Air Emission Inventory
Dunedin, Mosgiel and Alexandra 2005

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Executive summary

Air quality monitoring in Dunedin, Mosgiel and Alexandra has shown that concentrations of PM_{10} in excess of air quality guidelines and National Environmental Standards (NES) occur regularly during the winter months. The highest measured PM_{10} concentration for these areas are 88, 100 and 193 µg m^{-3} for Dunedin (1998), Mosgiel (2003) and Alexandra (2001) respectively. The NES specifies that PM_{10} concentrations must meet the NES target of 50 µg m^{-3} (24-hour average) by 2013 or councils will be unable to grant resource consents for discharges to air.

An air emission inventory carried out for the Otago Region in 1999 indicated that domestic home heating and industry were the main sources of PM_{10} in Dunedin, Mosgiel and Alexandra. This report outlines the results of a revised air emissions inventory for domestic heating and industry for these areas for 2005.

Contaminants included were particles (PM_{10} and $PM_{2.5}$), carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds and carbon dioxide. This report primarily focuses on emissions of particles (PM_{10}), as the only contaminant in breach of the NES. The inventory included Dunedin, Mosgiel and Alexandra as separate areas. The results from the emission inventory found that domestic heating emissions are the main contributor to winter time PM_{10} concentrations and industrial emissions are the main contributor to PM_{10} concentrations during summer.

Emissions from domestic home heating were assessed based on a survey carried out for the Ministry for the Environment in 2005 (Wilton, 2005). This indicated the proportions of households using different heating methods and fuels and the quantities of fuel burnt. Results showed that electricity was the most common heating method in all areas. The use of wood burners was common in Alexandra and Mosgiel, being used by 47% and 32% of households in these areas respectively. The use of solid fuel was less common in Dunedin, with 30% of households using wood and 12% using coal. Only 14% of householders indicated they used wood burners in Dunedin. Many households used more than one method to heat the main living area of their home.

The main source of PM_{10} emissions in all areas during the winter was domestic home heating, which accounted for 92%, 90% and 99% of total PM_{10} emissions in Dunedin, Mosgiel and Alexandra respectively. The main sources of industrial emissions was coal burning in Dunedin and Alexandra and wood burning in Mosgiel.

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1 Introduction

The Ministry for the Environment introduced National Environmental Standards (NES) for air quality in New Zealand in 2005. The main national standard of concern is that for PM_{10} (particles in the air less than 10 µm in diameter) requirement of 50 µg m^{-3} (24-hour average) with one allowable exceedence per airshed per year. This concentration has been exceeded in over 30 urban areas of New Zealand during the past decade.

Regional councils and unitary authorities are responsible for managing air quality to meet the NES. The regulations specify that if the NES is not met by 2013, councils won't be able to grant resource consents for discharges of PM_{10} to air for that airshed.

In addition, between September 2005 and 2013 consents for discharges to air can only be granted if councils can demonstrate a "straight-line path" to compliance that won't be impinged on by the granting of the consent. This applies only to the airshed which is non-compliant with the NES and if the proposed discharge is likely to result in a "significant" increase in PM_{10} concentrations.

The amended regulation (August, 2005) includes slightly different specifications for areas where an operative air quality plan specifies a curved line path, as an alternative to the straight-line path, to achieving the NES by 2013.

The NES for ambient air quality is particularly relevant for Otago because concentrations of PM_{10} exceed the NES of 50 µg m^{-3} (24-hour average) in a number of urban areas of the Otago Region during the winter months. The urban areas of Alexandra, Mosgiel and Dunedin have been identified as exceeding the NES. Maximum measured PM_{10} concentration in Dunedin is 88 µg m^{-3} compared with 100 µg m^{-3} in Mosgiel and 193 µg m^{-3} in Alexandra.

Emission inventories are an important tool in assessing the quantities of reductions in emissions required to achieve an air quality objective such as the NES. The first air emission inventory for the Otago Region was prepared in 1999. This indicated domestic home heating and industry were the main source of PM_{10} emissions during the winter months.

This report details the results of an air emission inventory carried out for Dunedin, Mosgiel and Alexandra for 2005. The inventory provides an estimate of the amount of PM_{10} discharged into the air from domestic home heating on a worst-case and average winter's day and the relative contribution to daily winter PM_{10} emissions from domestic home heating and industry.

2 Inventory design

The inventory has been designed with a focus on emissions of PM_{10}, because air quality monitoring shows this is the main issue of concern in Otago. Concentrations of other contaminants are unlikely to exceed air quality guidelines and National Environmental Standards. One exception may be the air quality guideline for benzo(a)pyrene (BaP), as concentrations of this contaminant have been found to be high in areas where PM_{10} concentrations are elevated as a result of emissions from domestic home heating. No NES has been proposed for BaP at this stage.

2.1 Selection of sources

The inventory includes detailed estimates of emissions from domestic and industry. Emission estimates for other sources such as motor vehicles and outdoor rubbish burning were not required for the inventory.

2.2 Selection of contaminants

The inventory included an assessment of emissions of suspended particles (PM_{10}), carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), carbon dioxide (CO_2) and fine particles ($PM_{2.5}$).

Emissions of PM_{10}, CO, SOx and NOx are included as these contaminants are included in the NES because of their potential for adverse health impacts. Carbon dioxide has been typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas (CO_2) emissions. However, these data are now typically collected nationally and for a broader range of greenhouse gases. Estimates of CO_2 have been retained in the inventory, but readers should be directed to national statistics should detailed data on this source be required (e.g., NIWA, 2001). The finer $PM_{2.5}$ size fraction was also included, as this size fraction is also of interest from a health impacts perspective.

Volatile organic compounds are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. Ozone formation is unlikely to be a key concern for Otago towns because emissions of precursors (VOCs and NOx) will be minimal, particularly during the summer months when atmospheric conditions are more conducive to ozone formation. In this report, VOC emissions have been estimated for existing sources, but data on emissions from VOC-specific sources (e.g. spray painting) has not been included.

2.3 Selection of areas

The study areas for the inventory are illustrated in Figures 2.1 and 2.2. The areas for Dunedin, Mosgiel and Alexandra comprise the following census area units:

<u>Dunedin</u>: Fryatt, High St-The Oval, High St-Stuart St, Stuart St-Frederick St, Opoho, North-East Valley, Pine Hill, Woodhaugh, North Dunedin, Otago University, Maori Hill, Balmacewen, Glenleith, Helensburgh, Wakari, Halfway Bush, Brockville, Roslyn North, Roslyn South, Mornington, Belleknowes, Kenmure, Caversham, Corstorphine West, Corstorphine East, Caledonian, South Dunedin, Forbury, St Clair, Musselburgh, Andersons Bay, Vauxhall, Ravensbourne, St Kilda West, St Kilda Central, St Kilda East, Green Island Central, Abbotsford and Concord.

Mosgiel: Mosgiel East, Mosgiel South

Alexandra: Census area unit for Alexandra

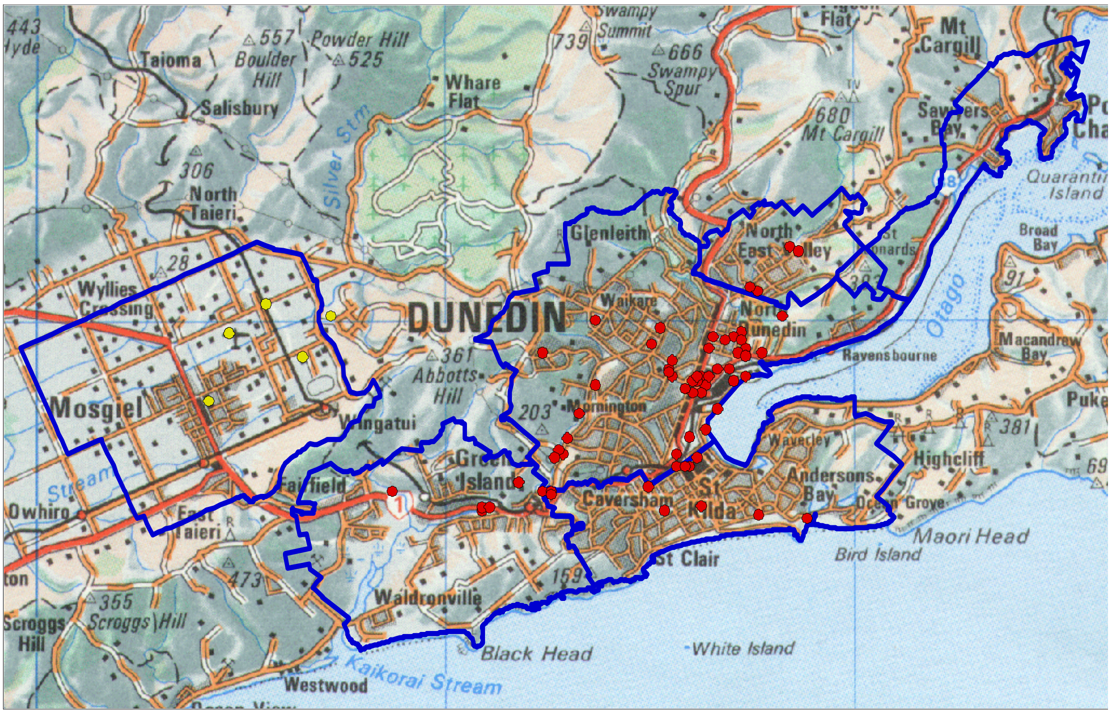

Figure 2.1 Dunedin and Mosgiel inventory study area (blue lines) and consented industry locations (red circles in Dunedin and yellow in Mosgiel) – map provided by Otago Regional Council

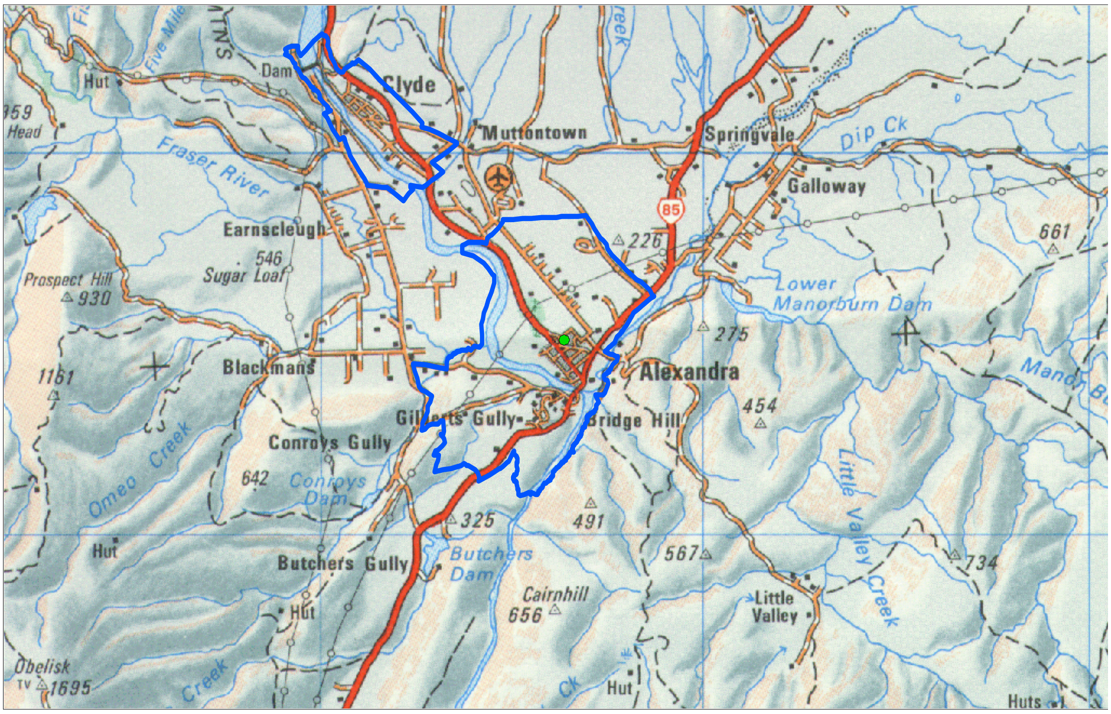

Figure 2.2 Alexandra inventory study area (blue line around Alexandra) and consented industry location (green circle) – map provided by Otago Regional Council

It should be noted that the study areas fall within, but don't include all of the airshed areas that have been gazetted for the Otago Region.

2.4 Temporal distribution

Data were collected based on daily data with some seasonal variations. Domestic heating data were collected based on average and worst-case wintertime scenarios and by month of the year. Industrial data were collected by season.

No differentiation was made for weekday and weekend sources.

No time of day breakdowns were obtained for the domestic heating data. Industrial data were collected based on the following time periods:

- 6am-10am
- 10am-4pm
- 4pm-10pm
- 10pm-6am

3 Domestic heating

3.1 Methodology

The activity data for domestic heating were collected using a telephone survey of around 150 households in each of Dunedin, Mosgiel and Alexandra (Table 3.1). The survey was carried out by Digipol during 2005. The number of households within each study area was based on 2001 census data for occupied dwellings extrapolated for 2005 based on the Statistics New Zealand 2004 population projection for Dunedin (Dunedin and Mosgiel) and Central Otago (Alexandra). These indicate an estimated population increase of 5% and 1% by 2021 in Dunedin City and Central Otago respectively. A copy of the survey questionnaire is shown in Appendix One.

Table 3.1 Home heating survey area and sample details

	Households	Sample size	Area (ha)	Sample error
Dunedin	31627	151	6654	8%
Mosgiel	2763	150	464	8%
Alexandra	1864	150	975	7.7%

Home heating methods were classified as electricity, open fires, wood burners ten years or older (pre 1995), wood burners five to ten years old (1995-2000), wood burners less than five years old (post 2000), pellet fires, multi-fuel burners, gas burners and oil burners.

Emission factors were applied to the results of the home heating survey to provide an estimate of emissions for each study area. The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. The basis for these is detailed in Appendix Two.

