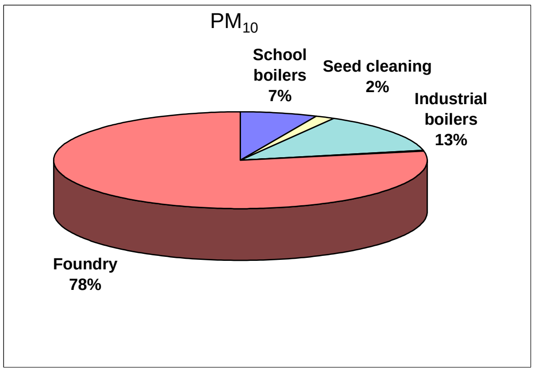
4.2 Industrial Emissions

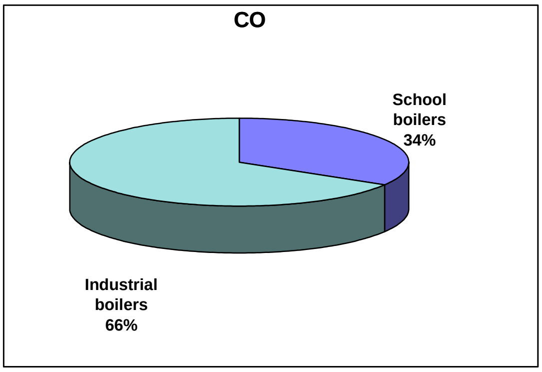
Figures 4.1 to 4.6 illustrate the contribution of different industrial sources to the total emissions from this sector.

For the purpose of allowing comparisons of emissions in Rangiora to those of other areas of the region, the total mass of emissions was divided by the number of hectares in the study area. This allows a comparison of mass of emission per area volume. Table 4.3 shows total emissions from the industrial sector, on a g/ha basis, and a breakdown for different periods of the day.

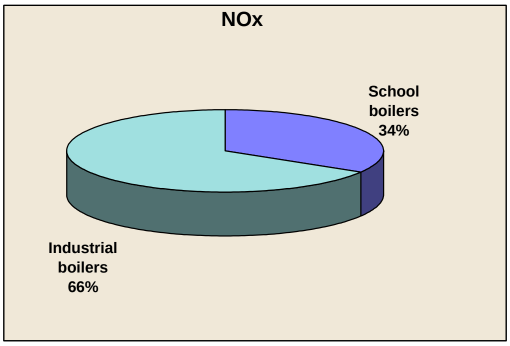
Table 4.3: Industrial emissions by time of day

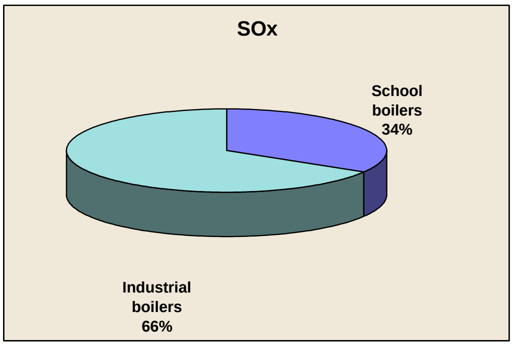
	PM_{10}		CO		NOx		SOx		VOC		CO_2	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
6am-10am	4	2	2	1	6	2	12	5	4	2	1658	708
10am-4pm	51	22	1	0	5	2	11	4	13	6	1794	766
4pm-10pm	3	1	1	0	4	2	8	4	2	1	1149	490
10pm-6am	4	2	2	1	6	2	12	5	0	0	1661	709
Total	62	27	6	2	21	8	43	18	19	9	6262	2673



