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Hamilton Emission Inventory 2005

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Executive Summary

Environment Waikato has monitored air quality in Hamilton since 1997. Contaminants monitored include suspended particles (PM_{10}) and carbon monoxide (CO) and intermittent monitoring of nitrogen dioxide (NO_2), benzene and ozone. Results show concentrations of PM_{10} in excess of the Ministry for the Environment's ambient air quality guideline and National Environmental Standard (NES) of 50 μgm^{-3} (24-hour average) have occurred up to four times per year. Concentrations of other contaminants are within guideline values and the NES.

This inventory evaluates the contribution of different sources to air emissions in Hamilton for 2005. Contaminants evaluated include PM_{10}, CO, nitrogen oxides (NOx), sulphur oxides (SOx), volatile organic compounds (VOC) and carbon dioxide (CO_2). Sources included in the inventory were domestic heating, motor vehicles, outdoor rubbish burning and industrial and commercial discharges.

Domestic home heating emissions were assessed based on a survey of home heating methods and fuels used in Hamilton during 2005. The survey found that gas was the most common heating method in Hamilton and was used by 64% of households to heat their main living area. Electricity use was also common, with 36% of household using this method in their main living area. Of those households using gas, about half used unflued gas heating.

The main source of daily wintertime PM_{10} emissions across the whole of Hamilton was found to be domestic home heating, which accounted for around 72% of emissions. The remaining 28% was distributed between motor vehicles (11%), outdoor burning (13%) and industrial emissions (4%). Motor vehicles also accounted for 68% and 76% of the CO and CO_2 and 91% of the NOx emissions.

Significant seasonal variations in emissions were found, with motor vehicles and outdoor burning contributing 41% and 38% of the daily summer PM_{10} emissions respectively. Domestic heating contributed 47% of the annual PM_{10} emissions, with motor vehicles and outdoor burning each contributing 22-23% of emissions.

In the central (CBD) area, motor vehicles contributed as much PM_{10} as domestic heating (both around 45%), whereas in the Melville (hospital) area, industry was the second most dominant source contributing 26% of the daily winter PM_{10}.

1 Introduction

The purpose of this inventory is to determine the relative contribution of different sources to emissions to air in Hamilton for 2005. The information will be of use in developing air quality strategies for improving air quality in the city.

Previous emission inventory studies have been carried out for Hamilton in 1997 and 2001, although the latter was limited to an assessment of domestic heating in the area. The 1997 study indicated that domestic heating was the main contributor to PM_{10} emissions contributing 90% of PM_{10}. Domestic heating also contributed 49% of CO, 7% of NOx, 34% of SOx and 35% of CO_2. The main source of NOx, CO and SOx was motor vehicles which contributed 93%, 51% and 65% of these emissions respectively.

Air quality monitoring in Hamilton has been carried out at the Peachgrove Road monitoring site since 1997. Contaminants measured at the site include suspended particles (PM_{10}) and CO (both ongoing), plus intermittent monitoring of NO_2, benzene and ozone. Results are detailed in annual air quality monitoring reports prepared by Environment Waikato.

Based on this monitoring, the main air contaminant of concern in Hamilton is PM_{10}. Suspended particulate (PM_{10}) refers to particles in the air that are less than 10 microns in diameter. These particles are sufficiently small that they can penetrate the lungs and cause adverse health impacts.

Concentrations of PM_{10} measured in Hamilton have exceeded the Ministry for the Environment's (MfE) ambient air quality guideline for PM_{10} of 50 µg m^{-3} (24-hour average) up to four times per year. All guideline exceedences occurred during the winter months. The annual average PM_{10} concentration is around 15 µg m^{-3} and is less than the guideline value of 20 µg m^{-3} (MfE, 2002). In September 2004, MfE introduced National Environmental Standards (NES) for ambient air quality including an NES of 50 µg m^{-3} (24-hour average) for PM_{10}. The NES allows for one breach per year and specifies that no resource consents for discharges to air shall be granted in areas where the NES is breached from 2013. The NES for air quality are effective from September 2005.

2 Inventory Design

The main focus of this study is on wintertime emissions, as high concentrations of contaminants, in particular PM_{10} occur during the winter. During these months meteorological conditions conducive to high pollution are more prevalent and contaminant emissions increase as a result of domestic home heating.

The inventory design includes an evaluation of:

- Sources to include in the inventory.
- Contaminants to include in the inventory.
- The study area and spatial resolution.
- The temporal resolution.

2.1 Selection of sources

The main anthropogenic sources of emissions to air in urban areas of New Zealand are typically domestic heating, transportation and industrial and commercial discharges. Natural sources typically include sea spray and wind blown dusts and vegetation. Estimation techniques for sea spray and dusts are limited and have not been included in the assessment. Vegetation emissions in the Waikato Region were estimated in 1996 (NIWA, 1999) but will be less significant in the urban areas.

The following sources were included in the 2005 Hamilton emission inventory:

- Domestic home heating
- Outdoor rubbish burning
- Motor vehicles
- Industry/ commercial discharges

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 National Environmental Standards for ambient air quality (MfE, 2004). Carbon dioxide is typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas CO_2 emissions. Emissions of $PM_{2.5}$ are estimated, as this finer fraction of PM_{10} may be responsible for health impacts.

Volatile organic compounds are often included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution, including ozone. Air quality monitoring of ozone in Hamilton during the summer of 2003/ 04 indicated concentrations within ambient air quality guidelines and the National Environmental Standards (NES). However, it is unlikely that maximum ozone concentrations will occur within the urban area of Hamilton and ongoing tracking of precursor emissions is recommended.

2.3 Selection of study areas

The study area was selected based on the urban area footprint for Hamilton in the Environment Waikato GIS database. Census area units corresponding with the urban area were identified. The area was revised slightly from the 2001 inventory to allow for the inclusion of new residential development to the north-east. The areas of Sylvestor, Burbush and Peacocke were also excluded because of their predominantly rural nature. The revised study area will need to be accounted for when comparing results to previous inventories for the purpose of assessing trends in emissions.

The 2001 emission inventory for Hamilton was segregated into seven study areas. These study areas have been retained for the 2005 inventory with slight revisions based on the exclusion of the CAUs identified above and the inclusion of Horsham Downs and Rotokauri. Figure 2.1 and Table 2.1 show the study area and seven-area breakdown by CAU.

Table 2-1: Census area unit definitions for the seven Hamilton study areas

Hamilton East	Centre (CBD-Lake)	Upper East (Flagstaff)	Mid East (Claudelands)	Te Rapa	Western (Frankton)	Hospital (Melville)
Peachgrove	Hamilton Central	Horsham Downs	Queenwood	Pukete	Maeroa	Glenview
Hamilton East	Hamilton Lake	Rototuna	Clarkin	Pukete West	Frankton Junction	Melville
Naylor		Flagstaff	Claudelands	Bryant	Swarbrick	Bader
Riverlea		Huntington	Chartwell	Te Rapa	Dinsdale South	
Hillcrest West			Chedworth	Rotokauri	Dinsdale North	
University			Porritt	Beerescourt	Brymer	
Silverdale			Insoll		Nawton	
			Fairview Downs			
			Enderley			

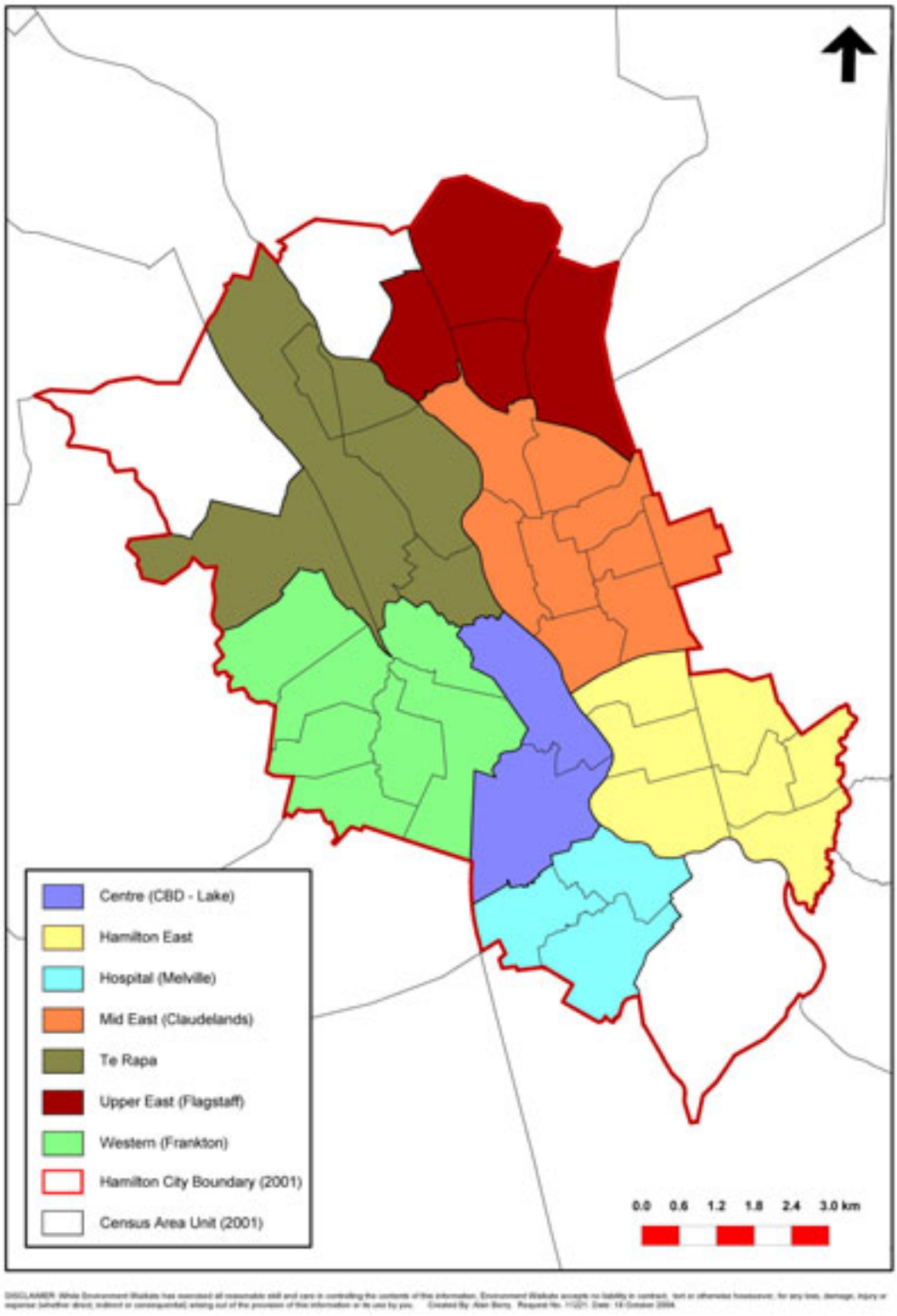

Figure 2-1: Hamilton 2005 study areas

2.4 Temporal distribution

The main focus of the study is on daily PM_{10} emissions during the winter period as this is when concentrations in Hamilton have exceeded the ambient air quality guidelines and NES for PM_{10} (24-hour average). In addition, the inclusion of an annual average guideline for PM_{10} in the 2000 ambient air quality guidelines (MfE, 2000) increases the importance of including emission estimates for different seasons. The inventory has therefore also been designed for the collection of seasonal data.

Data are presented for four different time of day periods. For domestic heating these are based on time of day distributions from the 2001 Hamilton domestic heating study as it is not possible to collect information on both time of day and seasonal variations in fuel use, owing to issues of survey length. The time of day breakdown is as follows:

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

3 Domestic home heating

3.1 Methodology

A home heating telephone survey for Hamilton was carried out during May and June 2005 by DigiPol Ltd. As indicated in section 2.3 the study area differed to that used in the 2001 domestic home heating survey. Table 3.1 shows the number of households and size of each of the seven areas compared with the 2001 study. The survey sample errors are also shown in Table 3.1 and are based on sampling for a finite population with replacement.

