Ashburton Inventory of Emissions

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Executive Summary

An inventory of emissions to air was conducted during 1997 for the urban areas of Ashburton. 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 44% of Ashburton households use electricity, 14% use gas and 52% use solid fuel to heat their main living area on a typical winter's night. Wood burners are used by approximately one third of Ashburton households, while open fires and multi-fuel burners are each used by ~10% of Ashburton households. Many households use more than one method of heating in their main living area.

Wood burners and open fires each emit approximately one-third of the PM_{10} emissions from domestic heating with the remainder coming from coal burners and multi-fuel burners. Overall two thirds of the PM_{10} emissions come from the burning of wood and one third from the burning of coal. Over 50% of these emissions occur during the evening (4pm to 10pm) period.

Passenger cars are responsible for approximately half of the SOx emissions and the majority of CO, NOx, VOC, and CO_2 emissions from transport. Heavy goods vehicles produce over half of the PM_{10} emissions from transport. About half of the emissions from transport occur during the 10am to 4pm period.

Combustion processes emit over 50% of the PM_{10}, CO, NOx, SOx, and CO_2 emissions from industry. Other industrial sources of PM_{10} include bitumen plants and seed cleaning and handling operations. The majority of VOC emissions from the industrial sector come from spray painting operations.

Overall the domestic heating sector is responsible for approximately three-quarters of the PM_{10}, half the CO, two-thirds of the VOCs and 60% of the CO_2. The transport sector contributes approximately half of the CO, ~70% of the NOx, and one third of the VOC emissions. Industry emits ~20% of the PM_{10}, NOx, and CO_2 and ~40% of the SOx emissions.

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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 Ashburton. It provides an estimate of quantities of specific contaminants released into the air from major sources within the urban area of Ashburton.

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 assess the effectiveness of different management options.

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 Ashburton
- Wintertime daily emissions including a breakdown for the following periods: 6am-10am, 10am-4pm, 4pm-10pm, 10pm-6 am.

1.2 Background

Ashburton is a rural servicing town in the Canterbury Region located between the

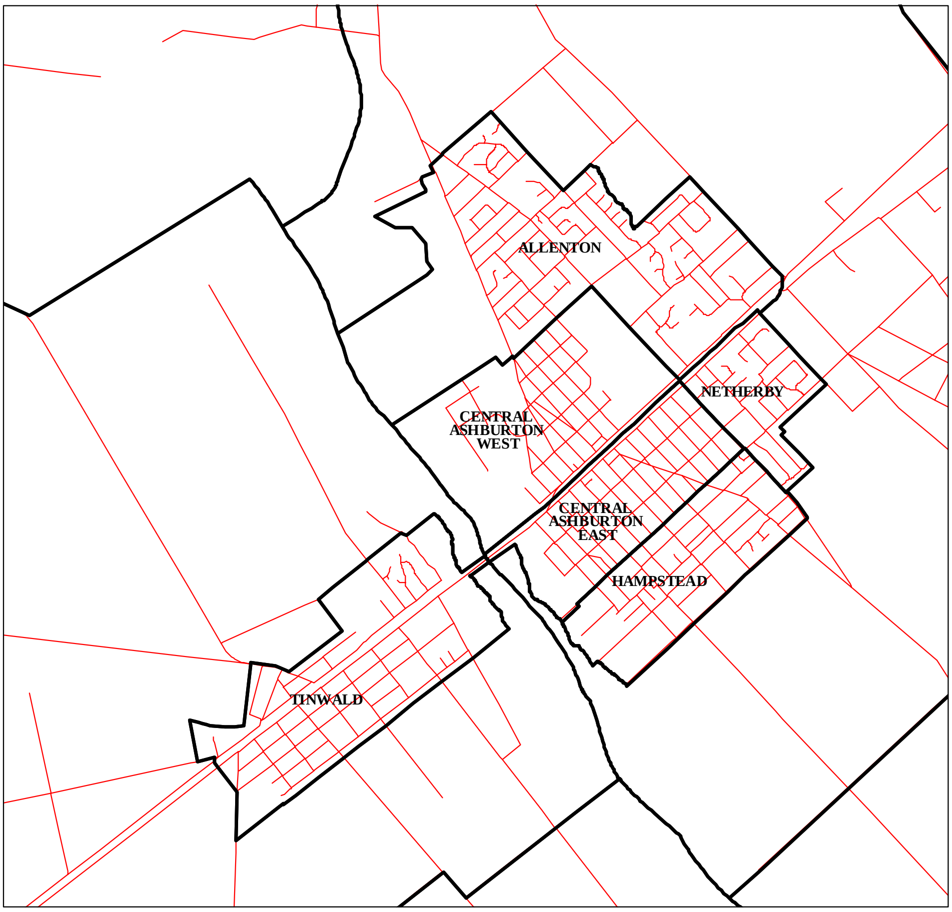


Figure 1.1 Urban areas of Ashburton

cities of Christchurch and Timaru. It has a population of around 14,000 and approximately 5,550 dwellings.

For the purpose of this investigation the urban area of Ashburton was defined as the areas of: Allenton, Central Ashburton West, Netherby, Central Ashburton East, Hampstead and Tinwald (figure 1.1).

Domestic home heating, transport and industrial discharges are likely to be the main sources of air contaminants discharging into the Ashburton area during the winter months. However, agricultural burning in the nearby rural areas is likely to be a significant source at other times of the year. This burning is typically carried out during the autumn. Backyard rubbish burning is also a potential source of air contaminants. There are currently no restrictions on backyard rubbish burning in Ashburton.

The major land transport connections to the remainder of the South Island's road and rail networks are via State Highway 1, the principal intercity road link, and via State Highway 77 to the inland Canterbury road network. The South Island main trunk railway parallels State Highway 1 through the town and connects Ashburton by rail to all the major communities in the South Island, with the exception of Nelson and places within central and west Otago.

As a result of the linear development based on these connections, through traffic concentrates near the town's commercial and retail centre. It was this concentration of traffic, and in particular the high proportion of heavy goods vehicles which led to the relocation of the state highway route from East to West Street in the mid 1980s.

Agricultural activities, in particular seed and grain related processes are the most common industrial activities in Ashburton. Industrial and school boilers and operations involving spray painting are also found in Ashburton. 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 15 Part A and B processes have been included in addition to emissions from 15 industrial or trade premises not meeting the Part A or B classification.

No restrictions are currently imposed on home heating methods in Ashburton. Open fires and wood and multi-fuel burners can be installed into new houses and there are no restrictions relating to the fuels burnt. A local source of coal (Mt Somers coal) is known to have a particularly high sulphur content and is expected to be widely used.

Air quality monitoring in Ashburton in recent years has been limited to smoke measurements conducted in 1992 and 1993. These indicated maximum 24 hour average smoke concentrations of 55 μgm^{-3} with average concentrations around 20 μgm^{-3}. Investigations into the relationship between smoke measurements and PM_{10} concentrations in Christchurch indicate good correlations for 24 hour averages. Further investigations into air quality in Ashburton are scheduled for 1998. This will 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

Table 2.1 Survey area for Ashburton

Survey area for Ashburton (based on census areas)	Area (ha)	Total number of households	Housing density (houses/ha)	Total houses surveyed	Error Level %
Allenton, Central Ashburton West, Netherby, Central Ashburton East, Hampstead and Tinwald	1238.7	5791	4.7	190	~7.0

Table 2.2: Home heating methods in Ashburton

Home heating method	% of households*	Number of households
Electricity or gas (or both)	54.2	3139
Solid fuel burners (incl. open fires)	52.6	3046
Oil fired heating	2.6	151

*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.

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 190 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 contained in appendix 1. The survey as 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 Ashburton. 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.

An analysis of the survey results found that about 3% of households use both electricity and gas and that some households use more than one type of solid fuel burner to heat their main living area on a typical winter's night.

Table 2.3: Breakdown of home heating methods in Ashburton

	Number of house holds	Percentage*
Electricity	2560	44.2
Total Gas	764	13.2
-flued gas	64	1.1
-unflued gas	701	12.1
Oil	151	2.6
Open fire/ visor	608	10.5
Log burner	1923	33.2
-10 years and older	793	13.7
-less than 10 years	1129	19.5
Enclosed coal burner	394	6.8
Modern multi-fuel burner	643	11.1
Pot belly	93	1.6
Incinerator		-

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

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

Table 2.4: fuel consumption across appliances

	Wood		Coal	
	% hh	kg	% hh	kg
Open fire	10.5	9244	6.8	3706
Wood burner 10 yrs or older	13.7	11656	-	-
Wood burner <10 yrs old	19.5	20740	-	-
Enclosed coal burner	6.8	4401	6.8	2662
Modern multi-fuel burner	11.1	9451	11.1	4314
Potbelly	1.6	1899	1.6	434
Incinerator	-	-	-	-
Total	**63.2**	**57391**	**26.3**	**11116**

- 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 both wood and coal can be burnt.

