

**Kaiapoi Inventory
of Emissions**

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Report U98(48)**

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Executive Summary

An inventory of emissions to air was conducted during 1997 for the urban area of Kaiapoi. Wintertime emissions of suspended particulate (PM₁₀), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), volatile organic compounds (VOCs), and carbon dioxide (CO₂) 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 41% of Kaiapoi households use electricity, 33% use gas and 57% use solid fuel to heat their main living area on a typical winter's night. Wood burners are used by approximately half of Kaiapoi households while open fires are used by approximately 6% of Kaiapoi households. Many households use more than one method of heating in their main living area.

Wood burners are responsible for over half of the PM₁₀ emissions from domestic heating with the remainder coming from open fires (28%) and coal and multi-fuel burners (16%). Just over 80% of the PM₁₀ emissions come from the burning of wood with the remainder coming from coal burning. Approximately 50% of the PM₁₀ emissions occur during the evening (4 p.m. to 10 p.m.) period.

Passenger cars are responsible for the majority of PM₁₀, CO, NO_x, SO_x, VOC, and CO₂ emissions from transport. Just under half of the emissions from transport occur during the 10 a.m. to 4 p.m. period.

Combustion processes are responsible for the majority of PM₁₀, CO, NO_x, SO_x, and CO₂ emissions from industry in Kaiapoi. The majority of VOC emissions from the industrial sector come from spray painting operations.

Overall the domestic heating sector is responsible for 96% of the PM₁₀, 44% of the CO, 38% of the SO_x and over 50% of the CO₂. The transport sector contributes over half of the CO and SO_x, most (92%) of the NO_x, and approximately one third of the CO₂ emissions. Industry emits approximately two thirds of the VOC emissions but less than 10% of emissions of all other contaminants.

Contents

	Executive Summary	1
1	Introduction.....	7
	1.1 Purpose and Scope	7
	1.2 Background.....	8
2	Domestic Home Heating.....	8
	2.1 Home heating survey	8
	2.2 Home heating emissions.....	11
3	Transport	18
	3.1 Transport emissions	20
4	Industry.....	22
	4.1 Identification of potential industrial dischargers	22
	4.2 Assessment of emissions from industrial processes	22
	4.3 Industrial Emissions	24
5	Total emissions for Kaiapoi	25
	5.1 Total emissions in Kaiapoi compared with other urban centres.....	27
6	Summary	28
7	References	28
Appendix 1	Home heating survey	31
Appendix 2	Transport model	35

Figures

1.1	Urban areas of Kaiapoi	7
2.1 & 2.2	Wood use and coal use across appliances	10
2.3	Proportion of fuel (kg) burnt in Kaiapoi on a typical winter's night	11
2.4 & 2.5	PM ₁₀ & CO emissions by appliance type	14
2.6 & 2.7	NOx and SOx emissions by appliance type	14
2.8 & 2.9	VOC and CO ₂ emissions by appliance type	14
2.10 & 2.11	PM ₁₀ and CO emissions by fuel type	15
2.12 & 2.13	NOx and SOx emissions by fuel type	15
2.14 & 2.15	VOC and CO ₂ emissions by fuel type	15
2.16 & 2.17	PM ₁₀ and CO emissions by fuel and appliance type	16
2.18 & 2.19	SOx and NOx emissions by fuel and appliance type	16
2.20 & 2.21	VOC and CO ₂ emissions by fuel and appliance type	16
2.22	PM ₁₀ emissions by time of day	17
3.1 & 3.2	CO emissions by time of day and by fuel type	20
3.3 & 3.4	NOx and SOx emissions by fuel type	21
3.5 & 3.6	VOC and CO ₂ emissions by fuel type	21
3.7 & 3.8	PM ₁₀ and CO emissions by vehicle type	21
3.9 & 3.10	NOx and SOx emissions by vehicle type	21
3.11 & 3.12	VOC and CO ₂ emissions by vehicle type	22
4.1 & 4.2	Industrial PM ₁₀ and CO emissions by source	24
4.3 & 4.4	Industrial SOx and NOx emissions by source	25
4.5 & 4.6	Industrial VOC and CO ₂ emissions by source	25
5.1 & 5.2	PM ₁₀ and CO emissions by sector	25
5.3 & 5.4	NOx and SOx emissions by sector	26
5.5 & 5.6	VOC and CO ₂ emissions by sector	26
5.7	Contributions to PM ₁₀ in Kaiapoi, Rangiora, Ashburton, Christchurch, Timaru and Waimate	27

Tables

2.1	Survey area for Kaiapoi	9
2.2	Home heating methods for Kaiapoi	9
2.3	Breakdown of home heating methods in Kaiapoi.....	10
2.4	Fuel consumption across appliances	10
2.5	Domestic heating methods used at different times of the day	11
2.6	Home heating methods in Kaiapoi compared to other urban centres	12
2.7	Emission factors for domestic home heating appliances	12
2.8	Home heating emissions by appliance type	13
2.9	Grams of emissions per hectare	17
2.10	Variations in emissions with time of day	17
3.1	Summary emissions (kg) for Kaiapoi by emission type, time of day and fuel consumed	19
3.2	Summary emissions (tonnes) for Kaiapoi by emission type, vehicle class and fuel used	20
4.1	Emission factors used for industrial combustion processes.....	23
4.2	Process emission factors	23
4.3	Industrial emissions by time of day	24
5.1	Total emissions by sector	26
5.2	Total emissions by time of day	26
5.3	Grams of emissions per household compared with other urban areas	27
5.4	Total emissions in Kaiapoi compared to other urban centres ..	30
A.1	Emission factors by emission type and traffic speed	35
A.2	Kaiapoi traffic by trip purpose and time of day	36
A.3	Christchurch area motor vehicle registrations	36
A.4	Emission factors related to proportions of vehicle types and engine size	36

1 Introduction

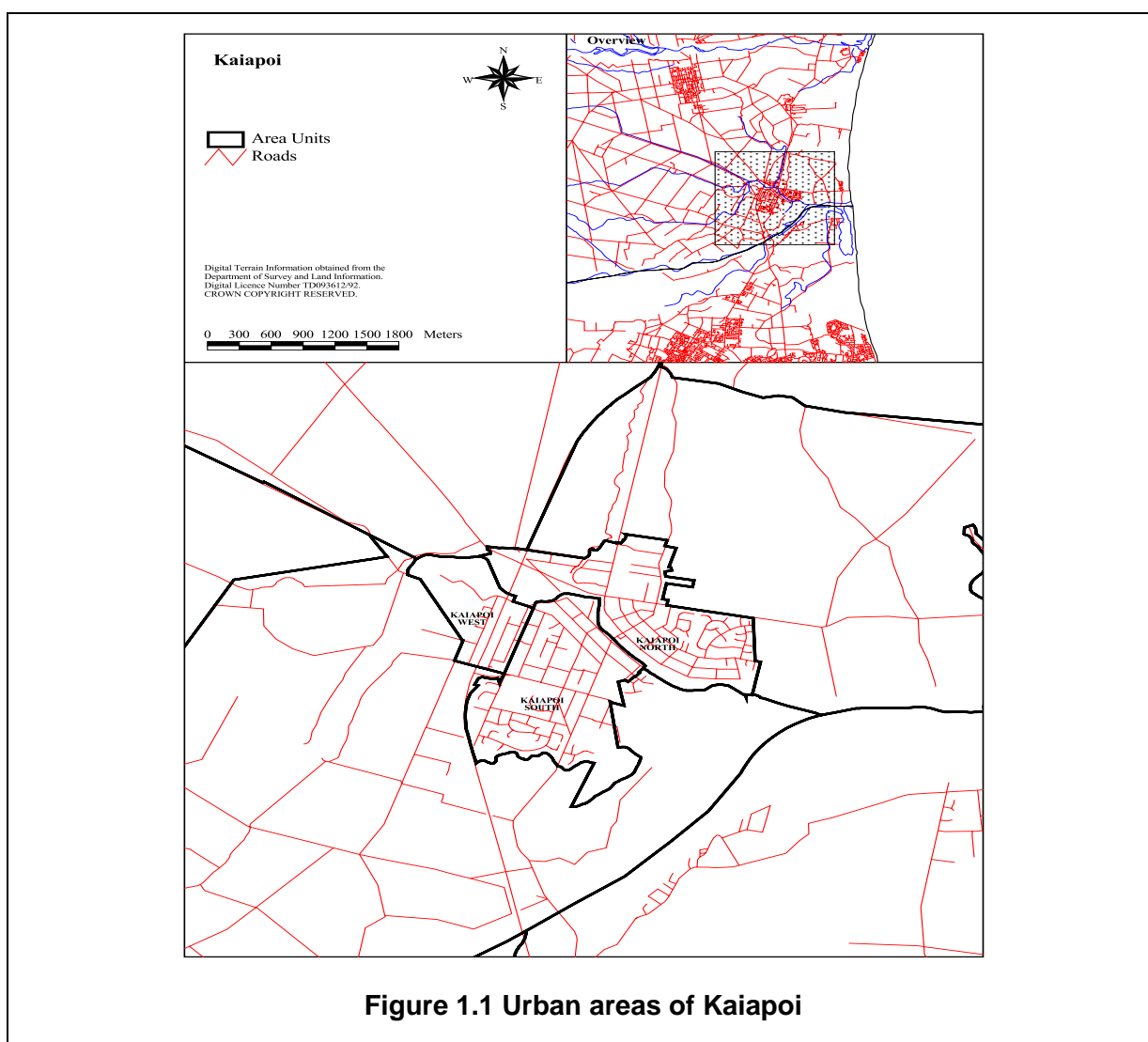
1.1 Purpose and Scope

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

Emission inventories are an important air quality management tool for determining the relative contribution of different sources to 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 (PM₁₀), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), volatile organic compounds (VOCs), and carbon dioxide (CO₂)
- Sources include domestic home heating, transport and industry
- The area under investigation includes the urban areas of Kaiapoi
- Wintertime daily emissions including a breakdown for the following periods; 6am-10am, 10am-4pm, 4pm-10pm, 10pm-6 am.