Table 3.2 Emission factors for domestic heating methods

	PM_{10} g/kg	CO g/kg	NOx g/kg	SO_2 g/kg	VOC g/kg	CO_2 g/kg	$PM_{2.5}$ g/kg
Open fire - wood	10	100	1.6	0.2	30	1600	10
Open fire - coal	21	80	4	5.0	15	2600	12
Pre 1995 burners	11	110	0.5	0.2	33	1800	11
1995-2000 burners	7	70	0.5	0.2	21	1600	0.97
Post 2000 burners	6	60	0.5	0.2	18	1800	6
Multi-fuel[1] - wood	13	130	0.5	0.2	39	1600	13
Multi-fuel[1] - coal	28	120	1.2	3.0	15	2600	12
Oil	0.3	0.6	2.2	3.8	0.25	3200	0.7
Gas	0.03	0.18	1.3	7.6E-09	0.2	2500	0.6

[1] - includes potbelly, incinerator, coal range and any enclosed burner that is used to burn coal

One of the assumptions underlying the emissions calculations is the average weight for a log of wood. Average log weights used for inventories in New Zealand have included 1.6 kg, 1.4 kg and more recently 1.9 kg. The latter value is based on a survey of 219 households in Christchurch during 2002 and represents the most comprehensive assessment of average fuel weight. A recent burner emission testing programme carried out in Tokoroa during 2005 gave an average log weight of 1.3 kg. The sample size (pieces of wood weighed) for this study was 845. However, these were spread across only 12 households so it is uncertain how representative of the Tokoroa population a fuel weight of 1.3 kg per log might be.

There is some potential for fuel size to vary by region although factors such as appliance design should limit these variations. The first three average fuel weight values noted above were based on measurements carried out in Christchurch. In addition, Environment Canterbury carried out some survey work of the size of chopped wood at five wood suppliers in Christchurch. A total of 132 logs were weighed and gave an average fuel weight of 2.3 kg per log (Scott, 2006, pers. comm.). The extent to which this represents wood weight used by households in Christchurch is uncertain, as further chopping of wood by the householder is possible.

Because of greater similarities between Christchurch and the Otago towns, and the greater number of households included in the Christchurch study, an average log weight of 1.9 kg was assumed for Dunedin, Mosgiel and Alexandra.

Emissions for each contaminant and for each time period and season were calculated based on the following equation:

Equation 3.1 **CE (g/day) = EF (g/kg) * FB (kg/day)**

Where:

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

The main assumptions underlying the emissions calculations are as follows:

- the average weight of a log of wood is 1.9 kg and
- the average weight of a bucket of coal is 9 kg.

3.2 Home heating methods

3.2.1 Dunedin

Electricity was the main heating method in Dunedin for 2005, with the survey indicating 77% of households used this method to heat their main living area (Table 3.3, Figure 3.1). Gas was used by 20% of households with over half using unflued gas systems. Around 31% of households used solid fuel heating methods, with 14% favouring wood burners, 11% using open fires and 6% using multi-fuel burners. Table 3.3 also shows that households rely on more than one method of heating their main living area during the winter months.

The proportion of households using solid fuel burners was lower than the previous inventory, which indicated that in 1999 around 30% of households in Dunedin used wood burners and 16% used open fires. While the open fire proportion is within the sample error of 8%, the proportion of dwellings using wood burners is low relative to 1999. The 2001 census data suggests that 47% of households in Dunedin used some form of wood burning and 27% used some sort of coal burning in 2001. This compares with 30% using wood and 12% using coal in 2005. It is uncertain whether these differences reflect changes in heating methods, differences in survey methodology or some undetected systematic or random errors within the sampling procedure.

Wood was the most common fuel for households using solid fuel heating methods in Dunedin, with 30% of households using this fuel compared to around 12% using coal.

About 143 tonnes of wood and around 42 tonnes of coal were burnt on an average winter's night.

Table 3.3 Home heating methods for household (HH) and fuels in Dunedin

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	77%	24,506		
Total Gas	20%	6,284	7	4%
Flued gas	7%	2,327		
Unflued gas	13%	3,956		
Oil	2%	628	0	0%
Open fire	11%	3,561		
Open fire - wood	11%	3,351	30	16%
Open fire - coal	9%	2,723	34	17%
Total Wood burner	14%	4,398	104	54%
Pre 1995 wood burner	4%	1,389	33	13%
1995-2000 wood burner	4%	1,157	27	18%
Post 2000 wood burner	6%	1,852	44	24%
Multi-fuel burners	6%	1,885		
Multi-fuel burners-wood	6%	1,885	9	5%
Multi-fuel burners-coal	3%	1,047	8	4%
Pellet burners	0%	-		
Total wood	30%	9,635	143	74%
Total coal	12%	3,770	42	22%
Total		31,627	192	

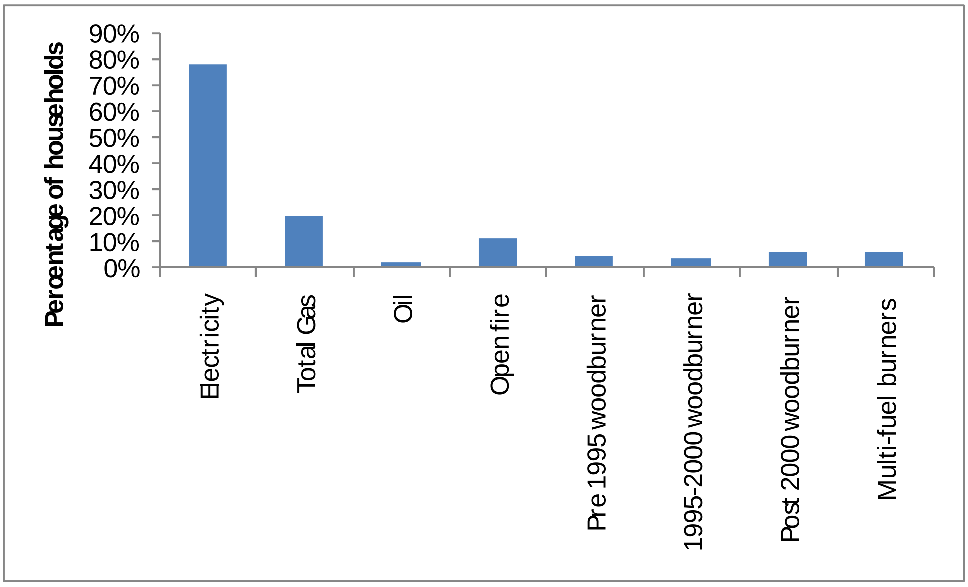

Figure 3.1 Appliance use for Dunedin

3.2.2 Mosgiel

In Mosgiel, electricity was the most commonly used home heating method for 2005, with 59% of households using this method to heat their main living area. Wood burners were used by 32% of households and 23% of households used multi-fuel burners (Figure 3.2). Around 16% of households used gas with the majority using unflued gas systems. Table 3.4 shows that households rely on more than one method of heating their main living area during the winter months.

The most common fuel for households using solid fuel heating methods in Mosgiel was wood, with 65% of households using this fuel. About 41 tonnes of wood is burnt on an average winter's night in Mosgiel. Coal was used by around 19% of Mosgiel households, with around eight tonnes being burnt per night.

Table 3.4 Home heating methods for households (HH) and fuels in Mosgiel

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	59%	1,639		
Total Gas	16%	442	0	1%
Flued gas	6%	161		
Unflued gas	10%	281		
Oil	4%	111	0.0	0%
Open fire	10%	276		
Open fire - wood	10%	276	5	10%
Open fire - coal	7%	203	1	2%
Total Wood burner	32%	884	26	53%
Pre 1995 wood burner	11%	309	9	17%
1995-2000 wood burner	6%	177	5	9%
Post 2000 wood burner	14%	398	12	27%
Multi-fuel burners	23%	626		
Multi-fuel burners-wood	23%	626	10	20%
Multi-fuel burners-coal	11%	313	7	14%
Pellet burners	1%	37	0.1	0%
Total wood	65%	1,787	41	82%
Total coal	19%	516	8	17%
Total		2,763	50	

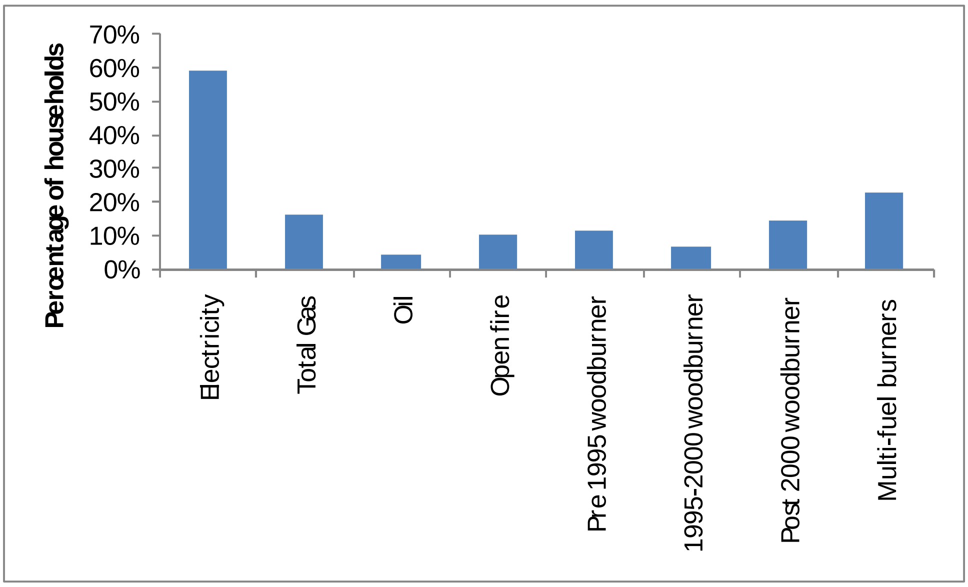

Figure 3.2 Appliance use for domestic heating for Mosgiel

3.2.3 Alexandra

Electricity and wood burners were the most commonly used home heating methods in Alexandra during 2005, with 59% and 47% of households using these methods in their main living areas (Figure 3.3). Around 13% of households used gas, and the majority used unflued gas systems. Table 3.5 shows that households rely on more than one method of heating their main living area during the winter months.

The most common fuel for households using solid fuel heating methods in Alexandra was wood, with 67% of households using this fuel. About 32 tonnes of wood is burnt on an average winter's night in Alexandra. Coal was used only by around 9% of households.

Multi-fuel burners were more common (18%) than open fires, which were only used by around 2% of households in Alexandra.

Table 3.5 Home heating methods for households (HH) and fuels in Alexandra

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	59%	1,106		
Total Gas	13%	236	0	0%
Flued gas	4%	69		
Unflued gas	9%	167		
Oil	5%	87	0	0%
Open fire	2%	37		
Open fire - wood	2%	37	3	9%
Open fire - coal	1%	12	0	0%
Total Wood burner	47%	870	22	62%
Pre 1995 wood burner	23%	428	11	34%
1995-2000 wood burner	13%	249	6	15%
Post 2000 wood burner	10%	193	5	13%
Multi-fuel burners	18%	336		
Multi-fuel burners-wood	18%	336	8	22%
Multi-fuel burners-coal	9%	162	2	6%
Pellet burners	1%	12	0.2	1%
Total wood	67%	1,243	32	93%
Total coal	9%	174	2	6%
Total		1,864	35	

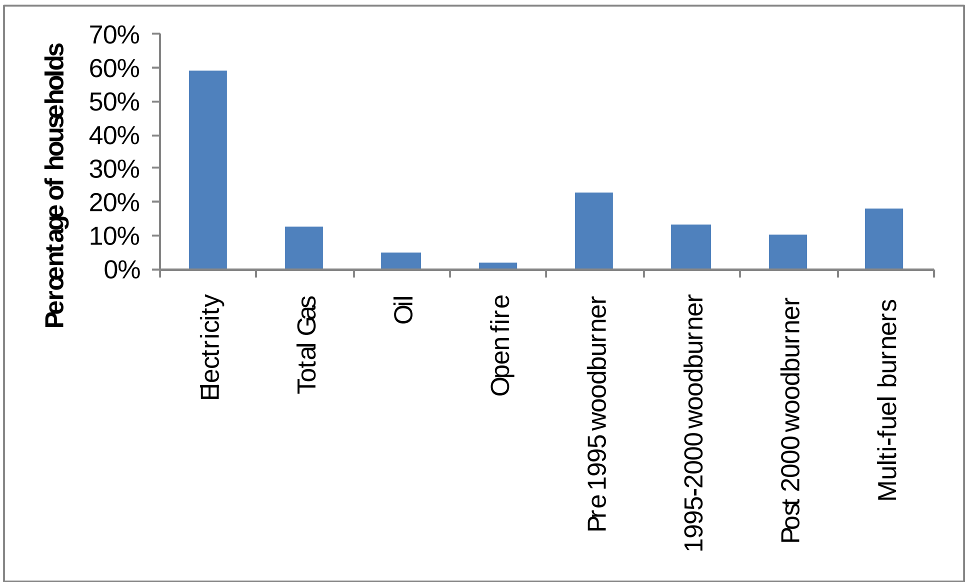

Figure 3.3 Appliance use for domestic heating for Alexandra

3.3 Emissions from domestic heating

3.3.1 Dunedin

Open fires burning coal contribute almost one-third of the PM_{10} emissions from domestic home heating in Dunedin on an average winter's day. Other key contributors are older (pre 1995) wood burners, which contribute 17% of the domestic PM_{10} emissions, and open fires burning wood (14%). Multi-fuel burners also contribute around 17% (Figure 3.4).

Estimates of wintertime contaminant emissions for different heating methods under worst-case and average scenarios are also shown in Tables 3.6 and 3.7. The emission estimates indicate the following:

- Around 3 tonnes of PM_{10} are discharged under the worst-case scenario of all households using solid fuel burners on a given night.
- Average daily wintertime PM_{10} emissions are less at around 2.1 tonnes per day. This accounts for days when households may not be using specific home heating methods. Unless otherwise specified, all results reported are for the average emissions.
- The majority of this PM_{10} is in the finer $PM_{2.5}$ size fraction.
- Overall, a slightly greater proportion of the PM_{10} emissions come from the burning of wood (57%) than from the burning of coal (43%).

Monthly variations in appliance use and average days per week used are shown in Figures 3.5 and 3.6. Table 3.8 shows seasonal variations in contaminant emissions. The majority of the annual PM_{10} from domestic home heating occurs during the months June, July and August (Figure 3.7). This coincides with the times when meteorological conditions are most conducive to elevated PM_{10} concentrations and when NES breaches occur in Dunedin.

