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Air emission inventory – Hamilton and Tokoroa 2012

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Air Emission Inventory – Hamilton and Tokoroa 2012

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Executive Summary

An emission inventory was carried out for Hamilton and Tokoroa to estimate emissions to air of air contaminants, in particular PM_{10}. Previously air emissions inventories have been carried out for Hamilton (2001 and 2005) and Tokoroa (2004 and 2007). The inventory estimates emissions to air from domestic heating, motor vehicle, industrial and commercial activities and outdoor burning. Natural source contributions (for example; sea salt and soil) are not included because the methodology to estimate emissions is less robust.

The inventory focuses on suspended particles (PM_{10}) the main contaminant of concern in urban areas of Waikato but also makes estimates of emissions of carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds, carbon dioxide, benzene and benzo(a)pyrene.

A domestic home heating survey was undertaken in 2012 to determine the proportions of households using different heating methods and fuels. In Hamilton, electricity is the most common method of heating the main living area with 63% of households using this source of heating. Gas was used by 36% of households and only 11% of households used wood burners. In Tokoroa wood burners were the most used heating method and were used by 50% of households. Electricity was only slightly less popular with 48% of households using this source. In both areas many householders use more than one method to heat the main living area of their home.

Domestic heating is the main source of winter PM_{10} emissions in Hamilton and Tokoroa accounting for 88% and 95% of emissions respectively. Other sources included transport (7% and 1%), outdoor burning (3% and 4%) and industry (2% and <1%). On an average winter's night, around 1344 and 612 kilograms of PM_{10} are discharged in Hamilton and Tokoroa respectively.

Total winter PM_{10} emissions are estimated to have decreased by 31% in Hamilton since 2005 as a result of decreases in all sources. In Tokoroa the reductions are less at 11% since 2007 with the majority occuring as a result of changes in domestic heating.

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1 Introduction

Emission inventories are carried out to determine the sources of emissions in a particular area for air quality management purposes and to evaluate changes in emission sources with time. Emission inventories are used by Governments and Local Government internationally to provide an estimate of the quantities of contaminants from anthropogenic sources that are emitted into the air and the relative contribution of sources to total emissions. The sources that are included in emissions inventories in New Zealand are generally the domestic heating, motor vehicle, industrial and commercial and outdoor burning sector. Natural source contributions (for example; sea salt and soil) are not included because methodologies are less robust.

In New Zealand the main air contaminant of concern in urban areas is PM_{10}. In the Waikato concentrations of PM_{10} breach the National Environmental Standard for PM_{10} (50 µg m^{-3} – 24-hour average with one allowable exceedence per year) in Tokoroa, although the areas of Hamilton, Putaruru, Taupo and Te Kuiti are all marginal with respect to NES compliance with each of these areas recording one exceedence of 50 µg m^{-3} in 2011.

This report primarily focuses on emissions of particles (PM_{10}) from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning. Other contaminants included in this emission inventory are carbon monoxide, nitrogen oxides, sulphur oxides volatile organic compounds, carbon dioxide, benzene and benzo(a)pyrene.

Previous emission inventories for Hamilton have been conducted in 2001 and 2005 and for Tokoroa inventories have been conducted in 2004 and 2007.

2 Inventory Design

The main air contaminant of concern in urban areas of the Waikato Region is PM_{10}. This inventory focuses on PM_{10} emissions and sources of PM_{10}, although estimates of other key contaminants are also made. It is unlikely that concentrations of other key contaminants are likely to exceed national environmental standards (NES) although monitoring indicates concentrations of benzene and benzo(a)pyrene (BaP) may be nearing guideline values in some areas. There are no national environmental standards for benzene or BaP.

2.1 Selection of sources

Estimates of emissions from the domestic heating, motor vehicles, industry and outdoor burning sector are included in the emissions inventory. 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}), carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), carbon dioxide (CO_2), benzene and benzo(a)pyrene (BaP). 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 in the NES because of their potential for adverse health impacts. Carbon dioxide has been typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas CO_2 emissions. However, these data are now 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 (VOCs) 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 Hamilton or Tokoroa would cause ozone problems based on knowledge of the ozone and VOC concentrations previously measured in Hamilton. However, ozone formation as a result of emissions from Auckland could impact on areas such as Thames. In this report, VOC emissions have been estimated for existing sources but data on emissions from VOC specific sources (e.g., spray painting) has not been included.

2.3 Selection of areas

The Hamilton inventory study area is based on the airshed area for Hamilton as gazetted by the Ministry for the Environment. This is shown in Figure 1.1. The airshed area is larger than the inventory area used in the 2005 Hamilton air emission inventory (Figure 2.2) and is largely defined by the Hamilton urban area with the inclusion of Temple View, to the west of Hamilton.

The Tokoroa inventory study area for 2012 is the airshed area that was gazetted by the Ministry for the Environment. This is similar to the 2007 emission inventory. However, prior inventories were based on census area units. Figure 2.3 illustrates the current and 2007 inventory boundary based on the airshed boundary, the earlier inventories based on census area units and also illustrate the urban area boundary used for other planning purposes.

The census area units used in the previous air emission inventories for Tokoroa were as follows: Paraonui, Parkdale, Matarawa, Stanley Park, Tokoroa Central, Aotea, and Strathmore.

The industrial assessment excludes emissions from Kinleith pulp and paper mill, as these were considered unlikely to significantly impact on PM_{10} concentrations in Tokoroa (Wilton, 2005b) and are outside the Tokoroa airshed.

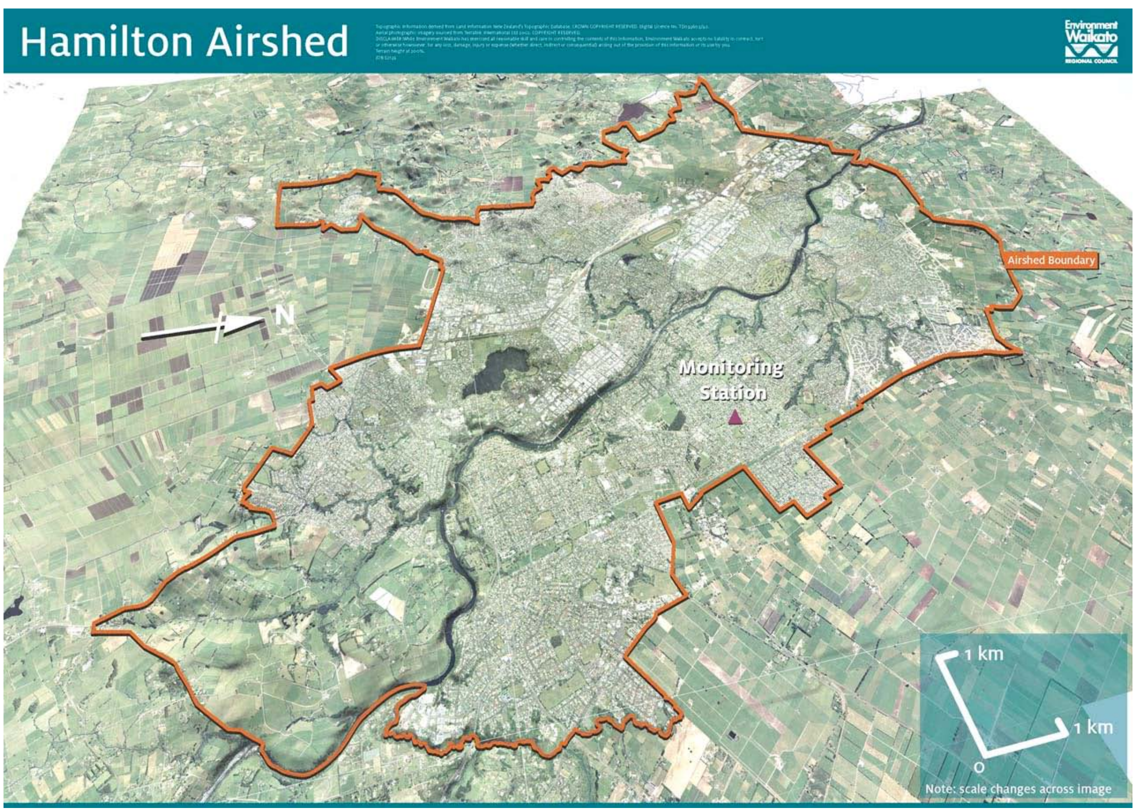

Figure 2.1: Hamilton Airshed (source Waikato Regional Council).