Table 3-1: Sample details for the 2001 and 2005 domestic heating survey for Hamilton

Area	2001				2005			
	Households	Sample	Area ha	Sample error	Households	Sample	Area Ha	Sample error
Central	2427	140	628	8%	2553	95	628	10%
Hamilton East	7791	141	1126	8%	8195	95	1126	10%
Hospital (Melville)	4569	146	1365	8%	4658	95	611	10%
Mid East (Claudelands)	8973	153	1243	8%	9438	95	1243	10%
Te Rapa	4896	141	2289	8%	5181	95	2090	10%
Upper East (Flagstaff)	2172	145	1420	8%	2537	95	1494	10%
Western (Frankton)	9870	146	1349	8%	10382	95	1349	10%
Total Hamilton	40698	1012	9420	3%	42943	665	8541	3.8%

The survey collected data relating to the type of home heating methods used in the main living area on a typical winter's night. Home heating methods queried included electricity, gas (flued or unflued), oil burners, open fires, wood burners and multi fuel burners. Data for wood burners was broken down to the following age categories: pre 1995, 1995-2000 and post 2000.

The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. These were reviewed for the Hamilton 2005 inventory to check that previously used factors were consistent with any more recent testing. As for the 2001 Hamilton domestic heating assessment, the open fire and multi fuel burner factors were based on the Christchurch 1999 emission factors. The basis for these is detailed in Wilton (2001). The wood burner emission rates were derived based on an evaluation of types of solid fuel burners installed and the revised age categories for burners. The gas and oil PM_{10} emission factors have also been revised as a result of more recent testing in New Zealand.

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	21
Pre 1995 burners	11	110	0.5	0.2	33	1600	11
1995-2000 burners	7	70	0.5	0.2	21	1600	7
Post 2000 burners	6	60	0.5	0.2	18	1600	6
Multi-fuel - wood	13	130	0.5	0.2	39	1600	13
Multi-fuel - coal	28	120	1.2	3.0	15	2600	28
Pellet burner	2	20	0.5	0.2	6	1600	2
Oil	0.3	0.6	2.2	3.8	0.25	3200	0.22
Gas	0.03	0.18	1.3	<0.01		2500	0.03

[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. There is some potential for fuel size to vary by region although factors such as appliance design should limit these variations. All three average fuel weight values were derived based on measurements carried out in Christchurch. The 1.9 kg average fuel weight value represents a 19% increase over the year 2001 Hamilton emission inventory, which used the initial average fuel weight of 1.6 kg. Compared to the 2001 inventory, the 2005 estimates of emissions from domestic heating will therefore be higher by 19%, as a result of a change in methodology.

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

Emissions calculated for the worst-case winter's day were based on the assumption that all households that used solid fuel for home heating were using it at the same time. Average winter's day emissions were also calculated. For this estimate, the daily fuel use was adjusted based on the average number of days per week each household used their heating method.

Daily emissions were also calculated for each month of the year to give an indication of the annual profile of PM_{10} emissions. These data were based on the average fuel use allowing for households not using particular heating methods on some nights during the week.

The main assumptions underlying the emissions calculations are as follows:

- The average weight of a log of wood is 1.9 kg. This weight was based on a survey carried out in Christchurch during 2002 (Lamb, 2003).
- The average weight of a bucket of coal is 9 kg.

There are uncertainties in both the estimates of fuel use and the emission factors used to estimate emissions from solid fuel burning. Fuel use uncertainties include the ability of householders to accurately estimate their daily fuel consumption, the conversion of pieces of wood to kilograms of fuel and in the case of small subgroups of appliance types, for example open fires, the applicability of the average fuel use of the small number of respondents in the sample size to the rest of the population of that burner category.

It is likely that some houses will overestimate average daily fuel consumption and some will underestimate consumption. For the larger appliance categories (e.g., wood and multi fuel burners) these are likely to balance out. There is a much higher degree of uncertainty for the smaller appliance categories such as open fires and pellet burners. To increase the number of respondents in each category average fuel use data for each appliance type were taken from responses across the whole of the Hamilton area, rather than separately for the individual study areas. These data were then applied to the survey results indicating the number of households using heating methods in each study area to estimate daily fuel use and emissions for each area.

The advantages of estimating average fuel use across responses for the whole of Hamilton is a more reliable estimate of fuel use for all areas as the greater number of data points increases the probability of a realistic average being achieved. This is particularly the case for solid fuel burning fuel estimates as a relatively small proportion of the sample population uses solid fuel burning for domestic home heating in Hamilton. The disadvantage in this method is that it does not allow for possible spatial variations in fuel use, for example spatial variations in lifestyle and demographic factors may result in certain areas of town using more fuel because they heat for longer periods of the day.

Similarly, data were collated across the different suburbs to give monthly variations in the proportions of households using different heating methods and the numbers of days per week burners were used on average. Seasonal variations in emissions are therefore illustrated for Hamilton as a whole.

A copy of the home heating survey used for the 2005 inventory is contained in Appendix One.

3.2 Home heating methods

Gas is the most common home heating method in Hamilton with 64% of households using some form of gas heating on a typical winter's night (Table 3.3). About half of the households using gas had flued gas systems. Unflued gas heaters emit contaminants such as nitrogen oxides, carbon monoxide and other toxic substances into the indoor environment. This is of concern as these emissions can lead to high concentrations of these contaminants in the indoor environment.

Only 20% of households in Hamilton use solid fuel burning for domestic home heating. This is low compared to other urban areas in the Region where domestic heating results in air quality issues (e.g., Tokoroa, Te Kuiti and Taupo). The main method of solid fuel burning is wood burners with 15% of households in Hamilton using this

method. Only around 1% of households in Hamilton burn coal for domestic home heating.

About half of the wood burners used in Hamilton are thought to be more than 10 years old. Multi fuel burners are used in the main living area by less than 2% of households in Hamilton. Wood is the main fuel for these burners with less than 1% of the multi fuel burner households also using coal. Overall around 8,000 household in Hamilton use wood and around 500 use coal.

Around 148 tonnes of wood and 10 tonnes of coal are used for domestic heating per day in Hamilton during the winter (Table 3.4).

Table 3-3: Methods of domestic heating for Hamilton and across all study areas

	Hamilton[2]		Centre (CBD-Lake)		Hamilton East		Hospital (Melville)		Mid East (Claudelands)		Te Rapa		Upper East (Flagstaff)		Western (Frankton)	
	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH
Electricity	36%	15,354	39%	994	44%	3,633	29%	1,359	42%	3,925	31%	1,582	41%	1,031	27%	2,831
Total Gas	64%	27,435	60%	1,532	51%	4,140	68%	3,154	65%	6,167	66%	3,436	70%	1,771	70%	7,236
Flued gas	31%	13,453	32%	808	25%	2,028	31%	1,443	37%	3,539	42%	2,170	37%	939	24%	2,527
Unflued gas	33%	13,982	28%	724	26%	2,112	37%	1,711	28%	2,629	24%	1,266	33%	832	45%	4,709
Oil	2%	843	1%	27	2%	169	3%	146	2%	187	0%	-	0%	-	3%	315
Open fire	3%	1,218	3%	81	7%	591	3%	146	2%	187	2%	109	0%	-	1%	105
Open fire - wood	3%	1,218	3%	81	7%	591	3%	146	2%	187	2%	109	0%	-	1%	105
Open fire - coal	1%	253	0%	-	0%	-	0%	-	1%	93	1%	55	0%	-	1%	105
Total Wood burner	15%	6,353	7%	188	18%	1,436	18%	825	11%	1,028	21%	1,091	13%	317	14%	1,468
Pre 1995 wood burner	7%	2,984	3%	81	9%	766	14%	635	3%	308	12%	600	4%	106	5%	489
1995-2000 woodburner	4%	1,710	2%	54	4%	287	0%	-	5%	514	3%	164	3%	79	6%	612
Post 2000 wood burner	4%	1,659	2%	54	5%	383	4%	190	2%	206	6%	327	5%	132	4%	367
Multi fuel burners	1.6%	698	1%	27	2%	169	1%	49	2%	187	2%	109	2%	53	1%	105
Multi fuel burners-wood	1.6%	698	1%	27	2%	169	1%	49	2%	187	2%	109	2%	53	1%	105
Multi fuel burners-coal	0.6%	242	0%	-	1%	84	1%	49	0%	-	2%	109	0%	-	0%	-
Pellet burners	0%	111	0%	-	1%	84	0%	-	0%	-	0%	-	1%	26	0%	-
Total wood	19%	8,270	12%	296	27%	2,197	22%	1,019	15%	1,402	25%	1,309	15%	370	16%	1,678
Total coal	1%	495	0%	-	1%	84	1%	49	1%	93	3%	164	0%	-	1%	105
Total		42,944		2,553		8,195		4,658		9,438		5,181		2,537		10,382

[1] - Households using multiple methods included more than once

[2] - Results for areas of Hamilton were weighted to give overall results for Hamilton

Table 3-4: Fuel use by appliance type for Hamilton and across all study areas

	Hamilton		Centre (CBD-Lake)		Hamilton East		Hospital (Melville)		Mid East (Claudelands)		Te Rapa		Upper East (Flagstaff)		Western (Frankton)	
	T /day	%	T /day	%	T /day	%	T /day	%	T /day	%	T /day	%	T /day	%	T /day	%
Electricity																
Total Gas	17	10%	1	16%	3	6%	2	9%	4	13%	2	7%	1	14%	5	12%
Oil	4	2%	0.1	2%	1	2%	1	3%	1	3%	0	0%	0	0%	2	4%
Open fire																
Open fire - wood	16	9%	1	17%	8	17%	2	8%	2	8%	1	5%	0	0%	1	4%
Open fire - coal	1	1%	0	0%	0	0%	0	0%	0	1%	0	1%	0	0%	0	1%
Total Wood burner	125	70%	4	60%	28	64%	16	70%	20	68%	21	71%	6	78%	29	76%
Pre 1995 wood burner	59	33%	2	26%	15	34%	12	54%	6	20%	12	39%	2	26%	10	25%
1995-2000 wood burner	34	19%	1	17%	6	13%	0	0%	10	34%	3	11%	2	20%	12	32%
Post 2000 wood burner	33	18%	1	17%	8	17%	4	16%	4	14%	6	21%	3	33%	7	19%
Multi fuel burners																
Multi fuel burners-wood	7	4%	0.3	4%	2	4%	0	2%	2	6%	1	4%	1	7%	1	3%
Multi fuel burners-coal	9	5%	0.0	0%	3	7%	2	8%	0	0%	4	13%	0	0%	0	0%
Pellet burners	0.2	0%	0.0	0%	0	0%	0	0%	0	0%	0	0%	0	1%	0	0%
Total wood	148	82%	5	82%	38	85%	19	81%	25	82%	24	79%	7	86%	31	82%
Total coal	10	5%	0	0%	3	7%	2	8%	0	1%	4	14%	0	0%	0	1%
Total	180		6		44		23		30		30		8		38	

3.3 Emissions from domestic heating

3.3.1 Hamilton - total

During winter the greatest amount of PM_{10} from domestic heating comes from pre 1995 wood burners (41%). Multi fuel burners contribute around 22% and open fires contribute around 11% of the PM_{10} emissions from domestic home heating (Figure 3.1).
Estimates of wintertime contaminant emissions for different heating methods under worst-case and average scenarios are also shown in Tables 3.5 and 3.6. The emission estimates indicate the following:

Just over 2 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 1.6 tonnes 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.
About 83% of the wintertime PM_{10} emissions come from the burning of wood with 17% from the burning of coal.

Monthly variations in appliance use and average days per week used are shown in Figures 3.2 and 3.3. Table 3.7 shows seasonal variations in contaminant emissions. The majority of the annual PM_{10} from domestic home heating occur during the months June, July and August (Figure 3.4).

3.3.2 Hamilton emissions by study area

Tables 3.8 to 3.14 show daily domestic contaminant emissions for the average case scenario for the Central, Hamilton East, Melville, Claudelands, Te Rapa, Flagstaff and Frankton study areas. The highest domestic PM_{10} emission densities occur in the hospital area (Melville) and Hamilton East with emission rates of 384 g/ha/day and 388 g/ha/day respectively. Of these two areas, the highest wintertime mass PM_{10} emission occurs in Hamilton East, where 436 kg/day is discharged from domestic sources, compared with 234 kg/day for Melville (Table 3.15). Flagstaff had the lowest emission density at only 38 g/ha for daily PM_{10} emissions (Table 3.13).