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

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.

Table 2.3 above indicates that 10.5% of households in Ashburton use an open fire and table 2.4 shows that 10.5% of households burn wood on their open fire. This indicates that the 6.8% of households burning coal on their open fire (table 4) also burn wood. Similarly all users of enclosed coal

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

burners, modern multi-fuel burners and potbellies in Ashburton burn both wood and coal.

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 newer model wood burners. Multi-fuel burners are the appliances in which the greatest quantity of coal is burnt.

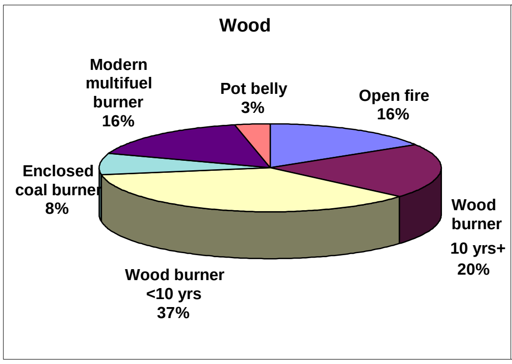


Figure 2.1: Wood use by appliance

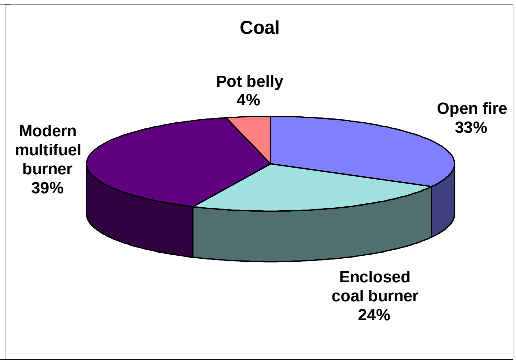


Figure 2.2: Coal use by appliance

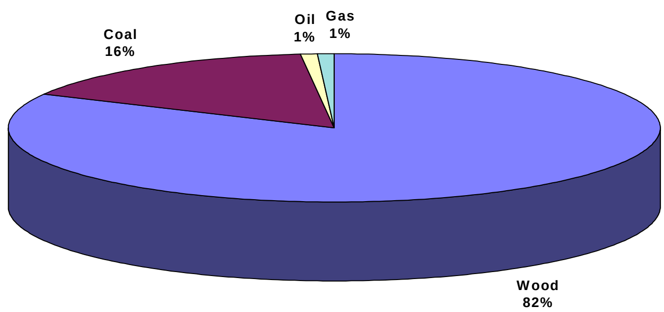


Figure 2.3: Proportion of fuel (kg) burnt in Ashburton on a typical winter's night

The relative weight of each fuel used for domestic home heating in Ashburton 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.

Table 2.5 provides an indication of the type and quantity of coal used on an average winter's day, by Ashburton residents. As was expected the Mt Somers coal with the high sulphur content is the most common coal used on a household basis. However, in terms of quantity burnt, it constitutes less than 20% of the total coal burnt on a typical winter's day.

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

Table 2.5: Type of coal used for domestic home heating in Ashburton

Coal type	Sulphur (S) content	% of households	Coal used (tonnes)	Coal used % of total
Mt Somers	2.24	4.2	2.0	16
Ohai	0.18	0.5	1.2	10
Giles Creek	0.49	1.5	2.3	18
West Coast	1.4[a]	2.6	1.5	12
Harrison	0.22	0.5	0.1	1
Primrose	-	2.6	1.7	14
Ubell	-	0.5	0.6	5
Linton	-	1	0.3	2
Don't know	0.9[b]	3.0	2.7	22
Total		16.4	12.4	100

[a] Average S content of Reefton and Greymouth coals
[b] Average of the coals for which the S content is known

Table 2.6: 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	62	56	42	71	19	45
10am - 4pm	36	36	81	71	50	81
4pm - 10pm	68	64	81	79	99	64
10pm - 6am	31	4	19	51	5	51
Average over 4 time periods	49%	40%	56%	68%	43%	60%

Wood burners and multi-fuels are the most common method used to heat the home during the 10pm to 6am period (table 2.6). 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. Gas use during the 10pm to 6am period is also uncommon with less than 5% of households using gas operating their appliances overnight. Less than 20% of households using open fires light them in the early morning (6am-10am) compared with 71% of wood burners. On average, wood burners, multi-fuels and oil are used to heat households for longer periods than gas, electricity and open fires.

Home heating methods in Ashburton compared to other urban centres

Table 2.7 compares home heating methods used in Ashburton with those of other urban centres. The use of multi-fuel burners, both enclosed and modern multi-fuels, in Ashburton is greater than in Rangiora, Kaiapoi, Waimate and Timaru (99% CI). The use of gas in Ashburton is significantly less than in Kaiapoi (99% Confidence Interval (CI)).

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) x FF (kg/day) ***(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)* ***(2)***

where

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

For example, the amount of fuel burnt

Table 2.7: Home heating methods in Ashburton 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	14.0	24	17
-flued gas	1.1	1.1	3.2	-		
-unflued gas	12.3	12.1	29.4	14.0		
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 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.

from 4pm to 10pm 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:

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

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 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

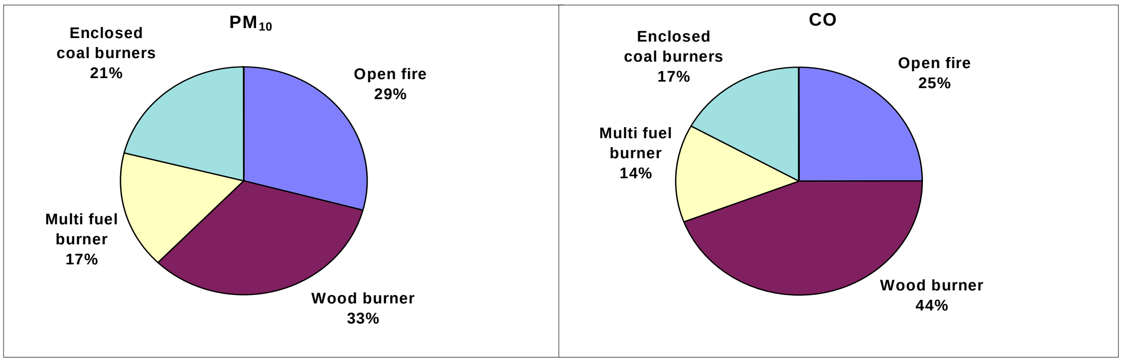


Figure 2.4 & Figure 2.5: PM_{10} and CO emissions by appliance type

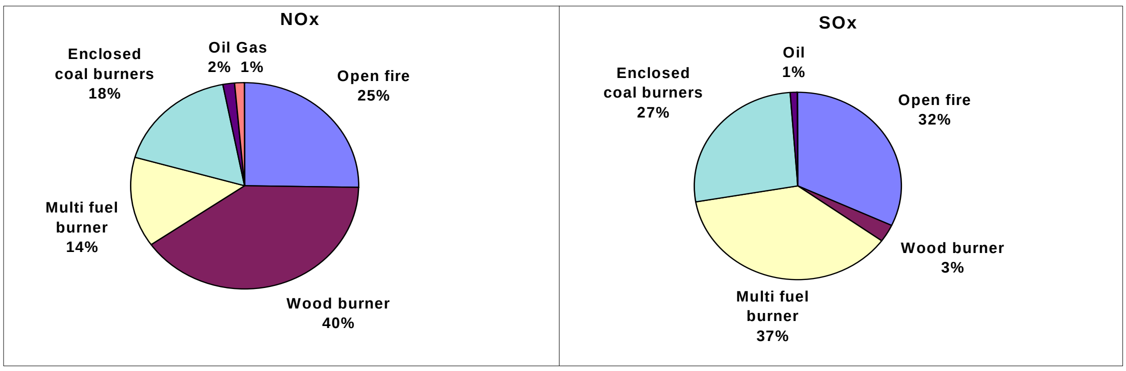


Figure 2.6 & 2.7: NOx and SOx emissions by appliance type

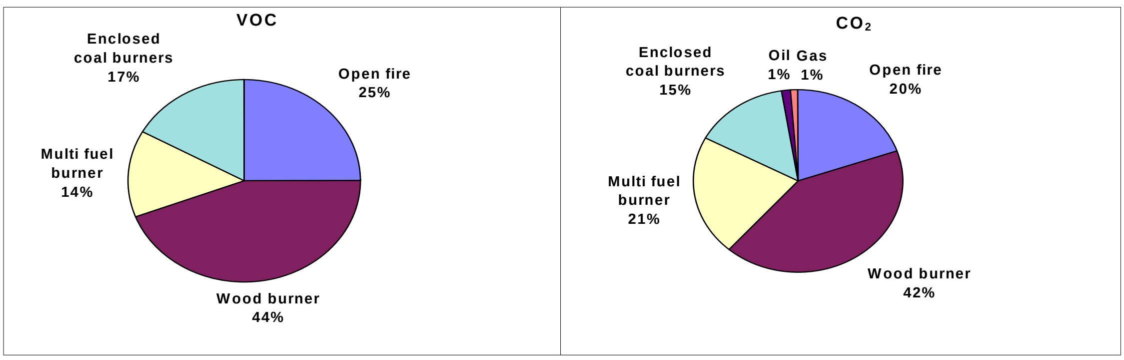


Figure 2.8 & 2.9: VOC and CO_2 emissions by appliance type

amount of contaminant in grams e.g., PM_{10}, CO, emitted per kg of fuel burnt. Emission factors are summarised in table 2.8.

