SEPTEMBER 2016

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Alexandra, Arrowtown, Mosgiel and Milton Air Emission Inventory – 2016

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EXECUTIVE SUMMARY

The main air contaminant of concern in urban areas of Otago is PM_{10}, particles in the air less than 10 microns in diameter. Concentrations of average daily PM_{10} have exceeded the National Environmental Standard (NES) limit of 50 µg/m^3 in many towns in the Region, with highest concentrations being measured in Alexandra, Arrowtown and Milton. Concentrations in excess of 50 µg/m^3 are also regularly measured in Mosgiel.

This report details an assessment of emissions to air in Alexandra, Arrowtown, Mosgiel and Milton. The purpose of the inventory is to evaluate the contribution of different sources and to assess the extent of any change in PM_{10} emissions from anthropogenic sources over time. Sources included in the inventory are domestic heating, motor vehicles and industrial and commercial activities. Natural source contributions (for example; sea salt and soil) are not included because the methodology to estimate emissions is less robust. Outdoor burning in not included as this activity is not permitted in these urban areas. While the evaluation focuses on PM_{10} other contaminants also evaluated include: $PM_{2.5}$, carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOC), carbon dioxide (CO_2) and benzene.

A domestic home heating survey was undertaken to determine the proportions of households using different heating methods and fuels. The results show that electricity and wood burners are the most common method of heating the main living area in the different areas with Alexandra having 66% use electricity and 58% use wood burners, Arrowtown having 67% and 54%, Milton 51% and 53% and Mosgiel 83% and 39%. For households using electricity heat pumps were the most common electric heating option (71% - 83% of households using heat pumps).

Domestic heating was the main source of anthropogenic PM_{10} emissions in all urban areas accounting for 99% of daily winter PM_{10} in Alexandra, Arrowtown and Mosgiel and 83% in Milton. The other main contributor in Milton is industry. Motor vehicle emissions are minimal at around 1% of daily winter PM_{10} emissions in all areas. On an average winter's night, around 171 kilograms of PM_{10} are discharged from these sources in Alexandra, 94 kg in Arrowtown, 119 kg in Milton and 271 kg in Mosgiel

A comparison of PM_{10} emissions to previous inventories (after adjusting for differences in methodology) suggests reductions in anthropogenic PM_{10} emissions of around 50% in all areas since around 2005/2006. The majority of this reduction occurs as a result of reduced coal use for domestic heating and the replacement of older wood burners with burners that meet the National Environmental Standard design criteria for wood burners. In Mosgiel a reasonable proportion (37%) of the reduction in emissions has occurred as a result of the closure or fuel switching within the industrial and commercial sector.

1 INTRODUCTION

The main air contaminant of concern in urban areas of Otago is PM_{10}, particles in the air less than 10 microns in diameter. Concentrations of PM_{10} have exceeded the National Environmental Standard (NES) limit of 50 µg/m^3 in many towns in the Region, with highest concentrations being measured in Alexandra, Arrowtown and Milton. Alexandra and Arrowtown comprise an air quality management area referred to as Air Zone 1, along with the towns of Cromwell and Clyde. Concentrations in excess of 50 µg/m^3 are also regularly measured other areas of the Region including Mosgiel, which with Milton forms part of Air Zone 2 as well as the areas of Green Island, Palmerston and South Dunedin.

Figure 1.1 shows the number of days PM_{10} has exceeded 50 µg/m^3 per year[1] in each of Alexandra, Arrowtown, Milton and Mosgiel. The number of exceedances will be strongly influenced by the frequency of meteorological conditions conducive to elevated concentrations. Arrowtown is influenced by a permanent change in the location of the monitoring site during 2014. Data suggests a downward trend in the number of exceedances per year for all locations excluding Mosgiel, although further statistical analysis is required to confirm reductions.

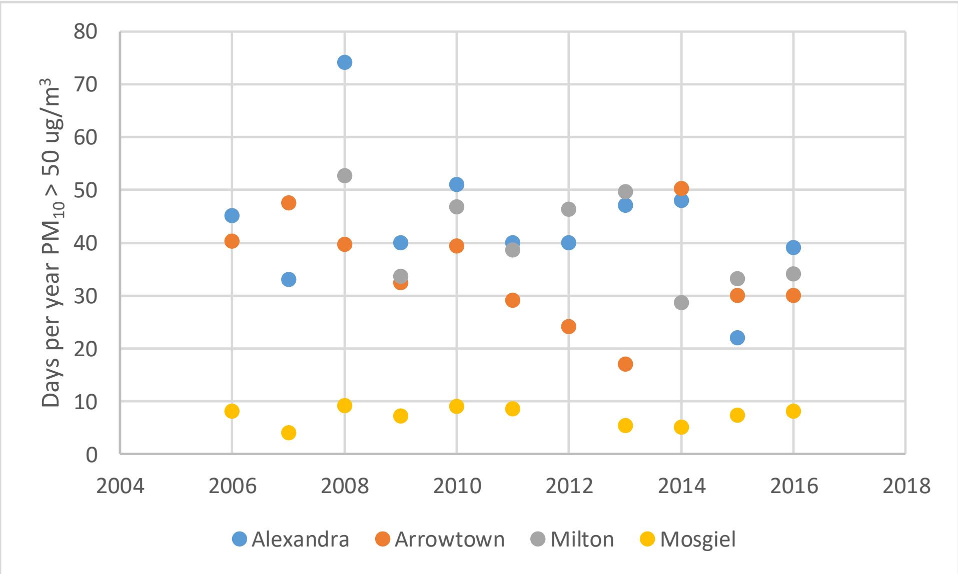

Figure 1-1: Estimated number of days when 50 µg/m^3 of PM_{10} (24-hour average) was exceeded per year

The NES for PM_{10} specifies a limit of 50 µg/m^3 (for PM_{10}) which can only be exceeded on one occasion per year. The NES was introduced in 2004 (Ministry for Environment, 2004) and took effect from September 2005. Full compliance with the NES is required by September 2020 in Air Zone 1 although concentrations must not exceed 50 µg/m^3 more than three times per year by September 2016.

Measures adopted by the Otago Regional Council (ORC) to reduce emissions include burner phase outs, education and financial incentives to upgrade burners. The ORC have been mindful throughout the process of the need to balance the requirement for warmth in homes.

[1] Estimates include statistical extrapolation for missing data (winter months only). The extrapolation used is measured exceedance days divided by total days measured (proportion of days 50 µg/m^3 was exceeded) times the number of days during winter for which there was no data.

Otago Regional Council carried out an emission inventory in 2005 for the towns of Alexandra, Mosgiel and Dunedin. This identified domestic home heating as the main source of PM_{10} in all three areas contributing 99%, 90% and 92% of the daily winter PM emissions respectively (Wilton, 2006).

The purpose of this emission inventory is to evaluate emissions to air for 2016 for the areas of Alexandra, Arrowtown, Mosgiel and Milton, the contribution of different sources to these emissions and to assess the extent of any change in emissions over time.

The sources that are included in emissions inventories in New Zealand are generally domestic heating, motor vehicle, industrial and commercial activities and outdoor burning. Natural source contributions (for example; sea salt and soil) are not included because methodologies are less robust. Outdoor burning is not included in the 2016 inventory as this activity is highly restricted in urban areas.

2 INVENTORY DESIGN

This emission inventory focuses on PM_{10} emissions as PM_{10} has been identified as the main contaminant of concern in urban New Zealand. It is unlikely that concentrations of other contaminants are likely to exceed national environmental standards (NES).

No NES exists for benzo(a)pyrene (BaP). However, concentrations of this contaminant have been found to be high and in excess of ambient air quality guidelines in Christchurch. A strong correlation was found with PM_{10} concentrations, which in Christchurch occur as a result of emissions from domestic home heating, and BaP concentrations (McCauley, 2005). BaP has not been included in the inventory as this contaminant owing to the main source being domestic heating and the strong correlations with PM_{10}. The other contaminant of concern in many urban areas of New Zealand is arsenic (Ancelet, Davy, & Trompetter, 2013). Arsenic is not included in the emission inventory as the main source is domestic burning of treated timber. Although this is prohibited under the Air Plan burning treated wood does occur in many urban areas of New Zealand, where it is similarly prohibited. The Otago Regional Council has not established whether there is an issue with arsenic in the Region.

2.1 Selection of sources

Estimates of emissions from the domestic heating, motor vehicles and industry are included in the emissions inventory. No outdoor burning emissions are estimated as this activity is highly restricted in these urban areas. The report also discusses PM_{10} emissions from a number of other minor sources.

2.2 Selection of contaminants

The inventory included an assessment of emissions of suspended particles (PM_{10}), fine particles ($PM_{2.5}$) carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), carbon dioxide (CO_2), and benzene. The latter contaminant has been included here because of the potential issues identified above.

Emissions of PM_{10}, CO, SOx and NOx are included as these contaminants are NES contaminants because of their potential for adverse health impacts. $PM_{2.5}$ has been included in the inventory because this size fraction may have significance in terms of the current review of the NES. 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 generally 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 (e.g., www.climatechange.govt.nz.) should detailed data on this source be required. Volatile organic compounds are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. It is unlikely that ozone formation from emissions within Alexandra, Arrowtown, Mosgiel or Milton would cause ozone problems. 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. It is likely that the inventory does not capture a number of sources of VOCs.

2.3 Selection of areas

As the towns form only parts of a larger airshed the inventory areas have been selected based on census area unit (CAU) boundaries. The census area units used in the emission inventory for each area are:

- Alexandra: Alexandra CAU
- Arrowtown: Arrowtown CAU

- Mosgiel: Mosgiel East and Mosgiel South CAUs
- Milton: Milton CAU

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. Motor vehicle data were collected for an average day as models do not contain seasonal variations in vehicle movements. Industrial data were collected by season.

No differentiation was made for weekday and weekend sources. Limited time-of-day breakdowns were obtained for the data.

3 DOMESTIC HEATING

3.1 Methodology

Domestic heating methods and fuel use used by households in the four inventory areas was collected using a household survey carried out during June and July 2016 (Appendix A). Table 3.1 shows the number of households based on 2013 census data, the estimated number of 2016 households[2], and survey details.

Table 3.1: Summary household, area and survey data.

	Households 2013 census	2016 estimated households	Sample size	Area (ha)	Sample error
Alexandra	2118	2169	324	976	5%
Arrowtown	984	1049	270	236	5%
Milton	792	792	255	202	5%
Mosgiel	3027	3063	333	464	5%

Home heating methods were classified as; electricity, open fires, wood burners 10 years or older (pre 2007), wood burners five to 10 years old (2007-2011), wood burners less than five years old (post 2011), pellet fires, multi fuel burners, gas burners and oil burners. The 2007-2011 and post 2011 wood burner categories would contain wood burners meeting the National Environmental Standard (NES) design criteria which was introduced in 2004 and effective from September 2005. In addition, burners installed during 2006 would also be NES-compliant. To simplify the calculations of emissions the pre 2007 burner category was adjusted to include an estimate of the number of burners installed during 2006 (based on the yearly installation rate for the 2007-2011 burners) and revised to be called the pre 2006 burner age category.

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 B.

Table 3.2: Emission factors for domestic heating methods.

	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	Benzene g/kg
Open fire - wood	7.5	7.5	105	1.2	0.2	30	1600	0.97
Open fire - coal	21	18	70	4	8	15	2600	0.00065
Pre 2006 burners	10	10	140	0.5	0.2	33	1600	0.97
Post 2006 burners	4.5	4.5	63	0.5	0.2	20	1600	0.97
Pellet burners	2	2	20	0.5	0.2	20	1600	0.97
Multi-fuel - wood	10	10	140	0.5	0.2	20	1600	0.97
Multi-fuel – coal	19	17	110	1.6	8	15	2600	0.00065
Oil	0.3	0.22	0.6	2.2	3.8	0.25	3200	

The average daily wood use on wood burners for each of the towns was calculated by dividing the annual fuel consumption (provided as an estimate of m^3 (or cords) per year) by the number of days per year the household indicated they burnt. For open fires and multi fuel burners wood use was estimated based on the reported daily pieces of wood used and a kilogram to log ratio of 1.6. The value of 1.6 kg/log was selected as the mid-point of the range found from different New Zealand evaluations (Wilton & Bluett, 2012, Wilton, Smith, Dey, & Webley,

[2] 2016 households were estimated using 2013 census data and estimated area changes in population for territorial local authority areas (Statistics New Zealand, 2014).

2006, Metcalfe, Sridhar, & Wickham, 2013). The log weight used for this work (1.6 kg/ piece) is the midpoint and average of the range of values.

Emissions for each contaminant 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 density of wood of 400 kg/m^3.
- The average weight of a bucket of coal is 9 kilograms.

3.2 Home heating methods Alexandra

Electricity and wood burners were the main heating methods in Alexandra with 66% and 58% of households respectively using these methods to heat their main living area (Table 3.3) during 2016. Heat pumps were the most common method type of electric heating method being used by 83% of households using electricity (Figure 3.1). Around 12% of households used gas for home heating and 8% use diesel oil. No households reported using open fires and less than 1% reported using coal on multi fuel burners. Table 3.3 also shows that households relied on more than one method of heating their main living area during the winter months.

Around 31 tonnes of wood was burnt per typical winter's night in Alexandra and around 0.2 tonnes of coal.