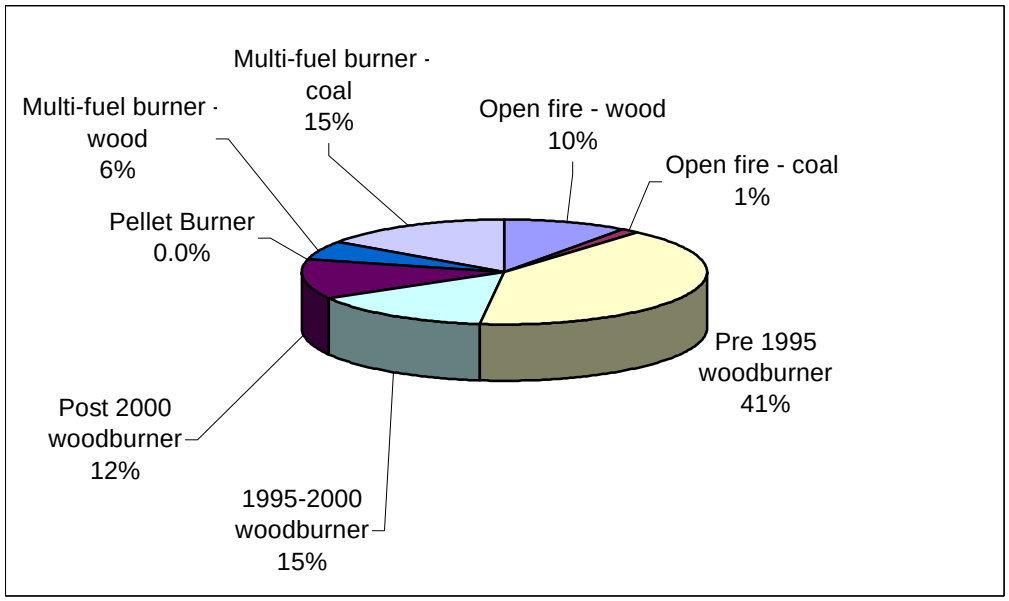

Figure 3-1: Relative contribution of different heating methods to average daily PM10 (July) from domestic heating in Hamilton

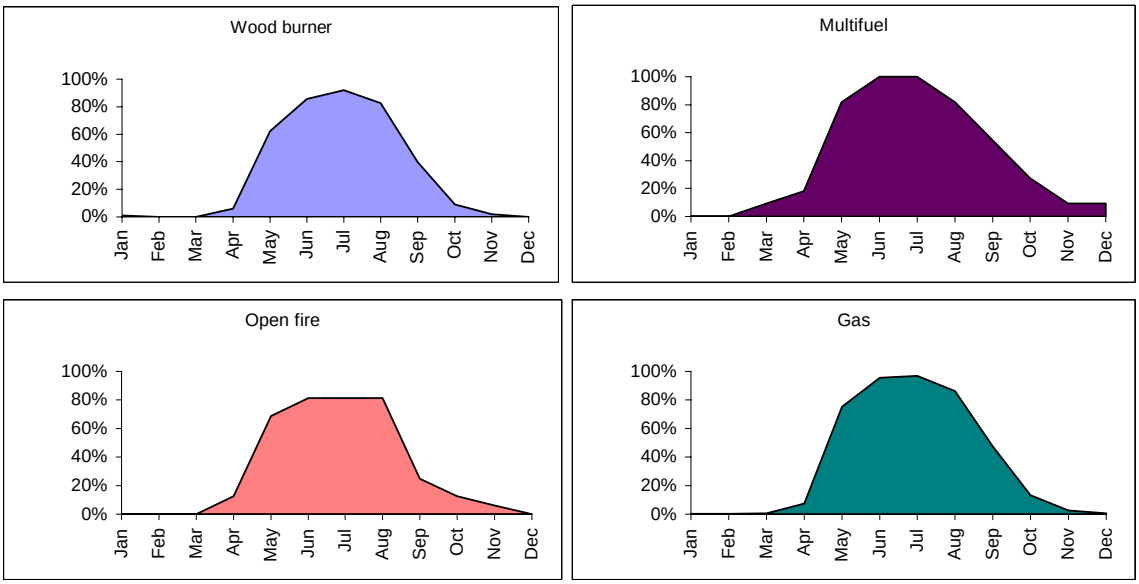

Figure 3-2: Monthly variations in appliance use in Hamilton

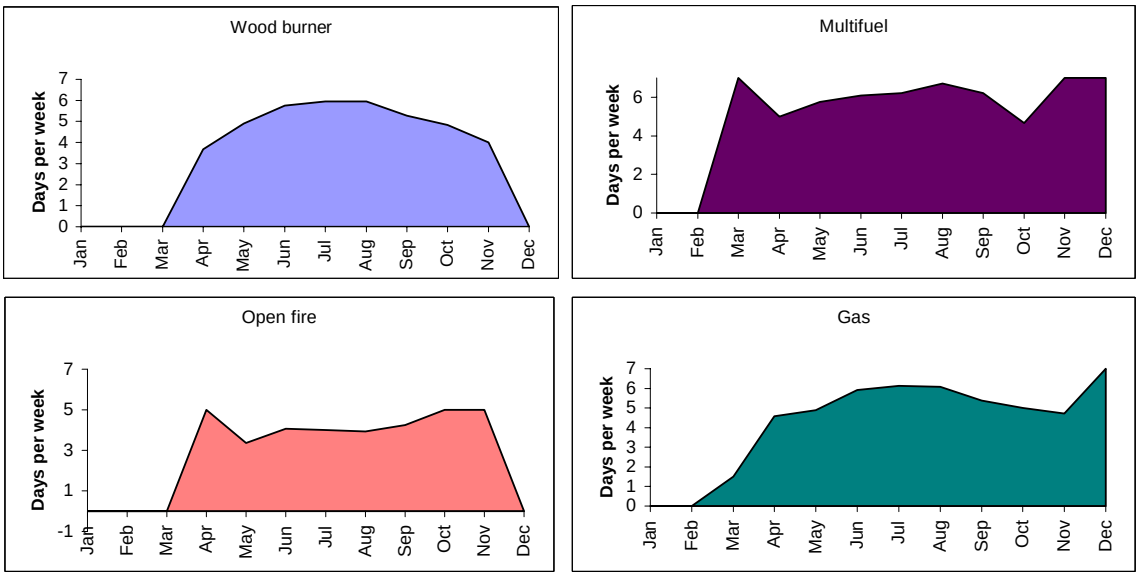

Figure 3-3: Average number of days per week appliances are used in Hamilton per month

Table 3-5: Hamilton worst-case winter 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	34.5	14%	345	40	16%	3447	404	18%	55	6	28%	7	1	7%	1034	121	18%	55	6	13%	345	40	17%
Open fire - coal	2.3	1%	48	6	2%	182	21	1%	9	1	5%	11	1	11%	34	4	1%	6	1	1%	27	3	1%
Wood burner																							
Pre 1995 wood burner	75.4	31%	830	97	38%	8297	971	42%	38	4	19%	15	2	15%	2489	291	44%	121	14	28%	830	97	41%
1996-2000 wood burner	43.2	18%	302	35	14%	3024	354	15%	22	3	11%	9	1	8%	907	106	16%	69	8	16%	302	35	15%
Post 2000 wood burner	41.9	17%	252	29	12%	2516	295	13%	21	2	10%	8	1	8%	755	88	13%	67	8	16%	252	29	12%
Pellet Burner	0.6	0%	1	0	0%	11	1	0%	0	0	0%	0	0	0%	3	0	0%	1	0	0%	1	0	0%
Multi fuel burner																							
Multi fuel burner - wood	8.0	3%	103	12	5%	1035	121	5%	4	0	2%	2	0	2%	310	36	5%	13	1	3%	103	12	5%
Multi fuel burner – coal	9.8	4%	275	32	13%	1177	138	6%	11	1	6%	29	3	29%	147	17	3%	25	3	6%	156	18	8%
Gas	20.5	8%	1	0	0%	4	0	0%	28	3	14%	0	0	0%	0	0	0%	51	6	12%	1	0	0%
Oil	6	2%	2	0	0%	3	0	0%	12	1	6%	21	2	21%	1	0	0%	18	2	4%	1	0	0%
Total Wood	204	84%	1833	215	85%	18329	2146	93%	140	16	70%	41	5	40%	5499	644	97%	326	38	76%	1833	215	91%
Total Coal	12	5%	322	38	15%	1359	159	7%	21	2	10%	41	5	40%	181	21	3%	31	4	7%	184	22	9%
Total	242		2158	253		19695	2306		200	23		103	12		5681	665		426	50		2018	236	

Table 3-6: Hamilton average winter 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	16	9%	160	19	10%	1600	187	11%	26	3	18%	3	0	4%	480	56	12%	26	3	8%	160	19	11%
Open fire - coal	1	1%	22	3	1%	85	10	1%	4	0	3%	5	1	7%	16	2	0%	3	0	1%	13	1	1%
Wood burner																							
Pre 1995 wood burner	59	33%	647	76	40%	6467	757	45%	29	3	21%	12	1	15%	1940	227	47%	94	11	29%	647	76	44%
1996-2000 wood burner	34	19%	236	28	15%	2357	276	16%	17	2	12%	7	1	9%	707	83	17%	54	6	17%	236	28	16%
Post 2000 wood burner	33	18%	196	23	12%	1961	230	14%	16	2	12%	7	1	8%	588	69	14%	52	6	16%	196	23	13%
Pellet Burner	0	0%	0	0	0%	5	1	0%	0	0	0%	0	0	0%	1	0	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel burner - wood	7	4%	92	11	6%	916	107	6%	4	0	3%	1	0	2%	275	32	7%	11	1	4%	92	11	6%
Multi fuel burner - coal	9	5%	243	28	15%	1042	122	7%	10	1	7%	26	3	33%	130	15	3%	23	3	7%	139	16	9%
Gas	17	10%	1	0	0%	3	0	0%	23	3	17%	0	0	0%	0	0	0%	43	5	14%	1	0	0%
Oil	4	2%	1	0	0%	3	0	0%	10	1	7%	17	2	22%	1	0	0%	14	2	4%	1	0	0%
Total Wood	148	82%	1331	156	83%	13307	1558	92%	92	11	66%	30	3	38%	3992	467	96%	238	28	74%	1331	156	90%
Total Coal	10	5%	265	31	17%	1127	132	8%	14	2	10%	31	4	40%	146	17	4%	25	3	8%	151	18	10%
Total	180		1598	187		14439	1690		139	16		78	9		4139	485		321	38		1483	174	

Table 3-7: Monthly variations in contaminant emissions in Hamilton

	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	233	95	249	577	0	233
February	0	233	95	249	577	0	233
March	37	284	93	249	663	37	284
April	129	284	93	249	755	129	284
May	988	284	93	249	1614	988	284
June	1493	287	94	249	2123	1493	287
July	1598	287	94	249	2229	1598	287
August	1448	287	94	249	2079	1448	287
September	606	259	95	249	1208	606	259
October	186	259	95	249	788	186	259
November	70	259	95	249	672	70	259
December	37	233	95	249	614	37	233
Total (kg/ year)	202015	97100	34446	90874	424434	202015	97100