The home heating emission factors used in the emission inventory were based on those derived by NIWA (CRC, 1997) for

Table 2.8: Emission factors for domestic home heating appliances

Appliance	PM_{10}	CO	NOx	SOx	VOC	CO_2
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	10	1.4	0.2	26	1700
Newer (< 10 yr) burner -wood	7.1	57	0.8	0.2	29	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	8	64	0.9	0.2	16	1700
Multi-fuel burner - coal	17.6	32	0.8	18	8	2800
Incinerator - wood	15.6	125	1.7	0.2	31	1700
Incinerator - coal	34.3	62	1.6	18	16	2800
Potbelly - wood	14.3	114	1.6	0.2	31	1700
Potbelly - coal	31.5	57	1.4	18	14	2800

Table 2.9: Home heating emissions by appliance type

	Daily fuel quantity (kg/day)	**PM_{10} kg**	**CO kg**	**NOx kg**	**SOx kg**	**VOC kg**	**CO2 kg**
Gas	521	0.05	0.2	1.0	0	0.1	1302
Oil	615	0.8	0.4	1.4	2	0.2	1969
Open fire - wood	9244	139	1109	15	2	277	15714
Open fire - coal	3706	122	222	6	67	56	10378
Wood burner (10yr+)	11656	149	1194	16	2	298	19815
Wood burner (<10yr)	20740	147	1178	16	4	295	35259
Enclosed coal burner -wood	4401	63	503	7	0.9	126	7482
Enclosed coal burner - coal	2662	84	152	4	48	38	7452
Modern multi-fuel- wood	9451	76	604	8	2	151	16067
Modern multi-fuel-coal	4314	76	138	4	78	35	12081
Potbelly - wood	1899	27	217	3	0.4	54	3229
Potbelly - coal	434	14	25	0.6	8	6	1216
Total - wood	57392	601	4807	66	11	1202	97566
Total – coal	11117	296	538	13	200	134	31127
Total	69643	898	5343	82	214	1336	131964

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. Slightly higher emission factors for newer (<10yr) woodburners and multi-fuel burners were used for Ashburton. This is because limitations regarding the installation of these appliances that exist in Christchurch which are likely to impact on emissions do not exist in Ashburton.

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 2.9. Emissions of each contaminant by appliance type are also illustrated in

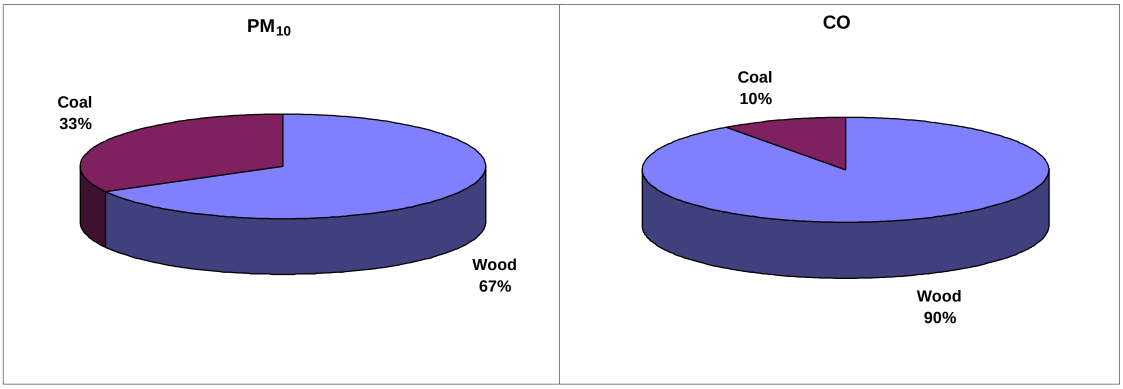


Figure 2.10 & 2.11: PM_{10} and CO emissions by fuel type

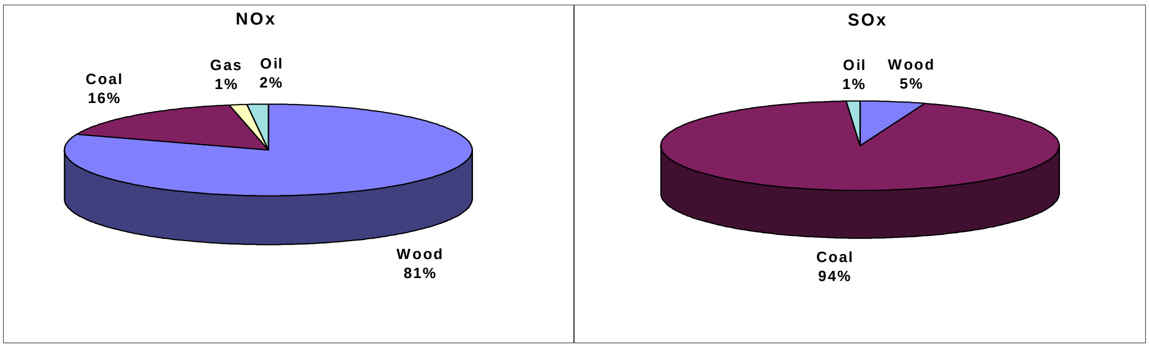


Figure 2.12 & 2.13: NOx and SOx emissions by fuel type

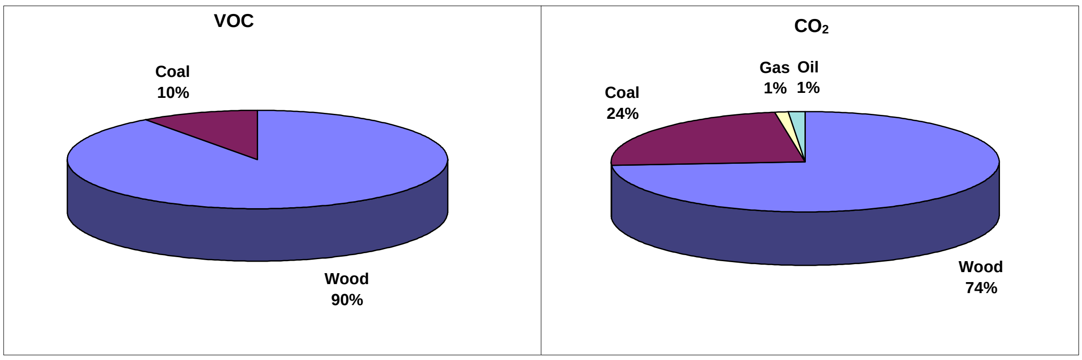


Figure 2.14 & 2.15: VOC and CO_2 emissions by fuel type

figures 2.4 to 2.9.

Open fires and wood burners each contribute to ~1/3 of the PM_{10} emissions.

Wood burners contribute over 40% of the CO, NOx, VOC and CO_2 emissions. Multi-fuel burners and open fires each result in >30% of SOx emissions.