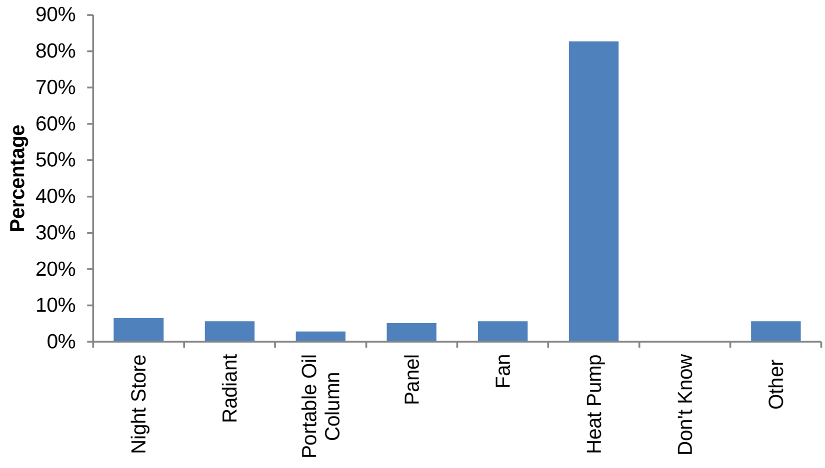

Figure 3-1: Electric heating options for Alexandra households (main living area)

Table 3.3: Home heating methods and fuels in Alexandra.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	66%	1,433		
Total Gas	12%	261		
Flued gas	8%	181		
Unflued gas	4%	80		
Oil	8%	174		
Open fire	0%	0		
Open fire - wood	0%	0	0.0	
Open fire - coal	0%	0	0.0	
Total Wood burner	58%	1,252	29.9	98%
Pre-2006 wood burner	10%	225	5.4	18%
2006-2011 wood burner	21%	448	10.7	35%
Post-2011 wood burner	27%	578	13.8	45%
Multi-fuel burners	0.6%	13		
Multi-fuel burners-wood	0.3%	7	0.1	0%
Multi-fuel burners-coal	0.6%	13	0.2	1%
Pellet burners	3%	67	0.5	1%
Wood fired cooker	0.6%	13		
Total wood	58%	1,259	30	99%
Total coal	1%	13	0.2	1%
Total		2,169	31	100%

3.3 Home heating methods Arrowtown

Table 3.4 shows electricity was the main heating method in Arrowtown with 67% of households using this method to heat their main living area. Wood burners were also common with 54% of households using them. Heat pumps were the most common method type of electric heating method with 71% of households using electricity using them (Figure 3.2). A small proportion of households reported using open fires or multi fuel burners with around three percent using coal as a fuel. Table 3.4 also shows that households relied on more than one method of heating their main living area during the winter months.

Around 15 tonnes of wood was burnt per typical winter's night in Arrowtown and around 0.2 tonnes of coal.

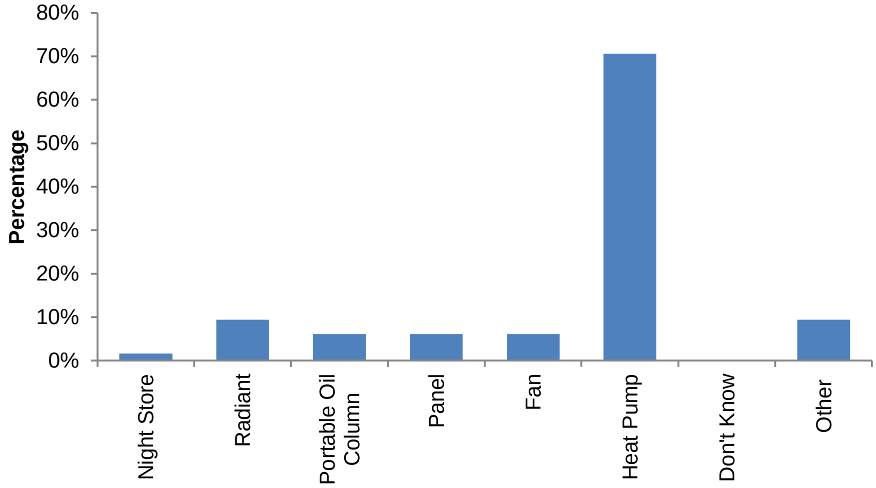

Figure 3-2: Electric heating options for Arrowtown households (main living area)

Table 3.4: Home heating methods and fuels in Arrowtown.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	67%	699		
Total Gas	19%	202		
Flued gas	16%	163		
Unflued gas	4%	39		
Oil	10%	101		
Open fire	8%	82		
Open fire - wood	7%	78	1.0	7%
Open fire - coal	1%	12	0.0	0%
Total Wood burner	54%	563	13.6	89%
Pre-2006 wood burner	13%	134	3.2	21%
2006-2011 wood burner	20%	214	5.2	34%
Post-2011 wood burner	21%	215	5.2	34%
Multi-fuel burners	3%	31		
Multi-fuel burners-wood	2%	23	0.3	2%
Multi-fuel burners-coal	2%	19	0.2	1%
Pellet burners	2%	19	0.1	0.9%
Wood fired cookers	1%	16		
Total wood	63%	664	15	98%
Total coal	3%	31	0.2	1%
Total		1,049	15	

3.4 Home heating methods in Milton

Wood burners and electricity were the most common heating methods in Milton with 53% and 51% of households using these methods respectively (Table 3.4) in their main living area during 2016. Multi fuel burners were used by 16% of households. Heat pumps were the most common method type of electric heating method and were used by 72% of households using electricity in their main living area (Figure 3.3).

Around 12 tonnes of wood and less than one tonne of coal were burnt per typical winter's night in Milton during 2016.

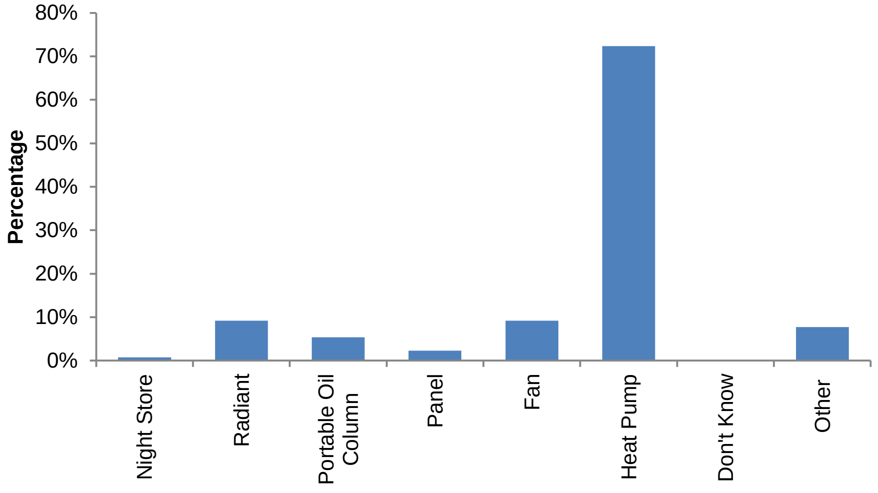

Figure 3-3: Electric heating options for Milton households (main living area)

Table 3.5: Home heating methods and fuels in Milton.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	51%	404		
Total Gas	9%	71		
Flued gas	4%	31		
Unflued gas	5%	41		
Oil	3%	25		
Open fire	1%	9		
Open fire - wood	1%	9	0.0	0%
Open fire - coal	0%	0	0.0	0%
Total Wood burner	53%	419	10.4	80%
Pre-2006 wood burner	18%	139	3.4	27%
2006-2011 wood burner	20%	162	4.0	31%
Post-2011 wood burner	15%	118	2.9	22%
Multi-fuel burners	15.7%	124		
Multi-fuel burners-wood	11.0%	87	1.5	12%
Multi-fuel burners-coal	12%	93	0.9	7%
Pellet burners	2%	19	0.1	1%
Wood fired cooker	1%	9		
Total wood	65%	516	12	93%
Total coal	12%	93	0.9	7%
Total		792	13	100%

3.5 Home heating methods in Mosgiel

Electricity was the most common heating method in Mosgiel with 83% of households using this method (Table 3.5). Heat pumps were the most common method type of electric heating method with 76% of households using electricity using them (Figure 3.4). Wood burners were used by around 39% of households and multi fuel burners by 11% during 2016. Table 3.5 also shows that households relied on more than one method of heating their main living area during the winter months.

Around 30 tonnes of wood and two tonnes of coal was burnt per typical winter's night in Mosgiel.

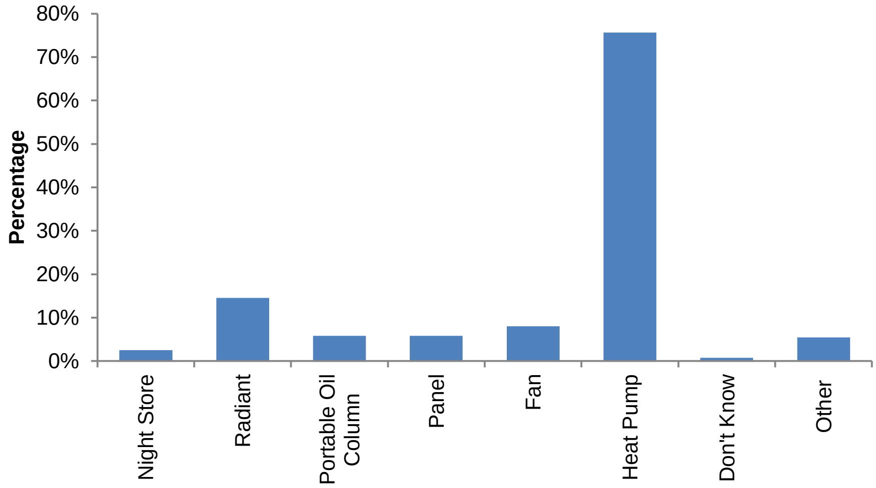

Figure 3-4: Electric heating options for Mosgiel households (main living area)

Table 3.6: Home heating methods and fuels in Mosgiel.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	83%	2,530		
Total Gas	9%	276		
Flued gas	6%	187		
Unflued gas	3%	89		
Oil	0%	9		
Open fire	1%	37		
Open fire - wood	1%	37	0.5	1%
Open fire - coal	0%	0	0.0	0%
Total Wood burner	39%	1,187	26.3	82%
Pre-2006 wood burner	21%	639	14.2	44%
2006-2011 wood burner	10%	311	6.9	21%
Post-2011 wood burner	8%	237	5.3	16%
Multi-fuel burners	11%	322		
Multi-fuel burners-wood	7%	212	2.7	9%
Multi-fuel burners-coal	7%	212	2.0	6%
Pellet burners	3%	92	0.6	1.8%
Wood fired cookers	1%	37		

Total wood	47%	1435	30	92%
Total coal	7%	212	2.0	6%
Total		3,063	32	

3.6 Emissions from domestic heating Alexandra

Around 169 kilograms of PM_{10} are emitted from domestic home heating in Alexandra on an average winter's night (Table 3.6). Days when households may not be using specific home heating methods are accounted for in this method. This may increase to around 186 kilograms if all households are using their wood burners on a given night (Table 3.7).

The majority of the daily PM_{10} emissions from domestic heating during the winter are from wood burners installed after 2006 because the largest number of dwellings have these burners (Figure 3.5). Wood burners installed pre 2006 contribute 32% of the daily winter PM_{10} and comprise only 18% of households using wood burners.

The seasonal variation in contaminant emissions is shown in Table 3.8. Figure 3.6 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during May, June, July and August.

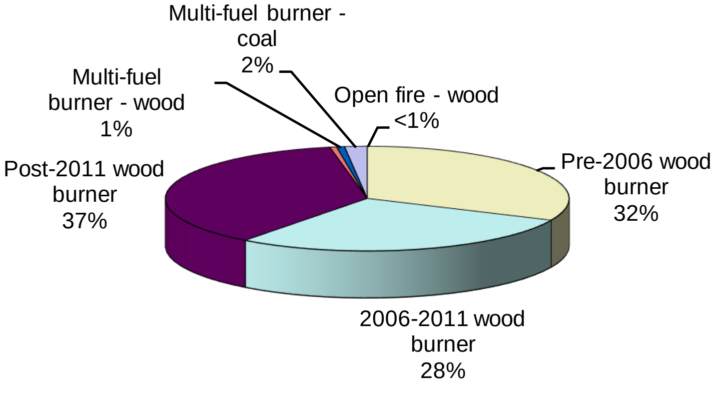

Figure 3-5: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Alexandra.

Table 3.7: Alexandra winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/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	0%	0	0	0%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner																										
Pre 2006 wood burner	5.4	18%	54	55	32%	755	773	32%	3	3	17%	1	1	15%	178	182	26%	9	9	18%	54	55	32%	5	5	18%
2006-2011 wood burner	10.7	35%	48	49	28%	675	691	29%	5	5	35%	2	2	29%	214	219	31%	17	18	35%	48	49	29%	10	11	35%
Post 2011 wood burner	13.8	45%	62	64	37%	871	893	37%	7	7	45%	3	3	37%	277	283	41%	22	23	45%	62	64	37%	13	14	45%
Pellet Burner	0.5	1%	0.9	1	1%	9	9	0%	0	0	1%	0	0	1%	9	9	1%	1	1	1%	1	1	1%	0	0	2%
Multi fuel burner																										
Multi fuel– wood	0.1	0%	1	1	1%	15	15	1%	0	0	0%	0	0	0%	2	2	0%	0	0	0%	1	1	1%	0	0	0%
Multi fuel – coal	0.2	1%	3	3	2%	18	18	1%	0	0	2%	1	1	17%	2	2	0%	0	0	1%	3	3	2%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	30.5	99%	166	170	98%	2325	2382	99%	15	16	98%	6	6	83%	680	697	100%	49	50	99%	166	170	98%	30	30	100%
Total Coal	0.2	1%	3	3	2%	18	18	1%	0	0	2%	1	1	17%	2	2	0%	0	0	1%	3	3	2%	0	0	0%
Total	31		169	174		2342	2400		16	16		7	8		682	699		49	50		169	173		30	30	