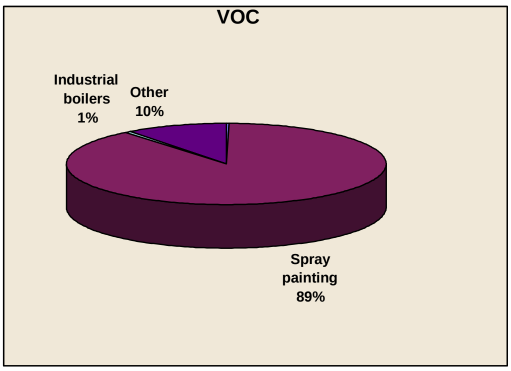


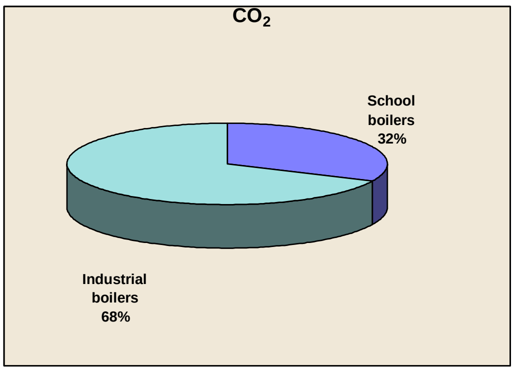
Figures 4.1 & 4.2: Industrial PM_{10} and CO emissions by source





Figures 4.3 & 4.4: Industrial SOx and NOx emissions by source

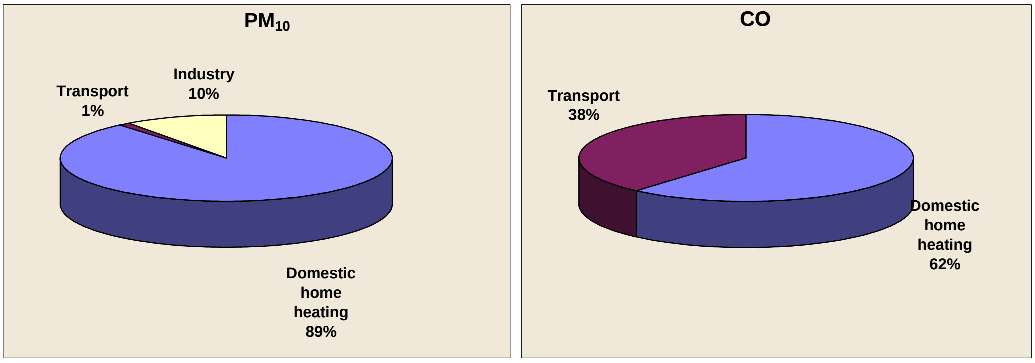




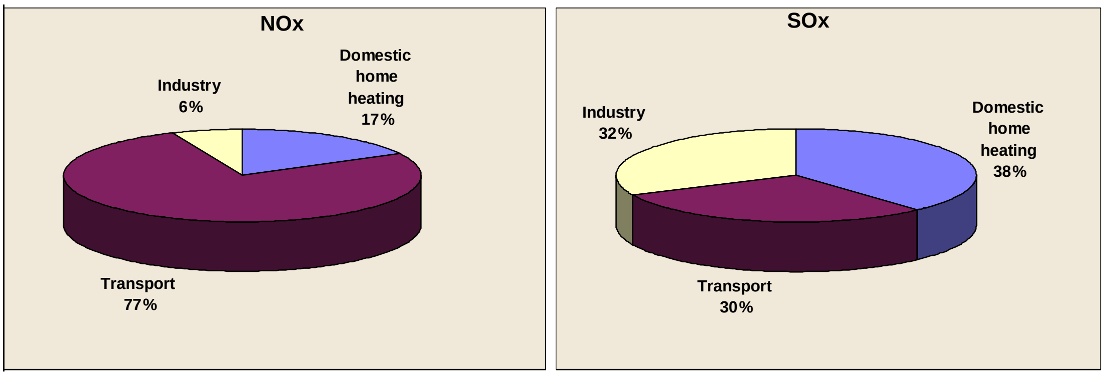
Figures 4.5 & 4.6: Industrial VOC and CO_2 emissions by source