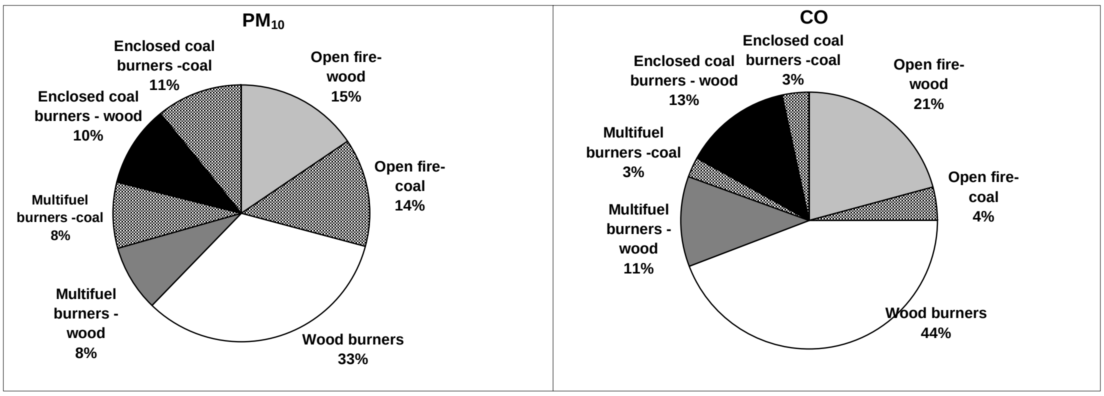
Home heating emissions by fuel type

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 CO, NOx, and VOC emissions. Coal burning results in 94% of the SOx emissions and 33% of the PM_{10}. Gas and SOx, and 2% of the CO_2 emissions. They are also responsible for less than 0.5% of PM_{10}, CO and VOC emissions.

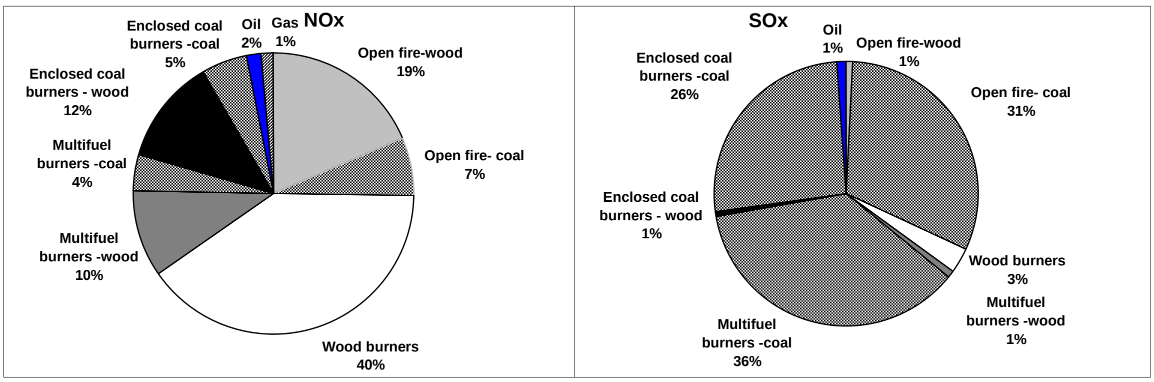
Home heating emissions by fuel and appliance type

Home heating emissions by fuel and appliance type are illustrated in figures 2.16 to 2.21. PM_{10} emissions on an appliance basis indicate an even contribution across fuels. Although coal has greater PM_{10} emissions per kg burnt a greater quantity of wood is burnt on each appliance type. Overall more emissions come from the burning of wood because of the large proportion of wood burners upon which coal is not burnt.

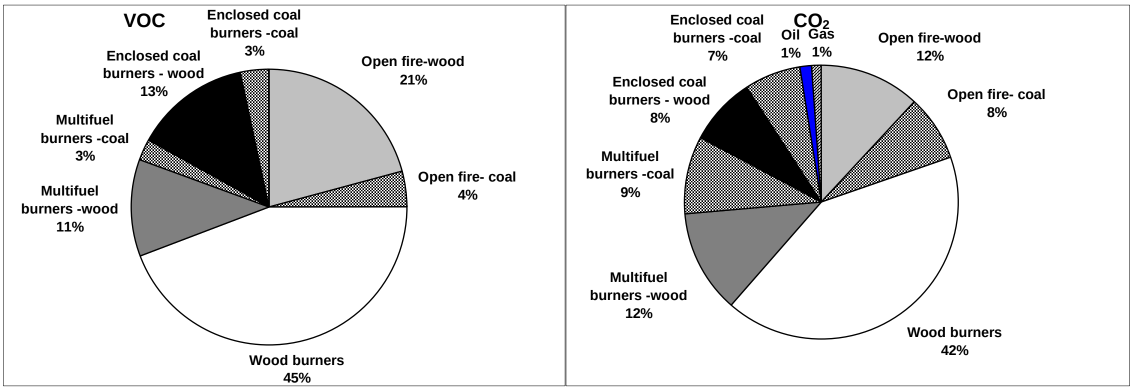
The majority of CO, NOx and VOC emissions from an open fire come from burning wood. Similar trends are observed for these contaminants with the multi-fuel and enclosed coal burners.



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

Table 2.10: 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 2.11: 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	101	82	606	489	9	8	24	20	152	122	15691	12664
10am-4pm	191	154	1110	896	17	14	49	39	277	224	27851	22478
4pm-10pm	472	381	2798	2259	43	34	111	89	700	565	66232	53456
10pm-6am	133	107	830	670	13	10	30	24	208	168	22192	17911
Total	897	724	5345	4314	82	66	214	173	1336	1079	131965	106509

Home heating emissions by time of day and emission density

For the purpose of allowing comparisons of emissions in Ashburton to those of other areas of the region the total kg 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 Ashburton area comprises of 1238.7 ha. Emissions of contaminants from the domestic home heating sector on a g/ha basis are illustrated in table 2.10.

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 2.11 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.

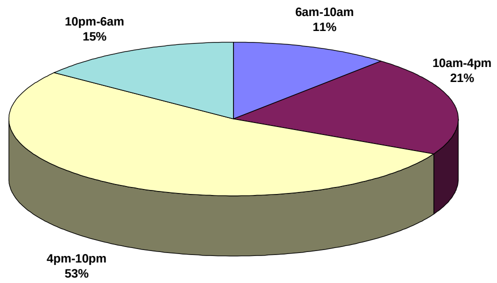


Figure 2.22: PM_{10} home heating emissions by time of day

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 nighttime by eight hours. Variations on this distribution are minimal for other contaminants.

Assessment of the effect of emissions on the 24 hour average contaminant concentrations requires a characterisation of the meteorological conditions. Such analysis is not yet available for Ashburton. 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.

Table 3.1 Distribution of vehicles by class and fuel use

Distribution of Vehicles by Class & Fuel Use				
Veh.Use	Car	LGV	HGV	Total
Fuel Type	%	%	%	%
Petrol	82.22	6.32	1.02	89.56
Diesel	2.78	2.34	5.32	10.44

Table 3.2: Factors for Engine Size and Fuel Use

Factors for Engine Size & Fuel Use					
Veh. Type		Petrol	Diesel	Total	
Car	%	81.6	2.5	84.0	
LightGoods	%	6.6	2.1	8.7	
HeavyGoods	%	1.6	5.7	7.4	
Totals		89.8	10.3	100.0	

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.

Table 3.3: Proportion of daily traffic at each station and weekly traffic total

Traffic Distribution at a number of Ashburton Sites							
TimeofDay	East Street	Chalmers Avenue	Saunders Street	Havelock Street	River Terrace	Park Street	Weighted Mean %
6am-10am	0.14	0.16	0.14	0.16	0.19	0.18	0.16
10am-4pm	0.49	0.47	0.46	0.49	0.49	0.59	0.49
4pm-10pm	0.33	0.33	0.35	0.32	0.29	0.22	0.32
10pm-6am	0.04	0.04	0.05	0.03	0.03	0.01	0.03
7DayTotals	51403	39607	3692	14630	45881	5786	160999

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 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 Ashburton 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 and 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.

Evaluation of the Daily Motor Vehicle Emissions in Ashburton

Any assessment of motor vehicle emissions needs to take account of the distribution of vehicle classes, as well as the division of fuel use within those classes. The division within the groups is based on analysis of the Vehicle

Registrations within the Christchurch Postal District.

These data were then modified to take account of the effect of engine size within the different vehicle classes.

Also of interest is the temporal distribution of traffic through the day and hence the varying incidence of vehicle emissions. The distribution of traffic across the daily time periods specified was based on a number of traffic counts taken in Ashburton during the study. Table 3.3 below shows the proportion of daily traffic at each of the stations counted and gives a weekly traffic total at each station in the bottom row. The sole exception to this was the total given for East Street is a six day total. The remaining day was used to measure the proportion of heavy goods vehicles on a non state highway road on a typical weekday during the study.

