Air emissions inventory – Wainuiomata and Upper Hutt 2006

A report prepared for Greater Wellington by Environet Ltd

Greater Wellington
Te Pane Matua Taiao

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Air Quality & IT Specialists

Air Emission Inventory – Wanuiomata & Upper Hutt

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Executive Summary

This report outlines the results of an air emission inventory carried out in the areas of Wainuiomata and Upper Hutt. The inventory was prepared at the request of Greater Wellington Regional Council to assist in the understanding of the quantity and location of PM_{10} discharged to air in these areas

The results from the inventory can be used in conjunction with meteorological modelling to establish a relationship between emissions and ambient air concentrations and to evaluate factors such as spatial variations in concentrations. The Greater Wellington Regional Council can then assess whether reductions in PM_{10} concentrations are necessary to ensure the airshed is compliant with National Environmental Standards for air quality by 2013.

Contaminants included in the inventory were particles (PM_{10} and $PM_{2.5}$), carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds and carbon dioxide. This report primarily focuses on emissions of particles (PM_{10}), as the only contaminant in breach of the NES in the Greater Wellington Region. Sources included in the inventory were domestic heating, motor vehicles, industrial and commercial activities and outdoor rubbish burning.

A home heating survey was carried out in Wainuiomata and Upper Hutt to determine heating methods and the frequency of outdoor rubbish burning. Electricity was found to be the most common method of home heating and was used by 51% and 48% of households in Wainuiomata and Upper Hutt respectively. Other common heating methods included gas (41% and 38% respectively) and wood burners (26% and 34% respectively). Outdoor rubbish burning was carried out by 5% of households in Wainuiomata and 7% of households in Upper Hutt. Many households used more than one method to heat the main living area of their home.

The main source of PM_{10} emissions in both areas was domestic home heating, which accounted for 91% and 87% of total PM_{10} emissions in Wainuiomata and Upper Hutt respectively. Other source contributions in Wainuiomata were motor vehicles (3%), outdoor burning (4%) and industrial emissions (2%). In Upper Hutt, motor vehicles contributed 4% and outdoor burning 9%. Emissions from industrial and commercial activities in Upper Hutt were negligible.

Contents

1 Introduction

This inventory was prepared at the request of Greater Wellington Regional Council to assist in the understanding of the quantity and location of PM_{10} discharged to air in Wainuiomata and Upper Hutt.

Emission inventories are the primary tool used in New Zealand to estimate quantities of emissions to air. In addition to providing information on the relative contribution of different sources to emissions of a contaminant, an inventory provides an estimate of the quantity of emissions contributing to the maximum measured concentrations and allows for the evaluation of the effectiveness of different management options in reducing concentrations.

Emissions inventories can be used in conjunction with meteorological modelling to establish a relationship between emissions and ambient air concentrations and to evaluate factors such as spatial variations in concentrations. The Greater Wellington Regional Council intend on carrying out this modelling to assess whether reductions in PM_{10} concentrations are necessary to ensure the airshed is compliant with National Environmental Standards for air quality by 2013.

The purpose of this inventory was therefore to estimate the amount of PM_{10} discharged into the air in these areas on a worst-case and average winter's night, that can be used as the basis for air quality modelling in these areas, and to provide information from which management measures to reduce PM_{10} can be evaluated.

2 Inventory Design

The inventory has been designed with a focus on emissions of PM_{10}, although it does include estimates of emissions of other contaminants. Monitoring of other contaminants has not been carried out in Wainuiomata. Monitoring of carbon monoxide and nitrogen dioxide in Upper Hutt suggests this contaminant is unlikely to exceed the NES. Similarly it is unlikely, based on monitoring carried out in other areas of New Zealand, that concentrations of other contaminants will exceed the NES.

2.1 Selection of sources

The inventory includes detailed estimates of emissions from domestic heating, outdoor burning, motor vehicles and industry. Emissions from a number of other minor sources are also discussed in the report.

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 comprise class one air quality indicators as described by MfE (1994) and are included in the NES because of their potential for adverse health impacts. Carbon dioxide is typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas CO_2 emissions. The finer $PM_{2.5}$ size fraction was also included, as this size fraction is also of interest from a health impacts perspective.

Volatile organic compounds are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. These have been retained in the inventory to allow an assessment of emissions of precursors to ozone should future monitoring indicate concentrations of concern.

2.3 Selection of areas

The study areas were based on the Greater Wellington Regional Council's "airsheds" for Wainuiomata and Upper Hutt defined for the purposes of the National Environmental Standards. As the airshed boundaries and census area unit boundaries differ, an estimation of the number of dwellings within meshblocks (a subset of census area units) not wholly within the airshed was required. The method used was an estimate of the proportion of dwellings within the meshblock that lay within the "airshed" based on the geographic distribution of address points within each meshblock area. This estimation was done by Greater Wellington Regional Council staff using their in-house GIS system.

Figure 2.1 shows the areas included in the Wainuiomata, Lower Hutt and Upper Hutt airsheds.