Table 3.8: Alexandra winter daily domestic heating emissions by appliance type (worst case average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/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	0%	0	0	0%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner																										
Pre 2006 wood burner	5.9	18%	59	61	32%	827	848	32%	3	3	17%	1	1	15%	195	200	26%	9	10	17%	59	61	32%	6	6	18%
2006-2011 wood burner	11.7	35%	53	54	28%	740	758	29%	6	6	34%	2	2	29%	235	241	31%	19	19	35%	53	54	29%	11	12	35%
Post 2011 wood burner	15.2	45%	68	70	37%	955	978	37%	8	8	45%	3	3	38%	303	311	40%	24	25	45%	68	70	37%	15	15	45%
Pellet Burner	0.6	2%	1	1	1%	12	13	0%	0	0	2%	0	0	2%	12	13	2%	1	1	2%	1	1	1%	1	1	2%
Multi fuel burner																										
Multi fuel– wood	0.1	0%	1	1	1%	15	15	1%	0	0	0%	0	0	0%	2	2	0%	0	0	0%	1	1	1%	0	0	0%
Multi fuel – coal	0.2	0%	3	3	2%	18	18	1%	0	0	2%	1	1	16%	2	2	0%	0	0	1%	3	3	1%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	34	100%	182	187	98%	2550	2612	99%	17	17	98%	7	7	84%	748	766	100%	54	55	99%	182	187	99%	33	33	100%
Total Coal	0	0%	3	3	2%	18	18	1%	0	0	2%	1	1	16%	2	2	0%	0	0	1%	3	3	1%	0	0	0%
Total	34		186	190		2567	2630		17	17		8	8		750	769		54	55		185	190		33	33	

Table 3.9: 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	Benzene kg/day
January	0	3	0	0	1	0	0	0
February	1	8	0	0	2	0	1	0
March	1	15	0	0	4	0	1	0
April	6	84	1	0	24	2	6	1
May	109	1505	10	5	438	32	108	19
June	164	2274	15	7	662	48	164	29
July	169	2342	16	7	682	49	169	30
August	148	2046	14	7	595	43	148	26
September	20	277	2	1	81	6	20	4
October	5	63	0	0	18	1	5	1
November	1	19	0	0	6	0	1	0
December	0	3	0	0	1	0	0	0
Total (kg/year)	19160	265173	1753	828	77200	5565	19121	3346

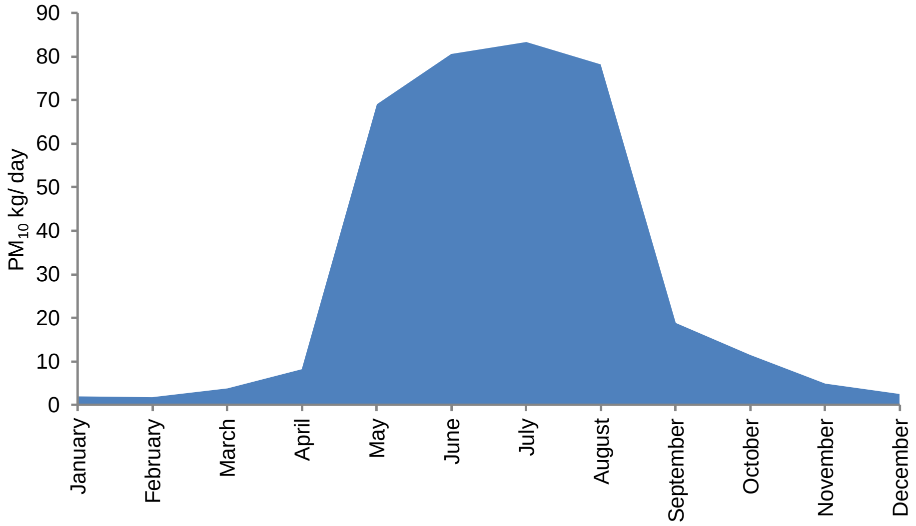

Figure 3-6: Monthly variations in PM_{10} emissions from domestic heating in Alexandra.

3.7 Emissions from domestic heating Arrowtown

Around half of the daily PM_{10} emissions from domestic heating during the winter are from post 2006 wood burners (Figure 3.7). Older wood burners contribute 34% of the daily domestic heating PM_{10} emissions and open fires 8%. Multi fuel burners are a minor contributor at around 5% of daily winter PM_{10}.

Tables 3.10 and 3.11 show the estimates of emissions for different heating methods under average and worst-case scenarios. Average daily wintertime PM_{10} emissions are around 94 kilograms per day. Days when households may not be using specific home heating methods are accounted for in this method. Under the worst-case scenario around 121 kilograms of PM_{10} are discharged from all households using solid fuel burners on a particular night.

The seasonal variation in contaminant emissions is shown in Table 3.12. Figure 3.8 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during June, July and August.

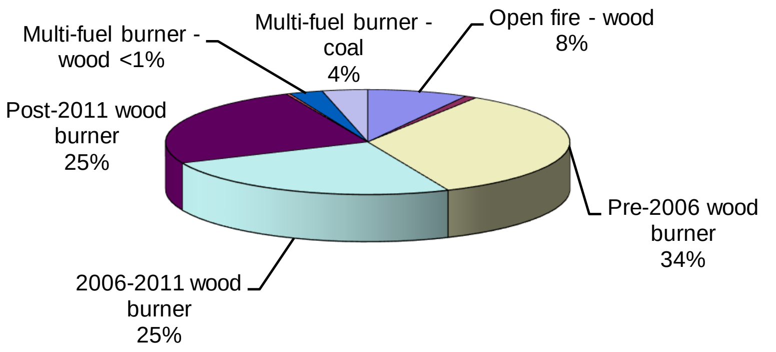

Figure 3-7: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Arrowtown.

Table 3.10: Arrowtown winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	1.0	7%	8	32	8%	106	449	8%	1	5	14%	0	1	4%	30	128	9%	2	7	7%	8	32	8%	1	4	7%
Open fire - coal	0.0	0%	1	4	1%	3	12	0%	0	1	2%	0	1	7%	1	3	0%	0	0	0%	1	3	1%	0	0	0%
Wood burner																										
Pre 2006 wood burner	3.2	21%	32.3	137	35%	453	1919	36%	2	7	19%	1	3	14%	107	452	30%	5	22	21%	32	137	35%	3	13	22%
2006-2011 wood burner	5.2	34%	23.3	99	25%	327	1384	26%	3	11	30%	1	4	22%	104	439	29%	8	35	34%	23	99	25%	5	21	35%
Post 2011 wood burner	5.2	34%	23.4	99	25%	328	1390	26%	3	11	30%	1	4	22%	104	441	29%	8	35	34%	23	99	25%	5	21	35%
Pellet Burner	0.1	1%	0.3	1	0%	3	12	0%	0	0	1%	0	0	1%	3	12	1%	0	1	1%	0	1	0%	0	1	1%
Multi fuel burner																										
Multi fuel– wood	0.3	2%	3	11	3%	35	150	3%	0	1	1%	0	0	1%	5	21	1%	0	2	2%	3	11	3%	0	1	2%
Multi fuel – coal	0.2	1%	3	14	4%	20	83	2%	0	1	3%	1	6	30%	3	11	1%	0	2	2%	3	13	3%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	15.0	99%	89	379	95%	1252	5303	98%	8	35	95%	3	13	63%	353	1494	99%	24	102	98%	89	379	96%	15	62	100%
Total Coal	0.2	1%	4	18	5%	23	96	2%	0	2	5%	2	7	37%	3	14	1%	1	2	2%	4	16	4%	0	0	0%
Total	15		94	397		1274	5399		9	37		5	20		356	1508		25	104		93	395		15	62	

Table 3.11: Arrowtown winter daily domestic heating emissions by appliance type (worst case average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																											
Open fire - wood	1.7	9%	13	54	10%	177	750	11%	2	9	18%	0	1	5%	51	214	11%	3	11	9%	13	54	11%	2	7	9%
Open fire - coal	0.1	0%	1	6	1%	5	21	0%	0	1	2%	1	2	9%	1	4	0%	0	1	1%	1	5	1%	0	0	0%
Wood burner																											
Pre 2006 wood burner	4.0	21%	40	170	33%	563	2387	34%	2	9	18%	1	3	13%	133	563	29%	6	27	20%	40	170	34%	4	17	21%
2006-2011 wood burner	6.4	33%	29	123	24%	406	1721	25%	3	14	28%	1	5	21%	129	546	28%	10	44	33%	29	123	24%	6	27	34%
Post 2011 wood burner	6.5	33%	29	123	24%	408	1729	25%	3	14	28%	1	5	21%	130	549	28%	10	44	33%	29	123	24%	6	27	34%
Pellet Burner	0.2	1%	0	1	0%	4	15	0%	0	0	1%	0	0	1%	4	15	1%	0	1	1%	0	1	0%	0	1	1%
Multi fuel burner																											
Multi fuel– wood	0.3	2%	3	14	3%	46	195	3%	0	1	1%	0	0	1%	7	28	1%	1	2	2%	3	14	3%	0	1	2%
Multi fuel – coal	0.2	1%	4	19	4%	26	109	2%	0	2	3%	2	8	30%	3	15	1%	1	3	2%	4	17	3%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	19	98%	115	486	95%	1604	6797	98%	11	46	94%	4	16	61%	452	1915	99%	31	130	97%	115	486	96%	19	79	100%
Total Coal	0	2%	6	25	5%	31	129	2%	1	3	6%	2	10	39%	5	19	1%	1	3	3%	5	22	4%	0	0	0%
Total	19		121	511		1635	6927		11	48		6	26		456	1934		31	133		120	508		19	79	

Table 3.12: Monthly variations in contaminant emissions from domestic heating in Arrowtown.

	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	Benzene kg/day
January	0	6	0	0	2	0	0	0
February	0	3	0	0	1	0	0	0
March	1	8	0	0	2	0	1	0
April	5	69	0	0	19	1	5	1
May	69	939	6	3	263	18	68	11
June	92	1254	9	5	350	24	92	14
July	94	1274	9	5	356	25	93	15
August	87	1180	8	4	330	23	86	14
September	13	179	1	0	51	4	13	2
October	5	71	0	0	20	1	5	1
November	1	21	0	0	6	0	1	0
December	1	8	0	0	2	0	1	0
Total (kg/year)	11287	153841	1034	557	43016	2978	11231	1767

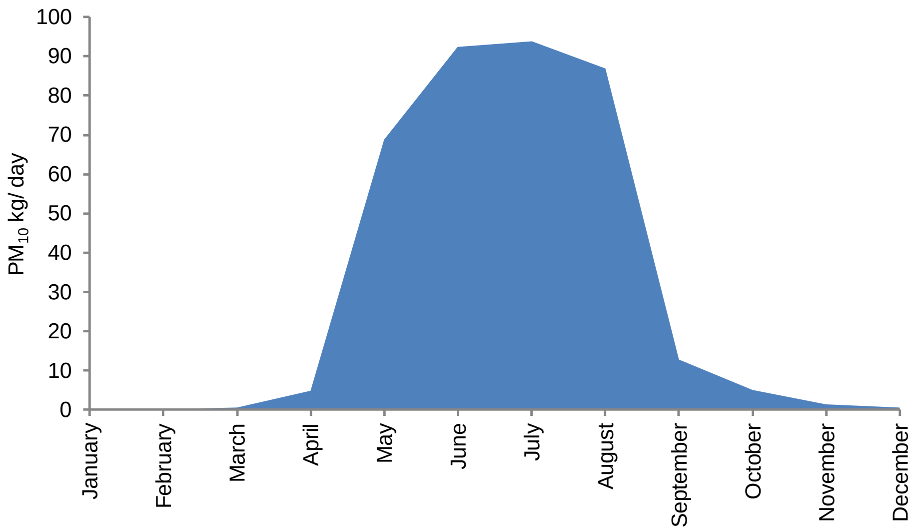

Figure 3-8: Monthly variations in PM_{10} emissions from domestic heating in Arrowtown.

3.8 Emissions from domestic heating Milton

Around 99 kilograms of PM_{10} are emitted from domestic home heating in Milton on an average winter's night (Table 3.13). Days when households may not be using specific home heating methods are accounted for in this method. This may increase to around 127 kilograms if all households are using their wood burners on a given night (Table 3.14).

The majority (35%) of the daily PM_{10} emissions from domestic heating during the winter are from pre 2006 wood burners (Figure 3.9). Around 31% of the daily winter PM_{10} emissions are from burners installed after 2006. Multi fuel burners contribute 34% with just over half of that occurring as a result of burning coal.

The seasonal variation in contaminant emissions is shown in Table 3.15. Figure 3.10 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during May, June, July and August.

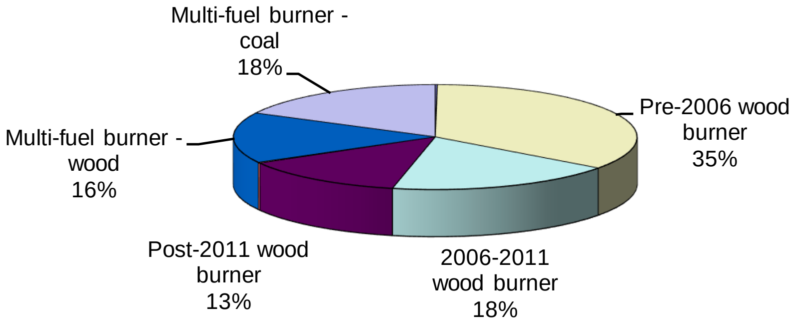

Figure 3-9: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Milton.