The part day emissions by emission type are assessed using the following formula:

Table 3.4: Transport emissions (kg) by time of day

Time of day	CO_2	CO	NO_x	SO_x	VOC	PM_{10}
6am –10am	7273	779	84	14	103	3
10am-4pm	21797	2334	252	41	310	9
4pm-10pm	14073	1507	163	26	200	6
10pm-6am	1493	160	17	3	21	1
Total	**44636**	**4780**	**517**	**84**	**634**	**18**

Table 3.5: Transport emissions (kg) by time of day and fuel type

	CO_2		CO		NO_x		SO_x		VOC		PM_{10}
Time of day	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel
6am–10am	6525	748	761	17	68	16	6	7	98	6	3
10am-4pm	19554	2243	2282	52	205	47	19	22	293	17	9
4pm-10pm	12624	1448	1473	34	133	30	12	14	189	11	6
10pm-6am	1339	154	156	4	14	3	1	1	20	1	1
Total by fuel type	40043	4594	4673	107	420	96	39	45	599	34	18
Total	**44636**		**4780**		**517**		**84**		**634**		**18**

Table 3.6: Transport emissions (kg) by vehicle class

	CO_2		CO		NO_x		SO_x		VOC		PM_{10}
Vehicle type	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Diesel
Passenger car	36388	1100	4246	26	382	23	35	11	545	8	4
Light goods	2926	939	341	22	31	20	3	9	44	7	4
Heavy goods	728	2554	85	60	8	54	1	25	11	19	10
Total by fuel	40043	4594	4673	107	420	96	39	45	599	34	18
Total	**44636**		**4780**		**517**		**84**		**634**		**18**

$$\text{Emission } d(\text{tonnes}) = 1/10^6 * \text{Veh. Kms} * \text{Time Fctr} * \text{Em Fctr } d \text{ at Speed } s \text{ (g/km)} \quad (4)$$

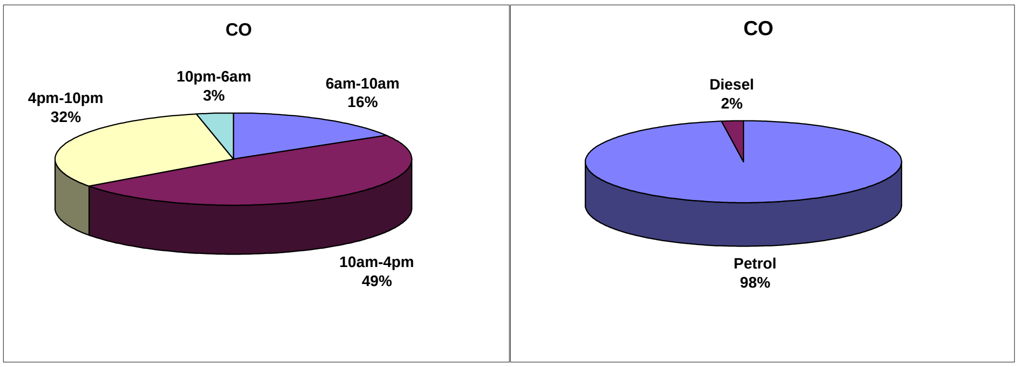
Repeated use of the formula with appropriate substitutions of the part day factors and emission factors by emission type gives emissions from the transport sector.

3.1 Transport emissions

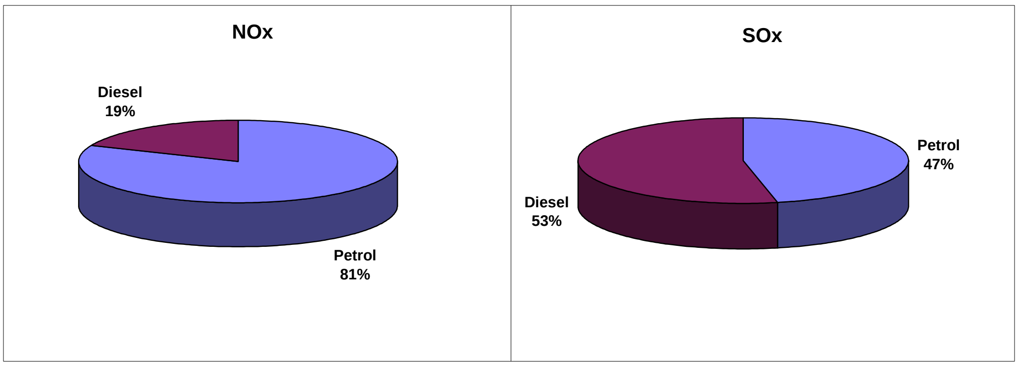
Table 3.4 shows the daily transport emissions (tonnes) of PM_{10}, CO, NOx, SOx, VOC and CO_2 and a breakdown of the time of day in which they occur.

The part day results were then subdivided, by fuels in use and by vehicle type, leading to Tables 3.2 and 3.3 and figures 3.1 to 3.12. These illustrate 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.

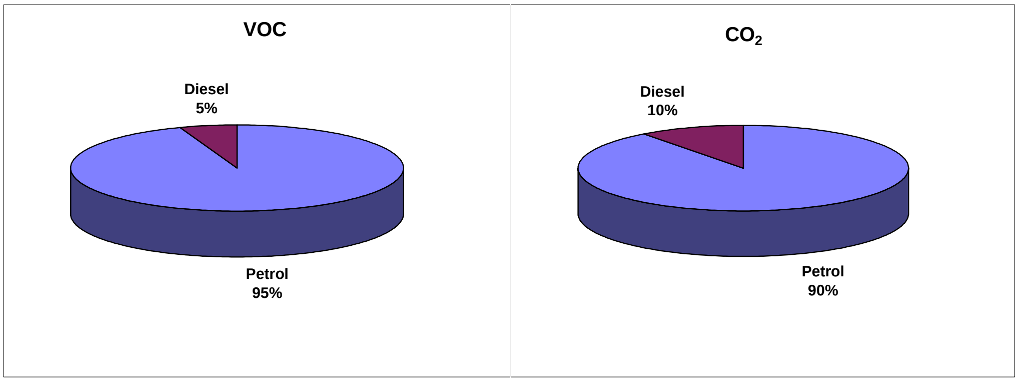
Passenger car emissions were found to contribute to over 80% of the CO, VOC, and CO_2 emissions and over 50% of the SOx and NOx come from the transport sector. Heavy goods vehicles produced the greater quantity of these SOx emissions.



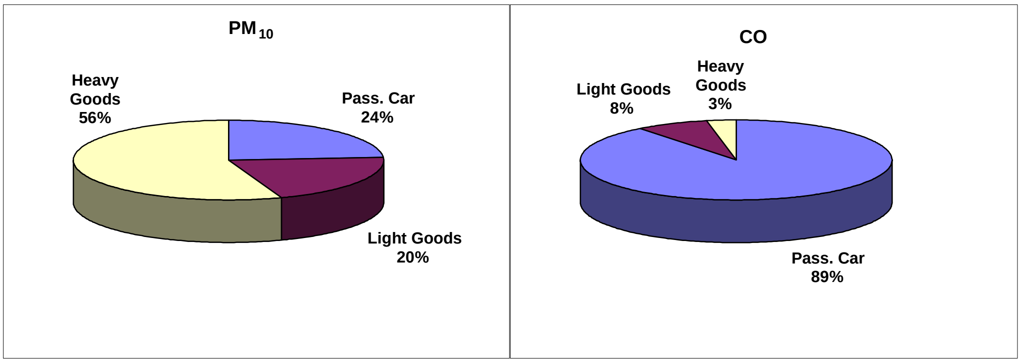
Figures 3.1 & 3.2: CO transport emissions by time of day and by fuel type



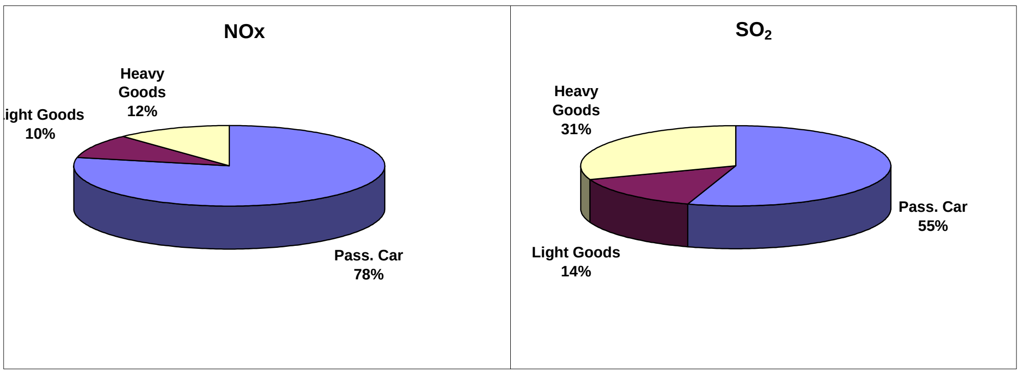
Figures 3.3 & 3.4: NOx and SOx transport emissions by fuel type