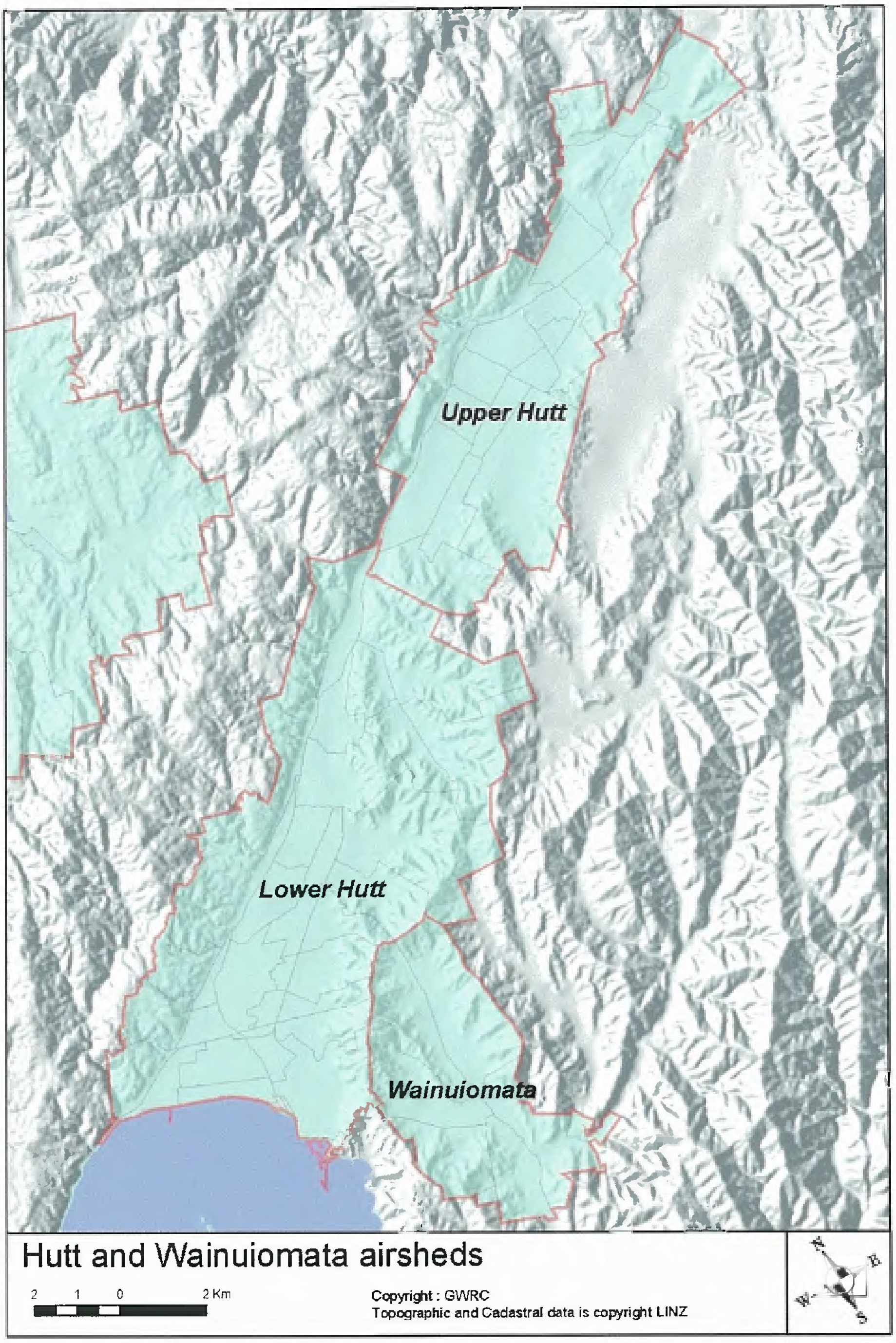

Figure 2.1: Airshed boundaries for Wanuiomata, Lower Hutt and Upper Hutt (map courtesy of John Gibson GWRC)

2.4 Temporal distribution

Most data were collected based on wintertime daily average emissions. Domestic heating data were collected based on average and worst-case wintertime emissions. For most sources, data were also collected by month of the year to provide an estimate of the relative contributions of different sources to annual average PM_{10} concentrations. No differentiation was made for weekday and weekend emissions, as variances are likely to be minimal for most sources. One exception is outdoor rubbish burning which may occur with greater frequency during the weekend.

Limited time of day breakdowns were obtained for the data. However, methods are available for allocating emissions data by time of day should this be required.

3 Home heating survey

3.1 Methodology

Home heating methods and fuels were obtained based on a telephone survey of 381 to 374 households within the Wainuiomata and Upper Hutt areas during the winter of 2006. The survey was carried out by Digipol during May 2006. The number of households within each study area was based on 2001 census data for occupied dwellings extrapolated for 2006 based on Statistics New Zealand population projections for the districts of Lower Hutt and Upper Hutt. A copy of the survey questionnaire is shown in Appendix one. Summary data for the survey and study area are shown in Table 3.1.

Table 3.1: Home heating survey area and sample details

	Households	Sample size	Area (ha)	Sample error
Wainuiomata	5861	374	2162	5%
Upper Hutt	12617	381	4376	5%

Home heating methods were classified as electricity, open fires, wood burners 10 years or older (pre 1996), wood burners 5-10 years old (1996-2001), wood burners less than 5 years old (post 2001), multi fuel burners, gas burners and oil burners. Multi fuel burners refer to burners that are designed to burn coal as well as or instead of wood and include potbelly stoves, incinerators and coal ranges as well as more modern multi fuel burners.

Emission factors were applied to the results of the home heating survey to provide an estimate of emissions for the Wainuiomata and Upper Hutt airsheds. The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. These were reviewed for 2006 to incorporate results from more recent "in situ" burner testing. Further details on the derivation of these factors is given 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	$PM_{2.5}$ g/kg
Open fire - wood	10	100	1.6	0.2	30	1600	10
Open fire - coal	21	80	4	5.0	15	2600	12
Pre 1996 burners	11	110	0.5	0.2	33	1800	11
1996-2001 burners	6.5	65	0.5	0.2	19.5	1800	6.5
Post 2001 burners	6	60	0.5	0.2	18	1800	6
Multi fuel[1] - wood	13	130	0.5	0.2	39	1600	13
Multi fuel[1] - coal	28	120	1.2	3.0	15	2600	12
Oil	0.3	0.6	2.2	3.8	0.25	3200	0.7
Gas	0.03	0.18	1.3	7.6E-09	0.2	2500	0.6

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

One area of uncertainty in the analysis 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. The most recent "in situ" burner emission testing programme, carried out in Tokoroa during 2005, gave an average log weight of 1.3 kilograms. The sample size (pieces of wood weighed) for this study was 845. However, these were spread across only 12 households so it is uncertain how representative the weight of 1.3 kilograms per log is.

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

Because of the uncertainty surrounding the applicability of fuel weights derived for Christchurch to Wanuiomata and Upper Hutt and the lower sized wood from the Tokoroa study (albeit a smaller household sample size) a fuel weight of 1.6 kilograms per log was used for this study.

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 kg.
- The average weight of a bucket of coal is 9 kg.

3.2 Home heating methods

3.2.1 Wainuiomata

The main methods of home heating in Wainuiomata during 2006 were electricity and gas with 51% and 41% of households using these methods to heat their main living area. Wood burners were used by around 26% of households. Of the households using gas, just under half used flued gas systems (Figure 3.1). Table 3.3 shows that households rely on more than one method of heating their main living area during the winter months.

Wood burning is the most common fuel for households using solid fuel heating methods in Wainuiomata with 37% of households using this fuel. About 35 tonnes of wood is burnt on an average winter's night. In comparison coal is used by only 3% of Wainuiomata households and less than one tonne of coal is burnt on an average winters night.

Table 3.3: Home heating methods and fuels in Wainuiomata

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	51%	2,962		
Total Gas	41%	2,429	2	5%
Flued gas	20%	1,145		
Unflued gas	22%	1,284		
Oil	2%	110	0.1	0%
Open fire	6%	329		
Open fire - wood	5%	313	4	12%
Open fire - coal	1%	78	0.3	1%
Total Wood burner	26%	1,504	25	60%
Pre 1996 wood burner	11%	669	11	25%
1996-2001 wood burner	5%	301	5	12%
Post 2001 wood burner	9%	535	9	23%
Multi fuel burners	6%	345		
Multi fuel burners-wood	6%	345	7	20%
Multi fuel burners-coal	2%	110	0.4	1%
Pellet burners	1%	78	0.3	1%
Total wood	37%	2,163	35	91%
Total coal	3%	188	0.7	2%
Total		5,861	38	

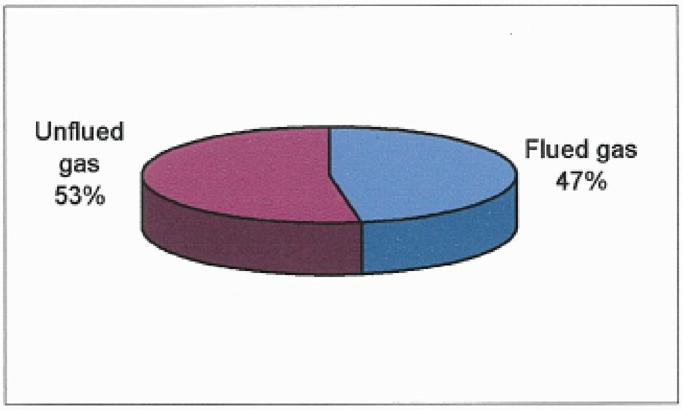

Figure 3.1: Gas use by appliance type for Wainuiomata

3.2.2 Upper Hutt

In Upper Hutt, electricity, gas and wood burners were the most commonly used home heating methods during 2006 with 48%, 38% and 34% of households using these methods to heat their main living area. Around 64% of households using gas used flued gas systems (Figure 3.2). Table 3.4 shows that households rely on more than one method of heating their main living area during the winter months.