Table 3.13: Milton winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	0.0	0%	0	1	0%	2	11	0%	0	0	0%	0	0	0%	1	3	0%	0	0	0%	0	1	0%	0	0	0%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	10.5																									
Pre 2006 wood burner	3.4	27%	34	171	35%	482	2387	39%	2	9	23%	1	3	7%	114	563	38%	6	27	25%	34	171	36%	3	17	29%
2006-2011 wood burner	4.0	31%	18	89	18%	253	1251	20%	2	10	27%	1	4	8%	80	397	27%	6	32	30%	18	89	19%	4	19	33%
Post 2011 wood burner	2.9	22%	13	65	13%	184	909	15%	1	7	19%	1	3	6%	58	288	19%	5	23	22%	13	65	14%	3	14	24%
Pellet Burner	0.1	1%	0.2	1	0%	2	12	0%	0	0	1%	0	0	0%	2	12	1%	0	1	1%	0	1	0%	0	1	1%
Multi fuel burner																										
Multi fuel– wood	1.5	12%	15	76	16%	215	1067	17%	1	4	10%	0	2	3%	31	152	10%	2	12	11%	15	76	16%	1	7	13%
Multi fuel – coal	0.9	7%	17	85	17%	100	494	8%	1	7	19%	7	36	75%	14	67	5%	2	12	11%	15	75	16%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	12.1	93%	81	403	83%	1139	5637	92%	6	30	81%	2	12	25%	286	1416	95%	19	95	89%	81	403	84%	12	58	100%
Total Coal	0.9	7%	17	85	17%	100	494	8%	1	7	19%	7	36	75%	14	67	5%	2	12	11%	15	75	16%	0	0	0%
Total	13		99	488		1238	6131		7	37		10	48		300	1483		22	107		97	478		12	58	

Table 3.14: Milton winter daily domestic heating emissions by appliance type (worst case average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	0.1	1%	1	6	1%	16	77	1%	0	1	2%	0	0	0%	4	22	1%	0	1	1%	1	6	1%	0	1	1%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner																										
Pre 2006 wood burner	4.5	27%	45	222	35%	629	3112	39%	2	11	23%	1	4	7%	148	734	38%	7	36	26%	45	222	36%	4	22	29%
2006-2011 wood burner	5.2	31%	24	116	18%	329	1630	21%	3	13	27%	1	5	9%	105	518	27%	8	41	30%	24	116	19%	5	25	33%
Post 2011 wood burner	3.8	23%	17	85	13%	239	1184	15%	2	9	19%	1	4	6%	76	376	19%	6	30	22%	17	85	14%	4	18	24%
Pellet Burner	0.2	1%	0	2	0%	4	18	0%	0	0	1%	0	0	0%	4	18	1%	0	1	1%	0	2	0%	0	1	1%
Multi fuel burner																										
Multi fuel– wood	1.9	11%	19	94	15%	266	1316	17%	1	5	10%	0	2	3%	38	188	10%	3	15	11%	19	94	15%	2	9	12%
Multi fuel – coal	1.1	7%	21	105	17%	123	609	8%	2	9	18%	9	44	74%	17	83	4%	3	14	10%	19	93	15%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	16	93%	106	525	83%	1482	7338	92%	8	39	82%	3	16	26%	375	1855	96%	25	125	90%	106	525	85%	15	76	100%
Total Coal	1	7%	21	105	17%	123	609	8%	2	9	18%	9	44	74%	17	83	4%	3	14	10%	19	93	15%	0	0	0%
Total	17		127	630		1605	7946		10	48		12	60		391	1938		28	139		125	617		15	76	

Table 3.15: Monthly variations in contaminant emissions from domestic heating in Milton.

	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	Benzene kg/day
January	2	30	0	0	7	1	2	0
February	2	25	0	0	6	0	2	0
March	4	56	0	0	13	1	4	1
April	10	127	1	1	31	2	10	1
May	82	1034	6	8	251	18	81	10
June	96	1210	7	9	294	21	94	11
July	99	1249	8	10	303	22	97	12
August	93	1169	7	9	283	20	91	11
September	23	292	2	2	71	5	22	3
October	14	173	1	1	42	3	13	2
November	6	70	0	1	16	1	6	1
December	3	35	0	0	8	1	3	0
Total (kg/year)	13340	167826	1012	1292	40632	2931	13065	1587

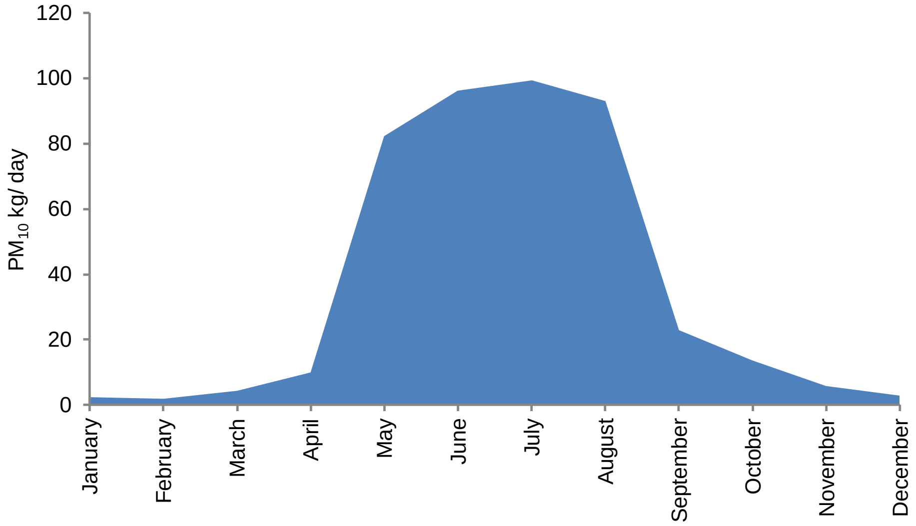

Figure 3-10: Monthly variations in PM_{10} emissions from domestic heating in Milton.

3.9 Emissions from domestic heating in Mosgiel

Around 267 kilograms of PM_{10} was emitted from domestic home heating in Milton on an average winter's day (Table 3.16). Days when households may not be using specific home heating methods are accounted for in this method. This may increase to around 323 kilograms if all households are using their wood burners on a given night (Table 3.17).

More than half of the daily winter PM_{10} emissions in Mosgiel were from older pre 2006 wood burners (Figure 3.11). Multi fuel burners emit 25% of the daily winter PM_{10} and post 2006 burners contributed 21%.

The seasonal variation in contaminant emissions is shown in Table 3.18. Figure 3.12 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during May June, July and August.

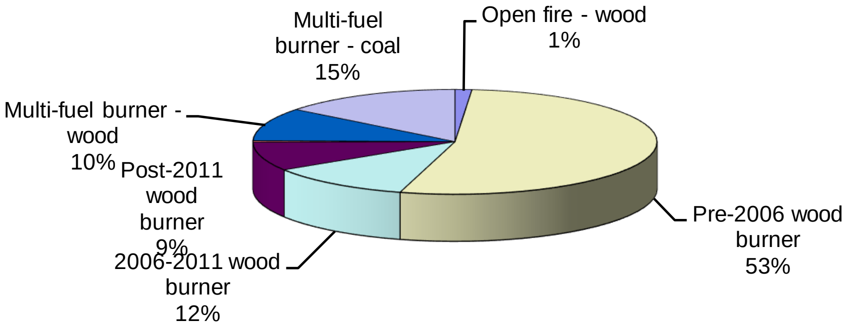

Figure 3-11: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Mosgiel.

Table 3.16: Mosgiel winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	0.5	1%	4	8	1%	50	108	1%	1	1	3%	0	0	0%	14	31	2%	1	2	1%	4	8	1%	0	1	2%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	26.3	82%																								
Pre 2006 wood burner	14.2	44%	142	305	53%	1983	4274	58%	7	15	38%	3	6	13%	467	1007	57%	23	49	42%	142	305	54%	14	30	47%
2006-2011 wood burner	6.9	21%	31	67	12%	434	936	13%	3	7	18%	1	3	6%	138	297	17%	11	24	21%	31	67	12%	7	14	23%
Post 2011 wood burner	5.3	16%	24	51	9%	332	715	10%	3	6	14%	1	2	5%	105	227	13%	8	18	16%	24	51	9%	5	11	17%
Pellet Burner	0.6	2%	1.2	3	0%	12	25	0%	0	1	2%	0	0	1%	12	25	1%	1	2	2%	1	3	0%	1	1	2%
Multi fuel burner																										
Multi fuel– wood	2.7	9%	27	59	10%	384	828	11%	1	3	7%	1	1	2%	55	118	7%	4	9	8%	27	59	10%	3	6	9%
Multi fuel – coal	2.0	6%	39	83	14%	223	481	7%	3	7	17%	16	35	73%	30	66	4%	5	11	10%	34	73	13%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	30.1	94%	229	493	86%	3195	6886	93%	15	33	83%	6	13	27%	792	1706	96%	48	104	90%	229	493	87%	29	63	100%
Total Coal	2.0	6%	39	83	14%	223	481	7%	3	7	17%	16	35	73%	30	66	4%	5	11	10%	34	73	13%	0	0	0%
Total	32		267	576		3418	7367		19	40		22	48		822	1772		53	115		263	566		29	63	

Table 3.17: Mosgiel winter daily domestic heating emissions by appliance type (worst case average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	0.8	2%	6	13	2%	82	178	2%	1	2	4%	0	0	1%	24	51	2%	1	3	2%	6	13	2%	1	2	2%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner																										
Pre 2006 wood burner	16.8	43%	168	362	52%	2350	5065	57%	8	18	37%	3	7	12%	554	1194	56%	27	58	41%	168	362	53%	16	35	46%
2006-2011 wood burner	8.2	21%	37	79	11%	515	1109	12%	4	9	18%	2	4	6%	163	352	16%	13	28	20%	37	79	12%	8	17	22%
Post 2011 wood burner	6.2	16%	28	61	9%	393	847	10%	3	7	14%	1	3	5%	125	269	13%	10	22	15%	28	61	9%	6	13	17%
Pellet Burner	0.9	2%	2	4	1%	18	40	0%	0	1	2%	0	0	1%	18	40	2%	1	3	2%	2	4	1%	1	2	3%
Multi fuel burner																										
Multi fuel– wood	3.4	9%	34	74	11%	480	1035	12%	2	4	8%	1	1	2%	69	148	7%	5	12	8%	34	74	11%	3	7	9%
Multi fuel – coal	2.5	7%	48	104	15%	279	602	7%	4	9	18%	20	44	74%	38	82	4%	7	14	10%	42	91	13%	0	0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	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	0%	0	0	0%
Total Wood	36	93%	275	592	85%	3839	8273	93%	19	40	82%	7	16	26%	953	2053	96%	58	125	90%	275	592	87%	35	76	100%
Total Coal	3	7%	48	104	15%	279	602	7%	4	9	18%	20	44	74%	38	82	4%	7	14	10%	42	91	13%	0	0	0%
Total	39		323	696		4118	8875		23	49		28	59		991	2135		65	139		317	684		35	76	

Table 3.18: 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	Benzene kg/day
January	1	13	0	0	4	0	1	0
February	1	13	0	0	4	0	1	0
March	2	27	0	0	7	0	2	0
April	14	187	1	1	45	3	14	2
May	186	2358	13	17	558	37	182	20
June	267	3424	19	22	825	54	262	29
July	267	3418	19	22	822	53	263	29
August	240	3103	17	18	755	49	236	27
September	37	495	2	2	118	7	37	4
October	16	214	1	1	49	3	16	2
November	5	72	0	0	17	1	5	1
December	2	24	0	0	6	0	2	0
Total (kg/year)	31849	409610	2214	2559	98442	6379	31325	3506

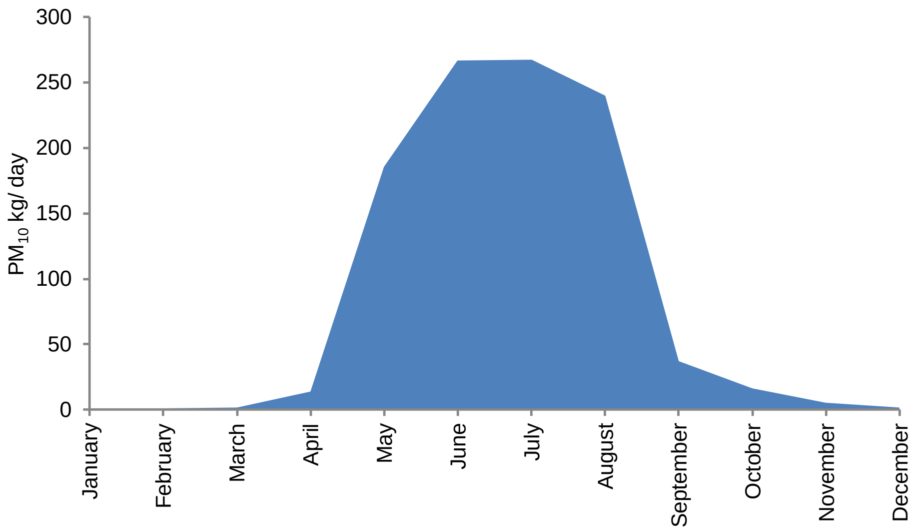

Figure 3-12: Monthly variations in PM_{10} emissions from domestic heating in Mosgiel.

4 TRANSPORT

4.1 Methodology

Motor vehicle emissions to air include tailpipe emissions and particulate emissions occurring as a result of the wear of brakes and tyres. Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) and the application of emission factors to these data.

Historically the emission factors used for motor vehicle emissions assessments in New Zealand were taken from the New Zealand Traffic Emission Rates (NZTER) database using local vehicle fleet profiles derived from motor vehicle registrations. The NZTER database was developed by the Ministry of Transport (MOT) based on measured emissions rates from actual vehicle emissions tests on New Zealand vehicles under various road and traffic conditions. However, assumptions underpinning the model were not documented. As a result, the Auckland Regional Council developed the Vehicle Emission Prediction Model (VEPM 5.1). Emissions factors for PM_{10}, CO, NOx, VOCs and CO_2 for this study have been based on VEPM 5.1. Default settings were used for all variables except for the vehicle fleet profile which was based on the district level vehicle registration data for the year ending 30 June 2016 and the temperature which was based on winter average temperature data for each of the towns provided by Otago Regional Council. These data for 5 degrees for Alexandra and Milton, 4 degrees for Arrowtown and 7 degrees for Mosgiel. Resulting emission factors are shown in Table 4.2.

Emission factors for SOx were estimated for diesel vehicles based on the sulphur content of the fuel (0.01%) and the assumption of 100% conversion to SO_2. Total VKT for diesel vehicles were estimated based on the proportion of diesels in the vehicle fleet.

The number of vehicle kilometres travelled (VKT) for the airshed was estimated using the New Zealand Transport Authority (NZTA) VKT data for 2013 available at the census area unit level. No updated VKT data were available at this spatial resolution.

Table 4.1: Vehicle registrations for the year ending June 2016.