5. Total emissions for Rangiora

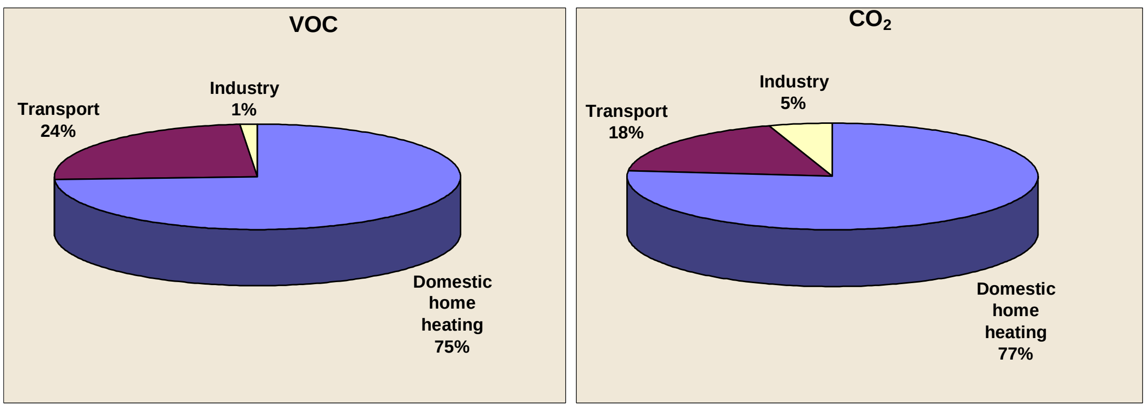
The proportional contribution of each sector to the total emissions in Rangiora is shown in table 5.1. This indicates that the greatest proportion of PM_{10} originates from emissions from the domestic home heating sector. This sector is also responsible for ~40% of the SOx, and over 60% of the CO, VOCs and CO_2. Transport is responsible for >80% of the NOx and almost 40% of the CO emissions. Industry contributes 32% of the SOx emissions, 26% of the PM_{10} and <10% of each of the other contaminants. Figures 5.1 to 5.6 compare the proportion of PM_{10}, CO, NOx, SOx, VOCs and CO_2 emissions arising from each sector.



Figures 5.1 and 5.2: PM_{10} and CO emissions by sector



Figures 5.3 & 5.4: NOx and SOx emissions by sector



Figures 5.5 and 5.6: VOC and CO_2 emissions by sector

Table 5.1: Total emissions on a typical winter's day, by sector

	PM_{10}		CO		NOx		SOx		VOC		CO_2	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Home heating	543	232	2316	1667	56	24	52	22	976	417	93774	40026
Transport	8	3	2437	1040	247	105	40	17	322	137	22296	9517
Industry	61	26	6	3	20	9	43	18	19	8	6261	2673
Total	612	261	4759	2710	323	138	135	57	1317	562	122331	52216

Table 5.2: Total emissions by time of day

	PM_{10}		CO		NOx		SOx		VOC		CO_2	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
6am-10am	79	34	1272	543	95	40	32	13	238	102	22086	9427
10am-4pm	142	61	1181	504	71	30	28	12	244	104	22420	9570
4pm-10pm	319	136	3217	1373	127	54	56	24	687	293	61459	26233
10pm-6am	72	31	677	289	31	13	20	9	148	63	16367	6986
	612	262	6347	2709	324	137	136	58	1317	562	122332	52216

Table 5.3: Total emissions for urban area (assuming 85% of emissions occur on 20% of land)

	PM_{10}	CO	NOx	SOx	VOC	CO_2
	g/ha	g/ha	g/ha	g/ha	g/ha	g/ha
Home heating	985	7083	102	94	1771	170112
Transport	14	4420	448	73	584	40447
Industry	130	13	43	92	41	13363
Total	1129	11516	593	259	2396	223922

The variation in total emissions of each contaminant over a 24-hour period during the winter is shown in table 5.2. This indicates that the majority of emissions are released during the evening (4pm-10pm) period.

The expression of emission as grams per household provides a basis for comparing emissions in different location. However, this is not ideal, as it does not account for differences in housing density. Housing density is important when considering contaminant concentrations as a greater area between sources allows for more dispersion of contaminants. Expressing emissions on a grams per hectare basis also has disadvantages as some area definitions used include a large amount of rural land with minimal emissions. This is the case for Rangiora as 85% of the houses are located on 20% of the land.

An estimate of emissions on a grams per hectare basis for the urban area of Rangiora is shown in table 5.3. This assumes that 85% of the emissions from domestic heating and transport occur within the urban area of Rangiora, and that this urban area is 469 hectares (20% of the total Rangiora area). The estimates in table 5.3 also assume that 100% of industrial emissions occur in the urban area of Rangiora.