The most common fuel for households using solid fuel heating methods in Upper Hutt was wood with 42% of households using this fuel. About 103 tonnes of wood is burnt on an average winter's night in Upper Hutt. Coal was used by around 2% of Upper Hutt households with around 800 kilograms being burnt per night.

Around 5% of Upper Hutt households use open fires and 4% use multi fuel burners to heat their main living area.

Table 3.4: Home heating methods and fuels in Upper Hutt

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	48%	6,093		
Total Gas	38%	4,835	3	3%
Flued gas	25%	3,113		
Unflued gas	14%	1,722		
Oil	1%	66	0.1	0%
Open fire	5%	629	-	0%
Open fire - wood	4%	563	9	8%
Open fire - coal	1%	132	0.8	1%
Total Wood burner	34%	4,239	92	85%
Pre 1996 wood burner	14%	1,717	37	40%
1996-2001 wood burner	9%	1,096	24	19%
Post 2001 wood burner	11%	1,425	31	27%
Multi fuel burners	4%	530		
Multi fuel burners-wood	4%	530	2	1%
Multi fuel burners-coal	1%	132	-	0%
Pellet burners	1%	99	1.0	1%
Total wood	42%	5,332	103	95%
Total coal	2%	265	0.8	1%
Total		12,617	107	

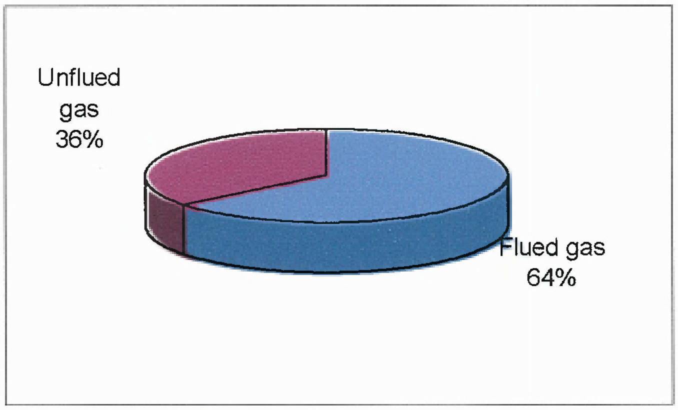

Figure 3.2: Gas use by appliance type for Upper Hutt

4 Domestic Heating Emissions

4.1 Wainuiomata

The greatest amount of PM_{10} from domestic heating during the winter comes from pre 1996 wood burners (36%) and multi fuel burners (27%). Open fires contribute around 13% (Figure 4.1).

Estimates of wintertime contaminant emissions for different heating methods under worst-case and average scenarios are also shown in Tables 4.1 and 4.2. The emission estimates indicate the following:

- Around 734 kilograms 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 348 kilograms per day. This accounts for days when households may not be using specific home heating methods.
- The majority of this PM_{10} is in the finer $PM_{2.5}$ size fraction.
- The majority (95%) of the wintertime PM_{10} emissions come from the burning of wood with 5% from the burning of coal.

Monthly variations in appliance use and average days per week used are shown in Figures 4.2 and 4.3. Table 4.3 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 4.4).

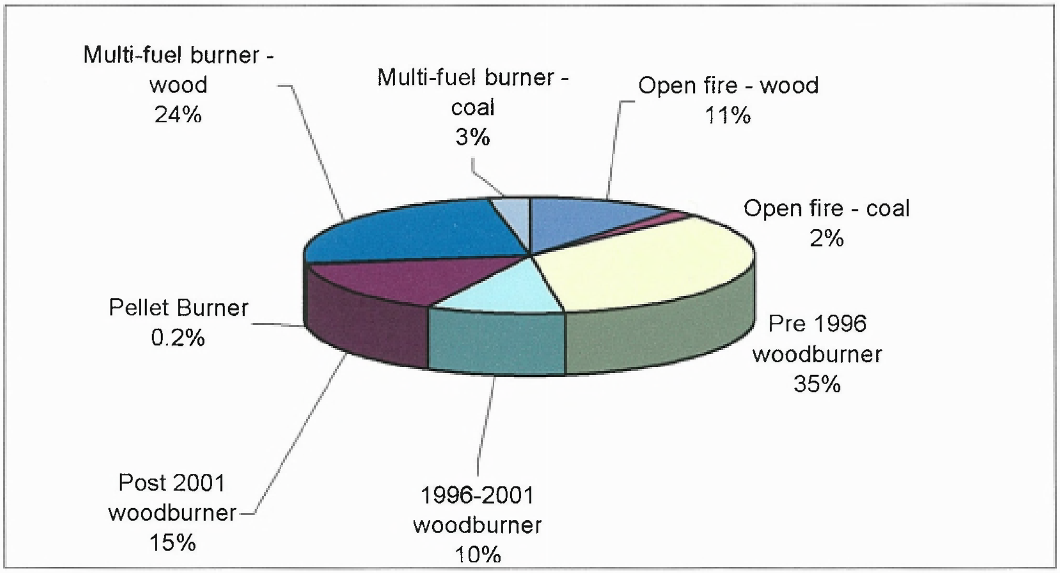

Figure 4.1: Relative contribution of different heating methods to average daily PM_{10} (July) from domestic heating in Wainuiomata