1.2 Background

Kaiapoi is an urban township in the Canterbury Region located approximately 11km north of Christchurch. It has a population of around 8,000 and approximately 2,900 dwellings.

For the purpose of this investigation the urban area of Kaiapoi was defined as the census areas of: Kaiapoi West, Kaiapoi North and Kaiapoi South (figure 1.1).

Domestic home heating, transport and industrial discharges are likely to be the main sources of air contaminants discharging into the Kaiapoi 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 Kaiapoi.

A small number of industrial activities that discharge to air are located in Kaiapoi. These tend to be a mix of minor activities including automotive and joinery spray-painting, and boilers. Emissions from approximately 11 industrial or trade premises have been included in the investigation.

Some areas of Kaiapoi were deemed Clean Air Zones under the Cleans 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 heating appliances in these areas is limited to appliances authorised for use in Clean Air Zones. This excludes open fires and burners not meeting the emission criteria applying at the time of installation. Further regulations prohibit the use of wood with a moisture content of more than 25% (wet weight) and coal with a sulphur content of >1% on any appliance.

Air quality monitoring in Kaiapoi in recent years has been limited to smoke measurements conducted during winter of

1993. These were limited to a 6 hour evening period between 5 p.m. and 11p.m. The highest 6 hour average concentration recorded for this period was $114 \mu\text{g m}^{-3}$. This is higher than the Canterbury Regional Council's air quality guideline of $50 \mu\text{g m}^{-3}$ for PM_{10} . Further investigations into air quality in Kaiapoi are scheduled for 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 households 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 sampling are contained in table 2.1.

fuel burner to heat their main living area on a typical winter's night.

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 that does not burn coal.
- An enclosed coal burner is an older model coal burner designed during or before the 1980s.

Table 2.1 Survey area for Kaiapoi

Survey area for Kaiapoi (based on census areas)	Area (ha)	Total number of households	Housing density (houses/ha)	Total houses surveyed	Error Level %
Kaiapoi North, Kaiapoi South and Kaiapoi West	562.2	3188	5.7	187	~7%

Table 2.2: Home heating methods in Kaiapoi

Home heating method	% of households*	Number of households
Electricity or gas (or both)	62.0	1976
Solid fuel burners (incl. open fires)	57.2	2142
Oil fired heating	-	-

*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.

Home heating methods and fuels

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

An analysis of the survey results found that about 12% of households in Kaiapoi use both electricity and gas and that some households use more than one type of solid

- A modern multi-fuel burner is a more recent burner in which either wood or coal can be burnt.

The following are the models or brands from the survey responses¹ included as either enclosed coal burners, modern multi-fuel burners, potbellies and incinerators:

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

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

Of the households that use open fires 90% burn wood either exclusively or in combination with coal (tables 2.3 & 2.4). Over 40% of the households using open fires are in the latter category, with only a small proportion (10%) depending solely on coal. All multi-fuel burners use either wood or a combination of wood and coal. Comparisons of

Table 2.3: Breakdown of home heating methods in Kaiapoi

	Number of households	Percentage*
Electricity	1294	40.6
Total Gas	1039	32.6
- flued gas	102	3.2
- unflued gas	937	29.4
Oil		-
Open fire/ visor	188	5.9
Log burner	1619	50.8
- 10 years and older	529	16.6
- less than 10 years	1090	34.2
Enclosed coal burner	16	0.5
Modern multi-fuel burner	102	3.2
Pot belly	64	2
Incinerator	128	4

tables 2.3 and 2.4 indicate that wood and coal are not the only fuels burnt in incinerators.

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 wood burners

Table 2.4: Fuel consumption across appliances

	Wood		Coal	
	% hh	kg	% hh	kg
Open fire	5.3	4060	3.2	1030
Wood burner 10yrs or older	16.6	14600		-
Wood burner <10 yrs old	34.2	7060		-
Enclosed coal burner	0.5	50	0.5	160
Modern multi-fuel burner	3.2	1360	1.6	620
Potbelly	1.1	320	1.1	160
Incinerator	2.1	1120	0.5	160
Total	63	28570	6.9	2130

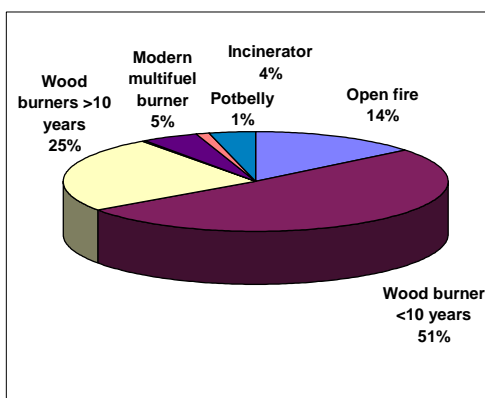


Figure 2.1: Wood use by appliance

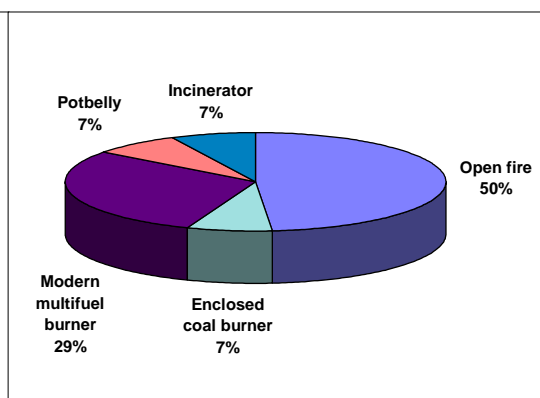


Figure 2.2: Coal use by appliance

less than 10 years old. Open fires and modern multi-fuel burners are the appliances in which the majority of coal is burnt.

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

Of the wood burnt on open fires and on wood burners, approximately 20% is self collected and 80% is purchased from a wood merchant². Of the wood burnt on

used to heat households for longer periods than other forms of home heating (table 2.5). Gas is the least common method of home heating during the 10pm - 6am period. Less than 20% of households using open fires light them in the early morning (6am-10am) compared with 66% for electricity.

Home heating methods in Kaiapoi compared to other urban centres

Table 2.6 compares home heating methods used in Kaiapoi with those of other urban

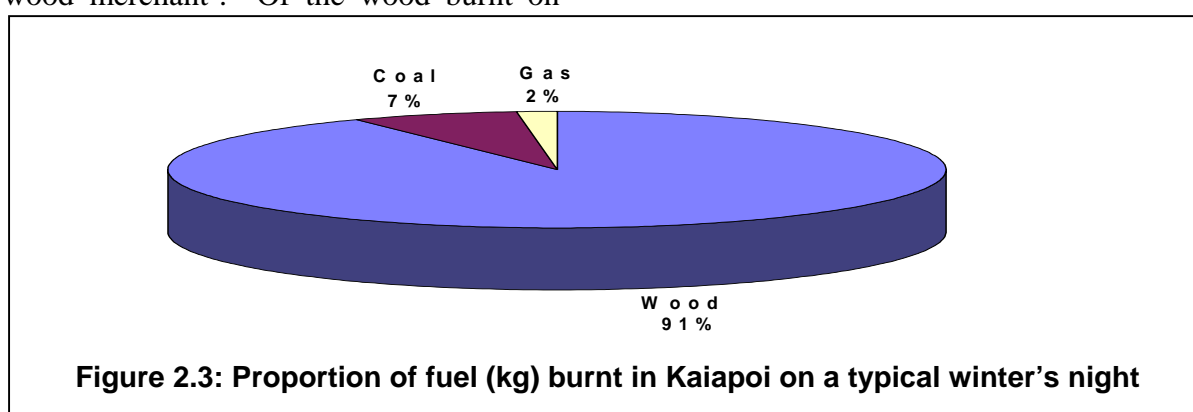


Figure 2.3: Proportion of fuel (kg) burnt in Kaiapoi on a typical winter's night

Table 2.5: Domestic 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 %	Wood burner %	Open fire %	Multi-fuel %
6am - 10am	66	46	45	17	43
10am - 4pm	32	29	58	17	49
4pm - 10pm	67	81	98	98	60
10pm - 6am	29	10	49	36	27
Average over 4 time periods	49	42	63	42	45

multi-fuel burners, approximately 30% is self collected and 70% is purchased from a wood merchant.

Wood burners are the most common method used to heat the home during the 10pm to 6am period and on average are

centres. Most notable is the use of gas which is greater in Kaiapoi than in any of the other main urban centres.

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

² Based on the proportions of households that do each. This assumes an equal fuel usage across households that collect versus households that purchase wood.

Emission Inventory for Kaiapoi

factor which takes into account the appliance on which the fuel is burnt i.e.,

$EF = \text{emission factor}$

$FF = \text{fuel burnt}$

$$CE \text{ (g/day)} = EF \text{ (g/kg)} * FF \text{ (kg/day)} \quad (1)$$

where $CE = \text{contaminant emission}$

An assessment of emissions from domestic home heating for different periods of the day was also conducted. This breakdown

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

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

⁽¹⁾ Emission inventories for Christchurch and Timaru were designed differently to account for 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 aren't specified in the Christchurch/Timaru inventories, the results can be interpreted in a similar manner.