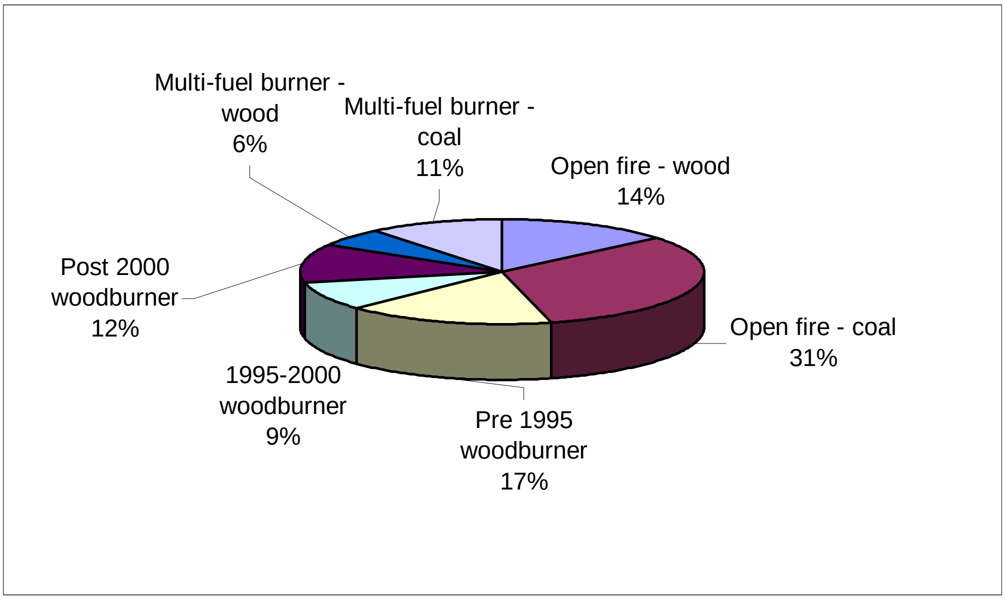

Figure 3.4 Relative contribution of different heating methods to average daily PM_{10} (July) from domestic heating in Dunedin

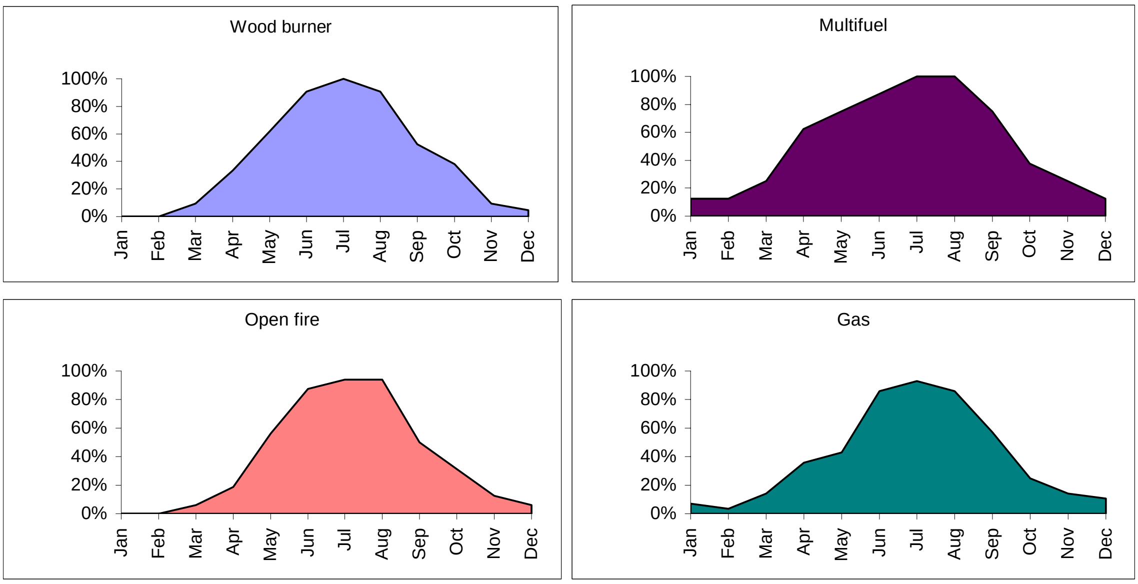

Figure 3.5 Monthly variations in appliance use in Dunedin

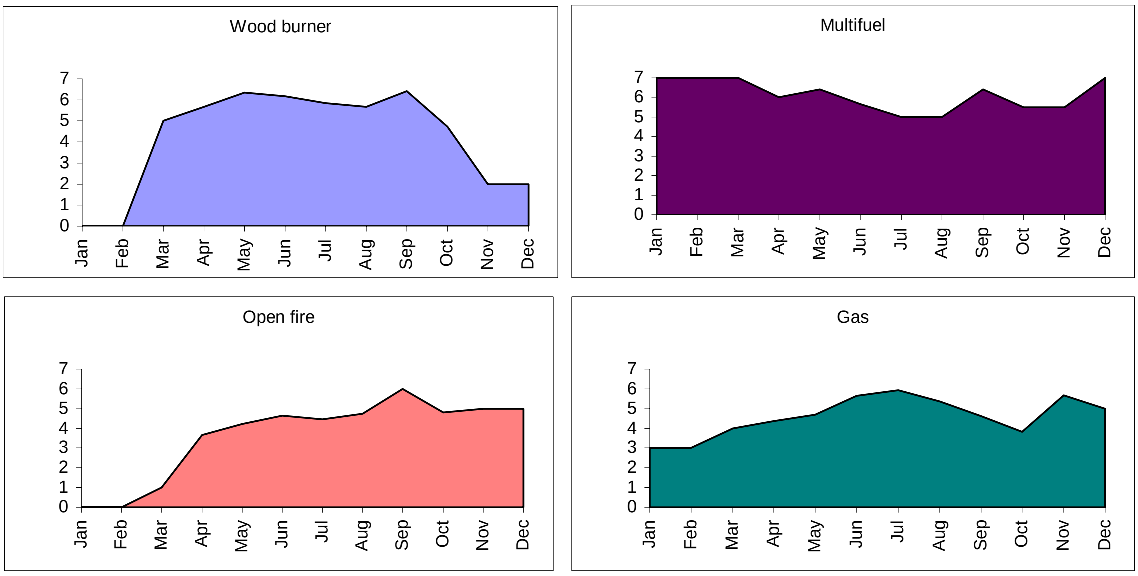

Figure 3.6 Average number of days per week appliances are used in Dunedin

Table 3.6 Dunedin worst-case winter (July) daily domestic heating emissions by appliance type

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	62	23%	616	93	20%	6155	925	26%	98	15	27%	12	2	4%	1847	278	29%	98	15	20%	616	93	24%
Open fire - coal	41	15%	858	129	28%	3267	491	14%	163	25	45%	204	31	73%	613	92	10%	106	16	22%	489	73	19%
Wood burner																							
Pre 1995 burners	38	14%	422	63	14%	4218	634	18%	19	3	5%	8	1	3%	1265	190	20%	61	9	13%	422	63	17%
1995-2000 burners	32	12%	224	34	7%	2237	336	10%	16	2	4%	6	1	2%	671	101	11%	51	8	10%	224	34	9%
Post 2000 burners	51	19%	307	46	10%	3068	461	13%	26	4	7%	10	2	4%	920	138	14%	82	12	17%	307	46	12%
Pellet Burner	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi-fuel burner																							
Multi-fuel burner – wood	22	8%	291	44	10%	2910	437	13%	11	2	3%	4	1	2%	873	131	14%	36	5	7%	291	44	11%
Multi-fuel burner – coal	12	4%	330	50	11%	1414	212	6%	14	2	4%	35	5	13%	177	27	3%	31	5	6%	188	28	7%
Gas	9	3%	0	0	0%	2	0	0%	12	2	3%	0	0	0%	0	0	0%	23	3	5%	0	0	0%
Oil	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	205	77%	1859	279	61%	18587	2793	80%	170	26	47%	41	6	15%	5576	838	88%	329	49	67%	1859	279	73%
Total Coal	53	20%	1188	178	39%	4681	704	20%	177	27	49%	240	36	85%	789	119	12%	137	21	28%	677	102	27%
Total	267		3047	458		23270	3497		360	54		281	42		6366	957		489	73		2536	381	

Table 3.7 Dunedin average winter (July) daily domestic heating emissions by appliance type

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%
Open fire																								
Open fire - wood	30	16%	299	45	14%	2992	450	19%	48	7	19%	6	1	3%	898	135	21%	48	7	13%	299	45	17%
Open fire - coal	34	17%	705	106	32%	2684	403	17%	134	20	52%	168	25	76%	503	76	12%	87	13	24%	402	60	23%
Wood burner																								
Pre 1995 burners	33	17%	361	54	17%	3611	543	23%	16	2	6%	7	1	3%	1083	163	25%	53	8	15%	361	54	20%
1995-2000 burners	27	14%	191	29	9%	1915	288	12%	14	2	5%	5	1	2%	574	86	13%	44	7	12%	191	29	11%
Post 2000 burners	44	23%	263	39	12%	2626	395	16%	22	3	8%	9	1	4%	788	118	18%	70	11	20%	263	39	15%
Pellet Burner	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi-fuel burner																								
Multi-fuel burner – wood	9	5%	120	18	6%	1197	180	7%	5	1	2%	2	0	1%	359	54	8%	15	2	4%	120	18	7%
Multi-fuel burner – coal	8	4%	236	35	11%	1010	152	6%	10	1	4%	25	4	11%	126	19	3%	22	3	6%	134	20	8%
Gas	7	4%	0	0	0%	1	0	0%	10	1	4%	0	0	0%	0	0	0%	18	3	5%	0	0	0%
Oil	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	143	74%	1234	185	57%	12341	1855	77%	104	16	40%	29	4	13%	3702	556	85%	229	34	64%	1234	185	70%
Total Coal	42	22%	940	141	43%	3694	555	23%	144	22	56%	193	29	87%	629	95	15%	109	16	31%	536	81	30%
Total	192		2174	327		16036	2410		258	39		222	33		4332	651		356	54		1770	266	

Table 3.8 Monthly variations in contaminant emissions from domestic heating in Dunedin

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	16	71	1	2	9	2	9
February	16	71	1	2	9	2	9
March	33	141	2	4	18	4	19
April	141	606	7	15	76	15	81
May	910	6301	98	98	1634	138	710
June	1899	13831	230	201	3719	311	1534
July	2175	16036	259	223	4332	357	1770
August	2246	16748	279	224	4545	362	1841
September	757	3890	111	122	842	98	495
October	323	1668	51	56	375	41	213
November	40	208	2	4	38	4	25
December	16	71	1	2	9	2	9
Total (kg/ year)	262892	1830159	31905	29114	479017	40925	206045

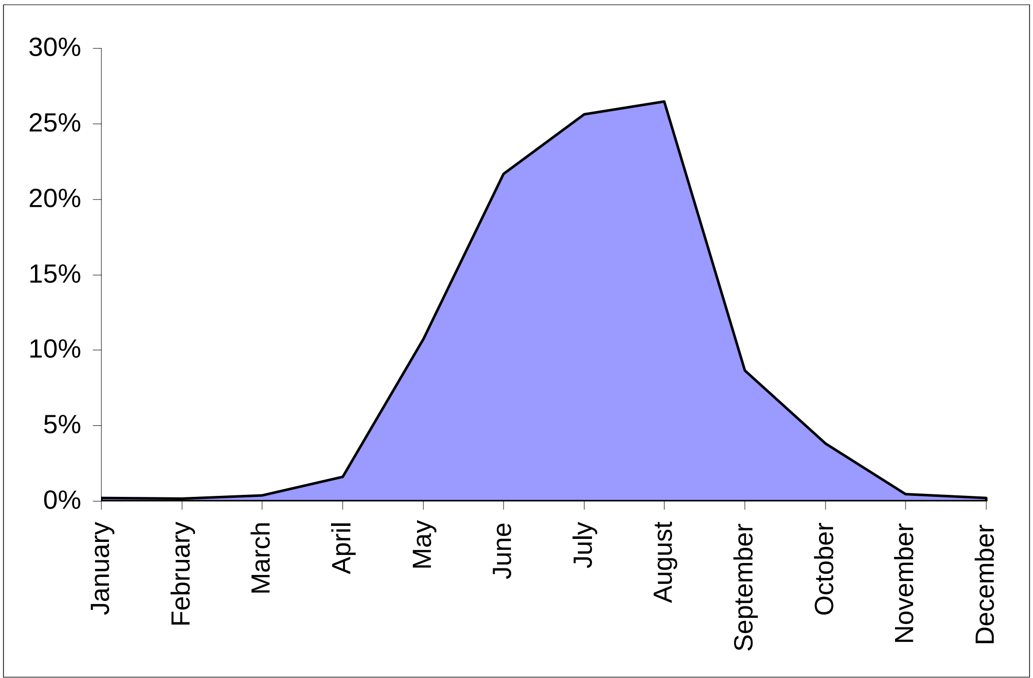

Figure 3.7 Proportion of annual PM_{10} emissions from domestic heating in Dunedin by month of year

3.3.2 Mosgiel

Multi-fuel burners emit the most PM_{10} of all heating methods in Mosgiel, contributing around 53% of the daily wintertime emissions. Older wood burners were the next greatest contributor, emitting around 17% of the daily PM_{10} (Figure 3.8).

Estimates of wintertime contaminant emissions for different heating methods under worst-case and average scenarios are also shown in Tables 3.9 and 3.10. The emission estimates indicate the following:

- Around 800 kg of domestic PM_{10} are discharged under the worst-case scenario of all households using solid fuel burners on a given night.
- Average daily wintertime PM_{10} emissions are less at around 600 kg per day. This accounts for days when households may not be using specific home heating methods.
- The majority of this PM_{10} is in the finer $PM_{2.5}$ size fraction.
- Just under two thirds of the wintertime PM_{10} emissions come from the burning of wood, with the remainder from the burning of coal.

Monthly variations in appliance use and average days per week used are shown in Figures 3.9 and 3.10. Table 3.11 shows seasonal variations in contaminant emissions. The majority of the annual PM_{10} from domestic home heating occur during the months of June, July and August (Figure 3.11). This coincides with the times when meteorological conditions are most conducive to elevated PM_{10} concentrations and when NES breaches occur in Mosgiel.