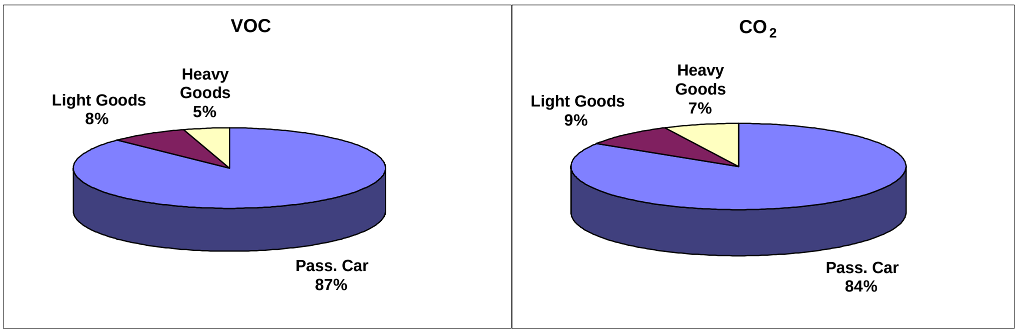
Figures 3.5 & 3.6: VOC and CO_2 transport emissions by fuel type



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 CO_2 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 Ashburton. Of the 15 activities with resource consents included in the investigation the majority came under "Part B" classification. Licensing of "Part C" processes was not required in Ashburton 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[3] were identified through a search of the Ashburton telephone directory and via consultation with the Ashburton 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.

[3] and therefore not currently requiring consents from the CRC

Assessment of emissions from industrial processes

Discharges to air from industrial activities generally arise from either combustion processes or as a result of the consumption or handling of raw materials 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:

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

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 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 the higher 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 primarily those used in the Christchurch emission inventory[4]. The Christchurch emission factors were derived by National Institute of Water and Atmospheric Research (NIWA) 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 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.

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}

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	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

[4] The PM_{10} emission factor of 3.08 g/kg (AP-42 USEPA, 1995) was used for the Ashburton Community Health boiler.

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 burning of waste in incinerators also produces emissions as a result of the combustion process. The fuel in such situations is more variable and it is more difficult to assign average emission factors. The incinerator at Ashburton Community Health is the only such industrial process in the Ashburton area. This burns primarily paper rubbish. No assessment of emissions from this operation is contained on the resource consent. Emission factors from the USEPA AP-42 classification were used to assess emissions from the incinerator. The emission factors used were:

- 3.2 kg PM_{10} per tonne of waste (assuming PM_{10} = 0.4 TSP (NIWA, 1997)
- 3.0 kg NOx per tonne of waste

Process emissions

The most common non combustion processes from which discharges to air occur in the Ashburton 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 (1996) emission factors (USEPA, 1994) are shown in table 4.2.

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)]					
Seed handling	0.0039kg[(4)]					

[(1)] Assuming a dryer drum hot mix process with a cyclone (from Christchurch emission inventory)
[(2)] Assuming the density of paint = 1 kg/l for conversion to tonnes (from Christchurch emission inventory)
[(3)] (From AP-42 (USEPA, 1994))
[(4)] (From AP-42 (USEPA, 1994))

Process emissions were calculated as follows:

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

The unit of material will be dependent on the process but could include for example, litres of paint sprayed, tonnes of seed handled, tonnes of asphalt produced, etc.

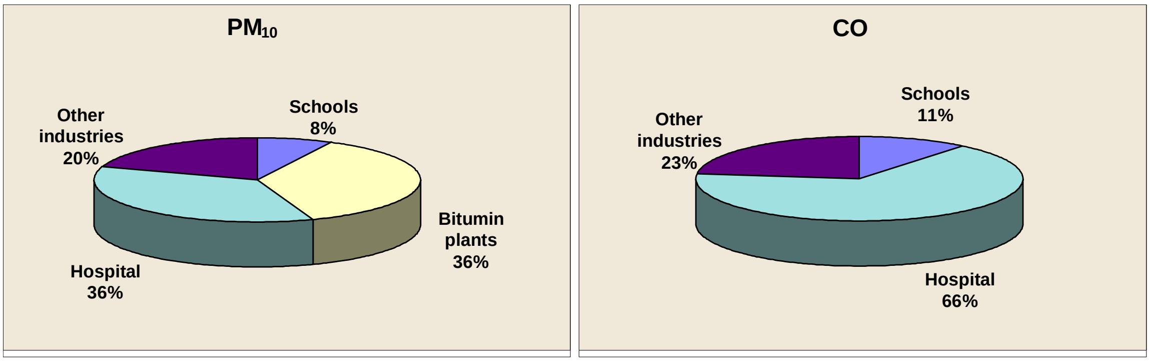
4.2 Industrial Emissions

Figures 4.1 to 4.6 illustrate the contribution of different industrial sources to the total emissions from this sector. With the exception of VOC emissions the Ashburton Community Health boiler is the most significant source of all contaminants investigated. It should be noted that this assessment of emissions is not an indication of the potential of different activities to have adverse effects on the environment. The potential for adverse effects is dependent on the height of release of the contaminants and their ability to disperse before reaching ground level. The resource consent for this activity indicates that potential adverse effects on the environment arising from these emissions are adequately mitigated by the height of the discharge (23.7m and 13m above ground).

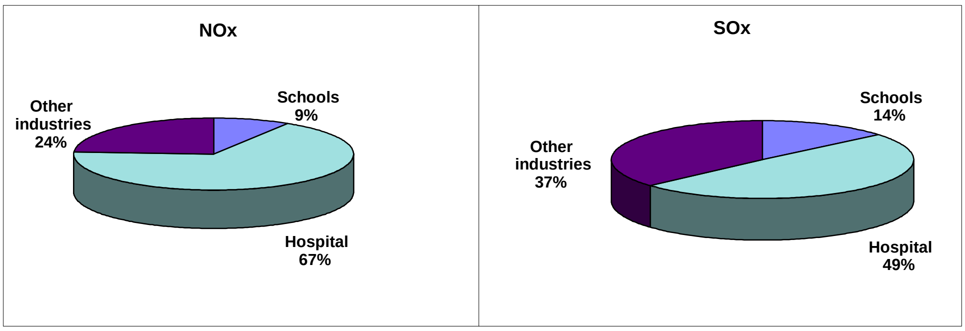
For the purpose of allowing comparisons of emissions in Ashburton to those of other areas of the region, the total mass of

Table 4.3: Industrial emissions by time of day

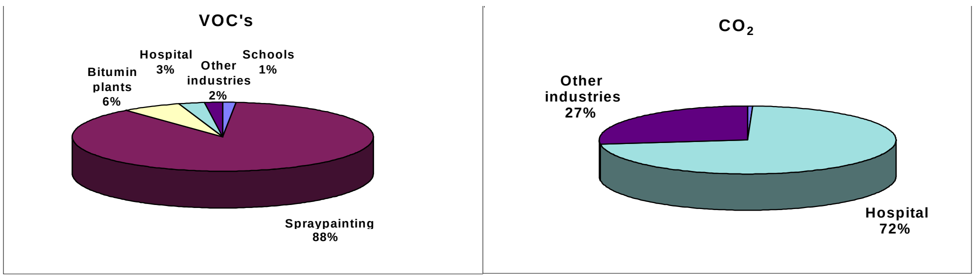
	PM_{10}		CO		NOx		SOx		VOC		CO_2	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
6am-10am	30	24	11	9	37	30	51	42	9	7	9412	7597
10am-4pm	44	35	14	11	47	38	61	49	23	19	1434	11327
4pm-10pm	18	15	9	7	32	26	43	35	5	4	8329	6722
10pm-6am	14	12	9	7	31	25	44	35	0	0	8126	6558
Total	106	86	44	35	147	119	199	160	37	30	39901	32204



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

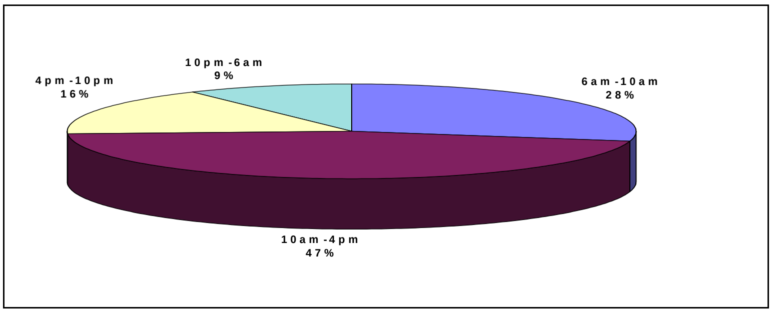


Figure 4.7 Industrial PM_{10} emissions by time of day

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.