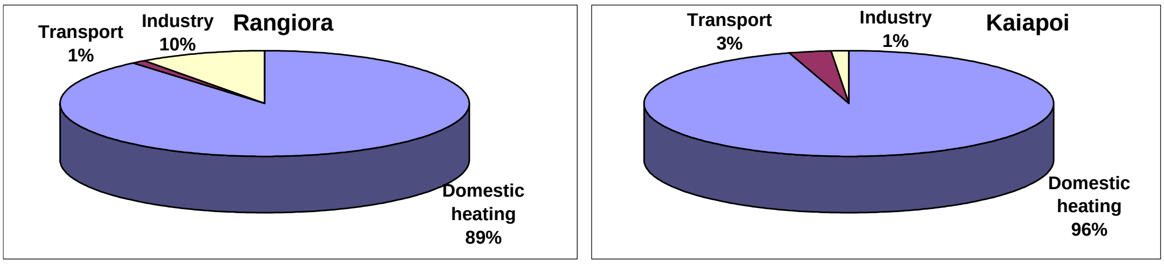
5.1 Total emissions in Rangiora compared with other urban centres

The relative contribution of PM_{10} emissions in Rangiora compared to Timaru, Waimate, Ashburton, Kaiapoi, and Christchurch is illustrated in figures 5.7 to 5.12. Figures 5.7 to 5.12 show that the relative contribution to PM_{10} emissions from domestic heating in Rangiora is estimated to be less than Christchurch, Kaiapoi, Ashburton and Waimate but similar to Timaru. In both these areas the estimated industrial contribution is large compared with Christchurch, Kaiapoi and Waimate but similar to Ashburton.

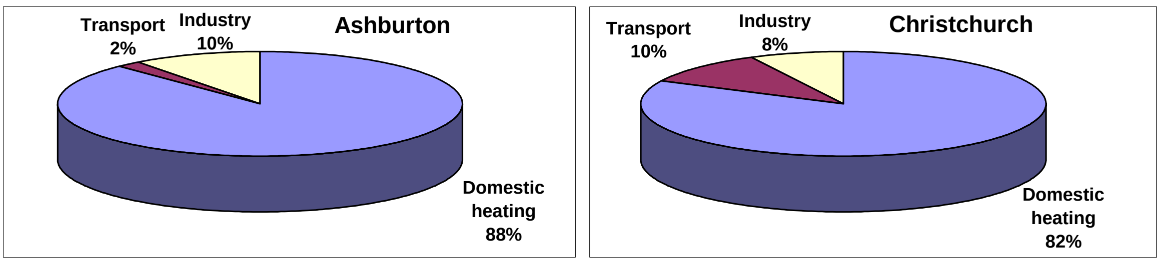
Table 5.4 compares total emissions in Rangiora expressed as grams per household to other urban areas of the region. This shows that on a household basis:

- Waimate has the highest PM_{10} emissions per household
- Christchurch has the highest CO and VOC emissions per household
- Timaru has the highest NOx, SOx and CO_2 emissions per household

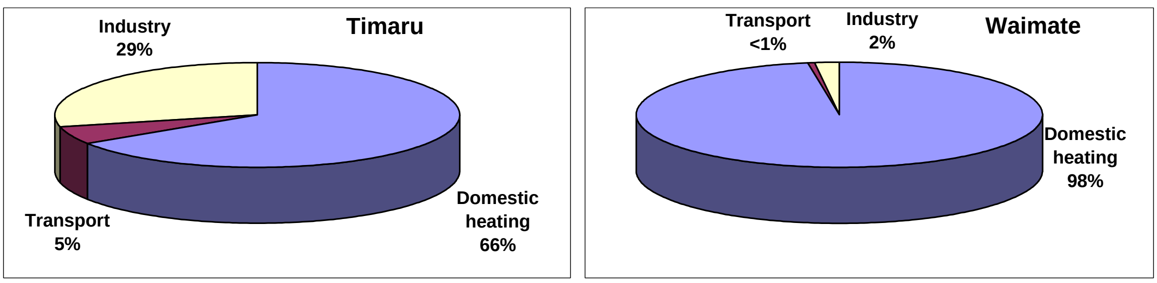
Emissions of PM_{10} in Rangiora are higher per household than in Christchurch and Kaiapoi. This is because a greater