⁽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.

Table 2.7: Emission factors for domestic home heating appliances

Appliance	PM₁₀	CO	NO_x	SO_x	VOC	CO₂
	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

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:

$$CE (g/time\ period) = EF (g/kg) * FF (kg/time\ period) \quad (2)$$

where

$$FF (kg/time\ period) = \frac{\text{no. of hours in time period} * \text{total fuel use/day}}{\text{no. of hours in all time periods}}$$

For example, the amount of fuel burnt from 4 pm to 10 pm for a household that heats the main living area from 4pm -10pm

and from 10am - 4pm and burns a total of 20 kg wood per day is as follows:

$$FF(kg/4pm-10pm) = \frac{6\ hrs * 20kg}{12\ hrs} = 10kg \quad (3)$$

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., moisture content, 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 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

Table 2.8: Home heating emissions by appliance type

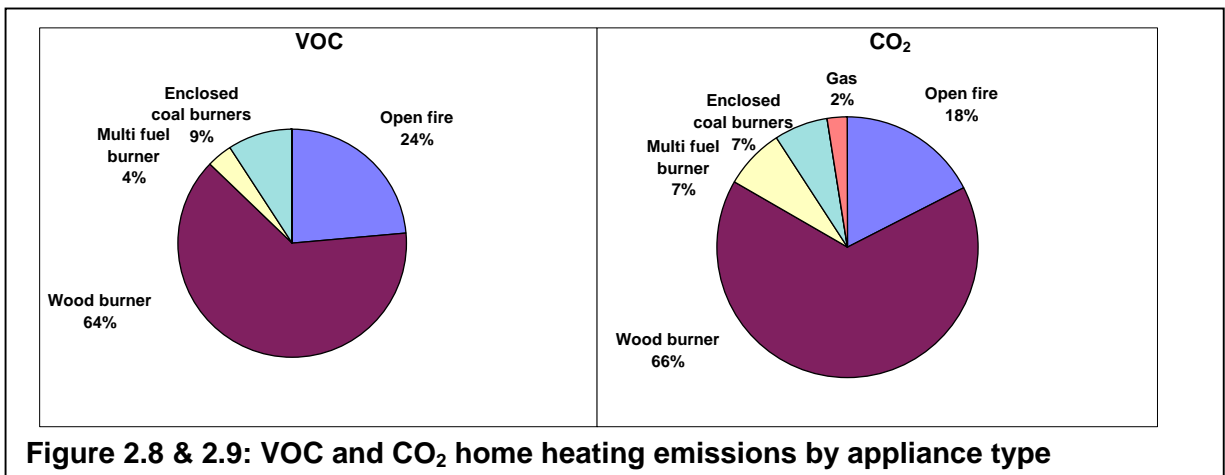
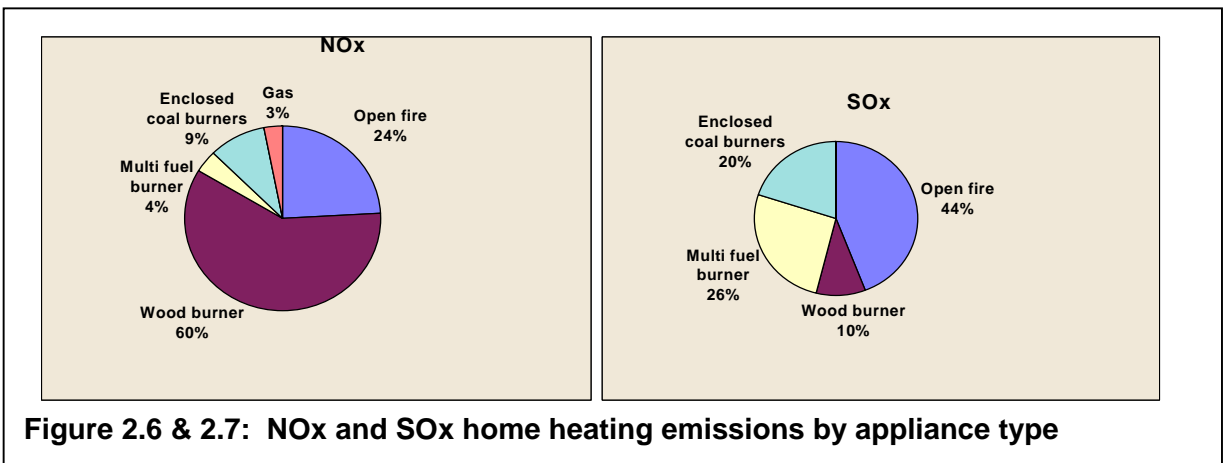
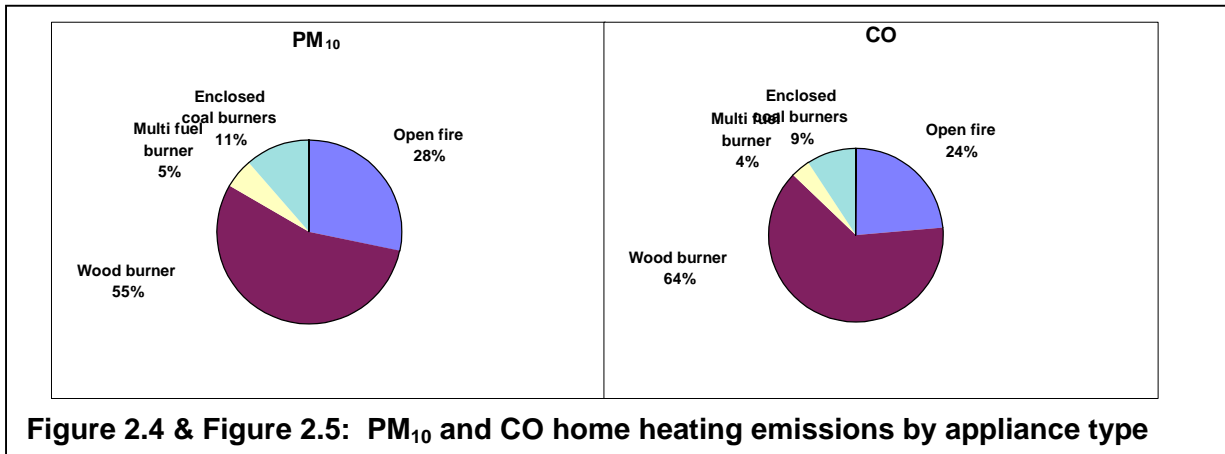
	Daily fuel quantity (kg/day)	PM ₁₀ kg	CO kg	Nox kg	Sox kg	VOC kg	CO ₂ kg
Gas	533	0	0	0	0	0	0
Oil	0	0	0	1	0	0	1333
Open fire - wood	4062	61	487	7	1	122	6905
Open fire - coal	1027	34	62	2	19	15	2877
Wood burner (10yr+)	14602	90	724	10	1	181	12010
Wood burner (<10yr)	7064	94	748	10	3	187	24824
Enclosed coal burner -wood	50	1	6	0	0	1	85
Enclosed coal burner - coal	156	5	9	0	3	2	436
Modern multi-fuel – wood	1363	9	70	1	0	17	2317
Modern multi-fuel -coal	622	9	16	0	11	4	1742
Potbelly - wood	324	5	37	1	0	9	550
Potbelly - coal	156	5	9	0	3	2	436
Incinerator - wood	1120	18	140	2	0	35	1904
Incinerator - coal	156	5	10	0	3	2	436
Total	31235	336	2318	34	44	577	55855

amount of contaminant in grams (e.g., PM₁₀, CO) emitted per kg of fuel burnt. The home heating emission factors used in the emission inventory were those derived by NIWA (CRC, 1997) for the Clean Air Zones of Christchurch and are summarised in table 2.6. These were developed from a literature survey 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 Kaiapoi there are

unlikely to be significant differences in appliance emissions across the township.