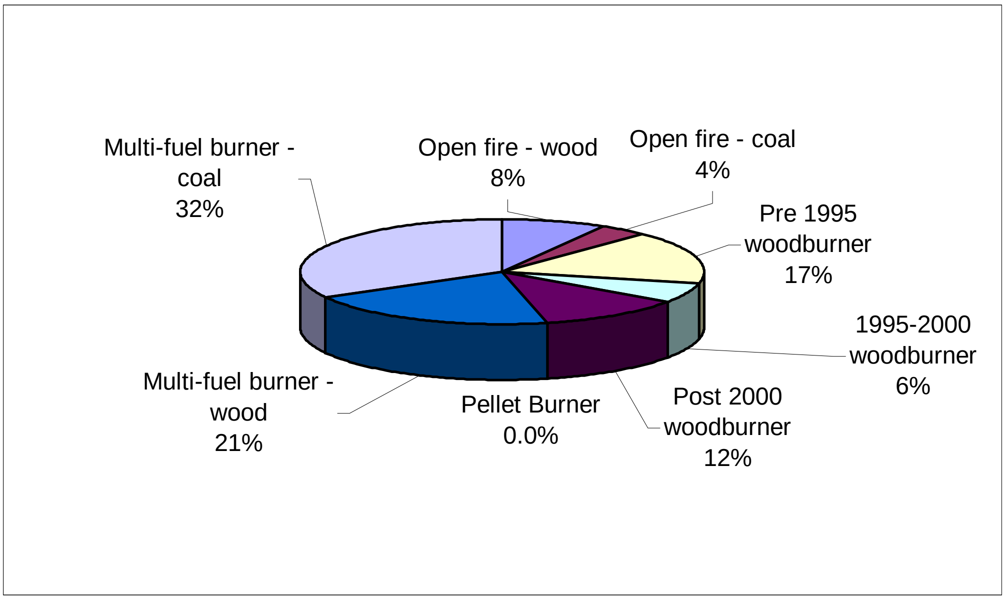

Figure 3.8 Relative contribution of different heating methods to average daily PM_{10} (July) from domestic heating in Mosgiel

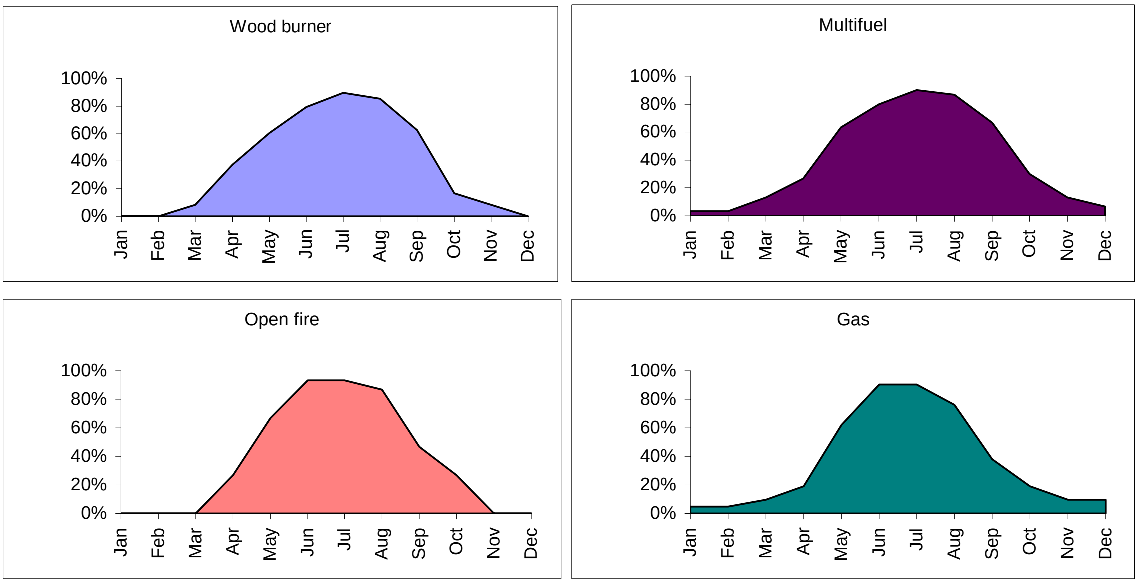

Figure 3.9 Monthly variations in appliance use in Mosgiel

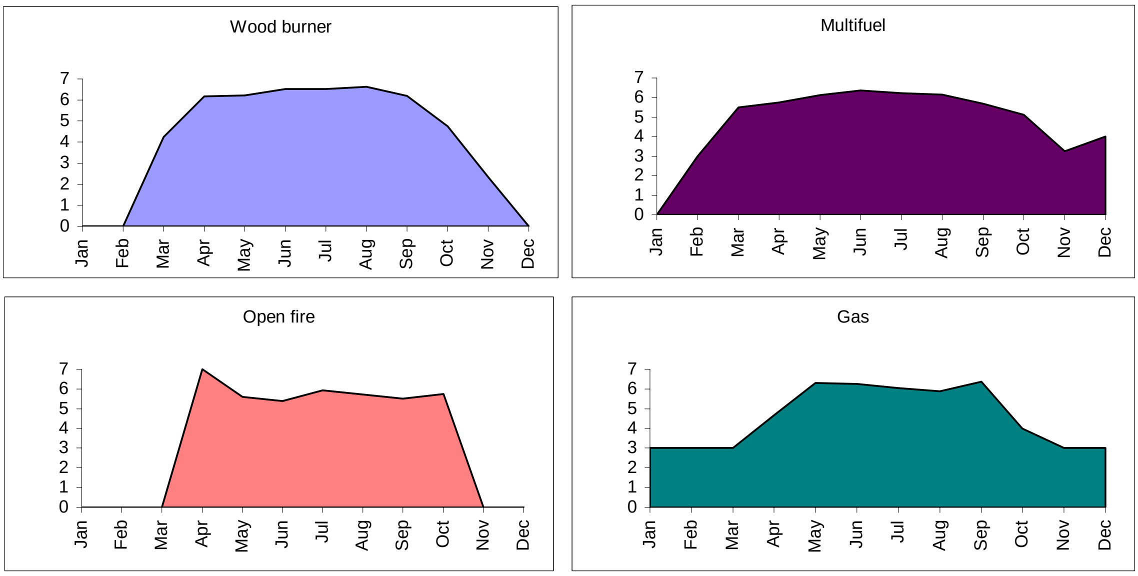

Figure 3.10 Average number of days per week appliances are used in Mosgiel per month

Table 3.9 Mosgiel worst-case winter (July) daily domestic heating emissions by appliance type

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	8	12%	77	166	9%	772	1665	12%	12	27	22%	2	3	3%	232	499	13%	12	27	11%	77	166	11%
Open fire – coal	2	3%	46	99	6%	175	377	3%	9	19	16%	11	24	22%	33	71	2%	6	12	5%	26	56	4%
Wood burner																							
Pre 1995 burners	10	15%	112	241	13%	1118	2410	17%	5	11	9%	2	4	4%	335	723	19%	16	35	14%	112	241	16%
1995-2000 burners	6	9%	41	88	5%	407	876	6%	3	6	5%	1	3	2%	122	263	7%	9	20	8%	41	88	6%
Post 2000 burners	13	20%	78	169	9%	784	1690	12%	7	14	12%	3	6	5%	235	507	13%	21	45	18%	78	169	11%
Pellet Burner	0	0%	0	0	0%	2	5	0%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%
Multi-fuel burner																							
Multi-fuel burner – wood	17	26%	219	471	26%	2185	4709	33%	8	18	15%	3	7	7%	656	1413	37%	27	58	23%	219	471	31%
Multi-fuel burner – coal	9	14%	256	553	31%	1099	2369	17%	11	23	19%	27	59	54%	137	296	8%	24	51	20%	146	315	21%
Gas	0	1%	0	0	0%	0	0	0%	1	1	1%	0	0	0%	0	0	0%	1	3	1%	0	0	0%
Oil	0	1%	0	0	0%	0	0	0%	1	2	1%	1	3	3%	0	0	0%	1	2	1%	0	0	0%
Total Wood	54	82%	527	1136	64%	5269	11355	81%	35	76	63%	11	23	21%	1581	3407	90%	86	185	73%	527	1136	75%
Total Coal	11	17%	302	652	36%	1274	2746	19%	19	42	35%	38	83	76%	170	367	10%	30	64	25%	172	372	25%
Total	66		829	1788		6543	14102		56	121		50	109		1751	3774		118	254		699	1507	

Table 3.10 Mosgiel average winter (July) daily domestic heating emissions by appliance type

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	5	10%	50	108	8%	501	1080	10%	8	17	20%	1	2	3%	150	324	12%	8	17	9%	50	108	10%
Open fire - coal	1	2%	23	51	4%	89	193	2%	4	10	11%	6	12	16%	17	36	1%	3	6	3%	13	29	3%
Wood burner																							
Pre 1995 burners	9	18%	101	217	17%	1006	2169	21%	5	10	12%	2	4	5%	302	651	24%	15	32	17%	101	217	20%
1995-2000 burners	5	11%	37	79	6%	366	789	8%	3	6	7%	1	2	3%	110	237	9%	8	18	10%	37	79	7%
Post 2000 burners	12	24%	71	152	12%	706	1521	15%	6	13	15%	2	5	7%	212	456	17%	19	41	21%	71	152	14%
Pellet Burner	0	0%	0	0	0%	1	2	0%	0	0	0%	0	0	0%	0	1	0%	0	0	0%	0	0	0%
Multi-fuel burner																							
Multi-fuel burner – wood	10	20%	126	271	21%	1258	2711	26%	5	10	12%	2	4	5%	377	813	30%	15	33	18%	126	271	25%
Multi-fuel burner – coal	7	14%	201	433	33%	861	1857	18%	8	18	21%	22	46	61%	108	232	8%	19	40	21%	115	247	22%
Gas	0	1%	0	0	0%	0	0	0%	0	1	1%	0	0	0%	0	0	0%	1	2	1%	0	0	0%
Oil	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	41	82%	384	827	63%	3838	8271	80%	26	56	66%	8	18	23%	1151	2481	90%	65	141	74%	384	827	75%
Total Coal	8	17%	225	484	37%	951	2049	20%	13	28	33%	27	58	77%	124	268	10%	22	46	25%	128	276	25%
Total	50		608	1311		4789	10321		39	85		35	76		1276	2750		88	190		512	1103	

Otago Regional Council

Table 3.11 Monthly variations in contaminant emissions from domestic heating in Mosgiel

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	0	0	0	0	0	0
February	0	1	0	0	0	0	0
March	12	102	1	0	29	2	11
April	64	614	4	2	180	11	62
May	349	2665	22	21	695	49	287
June	518	4026	36	32	1068	75	432
July	608	4789	39	35	1276	88	512
August	574	4525	37	33	1206	83	483
September	235	2166	15	8	628	36	221
October	40	334	2	2	92	5	35
November	3	34	0	0	10	0	3
December	0	2	0	0	1	0	0
Total (kg/ year)	73703	590135	4773	4131	158859	10717	62752

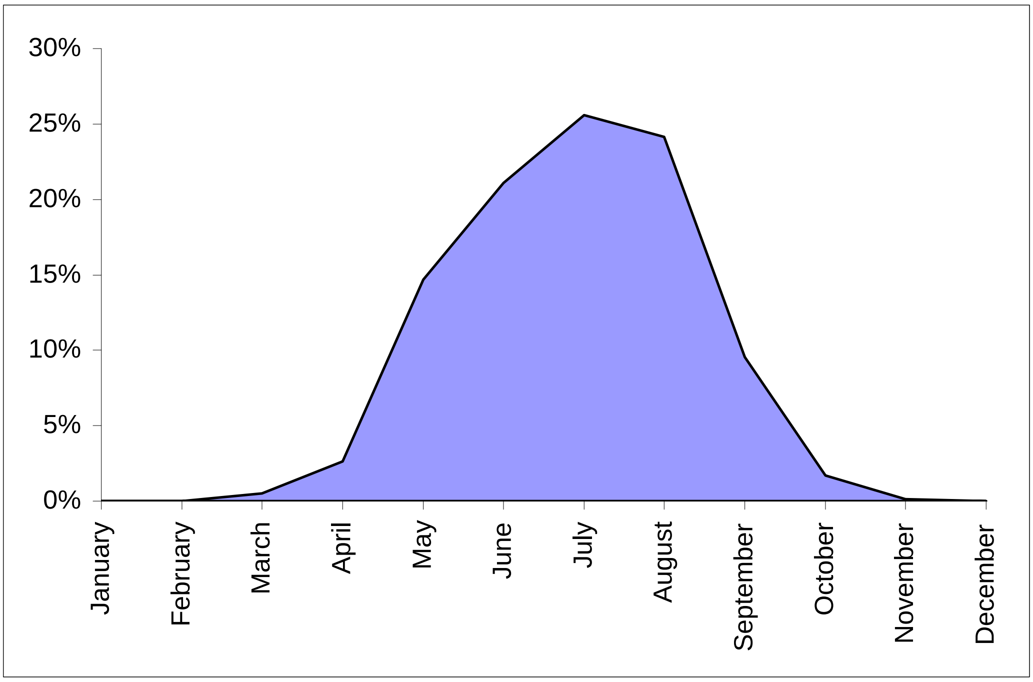

Figure 3.11 Proportion of annual PM_{10} emissions from domestic heating in Mosgiel by month of year

3.3.3 Alexandra

Older wood burners and multi-fuel burners are the greatest contributors to daily PM_{10} emissions from domestic heating in Alexandra, emitting 32% and 41% of PM_{10} emissions respectively (Figure 3.12).

Estimates of wintertime contaminant emissions for different heating methods under worst-case and average scenarios are also shown in Tables 3.12 and 3.13. The emission estimates indicate the following:

- Just less than 400 kg of domestic PM_{10} are discharged under the worst-case scenario of all households using solid fuel burners on a given night.
- Average daily wintertime PM_{10} emissions are less at around 377 kg per day. This accounts for days when households may not be using specific home heating methods.
- The majority of this PM_{10} is in the finer $PM_{2.5}$ size fraction.
- The majority (85%) of the wintertime PM_{10} emissions come from the burning of wood, with 15% from the burning of coal.

Monthly variations in appliance use and average days per week used are shown in Figures 3.13 and 3.14. Table 3.14 shows seasonal variations in contaminant emissions. The majority of the annual PM_{10} from domestic home heating occur during the months of June, July and August (Figure 3.15). This coincides with the times when meteorological conditions are most conducive to elevated PM_{10} concentrations and when NES breaches occur in Alexandra.