Figures 5.7 & 5.8: Contributions to PM_{10} emissions in Rangiora and Kaiapoi



Figures 5.9 & 5.10: Contributions to PM_{10} in Ashburton and Christchurch



Figures 5.11 & 5.12: Contributions to PM_{10} in Timaru and Waimate

Table 5.4 Grams of emissions per household for a typical winter's day compared with other urban areas

	hh	PM_{10} g/hh	CO g/hh	NOx g/hh	SOx g/hh	VOC g/hh	CO_2 g/hh
Rangiora	3692	166	1719	87	37	357	33134
Kaiapoi	3188	110	1646	163	34	301	28090
Timaru	9732	209	1765	305	170	436	70110
Christchurch	94856	141	1982	274	70	473	51316
Ashburton	5791	176	1755	129	86	347	37386
Waimate	1308	224	1711	50	55	392	36900

proportion of households use solid fuel burning to heat their main living area in Rangiora than in Christchurch or Kaiapoi.

Table 5.5 compares emissions on a g/ha (for the urban areas) and kilograms of emissions in Rangiora to other urban areas of the region.

6. Summary

Wintertime emissions from domestic heating, transport and industry were estimated for the urban areas of Rangiora. Estimates were based on surveying, traffic modelling, resource consent information and the application of emission factors.

- Survey results showed that approximately 51% of Rangiora households use electricity to heat their main living area on a typical winter's night. This compares to 13% that use gas and 66% that use solid fuel heating methods.
- Results indicate that many households use more than one method of domestic heating in their main living area.
- Wood burners were found to contribute over 70% of the PM_{10} emissions from domestic heating with the remainder coming from open fires (18%) and multi-fuel burners (9%).
- Over 80% of the PM_{10} emissions come from the burning of wood with the remainder (13%) coming from coal burning.
- Over half of the PM_{10} emissions occur during the evening (4 p.m. to 10 p.m.) period.
- Passenger cars are responsible for about 90% of the PM_{10}, CO, NOx, VOC and CO_2, and two thirds of the SOx emissions from transport. About 42% of the CO emissions from transport occur during the evening (4 p.m. – 10 p.m.) period.
- Industrial and school boilers are responsible for the majority of CO, NOx, SOx and CO_2 emissions from industry in Rangiora, with industrial boilers contributing approximately two thirds and school boilers one third of these emissions. The majority of VOC emissions from the industrial sector come from spray painting operations.
- Overall the domestic heating sector is responsible for 62% of the PM_{10} and CO, 38% of the SOx and ~75% of the VOCs and CO_2. The transport sector contributes 38% of the CO, 30% of the SOx, the majority (84%) of the NOx, and 24% of the VOC emissions.
- Industry emits 26% of the PM_{10} emissions, 32% of the SOx emissions and up to 5% of emissions of other contaminants.

7. References

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Table 5.5: Total emissions in Rangiora compared to other urban centres