Daily home heating emissions by appliance type

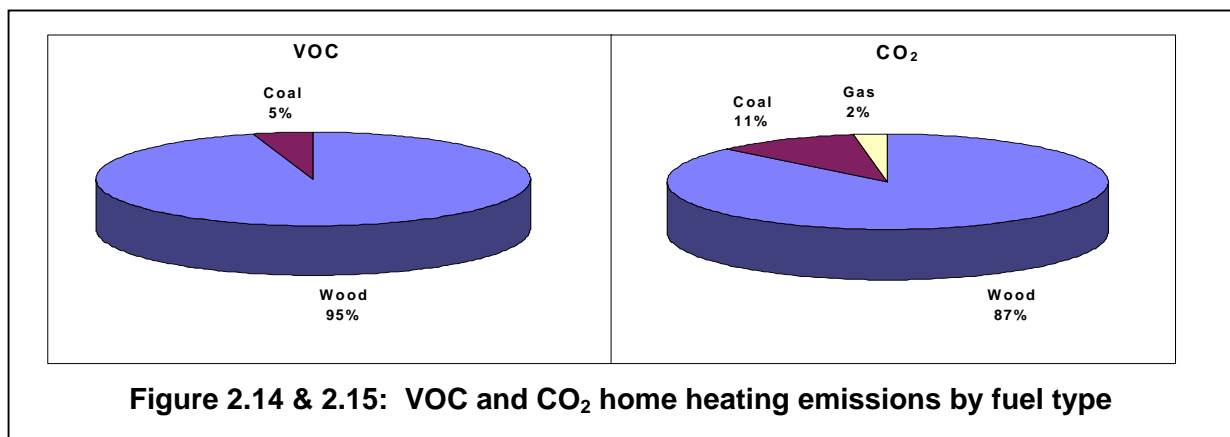
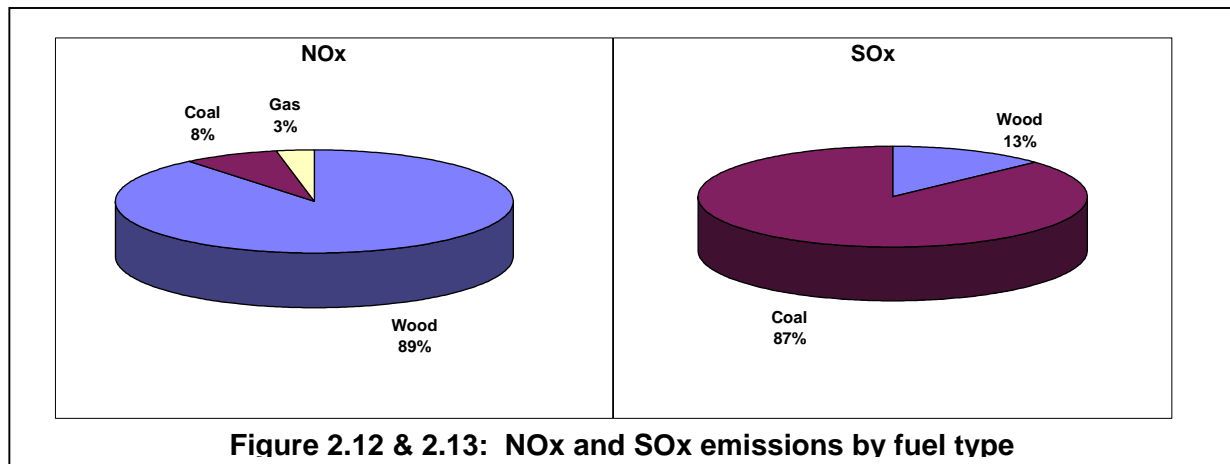
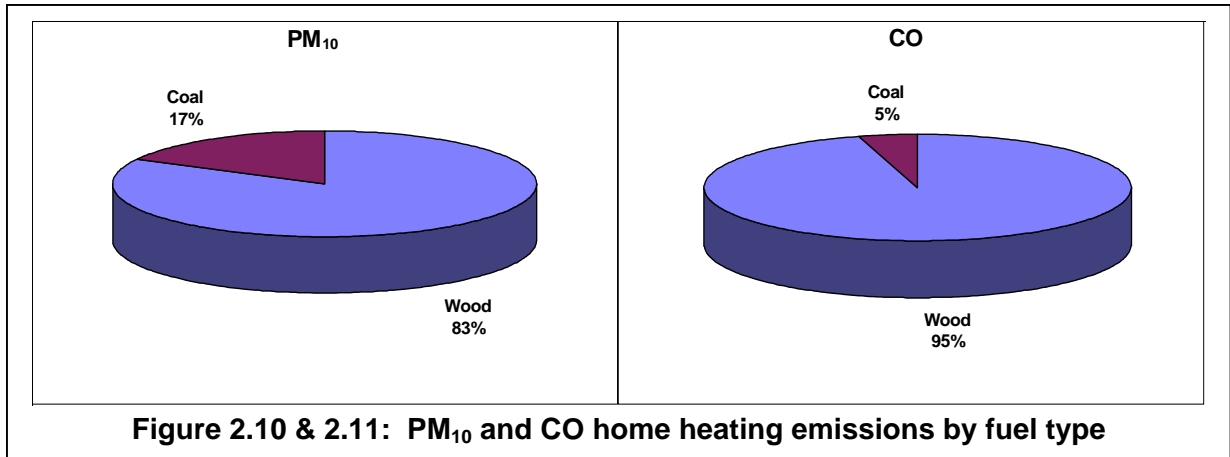
The approximate amount of fuel burnt on a typical winter's day by appliance type, and the resulting emissions are shown in table 2.7. Emissions of each contaminant by appliance type are also illustrated in figures 2.4 to 2.11.



A large proportion of PM₁₀ emissions from domestic home heating in Kaiapoi is from wood burners (55%). Wood burners also contribute over 60% of the CO, NO_x, VOC, and CO₂ emissions. Open fires produce over 40% of the SO_x emissions and almost one third of the PM₁₀.

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.



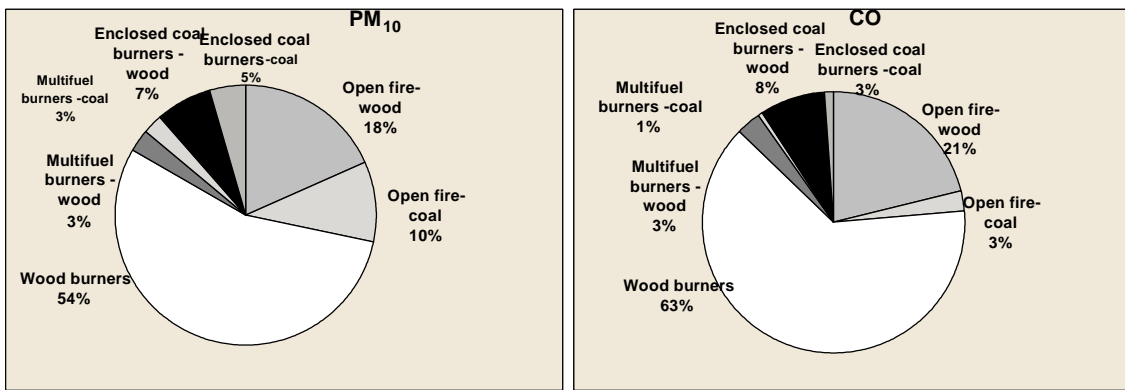
The burning of coal results in over 80% of the SO_x emissions while wood burning accounts for over 80% of emissions of all other contaminants. Gas contributes to 3% of the NO_x and 2% of the CO₂ emissions.

Home heating emissions by fuel and appliance type

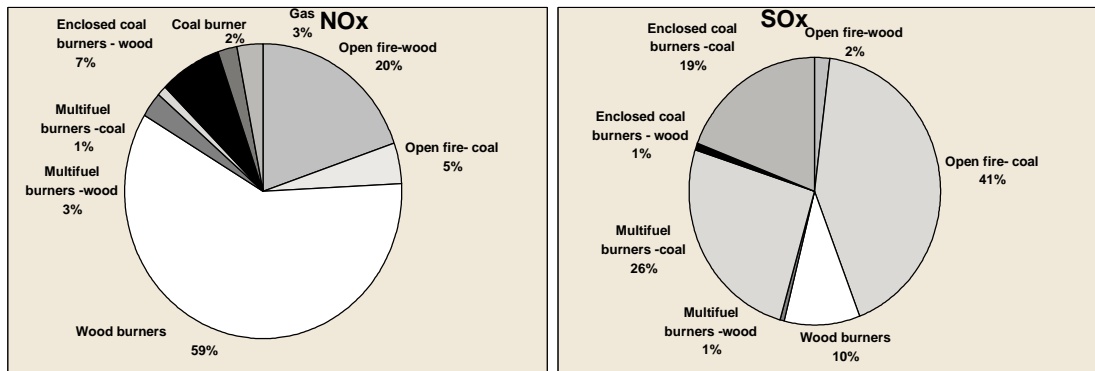
Home heating emissions by fuel and appliance type are illustrated in figures 2.16 to 2.21. PM₁₀ emissions are

reasonably similar between fuels for the different appliance types. Although coal has greater PM₁₀ emissions per kg burnt, a greater quantity of wood is burnt on each appliance. Overall more emissions come from the burning of wood.

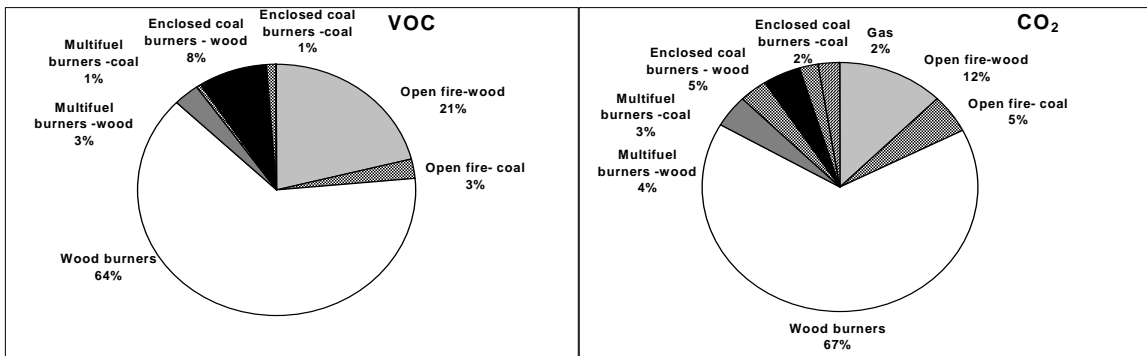
The majority of CO, NO_x and VOC emissions from open fires come from burning wood. Similar trends are observed for these contaminants with the multi-fuel and enclosed coal burners.



Figures 2.16 & 2.17: PM₁₀ and CO emissions by fuel and appliance type



Figures 2.18 & 2.19: SO_x and NO_x emissions by fuel and appliance type



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

SO_x emissions are mostly from the burning of coal, particularly on the open fire.