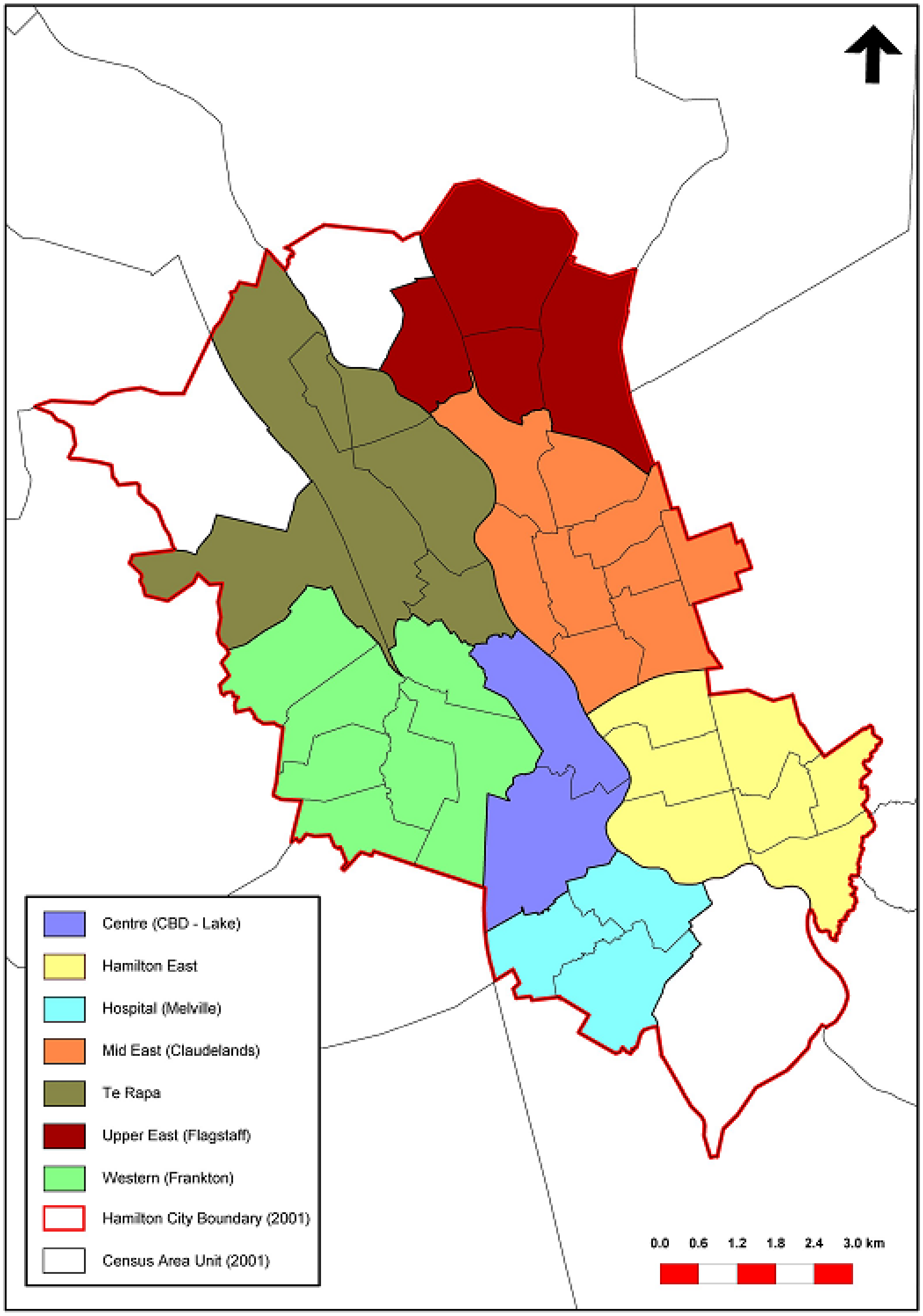

Figure 2.2: Hamilton Inventory Area 2005 (shaded), urban area and census area boundaries.

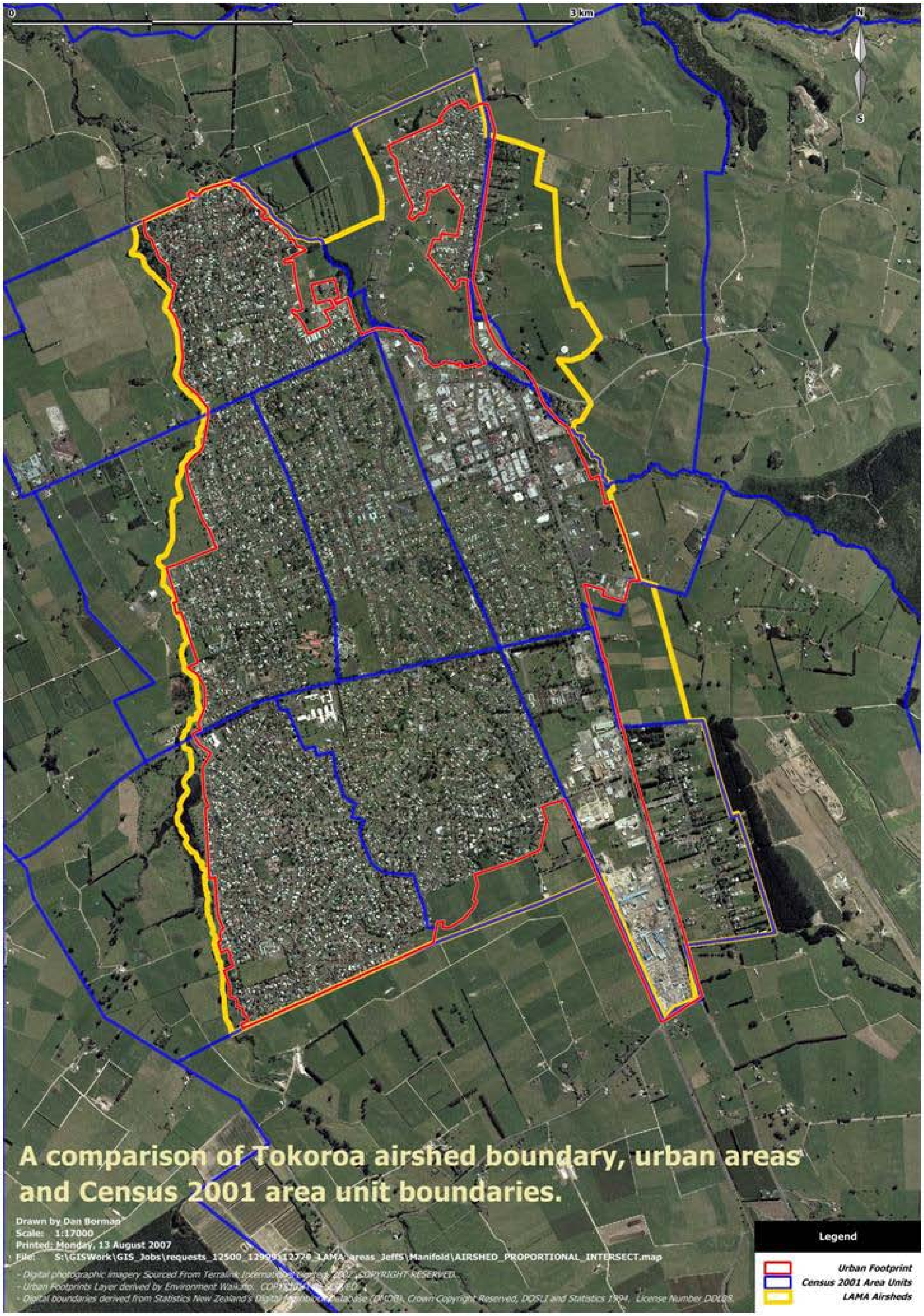

Figure 2.3: Tokoroa Airshed (source Waikato Regional Council).

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 data sources do not contain seasonal variations in vehicle movements. Industrial data were collected by season as was outdoor burning data.

No differentiation was made for weekday and weekend sources and 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 Hamilton and Tokoroa was collected using a household survey carried out by Digipol during June 2012 (Appendix A). Table 3.1 shows the number of households based on 2006 census data for the Airshed area, the estimated households for 2012, and survey details. The 2012 estimate for Hamilton was made using the Statistics New Zealand population projected increase of 1.1% per year for the Hamilton District. The number of households in Tokoroa was assumed to have remained constant which is consistent with South Waikato District Council's internal approach[1] since 2008 of assuming a static population rather than using the Statistics New Zealand population projected decrease of 0.9% per year for the South Waikato district as a whole. It is therefore important to note that this approach for Tokoroa is a potential limitation of this inventory. If the population has actually decreased since 2007, then any emission improvements achieved since the 2007 inventory will actually be less when calculated on a per capita basis.

Table 3.1: Summary household, area and survey data for the Hamilton and Tokoroa Airsheds.

	Households by census area unit 2006	Estimated households 2012	Sample size	Area (ha)	Sample error
Hamilton	46095	49137	380	9855	5%
Tokoroa	4869	4869	350	1049	5%

Home heating methods were classified as; electricity, open fires, wood burners 10 years or older (pre 2002), wood burners five to 10 years old (2003-2007), wood burners less than five years old (post 2007), pellet fires, multi fuel burners, gas burners and oil burners. The post 2007 wood burner category includes all wood burners meeting the NES design criteria and the 2003-2007 category includes a mix of NES compliant and non NES compliant wood burners.

[1] 2008 Census and Demographic Data Analysis, Status Report – for AMP Demand Section, prepared by Waugh Consultants Ltd.

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	CO g/kg	NOx g/kg	SO_2 g/kg	VOC g/kg	CO_2 g/kg	Benzene g/kg	BaP g/kg
Open fire - wood	10	100	1.6	0.2	30	1600	0.97	0.002
Open fire - coal	21	80	4	5.0	15	2600	0.00065	2.70E-06
Pre 2002 burners	11	110	0.5	0.2	33	1600	0.97	0.003
2002-2007 burners	7	70	0.5	0.2	21	1600	0.97	0.003
Post 2007 burners	4	40	0.5	0.2	12	1600	0.97	0.003
Pellet burners	2	20	0.5	0.2	6	1600	0.97	0.003
Multi-fuel[1] - wood	13	130	0.5	0.2	39	1600	0.97	0.002
Multi-fuel[1] – coal	28	120	1.2	3.0	15	2600	0.97	2.70E-06
Oil	0.3	0.6	2.2	3.8	0.25	3200	0.00065	
Gas	0.03	0.18	1.3	7.6E-09	0.2	2500	2.16E-05	

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

The average weight for a log of wood is one of the assumptions required for this inventory to convert householder's estimates of fuel use in logs per evening to a mass measurement required for estimating emissions. Average log weights used for inventories in New Zealand have included 1.6 kilograms, 1.4 kilograms and 1.9 kilograms. The latter value is based on a survey of 219 households in Christchurch during 2002. A 2005 burner emission testing programme carried out in Tokoroa gave an average log weight of 1.3 kilograms. The sample size (pieces of wood weighed) for this study was 845. These were spread across only 12 households so it is uncertain how representative of the Tokoroa population a fuel weight of 1.3 kilograms per log might be. More recently a similar study was carried out in Nelson, Rotorua and Taumaranui. Results of fuel use from that study indicated an average fuel weight of 1.7 kilograms per log. A value of 1.6 kilograms is recommended for use in this inventory.

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

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

Where:

CE = contaminant emission

EF = emission factor

FB = fuel burnt

The main assumptions underlying the emissions calculations are as follows:

- The average weight of a log of wood is 1.6 kilograms.
- The average weight of a bucket of coal is 9 kilograms.

3.2 Home heating methods

3.2.1 Hamilton

Electricity was the main form of home heating in Hamilton during 2012 with around 63% of households using this heating method in their main living area. Gas heating was the next most popular methods (36%). Of the solid fuel heating methods, wood burners are the most common with 11% of households using a wood burner in their main living area (Table 3.3).

Open fires are used by only two percent of Hamilton residents and a similar proportion use multi fuel burners to heat their main living area. For households that use gas, around one third used unflued gas systems. Table 3.3 also shows that households rely on more than one method of heating their main living area during the winter months[2].

Wood was the most common fuel for households using solid fuel heating methods with 15% of households using this fuel with around 116 tonnes of wood burnt per winter's night. Coal use in Hamilton is minimal with two percent of households using coal to heat their main living area. Around 6 tonnes of coal is burnt per winter's night.