		Rangiora		Ashburton		Timaru		Waimate		Kaiapoi		Christchurch	
	Source	kg	g/ha*	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
PM_{10}	home heating	543	985	897	724	1340	652	285	928	334	594	10971	618
PM_{10}	transport	8	14	18	14	110	54	1	5	12	22	1365	77
PM_{10}	industry	61	130	106	86	585	285	6	19	5	8	1018	57
	Total	**612**	**1129**	**1021**	**824**	**2035**	**991**	**293**	**952**	**351**	**624**	**13354**	**752**
CO	home heating	2316	7083	5345	4315	8559	4167	1865	6048	2316	4120	61962	3489
CO	transport	2437	4420	4780	3859	8438	4108	371	1183	2929	5209	125591	7073
CO	industry	6	13	44	35	185	90	3	9	3	5	478	27
	Total	**4759**	**11516**	**10169**	**8209**	**17182**	**8365**	**2239**	**7240**	**5248**	**9334**	**188031**	**10589**
NOx	home heating	56	102	82	66	125	61	28	90	34	61	937	53
NOx	transport	398	722	517	417	2161	1052	28	90	486	864	23655	1332
NOx	industry	20	43	147	119	681	331	10	31	11	20	1452	82
	Total	**474**	**867**	**746**	**602**	**2967**	**1444**	**66**	**211**	**531**	**945**	**26044**	**1467**
SOx	home heating	52	94	214	173	239	116	45	148	44	78	2490	140
SOx	transport	40	73	84	67	93	45	6	18	64	114	1130	64
SOx	industry	43	92	199	160	1321	643	21	67	21	37	3055	172
	Total	**135**	**259**	**497**	**400**	**1653**	**805**	**72**	**233**	**129**	**229**	**6675**	**376**
VOC	home heating	976	1771	1336	1079	2140	1042	466	1512	579	1030	15490	872
VOC	transport	322	584	634	512	2071	1008	44	141	388	689	28608	1611
VOC	industry	19	41	37	30	35	17	2	6	1727	3072	798	45
	Total	**1317**	**2396**	**2007**	**1621**	**4246**	**2067**	**512**	**1659**	**2694**	**4791**	**44896**	**2528**
CO_2	home heating	93774	170112	131965	106535	186822	90955	42338	136981	55854	99350	1375853	77482
CO_2	transport	22296	40447	44636	36035	235391	114601	3042	9694	33695	59934	2802943	157849
CO_2	industry	6261	13363	39901	32212	260096	126629	2885	9193	6406	11394	688883	38794
	Total	**122331**	**223923**	**216502**	**174782**	**682309**	**332186**	**48265**	**155868**	**95955**	**170678**	**4867679**	**274122**

* For Rangiora the analysis assumes that 85% of the transport and domestic emissions occur within the urban area of 469 ha and that 100% of the industrial emissions occur within the urban area. The Rangiora analysis has been reviewed to include this assumption because of the large quantity of rural land within the area defined as Rangiora.

Appendix 1: Home heating survey

Good afternoon/evening my name is ______ and I am calling on behalf of the Canterbury Regional Council. May I please speak to an adult in your household who knows about your home heating.
Good afternoon/evening my name is ______ and I am calling on behalf of the Canterbury Regional Council.
We are currently undertaking a survey in your area on methods of home heating. We wish to know what you use **to heat your main living area, on a typical Winter's day, and night.**

TICK ALL THOSE WHICH APPLY

1. Respondent's Area **Ashburton [ ] Rangiora [ ] Kaiapoi [ ] Waimate [ ]**
Respondent's phone number __________________

2. (a) Do you use an open fire (includes a visor fireplace) **in your MAIN living area on a TYPICAL Winter's day or night? YES [ ] NO [ ]** ***If NO, go to Question 3***.

(b) Do you use it
i. In the morning (between 6am and 10am) **YES** [ ] **NO** [ ]
ii. Day time (between 10am and 4pm) **YES** [ ] **NO** [ ]
iii. Evening (between 4pm and 10pm) **YES** [ ] **NO** [ ]
iv. Overnight (between 10pm and 6am) **YES** [ ] **NO** [ ]

(c) Do you use wood on your open fire? **YES [ ] NO [ ]** ***If NO, go to Part (f).***

(d) How much wood do you use per day**?** ***(ask them how many pieces of wood (logs) they use on an average Winter's day)*** ______________________

(e) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT [ ] COLLECT IT [ ] BOTH [ ]** ***If BOTH, ask % Collected _____% Bought ______***

(f) Do you use coal on your open fire? **YES [ ] NO [ ]** ***If NO, go to Question 3***.

(g) How much coal do you sue per day? ***(ask them how many buckets of coal they use on an average Winter's day)*** ______________________________

(h) What type of coal do you use? ____

3. (a) Do you use **any type** of electrical heating **in your MAIN living area on a TYPICAL Winter's day or night? YES [ ] NO [ ]** ***If NO, GO TO Question 4.***

(b) Do you use it
i. In the morning (between 6am and 10am) **YES** [ ] **NO** [ ]
ii. Day time (between 10am and 4pm) **YES** [ ] **NO** [ ]
iii. Evening (between 4pm and 10pm) **YES** [ ] **NO** [ ]
iv. Overnight (between 10pm and 6am) **YES** [ ] **NO** [ ]

4. (a) Do you use **any type** of gas heating **in your MAIN living area on a TYPICAL Winter's day or night? YES [ ] NO [ ]** ***If NO, GO TO Question 5***.