Home heating emissions by time of day and emission density

For the purpose of allowing comparisons of emissions in Kaiapoi 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 Kaiapoi area comprises of 562.2 ha. Emissions of contaminants from the domestic home heating sector on a g/ha basis is illustrated in table 2.8.

an assessment of emissions relative to times during which variations in meteorological conditions can impact substantially on air quality. For example, if meteorological measurements indicated that the wind was much stronger during the daytime, emissions that occurred at this time may make little contribution to the 24 hour average concentration.

Table 2.10 shows the variations in emissions over a 24 hour period. The distribution of PM₁₀ 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

Table 2.9: Grams of emissions per hectare

No. of Ha	Daily fuel quantity (kg/ha)	PM ₁₀ g/ha	CO g/ha	NO _x g/ha	SO _x g/ha	VOC g/ha	CO ₂ g/ha
562	56	486	3253	49	76	813	87067

Emissions were also examined in terms of the time of day during which they occur

hours, the daytime and evening by six hours and the nighttime by eight hours. Other contaminants show a similar

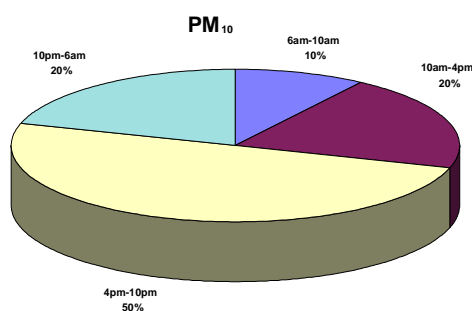


Figure 2.22: PM₁₀ emissions by time of day

Table 2.10: Variations in emissions with time of day

	PM ₁₀		CO		NO _x		SO _x		VOC		CO ₂	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
6am-10am	32	57	237	422	4	6	3	5	59	105	5805	10325
10am-4pm	68	121	487	865	7	13	7	12	122	216	11203	19927
4pm-10pm	166	296	1100	1957	16	29	28	50	275	489	26827	47719
10pm-6am	68	120	493	876	7	13	6	11	123	219	12019	21379
Total	334	594	2317	4120	34	61	44	78	579	1029	55854	99350

for a typical winter's day. This allows for

distribution.

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 Kaiapoi. 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 type and quantity of contaminants emitted 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 oxide 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 NO_x 1:2, for SO_x 1:10, VOCs 2:1, and PM₁₀ 1:30. In the case of PM₁₀ the lopsided nature of the ratio and the size of the amounts involved, means no value for PM₁₀ from petrol engines has been assessed.

In the road network of Kaiapoi 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 study 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 the case of Rangiora and Kaiapoi 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. This is described in Appendix 1.

For Kaiapoi the vehicle kilometres run has been split by road class (motorway and township road network), requiring two different speeds to be used in the analysis. This approach was taken because the

amount of travel on the motorway is greater than 26 % of total travel within the Kaiapoi road network.

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 the network and Transit New Zealand traffic counts have been used to estimate the amount of vehicle kilometres travelled on Christchurch's Northern Motorway. The motorway has been divided into sections, 1.5 kilometres to the south of Ohoka Road underpass, 1.5 kilometres between Ohoka Road and Smith Street underpass, and a section north of Smith Street 0.75 kilometres in length. The relative traffic flows (two ways) on these three sections of motorway, starting from the southern section, are 19,700 vpd (vehicles per day), 15500 vpd, and 7100 vpd. Vehicle kilometres travelled based on these flows and distances total 58,160 per day. This is included as part of a network total for Kaiapoi of 215,509 vehicle kilometres of

Table 3.1: Summary Emissions (kg) for Kaiapoi by Emission Type, Time of Day, and Fuel Used

Kaiapoi Road Network Motor Vehicle Emissions Based on Modelled Traffic Flows for 1996											
Emissions	CO ₂		CO		NO _x		SO _x		VOCs		PM ₁₀
Period	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel
6am-10am	6262	764	587	16	81	22	7	8	74	5	3
10am-4pm	13910	1700	1304	35	181	48	14	16	163	11	6
4pm-10pm	8871	537	830	11	115	15	10	6	104	3	3
10pm-6am	1529	124	143	2	20	3	2	1	26	1	0.6
Total by fuel	30570	3125	2865	64	397	88	32	32	367	20	
Total	33695		2929		486		64		388		12

travel. It was assumed that the motorway mean speed is 100 kilometres per hour and the township road network has an estimated mean speed of 35 kilometres per hour.

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.

3.1 Transport emissions

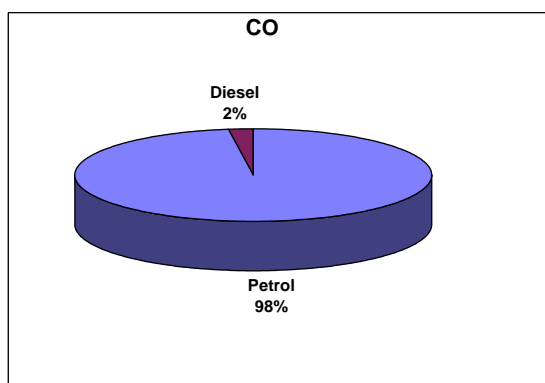
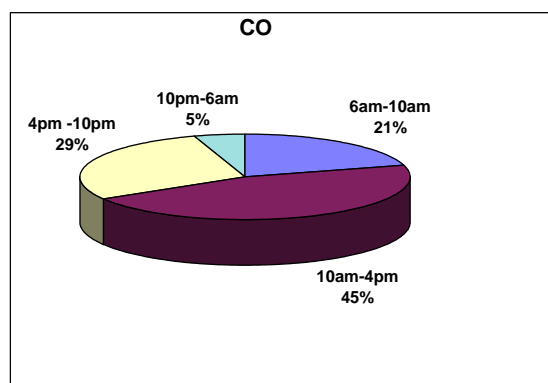
Table 3.1 shows the daily transport emissions (tonnes) of PM₁₀, CO, NO_x, SO_x, VOC and CO₂ and a breakdown of the time of day in which they occur. Table 3.2 details transport emissions in Kaiapoi by vehicle type.

Figures 3.1 to 3.12 illustrate transport emissions by time of day, fuel use and by vehicle type. They show that petrol vehicles are responsible for the majority of CO, NO_x, VOC and CO₂ emissions. Petrol and diesel vehicles both contribute 50% of the SO₂ emissions. No illustration of PM₁₀ emissions is provided as only PM₁₀ emissions from diesel fuel were considered.

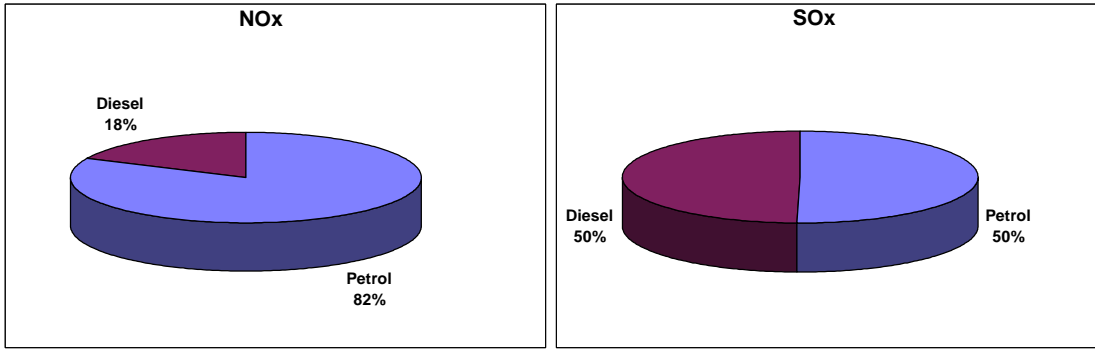
Passenger car emissions were found to contribute over 80% of the PM₁₀, CO, VOC, and CO₂ emissions and over 60% of the SO_x and NO_x from the transport sector.

Table 3.2: Summary Emissions (tonnes) for Kaiapoi by Emission Type, Vehicle Class, and Fuel Used

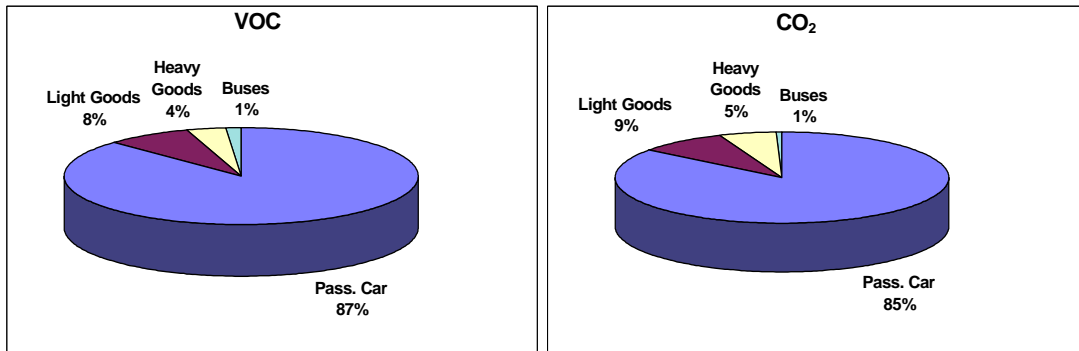
Kaiapoi Road Network Motor Vehicle Emissions Based on Modelled Traffic Flows for 1996											
Emissions	CO ₂		CO		NO _x		SO _x		VOCs		PM ₁₀
Vehicle Type	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel
Pass. Car	27790	940.7	2592	18	360	24	30	10	333	6	10
Light Goods	2135	789.4	199	15	28	20	2	7	25	5	1
Heavy Goods	570	1248.2	53	23	7	32	0.5	11	7	7	0.7
Buses	76	146.5	21	8	3	11	0.2	4	3	3	0.1
Total by fuel	30570	3124.8	2865	64	397	88	32	32	367	20	
Total		33695		2929		486		64		388	12