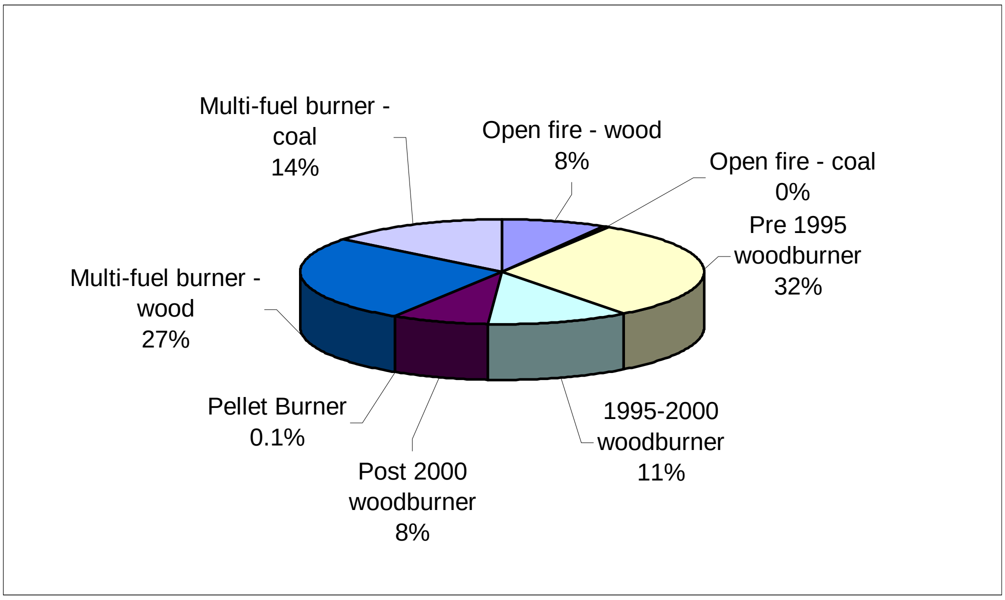

Figure 3.12 Relative contribution of different heating methods to average daily PM_{10} (July) from domestic heating in Alexandra

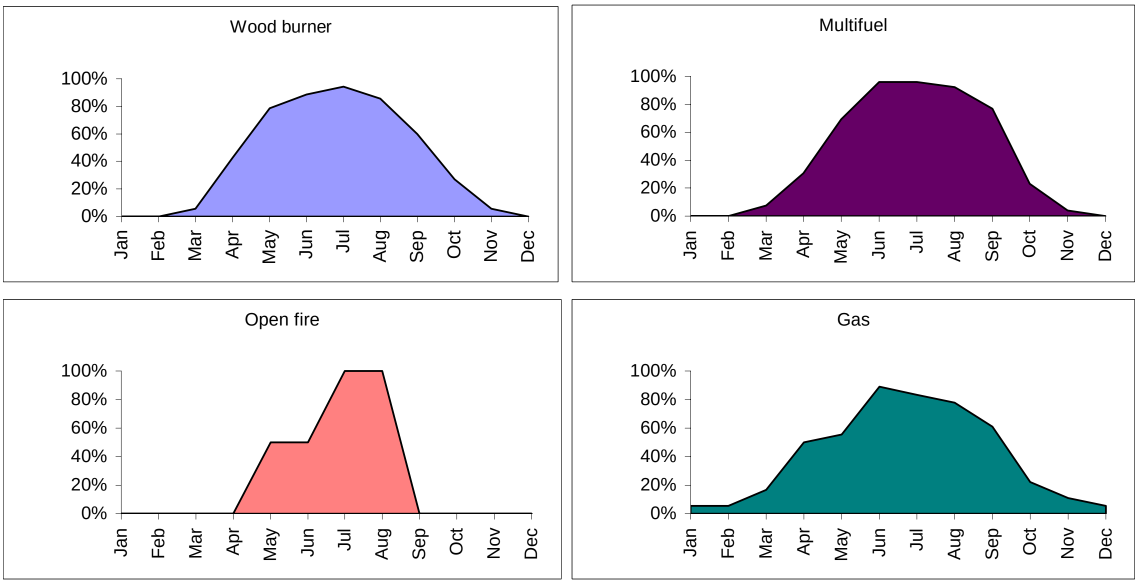

Figure 3.13 Monthly variations in appliance use in Alexandra

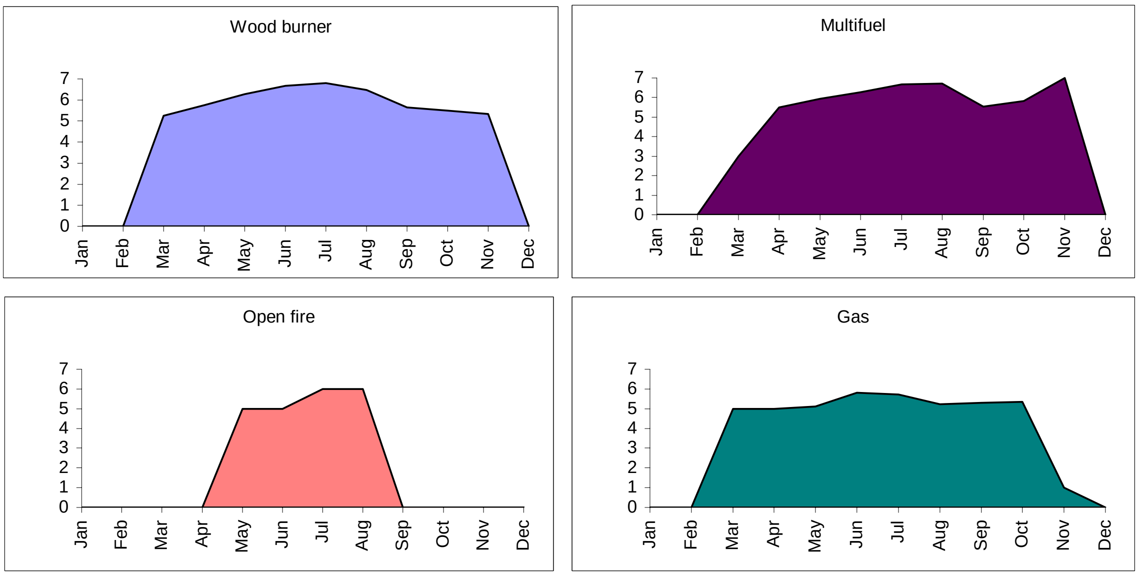

Figure 3.14 Average number of days per week appliances are used in Alexandra per month

Table 3.12 Alexandra worst-case winter (July) daily domestic heating emissions by appliance type

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	Kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%
Open fire																								
Open fire - wood	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Open fire - coal	0	0%	2	2	1%	9	9	0%	0	0	2%	1	1	3%	2	2	0%	0	0	0%	1	1	0%
Wood burner																								
Pre 1995 burners	12	33%	135	139	34%	1351	1386	38%	6	6	28%	2	3	15%	405	416	39%	20	20	31%	135	139	37%
1995-2000 burners	7	19%	50	51	13%	499	512	14%	4	4	16%	1	1	9%	150	154	15%	11	12	18%	50	51	14%
Post 2000 burners	6	15%	33	34	8%	333	341	9%	3	3	13%	1	1	7%	100	102	10%	9	9	14%	33	34	9%
Pellet Burner	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi-fuel burner																								
Multi-fuel burner – wood	9	24%	114	117	29%	1141	1170	32%	4	4	20%	2	2	11%	342	351	33%	14	14	22%	114	117	31%
Multi-fuel burner – coal	2	6%	61	63	15%	262	268	7%	3	3	12%	7	7	39%	33	34	3%	6	6	9%	35	36	9%
Gas	0	1%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	1	1	1%	0	0	0%
Oil	1	2%	0	0	0%	0	0	0%	2	2	7%	3	3	17%	0	0	0%	2	2	4%	0	0	0%
Total Wood	34	91%	332	341	84%	3324	3409	92%	17	17	78%	7	7	41%	997	1023	97%	54	55	86%	332	341	90%
Total Coal	2	6%	63	65	16%	271	278	8%	3	3	14%	7	7	43%	34	35	3%	6	6	9%	36	37	10%
Total	37		396	406		3595	3687		22	22		17	17		1032	1058		63	64		369	378	

Table 3.13 Alexandra average winter (July) daily domestic heating emissions by appliance type

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	Kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	3	9%	32	33	8%	319	327	9%	5	5	22%	1	1	5%	96	98	10%	5	5	9%	32	33	9%
Open fire - coal	0	0%	2	2	0%	6	7	0%	0	0	1%	0	0	3%	1	1	0%	0	0	0%	1	1	0%
Wood burner																							
Pre 1995 burners	11	30%	117	120	31%	1165	1195	34%	5	5	23%	2	2	17%	350	359	35%	17	17	29%	117	120	33%
1995-2000 burners	6	18%	43	44	11%	431	442	12%	3	3	14%	1	1	10%	129	132	13%	10	10	17%	43	44	12%
Post 2000 burners	5	14%	29	29	8%	287	294	8%	2	2	11%	1	1	7%	86	88	9%	8	8	13%	29	29	8%
Pellet Burner	0	1%	0	1	0%	5	5	0%	0	0	1%	0	0	0%	1	2	0%	0	0	1%	0	1	0%
Multi-fuel burner																							
Multi-fuel burner – wood	8	22%	101	104	27%	1010	1036	29%	4	4	17%	2	2	12%	303	311	30%	12	13	21%	101	104	29%
Multi-fuel burner – coal	2	6%	54	55	14%	232	238	7%	2	2	10%	6	6	45%	29	30	3%	5	5	9%	31	32	9%
Gas	0	0%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	0	1%	0	0	0%
Oil	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	0	0%
Total Wood	33	94%	322	330	85%	3217	3299	93%	20	20	88%	7	7	51%	965	990	97%	52	54	90%	322	330	91%
Total Coal	2	6%	56	57	15%	238	244	7%	3	3	11%	6	6	48%	30	31	3%	5	5	9%	32	33	9%
Total	35		377	387		3455	3543		23	23		13	13		995	1021		58	59		353	362	

Table 3.14 Monthly variations in contaminant emissions from domestic heating in Alexandra

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	1	7	0	0	2	0	1
April	42	403	2	1	119	7	41
May	202	1809	10	8	515	31	186
June	315	2816	16	12	802	47	290
July	377	3455	23	13	995	58	353
August	319	2899	19	11	833	48	297
September	110	951	5	5	265	15	99
October	13	99	1	1	26	2	11
November	0	1	0	0	0	0	0
December	0	0	0	0	0	0	0
Total (kg/ year)	42269	381472	2344	1511	109092	6404	39173

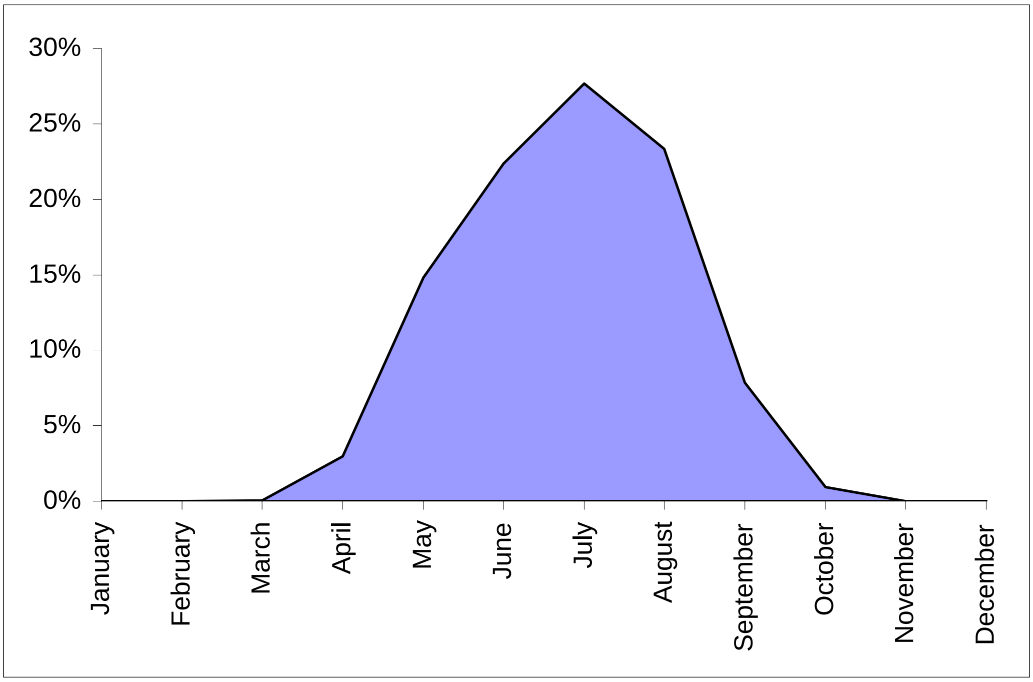

Figure 3.15 Proportion of annual PM_{10} emissions from domestic heating in Alexandra by month of year

4 Industrial and commercial

4.1 Methodology

Industrial and commercial activities were identified using the Otago Regional Council's resource consents database, searching other databases and phone directories and through discussions with Environmental Health Officers. A comprehensive list of industrial discharges was available for Dunedin because historical legislation (Clean Air Act 1972 and subsequent Transitional Regional Plan including Plan Change 1: Air Discharges) specified that combustion activities with a heat output of greater than 40 kW required licensing in the Dunedin City Council area (as it existed prior to amalgamation in 1989). This area excluded St Kilda, Green Island and Mosgiel.

The Otago Regional Council provided names, phone numbers and recommending reports for around 70 consented air discharges located within Dunedin, Mosgiel or Alexandra. Around ten were excluded from the analysis because their PM_{10} discharges were considered negligible. These were primarily LPG boilers that had required resource consents under the Transitional Regional Plan. Emissions from nine diesel boilers or generators were also not included because of their infrequent use. A total of 14 industrial activities holding resource consent for air discharges had also ceased their discharges. Industrial activities included in the report were dominated by combustion processes, the most common being coal burning, for both industrial (e.g. food processing) and commercial activities (e.g. heating of residential halls and schools) with a small number of process operations such as grain processing. A phone survey of 68 schools in Dunedin, Mosgiel and Alexandra was conducted to assess the discharges from boilers used to heat schools.

Information from the industries used in an emission inventory is referred to as activity data. This was obtained from a combination of recommending reports and through direct phone contact. Activity data from industry includes information such as the quantities of fuel used or in the case of non-combustion activities, materials used or produced. Emission factors are applied to these data to estimate emissions. Where available, emissions testing data were used in preference to emissions factors. Data were collected for winter, autumn, spring and summer.

Where emissions testing data were not available, combustion emissions were estimated using emission factor data as indicated in Equation 5.1.