(b) Is it **flued or unflued** gas heating? **FLUED** [ ] **UNFLUED** [ ] **BOTH** [ ]

(c) Do you use it
i. In the morning (between 6am and 10am) **YES** [ ] **NO** [ ]
ii. Day time (between 10am and 4pm) **YES** [ ] **NO** [ ]
iii. Evening (between 4pm and 10pm) **YES** [ ] **NO** [ ]
iv. Overnight (between 10pm and 6am) **YES** [ ] **NO** [ ]

(d) How much gas do you use? ***(ask them for the size of the gas bottle(s) and how often they would refill them*** (-sizes are 2kg, 2.5kg, 3kg, 4.5kg, 9kg, 18kg, 20kg, 45kg, 90kg)
Size#1______________ Freq#1______________
Size#2______________ Freq#2______________

5. (a) Do you use a log burner ***(This is not a multi-fuel burner, i.e. does not burn coal)*** in your **MAIN living area on a TYPICAL Winter's day or night.**
YES [ ] NO [ ] ***If NO, GO TO Question 6***.

(b) How old is your log burner? **10 yrs old or older** [ ] **Less than 10 yrs old** [ ]

(c) Do you use it
i. In the morning (between 6am and 10am) **YES** [ ] **NO** [ ]
ii. Day time (between 10am and 4pm) **YES** [ ] **NO** [ ]
iii. Evening (between 4pm and 10pm) **YES** [ ] **NO** [ ]
iv. Overnight (between 10pm and 6am) **YES** [ ] **NO** [ ]

(d) How much wood do you use per day? ***(ask them how many pieces of wood (logs) they use on an average Winter's day)*** __________________

(e) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT [ ]**
COLLECT IT [ ] BOTH [ ] ***If BOTH, ask % Collected _____% Bought ______***

6. (a) Do you a multi-fuel burner ***(this includes incinerators, pot belly stoves, McKay space heaters, etc. It is a burner which burns coal as well as wood)*** **in your MAIN living area on a TYPICAL Winter's day or night?**
YES [ ] NO [ ] ***If NO, GO TO Question 7.***

(b) How old is your multi-fuel burner? **10 yrs old or older** [ ] **Less than 10 yrs old** [ ]

(c) What type of multi-fuel burner is it? ____

(d) Do you use it
i. In the morning (between 6am and 10am) **YES** [ ] **NO** [ ]
ii. Day time (between 10am and 4pm) **YES** [ ] **NO** [ ]
iii. Evening (between 4pm and 10pm) **YES** [ ] **NO** [ ]
iv. Overnight (between 10pm and 6am) **YES** [ ] **NO** [ ]

(e) How much wood do you use per day? ***(ask them how many pieces of wood (logs) they use on an average Winter's day)*** ______________________

(f) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT [ ]** **COLLECT IT [ ]** **BOTH [ ]** ***If BOTH, ask % Collected _____% Bought ______***

(g) Do you use coal on your multi-fuel burner? YES [ ] NO [ ] *If NO, go to Question 7.*

(h) How much coal do you use per day? ***(ask them how many buckets of coal they use on an average Winter's day)*** ______________________________

(i) What type of coal do you use? ____

7. (a) Do you use an oil-fired heating system **in your MAIN living area on a TYPICAL Winter's day or night?** **YES** [ ] **NO** [ ] ***If NO, go to END.***

(b) Do you use it

i.	In the morning (between 6am and 10am)	**YES** [ ]	**NO** [ ]
ii.	Day time (between 10am and 4pm)	**YES** [ ]	**NO** [ ]
iii.	Evening (between 4pm and 10pm)	**YES** [ ]	**NO** [ ]
iv.	Overnight (between 10pm and 6am)	**YES** [ ]	**NO** [ ]

(c) How much oil do you use? ____

(END) THANK YOU VERY MUCH FOR YOUR HELP WITH THIS SURVEY.

Appendix 2: Transport Model

Estimating the Number of Trips Made Within the Study Area

Totals of trips beginning or ending within each zone were generated across the selected areas according to the number of households within each zone, the number of persons in full time employment within each zone, (except in the case of retail employment, part time employment is included as a separate variable) and by the number of motor vehicles within each zone.