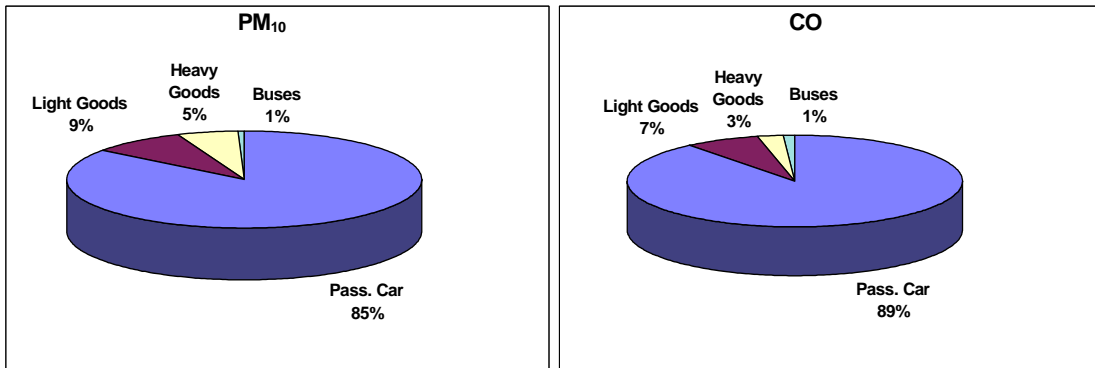
Figures 3.1 & 3.2: CO transport emissions by time of day and by fuel type



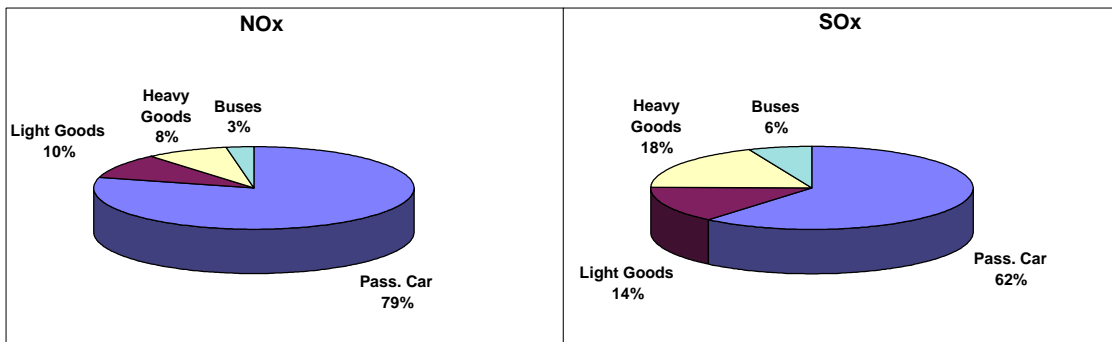
Figures 3.3 & 3.4: NOx and SOx transport emissions by fuel type



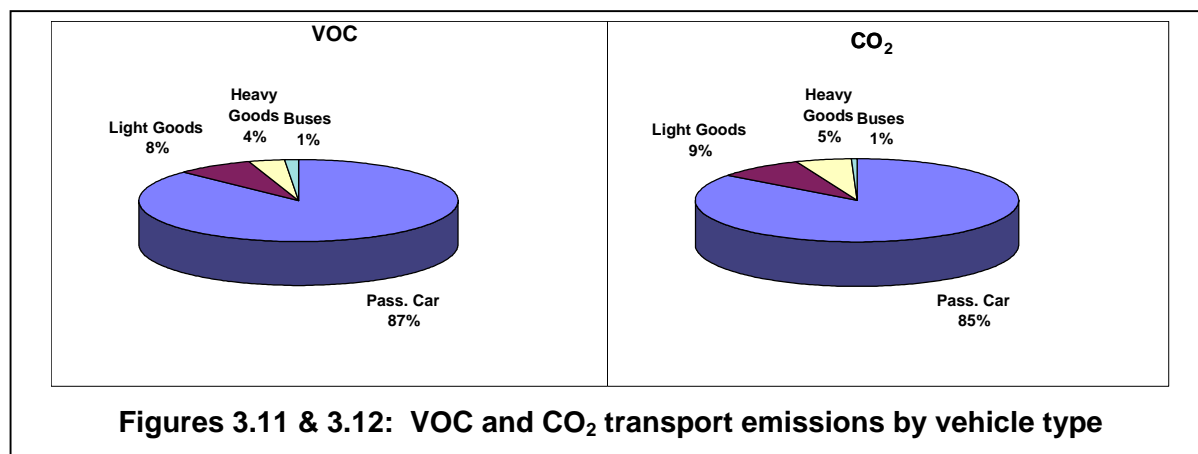
Figures 3.5 & 3.6: VOC and CO₂ transport emissions by fuel type



Figures 3.7 & 3.8: PM₁₀ and CO transport emissions by vehicle type



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



4 Industry

4.1 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 Kaiapoi. A total of 3 consents were found.

Other potential discharges classified as "Part C" processes³ were identified through a search of the Kaiapoi telephone directory and via consultation with the Kaiapoi District Council.

Activities identified as potential dischargers to air were examined in terms of the contaminants PM₁₀, CO, SO_x, NO_x, CO₂ 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.

4.2 Assessment of emissions from industrial processes

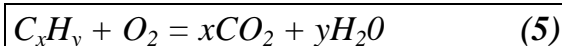
Discharges to air from industrial activities generally arise from either combustion

³ and therefore not currently requiring consents from the CRC.

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.

Emissions from combustion

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:



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 (CO₂) is produced as 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 (N₂), which is present in the air we breathe, reacting with the oxygen (O₂) 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; and 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 winter-time 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.

Daily and annual emissions were calculated as follows:

$$\text{Contaminant emission (kg/day)} = \text{fuel use (tonnes/day)} \times \text{contaminant emission factor (kg/tonne)} \quad (6)$$

For example, calculations for PM₁₀ emissions from an industry using 1.5 tonnes of coal per day are shown in equation 7.

$$PM_{10} \text{ emission} = 1.5 \text{ tonnes/day} \times 5 \text{ kg/tonne}$$

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

Fuel	Boiler size	PM ₁₀ kg/tonne	CO kg/tonne	NO _x kg/tonne	SO _x kg/tonne	VOC kg/tonne	CO ₂ 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 (from Christchurch and Timaru emission inventories)

	PM ₁₀	CO	NO _x	SO _x	VOC	CO ₂
Spray-painting - per tonne paint used					560 kg ⁽¹⁾	
Timber treatment per tonne of chemicals used					600 kg ⁽²⁾	

⁽¹⁾ Assuming the density of paint = 1 kg/l for conversion to tonnes

⁽²⁾ Assuming average surface coating operation

$$= 7.5 \text{ kg } PM_{10} \text{ per day} \quad (7)$$

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 were obtained via a telephone survey of all industries in the area.

Process emissions

The most common non-combustion process from which discharges to air occur in the Kaiapoi area is spray-painting. Emission factors for these and other non-combustion sources were obtained from emission inventories prepared by NIWA for Christchurch. These were taken from the USEPA (1996) and WHO (1993) and are shown in table 4.2.

Processes emissions were calculated as follows:

$$\text{Emissions (kg/day)} = \text{quantity of product used (units/day)} \times \text{emission factor (kg/unit)} \quad (8)$$

The unit of material will be dependent on

the process but could include for example, litres of paint sprayed.

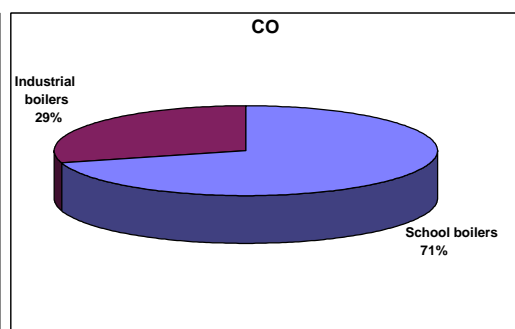
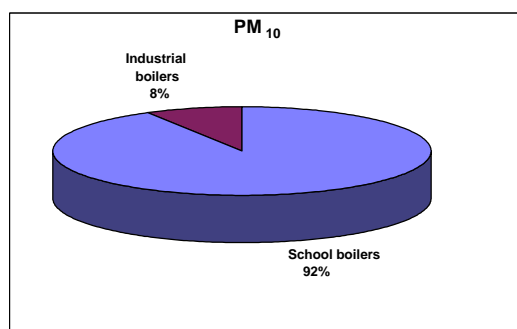
4.3 Industrial Emissions