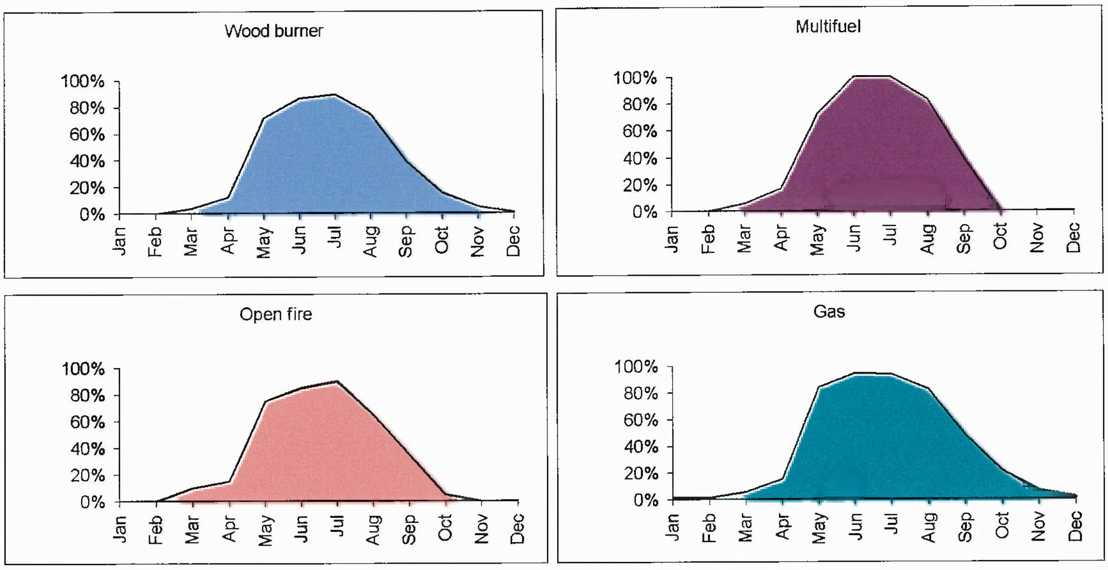

Figure 4.2: Monthly variations in appliance use in Wainuiomata

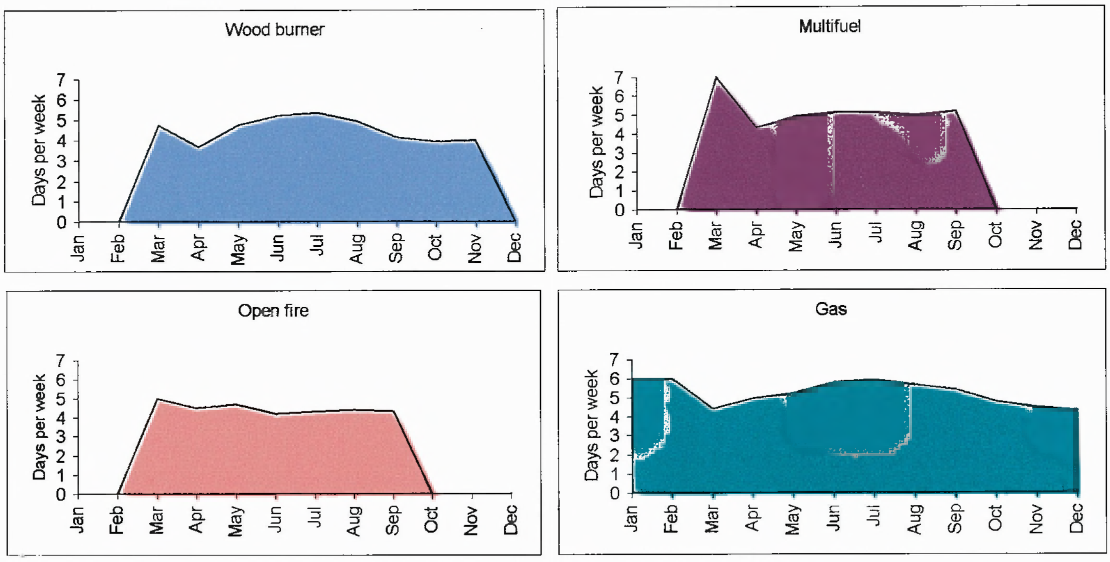

Figure 4.3: Average number of days per week appliances are used in Wainuiomata per month

Table 4.1: Wainuiomata 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	5.8	10%	58	27	11%	582	269	12%	9	4	23%	1	1	6%	175	81	12%	9	4	10%	58	27	11%
Open fire - coal	1.0	2%	21	10	4%	79	37	2%	4	2	10%	5	2	27%	15	7	1%	3	1	3%	12	5	2%
Wood burner	36.1																						
Pre 1996 wood burner	16.1	29%	177	82	33%	1766	817	35%	8	4	20%	3	1	18%	530	245	36%	26	12	28%	177	82	34%
1996-2001 wood burner	7.2	13%	51	23	9%	506	234	10%	4	2	9%	1	1	8%	152	70	10%	12	5	12%	51	23	10%
Post 2001 wood burner	12.8	23%	77	36	14%	771	356	15%	6	3	16%	3	1	14%	231	107	16%	21	10	22%	77	36	15%
Pellet Burner		0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel burner – wood	9.4	17%	123	57	23%	1226	567	24%	5	2	12%	2	1	10%	368	170	25%	15	7	16%	123	57	24%
Multi fuel burner – coal	1.0	2%	28	13	5%	118	55	2%	1	1	3%	3	1	16%	15	7	1%	3	1	3%	16	7	3%
Gas	2.3	4%	0	0	0%	0	0	0%	3	1	8%	0	0	0%	0	0	0%	6	3	6%	0	0	0%
Oil	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	51	92%	485	224	91%	4851	2244	96%	32	15	80%	10	5	57%	1455	673	98%	82	38	88%	485	224	95%
Total Coal	2	4%	48	22	9%	197	91	4%	5	2	13%	8	4	43%	30	14	2%	5	2	6%	28	13	5%
Total	56		534	247		5049	2335		40	19		18	8		1485	687		93	43		513	237	

Table 4.2: Wainuiomata 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	3.9	10%	39	18	11%	385	178	11%	6	3	23%	1	0	7%	116	53	11%	6	3	10%	39	18	11%
Open fire - coal	0.3	1%	7	3	2%	28	13	1%	1	1	5%	2	1	16%	5	2	1%	1	0	1%	4	2	1%
Wood burner	25.1																						
Pre 1996 wood burner	11.0	29%	121	56	35%	1212	560	36%	6	3	21%	2	1	21%	363	168	36%	18	8	28%	121	56	35%
1996-2001 wood burner	5.0	13%	35	16	10%	347	160	10%	2	1	9%	1	0	9%	104	48	10%	8	4	12%	35	16	10%
Post 2001 wood burner	8.8	23%	53	24	15%	529	245	16%	4	2	17%	2	1	17%	159	73	16%	14	7	22%	53	24	15%
Pellet Burner	0.3	1%	0.6	0	0%	6	3	0%	0	0	1%	0	0	1%	2	1	0%	0	0	1%	1	0	0%
Multi fuel burner																							
Multi fuel burner – wood	6.6	17%	85	39	24%	852	394	25%	3	2	12%	1	1	12%	256	118	25%	10	5	17%	85	39	25%
Multi fuel burner – coal	0.4	1%	11	5	3%	45	21	1%	0	0	2%	1	1	11%	6	3	1%	1	0	2%	6	3	2%
Gas	1.8	5%	0	0	0%	0	0	0%	2	1	9%	0	0	0%	0	0	0%	4	2	7%	0	0	0%
Oil	0.1	0%	0	0	0%	0	0	0%	0	0	1%	1	0	5%	0	0	0%	0	0	1%	0	0	0%
Total Wood	35.5	93%	333	154	95%	3331	1541	98%	22	10	83%	7	3	67%	999	462	99%	57	26	89%	333	154	97%
Total Coal	0.7	2%	18	8	5%	73	34	2%	2	1	7%	3	1	27%	11	5	1%	2	1	3%	10	5	3%
Total	38		351	162		3404	1574		27	12		11	5		1010	467		64	29		343	159	