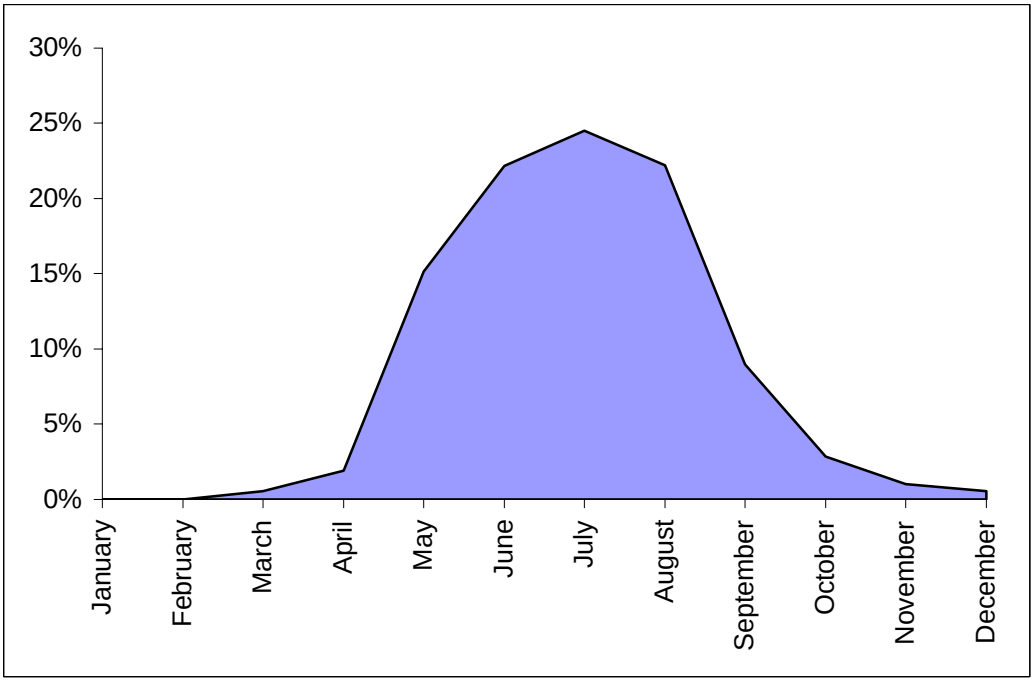

Table 3-8: Proportion of annual PM10 emissions in Hamilton by month of year

Table 3-9: Central average winter 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	1.1	17%	11	17	23%	106	169	23%	2	3	32%	0	0	14%	32	51	23%	2	3	15%	11	17	23%
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%
Wood burner																							
Pre 1995 wood burner	1.6	26%	17	28	38%	175	278	38%	1	1	15%	0	1	21%	52	83	39%	3	4	23%	17	28	38%
1996-2000 wood burner	1.1	17%	7	12	16%	74	118	16%	1	1	10%	0	0	14%	22	35	16%	2	3	15%	7	12	16%
Post 2000 wood burner	1.1	17%	6	10	14%	64	101	14%	1	1	10%	0	0	14%	19	30	14%	2	3	15%	6	10	14%
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	0%
Multi fuel burner																							
Multi fuel burner - wood	0.3	4%	4	6	8%	35	56	8%	0	0	3%	0	0	4%	11	17	8%	0	1	4%	4	6	8%
Multi fuel burner - 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%
Gas	1.0	16%	0	0	0%	0	0	0%	1	2	25%	0	0	0%	0	0	0%	2	4	22%	0	0	0%
Oil	0.1	2%	0	0	0%	0	0	0%	0	0	6%	1	1	35%	0	0	0%	0	1	4%	0	0	0%
Total Wood	5.0	82%	45	72	100%	453	722	100%	4	6	69%	1	2	65%	136	217	100%	8	13	74%	45	72	100%
Total 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%
Total	6		45	72		454	722		5	8		2	2		136	217		11	17		45	72	

Table 3-10: Hamilton East average winter 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	7.8	17%	78	69	18%	777	690	20%	12	11	34%	2	1	8%	233	207	21%	12	11	16%	78	69	19%
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%
Wood burner																							
Pre 1995 wood burner	15.1	34%	166	147	38%	1660	1474	43%	8	7	21%	3	3	15%	498	442	45%	24	21	31%	166	147	42%
1996-2000 wood burner	5.7	13%	40	35	9%	396	352	10%	3	3	8%	1	1	6%	119	106	11%	9	8	12%	40	35	10%
Post 2000 wood burner	7.5	17%	45	40	10%	453	402	12%	4	3	10%	2	1	8%	136	121	12%	12	11	15%	45	40	11%
Pellet Burner	0.2	0%	0	0	0%	4	3	0%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel burner - wood	1.7	4%	22	20	5%	222	197	6%	1	1	2%	0	0	2%	67	59	6%	3	2	3%	22	20	6%
Multi fuel burner - coal	3.0	7%	85	75	19%	364	323	9%	4	3	10%	9	8	45%	45	40	4%	8	7	10%	48	43	12%
Gas	2.6	6%	0	0	0%	0	0	0%	4	3	10%	0	0	0%	0	0	0%	7	6	8%	0	0	0%
Oil	0.9	2%	0	0	0%	1	0	0%	2	2	5%	3	3	17%	0	0	0%	3	3	4%	0	0	0%
Total Wood	37.9	85%	351	312	80%	3511	3118	91%	28	24	75%	8	7	38%	1053	936	96%	61	54	78%	351	312	88%
Total Coal	3.0	7%	85	75	19%	364	323	9%	4	3	10%	9	8	45%	45	40	4%	8	7	10%	48	43	12%
Total	44		436	388		3875	3442		37	32		20	18		1099	976		78	69		400	355	

Table 3-11: Melville average winter 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	1.9	8%	19	31	8%	191	313	9%	3	5	17%	0	1	3%	57	94	10%	3	5	7%	19	31	9%
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%
Wood burner																							
Pre 1995 wood burner	12.5	54%	137	225	59%	1375	2249	67%	6	10	35%	2	4	21%	412	675	71%	20	33	48%	137	225	64%
1996-2000 wood burner	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Post 2000 wood burner	3.7	16%	22	37	10%	225	368	11%	2	3	11%	1	1	6%	67	110	12%	6	10	14%	22	37	11%
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	0%
Multi fuel burner																							
Multi fuel burner - wood	0.5	2%	6	10	3%	64	104	3%	0	0	1%	0	0	1%	19	31	3%	1	1	2%	6	10	3%
Multi fuel burner - coal	1.7	8%	49	80	21%	209	342	10%	2	3	11%	5	9	44%	26	43	4%	5	7	11%	28	45	13%
Gas	2.0	9%	0	0	0%	0	1	0%	3	4	15%	0	0	0%	0	0	0%	5	8	12%	0	0	0%
Oil	0.8	3%	0	0	0%	0	1	0%	2	3	9%	3	5	25%	0	0	0%	2	4	6%	0	0	0%
Total Wood	18.7	81%	185	303	79%	1855	3034	90%	11	19	64%	4	6	31%	556	910	95%	30	49	71%	185	303	87%
Total Coal	1.7	8%	49	80	21%	209	342	10%	2	3	11%	5	9	44%	26	43	4%	5	7	11%	28	45	13%
Total	23		234	384		2064	3377		18	29		12	19		583	953		42	68		213	349	

Table 3-12: Claudelands average winter 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	2.5	8%	25	20	11%	245	198	11%	4	3	16%	0	0	5%	74	59	12%	4	3	7%	25	20	11%
Open fire - coal	0.4	1%	8	7	4%	31	25	1%	2	1	7%	2	2	18%	6	5	1%	1	1	2%	5	4	2%
Wood burner																							
Pre 1995 wood burner	6.1	20%	67	54	30%	668	538	31%	3	2	13%	1	1	11%	200	161	31%	10	8	18%	67	54	31%
1996-2000 wood burner	10.1	34%	71	57	32%	709	570	33%	5	4	21%	2	2	19%	213	171	33%	16	13	30%	71	57	33%
Post 2000 wood burner	4.0	14%	24	20	11%	243	196	11%	2	2	8%	1	1	8%	73	59	11%	6	5	12%	24	20	11%
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	0%
Multi fuel burner																							
Multi fuel burner - wood	1.9	6%	25	20	11%	245	197	11%	1	1	4%	0	0	4%	74	59	12%	3	2	6%	25	20	11%
Multi fuel burner - 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%
Gas	3.9	13%	0	0	0%	1	1	0%	5	4	22%	0	0	0%	0	0	0%	10	8	18%	0	0	0%
Oil	1.0	3%	0	0	0%	1	0	0%	2	2	9%	4	3	35%	0	0	0%	3	3	6%	0	0	0%
Total Wood	24.6	82%	211	170	96%	2111	1699	98%	15	12	63%	5	4	46%	633	510	99%	39	32	74%	211	170	98%
Total Coal	0.4	1%	8	7	4%	31	25	1%	2	1	7%	2	2	18%	6	5	1%	1	1	2%	5	4	2%
Total	30		220	177		2143	1725		24	19		11	9		639	514		53	43		216	174	

Table 3-13: Te Rapa average winter 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	1.4	5%	14	7	4%	143	69	5%	2	1	10%	0	0	2%	43	21	6%	2	1	4%	14	7	5%
Open fire - coal	0.2	1%	5	2	1%	18	9	1%	1	0	4%	1	1	6%	3	2	0%	1	0	1%	3	1	1%
Wood burner																							
Pre 1995 wood burner	11.8	39%	130	62	39%	1300	622	48%	6	3	27%	2	1	13%	390	187	54%	19	9	35%	130	62	46%
1996-2000 wood burner	3.2	11%	23	11	7%	226	108	8%	2	1	7%	1	0	4%	68	32	9%	5	2	9%	23	11	8%
Post 2000 wood burner	6.4	21%	39	19	12%	387	185	14%	3	2	15%	1	1	7%	116	56	16%	10	5	19%	39	19	14%
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	0%
Multi fuel burner																							
Multi fuel burner - wood	1.1	4%	14	7	4%	143	68	5%	1	0	3%	0	0	1%	43	21	6%	2	1	3%	14	7	5%
Multi fuel burner - coal	3.9	13%	110	52	33%	470	225	17%	5	2	21%	12	6	66%	59	28	8%	10	5	19%	62	30	22%
Gas	2.2	7%	0	0	0%	0	0	0%	3	1	13%	0	0	0%	0	0	0%	5	3	10%	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%
Total Wood	24.0	79%	220	105	66%	2199	1052	82%	14	6	62%	5	2	27%	660	316	91%	38	18	70%	220	105	77%
Total Coal	4.1	14%	114	55	34%	488	233	18%	5	3	25%	13	6	73%	62	30	9%	11	5	20%	65	31	23%
Total	30		334	160		2687	1285		22	11		18	8		722	345		55	26		285	136	

Table 3-14: Flagstaff average winter 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	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%
Wood burner																							
Pre 1995 wood burner	2.1	26%	23	15	41%	229	153	41%	1	1	21%	0	0	30%	69	46	41%	3	2	24%	23	15	41%
1996-2000 wood burner	1.6	20%	11	7	19%	109	73	19%	1	1	16%	0	0	23%	33	22	19%	2	2	18%	11	7	19%
Post 2000 wood burner	2.6	33%	16	10	28%	156	105	28%	1	1	26%	1	0	38%	47	31	28%	4	3	30%	16	10	28%
Pellet Burner	0.1	1%	0	0	0%	1	1	0%	0	0	1%	0	0	1%	0	0	0%	0	0	1%	0	0	0%
Multi fuel burner																							
Multi fuel burner - wood	0.5	7%	7	5	12%	69	46	12%	0	0	5%	0	0	8%	21	14	12%	1	1	6%	7	5	12%
Multi fuel burner - 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%
Gas	1.1	14%	0	0	0%	0	0	0%	2	1	31%	0	0	0%	0	0	0%	3	2	20%	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%
Total Wood	6.8	86%	57	38	100%	565	378	100%	3	2	69%	1	1	100%	170	113	100%	11	7	80%	57	38	100 %
Total 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%
Total	8		57	38		565	378		5	3		1	1		170	113		14	9		57	38	

Table 3-15: Frankton average winter 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	1.4	4%	14	10	5%	138	102	5%	2	2	8%	0	0	2%	41	31	5%	2	2	3%	14	10	5%
Open fire - coal	0.4	1%	9	7	3%	35	26	1%	2	1	6%	2	2	15%	7	5	1%	1	1	2%	5	4	2%
Wood burner																							
Pre 1995 wood burner	9.6	25%	106	79	39%	1060	786	40%	5	4	17%	2	1	13%	318	236	40%	15	11	23%	106	79	40%
1996-2000 wood burner	12.1	32%	84	63	31%	844	625	32%	6	4	21%	2	2	16%	253	188	32%	19	14	28%	84	63	32%
Post 2000 wood burner	7.2	19%	43	32	16%	434	322	16%	4	3	13%	1	1	10%	130	96	16%	12	9	17%	43	32	16%
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	0%
Multi fuel burner																							
Multi fuel burner - wood	1.1	3%	14	10	5%	138	102	5%	1	0	2%	0	0	1%	41	31	5%	2	1	2%	14	10	5%
Multi fuel burner - 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%
Gas	4.6	12%	0	0	0%	1	1	0%	6	5	21%	0	0	0%	0	0	0%	11	9	17%	0	0	0%
Oil	1.7	4%	0	0	0%	1	1	0%	4	3	13%	6	5	43%	0	0	0%	5	4	8%	0	0	0%
Total Wood	31.4	82%	261	194	96%	2613	1937	99%	17	13	60%	6	5	42%	784	581	99%	50	37	74%	261	194	98%
Total Coal	0.4	1%	9	7	3%	35	26	1%	2	1	6%	2	2	15%	7	5	1%	1	1	2%	5	4	2%
Total	38		271	201		2650	1964		29	21		15	11		791	586		68	50		267	198	

3.3.3 Daily variations in domestic heating emissions by study area

Emissions estimates for domestic home heating were allocated to different time of day categories based on the time of day breakdown for the 2001 Hamilton emission inventory. Table 3.15 shows the proportion of each contaminant estimated to occur within each time of day period for Hamilton in 2001 and the subsequent 2005 emission estimates for each time period. Data are based on the average case scenario, which allows for not all households using a particular heating method on a given night.