Equation 5.1 Emissions (kg) = Emission factor (kg/tonne) x Fuel use (tonnes)

The emission factors used to estimate the quantity of emissions discharged are shown in Table 4.1. The coal and wood fired boiler emission factors for PM_{10} are based on an evaluation of test data for boilers in New Zealand (Wilton, et. al., 2007). Emission factors for $PM_{2.5}$ are based on the USEPA AP42 database[1] particle size distribution factors, as are emission factors for CO, NOx and SOx. The VOC and CO_2 and all gas emission factors are based on factors derived by NIWA for the Christchurch 1996 emission inventory (NIWA, 1998).

[1] http://www.epa.gov/ttn/chief/ap42/index.html

Table 4.1 Emission factors for industrial discharges

	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SO_2 * g/kg	VOC g/kg	CO_2 g/kg
Chain grate	2.1	0.8	3.0	3.8	18.0	0.1	2400
Spreader and Vekos	6.7	2.3	2.5	5.0	18.0	0.1	2400
Spreader stoker (sprinklers)	3.8	1.4	3.0	3.8	18.0	0.1	2400
Underfeed stokers	1.9	1.2	5.5	4.8	18	0.1	2400
Low Ram	3.0	1.1	3.0	5.0	18.0	0.1	2400
Wood boiler	3.3	2.7	6.8	0.8	0.0	0.1	1069
Diesel boiler	0.5	.3	0.7	3.2	10.5	0.2	3194
Light fuel oil	1.1		0.7	6.3	3.9	0.2	3194

*** Based on a sulphur content of 1% - the sulphur content of coal used ranged from 0.18%-2%.**

4.2 Industrial and commercial emissions

4.2.1 Dunedin

Table 4.2 shows that around 202 kg of PM_{10} per day is estimated to be discharged in Dunedin from industrial and commercial activities during the winter months. The main sources are industrial coal boilers, which contribute around 94% of the PM_{10} (Figure 4.1). The key activities contributing to the emissions are as follows:

- Meridian Solutions: 17%
- Sealord Group Limited*: 13%
- Colyer Mair Assets Limited: 10%
- Keep it Clean: 10%

*Sealord Group Limited ceased operating in Dunedin in December 2006.

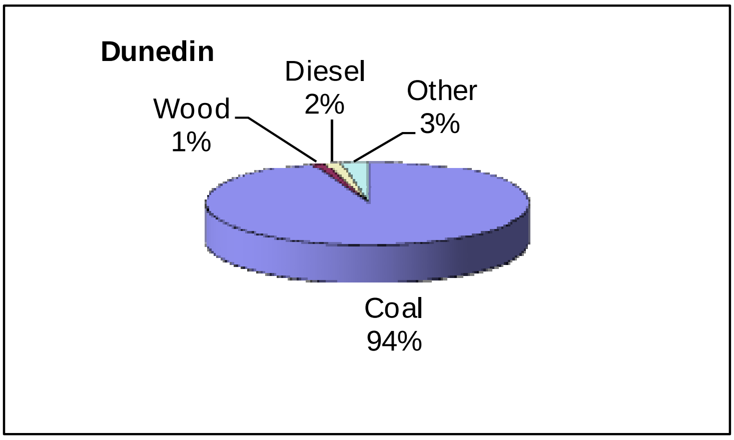

Figure 4.1 Relative contribution to daily winter PM_{10} emissions in Dunedin from different fuels/ sources

4.2.2 Mosgiel

Daily wintertime PM_{10} emissions in Mosgiel are estimated at around 69 kg per day (Table 4.2). The majority (95%) of this is from a wood fired boiler at New Zealand Wood Mouldings Limited. Other sources include coal fired boilers and an incinerator at Agresearch.

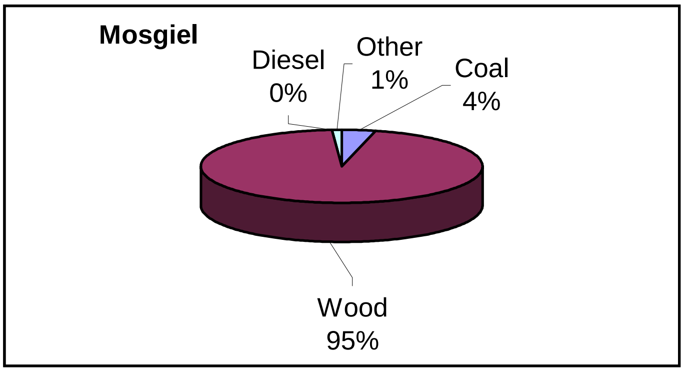

Figure 4.2 Relative contribution to daily winter PM_{10} emissions in Mosgiel from different fuels/ sources

4.2.3 Alexandra

Only a small number of industrial activities were identified for Alexandra. These included two coal fired boilers and three diesel boilers. A total of two kg of PM_{10} was estimated per winter's day from these activities (Table 4.2). The majority of this comes from the burning of coal (Figure 4.3).

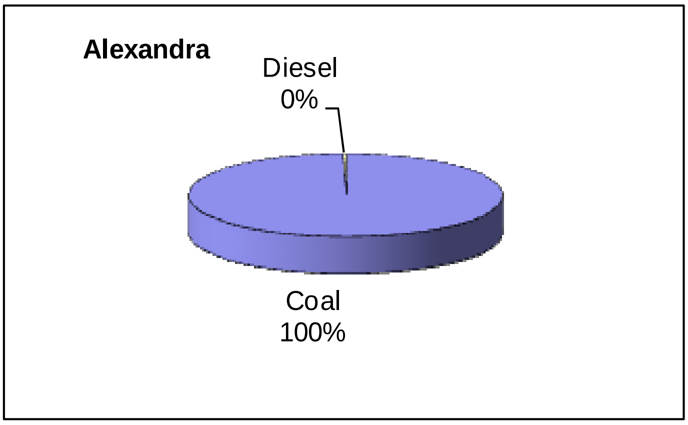

Figure 4.3 Relative contribution to daily winter PM_{10} emissions in Alexandra from different fuels/ sources

Table 4.2 Summary of wintertime industrial/ commercial emissions in Dunedin, Mosgiel and Alexandra

		PM_{10}		CO		NOx		SOx	
	Hectares	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**	**Kg**	**g/ha**
Dunedin	6,654	202	30	935	140	576	87	1162	175
Mosgiel	464	69	149	13	29	26	56	312	673
Alexandra	975	2	2	7	7	6	6	22	22
		VOC		CO_2		$PM_{2.5}$			
	Hectares	**kg**		**t**	**kg/ha**	**kg**	**g/ha**		
Dunedin	6654	9	1	353	53	106	16		
Mosgiel	464	0	0	4	10	64	137		
Alexandra	975	0	0	3	3	1	1		

5 Total emissions

5.1 Dunedin

Around 2.4 tonnes of PM_{10} is discharged to air in Dunedin from domestic heating and industry on an average winter's day. This is based on the average weekday contributions during July. The proportion of PM_{10} that is from the burning of solid fuel for domestic home heating is around 92% (Figure 5.1), which is similar to Mosgiel but lower than Alexandra (99%). Of the industrial contributions (10% of total) the main source (contributing 96%) is industrial coal burning.

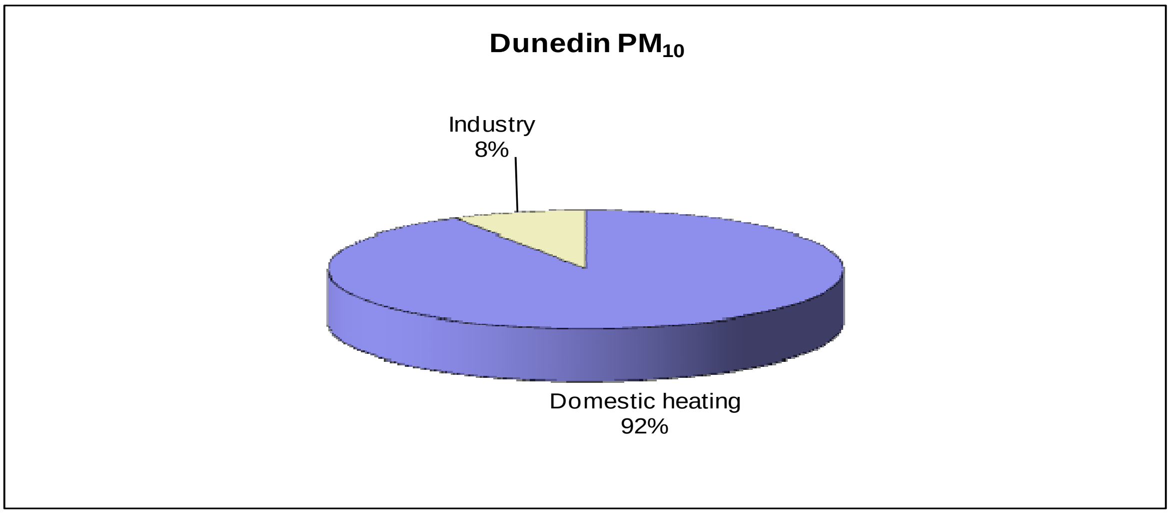

Figure 5.1 Relative contribution of domestic heating and industry sources to daily winter PM_{10} emissions in Dunedin

Domestic home heating is also the main sources of $PM_{2.5}$, CO and VOCs, and industry is the main source of NOx and SOx (Figure 5.2).

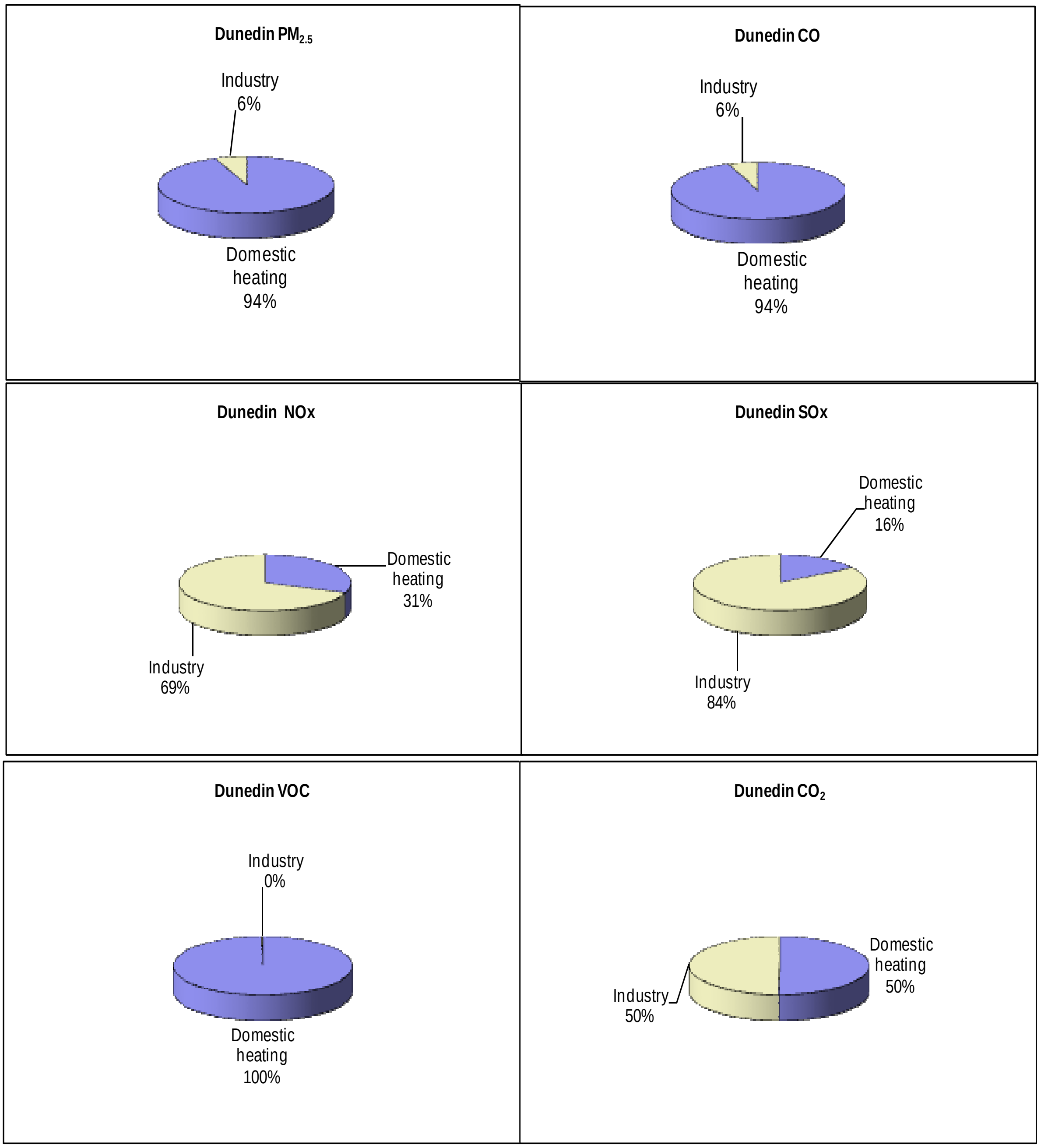

Figure 5.2 Relative contribution of sources to wintertime contaminant emissions in Dunedin

Table 5.1 shows estimated daily contaminant emissions in Dunedin and an indication of the likely time of day breakdown for these emissions. The domestic heating emissions distribution has been estimated based on the distribution for Nelson as data were not collected for Dunedin, Mosgiel or Alexandra.

Table 5.2 shows estimated seasonal variations in PM_{10} emissions. Although domestic home heating is the dominant source of PM_{10} emissions during the winter months (contributing 2.2 tonnes per day during July) during the summer, industry is the dominant contributor (155 kg per day during December). Industrial contributions are based on average seasonal, rather than monthly, fluctuations.