Figure 4.7 shows industrial emissions by time of day.

5. Total emissions for Ashburton

The proportional contribution of each sector to the total emissions in Ashburton is shown in table 5.1. This indicates that the greatest proportion of PM_{10} originates from emissions from the domestic home

Table 5.1: Total emissions 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	897	724	5345	4315	82	66	214	173	1336	1079	131965	106535
Transport	18	14	4780	3859	517	417	84	67	634	512	44636	36035
Industry	106	86	44	35	147	119	199	160	37	30	39901	32212
Total	1021	824	10169	8209	746	602	497	400	2007	1621	216502	174782

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	134	108	1396	1127	131	105	89	72	264	213	32376	26137
10am-4pm	244	197	3458	2792	317	256	150	121	610	493	63682	51410
4pm-10pm	496	400	4315	3483	237	192	180	145	904	730	88634	71554
10pm-6am	148	119	999	807	61	49	77	62	229	185	31811	25681
	1022	824	10168	8209	746	602	496	400	2007	1621	216503	174782

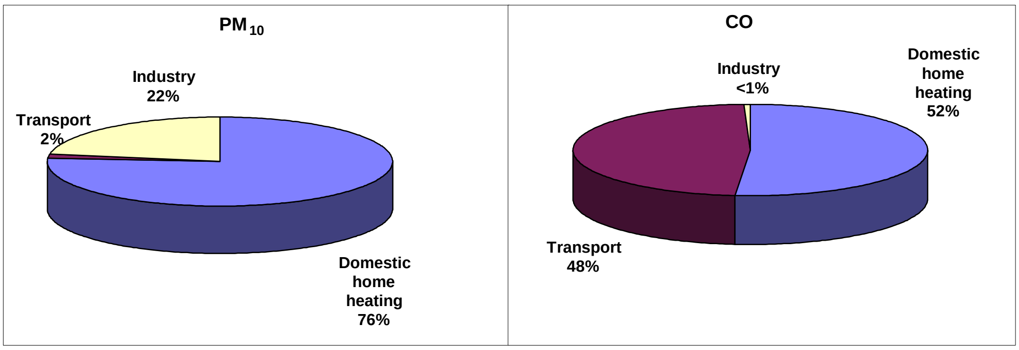
Table 5.3 Grams of emissions per household compared with other urban areas

	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	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

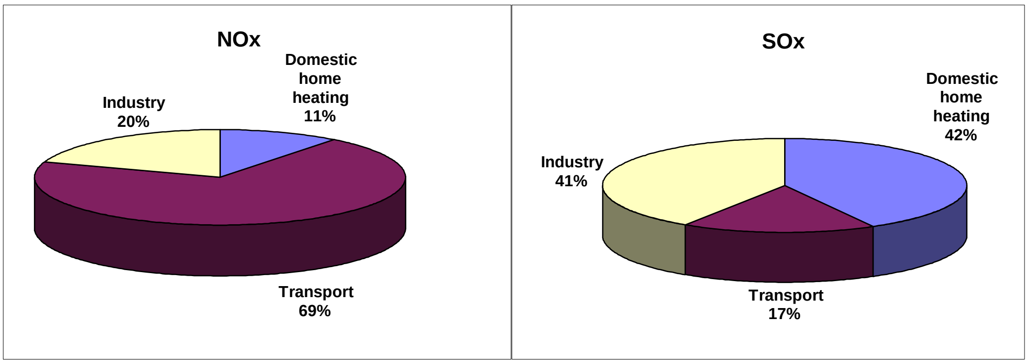
heating sector. This sector is also responsible for over 50% of the CO, 40% of the SOx, and over 60% of the VOCs and CO_2. Transport is responsible for 70% of the NOx and for almost 50% of the CO emissions. Industry contributes 40% of the SOx emissions and <25% of each of the other contaminants. Figures 5.1 to 5.6 compare the proportion of PM_{10}, CO, NOx, SOx, VOCs and CO_2 emissions arising from each sector.

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.

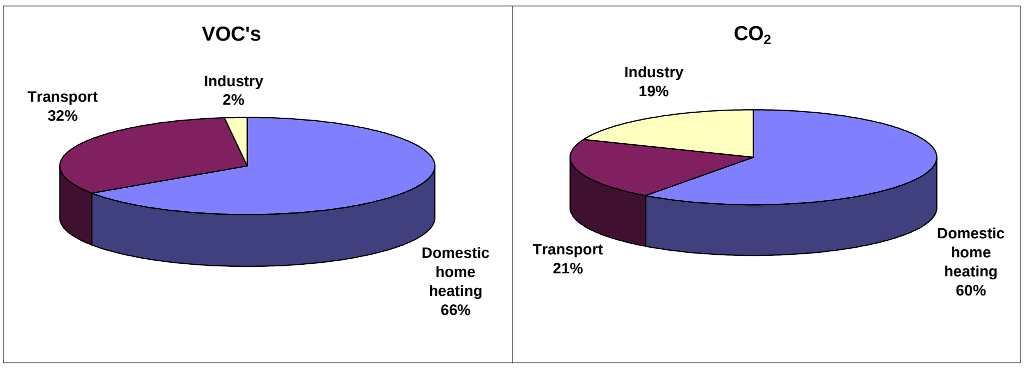
5.1 Total emissions in Ashburton



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 & 5.6: VOC and CO_2 emissions by sector

compared with other urban centres

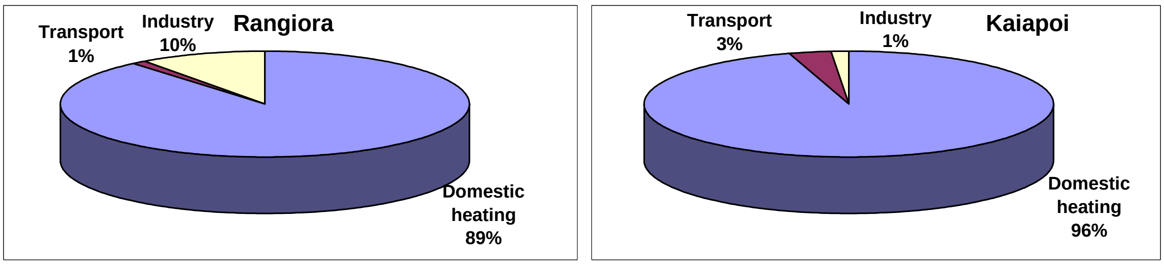
Table 5.3 compares total emissions in Rangiora expressed as grams per household to other urban areas of the region. This shows that on a household basis:

- 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.

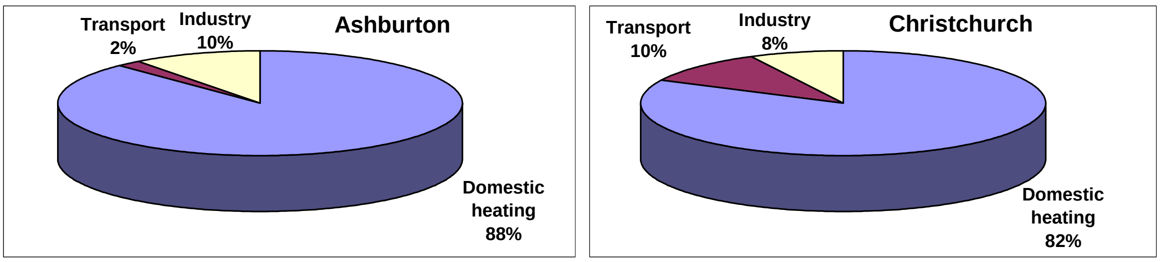
Table 5.3 shows that emissions of PM_{10} per household are greater for Ashburton than for Christchurch. This is because in Ashburton a greater proportion of households use solid fuel burning to heat their main living area on a typical winter's night than in Christchurch, and because a greater proportion of these households use coal.

Table 5.4 compares emissions on a g/ha basis and emissions in kg in Ashburton to other urban areas of the region.