This table also provides a comparison of the total quantity of contaminants estimated for each study area. Whereas the greatest amount of PM_{10} is emitted at Hamilton East (436 kg/day), the lowest mass emission is in the central study area where only 44 kilograms of PM_{10} is emitted per day.

Table 3-16: Daily variations in contaminant emissions from domestic home heating

	PM_{10}					CO					NOx					SOx				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am		6am-10am	10am-4pm	4pm-10pm	10pm-6am		6am-10am	10am-4pm	4pm-10pm	10pm-6am		6am-10am	10am-4pm	4pm-10pm	10pm-6am	
Hamilton 2001 distribution	8%	12%	65%	15%		8%	12%	65%	14%		7%	10%	65%	18%		6%	9%	62%	23%	
Hamilton total 2005	127	193	1037	242	1598	1165	1753	9437	2084	14439	10	15	90	25	139	5	7	48	18	78
Central	4	5	29	7	45	37	55	297	65	454	0	1	3	1	5	0	0	1	0	2
Hamilton East	35	53	283	66	436	313	471	2533	559	3875	3	4	24	6	37	1	2	12	5	20
Hospital (Melville)	19	28	152	35	234	167	251	1349	298	2064	1	2	12	3	18	1	1	7	3	12
Mid East (Claudelands)	17	27	143	33	220	173	260	1401	309	2143	2	3	16	4	24	1	1	7	2	11
Te Rapa	26	40	217	51	334	217	326	1756	388	2687	2	2	14	4	22	1	2	11	4	18
Upper East (Flagstaff)	4	7	37	9	57	46	69	369	82	565	0	1	3	1	5	0	0	1	0	1
Western (Frankton)	21	33	176	41	271	214	322	1732	382	2650	2	3	19	5	29	1	1	9	3	15
	VOC					CO_2					$PM_{2.5}$									
	6am-10am	10am-4pm	4pm-10pm	10pm-6am		6am-10am	10am-4pm	4pm-10pm	10pm-6am		6am-10am	10am-4pm	4pm-10pm	10pm-6am						
Hamilton 2001 distribution	8%	12%	65%	65%	65%	8%	12%	64%	16%		8%	12%	65%	15%						
Hamilton total 2005	332	500	2719	589	4139	26	37	206	52	321	12	18	94	20	144					
Central	11	16	89	19	136	1	1	7	2	11	0	1	3	1	5					
Hamilton East	88	133	722	156	1099	6	9	50	13	78	3	4	24	5	37					
Hospital (Melville)	47	70	383	83	583	3	5	27	7	42	2	2	12	3	18					
Mid East (Claudelands)	51	77	420	91	639	4	6	34	9	53	2	3	16	3	24					
Te Rapa	58	87	474	103	722	4	6	35	9	55	2	3	15	3	23					
Upper East (Flagstaff)	14	20	111	24	170	1	2	9	2	14	1	1	4	1	7					
Western (Frankton)	63	96	520	112	791	6	8	44	11	68	3	4	20	4	30					

4 Motor Vehicles

4.1 Methodology

The method used to estimate emissions from motor vehicles in Hamilton involved collecting data on vehicle kilometres travelled (VKT) under different levels of congestion, and the application of emission factors to these data. The Hamilton road network model was used to derive VKTs for different levels of congestion for the year 2005.

4.1.1 Emission factors

The New Zealand Traffic Emission Rates (NZTER) database was used to estimate motor vehicle emission factors for PM_{10}, CO, NOx and VOC. These were based on a vehicle fleet profile derived from motor vehicle registrations for Hamilton at 31 December 2004 (Table 4.1). The percentages of different vehicles are similar to the national vehicle fleet profile for 1998 described in the Ministry of Transport's Vehicle Fleet Emission Control Strategy (Table 4.2). 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/traffic conditions. Emission rates for SOx and CO_2 are not included in the NZTER database and were selected based on emission rates derived by the Fuel and Energy Group for the national vehicle fleet profile.

Similarly, no emission factors for $PM_{2.5}$ are included in the NZTER emission factor database. For this study, $PM_{2.5}$ emission factors were based on estimates of PM_{10} emissions using data from the British Colombia Lower Fraser Valley (GVRD, 1995) adjusted for the Hamilton vehicle fleet profile. This indicated that around 61% of the PM_{10} tailpipe emissions would be in the $PM_{2.5}$ size fraction in the Hamilton area.

In addition to tailpipe emissions, PM_{10} from the wearing of brakes and tyres were also included in the emissions assessments. Emission factors for PM_{10} and $PM_{2.5}$ from these sources were also derived from the British Colombia Lower Fraser Valley data adjusted for the Hamilton vehicle fleet profile. The extent to which these conversions based on overseas data are applicable to New Zealand vehicle emissions is uncertain. Consequently emission estimates for $PM_{2.5}$ from motor vehicles and PM_{10} and $PM_{2.5}$ from the wearing of tyre and brakes should be treated with caution.

Table 4-1: Vehicle registrations in Hamilton (December 2004)

	Petrol	Diesel	LPG	Other	Total
Cars	74,149	5,816	22	11	79,998
Light commercial vehicle	2,764	6,002	11	2	8,777
Bus	76	460	3	25	564
Heavy truck	921	2001	4	1	2,926
Miscellaneous	62	367	2		431
Motorcycle	1,427			1	1,428
Total	79,399	14,645	41	39	94,124
Percentage	84%	16%	0%	0%	100%

Table 4-2: New Zealand vehicle fleet profile from MOT (1998)

	Petrol	Diesel	CNG	LPG	Electric	Total
Cars	1798000	103100	280	640		1902020
LCV	212000	148600	130	230		360960
Bus	600	6600	80	170	1200	8650
Heavy truck	3200	68000	280	330		71810
Miscellaneous	6200	18600				24800
Motorcycle	79000					79000
Total	2099000	344900	770	1370	1200	2447240
Total percentage	85.8%	14.1%	0.0%	0.1%	0.0%	100.0%

As indicated above, VKT data were collected for different levels of congestion. In addition, road areas are treated as either suburban or urban depending on the road characteristics. This is because different driving patterns occur for different road conditions and these patterns, as well as extent of congestion, impact on emissions.

The area of Hamilton Central (Central Business District and Hamilton Lakes) area was treated as an urban area driving regime. The remainder of areas were classified as "suburban" driving regimes. Three different levels of congestion were included in the motor vehicle analysis. These are referred to as Levels Of Service (LOS) and include free flow (LOS category A-B), interrupted flow (LOS category C-D) and congested (LOS category E-F).

The emission factors for each contaminant and each LOS category for Hamilton for 2005 for the urban and suburban driving regimes are shown in Table 4.3. The NZTER derived emission rates are based on 20% of the VKTs occurring under cold start conditions.

Table 4-3: Hamilton emission factors for 2005 based on a suburban driving regime

	Urban driving regime						
	CO g/km	CO_2 g/km	HC g/km	NOX g/km	SOX g/km	PM_{10} g/km	$PM_{2.5}$ g/km
Congested (E-F)	27.16	726.75	3.97	17.08	0.399	0.15	0.090
Interrupted (C-D)	17.50	557.43	1.74	1.65	0.316	0.10	0.062
Free flow (A-B)	13.86	409.58	2.04	1.33	0.255	0.08	0.051
	Suburban driving regime						
Congested (E-F)	17.10	475.85	2.42	1.52	0.281	0.11	0.068
Interrupted (C-D)	13.69	406.10	1.91	1.43	0.235	0.08	0.049
Free flow (A-B)	11.16	365.44	1.79	1.32	0.215	0.07	0.043

4.1.2 Vehicle kilometres travelled

The daily vehicle kilometres travelled (VKT) in Hamilton for 2005 were estimated by Gabbites Porter using the TRACKs road network modelling system. Table 4.4 shows the number of VKT for each of the different time periods, for each of the different levels of congestion for 2005 for the seven study areas of Hamilton.

Table 4-4: Daily VKT estimates for Hamilton by level of service (LOS) and time of day

	Total VKT	VKT Level of Service			Time of day			
		A-B	C-D	E-F	6am-10am	10am-4pm	4pm-10pm	10pm-6am
Melville	221,421	171786	42736	6899	55141	82196	73261	10823
Te Rapa	587,190	363704	200148	23338	144351	230137	180996	31705
Frankton	436,984	328374	101320	7289	107767	167531	139694	21992
CBD	405,527	291277	107659	6591	93515	162317	128126	21569
Hamilton East	399,380	325353	67737	6290	98230	150747	130142	20260
Claudlands	399,283	296409	95375	7499	96968	148945	133742	19629
Flagstaff	181,528	151525	26134	3869	43075	67540	61772	9142
Total Hamilton	**2,631,312**	**1,928,428**	**641,109**	**61,776**	**639,046**	**1,009,413**	**847,733**	**135,119**

Emissions for the year 2005 were estimated by multiplying the VKT estimates in Table 4.4 by the emission factors shown in Table 4.3. Equation 4.1 shows the calculation used to determine the amount of emissions for each time period.

*Equation 4.1 Emissions(g)=Emission Factor (g/km) * VKT (km)*

The emissions over a 24-hour period were calculated by totalling the emissions calculated during the four emission inventory time-periods.

4.2 Motor vehicle emissions

The road network model indicates a daily total of 2,631,312 VKTs Hamilton during 2005. Traffic conditions are relatively free flowing and the majority of the VKTs occur during the 6am to 10pm periods.

Combined with the emissions factors, this indicates that around 249 kilograms of PM_{10} is estimated to be produced as a result of vehicle emissions in Hamilton. Of this 202 kg is estimated to be from tailpipe emissions with 47 kg from brake wear and tyres (Figure 4.1).

Based on overseas emission data adjusted for the Hamilton vehicle fleet, approximately 61% of the tailpipe and 33% of the brake and tyre wear PM_{10} emissions are in the finer $PM_{2.5}$ size fraction. If these data are applicable to motor vehicle emissions in New Zealand, about 56% of the PM_{10} emissions from motor vehicles in Hamilton are likely to be in the finer $PM_{2.5}$ size fraction.

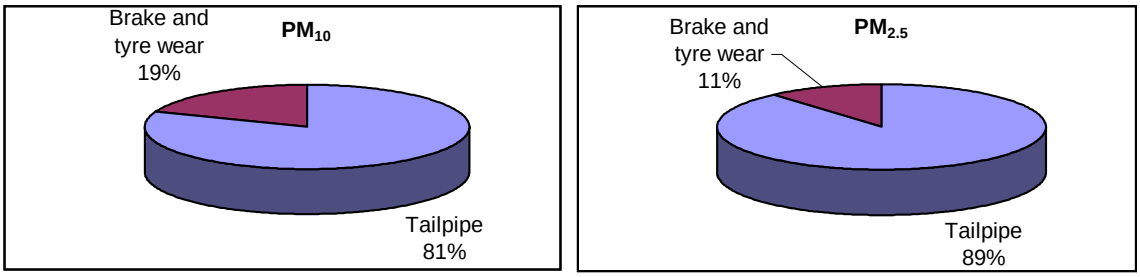

Figure 4-1: Breakdown of PM10 (left) and PM2.5 (right) emissions from motor vehicles

Figure 4.2 shows variations in motor vehicle PM_{10} emissions in Hamilton by time of day. The majority of the emissions occur during the daytime (10am-4pm) period and evening periods with smaller contributions during the morning (24%) and night time (5%) periods.