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

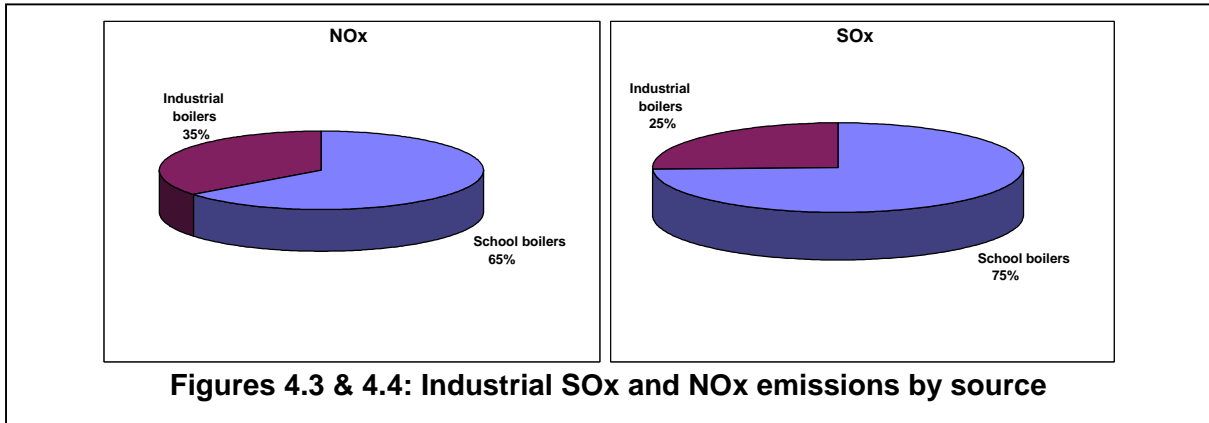
For the purpose of allowing comparisons of emissions in Kaiapoi to those of other areas of the region, the total mass of industrial emissions was divided by the number of hectares in the study area. This allows a comparison of mass of emission per area volume. Table 4.3 shows total emissions from the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

Table 4.3: Industrial emissions by time of day

	PM ₁₀		CO		NO _x		SO _x		VOC		CO ₂	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
6am-10am	4	8	2	4	9	15	17	31	381	678	3631	6459
10am-4pm	0	0	0	1	2	4	3	5	1132	2013	2315	4117
4pm-10pm	0	0	0	0	0	1	0	1	198	353	312	554
10pm-6am	0	0	0	0	0	0	0	0	16	28	148	264
Total	5	8	3	5	11	20	21	37	1727	3072	6406	11394



Figures 4.1 & 4.2: Industrial PM₁₀ and CO emissions by source

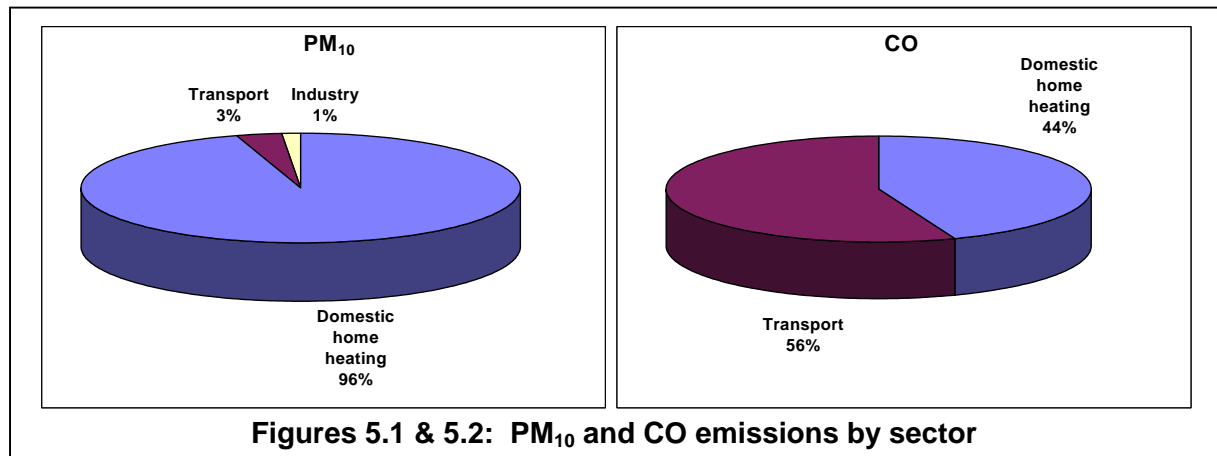


5 Total emissions for Kaiapoi

The proportional contribution of each sector to the total emissions in Kaiapoi is shown in table 5.1. This indicates that the greatest proportion of PM₁₀ originates from emissions from the domestic home heating sector. This sector is also responsible for over 40% of the CO, almost 40% of the SO_x, and approximately 60% of the VOCs and CO₂. Transport is responsible for 90% of the NO_x and for

over 50% of the CO emissions. Industry contributes over 60% of the VOC emissions. Figures 5.1 to 5.6 compare the proportion of PM₁₀, CO, NO_x, SO_x, VOCs and CO₂ emissions arising from each sector.

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 PM₁₀ emissions are released during the evening



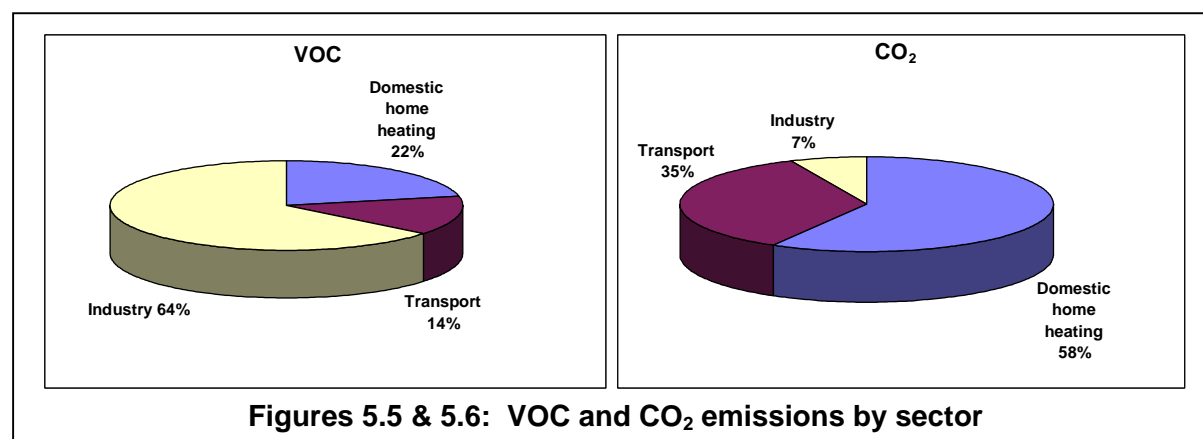
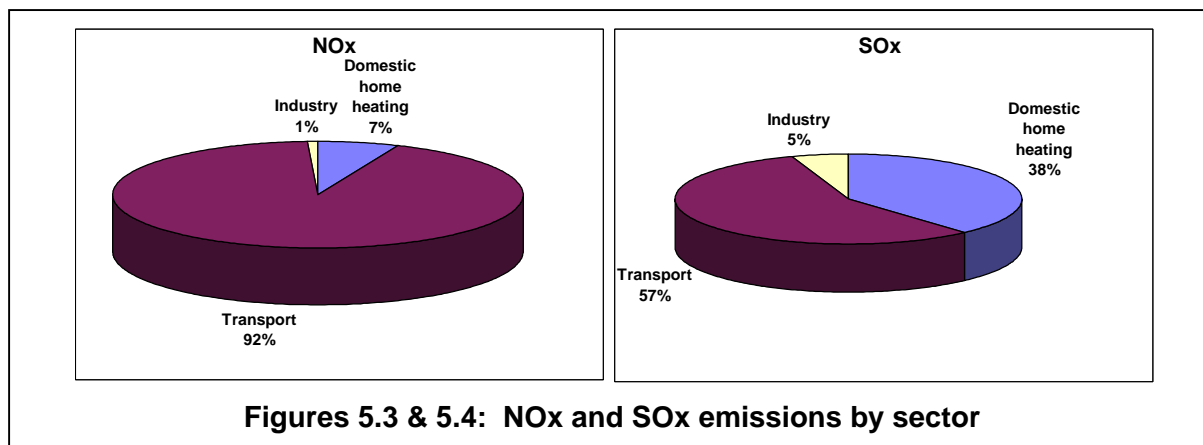


Table 5.1: Total emissions on a typical winter's day by sector

	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	334	594	2316	4120	34	61	44	78	579	1030	55854	99350
Transport	12	22	2929	5209	486	864	64	114	380	675	33695	59934
Industry	5	8	3	5	11	20	21	37	1727	3072	6406	11394
Total	351	624	5248	9334	531	945	129	229	2686	4777	95955	170678

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	39	69	842	1498	115	205	34	61	923	519	16462	29281
10am-4pm	74	132	1826	3248	238	424	40	71	2540	1428	29127	51808
4pm-10pm	170	302	1941	3453	147	261	45	79	1033	581	36547	65008
10pm-6am	68	121	638	1135	30	54	9	17	295	166	13820	24582
Total	351	624	5248	9334	531	944	129	229	4791	2694	95955	170678

(4pm - 10pm) period. The majority of the CO and VOC emission occur during the 10am-4pm period.