[2] Percentages in Table 3.3 refer to the percentage of households that use a specific heating method. In some cases, households will rely on more than one heating method and therefore the sum of the percentages will total more than 100%.

Table 3.3: Home heating methods and fuels in Hamilton.

	Heating Methods		Fuel Use	
	% of Households	Number of Households	t/day	%
Electricity	63%	31,034		
Total Gas	36%	17,457	4.5	4%
Flued gas	23%	11,492		
Unflued gas	12%	5,964		
Oil	0%	129	0.0	0%
Open fire	2%	905		
Open fire – wood	2%	905	10.8	8%
Open fire – coal	0%	129	0.7	1%
Total Wood burner	11%	5,560	96.3	76%
Pre 2002 wood burner	6%	3,089	53.5	42%
2002-2007 wood burner	3%	1,236	21.4	17%
Post 2007 wood burner	3%	1,236	21.4	17%
Multi fuel burners	2%	1,034		
Multi fuel burners-wood	2%	776	9.2	7%
Multi fuel burners-coal	2%	776	5.3	4%
Pellet burners	0%	0		
Total wood	15%	7,241	116	92%
Total coal	2%	905	6	5%
Total		49,137[1]	127	100%

[1] – total number of households in Hamilton

3.2.2 Tokoroa

Table 3.4 shows that wood burners are the most common heating methods for households in Tokoroa during 2012 with 50% of households using this heating method. The second most common method for home heating was electricity (48%) followed by gas (18%).

Open fires are used by two percent of Tokoroa residents and three percent of residents use multi fuel burners to heat their main living area. For households that use gas half used unflued gas systems. Table 3.4 also shows that households rely on more than one method of heating their main living area during the winter months[3].

[3] Percentages in Table 3.4 refer to the percentage of households that use a specific heating method. In some cases, households will rely on more than one heating method and therefore the sum of the percentages will total more than 100%.

Wood was the most common fuel for households using solid fuel heating methods in Tokoroa, with 53% of households using this fuel with around 68 tonnes of wood burnt per winter's night. Coal use is only used by one percent of households in Tokoroa.

Table 3.4: Home heating methods and fuels in Tokoroa.

	Heating methods		Fuel Use	
	% of Households	Number of Households	t/day	%
Electricity	48%	2,337		
Total Gas	18%	876	0.3	0%
Flued gas	9%	453		
Unflued gas	9%	423		
Oil	0%	14	0.0	0%
Open fire	2%	83		
Open fire – wood	2%	83	1.8	3%
Open fire – coal	0%	14	0.2	0%
Total Wood burner	50%	2,435	64.4	91%
Pre 2002 wood burner	20%	977	25.9	37%
2002-2007 wood burner	14%	664	17.6	25%
Post 2007 wood burner	16%	793	21.0	30%
Multi fuel burners	3%	125		
Multi fuel burners-wood	2%	83	2.2	3%
Multi fuel burners-coal	1%	56	1.3	2%
Pellet burners	1%	28	0.3	0.49%
Total wood	53%	2601	68	97%
Total coal	1%	70	2	2.1%
Total		4,869[1]	71	100%

[1] – total number of households in Tokoroa

3.3 Emissions from domestic heating

3.3.1 Hamilton

In Hamilton, 50% of PM_{10} from domestic heating during the winter comes from pre 2002 wood burners (Figure 3.1). Wood burners installed between 2002 and 2007 contribute to 13% of domestic heating PM_{10} emissions and modern wood burners 7%. Multi fuel burners contribute 20% and open fires contribute 10% of PM_{10} from domestic heating.

Tables 3.5 and 3.6 show the estimates of wintertime contaminant emissions for different heating methods under average and worst-case scenarios. The tables indicate that the daily wintertime (July) PM_{10} emissions are around 1177 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 1667 kilograms of PM_{10} are discharged from all households using solid fuel burners on a particular night. On an average winter's night (based on July) 96% of domestic PM_{10} emissions come from the burning of wood, with four percent from the burning of coal.

Figure 3.2 shows the monthly variation in appliance use and average days per week used. The seasonal variation in contaminant emissions is shown in Table 3.7. Figure 3.3 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during June, July and August.

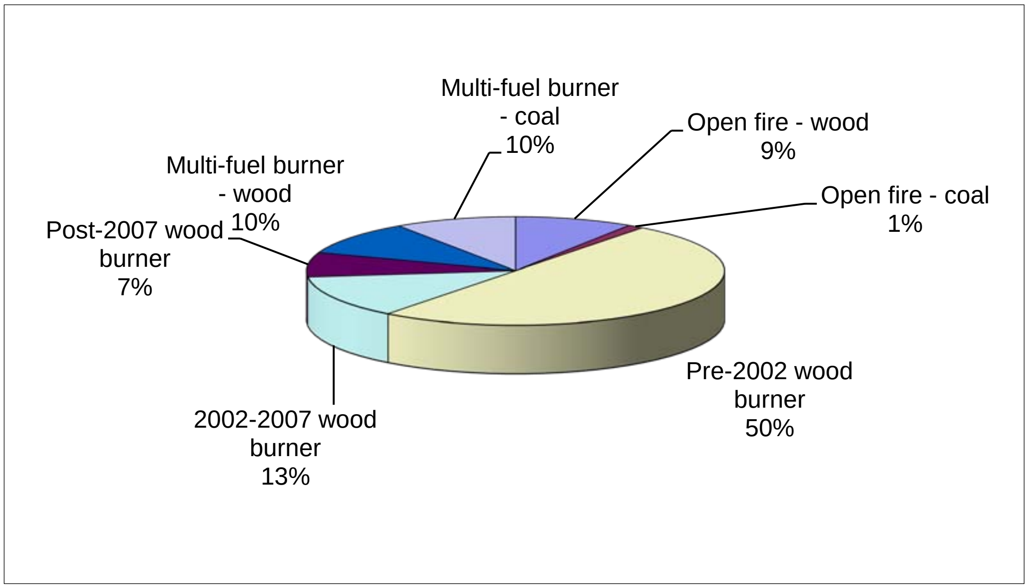

Figure 3.1: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Hamilton.

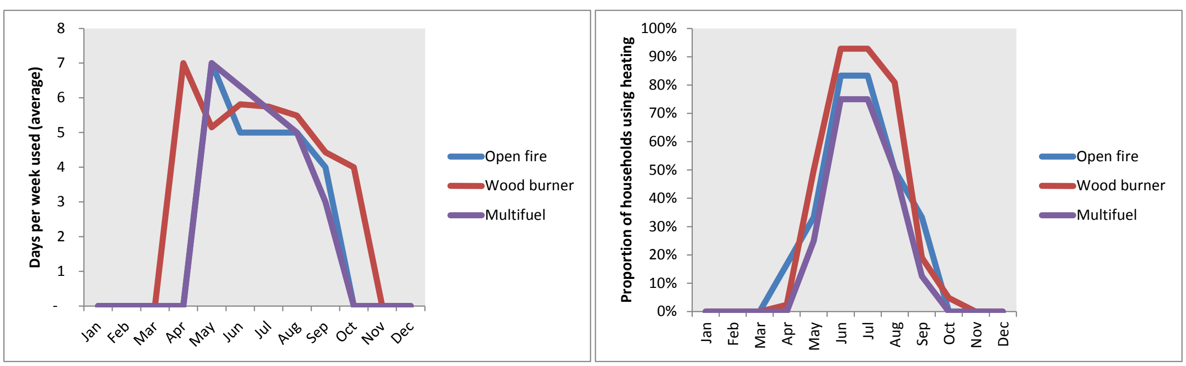

Figure 3.2: Days per week appliances are used (left) and monthly variations in appliance use in Hamilton.

Table 3.5: Hamilton winter daily domestic heating emissions by appliance type (winter average).

	Fuel use		PM_{10}			CO			NOx			SOx			VOC			CO_2			Benzene			BaP		
	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	10.8	8%	108	11	9%	1078	109	10%	17	2	20%	2	0	5%	323	33	10%	17	2	8%	10	1	9%	0.0	0.0	7%
Open fire - coal	0.7	1%	15	1	1%	55	6	0%	3	0	3%	3	0	8%	10	1	0%	2	0	1%	0	0	0%	0.0	0.0	0%
Wood burner	96.3																									
Pre 2002 wood burner	53.5	42%	589	60	50%	5887	597	53%	27	3	31%	11	1	25%	1766	179	54%	86	9	40%	52	5	46%	0.2	0.0	49%
2002-2007 wood burner	21.4	17%	150	15	13%	1499	152	13%	11	1	13%	4	0	10%	450	46	14%	34	3	16%	21	2	18%	0.1	0.0	20%
Post 2007 wood burner	21.4	17%	86	9	7%	856	87	8%	11	1	13%	4	0	10%	257	26	8%	34	3	16%	21	2	18%	0.1	0.0	20%
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	0%	0.0	0.0	0%
Multi fuel burner																										
Multi fuel– wood	9.2	7%	119	12	10%	1192	121	11%	5	0	5%	2	0	4%	358	36	11%	15	1	7%	9	1	8%	0.0	0.0	6%
Multi fuel – coal	5.3	4%	111	11	9%	636	65	6%	6	1	7%	16	2	37%	79	8	2%	14	1	6%	0	0	0%	0.0	0.0	0%
Gas	4.5	4%	0	0	0%	1	0	0%	6	1	7%	0	0	0%	0	0	0%	11	1	5%	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	0.0	0%
Total Wood	116.3	92%	1051	107	89%	10511	1067	94%	70	7	82%	23	2	55%	3153	320	97%	186	19	87%	113	11	100%	0.3	0.0	100%
Total Coal	6.0	5%	126	13	11%	691	70	6%	9	1	11%	19	2	45%	90	9	3%	16	2	7%	0	0	0%	0.0	0.0	0%
Total	127		1177	119		11204	1137		85	9		43	4		3243	329		213	22		113	11		0.3	0.0	

Table 3.6: Hamilton worst-case winter daily domestic heating emissions by appliance type.