Table 5.1 Total daily estimated wintertime emissions by time of day for Dunedin

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total PM_{10} kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total $PM_{2.5}$ kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total NOx (kg)
Domestic heating	224	176	1522	252	2174	180	134	1260	196	1770	1294	1947	10481	2314	16036	25	18	193	22	258
Industry	64	64	35	38	202	34	33	19	20	106	230	257	201	248	935	162	164	114	135	576
Total	288	241	1557	290	2376	214	167	1280	216	1876	1523	2204	10682	2562	16970	187	182	308	157	834

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total SOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO_2 (t)
Domestic heating	25	28	137	31	222	433	305	3135	458	4332	29	41	229	58	356
Industry	418	352	195	197	1162	3	3	2	2	9	93	99	73	88	353
Total	443	380	332	229	1383	436	308	3137	461	4341	122	140	301	146	710

Table 5.2 Monthly variations in estimated daily PM_{10} emissions in Dunedin

	Domestic Heating		Industry		Total
	kg/day	%	kg/day	%	
January	16	8%	155	90%	172
February	16	8%	155	90%	172
March	33	16%	124	79%	157
April	141	45%	124	47%	265
May	910	84%	124	12%	1034
June	1899	88%	202	10%	2101
July	2174	90%	202	8%	2376
August	2246	90%	202	8%	2447
September	757	78%	173	19%	930
October	323	60%	173	35%	496
November	40	16%	173	81%	213
December	16	8%	155	90%	172
Total kg /year	262892		59682		322574

5.2 Mosgiel

Around 677 kg of PM_{10} is discharged to air from domestic heating and industry in Mosgiel on an average winter's day (average weekday during July). The main source is solid fuel burning for domestic home heating, which contributes 90% of the daily PM_{10} (Figure 5.3). The main source of industrial PM_{10} is a wood boiler used by New Zealand Wood Moulding Limited.

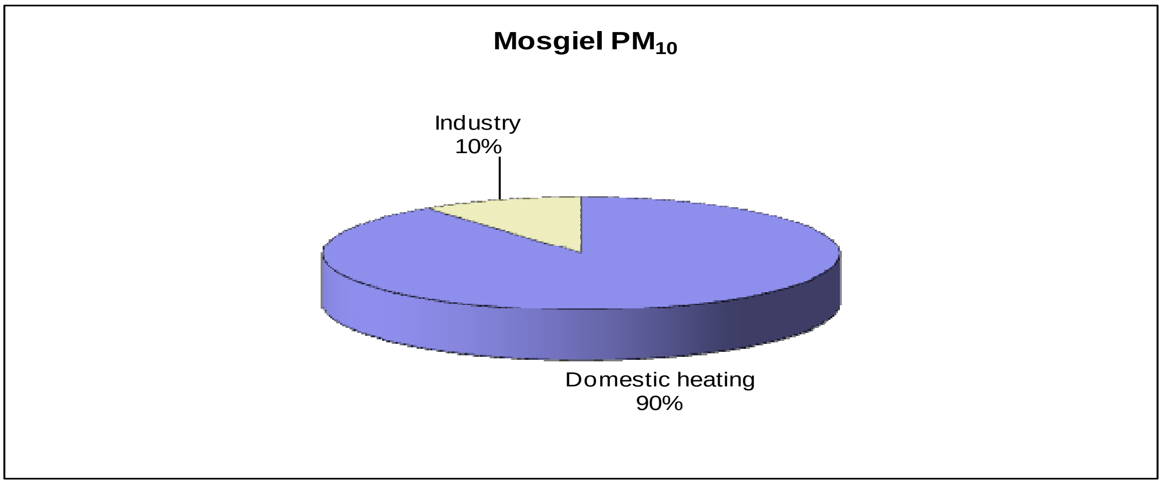

Figure 5.3 Relative contribution of sources to daily winter PM_{10} emissions in Mosgiel

Domestic heating is also the main contributor to CO, $PM_{2.5}$, VOC, NOx and CO_2 emissions in Mosgiel (Figure 5.4).

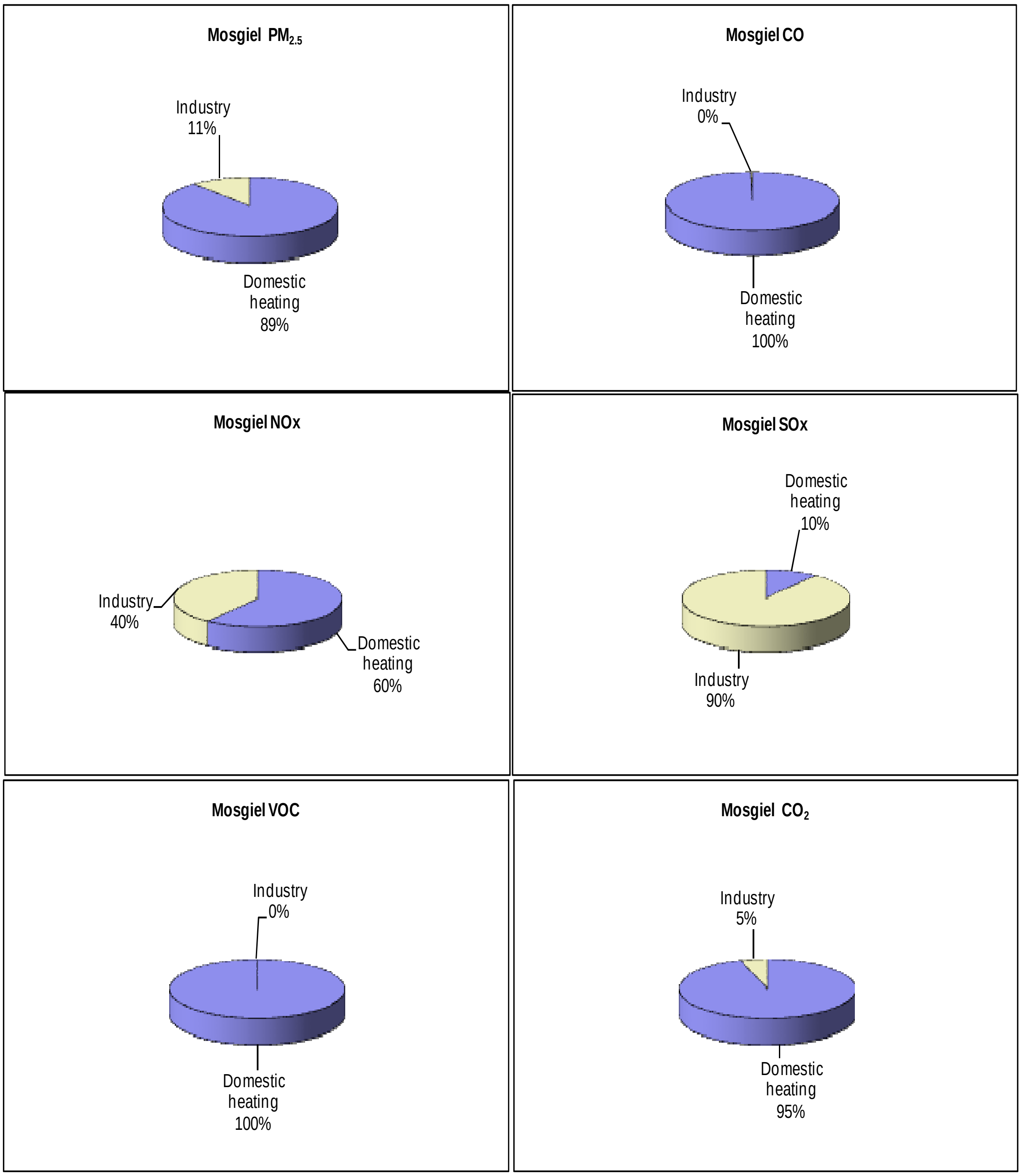

Figure 5.4 Relative contribution of sources to contaminant emissions in Mosgiel

An estimate of daily variations in contaminant emissions in Mosgiel is shown in Table 5.3. The domestic heating distribution is based on daily emission profiles for Nelson and may not be representative of Mosgiel.

Table 5.4 shows estimated seasonal variations in PM_{10} emissions. Although domestic home heating is the dominant source of PM_{10} emissions during the winter months (contributing 608 kg per day during July), during the summer, industry is the dominant contributor (contributing 67 kg per day during December). Note industrial contributions are based on average seasonal, rather than monthly, fluctuations.

Table 5.3 Total daily estimated wintertime emissions by time of day for Mosgiel

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total PM_{10} kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total $PM_{2.5}$ kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total NOx (kg)
Domestic heating	63	49	426	71	608	52	39	364	57	512	386	581	3130	691	4789	4	3	30	3	40
Industry	13	17	17	22	69	11	16	16	20	64	6	2	3	2	13	8	6	6	7	26
Total	76	67	443	92	677	63	55	380	77	575	393	584	3133	693	4802	12	9	36	10	66

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total SOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO_2 (t)
Domestic heating	4	4	22	5	35	128	90	923	135	1276	7	10	56	14	88
Industry	65	74	76	96	312	0	0	0	0	0	3	1	1	0	4
Total	69	79	98	101	347	128	90	923	135	1276	10	11	57	15	92

Table 5.4 Monthly variations in estimated daily PM_{10} emissions in Mosgiel

	Domestic Heating		Industry		Total
	kg/day	%	kg/day	%	
January	0	0%	67	100%	67
February	0	0%	67	100%	67
March	12	15%	67	85%	79
April	64	49%	67	51%	132
May	349	84%	67	16%	417
June	518	88%	69	12%	587
July	608	90%	69	10%	677
August	574	89%	69	11%	643
September	235	78%	67	22%	302
October	40	37%	67	63%	107
November	3	5%	67	95%	71
December	0	0%	67	100%	67
Total kg year	73703		24739		98442

5.3 Alexandra

Around 380 kg of PM_{10} is discharged to air from domestic heating and industry in Alexandra on an average winter's day (average weekday during July). Solid fuel burning for domestic home heating is the main source, contributing around 99% of the daily PM_{10} (Figure 5.5). The contribution of industry to PM_{10} emissions in Alexandra is negligible at 1%.

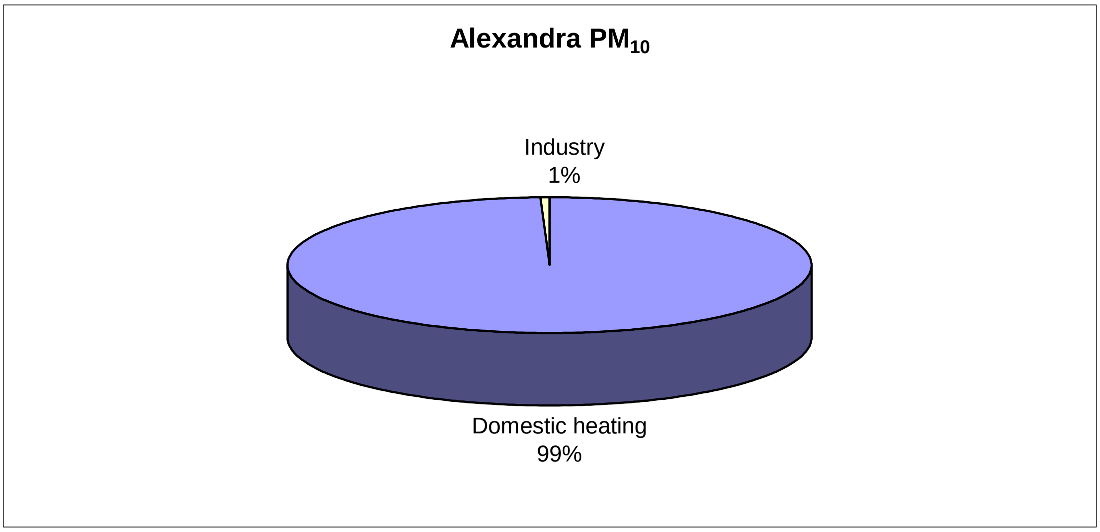

Figure 5.5 Relative contribution of sources to daily winter PM_{10} emissions in Alexandra

Domestic heating is also the main contributor to all other emissions in Alexandra except SOx (Figure 5.6).

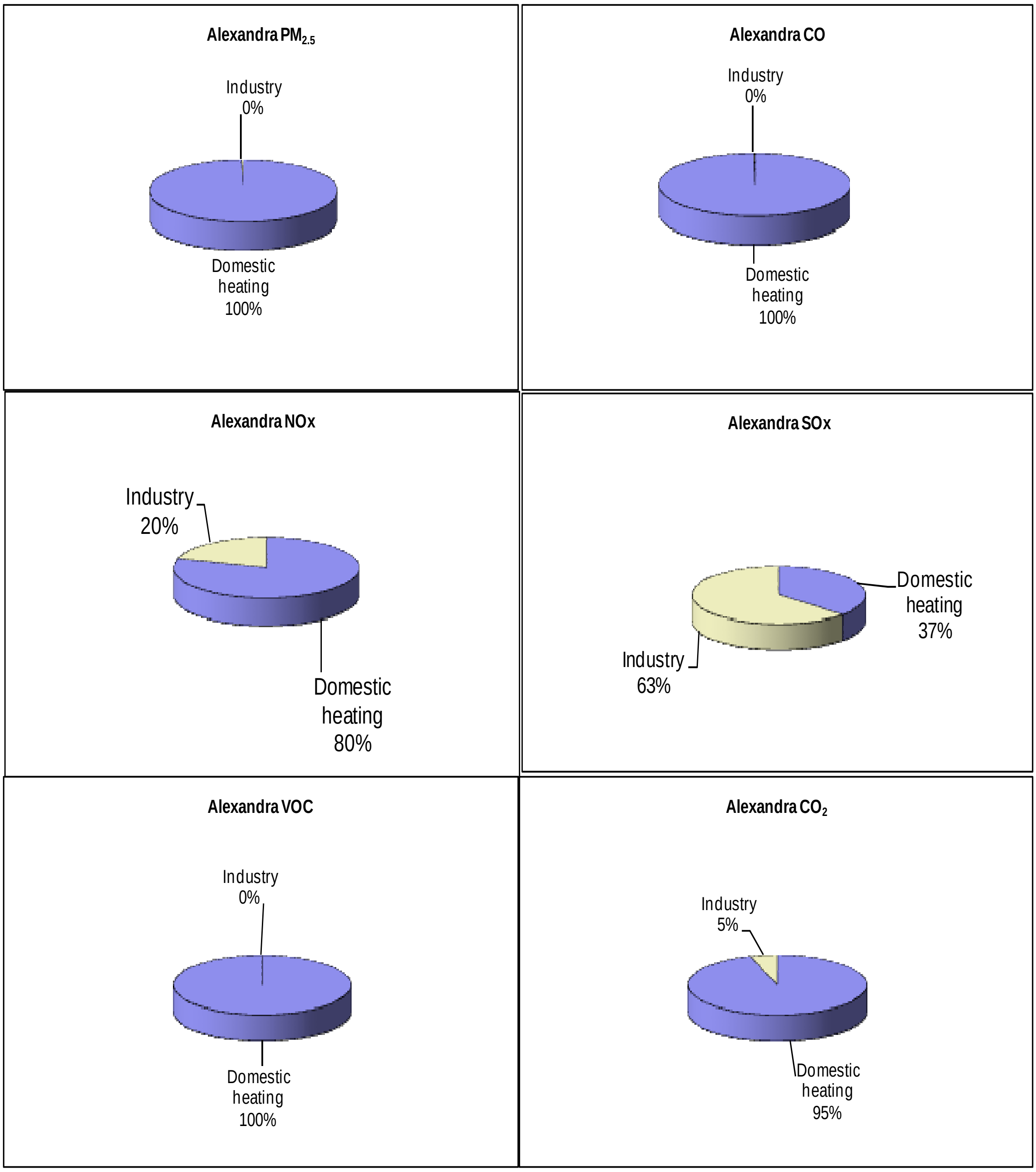

Figure 5.6 Relative contribution of sources to contaminant emissions in Alexandra

An estimate of daily variations in wintertime contaminant emissions is shown in Table 5.5. For domestic heating, this is based on daily emission profiles for Nelson and may not be representative of Alexandra.