QLDC	Petrol	Diesel	LPG	Other	Total
Cars	22,080	4,452	4	1	26,537
LCV	1,244	3,079	0	1	4,324
Bus	80	495			575
HCV		2,100			2,100
Miscellaneous	439	402	7	1	849
Motorcycle	1,240				1,240
Total	25083	10527	11	3	35,624
Central Otago	**Petrol**	**Diesel**	**LPG**	**Other**	**Total**
Cars	12,679	2,229	6	1	14,915
LCV	1,004	2,830	1	0	3,835
Bus	21	133			154
HCV		1,862			1,862
Miscellaneous	295	761	5	3	1,064
Motorcycle	892				892
Total	14891	7815	12	4	22,722
Clutha District	**Petrol**	**Diesel**	**LPG**	**Other**	**Total**

Cars	73,155	7,109	21	6	80,291
LCV	3,976	6,940	14	2	10,932
Bus	155	440			595
HCV		5,302			5,302
Miscellaneous	1344	1097	51	2	2,494
Motorcycle	4,055				4,055
Total	82685	20888	86	10	103,669
Dunedin District	**Petrol**	**Diesel**	**LPG**	**Other**	**Total**
Cars	10,407	1,508	1	1	11,917
LCV	978	2,710	2	0	3,690
Bus	37	105			142
HCV		1,791			1,791
Miscellaneous	287	892	3	0	1,182
Motorcycle	558				558
Total	12267	7006	6	1	19,280

Table 4.2: Emission factors for 2016

	CO g/VKT	CO_2 g/VKT	VOC g/VKT	NOx g/VKT	PM_{10} g/VKT	PM brake & tyre g/VKT	Benzene g/VKT
Alexandra	3.58	245	0.22	0.65	0.032	0.01	0.01
Arrowtown	3.69	234	0.22	0.59	0.029	0.01	0.01
Milton	3.58	250	0.22	0.69	0.033	0.01	0.01
Mosgiel	3.94	227	0.23	0.52	0.021	0.01	0.01

Table 4.3: Total VKT (2013) for each area.

	Total VKT
Alexandra	42013
Arrowtown	12320
Milton	19364
Mosgiel	44622

Emissions were calculated by multiplying the appropriate average emission factor by the VKT as follows:

Emissions (g) = Emission Rate (g/VKT) * VKT

4.2 Motor vehicle emissions

Just less than two kilograms per day of PM_{10} are estimated to occur from motor vehicle emissions in Alexandra and Mosgiel and less than one kilogram per day in Arrowtown and Milton (Table 4.4). Around 24% of the PM_{10} from motor vehicles is estimated to occur as a result of the wearing of brakes and tyres.

Table 4.4: Summary of daily motor vehicle emissions

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Alexandra	976	1.8	1.8	150	154	27	28	0.2	0.2
Arrowtown	236	0.5	2.0	45	193	7	31	0.1	0.2
Milton	202	0.8	4.1	69	343	13	66	0.1	0.4
Mosgiel	464	1.4	2.9	176	378	23	50	0.2	0.4

		VOC		CO_2		Benzene		$PM_{2.5}$	
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha		
Alexandra	976	9	9	10	11	0.4	0	1.6	1.6
Arrowtown	236	3	12	3	12	0.1	0	0.5	0.5
Milton	202	4	21	5	24	0.2	1	0.7	3.7
Mosgiel	464	10	22	10	22	0.4	2	1.7	8.4

5 INDUSTRIAL AND COMMERCIAL

5.1 Methodology

Identification of industrial or commercial activities discharging to air in Alexandra, Arrowtown, Milton and Mosgiel was based on the current resource consent database held by the Otago Regional Council. One industrial and commercial premise was included in the inventory for Alexandra, none for Arrowtown, two for Milton and four for Mosgiel.

The selection of industries for inclusion in this inventory was based on potential for PM_{10} emissions. Industrial activities such as spray painting or dry cleaning operations, which discharge primarily VOCs were not included in the assessment.

For a few industries included in the assessment site specific emissions data was available from the resource consent application or other Council records. In these cases emissions were estimated based on equation 5.1.

Equation 5.1 Emissions (kg/day) = Emission rate (kg/hr) x hrs per day (hrs)

Where site specific emissions data were not available, emissions were estimated using activity data and emission factor information, as indicated in Equation 5.2. 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. Activity data was collected using a phone and email survey. Data were collected for winter, autumn, spring and summer.

Equation 5.2 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 5.1. The coal fired boiler emission factors for PM_{10} are based on New Zealand specific emission factors as described in Wilton & Baynes, (2010). Other emission factors are from the USEPA AP42 database3.

Fugitive dust emissions from industrial and commercial activities were not included in the inventory assessment because of difficulties in quantifying the emissions.

Table 5.1: Emission factors for industrial discharges.

	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg	$PM_{2.5}$ g/kg	Benzene g/kg
Pellet boiler	0.8	6.8	0.8	0.0	0.1	1069	0.7	
Diesel boiler	0.3	0.67	3.2	0.1	0.2	3194		
	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr	kg/hr
Crematorium	0.04		0.1			78	0.04	
	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³
LPG boiler	0.10	0.96	1.7	0.0	0.0	1560	0.10	0.002

5.2 Industrial and commercial emissions

Table 5.2 shows the daily winter PM_{10} and other contaminant emissions from consented industrial or commercial activities in Alexandra, Arrowtown, Milton and Mosigel. The area with the greatest amount industrial PM_{10} emissions is Milton.

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

Table 5.2: Summary of daily winter industrial emissions

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Alexandra	976	0.05	0	0	0	0	0	0	0
Arrowtown	236	0	0	0	0	0	0	0	0
Milton	202	20	98	70	345	15	74	44	218
Mosgiel	464	2	5	18	39	16	35	0	0
		VOC		CO_2		$PM_{2.5}$		Benzene	
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha		
Alexandra	976	0	0	0	0	0	0	0.0	0.0
Arrowtown	236	0	0	0	0	0	0	0	0.0
Milton	202	2	7	14	69	16	80	0.2	0.9
Mosgiel	464	0	0	16	34	2	4	0	0.4

6 OTHER SOURCES OF EMISSIONS

This inventory includes all likely major sources of PM_{10} that can be adequately estimated using inventory techniques. Other sources of emissions not included in the inventory that may contribute to measured PM_{10} concentrations at some times during the year include dusts (a portion of which occur in the PM_{10} size fraction) and sea spray, although the latter is likely to be minimal in Alexandra and Arrowtown.

Lawn mowers, leaf blowers and chainsaws can also contribute small amounts of particulate. These are not typically included in emission inventory studies owing to the relatively small contribution, particularly in areas where solid fuel burning is a common method of home heating. Based on data for other areas, PM_{10} emissions from lawn mowing in all areas are likely to be less than one kilogram per day[4].

[4] Pacific Air and Environment (1999) indicates around 0.07 grams of PM_{10} are emitted per household per day for the Wellington Region.

7 TOTAL EMISSIONS

7.1 Total emissions Alexandra

Around 171 kilograms of PM_{10} is discharged to air in Alexandra on an average winter's day. This compares with around 367 kilograms per day for 2005 (based on the 2005 inventory adjusted for differences in methodology). This suggests a reduction in PM_{10} emissions of around 51% for Alexandra since 2005 (Figure 7.1). The majority of the reduction occurs as a result of changes in domestic heating, in particular a reduction in the proportion of households using coal and as a result of the replacement of older burners with those that meet the NES design criteria for wood burners. Figure 7.2 shows that domestic home heating is the main source of PM_{10} emissions contributing 99% of the daily wintertime emissions. Motor vehicles contribute the one percent and industry has minimal contribution to the daily wintertime PM_{10} emissions.

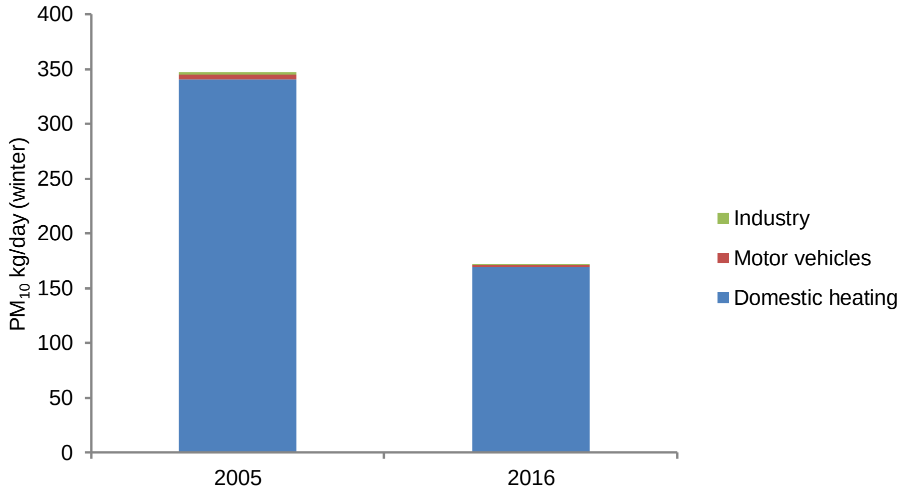

Figure 7-1: Comparison of estimated changes in PM_{10} emissions in Alexandra from 2005 to 2016.

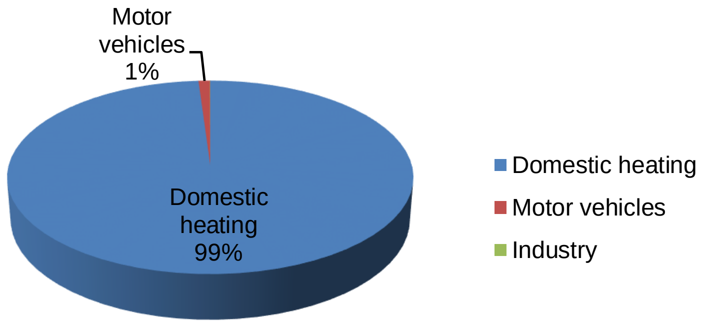

Figure 7-2: Relative contribution of sources to daily winter PM_{10} emissions in Alexandra.

Domestic home heating is also the main source of $PM_{2.5}$, CO, SOx, VOCs and CO_2 in Alexandra. Motor vehicles are the main source of NOx (Figure 7.3).

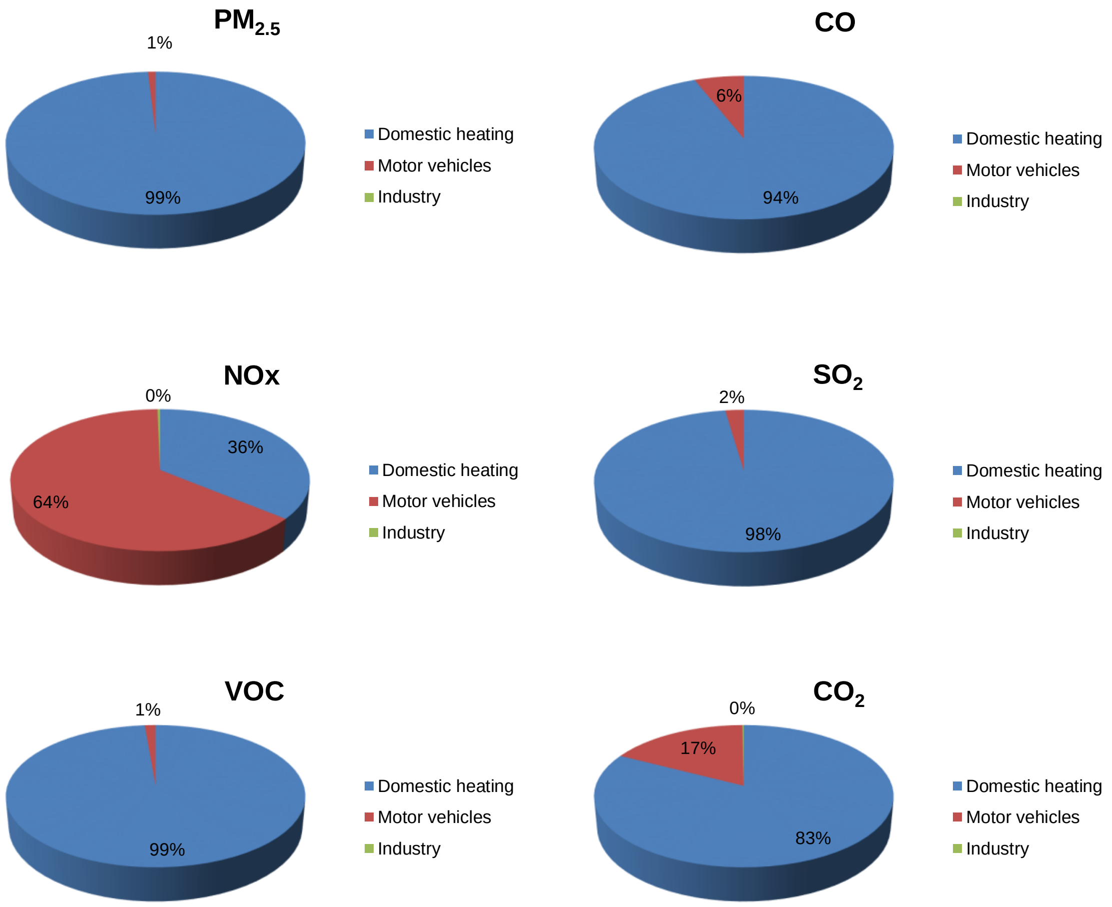

Figure 7-3: Relative contribution of sources to contaminant emissions in Alexandra.

Daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) are shown in Table 7.1. Table 7.2 shows seasonal variations in PM_{10} emissions. Although domestic home heating is the dominant source of PM_{10} emissions during the winter months, during the summer motor vehicles is the main contributor to PM_{10} emissions.

Table 7.1: Daily contaminant emissions from all sources in Alexandra (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	169	174	2342	2400	16	16	7	8
Transport	2	2	150	154	27	28	0	0
Industry	0	0	0	0	0	0	0	0
Total	171	175	2493	2554	43	44	8	8
	VOC		CO_2		$PM_{2.5}$		Benzene	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	682	699	49	50	169	173	30	30
Transport	9	9	10	11	2	2	0.4	0.4
Industry	0	0	0	0	0	0		
Total	692	709	60	61	171	175	31	31

Table 7.2: Monthly variations in daily PM_{10} emissions in Alexandra.