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			BaP		
	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	18.1	10%	181	18	11%	1810	184	12%	29	3	24%	4	0	6%	543	55	12%	29	3	10%	18	2	11%	0.0	0.0	8%
Open fire - coal	1.2	1%	24	2	1%	93	9	1%	5	0	4%	6	1	9%	17	2	0%	3	0	1%	0	0	0%	0.0	0.0	0%
Wood burner	126.4																									
Pre 2002 wood burner	70.2	40%	773	78	46%	7727	784	49%	35	4	29%	14	1	22%	2318	235	51%	112	11	38%	68	7	44%	0.2	0.0	47%
2002-2007 wood burner	28.1	16%	197	20	12%	1967	200	13%	14	1	12%	6	1	9%	590	60	13%	45	5	15%	27	3	18%	0.1	0.0	19%
Post 2007 wood burner	28.1	16%	112	11	7%	1124	114	7%	14	1	12%	6	1	9%	337	34	7%	45	5	15%	27	3	18%	0.1	0.0	19%
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%	0.0	0.0	0%
Multi fuel burner																										
Multi fuel– wood	15.1	9%	196	20	12%	1963	199	12%	8	1	6%	3	0	5%	589	60	13%	24	2	8%	15	1	9%	0.0	0.0	7%
Multi fuel– coal	8.7	5%	183	19	11%	1047	106	7%	10	1	9%	26	3	41%	131	13	3%	23	2	8%	0	0	0%	0.0	0.0	0%
Gas	5.6	3%	0	0	0%	1	0	0%	7	1	6%	0	0	0%	0	0	0%	14	1	5%	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	0%
Total Wood	160	91%	1459	148	88%	14591	1481	93%	100	10	82%	32	3	50%	4377	444	97%	255	26	87%	155	16	100%	0.4	0.0	100%
Total Coal	10	6%	208	21	12%	1140	116	7%	15	2	12%	32	3	50%	148	15	3%	26	3	9%	0	0	0%	0.0	0.0	0%
Total	175		1667	169		15733	1596		122	12		64	6		4526	459		295	30		155	16		0.4	0.0	

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	Benzene kg/day	BaP kg/day
January	0	0	0	0	0	0	0	0.0
February	0	0	0	0	0	0	0	0.0
March	0	0	0	0	0	0	0	0.0
April	16	163	1	0	49	3	2	0.0
May	561	5367	42	20	1561	103	55	0.2
June	1215	11522	87	45	3326	218	115	0.3
July	1177	11204	85	43	3243	213	113	0.3
August	895	8617	63	30	2516	166	89	0.3
September	121	1182	11	4	352	24	12	0.0
October	19	186	2	0	56	5	2	0.0
November	0	0	0	0	0	0	0	0.0
December	0	0	0	0	0	0	0	0.0
Total (kg/year)	122783	1172613	8913	4341	340461	22429	11899	35

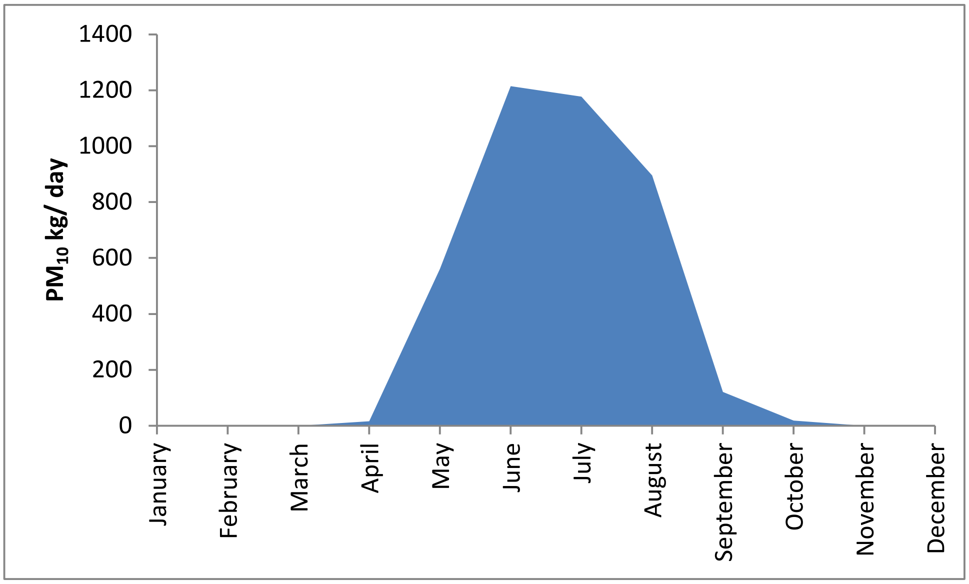

Figure 3.3: Monthly variations in PM_{10} emissions from domestic heating in Hamilton

3.3.2 Tokoroa

In Tokoroa wood burners installed before 2002 contribute 50% of the PM_{10} emissions from domestic home heating. Wood burners installed between 2002 and 2007 contribute around 21% and modern wood burners are responsible for 15% of the daily winter PM_{10} from domestic heating. Open fires contribute around 3% and multi fuel burners around 10% (Figure 3.4).

Tables 3.8 and 3.9 show the estimates of wintertime contaminant emissions for different heating methods under average and worst-case scenarios. During winter 2012 the average daily wintertime PM_{10} emissions are estimated to be around 571 kilograms per day, accounting for days when households may not be using specific home heating methods. Under the worst-case scenario around 655 kilograms of PM_{10} are discharged from all households using solid fuel burners on a given night. On an average winter's night the majority of domestic PM_{10} emissions come from the burning of wood (95%), with 5% from the burning of coal.

Figure 3.5 shows the monthly variations in appliance use and average days per week different appliance types are used. While it seems counter intuitive that the frequency (days per week) of wood burning would be higher during the months of December and January (was shown) a smaller proportion of households are burning during this time. This group probably reflects the more hard core wood burners that are probably also using the burners for hot water heating and therefore tend to use them more regularly. Seasonal variations in contaminant emissions are shown in Table 3.10. Figure 3.6 indicates that the majority of the annual PM_{10} from domestic home heating occur during the months June, July and August.

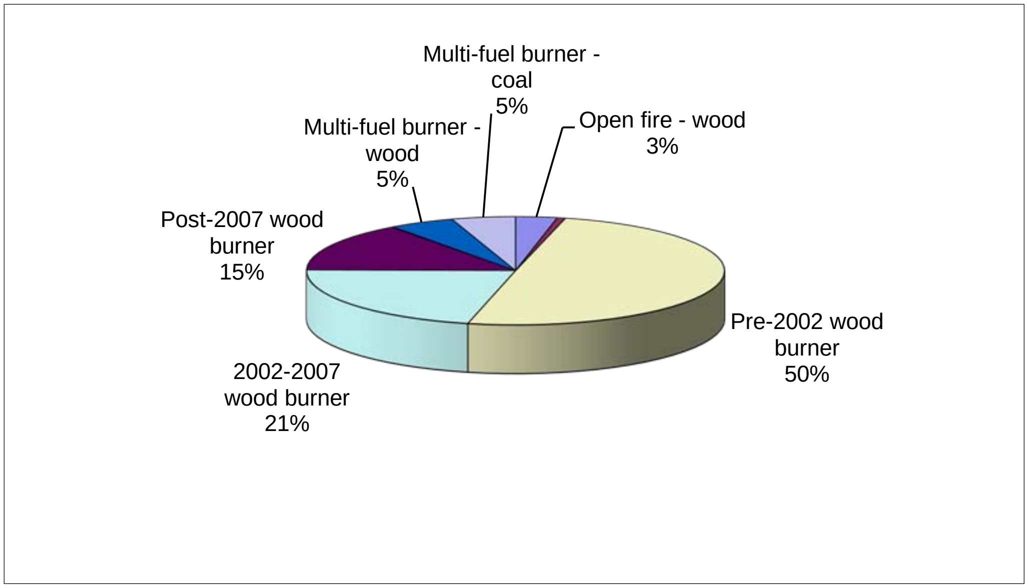

Figure 3.4: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Tokoroa.

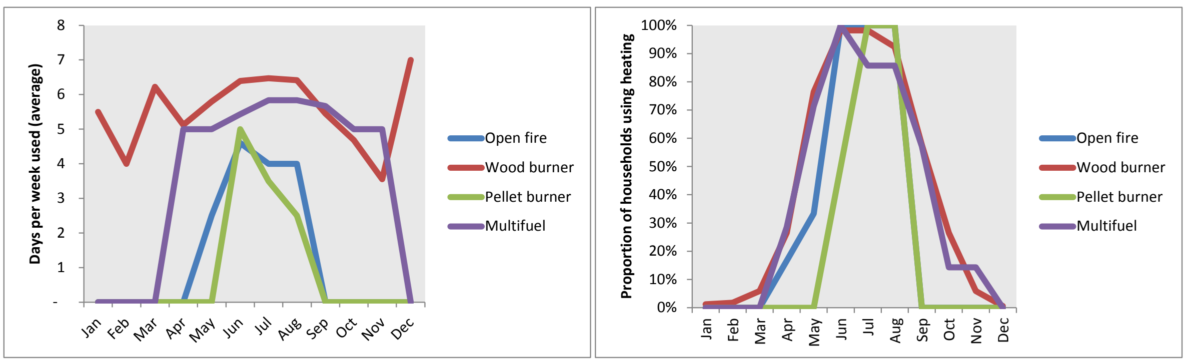

Figure 3.5: Daily appliance use and monthly variations in appliance use in Tokoroa.

Table 3.8: Tokoroa winter daily domestic heating emissions by appliance type (winter average).

	Fuel use		PM_{10}			CO			NOx			SOx			VOC			CO_2			Benzene			BaP		
	t/d	%	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	1.8	3%	18	17	3%	183	175	3%	3	3	7%	0	0	2%	55	52	3%	3	3	3%	2	2	3%	0.0	0	2%
Open fire - coal	0.2	0%	4	3	1%	14	13	0%	1	1	2%	1	1	5%	3	2	0%	0	0	0%	0	0	0%	0.0	0	0%
Wood burner	64.8																									
Pre 2002 wood burner	25.9	37%	285	271	50%	2846	2713	51%	13	12	33%	5	5	28%	854	814	52%	41	39	36%	25	24	38%	0.1	0	38%
2002-2007 wood burner	17.6	25%	123	117	22%	1230	1173	22%	9	8	22%	4	3	19%	369	352	22%	28	27	24%	17	16	26%	0.1	0	26%
Post 2007 wood burner	21.0	30%	84	80	15%	840	800	15%	10	10	27%	4	4	22%	252	240	15%	34	32	29%	20	19	30%	0.1	0	31%
Pellet Burner	0.3	0%	0.7	1	0%	7	7	0%	0	0	0%	0	0	0%	2	2	0%	1	1	0%	0	0	1%	0.0	0	1%
Multi fuel burner																										
Multi fuel – wood	2.2	3%	29	28	5%	289	276	5%	1	1	3%	0	0	2%	87	83	5%	4	3	3%	2	2	3%	0.0	0	2%
Multi fuel – coal	1.3	2%	28	27	5%	161	153	3%	2	2	4%	4	4	22%	20	19	1%	3	3	3%	0	0	0%	0.0	0	0%
Gas	0.3	0%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	1	1	1%	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	0%
Total Wood	68.8	97%	540	514	94%	5395	5143	97%	36	35	93%	14	13	74%	1619	1543	99%	110	105	96%	67	64	100%	0.2	0	100%
Total Coal	1.5	2%	32	30	6%	175	167	3%	2	2	6%	5	5	26%	23	22	1%	4	4	3%	0	0	0%	0.0	0	0%
Total	71		571	545		5570	5310		39	37		19	18		1641	1565		115	109		67	64		0.2	0	

Table 3.9: Tokoroa worst-case winter daily domestic heating emissions by appliance type.