5.1 Total emissions in Kaiapoi compared with other urban centres

The relative contribution of PM₁₀ emissions in Kaiapoi compared to Timaru, Waimate, Rangiora, Ashburton, and Christchurch are illustrated in figure 5.7. The relative contribution of the domestic

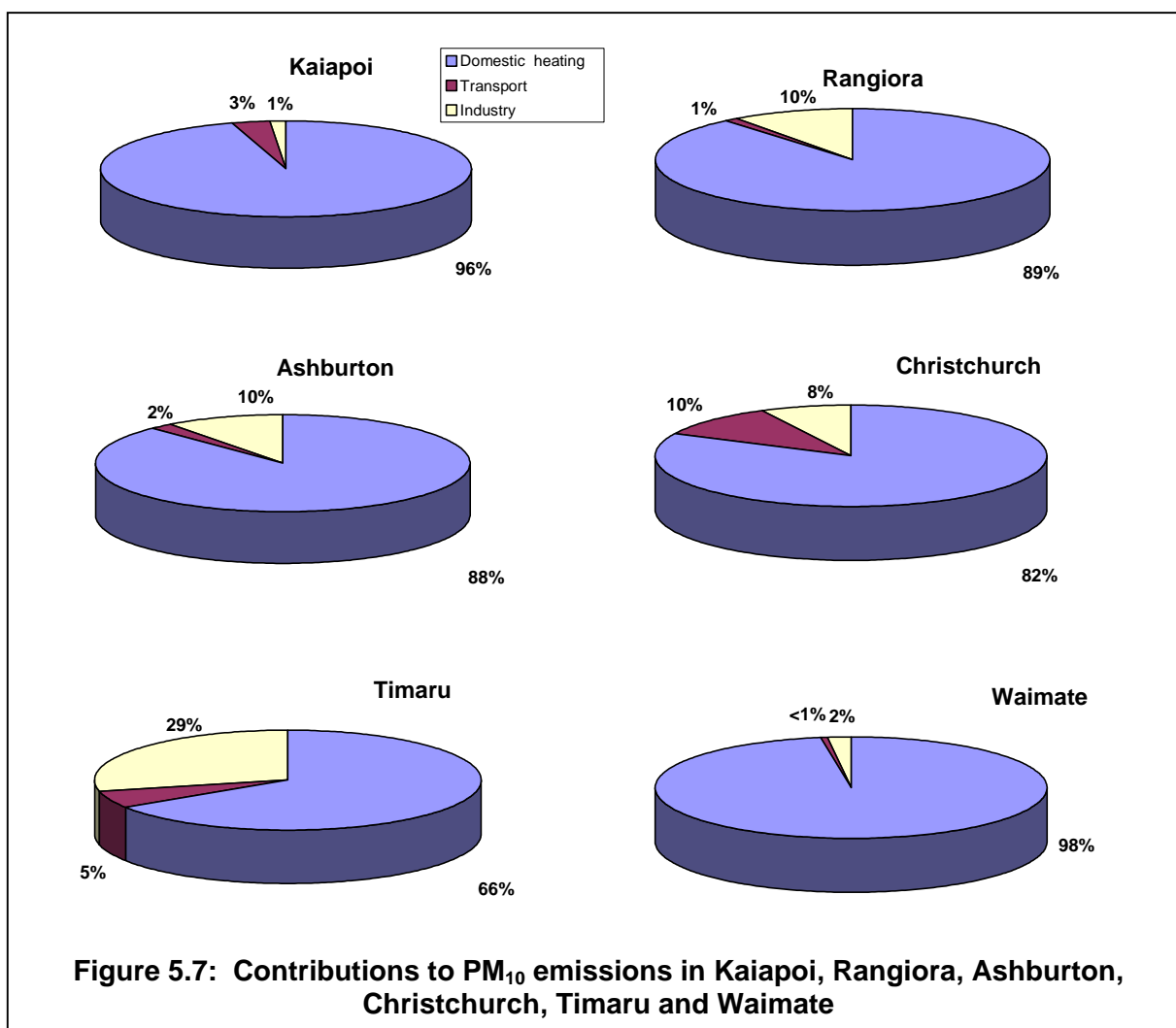
heating sector to PM₁₀ emissions is similar to Waimate and slightly higher than other urban centres.

Table 5.3 compares total emissions in Kaiapoi expressed as grams per household to other urban areas of the region. This shows that on a household basis:

- Waimate has the highest PM₁₀ emission per household

Table 5.3 Grams of emissions per household for a typical winter's day compared with other urban areas

	hh	PM ₁₀ g/hh	CO g/hh	NO _x g/hh	SO _x g/hh	VOC g/hh	CO ₂ g/hh
Rangiora	3692	166	1719	128	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



- Christchurch has the highest CO and VOC emissions per household
- Timaru has the highest NO_x, SO_x and CO₂ emissions per household

Table 5.3 shows Kaiapoi has the lowest PM₁₀ emissions per household of all the areas examined. Although the proportion of households that use solid fuel burning in Kaiapoi is higher than in Christchurch, a greater proportion of the appliances used in Kaiapoi are less than 10 years old and consequently have lower emissions. In addition, the contribution of industry and motor vehicles to PM₁₀ emissions in Kaiapoi is low compared to Christchurch, Timaru, Ashburton and Rangiora.

6 Summary

Table 5.4 compares emissions in Kaiapoi to other urban areas of the region. Wintertime emissions from domestic heating, transport and industry were estimated for the urban areas of Kaiapoi. Estimates were based on surveying of households and industry, traffic modelling, resource consent information and the application of emission factors.

- Survey results showed that approximately 41% of Kaiapoi households use electricity to heat their main living area on a typical winter's night. This compares to 24% that use gas and 57% 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 half of the PM₁₀ emissions from domestic heating with the remainder coming from open fires (28%) and multi-fuel burners (16%).
- Approximately 80% of the PM₁₀ emissions come from the burning of

wood with the remainder coming from coal burning.

- Approximately 50% of the PM₁₀ emissions occur during the evening (4 p.m. to 10 p.m.) period.
- Passenger cars are responsible for the majority of the PM₁₀, CO, NO_x, SO_x, VOC and CO₂ emissions from transport. Just under half of the emissions from transport occur during the evening (4 p.m. – 10 p.m.) period.
- Combustion processes are responsible for the majority of PM₁₀, CO, NO_x, SO_x and CO₂ emissions from industry in Kaiapoi. The majority of VOC emissions from the industrial sector come from spray painting operations.
- Overall the domestic heating sector is responsible for 96% of the PM₁₀, 44% of the CO, and over 50% of the CO₂. The transport sector contributes over half of the CO and SO_x, the majority (92%) of the NO_x, and approximately two-thirds of the VOC emissions.
- Industry emits approximately two-thirds of the VOC emissions but less than 10% of emissions of other contaminants.

7 References

- Canterbury Regional Council; 1997. Christchurch Inventory of Total Emissions. Canterbury Regional Council Report No. R97/7.
- Lamb, C G; 1997. Home Heating Methods Survey: A survey of heating methods used in Ashburton, Waimate, Kaiapoi and Rangiora. Canterbury Regional Council U97/80.
- United States Environmental Protection Agency (USEPA); 1996. Compilation of Air Pollution Emission Factors

(AP-42), Research Triangle Park,
North Carolina, United States of
America

Table 5.4: Total emissions in Kaiapoi compared to other urban centres

		Kaiapoi		Ashburton		Timaru		Waimate		Rangiora		Christchurch	
	Source	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha*	kg	g/ha
PM ₁₀	home heating	334	594	897	724	1340	652	285	928	543	985	10971	618
PM ₁₀	transport	12	22	18	14	110	54	1	5	8	14	1365	77
PM ₁₀	industry	5	8	106	86	585	285	6	19	61	130	1018	57
	Total	351	624	1021	824	2035	991	293	952	612	1129	13354	752
CO	home heating	2316	4120	5345	4315	8559	4167	1865	6048	2316	7083	61962	3489
CO	transport	2929	5209	4780	3859	8438	4108	371	1183	2437	4420	125591	7073
CO	industry	3	5	44	35	185	90	3	9	6	13	478	27
	Total	5248	9334	10169	8209	17182	8365	2239	7240	4759	11516	188031	10589
NO _x	home heating	34	61	82	66	125	61	28	90	56	102	937	53
NO _x	transport	486	864	517	417	2161	1052	28	90	398	722	23655	1332
NO _x	industry	11	20	147	119	681	331	10	31	20	43	1452	82
	Total	531	945	746	602	2967	1444	66	211	474	867	26044	1467
SO _x	home heating	44	78	214	173	239	116	45	148	52	94	2490	140
SO _x	transport	64	114	84	67	93	45	6	18	40	73	1130	64
SO _x	industry	21	37	199	160	1321	643	21	67	43	92	3055	172
	Total	129	229	497	400	1653	805	72	233	135	259	6675	376
VOC	home heating	579	1030	1336	1079	2140	1042	466	1512	976	1771	15490	872
VOC	transport	388	689	634	512	2071	1008	44	141	322	584	28608	1611
VOC	industry	1727	3072	37	30	35	17	2	6	19	41	798	45
	Total	2694	4791	2007	1621	4246	2067	512	1659	1317	2396	44896	2528
CO ₂	home heating	55854	99350	131965	106535	186822	90955	42338	136981	93774	170112	1375853	77482
CO ₂	transport	33695	59934	44636	36035	235391	114601	3042	9694	22296	40447	2802943	157849
CO ₂	industry	6406	11394	39901	32212	260096	126629	2885	9193	6261	13363	688883	38794
	Total	95955	170678	216502	174782	682309	332186	48265	155868	122331	223923	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.*

Emission Inventory for Kaiapoi

- (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.

Emission Inventory for Kaiapoi

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 zonefile 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, 91DEM.W.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 to accommodate the increased number of zones.

A street representing Hilton Street and Raven Quay (the principal shopping streets) was added to the network, together with part of Otaki Street, Broom and Hugh Streets, and the section of Peraki Street south of Hugh Street.

Following the final assignment of the expanded trip matrix to the extended road network model, the selected areas of Kaiapoi 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.

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

Emission Factors by Emission Type and Speed							
Speed	Fuel	CO ₂	CO	NO _x	SO _x	VOCs	PM ₁₀
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

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*. The table gave rise to the following:

Table A.2 Kaiapoi 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 gives vehicle numbers 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. These factors are given in Table A.4 below.

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.1 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.