Seasonal variations in PM_{10} emissions are shown in Table 5.6. Domestic home heating is the dominant source of PM_{10} emissions during the winter months (contributing 377kg per day in July). Neither source contributes significant PM_{10} during summer.

Table 5.5 Total estimated daily wintertime emissions by time of day for Alexandra

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total PM_{10} kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total $PM_{2.5}$ kg	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total NOx (kg)
Domestic heating	39	31	264	44	377	36	27	252	39	353	279	419	2258	499	3455	2	2	17	2	23
Industry	2	0	0	0	2	1	0	0	0	1	5	1	0	0	7	5	1	0	0	6
Total	41	31	264	44	380	37	27	252	39	355	284	421	2258	499	3461	7	3	17	2	29

Total emissions (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total SOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Total CO_2 (t)
Domestic heating	1	2	8	2	13	100	70	720	105	995	5	7	37	9	58
Industry	18	4	0	0	22	0	0	0	0	0	2	1	0	0	3
Total	19	6	8	2	35	100	70	720	105	995	7	7	37	9	61

Table 5.6 Monthly variations in estimated daily PM_{10} emissions in Alexandra

	Domestic Heating		Industry		Total
	kg/day	%	kg/day	%	
January	0	0%	0	100%	0
February	0	0%	0	100%	0
March	1	44%	1	57%	2
April	42	98%	1	2%	43
May	202	100%	1	0%	203
June	315	99%	2	1%	317
July	377	99%	2	1%	380
August	319	99%	2	1%	321
September	110	99%	1	1%	111
October	13	93%	1	7%	13
November	0	21%	1	79%	1
December	0	0%	0	100%	0
Total kg year	42269		389		42658

References

Dasch, J. M. 1982: Particulate and Gaseous Emissions from Wood Burning Fireplaces, Environmental Science and Technology, Vol. 16, No 10, pg 639-645.

Environment Australia, 2001, National Pollutant Inventory, http://www.environment.gov.au/epg/npi/handbooks/aedmanuals/aedmanuals.html

ESR, 1999, Otago inventory of domestic emissions. Unpublished report prepared for Otago Regional Council.

GVRD 1998, 1995 Emission inventory for the Lower Fraser Valley Airshed: Technical Appendix: Detailed Listing of Methodology and Results. Greater Vancouver Regional District and Fraser Valley Regional District.

Hennessy, W., and Gong, D., 2005, Review of particulate emissions from industrial coal combustion in New Zealand. Coal Research New Zealand Report 05-11025.

Lamb, C., 1999, Christchurch Home Heating Survey: A survey of domestic home heating methods and fuels in the Christchurch metropolitan area. Environment Canterbury Report U00/34.

Ministry for the Environment, 1994, Ambient Air Quality Guidelines. Ministry for the Environment, Wellington.

Ministry for the Environment, 2002*. Ambient Air Quality Guidelines for New Zealand.* Ministry for the Environment.

NIWA, 1998, Christchurch inventory of Total Emissions. Environment Canterbury Report R98/20.

NIWA, 2001, Greenhouse gas emission inventory for New Zealand. http://www.niwascience.co.nz/ncces/ghge/

Scott, A., 2004, Impact of strategies to reduce residential heating emissions in Christchurch - an update, Unpublished, draft Environment Canterbury Report.

Stern, C. H.; Jaasma, D.R.; Shelton, J.W.; Satterfield G. 1992: Parametric Study of Fireplace Particulate Matter and Carbon Monoxide Emissions, Journal Air Waste Manage. Assoc. Vol 42, No6, pg 777-783.

USEPA AP42, 2001, Emissions Database http://www.epa.gov/ttn/chief/ap42/

Wilton E. and Smith J. (2006). Real Life Emissions Testing of Pre 1994 Wood burners in New Zealand. Report No. TR2006/05, Environment Waikato.

Wilton, E., Anderson, B., Iseli, J., 2007, Cost effectiveness of policy options for boilers – Rangiora. Environment Canterbury Report – In press.

Appendix 1 Home Heating Questionnaire

1. Good morning / afternoon/evening - Is this a home or business number?(- terminate if business)
Hi, I'm _________from DigiPoll and I am calling on behalf of the Ministry for the Environment
May I please speak to an adult in your household who knows about your home heating systems? 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 during a typical year. The survey will take about 5 minutes. Is it a good time to talk to you now?

2. (a) Do you use any type of electrical heating in your MAIN living area during a typical year?

(b) What type of electrical heating do you use? Would it be...

- ☐ Night Store
- ☐ Radiant
- ☐ Portable Oil Column
- ☐ Panel
- ☐ Fan
- ☐ Heat Pump
- ☐ Don't Know/Refused
- ☐ Other (specify)

(c). Do you use any other heating system in your main living area in a typical year? *(If yes then question 3 otherwise Q9)*

3. (a) Do you use any type of gas heating in your MAIN living area during a typical year? *(If No then question 4)*

(b) Is it flued or unflued gas heating? If necessary: (A flued gas heating appliance will have an external vent or chimney)

(c) Which months of the year do you use your gas burner

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(d) How many days per week would you use your gas burner during

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(e) Do you use mains or bottled gas for home heating?

(f) What size gas bottle do you use?

(f.2) How many times in a winter would you refill your x kg gas bottle? Interviewer: Winter is defined as May to August inclusive.

4. (a) Do you use a log burner in your MAIN living area during a typical year? (This is a fully enclosed burner but does not include multi fuel burner i.e., those that burn coal) *(If No then question 5)*

(b) Which months of the year do you use your log burner

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(c) How many days per week would you use your log burner during?

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(d) How old is your log burner?

(e) In a typical year, how many pieces of wood do you use on an average winters day? Interviewers note : winter is defined as May to August inclusive.

(f) ask only If they used their log burner during non winter months How many pieces of wood do you use per day during the other months? Interviewers note : winter is defined as May to August inclusive.

(g) In a typical year, how much wood would you use per year on your log burner? (record wood use in cubic metres - note 1 cord equals 3.6 cubic meters of loosely piled blocks, one trailer equals about 1.65 cubic metres without cage, or 2.2 with cage)

(h) Do you buy wood for your log burner, or do you receive it free of charge?

(i) What proportion would be bought?

5. (a) Do you use an enclosed burner which burns coal as well as wood – i.e., a multi fuel burner in your MAIN living area during a typical year? (This includes incinerators, pot belly stoves, McKay space heaters etc but does not include open fires.) *(If No then question 6)*

(b) Which months of the year do you use your multi fuel burner?

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(c) How many days per week would you use your multi fuel burner during?

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(d) How old is your multi fuel burner?

(e) What type of multi fuel burner is it?

(f) In a typical year, how much wood do you use on your multi fuel burner per day during the winter? (ask them how many pieces of wood (logs) they use on an average winters day) Interviewer: Winter is defined as May to August inclusive

(g) ask only If they used their multi fuel burner during non winter months How much wood do you use per day during the other months?

(h) In a typical year, how much wood would you use per year on your multi fuel burner?_____ (record wood use in cubic metres - note 1 cord equals 3.6 cubic meters of loosely piled blocks one trailer equals about 1.65 cubic metres without cage, or 2.2 with

(i) Do you use coal on your multi fuel burner?

(j) How many buckets of coal do you use per day during the winter? (how many buckets of coal used on an average winters day) Interviewer: Winter is defined as May to August inclusive .

(k) Ask only If they used their multi fuel burner during non winter months How much coal do you use per day during the other months?

(l) Do you buy wood for your multi fuel burner, or do you receive it free of charge?

(m) What proportion would be bought?

6. (a) Do you use an open fire (includes a visor fireplace which is one enclosed on three sides but open to the front) in your MAIN living area during a typical year? *(If No then question 7)*

(b) Which months of the year do you use your open fire

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(c) How many days per week would you use your open fire during?

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(d) Do you use wood on your open fire?

(e) On a typical year, how much wood do you use per day during the winter? (ask them how many pieces of wood (logs) they use on an average winters day) Interviewer: Winter is defined as may to August inclusive

(f) Ask only If they used their open fire during non winter months How much wood do you use per day during the other months?

(g) In a typical year, how much wood would you use per year on your open fire? (record wood use in cubic metres - note 1 cord equals 3.6 cubic meters of loosely piled blocks one trailer equals about 1.65 cubic metres without cage, or 2.2 with cage)

(h) Do you use coal on your open fire?

(i) How many buckets of coal do you use per day during the winter? (how many buckets of coal used on an average winters day)____ Interviewer: Winter is defined as may to August inclusive

(j) Ask only If they used their open fire during non winter months How much coal do you use per day during the other months?

(k) Do you buy wood for your open fire, or do you receive it free of charge?

(l) What proportion would be bought?

7. (a) Do you use a pellet burner in your MAIN living area during a typical year? *(If No then question 8)*

(b) Which months of the year do you use your pellet burner

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(c) How many days per week would you use your pellet burner during?

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(d) How old is your pellet burner?

(e) What make and model is your pellet burner? First, can you tell me the make?

(e) and what model is your pellet burner?

(f) In a typical year, how many kilograms of pellets do you use on an average winters day? Interviewers note : winter is defined as May to August inclusive.

(g) Ask only If they used their pellet burner during non winter months How many kgs of pellets do you use per day during the other months? Interviewers note : winter is defined as May to August inclusive.

(h) In a typical year, how many kilograms of pellets would you use per year on your pellet burner?

8. (a) Do you use any other heating system in your MAIN living area during a typical year? *(If No then question 9)*

(b) What type of heating system do you use (if they respond with diesel or oil burner go to question c otherwise go to Q8)

(c) Which months of the year do you use your oil burner

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(d) How many days per week would you use your diesel/oil burner during?

☐ Jan	☐ Feb	☐ March	☐ April	☐ May	☐ June
☐ July	☐ Aug	☐ Sept	☐ Oct	☐ Nov	☐ Dec

(e) How much oil do you use per year ?

9. Do you burn rubbish or garden waste outside in the open or in an incinerator or rubbish bin

How many days would you burn rubbish outdoors during

a) winter (June, July, August)

b) spring (September, October, November)

c) summer (December, January, February)

d) autumn (March, April, May)

How much garden waste or rubbish would you burn each session. We are looking for cubic metres, or number of wheelbarrows full per fire.

10. Does you home have insulation?

- ☐ Ceiling
- ☐ Under floor
- ☐ Wall
- ☐ Cylinder wrap
- ☐ Double glazing
- ☐ None
- ☐ Don't know
- ☐ Other

DEMOGRAPHICS We would like to ask some questions about you now, just to make sure we have a cross-section of people for the survey. We keep this information strictly confidential.

D1. Would you mind telling me in what year you were born ?

D2. Which of the following describes you and your household situation?

- ☐ Single person below 40 living alone
- ☐ Single person 40 or older living alone
- ☐ Young couple without children
- ☐ Family with oldest child who is school age or younger
- ☐ Family with an adult child still at home
- ☐ Couple without children at home
- ☐ Flatting together
- ☐ Boarder

D3 With which ethnic group do you most closely relate?

Interviewer: tick gender.

How many people live at your address?

Do you own your home or rent it?

D5 What is your employment status:

Thank you for your time today. Your answers will be very helpful. In case you missed it, my name is ---------- from DigiPoll in Hamilton. Have a nice day/evening.

Appendix 2 Emission factors for domestic heating

Emission factors for domestic heating were those used in the Ministry for the Environment's (2005) assessment of burner removals to meet the NES in 31 urban areas of New Zealand. With the exception of gas, oil and post 1990 wood burners, these were based largely on the review of New Zealand emission rates carried out for the Christchurch 1999 emission inventory with adaptations made for different burner age categories. The latter review resulted in revised factors for open fires burning wood and the burning of coal on open fires and multi-fuel burners. The open fire wood emission factor was reduced from 15 g/kg (used in previous inventories) to 10 g/kg. This was based on a combination of overseas literature, in particular the studies by Stern (1992) and Dasch (1982), and the results of a limited number of tests carried out in New Zealand. The New Zealand tests were carried out by Applied Research and gave emission rates of around 7 g/kg.

An emission factor of 21 g/kg was selected for coal burning on an open fire and was based on the average of the tests carried out in New Zealand, weighted for the more predominant use of bituminous coals, based on the 80% to 20% figures quoted by Hennessy (1999). Previous emission factors were around 33 g/kg. An emission factor for PM_{10} for multi-fuel burners burning coal of 28 g/kg was selected based on a weighted average of the test results available for different appliance types.

Emission factors for the post 1996 wood burner categories were based on data collected in Nelson on burner types in different age categories. The older wood burner emission rates were based on testing of older wood burners "in situ" in Tokoroa during 2005 as detailed in Wilton and Smith, 2006, with adjustments for wet wood. The gas and oil PM_{10} emission factors have also been revised as a result of more recent testing in New Zealand (Scott, 2004).

Domestic heating emission factors for CO, NOx, SOx and CO_2 for all but post 1995 burners were also based on the Christchurch 1999 emission factor revisions.

Emission factors for $PM_{2.5}$ data for the burning of wood are based on the assumption that 100% of the PM_{10} emissions are $PM_{2.5}$ (USEPA, 1997). For coal burning USEPA AP-42 generalised particle size distributions for the $PM_{2.5}$ component were used. Oil burning emission rates were based on AP-42 data for a utility boiler. No data for LPG gas use was available so it was assumed that 100% of the PM_{10} would be in the finer $PM_{2.5}$ size fraction, based on AP-42 data for natural gas.