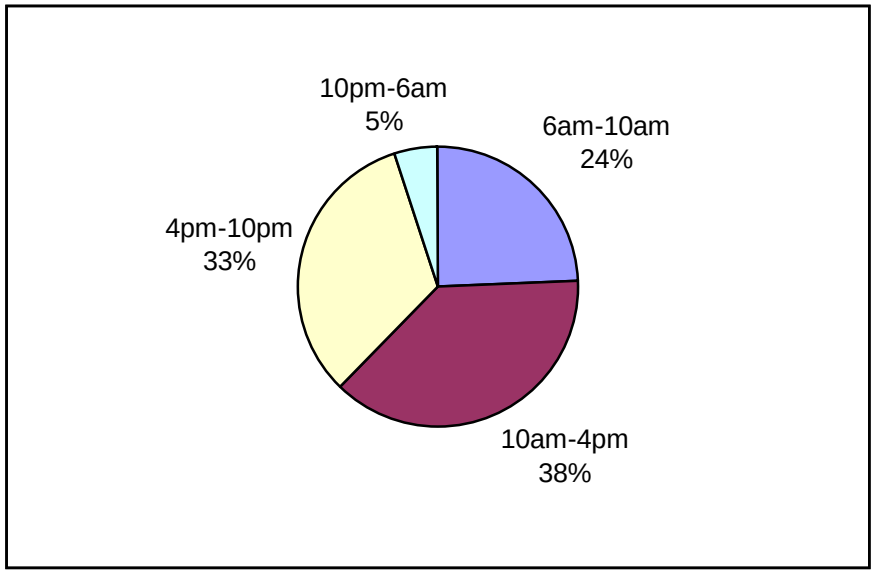

Figure 4-2: Daily variations in PM10 emissions from motor vehicles

Other contaminant emissions from motor vehicles in Hamilton include around 32.6 tonnes of CO, 3.7 tonnes of NOx and 604 kg of SOx. In comparison, in Christchurch, where CO concentrations exceed ambient air quality guidelines at least once during most winters, motor vehicles emit around 109 tonnes of CO within the main urban area.

Tables 4.5 and 4.6 show emissions from motor vehicles in Hamilton by time of day and by weight and grams per hectare respectively.

Table 4-5: Emissions from motor vehicles by time of day

	PM_{10}					CO					NOx					SOx				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	NOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	SOx (kg)
Melville	5	7	7	1	20	651	952	897	121	2620	74	110	100	14	299	12	18	17	2	49
Te Rapa	14	21	17	3	55	1819	2779	2247	354	7199	199	313	248	42	803	33	51	41	7	132
Frankton	10	15	13	2	40	1290	1967	1675	245	5177	146	226	189	29	591	24	37	31	5	97
CBD	10	17	14	2	43	1422	2404	1976	299	6101	159	232	259	29	679	26	44	36	6	111
Hamilton East	9	14	12	2	36	1155	1713	1572	226	4666	132	201	177	27	537	22	33	29	4	88
Claudelands	9	13	13	2	37	1166	1714	1643	219	4742	132	199	183	26	540	22	32	30	4	88
Flagstaff	4	6	6	1	17	510	771	731	102	2115	58	90	83	12	244	10	15	14	2	40
Total Hamilton	**61**	**94**	**81**	**12**	**249**	**8,013**	**12,302**	**10,741**	**1,566**	**32,622**	**901**	**1,372**	**1,240**	**179**	**3,693**	**148**	**230**	**197**	**30**	**604**
	VOC					**CO_2**					**$PM_{2.5}$**									
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO_2 (t)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	$PM_{2.5}$ (kg)					
Melville	101	149	137	19	406	25	58	34	4	122	3	4	4	1	11					
Te Rapa	272	422	339	57	1091	59	105	74	12	250	8	12	10	2	31					
Frankton	198	305	257	39	799	48	105	62	8	223	6	8	7	1	22					
CBD	185	319	260	44	808	49	110	67	9	236	6	10	8	1	24					
Hamilton East	179	271	240	36	727	46	109	61	7	222	5	8	7	1	20					
Claudelands	179	269	248	35	731	44	96	60	7	207	5	7	7	1	20					
Flagstaff	79	122	113	16	331	20	49	28	3	100	2	3	3	0	9					
Total Hamilton	**1,193**	**1,857**	**1,595**	**247**	**4,893**	**291**	**633**	**385**	**50**	**1,360**	**34**	**53**	**45**	**7**	**139**					

Table 4-6: Summary of motor vehicle emissions in Hamilton

		PM_{10}		CO		NOx		SOx	
	Hectares	**kg**	**g/ha**	**Kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Melville	611	20	33	2,620	4287	299	489	49	80
Te Rapa	2090	55	26	7,199	3444	803	384	132	63
Frankton	1349	40	30	5,177	3837	591	438	97	72
CBD	628	43	69	6,101	9709	679	1081	111	177
Hamilton East	1126	36	32	4,666	4145	537	477	88	78
Claudelands	1243	37	30	4,742	3817	540	435	88	71
Flagstaff	1494	17	11	2,115	1416	244	163	40	27
Total Hamilton	8541	249	29	32,622	3819	3,693	432	604	71
		VOC		**CO_2**		**$PM_{2.5}$**			
	Hectares	**kg**		**T**	**kg/ha**	**kg**	**g/ha**		
Melville	611	406	664	122	199	11	19		
Te Rapa	2090	1091	522	250	119	31	15		
Frankton	1349	799	592	223	166	22	17		
CBD	628	808	1286	236	375	24	39		
Hamilton East	1126	727	646	222	198	20	18		
Claudelands	1243	731	588	207	166	20	16		
Flagstaff	1494	331	221	100	67	9	6		
Total Hamilton	8541	4893	573	1360	159	139	16		

5 Industrial and Commercial

5.1 Methodology

Industrial activities that discharge to air in Hamilton are limited to a small number of combustion processes such as coal fired boilers used in hospital and schools as well as a few small process activities. A large number of commercial buildings in Hamilton use gas fired boiler systems, which emit very little PM_{10}, in comparison to coal and wood boilers.

Non-consented activities were identified by Environment Waikato staff through consultation with the Hamilton City Council, the Ministry of Education, energy suppliers and use of business directories and telephone books. The methodology used to estimate emissions from these activities involved the collection of data relating to the process e.g., boiler, referred to as activity data and the application of emission factors to these data.

Activity data were collected by Environment Waikato staff, through contact with local industrial and commercial activities and local schools. The selection of industries for inclusion in the inventory was primarily based on potential for PM_{10} emissions. Industrial activities such as spray painting or dry cleaning operations, which discharge primarily volatile organic compounds (VOC) were not included in the assessment. Medium and small scale gas combustion processes were also excluded because of the relatively small amount of PM_{10} discharged

The 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 5.1. The coal fired boiler emission factors for PM_{10} are based on Coal Research Limited emission factors. Emission factors for $PM_{2.5}$ are based on AP42 particle size distribution factors, as are emission factors for PM_{10} from wood fired boilers and diesels and CO, NOx and SOx. The VOC and CO_2 emission factors are based on factors derived by NIWA for the Christchurch 1996 emission inventory.

Table 5-1: 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
Coal boiler (underfeed stoker)	3.1	1.9	5.5	4.8	13.5	0.1	2400
Coal boiler (chaingrate)	1.8	0.7	3.0	3.8	18	0.1	2400
Diesel boilers	0.47	0.11	0.67	3.24	10.5	0.2	3194
	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3	g/m^3
Natural gas	0.12	0.12	1.34	1.6	0.0096	0.088	1920

5.2 Industrial and commercial emissions

The main source of industrial and commercial air emissions in Hamilton is the Waikato Hospital boiler which burns around 35 tonnes of coal per day. Just less than 100 kilograms of PM_{10} are estimated to be emitted per day during the winter months from industrial and commercial activities in the urban areas of Hamilton. Figure 5.1 shows the estimated contribution of different activities to wintertime daily PM_{10} emissions in Hamilton. Tables 5.2 and 5.3 show estimated emissions by study area.

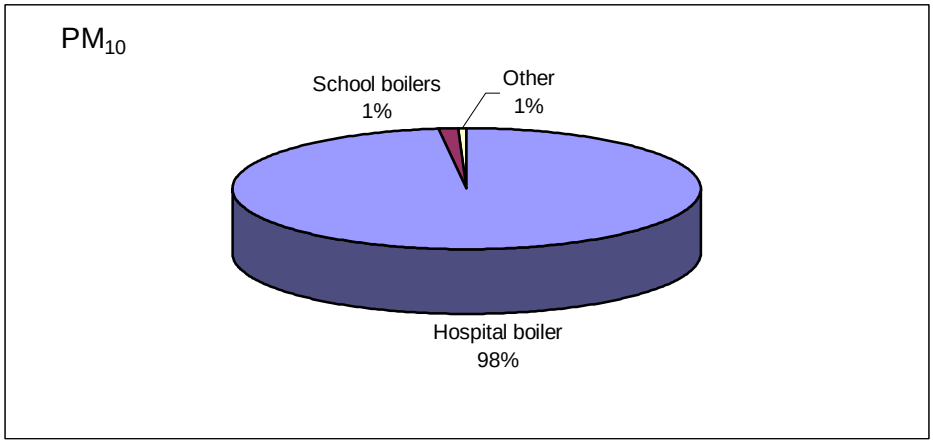

Figure 5-1: Relative contribution of industrial and commercial sources to wintertime PM_{10} emissions in Hamilton

Table 5-2: Summary of daily Hamilton industrial/ commercial emissions during winter

		PM_{10}		CO		NOx		SOx	
	Hectares	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Melville	611	93	152	165	269	142	233	539	882
Te Rapa	2090	1	0	1	1	2	1	3	1
Frankton	2137	0	0	0	0	0	0	1	1
CBD	628	0	0	0	1	0	0	1	2
Hamilton East	1126	0	0	0	0	0	0	1	1
Claudlands	1243	0	0	0	0	0	0	1	1
Flagstaff	1494	0	0	0	0	0	0	1	1
Total Hamilton	8541	94	11	168	20	146	17	547	64
		VOC		**CO_2**		**$PM_{2.5}$**			
	Hectares	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**		
Melville	611	2	3	72	118	57	93		
Te Rapa	2090	0	0	1	1	0	0		
Frankton	2137	0	0	0	0	0	0		
CBD	628	0	0	0	0	0	0		
Hamilton East	1126	0	0	0	0	0	0		
Claudlands	1243	0	0	0	0	0	0		
Flagstaff	1494	0	0	0	0	0	0		
Total Hamilton	8541	2	0	74	9	57	7		

Table 5-3: Daily winter industrial/commercial emissions for Hamilton by time of day

	Suspended Particulate – PM_{10}					Suspended Particulate - $PM_{2.5}$					Carbon monoxide					Nitrogen oxides				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	$PM_{2.5}$ (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	NOx (kg)
Melville	16	23	23	31	93	10	14	14	19	57	28	41	41	55	165	24	36	35	47	142
Te Rapa	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	2	0	0	2
Frankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CBD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hamilton East	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Claudelands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flagstaff	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Hamilton	17	24	23	31	94	10	14	14	19	57	30	42	41	55	168	26	38	35	47	146
	Sulphur oxides					**Volatile organic compounds**					**Carbon dioxide**									
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	SOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO_2 (t)					
Melville	91	135	135	179	539	0	0	0	1	2	12	18	18	24	72					
Te Rapa	1	1	0	0	3	0	0	0	0	0	0	1	0	0	1					
Frankton	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0					
CBD	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0					
Hamilton East	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0					
Claudelands	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0					
Flagstaff	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0					
Total Hamilton	96	137	135	179	547	0	0	0	1	2	13	19	18	24	74					

6 Outdoor burning

Outdoor burning includes the burning of domestic rubbish and garden waste in purpose built incinerators, drums or on open ground. Emissions from outdoor burning can contribute to concentrations of contaminants in ambient air and can cause localised smoke and nuisance problems. In some urban areas of New Zealand outdoor burning is prohibited because of these impacts. Presently there are no regulations restricting outdoor burning in Hamilton, although section 17 of the Resource Management Act (1991) or section 29 of the Health Act could be used to control these emissions if individual discharges were causing adverse effects.

6.1 Methodology

Emissions from outdoor burning during the winter months were estimated for Hamilton based on data collected as part of the 2005 Hamilton domestic home heating emission survey. This data included frequency of burning and average quantity of material burnt. The proportion of green waste (60%) versus household rubbish burnt (40%) was based on data collected in Otago. Emissions were calculated using the emission factors in Table 6.1.

Table 6-1: Outdoor burning emission factors (AP42, 2002)

	$PM_{2.5}$ g/kg	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg
Garden rubbish	8	8	42	3	0.5	4	1470
Household rubbish	17	19	42	3	0.5	4.278	1470
Emission factor	11.7	12.5	42.0	3.0	0.5	4.3	1470

6.2 Emissions from outdoor burning

Outdoor burning emission estimates for Hamilton (Table 6.2) indicate that around 287 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months. Of this, the majority (93%) is within the finer, $PM_{2.5}$ size fraction. Outdoor burning also produces around 965 kg of carbon monoxide and around 34 tonnes of carbon dioxide per day during winter.

It should be noted, however, that there are a number of uncertainties relating to this estimation. In particular it is assumed that burning is carried out evenly throughout the winter, whereas in reality it is highly probable that a disproportionate amount of burning is carried out during weekend days. Thus on some days no PM_{10} from outdoor burning may occur and on other days it might be many times the amount estimated in this assessment.