	Domestic Heating		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	11%	0.05	2%	2	86%	2
February	1	24%	0.05	2%	2	73%	2
March	1	37%	0.05	2%	2	62%	3
April	6	77%	0.05	1%	2	22%	8
May	109	98%	0.05	0%	2	2%	110
June	164	99%	0.05	0%	2	1%	166
July	169	99%	0.05	0%	2	1%	171
August	148	99%	0.05	0%	2	1%	150
September	20	92%	0.05	0%	2	8%	22
October	5	72%	0.05	1%	2	28%	6
November	1	43%	0.05	2%	2	56%	3
December	0	10%	0.05	2%	2	88%	2
Total kg year	19160		18		640		

7.2 Total emissions Arrowtown

Around 94 kilograms of PM_{10} is discharged to air in Arrowtown on an average winter's day. This compares with an estimated 183 kilograms per day for 2006 (MfE indicators database) suggesting a reduction in emissions of around 48% since 2006 (Figure 7.3). The majority of the reduction occurs as a result of changes in domestic heating, in particular a reduction in the proportion of households using coal and as a result of the replacement of older burners with those that meet the NES design criteria for wood burners. Figure 7.4 shows that domestic heating contributes 99% of the daily winter PM_{10} emissions with one percent from motor vehicles and a negligible amount from industry.

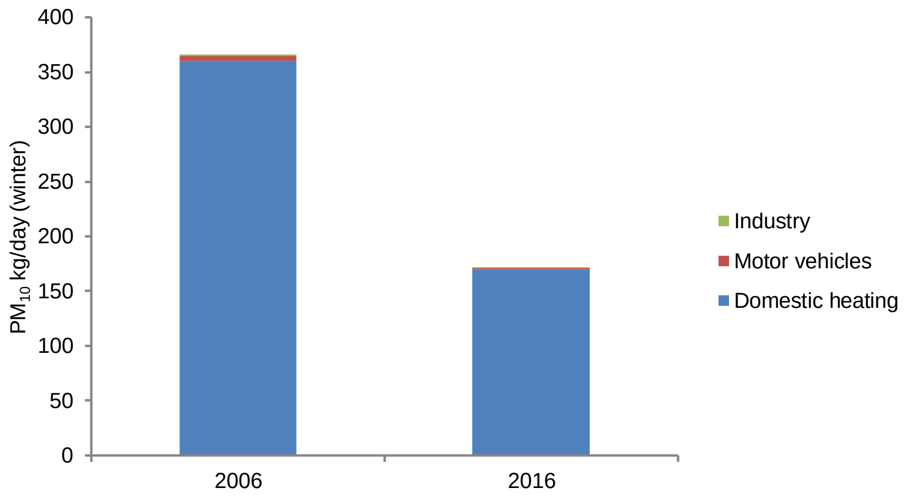

Figure 7-4: Comparison of estimated changes in PM_{10} emissions in Arrowtown from 2006 to 2016.

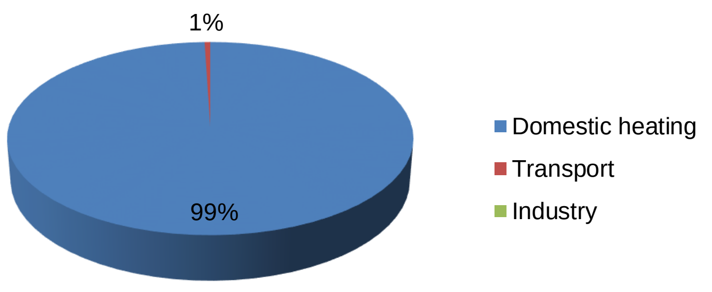

Figure 7-5: Relative contribution of sources to daily winter PM_{10} emissions in Arrowtown.

Domestic home heating is also the main source of daily winter $PM_{2.5}$, CO, NOx, SOx, VOCs and CO_2 (Figure 7.6).

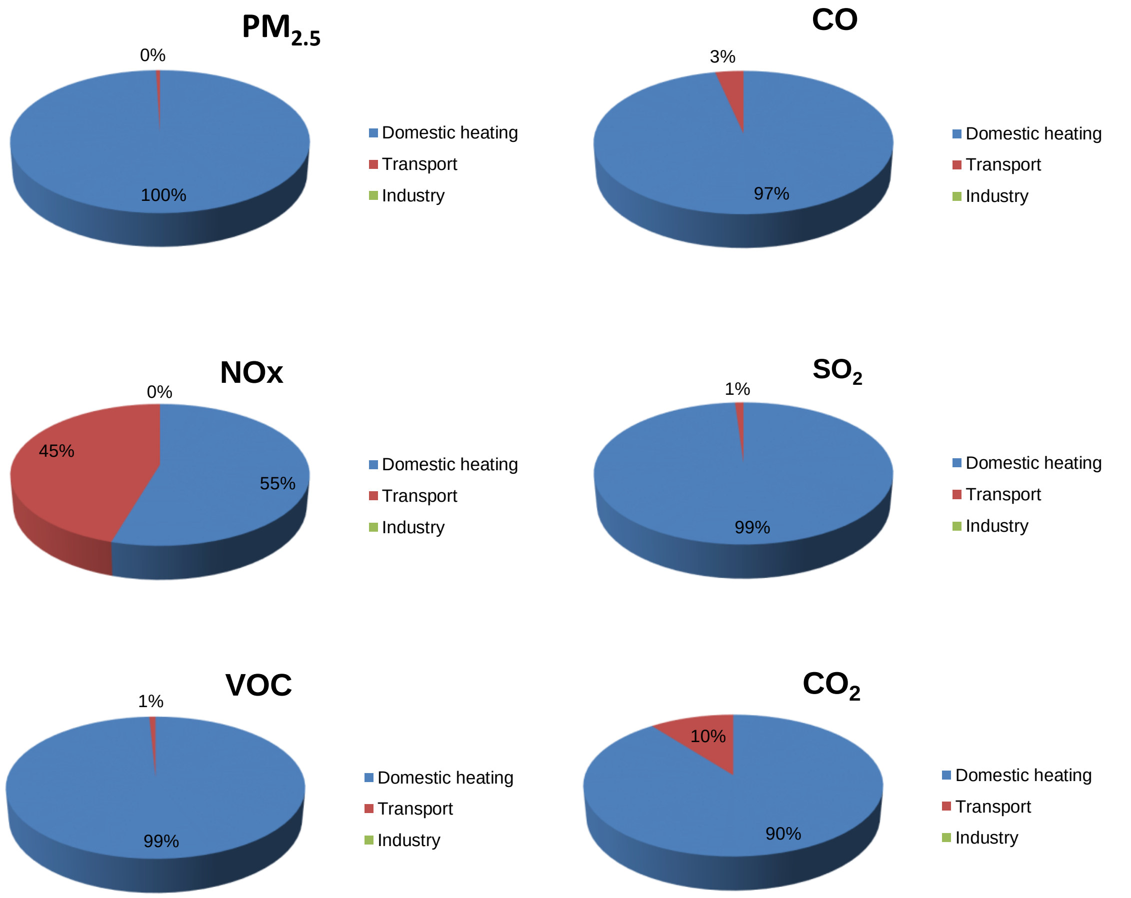

Figure 7-6: Relative contribution of sources to daily winter contaminant emissions in Arrowtown.

Daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) are shown in Table 7.3. Table 7.4 shows seasonal variations in PM_{10} emissions. During the summer motor vehicles and domestic heating are the dominant contributors to PM_{10} emissions.

Table 7.3: Daily contaminant emissions from all sources in Arrowtown (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	94	397	1274	5399	9	37	5	20
Transport	0	2	45	193	7	31	0	0
Industry	0	0	0	0	0	0	0	0
Total	94	399	1320	5592	16	67	5	20

	VOC		CO_2		$PM_{2.5}$		Benzene	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	356	1508	25	104	93	395	15	62
Transport	3	12	3	12	0.5	1.9	0.1	0.5
Industry	0	0	0	0	0.0	0.0		
Total	359	1520	27	117	94	397	15	62

Table 7.4: Monthly variations in daily PM_{10} emissions in Arrowtown.

	Domestic Heating		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	47%	0	0%	0.5	53%	1
February	0	31%	0	0%	0.5	69%	1
March	1	55%	0	0%	0.5	45%	1
April	5	91%	0	0%	0.5	9%	5
May	69	99%	0	0%	0.5	1%	69
June	92	99%	0	0%	0.5	1%	93
July	94	99%	0	0%	0.5	1%	94
August	87	99%	0	0%	0.5	1%	87
September	13	96%	0	0%	0.5	4%	13
October	5	91%	0	0%	0.5	9%	6
November	1	75%	0	0%	0.5	25%	2
December	1	56%	0	0%	0.5	44%	1
Total kg year	11287		0		174		

7.3 Total emissions Milton

Around 119 kilograms of PM_{10} is discharged to air in Milton on an average winter's day. No previous inventory has been carried out for Milton. However, some trend information is available through a national emissions assessment (MfE 2015). A comparison of the emission estimates from that study and the inventory estimates for 2016 are shown in Figure 7.7 and indicates that emissions may have reduced by around 50% since 2006. The majority of the reduction occurs as a result of changes in domestic heating, in particular a reduction in the proportion of households using coal and as a result of the replacement of older burners with those that meet the NES design criteria for wood burners.

Figure 7.8 shows that domestic home heating is the main source of PM_{10} emissions contributing 83% of the daily wintertime emissions. Industry contributes around 16% of the daily winter PM_{10} emissions and motor vehicles contribute 1%.

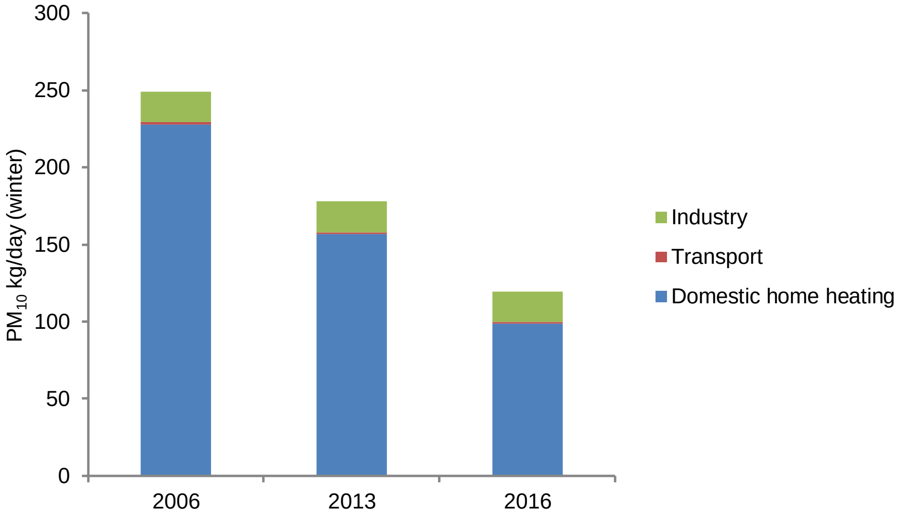

Figure 7-7: Comparison of estimated changes in PM_{10} emissions in Milton from 2006 to 2016.

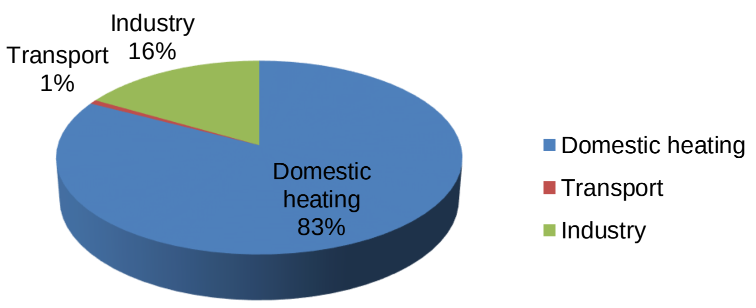

Figure 7-8: Relative contribution of sources to daily winter PM_{10} emissions in Milton.

Domestic home heating is also the main source of $PM_{2.5}$, CO and VOCs in Milton. Industry is the main source of SOx, NOx and contributes over a third of the CO_2 emissions (Figure 7.9).

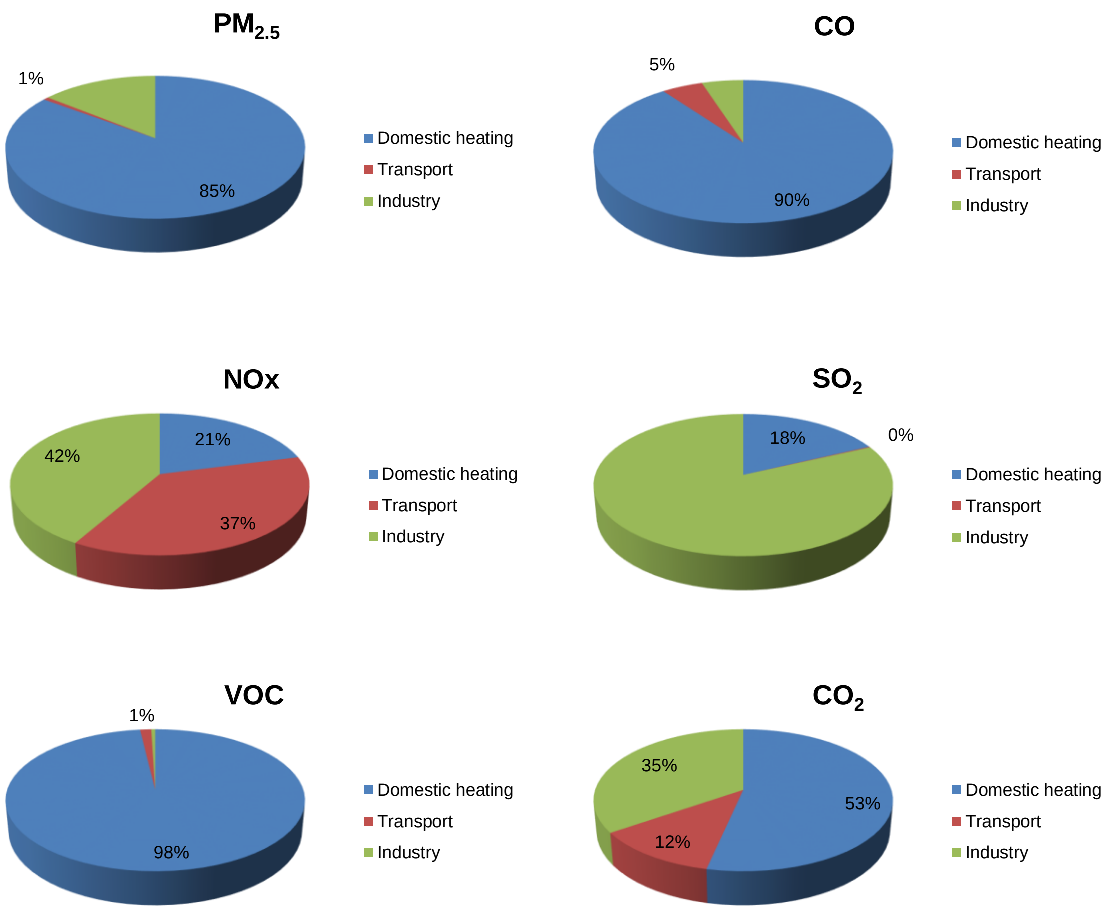

Figure 7-9: Relative contribution of sources to contaminant emissions in Milton.

Daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) are shown in Table 7.5. Table 7.6 shows seasonal variations in PM_{10} emissions. Although domestic home heating is the dominant source of PM_{10} emissions during the winter months, during the summer, industry is the dominant contributor to PM_{10} emissions.

Table 7.5: Daily contaminant emissions from all sources in Milton (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	99	488	1238	6131	7	37	10	48
Transport	1	4	69	343	13	66	0	0
Industry	20	98	70	345	15	74	44	218
Total	119	591	1377	6818	36	177	54	267

	VOC		CO_2		$PM_{2.5}$		Benzene	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	300	1483	22	107	97	478	12	58
Transport	4	21	5	24	1	4	0.2	1.0
Industry	2	7	14	69	16	80	0.2	0.9
Total	305	1512	41	201	113	562	12	60.3

Table 7.6: Monthly variations in daily PM_{10} emissions in Milton.

	Domestic Heating		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day
January	2	10%	20	86%	1	4%	23
February	2	9%	20	88%	1	4%	23
March	4	18%	20	79%	1	3%	25
April	10	32%	20	65%	1	3%	31
May	82	80%	20	19%	1	1%	103
June	96	82%	20	17%	1	1%	117
July	99	83%	20	17%	1	1%	119
August	93	82%	20	17%	1	1%	114
September	23	52%	20	46%	1	2%	44
October	14	40%	20	58%	1	2%	34
November	6	22%	20	75%	1	3%	26
December	3	12%	20	84%	1	4%	24
Total kg year	13316		7267		303		

7.4 Total emission Mosgiel

Around 271 kilograms of PM_{10} is discharged to air in Mosgiel on an average winter's day. This compares with an estimated 533 kilograms per day for 2005 indicating a reduction in emissions of around 49% (Figure 7.10). Just over one third of the reduction in emissions occurs as a result of industry closure or fuel switching with the remainder estimated to occur as a result of a reduction in the proportion of households using coal and the replacement of older burners with those that meet the NES design criteria for wood burners.

Figure 7.11 shows that domestic home heating is the main source of PM_{10} emissions contributing 99% of the daily wintertime emissions.

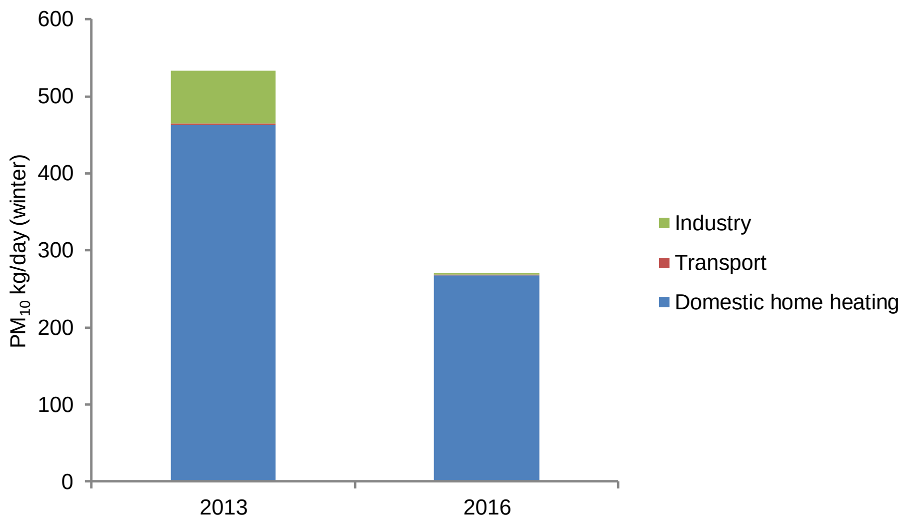

Figure 7-10: Comparison of estimated changes in PM_{10} emissions in Mosgiel from 2006 to 2016.

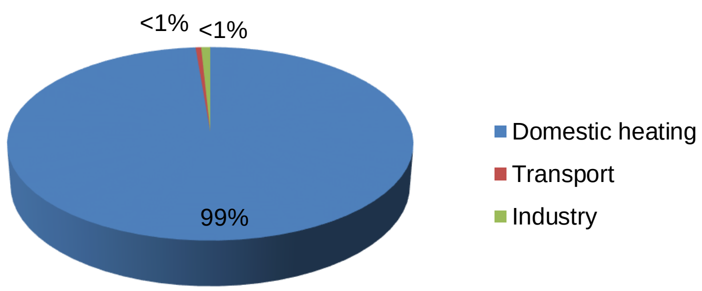

Figure 7-11: Relative contribution of sources to daily winter PM_{10} emissions in Mosgiel.

Domestic home heating is also the main source of $PM_{2.5}$, CO, SOx, VOCs and CO_2 in Mosgiel. Motor vehicles are the main source of NOx (Figure 7.12).

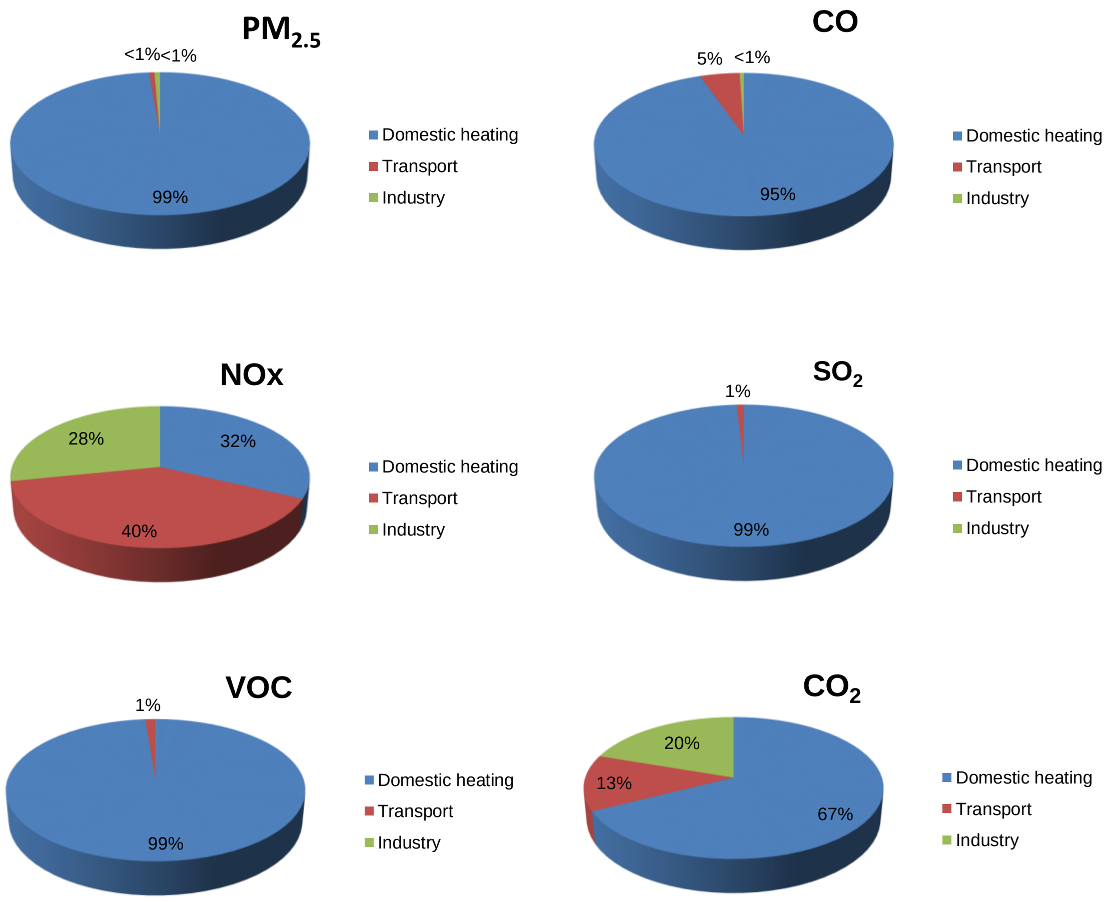

Figure 7-12: Relative contribution of sources to contaminant emissions in Mosgiel.

Daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) are shown in Table 7.7. Table 7.8 shows seasonal variations in PM_{10} emissions. Although domestic home heating is the dominant source of PM_{10} emissions during the winter months, during the summer, motor vehicles and industry are the dominant contributors to PM_{10} emissions.

Table 7.7: Daily contaminant emissions from all sources in Mosgiel (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	267	576	3418	7367	19	40	22	48
Transport	1	3	176	378	23	50	0	0
Industry	2	5	18	39	16	35	0	0
	0	0	0	0	0	0	0	0
Total	271	583	3612	7784	58	125	22	48
	VOC		CO_2		$PM_{2.5}$		Benzene	
	kg	g/ha	kg	g/ha	kg	g/ha		
Domestic home heating	822	1772	53	115	263	566	29	63
Transport	10	22	10	22	1.7	3.7	0.4	1.0
Industry	0	0	16	34	1.8	3.9	0.0	0.0
	0	0	0	0	0.0	0.0	0.0	0.0
Total	833	1794	79	171	266	573	30	64

Table 7.8: Monthly variations in daily PM_{10} emissions in Mosgiel.

	Domestic Heating		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day
January	1	27%	1	35%	1	38%	4
February	1	26%	1	37%	1	37%	4
March	2	36%	2	40%	1	25%	6
April	14	79%	2	13%	1	8%	17
May	186	98%	2	1%	1	1%	189
June	267	99%	2	1%	1	1%	271
July	267	99%	2	1%	1	1%	271
August	240	99%	2	1%	1	1%	243
September	37	93%	1	3%	1	3%	39
October	16	86%	1	7%	1	7%	19
November	5	67%	1	16%	1	17%	8
December	2	41%	1	28%	1	31%	4
Total kg year	31849		639		497		

REFERENCES

Ancelet, T., Davy, P., & Trompetter, B. (2013). Source apportionment of PM10 and PM2.5 in Nelson Airshed A. GNS Science Consultancey Report 2013/146. 95p.

Bluett, J., Smith, J., Wilton, E., & Mallet, T. (2009). Real world emission testing of domestic wood burners. Presented at the 19th International Clean Air and Environment Conference, Perth.

Metcalfe, J., Sridhar, S., & Wickham, L. (2013). Domestic fire emissions 2012: options for meeting the national environmental standard for PM10. Auckland Council technical report, TR 2013/022.

Ministry for Environment. (2004). Resource Management (National Environmental Standards for Air Quality) Regulations 2004. New Zealand Government. Retrieved from http://www.legislation.govt.nz/regulation/public/2004/0309/latest/DLM286835.html?search=ts_regulation_air+quality_resel&p=1&sr=1

Smith, J., Bluett, J., Wilton, E., & Mallet, T. (2009). In home testing of particulate emissions from NES compliant woodburners: Nelson, Rotorua and Taumaranui 2007. NIWA report number CHC2008-092.

Smithson, J. (2011). *Inventory of emissions to air in Christchurch 2009*. Environment Canterbury Report R11/17.

Stern, C. H., Jaasma, D. R., Shelton, J. W., & Satterfield, G. (1992). Parametric Study of Fireplace Particulate Matter and Carbon Monoxide Emissions. *Journal of the Air & Waste Management Association*, *42*(6), 777–783. http://doi.org/10.1080/10473289.1992.10467029

Wilton, E. (2006). Air Emission Inventory - Dunedin, Mosgiel and Alexandra 2005. Otago Regional Council.

Wilton, E. (2014). Nelson Air Emission Inventory - 2014. Nelson City Council Technical Report.

Wilton, E., & Baynes, M. (2010). Improving PM10 Emission Factors from Industrial Boilers in New Zealand - Stage 2. Report prepared for the Foundation of Research, Science and Technology.

Wilton, E., & Bluett, J. (2012). Factors influencing particulate emissions from NES compliant woodburners in Nelson, Rotorua and Taumarunui 2007. NIWA Client Report 2012- 013.

Wilton, E., Smith, J., Dey, K., & Webley, W. (2006). Real life testing of woodburner emissions. *Clean Air and Environmental Quality*, *40*(4), 43–47.

APPENDIX A: QUESTIONNAIRE

1. Good morning / afternoon/evening - Is this a home or business number?(- terminate if business)
Hi, I'm _________from and I am calling from _____ on behalf Otago Regional Council.

QA1 Can you please confirm you live in Alexandra/Arrowtown/Milton/Mosgiel

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 5-7 minutes depending on your answers. 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?