Table 4.3: Monthly variations in contaminant emissions in Wainuiomata

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	3	25	0	0	7	1	3
April	11	102	1	0	30	2	10
May	248	2402	19	7	713	46	242
June	334	3236	25	9	960	61	326
July	351	3404	26	10	1010	63	343
August	269	2613	19	7	776	48	263
September	75	727	6	2	216	13	73
October	8	77	1	0	23	2	8
November	1	15	0	0	4	0	1
December	0	0	0	0	0	0	0
Total (kg/ year)	39843	386539	3013	1141	114742	7194	38983

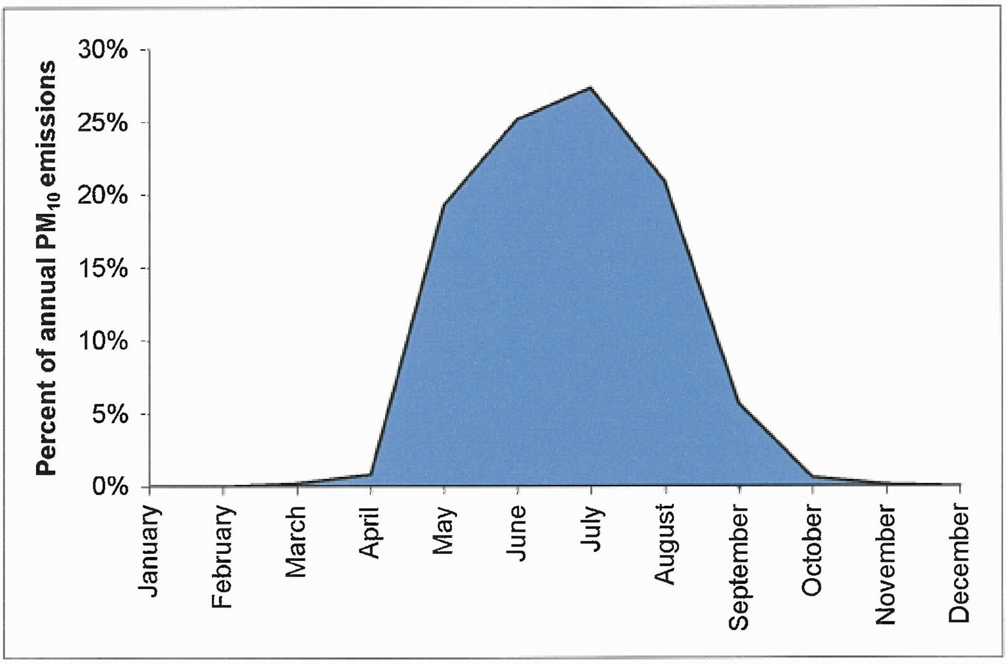

Figure 4.4: Proportion of annual PM_{10} emissions in Wainuiomata by month of year

4.2 Upper Hutt

The greatest amount of PM_{10} from domestic heating during the winter in Upper Hutt is emitted by older pre 1996 wood burners which contribute around 46% of the daily average wintertime PM_{10}. Overall, wood burners contribute 86% of the PM_{10}, with open fires contributing 12% and multi fuel burners 2% (Figure 4.5).

Estimates of wintertime contaminant emissions for different heating methods under worst-case and average scenarios are also shown in Tables 4.4 and 4.5. The emission estimates indicate the following:

- Around 1.2 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 887 kilograms per day. This accounts for days when households may not be using specific home heating methods.
- The majority of this PM_{10} is in the finer $PM_{2.5}$ size fraction.
- The majority (98%) of the wintertime PM_{10} emissions come from the burning of wood with 2% from the burning of coal.

Monthly variations in appliance use and average days per week used are shown in Figures 4.6 and 4.7. Table 4.6 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 4.8).

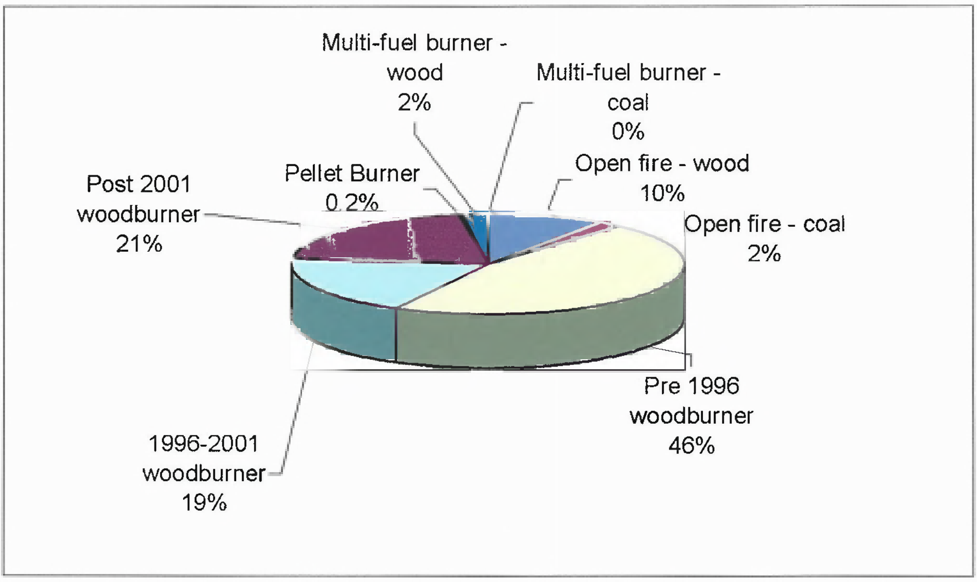

Figure 4.5: Relative contribution of different heating methods to average daily PM_{10} (July) from domestic heating in Upper Hutt