	Fuel Use		PM_{10}			CO			NOx			SOx			VOCs			CO_2			Benzene			BaP		
	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	3.2	4%	32	31	5%	321	306	5%	5	5	11%	1	1	3%	96	92	5%	5	5	4%	3	3	4%	0.0	0	3%
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	0%
Wood burner	71																									
Pre 2002 wood burner	28	36%	313	299	48%	3133	2987	49%	14	14	31%	6	5	27%	940	896	50%	46	43	35%	28	26	37%	0.1	0	38%
2002-2007 wood burner	19	24%	135	129	21%	1354	1291	21%	10	9	21%	4	4	18%	406	387	22%	31	30	24%	19	18	25%	0.1	0	26%
Post 2007 wood burner	23	29%	92	88	14%	924	881	14%	12	11	26%	5	4	22%	277	264	15%	37	35	28%	22	21	30%	0.1	0	30%
Pellet Burner	0.7	1%	1	1	0%	14	13	0%	0	0	1%	0	0	1%	4	4	0%	1	1	1%	1	1	1%	0.0	0	1%
Multi fuel burner																										
Multi fuel– wood	3.1	4%	41	39	6%	405	386	6%	2	1	3%	1	1	3%	122	116	6%	5	5	4%	3	3	4%	0.0	0	3%
Multi fuel– coal	1.9	2%	39	38	6%	225	215	4%	2	2	5%	6	5	27%	28	27	2%	5	5	4%	0	0	0%	0.0	0	0%
Gas	0.4	0%	0	0	0%	0	0	0%	1	0	1%	0	0	0%	0	0	0%	1	1	1%	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	78	97%	615	586	94%	6152	5864	96%	43	41	94%	16	15	73%	1846	1759	98%	125	119	96%	76	72	100%	0.2	0	100%
Total Coal	2	2%	39	38	6%	225	215	4%	2	2	5%	6	5	27%	28	27	2%	5	5	4%	0	0	0%	0.0	0	0%
Total	80		655	624		6377	6079		45	43		21	20		1874	1786		131	125		76	72		0.2	0	

Table 3.10: Monthly variations in contaminant emissions in Tokoroa.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	Benzene kg/day	BaP kg/day
January	4	40	0	0	12	1	1	0
February	4	43	0	0	13	1	1	0
March	23	225	1	1	68	5	3	0
April	89	887	6	2	266	18	11	0
May	387	3786	25	12	1116	78	45	0
June	569	5561	39	18	1638	114	66	0
July	568	5556	38	18	1639	114	67	0
August	534	5219	36	17	1538	107	62	0
September	205	2052	13	5	615	42	25	0
October	79	789	5	2	237	16	10	0
November	16	155	1	0	47	3	2	0
December	3	25	0	0	8	1	0	0
Total (kg/year)	75980	745703	5080	2324	220421	15334	8991	27

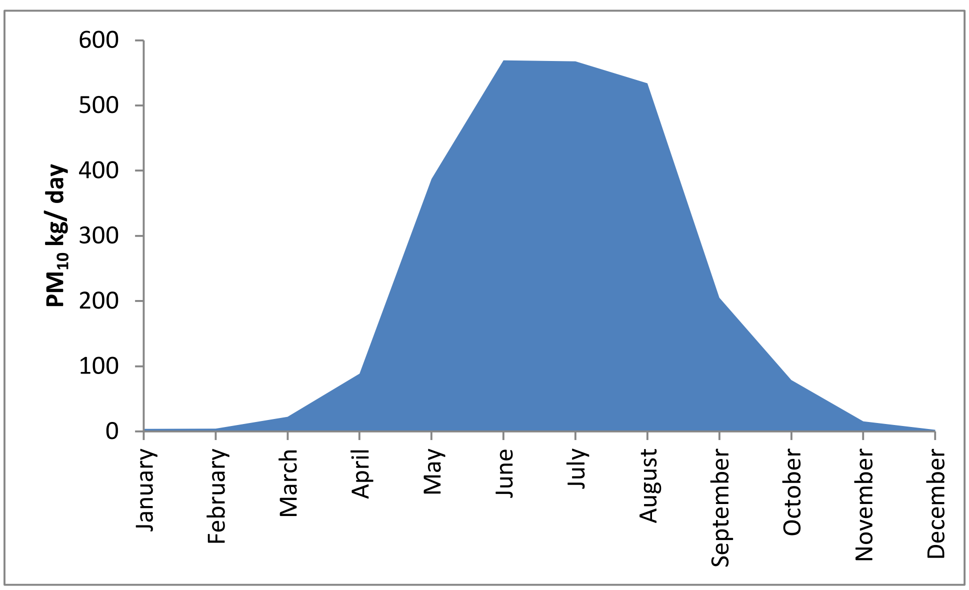

Figure 3.6: Monthly variations in PM_{10} emissions from domestic heating in Tokoroa.

4 Motor vehicles

Motor vehicle emissions to air include tailpipe emissions (all contaminants) 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 3.0). Emissions factors for PM_{10}, CO, NOx, VOCs and CO_2 for this study have been based on VEPM 5.0. Default settings were used for all variables except:

- Vehicle fleet profile
    - Hamilton - based on vehicle registrations for Hamilton for year ending 30 April 2012
    - Tokoroa - based on vehicle registrations for South Waikato District for year ending 30 April 2012
- Annual average temperature
    - Hamilton – based on a winter average temperature of 10.9 °C for 2011
    - Tokoroa – based on a winter average temperature of 7.4 °C for 2011

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 SOx. Total VKT for diesel vehicles were estimated based on the proportion of diesels in the vehicle fleet.

The scope of the inventory was extended over previous inventories for the Waikato to include BaP emission estimates because of the potential for this contaminant to be of concern. No emission factor data for BaP are available for motor vehicle emissions in New Zealand. Emission factors for BaP used here have been taken from USEPA - emission factors for estimating mobile source PAH emissions in the National Toxics Inventory (www.epa.gov/ttn/chief/nti/index.html#info). These are based on a proportion of the PM and was estimated at 0.0001 x PM for this study based on the proportion of heavy versus light vehicles. This estimate will be highly approximate because of differences in fuel composition and should therefore be treated with caution. Table 4.2 details the emission factors used to estimate motor vehicle emissions for 2012 for Hamilton and Tokoroa.

Table 4.1: Vehicle registrations in Hamilton and South Waikato District for the year ending April 2012.

Hamilton	**Petrol**	**Diesel**	**LPG**	**Other**	**Total**
Cars	72,390	4,759	21	1	77,171
LCV	2,425	4,554	4	0	6,983
Bus	80	913			993
HCV		3,390			3,390
Miscellaneous	1019	552	76	0	1,647
Motorcycle	1,495				1,495
Total	77409	14168	101	1	91,679
Tokoroa	**Petrol**	**Diesel**	**LPG**	**Other**	**Total**
Cars	9,210	878	8	0	10,096
LCV	748	1,423	2	0	2,173
Bus	18	43			61
HCV		1,054			1,054
Miscellaneous	125	307	1	0	433
Motorcycle	308				308
Total	10409	3705	11	0	14,125

Table 4.2: Emission factors for 2012 for Hamilton and Tokoroa

	Hamilton g/VKT	Tokoroa g/VKT	Source
CO	5.8	5.8	VFEM 5.0
CO_2	254.5	251.4	VFEM 5.0
VOC	0.3	0.3	VFEM 5.0
NOx	0.7	0.72	VFEM 5.0
PM_{10}	0.03	0.04	VFEM 5.0
PM_{10} Brake and Tyre	0.01	0.01	VFEM 5.0
$PM_{2.5}$	0.02	0.025	British Columbia Lower Fraser Valley
$PM_{2.5}$ Brake and Tyre	0.01	0.006	British Columbia Lower Fraser Valley
Benzene	0.02	0.02	Proportion of VOC from Australian Pollution Inventory
SOx	0.002	0.002	Order of magnitude estimate only based on S content of diesel
BaP	0.000003		USEPA – National Toxics Inventory

Estimates of VKT were obtained from the Ministry of Transport by CAU for the year ending 2010 (Badger, 2012, pers comm). These are based on modelling and overestimate VKTs relative to vehicle registration information for 2010 (MOT, 2012) by around 8%. To align the model estimates to the vehicle registration data VKTs were adjusted downwards by 8%.

Table 4.3 shows the estimated number of VKTs for Hamilton and Tokoroa for 2010 which are considered the best available information from which to estimate 2012 motor vehicle emissions. Time of day estimates were based on the time of day breakdown from the Hamilton 2005 air emissions inventory.

Table 4.3: VKT by time of day for Hamilton and Tokoroa.

	Total VKT	Time of day			
		6am-10am	10am-4pm	4pm-10pm	10pm-6am
Hamilton	2134711	522382	808806	698095	105428
Tokoroa	99818	24426	37819	32643	4930

Emissions for each time period were calculated by multiplying the emission factor by the VKT for that time period.

Emissions (g) = Emission Rate (g/VKT) * VKT (A-B)

4.1 Motor vehicle emissions

4.2 Hamilton

Around 96 kilograms per day of PM_{10} are estimated to occur from motor vehicle emissions in Hamilton. Around 30% of this is estimated to occur as a result of the wearing of brakes and tyres.

Other contaminant emissions from motor vehicles in Hamilton include around 12 tonnes of CO, 1525 kilograms of NOx and four kilograms of SOx (Table 4.4). In comparison, in Christchurch, where CO concentrations occasionally exceed ambient air quality guidelines during winter months, motor vehicles emit around 109 tonnes of CO within the main urban area.

4.3 Tokoroa

Around five kilograms per day of PM_{10} are emitted from motor vehicles in Tokoroa (Table 4.4). Of this, around 25% is estimated to occur as a result of the wearing of brakes and tyres. Other contaminant emissions from motor vehicles in Tokoroa include around 580 kilograms of CO and 72 kilograms of NOx.