1	Yes
2	No >>> q3
99	Don't Know/refused >>> q3

(b) What type of electrical heating do you use? Would it be... (multiple choice – Read out)

1	Night Store
2	Radiant
3	Portable Oil Column
4	Panel
5	Fan
6	Heat Pump
99	Don't Know/Refused
90	Other (specify)

(d) Do you use any other heating system in your main living area in a typical year?
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to Q9)
3. (a) Do you use any type of gas heating in your MAIN living area during a typical year?
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to Q4)
(b) Is it flued or unflued gas heating? If necessary: (A flued gas heating appliance will have an external vent or chimney)
1 – Flued, 2 – Unflued, 3 – Both, 99 – Don't know
(c) Do you use mains or bottled gas for home heating?
1 – Mains, 2 – Bottled, 99 – Don't know (If 1 or 99 skip to 4a)
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)
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to Q5)

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

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

(For each month used)
(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

For each month; 1 – Tick to type - _____ (numeric response), 99 – Don't know/Refused

(d) How old is your log burner?

1	10 yrs+
2	5- 10 yrs old
3	Less than five years old
99	Don't know/refused

(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.

1	Tick to type
99	Don't know

(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.

1	Tick to type
99	Don't know

(g) In a typical year, how much wood would you use per year on your log burner? (record wood used 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)

1	Tick to type
99	Don't know

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

1	Only buy it
2	Only receive it free
3	Both free and bought wood

IF (h) = 3 - (i) What proportion would be bought?

1	Tick to type
99	Don't know

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)*
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to Q6)

(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

(For each month used)
(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

For each month; 1 – Tick to type - _____ (numeric response), 99 – Don't know/Refused

(d) How old is your multi fuel burner?

1	10 yrs+
2	5- 10 yrs old
3	Less than five years old
99	Don't know/refused

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

1	Tick to type
99	Don't know

(g) ask only If they used their multi fuel burner during non winter months how many pieces of wood (logs) do you use per day during the other months?

1	Tick to type
99	Don't know

(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

1	Tick to type
99	Don't know

(i) Do you use coal on your multi fuel burner?
1 – Yes, 2 – No, 99 – Don't know (if 2 or 99 then skip to (l)
(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 .

1	Tick to type
99	Don't know

(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?

1	Tick to type
99	Don't know

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

1	Only buy it
2	Only receive it free
3	Both free and bought wood

IF (l=3) then (m) What proportion would be bought?

1	Tick to type
99	Don't know

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?
1 – Yes, 2 – No, 99 – Don't know (if 2 or 99 then skip to 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

(For each month used)
(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

For each month; 1 – Tick to type - _____ (numeric response), 99 – Don't know/Refused

(d) Do you use wood on your open fire?
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to h)

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

1	Tick to type
99	Don't know

(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?

1	Tick to type
99	Don't know

(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)

1	Tick to type
99	Don't know

(h) Do you use coal on your open fire?
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to k)

(i) How many buckets of coal do you use per day during the winter. Interviewer: Winter is defined as may to August inclusive

1	Tick to type
99	Don't know

(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?

1	Tick to type
99	Don't know

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

1	Only buy it
2	Only receive it free
3	Both free and bought wood

If (k=3) then - (l) What proportion would be bought?

1	Tick to type
99	Don't know

7. (a) Do you use a pellet burner in your MAIN living area during a typical year?
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to 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

(For each month used)
(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

For each month; 1 – Tick to type - _____ (numeric response), 99 – Don't know/Refused
(d) How old is your pellet burner?

1	10 yrs+
2	5- 10 yrs old
3	Less than five years old
99	Don't know/refused

(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.

1	Tick to type
99	Don't know

(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?

1	Tick to type
99	Don't know

(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
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to 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 Q9)

1	Diesel or oil burner
2	Other specify>>> Wood Cooker
99	Don't know/refused

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

1	Tick to type
99	Don't know

9 (a) Do you use a wood fuelled cooking appliance? This is an appliance primarily used for cooking includes an oven and hot plate. (Note to interviewers - pot belly stoves, chip heaters or wood burners are not wood fired cookers) during a typical year?
1 – Yes, 2 – No, 99 – Don't know (If 2, 99 skip to 10)

(b) Which months of the year do you use your wood fired cooker?

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

(For each month used)
(b) How many days per week would you use your wood fired cooker during?

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

For each month; 1 – Tick to type - _____ (numeric response), 99 – Don't know/Refused

(d) How old is your wood fired cooker?

1	10 yrs+
2	5- 10 yrs old
3	Less than five years old
99	Don't know/refused

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

1	Tick to type
99	Don't know

10. Does you home have insulation?
- ☐ Ceiling
- ☐ Under floor
- ☐ Wall
- ☐ Cylinder wrap
- ☐ Double glazing
- ☐ None
- ☐ Don't know
- ☐ Other specify

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. Can you please tell me which of the following age group do you belong to ?

1	18-39
2	40-64
3	65+
99	Refused

D2 With which ethnic group do you most closely relate?

1	New Zealander of European descent
2	New Zealander of Maori descent
3	European

4	Samoan
5	Cook Island
6	Other Pacific Islander
7	Chinese
8	Indian
10	Other Asian
99	Refused
9	Other

Interviewer: tick gender.

1	Male
2	Female

D5 Do you own your home or rent it?

1	Own
2	Rent
97	Refused/not sure

D6 Approximately how old is your home?

1	10 years or less
2	11 – 20 years
3	21 – 40 years
4	41 + years
97	Refused/not sure

D7 How many bedrooms does your home have?

1	Tick to type
97	Refused

D8 Which of the following best describes your total household income per year before tax?

1	Less than $15,000
2	$15,000 - $30,000
3	$30,001 - $50,000
4	$50,001 - $80,000
5	$80,001 - $100,000
6	$100,000 - $150,000
7	Over $150,000
98	Don't know/Refused

D9 How long have you lived in this house

1	1 – 2 years
2	3 – 5 years
3	6 -7 years
4	8 – 9 years
5	10 – 14 years
6	15 – 20 years
7	20+ years
98	Don't know/Refused

D10 How would you rate the level of warmth in your home during winter

1	Too cold
2	Adequate

3	Warm
98	Don’t know/ refused

D11. If used wood for heating - Do you check the moisture content of your wood

1	Yes
2	No
97	Refused/not sure

D12. If yes to D11 – How do you evaluate the moisture content?

1	Visual inspection for cracks
2	Moisture meter
90	Other specify
98	Don’t know/Refused

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

APPENDIX B: EMISSION FACTORS FOR DOMESTIC HEATING.

Emission factors were based on the review of New Zealand emission rates carried out by Wilton et al., (2015) for the Ministry for the Environments air quality indicators programme. This review evaluated emission factors used by different agencies in New Zealand and where relevant compared these to overseas emission factors and information. Preference was given to New Zealand based data where available including real life testing of pre 1994 and NES compliant wood burners (Wilton & Smith, 2006; Smith, et. al., 2008) and burners meeting the NES design criteria for wood burners (Bluett, Smith, Wilton, & Mallet, 2009; Smith, Bluett, Wilton, & Mallet, 2009).

The PM_{10} open fire emission factor was reduced in the review relative to previous factors. Some very limited New Zealand testing was done on open fires during the late 1990s. Two tests gave emissions of around 7.2 and 7.6 g/kg which at the time was a lot lower than the proposed AP42 emission factors (http://www.rumford.com/ap42firepl.pdf) for open fires and the factors used in New Zealand at the time (15 g/kg). An evaluation of emission factors for the 1999 Christchurch emission inventory revised the open fire emission factor down from 15 g/kg to 10 g/kg based on the testing of Stern, Jaasma, Shelton, & Satterfield, (1992) in conjunction with the results observed for New Zealand (as reported in Wilton, 2014). The proposed AP42 emission factors (11.1 g/kg dry) now suggest that the open fire emission factor may be lower still and closer to the result of the limited testing carried out in New Zealand. Consequently a factor of 7.5 g/kg for PM_{10} (wet weight) is proposed to be used for open fires in New Zealand based on the likelihood of the Stern et al., (1992) data being dry weight (indicating a lower emission factor), the data supporting a proposed revised AP 42 factor and the results of the New Zealand testing being around this value. It is proposed that other contaminant emissions for open fires be based on the proposed AP42 emission factors adjusted for wet weight.

The emission factor for wood use on a multi fuel burner was also reduced from 13 g/kg (used in down to the same value as the pre 2004 wood burner emission factor (10 g/kg). The basis for this was that there was no evidence to suggest that multi fuel burners burning wood will produce more emissions than an older wood burner burning wood.

Emission factors for coal use on a multi fuel burner are based on limited data, mostly local testing. Smithson, (2011) combines these data with some further local testing to give a lower emission factor for coal use on multi fuel burners. While these additional data have not been viewed, and it uncertain whether bituminous and subbituminous coals are considered, the value used by Smithson has been selected. The Smithson, (2011) values for coal burning on a multi fuel burner have also been used for other contaminants. It is our view that many of the more polluting older coal burner (such as the Juno) will have been replaced over time with more modern coal burners.

No revision to the coal open fire particulate emission factor was proposed as two evaluations (Smithson, (2011) and Wilton 2002) resulted in the same emission factor using different studies. Emissions of sulphur oxides will vary depending on the sulphur content of the fuel, which will vary by location. A value of 8 g/kg is proposed for SO_x based on an assumed average sulphur content of 0.5 g/kg and relationships described in AP42 for handfed coal fired boilers (15.5 x sulphur content).

Emission factors for $PM_{2.5}$ were based on the assessment carried out by Wilton et al., (2015) for the Ministry for the Environments air quality indicators programme. This included the steering committee evaluation of a 100% ratio of $PM_{2.5}$ to PM_{10} for wood burners (historically a value of around 97% had been used based on USEPA data). For coal burning the assessment concluded that a ratio of 88% of $PM_{2.5}$ to PM_{10} with the basis being http://www.dustconf.com/CLIENT/DUSTCONF/UPLOAD/S4/EHRLICH_.PDF.

An emission factor of 0.5 g/kg was proposed for NO_x from wood burners based on the AP42 data because the non-catalytic burner measurements were below the detection limit but the catalytic converter estimates (and conventional burner estimates) weren't. This value is half of the catalytic burner NO_x estimate.

A ratio of 14 x PM_{10} values was used for CO emission estimates as per the AP42 emissions table for wood stoves. This is selected without reference to any New Zealand data owing to the latter not being in any publicly available form.

APPENDIX C: SUMMARY SURVEY DATA

Table 1 shows that proportion of firewood burnt on wood burners that is bought versus self-collected for the four urban areas. Of the four areas Milton has the greatest proportion of self-collected wood. Figure 2 shows the amount of insulation in the four areas. The prevalence of double glazing is high at around 50% in Alexandra, Arrowtown and Mosgiel but slightly lower in Milton (35%). The majority of dwellings have at least ceiling insulation.

Table 0.1:: Proportion of wood used on wood burners that is bought and self-collected

Firewood	Alexandra	Arrowtown	Milton	Mosgiel
Bought	59%	66%	43%	62%
Self-collected	41%	44%	57%	38%

Table 0.2:: Prevalence of household insulation by type

Household insulation	Alexandra		Arrowtown		Milton		Mosgiel	
	Households	%	Households	%	Households	%	Households	%
Ceiling	1968	91%	932	89%	702	89%	2815	92%
Underfloor	797	37%	431	41%	307	39%	1481	48%
Wall	1326	61%	734	70%	413	52%	1711	56%
Cylinder wrap	616	28%	260	25%	152	19%	966	32%
Double glazing	1018	47%	579	55%	276	35%	1407	46%
None	7	0%	16	1%	37	5%	37	1%
Don't know	100	5%	39	4%	31	4%	138	5%
Other	40	2%	12	1%	19	2%	55	2%
Households	2169		1049		792		3063	

Table 0.3:: Do you check the moisture content of your wood and if so how?

	Alexandra	Arrowtown	Milton	Mosgiel
Proportion that check wood	38%	43%	38%	29%
Proportion that responded on method of inspection				
Visual inspection	36%	47%	41%	36%
Moisture meter	9%	4%	10%	4%
Other specify	55%	49%	49%	60%
Don't know/Refused	0	0	0	0

Table 3 shows the proportion of households that reported that they check the moisture content of the wood they use ranges from 29% in Milton to 43% in Arrowtown. A number of households that responded that they did not check the moisture content of the wood also gave responses in the “other” category, typically that that they purchased the wood dry from the supplier or that they seasoned the wood themselves by keeping it for year before using. These responses were recorded under the other category by the survey company. The most common “other methods” for determining the wood wetness by households responding that answered “yes” to checking it was evaluating the weight of the wood to see if it was "heavy" and therefore wet and storing it for years to make sure it was seasoned.

Tables 4 to 6 summarise level of warmth, age of dwelling and length of time in a dwelling for each of the four areas. Table 7 compares the survey responses for households using wood and coal to the 2006 and 2013 census. The results mostly seem realistic relative to the 2013 census. Coal use for Milton and Mosgiel is lower in 2016 than reported for the 2013 census however.

Table 0.4: How would you rate the level of warmth in your home during winter?

	Alexandra Households	Arrowtown Households	Milton Households	Mosgiel Households
Too cold	6%	7%	9%	7%
Adequate	35%	28%	40%	35%
Warm	58%	64%	51%	57%
Unsure/ refused	1%	1%	0%	1%

Table 0.5: How old is your dwelling?

	Alexandra %	Arrowtown %	Milton %	Mosgiel %
10 years or less	18%	24%	13%	16%
11 - 20 years	12%	27%	8%	14%
21 - 40 years	33%	30%	21%	21%
41 + years	34%	16%	55%	42%
Refused/not sure	3%	3%	3%	7%

Table 0.6: How long have you lived in this dwelling

	Alexandra Households	Arrowtown Households	Milton Households	Mosgiel Households
1 - 2 years	20%	20%	17%	16%
3 - 5 years	20%	21%	15%	18%
6 -7 years	9%	10%	8%	7%
8 - 9 years	8%	7%	7%	7%
10 - 14 years	15%	16%	16%	17%
15- 20 years	9%	14%	10%	17%
20+ years	18%	10%	26%	18%
Don't know/Refused	1%	1%	1%	0%

Table 0.7: Comparison of survey results to households using wood and coal from 2006 and 2013 census

	Alexandra			Arrowtown			Milton			Mosgiel		
	2006	2013	2016	2006	2013	2016	2006	2013	2016	2006	2013	2016
Wood	1118	1119	1259	568	557	664	524	557	516	1313	1257	1435
Coal	342	37	13	186	28	31	369	220	93	629	383	212