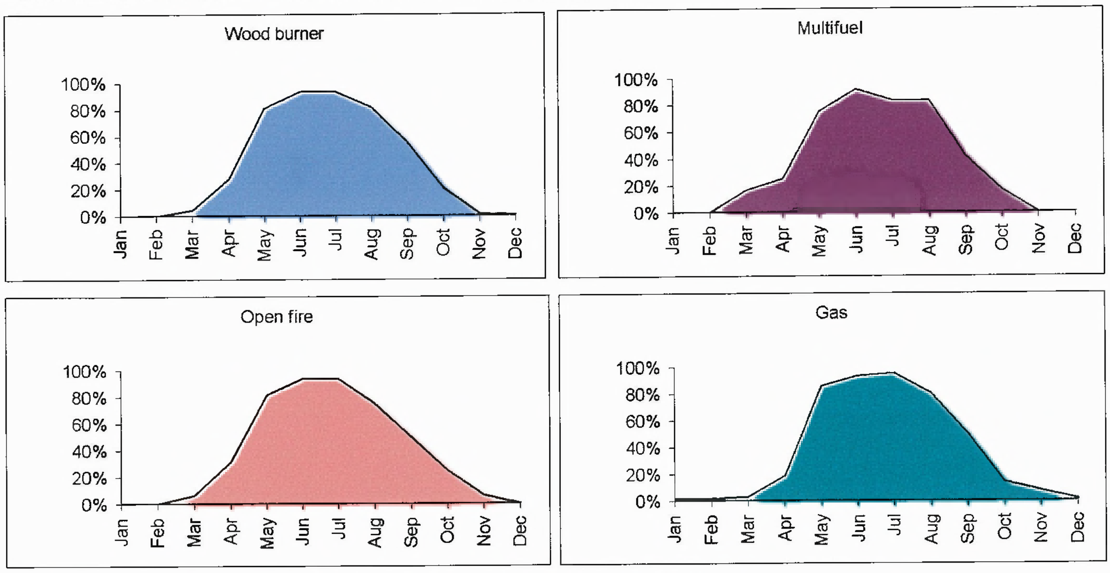

Figure 4.6: Monthly variations in appliance use in Upper Hutt

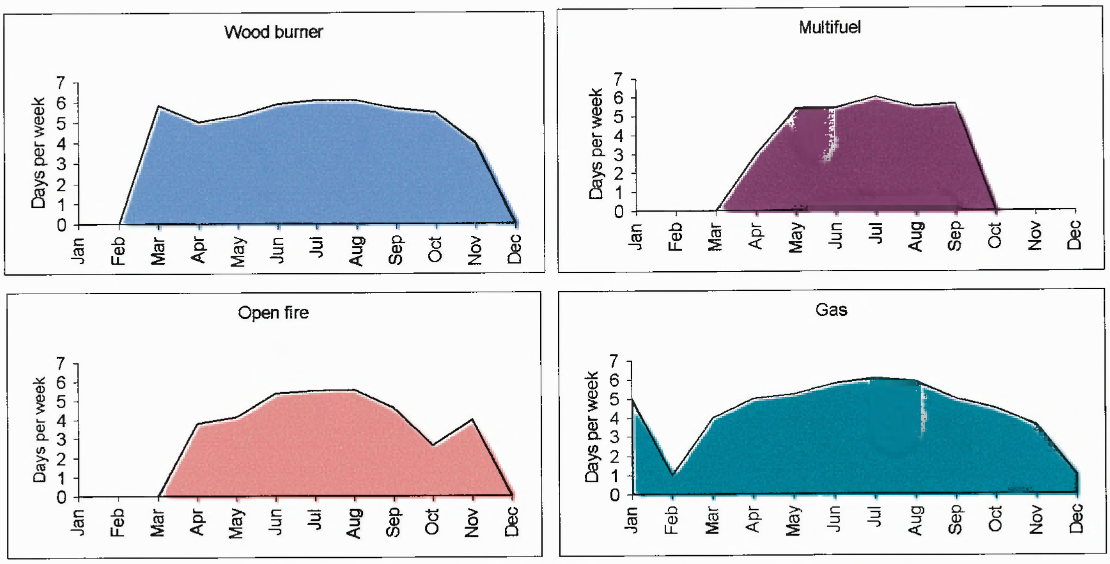

Figure 4.7: Average number of days per week appliances are used in Upper Hutt per month

Table 4.4: Upper Hutt 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	15.6	11%	156	36	13%	1557	356	13%	25	6	26%	3	1	9%	467	107	13%	25	6	11%	156	36	13%
Open fire - coal	1.2	1%	25	6	2%	95	22	1%	5	1	5%	6	1	17%	18	4	1%	3	1	1%	14	3	1%
Wood burner	112.6																						
Pre 1996 wood burner	45.6	32%	502	115	41%	5017	1146	42%	23	5	24%	9	2	26%	1505	344	42%	73	17	31%	502	115	41%
1996-2001 wood burner	29.1	21%	204	47	17%	2038	466	17%	15	3	15%	6	1	16%	611	140	17%	47	11	20%	204	47	17%
Post 2001 wood burner	37.8	27%	227	52	18%	2271	519	19%	19	4	20%	8	2	21%	681	156	19%	61	14	26%	227	52	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%
Multi fuel burner																							
Multi fuel burner – wood	7.2	5%	94	21	8%	938	214	8%	4	1	4%	1	0	4%	281	64	8%	12	3	5%	94	21	8%
Multi fuel burner – coal	0.8	1%	22	5	2%	95	22	1%	1	0	1%	2	1	7%	12	3	0%	2	0	1%	13	3	1%
Gas	4.0	3%	0	0	0%	1	0	0%	5	1	6%	0	0	0%	0	0	0%	10	2	4%	0	0	0%
Oil	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	135	96%	1182	270	96%	11820	2701	98%	85	19	88%	27	6	76%	3546	810	99%	217	49	93%	1182	270	98%
Total Coal	2	1%	47	11	4%	191	44	2%	6	1	6%	8	2	24%	30	7	1%	5	1	2%	27	6	2%
Total	141		1229	281		12012	2745		96	22		35	8		3576	817		232	53		1209	276	

Table 4.5: Upper Hutt 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	8.7	8%	87	20	10%	866	198	10%	14	3	20%	2	0	7%	260	59	10%	14	3	8%	87	20	10%
Open fire - coal	0.8	1%	17	4	2%	64	15	1%	3	1	5%	4	1	16%	12	3	0%	2	0	1%	10	2	1%
Wood burner	92.9																						
Pre 1996 wood burner	37.2	35%	410	94	46%	4095	936	47%	19	4	27%	7	2	30%	1229	281	47%	60	14	34%	410	94	47%
1996-2001 wood burner	23.8	22%	166	38	19%	1663	380	19%	12	3	17%	5	1	19%	499	114	19%	38	9	22%	166	38	19%
Post 2001 wood burner	30.9	29%	185	42	21%	1854	424	21%	15	4	22%	6	1	25%	556	127	21%	49	11	28%	185	42	21%
Pellet Burner	1.0	1%	2.0	0	0%	20	5	0%	0	0	1%	0	0	1%	6	1	0%	2	0	1%	2	0	0%
Multi fuel burner																							
Multi fuel burner – wood	1.6	1%	21	5	2%	205	47	2%	1	0	1%	0	0	1%	62	14	2%	3	1	1%	21	5	2%
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	3.3	3%	0	0	0%	1	0	0%	4	1	7%	0	0	0%	0	0	0%	8	2	5%	0	0	0%
Oil	0.1	0%	0	0	0%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	0	0%
Total Wood	103.1	96%	870	199	98%	8703	1989	99%	61	14	89%	21	5	83%	2611	597	100%	165	38	94%	870	199	99%
Total Coal	0.8	1%	17	4	2%	64	15	1%	3	1	5%	4	1	16%	12	3	0%	2	0	1%	10	2	1%
Total	107		887	203		8768	2004		69	16		25	6		2623	599		176	40		880	201	