Table 6.3 shows seasonal variations in outdoor burning emissions in Hamilton. Emissions from outdoor burning are reasonably consistent throughout the year, with PM_{10} emissions ranging from 233 kg/day in summer to 287kg/day in winter.

Table 6-2: Wintertime outdoor burning emission estimates for Hamilton by area

	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
Melville	8	27	2	0	3	1	7
Te Rapa	13	42	3	1	4	1	12
Frankton	39	132	9	2	14	5	37
Centre	11	37	3	0	4	1	10
Hamilton East	128	429	31	5	44	15	119
Claudlands	71	239	17	3	25	8	67
Flagstaff	17	59	4	1	6	2	16
Hamilton	287	965	69	11	99	34	269

Table 6-3: Seasonal variations in outdoor burning emissions in Hamilton

Outdoor burning	PM_{10}	CO	NOx	SOx	VOC	CO_2	$PM_{2.5}$
	kg/day	kg/day	kg/day	kg/day	kg/day	t/day	kg/day
January	233	784	56	9	80	27	218
February	233	784	56	9	80	27	218
March	284	954	68	11	98	33	266
April	284	954	68	11	98	33	266
May	284	954	68	11	98	33	266
June	287	965	69	11	99	34	269
July	287	965	69	11	99	34	269
August	287	965	69	11	99	34	269
September	259	870	62	10	89	30	242
October	259	870	62	10	89	30	242
November	259	870	62	10	89	30	242
December	233	784	56	9	80	27	218
Total (kg/ year)	97100	326255	23304	3884	33402	11419	90885

7 Total Emissions

7.1 Hamilton

Around 2.2 tonnes of PM_{10} are discharged over the urban areas of Hamilton on an average winter's day. The majority (around 1.5 tonnes) is from the burning of solid fuel for domestic home heating. Motor vehicles contribute around 11% of the daily wintertime PM_{10}, with outdoor burning resulting in 13% and industry 4% (Figure 7.1). The main source of industrial PM_{10} emissions in Hamilton is the burning of coal in the hospital boiler.

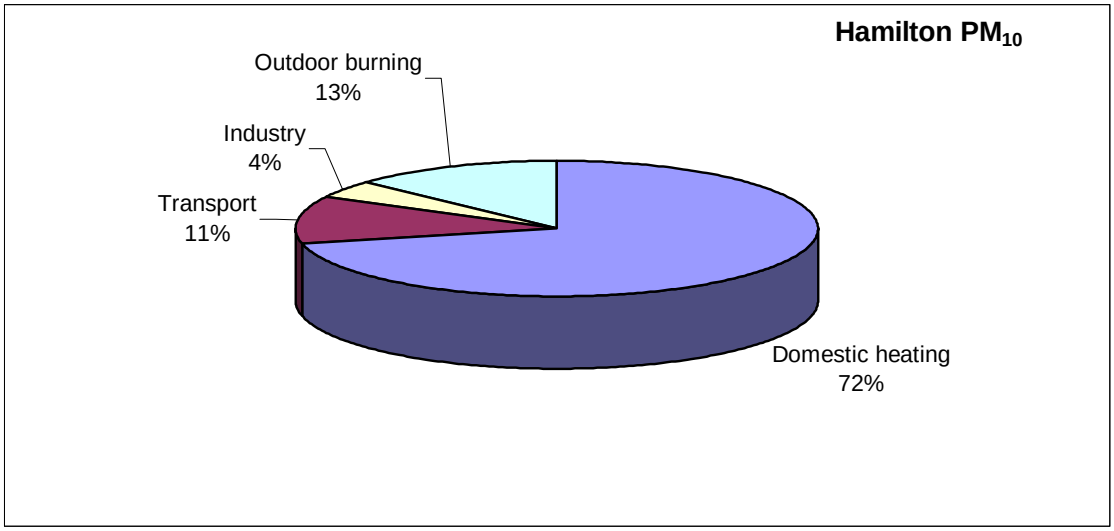

Figure 7-1: Relative contribution of sources to daily winter PM10 emissions in Hamilton:

Motor vehicles are the main source of most other air contaminants shown in Figure 7.2. This source contributes 68% of the CO emissions, 76% of the CO_2 emissions and 91% of the NOx emissions during winter in Hamilton.

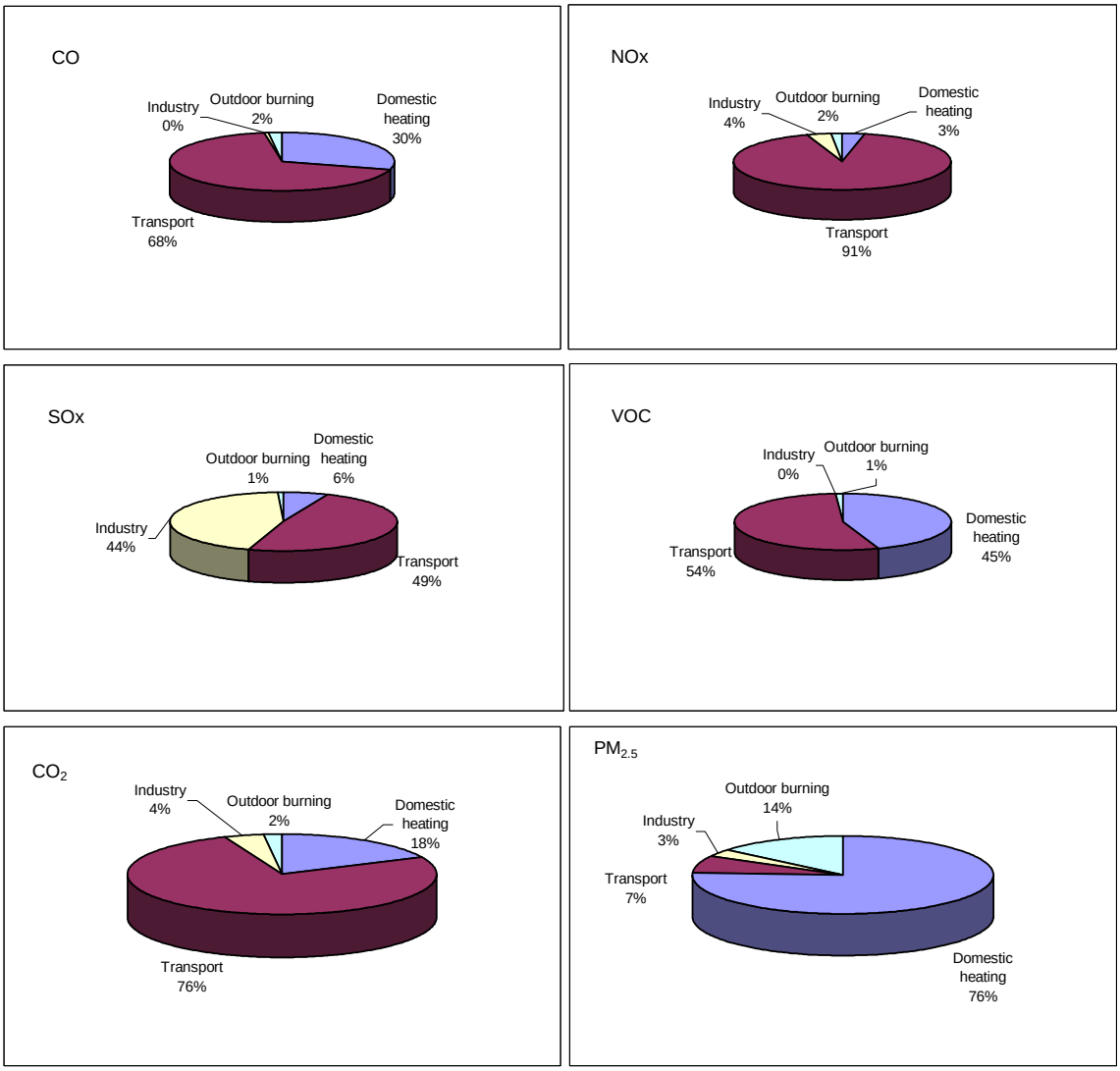

Figure 7-2: Relative contribution of sources to contaminant emissions during winter in Hamilton

Table 7.1 shows daily variations in contaminant emissions in Hamilton for an average winter's day. The majority of emissions are estimated to occur during the evening (4pm – 10pm) period.

Although domestic home heating is the dominant source of PM_{10} emissions during the winter months, during the summer, motor vehicles and outdoor burning are the dominant contributors to PM_{10} emissions contributing 41% and 38% of the daily PM_{10} respectively (Table 7.2). While there is considerable seasonal variation in the domestic burning contribution to PM_{10} emissions, the discharges of PM_{10} from outdoor burning, industry and motor vehicles are relatively consistent throughout the year.

Table 7-1: Total daily wintertime emissions by time of day for Hamilton

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	127	193	1037	242	1598	119	179	968	218	1483	1165	1753	9437	2084	14439	10	15	90	25	139
Motor vehicle	61	94	81	12	249	34	53	45	7	139	8013	12302	10741	1566	32622	901	1372	1240	179	3693
Industry	17	24	23	31	94	10	14	14	19	57	30	42	41	55	168	26	38	35	47	146
Outdoor burning	72	215			287	67	202			269	241	724			965	17	52			69
Total	276	526	1141	285	2229	230	448	1027	243	1949	9448	14821	20220	3705	48194	954	1476	1366	251	4047

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 CO2 (t)
Domestic heating	5	7	48	18	78	332	500	2719	589	4139	26	37	206	52	321
Motor vehicle	145	225	193	29	593	1193	1857	1595	247	4893	289	627	382	50	1348
Industry	96	137	135	179	547	0	0	0	1	2	13	19	18	24	74
Outdoor burning	3	9			11	25	74			99	8	25			34
Total	249	378	376	227	1229	1550	2431	4315	837	9133	336	708	606	126	1776

Table 7-2: Monthly variations in daily PM_{10} emissions in Hamilton

	Domestic Heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	
January	0	0%	233	40%	95	16%	249	43%	577
February	0	0%	233	40%	95	16%	249	43%	577
March	37	6%	284	43%	93	14%	249	38%	663
April	129	17%	284	38%	93	12%	249	33%	755
May	988	61%	284	18%	93	6%	249	15%	1614
June	1493	70%	287	14%	94	4%	249	12%	2123
July	1598	72%	287	13%	94	4%	249	11%	2229
August	1448	70%	287	14%	94	5%	249	12%	2079
September	606	50%	259	21%	95	8%	249	21%	1208
October	186	24%	259	33%	95	12%	249	32%	788
November	70	10%	259	39%	95	14%	249	37%	672
December	37	6%	233	38%	95	15%	249	41%	614
Total kg year	202015	48%	97100	23%	34446	8%	90874	21%	424434

7.2 Total emissions by study area

Although domestic home heating is the dominant source of PM_{10} emissions across the whole of the Hamilton area, there are significant spatial variations in the contribution of sources to PM_{10}. In particular, motor vehicles are estimated to contribute as much PM_{10} as domestic heating (both around 45%) in the central (CBD) area of Hamilton and industry is estimated to contribute 26% of the daily PM_{10} in the Melville (hospital) area (Figure 7.3).

The greatest quantity of PM_{10} is discharged during the winter in the areas of Hamilton East (601 kg/day) followed by Te Rapa (403 kg/day), Melville (356 kg/day) and Frankton (351 kg/day).

Tables 7.2–7.8 show daily winter contaminant emissions by time of day and source for each study area. The relative emission densities for each study area are shown in Table 7.9. This shows the area with the highest emission density is Melville with around 582 grams of PM_{10} per hectare of land (g/ha). This is slightly higher than in Hamilton East (533 g/ha). Both areas have emission densities for PM_{10} that are more than twice those of all other areas. It is likely that PM_{10} concentrations will be highest either in or downwind of these areas.

The highest emission densities for CO and NOx occur within the Central area (10491 and 1094 g/ha respectively) because of the greater impact of motor vehicles in this area. Emission rates from SOx are highest in Melville (982 g/ha) as a result of coal burning in the hospital boiler.