The demographics for the whole of the greater Christchurch area are contained in a zone file DEM96M.CSV (1 record for each of the 290 internal zones and a further record for each of the 9 external zones). Trips produced and attracted by each zone were estimated using a utility CTSGEN operating on the named file, a base year data file, 91DEMW.CSV, and a car availability file 91PROPS.CSV. The output trip file PA96M.005 was then modified and converted, from a production and attraction trip file to an origin/destination trip file, in a succession of redistribution and assignment loops. The redistribution is necessary because of the observation that if trip making is made relatively cheaper (faster or shorter as a result of network changes) then in assignments subsequent to the network changes more trips will be assigned. The converse also holds to be true.

Obtaining a Road Network Model

The road network model to which trips were assigned was obtained from Christchurch City Council and defined as CH95NU.007. It was modified in the Rangiora areas to accommodate the increased number of zones.

Racecourse Road/ West belt was added in the north together with Seddon Street and Blackett Street east of White Street. White Street between Seddon Street and Johns Road was also added, as was the section of Johns Road between White Street and Pentecosts Road, and Pentecosts Road/ Townsend Road to Fernside Road. To the east of Rangiora, East Belt and part of Northbrook Road were added, as was Boys Road between Percival Street and Woodend Rangiora Road.

Following the final assignment of the expanded trip matrix to the extended road network model, the selected areas of Rangiora were isolated using the TRACKS screen editor utility NEX. The vehicle kilometres run along with the vehicle travelling times for 24 hours were extracted from the loaded network table CH96NL.036, together with estimates of noise, fuel used, and pollutants.

Estimates of part day fuel use and emissions within the selected areas were made using the distribution of vehicle trips by trip purposes stated in Table 3.7 of Christchurch City Council's *CTS Revised Vehicle Driver Models: Calibration and Validation Report.* This data provided the basis for tables A.1 and A.2.

Table A.1 Emission Factors by Emission Type and Traffic Speed

Emission Factors by Emission Type and Speed							
Speed	Fuel	CO2	CO	NOx	SOx	VOCs	PM10
km/h	g/km	g/km	g/km	g/km	g/km	g/km	g/km
30	102.95	175.95	18.84	2.04	0.33	2.50	6.62
35	99.50	157.59	16.32	2.04	0.32	2.16	6.43
100	89.52	153.00	5.87	2.68	0.29	0.62	5.30

Table A.2 Rangiora Traffic by Trip Purpose and Time of Day

Period	**AM Peak**	**Interpeak**	**PM Peak**	**Evening**	**Night**	**Totals**
TripPurp	**%**	**%**	**%**	**%**	**%**	**%**
Private	12.16	51.41	19.14	14.57	2.72	100.0
LightGds	16.9	70.4	10.2	1.3	1.2	100.0
HeavyGds	15.8	67.7	9.6	2.2	4.7	100.0

This distribution is modified by the observed splits in motive power. Analysis of 1996 Motor Vehicle Registration District data, by motive power and vehicle type for the Christchurch Postal resulted in table A.3.

Table A.3: Christchurch area Motor Vehicle Registrations

Motor Vehicle Registration Data:ChCh Postal District				
Vehicle Type and Motive Power				
Veh. Type	Pass.Car	L.G.V	H.G.V	Bus
Petrol	195507	3095	2497	331
Diesel	6654	5549	5322	631

Based on proportion of trips, by trip purpose and time of day, and the subdivision of fuel use by vehicle type for engine size proportionality factors have been deduced (table A.4.).

Table A.4 Emission Factors related to Proportions of Vehicle Types and Engine Size.

Factors for Engine Size & Fuel Use				
Veh. Type		Petrol	Diesel	Total
Car	%	82.47	2.792	85.27
LightGoods	%	6.335	2.343	8.678
HeavyGoods	%	1.691	3.704	5.396
Bus	%	0.225	0.435	0.66

These proportionality factors when multiplied by emission factors from Table A.4 and by estimated vehicle kilometres of travel within the selected network, will give emissions produced, by time of day, and by emission type, for the selected road network.