Table 4.6: Monthly variations in contaminant emissions in Upper Hutt

	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	71	0	73	145	0	71
February	0	71	0	73	145	0	71
March	2	103	0	73	179	2	103
April	65	103	0	73	242	65	103
May	657	103	0	73	834	657	103
June	880	88	0	73	1042	880	88
July	887	88	0	73	1049	887	88
August	774	88	0	73	937	774	88
September	389	111	0	73	573	389	111
October	32	111	0	73	216	32	111
November	0	111	0	73	185	0	111
December	0	71	0	73	145	0	71
Total (kg/ year)	112947	34097	172	26774	173989	112947	34097

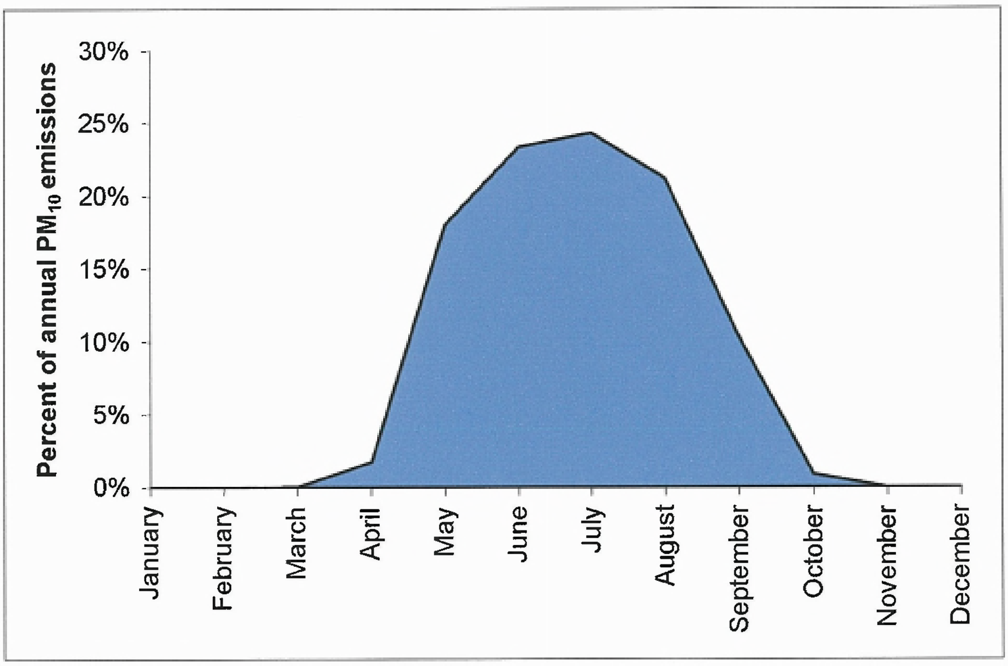

Figure 4.8: Proportion of annual PM_{10} emissions in Upper Hutt by month of year

5 Motor vehicles

5.1 Methodology

Estimates of emissions from motor vehicles in New Zealand typically involve collecting data on vehicle kilometres travelled (VKT) per day under different levels of congestion. Emission factors are then applied to these data to give estimates of emissions for a likely range of congestion conditions.

In the larger urban centres, estimates of VKTs are often made using local road network models. The areas of Wainuiomata and Upper Hutt are included in the Greater Wellington Region road network model owned and operated by the Greater Wellington Regional Council.

The emission factors used to estimate motor vehicle emissions for PM_{10}, CO, NOx and VOC were taken from the New Zealand Traffic Emission Rates (NZTER) database. The vehicle fleet emission model including information on a revised vehicle fleet profile was being developed by the Ministry of Transport at the time this report was prepared but was not available for use. An estimate of the fleet profile for Wellington was therefore made based on vehicle registration data for the city and surrounding suburbs obtained from Land Transport New Zealand (Table 5.1). The distribution of vans/ trucks and utilities to light, medium and heavy-duty vehicles was based on the 1998 New Zealand fleet profile (VFECS, 1998).

Table 5.1: Vehicle registration data for Wellington for year ending 30 December 2005

Vehicle Type	CNG	Diesel	Electric	LPG	Other	Petrol	Total
Agricultural Machine	0	18	0	0	0	6	24
ATV	0	0	1	0	0	301	302
Bus	4	1,286	61	2	0	213	1,566
Goods van, truck, utility	12	20,592	0	11	2	12,502	33,119
Mobile machine	1	549	13	44	3	91	701
Moped	0	1	10	0	2	1,391	1,404
Motor caravan	0	858	0	2	0	113	973
Motorcycle	0	0	0	0	0	5,201	5,201
Passenger car/ van	3	12,902	1	125	16	224,090	237,137
Special purpose vehicle	0	742	0	0	0	90	832
Tractor	0	584	0	1	2	78	665
Total	**20**	**37,532**	**86**	**185**	**25**	**244,076**	**281,924**

Emissions from motor vehicles increase significantly when traffic is congested. Thus different emission rates are used for kilometres travelled when traffic is congested or semi congested. The three different levels of congestion/ driving conditions typically used in emission inventory studies are free flow conditions, interrupted flow conditions and congested flow conditions. The emission factors for each contaminant for the different flow conditions are shown in Table 5.2. These are based on the assumption that 27% of the VKTs in Wainuiomata and 12% of the VKTs in Upper Hutt occur under cold running conditions. These percentages are based on data provided by Greater Wellington Regional Council staff.

Table 5.2: Emission factors for Wainuiomata and Upper Hutt based on the national vehicle fleet profile for 2005

Wainuiomata	CO g/VKT	CO_2 g/VKT	VOC g/VKT	NOx g/VKT	SOx g/VKT	PM_{10} g/VKT	$PM_{2.5}$ g/VKT
Free flow conditions (A-B)	9.39	365.65	1.53	1.31	0.216	0.07	0.038
Interrupted conditions (C-D)	11.76	406.38	1.65	1.41	0.235	0.07	0.042
Congested conditions (E-F)	15.06	475.84	2.15	1.50	0.281	0.10	0.06
Upper Hutt	**CO g/VKT**	**CO_2 g/VKT**	**VOC g/VKT**	**NOx g/VKT**	**SOx g/VKT**	**PM_{10} g/VKT**	**$PM_{2.5}$ g/VKT**
Free flow conditions (A-B)	8.15	365.65	1.31	1.29	0.216	0.06	0.036
Interrupted conditions (C-D)	10.66	406.38	1.44	1.39	0.235	0.07	0.041
Congested conditions (E-F)	14.17	475.84	1.97	1.50	0.281	0.10	0.06

Emissions for each time period were calculated by multiplying the appropriate average emission factor by the VKT for that time period and level of service.

Emissions (g) = Emission Rate (g/km) x VKT

In addition to tailpipe emissions, PM_{10} from the wearing of brakes and tyres were also included in the emissions assessment. 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 Wellington 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.