Table 4.4: Summary of daily motor vehicle emissions in Hamilton and Tokoroa.

		PM_{10}		CO		NOx		SOx	
	Hectares	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Hamilton	9855	96	10	12338	1252	1525	155	4	0
Tokoroa	1049	5	5	580	553	72	69	0	0
		VOC		**CO_2**		**Benzene**		**BaP**	
	Hectares	**kg**	**g/ha**	**t**	**kg/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Hamilton	9855	732	74	543	55	42	4	0.01	0
Tokoroa	1049	35	33	25	24	2	2	0.0003	0

5 Industrial and Commercial

5.1 Methodology

An evaluation of potential discharges to air from industrial and commercial sources in Hamilton and Tokoroa was undertaken to identify activities that discharge PM_{10}. Waikato Regional Council staff provided information on consented activities and a list of schools and heating methods.

Schools with coal fired boilers were contacted to establish if their coal boilers were still operational and to determine fuel consumption and use details. Of the 12 schools that had previously reported using coal, only three continued to do so in 2012. For those no longer using coal, heat pumps, natural gas and pellet boilers were the main alternative heating methods. Emissions from gas boilers were not included in the inventory as the PM_{10} emissions from them are negligible for small to medium size boilers.

Seventeen industrial and commercial premises were included in the inventory. The majority of these were in Hamilton.

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 most industries included in the assessment, site specific emissions data was available from the resource consent application. 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 survey or data provided by Waikato Regional Council staff. 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 and pellet boiler emission factors for PM_{10} are based on New Zealand specific emission factors as described in Wilton et. al. 2007. Other emission factors are from the USEPA AP42 database[4].

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	BaP g/kg
Underfeed stokers	2.0	5.5	4.8	13.5	0.1	2400	0.00002
Pellet boiler	0.83	6.8	0.8	0.0	0.1	1069	0.03
Abrasive blasting	0.69						
Meat smoking	26.5						
	kg/m^3	**kg/m^3**	**kg/m^3**	**kg/m^3**	**kg/m^3**	**kg/m^3**	**kg/m^3**
Natural gas AP42	0.00012	0.00134	0.00160	0.00001	0.00009	1.92000	1.9E-11

5.2 Industrial and commercial emissions

5.3 Hamilton

Discharges from 15 industrial and commercial activities were included in the assessment for Hamilton. This includes four asphalt plants industries, the hospital boiler, three school boilers, two abrasive blasters and a range of less common industrial discharge types. The most significant change in industrial discharges in Hamilton is the conversion of the Waikato Hospital from coal to natural gas. This has resulted in a significant decrease in industrial PM_{10} emissions. Table 5.2 shows the industrial contribution to PM_{10} emissions for 2012 is around 24 kilograms of PM_{10} per winters' day. This compares to around 93 kg/day in 2005.

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

5.4 Tokoroa

Discharges from two industrial and commercial activities were included in the assessment. Activity data was available for an additional two industries but was not included because the industries were not operational by June 2012.

Discharges from Kinleith were not included in the emission inventory because the industry is outside of the inventory airshed area.

Around 7 kilograms of PM_{10} are discharged to air from industrial and commercial activities during winter in Tokoroa.

Table 5.2: Summary of industrial emissions (daily winter) in Hamilton and Tokoroa.

		PM_{10}		CO		NOx		SOx	
	Hectares	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Hamilton	9855	24	2	10	1	18	2	4	0
Tokoroa	1049	7	7	18	17	15	15	0	0
		VOC		CO_2		**Benzene**		**BaP**	
	Hectares	**kg**	**g/ha**	**t**	**kg/ha**	**kg**	**g/ha**		
Hamilton	9855	1	0	25	3	24	2	0	0
Tokoroa	1049	0	0	8	7	0	0	0	0

6 Outdoor burning

Outdoor burning of green wastes or household material can contribute to PM_{10} concentrations and also discharge other contaminants to air. In some urban areas of New Zealand outdoor burning is prohibited because of the adverse health and nuisance effects associated with these emissions. Outdoor burning includes any burning in a drum, incinerator or open air on residential properties in the study area.

The Waikato Regional Plan permits outdoor burning of specified materials including untreated wood, vegetative matter, paper and cardboard and other similar materials subject to a number of conditions (Rule 6.1.13.1). The conditions include ensuring that the effects of the discharge do not go beyond the boundary of the property and are sourced from the property where the burning occurs.

6.1 Methodology

Emissions from outdoor burning in Hamilton and Tokoroa were estimated for the winter months based on data collected during the 2012 domestic home heating survey. The survey showed 4% of households in Hamilton and 10% in Tokoroa burnt rubbish in the outdoors during the winter. The average number of fires per day during winter was 11 and 27 in Hamilton and Tokoroa respectively. Emissions were calculated based on the assumption of an average weight of material per burn of 150 kilograms and using the emission factors in Table 6.1. This was based on an average fires size of 2 m^3 for Tokoroa and 1.2 m^3 for Hamilton (based on survey responses) and an estimated average weight of 75 kg/m^3. Emission factors of benzene and BaP were based on wood burning for domestic heating and are indicative only. Emissions of these contaminants will be largely influenced by the material burnt, in particular the inclusion of household rubbish and plastics.

Estimates of PM_{10} and other emissions for each area are detailed in sections 6.2 to 6.4. It should be noted, however, that there are a number of uncertainties relating to the calculations. 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 6.1: Outdoor burning emission factors (AP42, 2002).

	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg	Benzene g/kg	BaP g/kg
Outdoor burning	8	42	3	0.5	4	1470	0.97	0.003

6.2 Hamilton

In Hamilton around 47 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average from outdoor burning. Outdoor burning also produces around 158 kilograms of carbon monoxide and around six tonnes of carbon dioxide on average per day during winter.

Table 6.2: Outdoor burning emission estimates for Hamilton.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	VOC kg/ day	CO_2 t/ day	Benzene kg/day
Summer (Dec-Feb)	33	110	8	1	11	4	1
Autumn (Mar-May)	41	137	10	2	14	5	2
Winter (June-Aug)	47	158	11	2	16	6	2
Spring (Sept-Nov)	47	158	11	2	16	6	2

6.3 Tokoroa

Table 6.3 shows an average of around 29 kilograms of PM_{10} per day from outdoor burning in Tokoroa during the winter months. Outdoor burning also produces around 97 kilograms of carbon monoxide per day during the winter.

Table 6.3: Outdoor burning emission estimates for Tokoroa

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	VOC kg/ day	CO_2 t/ day	Benzene kg/day
Summer (Dec-Feb)	12	40	3	0	4	1	0
Autumn (Mar-May)	12	39	3	0	4	1	0
Winter (June-Aug)	29	97	7	1	10	3	1
Spring (Sept-Nov)	19	63	5	1	6	2	1

7 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.

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[5].

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

8 Total emissions

8.1 Hamilton

In Hamilton around 1344 kilograms of PM_{10} is discharged to air on an average winter's day. Figure 8.1 shows that domestic home heating is the main source of these emissions contributing 88% of the daily wintertime emissions. Transport contributes to seven per cent, outdoor burning contributes to three per cent and industry around two per cent of the total wintertime PM_{10} emissions.

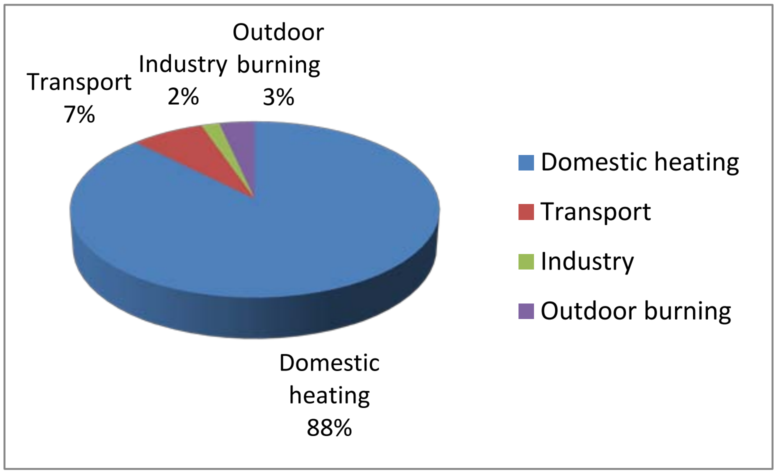

Figure 8.1: Relative contribution of sources to daily winter PM_{10} emissions in Hamilton.

Figure 8.2 shows an estimate of the spatial distribution of PM_{10} emissions from all sources in Hamilton. The estimate of spatial distribution is based on the location of households burning wood and coal from the 2006 census combined with the 2012 emission inventory estimates for domestic heating. For motor vehicles the spatial distribution is based on the VKT estimates per CAU. Industrial PM_{10} emissions are allocated to the CAU within which the industry is located. Emissions from other sources are included but are assumed to be spatially uniform across the study area.