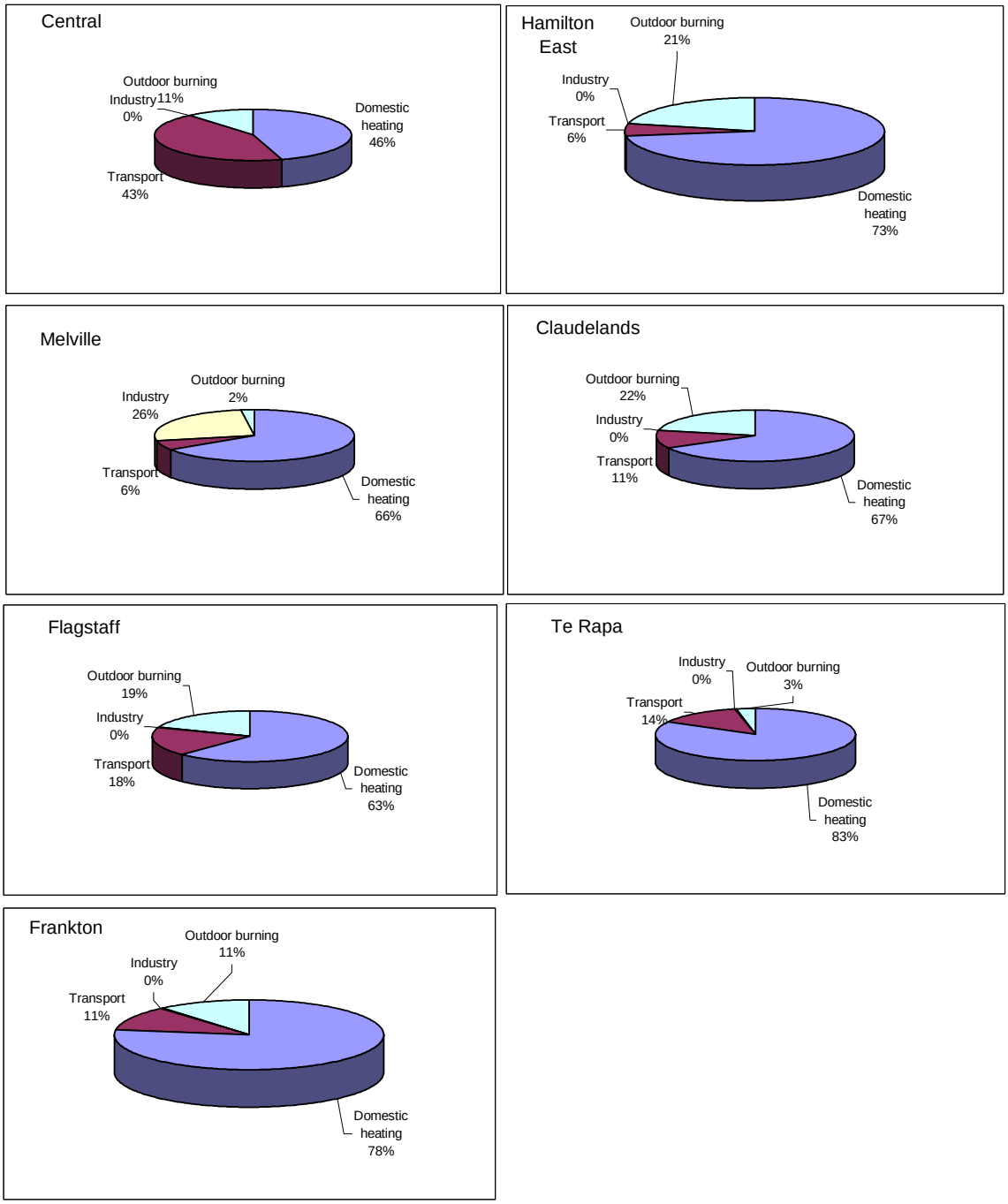

Figure 7-3: Spatial variations in the relative contribution of different sources to daily wintertime PM10 emissions across Hamilton

Table 7-3: Total daily wintertime emissions by time of day for Central Hamilton

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	4	5	29	7	45	4	5	30	7	45	37	55	297	65	454	0	1	3	1	5
Motor vehicle	10	17	14	2	43	6	10	8	1	24	1422	2404	1976	299	6101	159	232	259	29	679
Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor burning	3	8			11	3	8			10	9	28			37	1	2			3
Total	17	31	43	9	100	12	23	38	8	80	1468	2488	2272	364	6592	161	235	263	30	687

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 CO2 (t)
Domestic heating	0	0	1	0	2	11	16	89	19	136	1	1	7	2	11
Motor vehicle	25	43	35	5	109	185	319	260	44	808	49	109	66	9	232
Industry	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Outdoor burning	0	0			0	1	3			4	0	1			1
Total	26	44	36	6	112	197	338	349	63	948	50	111	73	10	245

Table 7-4: Total daily wintertime emissions by time of day for Melville

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	19	28	152	35	234	17	26	139	31	213	167	251	1349	298	2064	1	2	12	3	18
Motor vehicle	5	7	7	1	20	3	4	4	1	11	651	952	897	121	2620	74	110	100	14	299
Industry	16	23	23	31	93	10	14	14	19	57	28	41	41	55	165	24	36	35	47	142
Outdoor burning	2	6			8	2	6			7	7	20			27	0	1			2
Total	41	65	182	67	356	31	50	157	51	289	851	1264	2287	474	4877	100	149	147	65	461

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	1	7	3	12	47	70	383	83	583	3	5	27	7	42
Motor vehicle	12	18	16	2	48	101	149	137	19	406	25	58	34	4	121
Industry	91	135	135	179	539	0	0	0	1	2	12	18	18	24	72
Outdoor burning	0	0			0	1	2			3	0	1			1
Total	103	154	158	184	599	148	222	520	103	993	41	81	78	35	235

Table 7-5: Total daily wintertime emissions by time of day for Hamilton East

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	35	53	283	66	436	32	48	261	59	400	313	471	2533	559	3875	3	4	24	6	37
Motor vehicle	9	14	12	2	36	5	8	7	1	20	1155	1713	1572	226	4666	132	201	177	27	537
Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor burning	32	96			128	30	90			119	107	322			429	8	23			31
Total	76	162	295	68	601	67	146	267	60	540	1575	2505	4105	785	8971	143	228	201	33	605

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	12	5	20	88	133	722	156	1099	6	9	50	13	78
Motor vehicle	21	32	28	4	86	179	271	240	36	727	45	108	60	7	221
Industry	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Outdoor burning	1	4			5	11	33			44	4	11			15
Total	25	38	41	9	112	278	437	962	193	1870	56	128	110	20	314

Table 7-6: Total daily wintertime emissions by time of day for Claudelands

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	17	27	143	33	220	17	26	141	32	216	173	260	1401	309	2143	2	3	16	4	24
Motor vehicle	9	13	13	2	37	5	7	7	1	20	1166	1714	1643	219	4742	132	199	183	26	540
Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor burning	18	53			71	17	50			67	60	180			239	4	13			17
Total	44	93	155	35	328	39	84	148	33	303	1399	2154	3044	528	7125	138	215	199	30	582

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	1	7	2	11	51	77	420	91	639	4	6	34	9	53
Motor vehicle	21	32	29	4	87	179	269	248	35	731	43	95	59	7	205
Industry	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Outdoor burning	1	2			3	6	18			25	2	6			8
Total	23	35	36	7	101	236	365	668	126	1395	50	108	94	16	267

Table 7-7: Total daily wintertime emissions by time of day for Te Rapa

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	26	40	217	51	334	23	34	186	42	285	217	326	1756	388	2687	2	2	14	4	22
Motor vehicle	14	21	17	3	55	8	12	10	2	31	1819	2779	2247	354	7199	199	313	248	42	803
Industry	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	2	0	0	2
Outdoor burning	3	9			13	3	9			12	11	32			42	1	2			3
Total	44	71	234	53	403	34	55	196	43	328	2046	3138	4003	742	9930	202	320	263	46	830

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	11	4	18	58	87	474	103	722	4	6	35	9	55
Motor vehicle	32	50	40	7	129	272	422	339	57	1091	59	104	73	11	248
Industry	1	1	0	0	3	0	0	0	0	0	0	1	0	0	1
Outdoor burning	0	0			1	1	3			4	0	1			1
Total	35	54	51	11	150	331	513	813	159	1817	64	112	108	20	305

Table 7-8: Total daily wintertime emissions by time of day for Flagstaff

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	4	7	37	9	57	5	7	37	8	57	46	69	369	82	565	0	1	3	1	5
Motor vehicle	4	6	6	1	17	2	3	3	0	9	510	771	731	102	2115	58	90	83	12	244
Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor burning	4	13			17	4	12			16	15	44			59	1	3			4
Total	13	26	42	9	91	11	22	40	9	82	571	884	1101	184	2739	60	94	87	13	253

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	0	0	1	0	1	14	20	111	24	170	1	2	9	2	14
Motor vehicle	9	14	13	2	39	79	122	113	16	331	20	48	28	3	100
Industry	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Outdoor burning	0	1			1	1	4			6	1	2			2
Total	10	15	14	2	42	94	147	224	40	506	22	51	37	6	115

Table 7-9: Total daily wintertime emissions by time of day for Frankton

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	21	33	176	41	271	21	32	174	39	267	214	322	1732	382	2650	2	3	19	5	29
Motor vehicle	10	15	13	2	40	6	8	7	1	22	1290	1967	1675	245	5177	146	226	189	29	591
Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Outdoor burning	10	29			39	9	28			37	33	99			132	2	7			9
Total	41	78	189	43	351	36	68	181	40	326	1537	2387	3407	628	7959	151	236	208	34	629

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	1	9	3	15	63	96	520	112	791	6	8	44	11	68
Motor vehicle	23	36	30	5	95	198	305	257	39	799	48	105	61	8	222
Industry	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Outdoor burning	0	1			2	3	10			14	1	3			5
Total	26	39	40	8	112	265	410	777	152	1604	54	116	105	19	294

Table 7-10: Summary emissions for Hamilton by study area

		PM_{10}		CO		NOx		SOx	
	Hectares	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Central	628	100	159	6592	10491	687	1094	112	178
Hamilton East	1126	601	533	8971	7969	605	537	112	100
Melville	611	356	582	4877	7977	461	754	599	980
Claudlands	1243	328	264	7125	5734	582	468	101	81
Te Rapa	2090	403	193	9930	4750	830	397	150	72
Flagstaff	1494	91	61	2739	1834	253	170	42	28
Frankton	2137	351	164	7959	3725	629	294	112	52
Total Hamilton	8541	2229	261	48194	5642	4047	474	1229	144
		VOC		**CO_2**		**$PM_{2.5}$**			
	Hectares	**kg**		**t**	**kg/ha**	**kg**	**g/ha**		
Central	628	948	1509	245	389	80	128		
Hamilton East	1126	1870	1661	314	279	540	479		
Melville	611	993	1625	235	385	289	473		
Claudlands	1243	1395	1123	267	215	303	244		
Te Rapa	2090	1817	869	305	146	328	157		
Flagstaff	1494	506	339	115	77	82	55		
Frankton	2137	1604	751	294	138	326	153		
Total Hamilton	8541	9133	1069	1776	208	1949	228		

8 Conclusion

This inventory evaluates the contribution of different sources to emissions of PM_{10}, CO, NOx, SOx, VOC and CO_2. Sources included in the inventory were domestic heating, motor vehicles, outdoor rubbish burning and industrial and commercial discharges.

Domestic home heating emissions were assessed based on a survey of home heating methods and fuels used in Hamilton during 2005. The survey found that gas was the most common heating method in Hamilton and was used by 64% of households to heat their main living area. Electricity use was also common, with 36% of households using this method in their main living area. Of those households using gas, about half used unflued gas heating.

Domestic home heating was found to be the main source of daily wintertime PM_{10} emissions across the whole of Hamilton, accounting for around 72% of emissions. The remaining 28% was distributed between motor vehicles (11%), outdoor burning (13%) and industrial emissions (4%). Motor vehicles also accounted for 68% and 76% of the CO and CO_2 and 91% of the NOx emissions.

Significant seasonal variations in emissions were found, with motor vehicles and outdoor burning contributing 41% and 38% of the daily summer PM_{10} emissions respectively. Domestic heating contributed 48% of the annual PM_{10} emissions, with motor vehicles and outdoor burning each contributing 21-23% of emissions.

Spatial variations in sources of emissions were apparent with motor vehicles contributing as much PM_{10} as domestic home heating in the central (CBD) area, whereas in the Melville (hospital) area, industry was the second most dominant source (exceeded only by domestic home heating) and contributed 26% of the daily winter PM_{10}.

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Appendix One: 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 Environment Waikato
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?

2b. 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

(b) 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)

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?

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?

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.