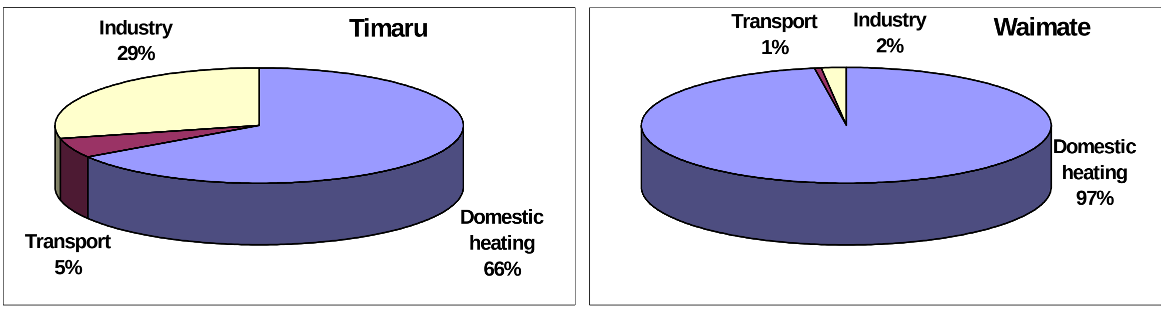
The relative contribution of PM_{10} emissions in Ashburton compared to



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

Timaru, Waimate, Rangiora, Kaiapoi, and Christchurch are illustrated in figures 5.7 to 5.12.

6. Summary

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

- Survey results showed that approximately 44% of Ashburton households use electricity to heat their main living area on a typical winter's night. This compares to 14% that use gas and 52% 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 and open fires were each found to contribute about one-third of the PM_{10} emissions from domestic heating with the remainder coming from coal and multi-fuel burners.
- Overall two-thirds of the PM_{10} emissions come from the burning of wood with the remaining one-third coming from coal burning.
- Approximately half of the PM_{10} emissions occur during the evening (4 p.m. to 10 p.m.) period.
- Passenger cars are responsible for the majority of the PM_{10}, CO, NOx, VOC and CO_2, and half of the SOx emissions from transport. About half of the CO emissions from transport occur during the day (10am - 4pm) period.
- Industrial and school boilers are responsible for over 50% of the PM_{10}, CO, NOx, SOx and CO_2 emissions from industry in Ashburton. The majority of VOC emissions from the industrial sector come from spray painting operations.
- Overall the domestic heating sector is responsible for three-quarters of the PM_{10}, half of the CO, two-thirds of the VOCs and 60% of the CO_2. The transport sector contributes approximately half of the CO, the majority (70%) of the NOx, and one-third of the VOC emissions.
- Industry emits 20% of the PM_{10}, NOx and CO_2 emissions and 40% of the SOx emissions.

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 Ashburton compared to other urban centres

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

(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: Calculation of transport emissions

Estimation of Daily Trips in the Ashburton Road Network

Statistics New Zealand divided the town by suburb into 6 well-defined areas. These six subdivisions were further broken down into zones in the road network model used in 1983 for transport planning purposes. This model has been revived and pro-rata increases in housing and employment have been adopted to replicate traffic observed in Ashburton in the early 1990s.

Private purpose trips produced within Ashburton were estimated on the basis of 5.5 private purpose vehicle trips per household, distributed in accordance with table A.1, with uniform distribution across the cells for which only aggregate information was available. Light goods vehicle trips were estimated as 70% of the number of retail employees in the specific zones, and heavy goods vehicle trips were estimated as 40% of total employees within the zones. The relatively high ratio of heavy goods to light goods trips in Ashburton is considered reasonable, because of the rural servicing nature of much of the towns transport. The distribution of all internal trips is based on the relative scale of activities, residential, retail, and industrial within each zone and spread of interzonal traffic given in the Traffic Design Group's (TDG) *Ashburton Town Centre Study* and gave an internal total of 39,300 trips.

External trips were based entirely on the scale of, and distribution from that same study, with the band width shown in their external trips origin-destination diagram of 1 mm equating to 550 trips.

The trip productions shown in table A.2 once distributed became the basis of trips between internal zones in the Ashburton zonefile. Trips produced from external zones were estimated as half of the number of the two-way trips between T.D.G sectors listed in table A.3. These were distributed to represent trips produced in an external but attracted to an internal zone.

Trips that both began and ended in an external zone were based on traffic counts obtained from Transit NZ for the state highway connections to Ashburton.

These counts were halved to approximate one directional traffic, and then the already estimated external to internal zone trips were subtracted to leave a residual which represented external to external trips. The estimates of external trips were then appended to the internal trip zonefile to create a matrix of 24-hour trip productions. The zonefile was then converted to csv (comma separated variable) file so as to be read into a TRACKS compatible format. TRACKS matrix utilities were then used to convert the Production/Attraction matrix into an Origin/Destination matrix ready for assignment to the model road network.

Table A.1 Statistics NZ Area Units and Zonal Subdivision of Ashburton

Suburb	A.U.	Model	H/H		Rtl	Emp	Oth	Emp	Trip	Prdn	
		Zones	1983	1991	1983	1991	1983	1991	Pvte	L.G.	H.G.
Allenton	3	13	276	285	20	20	80	96	1568	15	46
		14	363	375	30	30	100	120	2063	23	60
		15	544	562	50	50	180	216	3091	38	106
		16	492	509	95	120	264	317	2800	90	144
Central	6	1	60	62	40	40	300	361	341	30	160
Ashburton		2									
east		3	10	10	485	615	494	594	55	461	484
		8	80	83	10	10	30	36	457	8	18
		9	130	134	80	101	110	132	737	76	93
		10	279	288	60	60	140	168	1584	45	91
		11	96	99	80	101	130	156	528	76	103
Central	4	4									
Ashburton		5	402	416	210	266	500	601	2288	200	347
west		6									
		7	200	207	25	25	213	256	1139	19	112
Hampstead	7	12	142	147	17	17	150	180	809	13	79
		18	442	457	21	21	60	72	2514	16	37
		19	492	509	21	21	102	123	2800	16	57
Netherby	5	17	534	552	51	51	102	123	3036	37	70
Tinwald	8	20	798	825	108	137	266	320	4538	103	98
		21									

Table A.2: Sector Internal Trips Based on T.D.G Origin/Destination Diagram

From **To**	TD1	TD2	TD3	TD4	TD5	TD6	TD7
TD 1		136	223	295	177	64	105
TD 2	431		539	604	675	244	343
TD 3	1203	920		1179	761	443	467
TD 4	2035	1310	1497		1465	1112	659
TD 5	898	1090	716	1090		812	439
TD 6	767	932	989	2058	1922		502
TD 7	947	990	782	867	782	370	

Table A.3: Sector External Trips Based on T.D.G Origin/Destination Diagram

From **To**	TD7	TD8	TD9	TD10	TD11	TD12
TD 1	3850		440	1100	275	55
TD 2	3135		440	990	165	55
TD 3	3465		330	825	440	220
TD 4	3025		605	1595	990	110
TD 5	2420		1155	1100	440	55
TD 6	1045		330	660	330	55
TD 7		12860	825	413	165	110

Development of a Road Network Model

The network used was based on the map included in the Street Finder booklet. This map was overlaid with a New Zealand Geographical Survey map grid that was used to provide a northerly direction. A Cartesian co-ordinate system based on a north point and the intersection of the two principal traffic routes just north-east of the Ashburton River Bridge being designated an arbitrary position X=5000 and Y=3000. Distances were taken from the Ashburton District Road Asset Maintenance Management System spreadsheet, which also provided a wealth of traffic information. The newly created road network co-ordinate file was read into a TRACKS utility that converted it into map form. From that point a screen editor was used to attribute street names and traffic management information to each of the links in the network.

For the purposes of assignment of traffic to the model network internal trip from one the Tinwald zones was combined with Main South Road traffic accessing Tinwald south of Hassal Street, similarly traffic entering and leaving Ashburton on Wakanui Road was combined with traffic generated in the north-east of Hamstead. Other external generators of traffic, included in the model, were Seafield Road, State Highway 1 north east of Racecourse Road and Alford Forest Road (S.H.77).

Assignment of Traffic to the Ashburton Model Network

The combined matrix of 24-hour trips was read into the TRACKS system to form a total matrix of trips produced and attracted by activities in Ashburton. Trips generated within the former Borough of Ashburton totalled 39,300 and trips within Ashburton but with either an origin or destination or both outside the former borough were almost equal at 36,200. This meant a Production and Attraction matrix of 76,220 trips which was then transformed, to reverse the direction of trips in the parent matrix, and then half of the cell totals from each of the two matrices were added together to provide the estimated origin/ destination trip matrix. That O/D Trip Matrix was then assigned to the model road network.

The results of the assignment were that in 24 hours traffic in the Ashburton network travelled 253,687 kilometres and the total travel time was 493,338 minutes. These statistics give a mean trip length 3.3 kilometres at an average speed of 30.8 km/h.