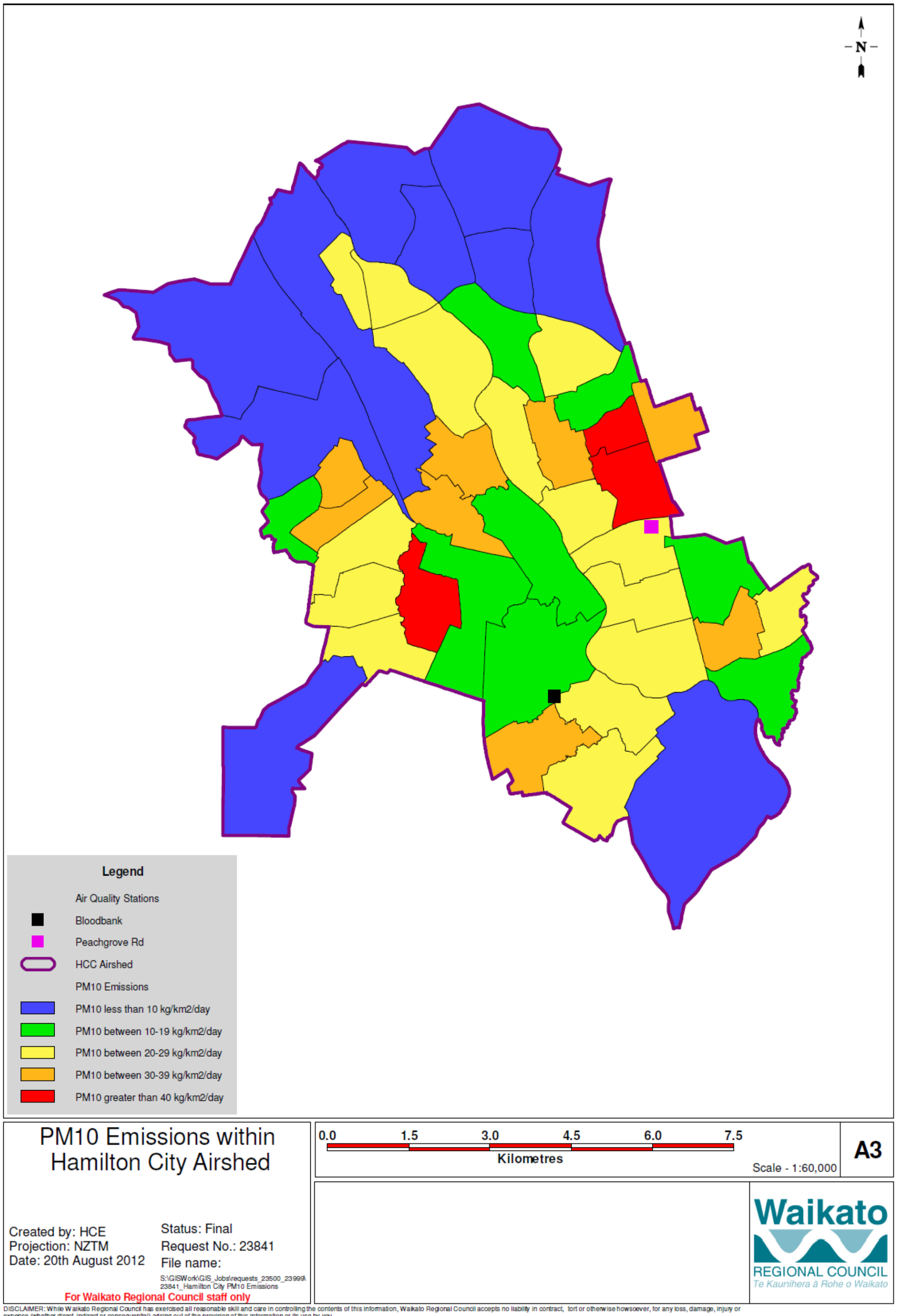

Figure 8.2: Estimate of the spatial distribution of PM_{10} emissions from all sources in Hamilton

Domestic home heating is also the main source of benzene CO, SOx and VOCs in Hamilton. Motor vehicles are the main source of NOx and CO_2 (Figure 8.3). Domestic home heating contributes 96% of the BaP emissions with the remaining 4% from motor vehicles. No estimates of the BaP contribution from outdoor burning were made.

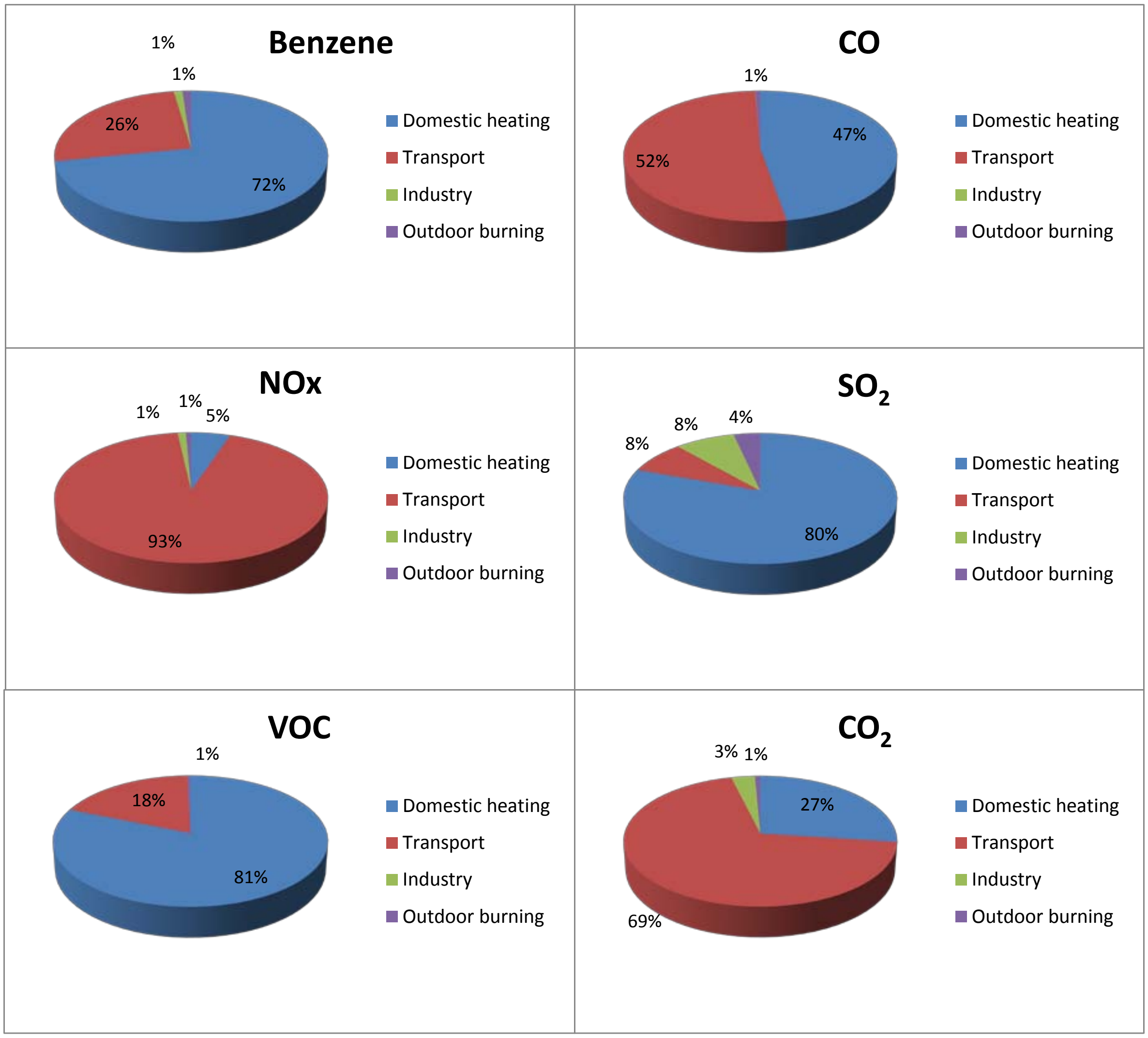

Figure 8.3: Relative contribution of sources to contaminant emissions in Hamilton.

Table 8.1 shows daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) and Table 8.2 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 and outdoor burning are the dominant contributors to PM_{10} emissions.

Table 8.1: Daily contaminant emissions from all sources in Hamilton (winter average).

	PM_{10}		**CO**		**NOx**		**SOx**	
	kg	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Domestic home heating	1177	119	11204	1137	85	9	43	4
Transport	96	10	12338	1252	1525	155	4	0
Industry	29	3	10	1	18	2	4	0
Outdoor burning	47	5	158	16	11	1	2	0
Total	1344	136	23709	2406	1640	1667	53	56
	VOC		**CO_2**		**Benzene**		**BaP**	
	kg	**g/ha**	**t**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Domestic home heating	3243	329	213	22	117	12	0	0
Transport	732	74	543	55	42	4	0	0
Industry	1	0	25	3	2	0	0	0
Outdoor burning	16	2	6	1	2	0	0	0
Total	3993	405	787	80	162	16	0	0

Table 8.2: 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**	**%**	**kg/day**
January	0	0%	33	22%	22	13%	96	56%	151
February	0	0%	33	22%	22	13%	96	56%	151
March	0	0%	41	26%	23	12%	96	52%	160
April	16	8%	41	23%	23	11%	96	47%	177
May	561	75%	41	6%	24	3%	96	13%	723
June	1215	86%	47	3%	24	2%	96	7%	1382
July	1177	86%	47	3%	24	2%	96	7%	1344
August	895	82%	47	4%	24	2%	96	9%	1062
September	121	38%	47	16%	23	7%	96	30%	287
October	19	9%	47	25%	22	10%	96	45%	1845
November	0	0%	47	28%	22	11%	96	49%	166
December	0	0%	33	22%	22	13%	96	56%	151
Total kg year	122783		15288		8441		35132		181644

8.1.1 Comparison to 2005 emission estimates

The reported 2005 domestic heating emission estimates were 1598 kilograms per day of PM_{10}. However these were based on the assumption of an average log weight of 1.9 kilograms compared with 1.6 kilograms in this assessment. If 2005 data are adjusted for this difference it gives a daily winter PM_{10} estimate of 1387 kilograms. The 2012 emission inventory estimates around 1177 kilograms of PM_{10} on an average winter's day, a 15% decrease in emissions.

Revised total emissions for 2005 are 1944 kilograms of PM_{10} per day after an adjustment was also made to 2005 motor vehicle emissions[6]. This compares with an estimated 1344 kilograms per day for 2012 suggesting an overall decrease in PM_{10} emissions of 31% since 2005 and occurs as a result of a decrease in emissions from all PM_{10} sources in Hamilton. The estimated lower vehicle emissions compared with that estimated in 2005 is not unexpected due to significant improvements in engine technology and the increased vehicle kilometres travelled resulting in an improvement in PM_{10} emissions from motor vehicles.

8.2 Tokoroa

In Tokoroa around 612 kilograms of PM_{10} is discharged to air on an average winter's day. The main source of PM_{10} emissions is domestic home heating which contributes 93% of the daily wintertime PM_{10} (Figure 8.4). Outdoor burning contributes 5% to total PM_{10} emissions, while the transport and industry each contribute 1%.

[6] The 2012 emission inventory method for estimating vehicle kilometres travelled (VKTs) is based on Ministry of Transport VKT per year data collected nationally from the vehicle warrant of fitness (WOF) process and is therefore reasonably well validated. The 2005 emission inventory method for estimating VKTs was based on road network models. This different method for estimating the trends in emissions has been accounted for.

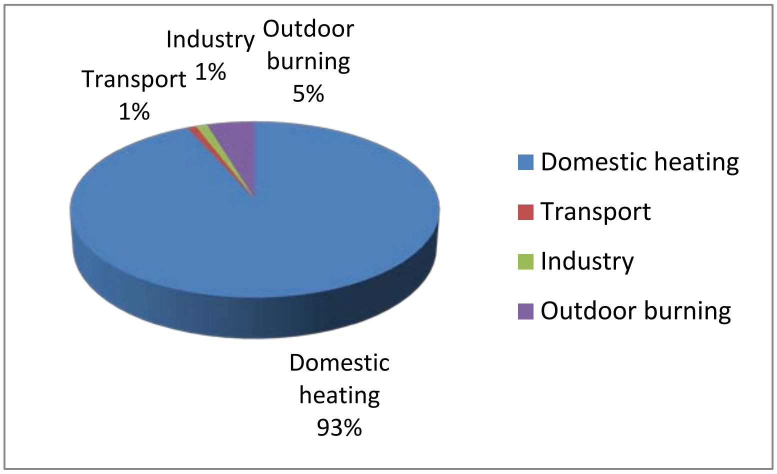

Figure 8.4: Relative contribution of sources to daily winter PM_{10} emissions in Tokoroa

Domestic home heating is also the main source of benzene, CO, SOx and VOCs and CO_2. Motor vehicles are the main source of NOx emissions (Figure 8.5). No outdoor burning BaP estimates were made but of the other three sources domestic home heating contributed almost all of the BaP in Tokoroa.

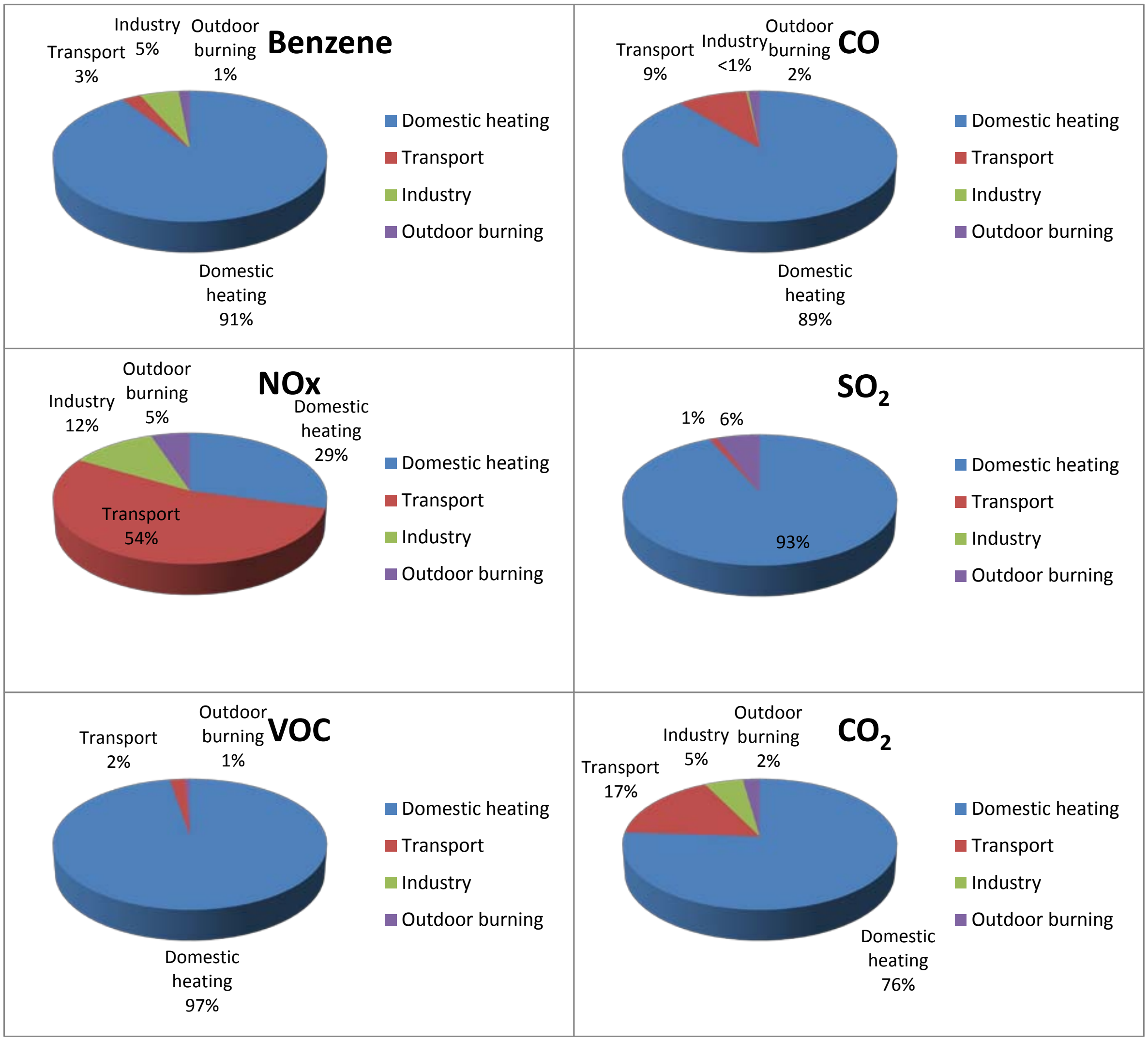

Figure 8.5: Relative contribution of sources to contaminant emissions in Tokoroa

Table 8.3 shows the daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha). Table 8.4 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, outdoor burning is the dominant contributor to PM_{10} emissions.

Table 8.3: Daily contaminant emissions from all sources in Tokoroa (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Domestic home heating	571	545	5570	5310	39	37	19	18
Transport	5	5	580	553	72	69	0	0
Industry	7	7	18	17	15	15	0	0
Outdoor burning	29	28	97	92	7	7	1	1
Total	612	584	6265	5972	134	127	20	19
	VOC		**CO_2**		**BaP**		**Benzene**	
	kg	**g/ha**	**t**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Domestic home heating	1641	1565	115	109	69	66	0	0
Transport	35	33	25	24	2	2	0	0
Industry	0	0	8	7	4	4	0	0
Outdoor burning	10	9	3	3	1	1	0	0
Total	1686	1607	151	144	76	73	0	0

Table 8.4: Monthly variations in daily PM_{10} emissions in Tokoroa.

	Domestic Heating		Outdoor Burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	4	18%	12	53%	1.2	5%	5	24%	22
February	4	19%	12	52%	1.3	6%	5	23%	23
March	23	55%	12	28%	1.8	4%	5	13%	41
April	89	83%	12	11%	1.8	2%	5	5%	107
May	387	95%	12	3%	1.8	0%	5	1%	406
June	569	93%	29	5%	7.1	1%	5	1%	610
July	568	93%	29	5%	6.9	1%	5	1%	609
August	534	93%	29	5%	6.9	1%	5	1%	575
September	205	89%	19	8%	1.7	1%	5	2%	231
October	79	75%	19	18%	1.6	2%	5	5%	105
November	16	38%	19	46%	1.7	4%	5	13%	41
December	3	12%	12	57%	1.2	6%	5	25%	21
Total kg year	75980		6497		1064		1925		

8.2.1 Comparison to 2007 emission estimates

The reported 2007 domestic heating emission estimates were 517 kilograms per day of PM_{10}. However these were based on the assumption of an average log weight of 1.3 kilograms compared with 1.6 kilograms in this assessment. If 2007 data are adjusted for this difference it gives a daily winter PM_{10} estimate of 631 kilograms. The 2012 emission inventory estimates around 571 kilograms of PM_{10} on an average winter's day, a 10% decrease in emissions.

Revised total emissions for 2007 are 684 kilograms of PM_{10} per day after an adjustment was also made to 2007 motor vehicle emissions. This compares with an estimated 612 kilograms per day for 2012 suggesting an overall decrease in PM_{10} emissions of 11% since 2007.

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Appendix A: 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?

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

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

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

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

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

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

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

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

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

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

(f) What size gas bottle do you use?

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

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

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

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

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

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

(d) How old is your log burner?

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

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

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

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

(i) What proportion would be bought?

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

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

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

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

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

(d) How old is your multi fuel burner?

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

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

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

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

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

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

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

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

(m) What proportion would be bought?

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

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

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

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

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

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

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

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

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

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

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

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

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

(l) What proportion would be bought?

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

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

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

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

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

(d) How old is your pellet burner?

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

(e) and what model is your pellet burner?

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

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

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

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

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

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

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

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

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

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

9. 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 decade/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.

D4 How many people live at your address?

D5 Do you own your home or rent it?

D6 Approximately how old is your home?

D7 How many bedrooms does your home have?

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

Appendix B: Emission factors for domestic heating.

Emission factors for wood burners were based largely on the review of New Zealand emission rates carried out for the Christchurch 1999 emission inventory with adaptations made for different burner age categories and with adjustments made to account for more recent real life testing of pre 1994 and NES compliant wood burners (Wilton & Smith, 2006; Smith, et. al., 2008).

The Christchurch 1999 review resulted in revised factors for open fires burning wood and the burning of coal on open fires and multi fuel burners. The open fire wood emission factor was reduced from 15 g/kg (used in previous inventories) to 10 g/kg. This was based on a combination of overseas literature, in particular the studies by Stern (1992) and Dasch (1982), and the results of a limited number of tests carried out in New Zealand. The New Zealand tests were carried out by Applied Research and gave emission rates of around 7 g/kg.

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

The older wood burner emission rates were based on testing of older wood burners “in situ” in Tokoroa during 2005 as detailed in Wilton and Smith, 2006. The burner age category for the latter testing is older (pre 1994) than the category included here (pre 2002). However, the emissions are retained at this level because no standards for new burner installations existed for either area prior to 2002. Post 2007 emission factors were based on an emission factor of 4 g/kg based on the results of Smith et. al., 2008 combined with more recent testing of Bluett, et.al. (2011). The average of the emission factor for NES compliant burners and older burners of 7 g/kg PM_{10} was used for burners in the age category 2002 to 2007.

The gas and oil PM_{10} emission factors were based on testing in New Zealand (Scott, 2004).

Domestic heating emission factors for CO, NOx, SOx and CO_2 were also based on the Christchurch 1999 emission factor revisions with adjustments made for relationships with PM_{10} where appropriate.

Emissions factors for BaP were based on AP42 factors for conventional wood burners (no baffles) for open fires and on phase II burners (with baffles, non catalytic) for wood burners. Benzene emission factors were based on AP42 for conventional wood burners. Benzene emission factors for coal burning was based on AP42 coal fired boiler data because no domestic information was available. Emission factors for BaP for coal burning was based on AP42 factors for burning anthracite coal on open fires as no data were available for bituminous or sub bituminous coals.