5.2 Motor vehicle emissions

5.2.1 Wainuiomata

Table 5.3 shows the estimated VKTs for Wainuiomata for 2006 is around 164,000 per day. Conditions are mostly free flowing with about half of the VKTs occurring during the morning and evening peak traffic periods occurring under interrupted flow conditions.

Table 5.3: Estimated daily VKTs for Wainuiomata

	VKT Wainuiomata airshed				
	7am-9am	**9am-4pm**	**4pm-6pm**	**6pm-7am**	**Total**
Free flowing (A-B)	10,414	58,401	12,855	44,576	142,932
Interrupted (C-D)	10,662	0	10,565	0	21,227
Congested (E-F)	0	0		0	0
VKT total	21,076	58,401	23,420	44,576	164,159

The amount of PM_{10} from motor vehicle emissions in Wainuiomata is estimated to be around 12 kilograms per day (Table 5.5). Around 15% of this is estimated to occur as a result of the wearing of brakes and tyres.

Other contaminant emissions from motor vehicles in Wainuiomata include around 1.4 tonnes of CO, 196 kilograms of NOx and 32 kilograms of SOx. In comparison, in Christchurch, where CO concentrations exceed ambient air quality guidelines at least once during most winters, motor vehicles emit around 100 tonnes of CO within the main urban area.

5.2.2 Upper Hutt

Table 5.4 shows the estimated VKTs for Upper Hutt for 2006 is around 690,000 per day. This shows conditions are often interrupted or congested, throughout the day and evening as well as during peak traffic periods.

Table 5.4: Estimated daily VKTs for Wainuiomata

	VKT Upper Hutt airshed				
	7am-9am	**9am-4pm**	**4pm-6pm**	**6pm-7am**	**Total**
Free flowing (A-B)	41,390	146,437	45,628	63,186	338,480
Interrupted (C-D)	37,492	101,140	41,196	43,641	252,365
Congested (E-F)	15,388	36,554	18,472	15,773	96,631
VKT total	94,270	284,130	105,296	122,600	687,476

Around 43 kilograms of PM_{10} per day are estimated to be emitted in Upper Hutt from motor vehicles (Table 5.5). Around 21% of this is estimated to occur as a result of the wearing of brakes and tyres.

Other contaminant emissions from motor vehicles in Upper Hutt include around 4.9 tonnes of CO, 697 kilograms of NOx and 117 kilograms of SOx. .

Table 5.5: Summary of motor vehicle emissions in Wainuiomata and Upper Hutt.

		PM_{10}		CO		NOx		SOx	
	Hectares	**kg**	**g/ha**	**Kg**	**g/ha**	**kg**	**g/ha**	**kg**	**g/ha**
Wainuiomata	2162	12	5	1470	680	196	91	32	15
Upper Hutt	4376	43	10	4922	1125	697	159	117	27

		VOC		CO_2		$PM_{2.5}$		
	Hectares	**kg**		**T**	**kg/ha**	**kg**	**g/ha**	
Wainuiomata	2162	235	109	55	25	7	3	
Upper Hutt	4376	734	168	199	46	24	5	

6 Industrial and Commercial

6.1 Methodology

Industries discharging to air within the Wainuiomata and Upper Hutt airsheds were identified by Greater Wellington Regional Council. 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. Where available, results from stack testing were used to estimate emissions. Activity data were collected 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.

Emissions from 17 consented activities were included in the assessment. The types of discharges included combustion (gas), incineration/crematorium, boilers, abrasive blasting, quarrying, concrete manufacturing and tyre manufacturing.

Emissions data were estimated using emission factor data as per the example shown in Equation 6.1.

Equation 6.1 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 6.1. Emission factors for most sources are based on the USEPA AP42 database[1] and the associated particle size distribution factors. The natural gas factors are based on factors derived by NIWA for the Christchurch 1996 emission inventory (NIWA, 1998).

Table 6.1: 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
Abrasive Blasting	0.69						
Concrete production	0.01						
Quarrying	0.003	0.0008					
Incineration	1.51	1.00	1.48	1.78	1.09		
	g/hour			g/hour			g/hour
Crematorium	0.035			0.1			78
	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3
Natural gas	0.12	0.12	1.34	1.6	0.0096	0.088	1920

6.2 Industrial and commercial emissions

6.2.1 Wainuiomata

The amount of PM_{10} originating from industrial or commercial activities in Wainuiomata per day during the winter is around 7 kilograms (Table 6.2). The majority of this is from non-combustion

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

activities such as quarrying and is not less than 2.5 microns in diameter. Emissions of other contaminants in Wainuiomata from sources included in the inventory are negligible.

6.2.2 Upper Hutt

Table 6.2 shows that less than one kg of PM_{10} is estimated to be emitted from industrial and commercial activities in Upper Hutt per day during the winter months. While a reasonable number of consented air discharge activities are located in Upper Hutt, the majority are for small-scale gas fired boilers, which emit very little PM_{10}. Emissions of other contaminants from industrial and commercial activities for Upper Hutt are also negligible.

Table 6.2: Summary of Wainuiomata and Upper Hutt industrial/ commercial emissions

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Total Upper Hutt	4376	0.5	0.1	0.5	0.1	1.0	0.2	0.2	0.1
Total Wainuiomata	2162	6.7	3.1	0.0	0.0	0.1	0.0	0.0	0.0
		VOC		CO_2		$PM_{2.5}$			
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha		
Total Upper Hutt	4376	0.0	0.0	0.7	0.2	0.4	0.1		
Total Wainuiomata	2162	0.0	0.0	0.1	0.0	1.5	0.7		

7 Outdoor burning

Outdoor burning includes any backyard burning of household or garden wastes in a drum, incinerator or in the open air. Emissions from outdoor burning can contribute to PM_{10} and $PM_{2.5}$ concentrations and can cause localised health 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 Wainuiomata or Upper Hutt. 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.

7.1 Methodology

The domestic home heating survey described in section 3.1 was also used to collect information relating to outdoor rubbish burning. Survey results showed that outdoor burning was carried out by around 5% of households in Wainuiomata and 7% of households in Upper Hutt. On average there are around 7 fires per day during the winter in Wainuiomata and 39 per day in Upper Hutt. The proportion of green waste (60%) versus household rubbish burnt (40%) was based on data collected in Otago (ESR, 1999). Emissions were calculated based on the assumption of an average weight of material per burn of 180 kg and using the emission factors in Table 7.1.

Table 7.1: 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

7.2 Emissions from outdoor burning

7.2.1 Wainuiomata

During the winter it is likely that around 15 kg of PM_{10} per day is emitted from outdoor burning. Table 7.2 shows 14 kilograms (93%) of the PM_{10} is within the finer, $PM_{2.5}$ size fraction. Outdoor burning also produces around 52 kg of carbon monoxide and around 1.8 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 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 7.2: Seasonal variations in outdoor burning emissions in Wainuiomata

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	14	47	3	1	5	2	13
February	14	47	3	1	5	2	13
March	15	50	4	1	5	2	14
April	15	50	4	1	5	2	14
May	15	50	4	1	5	2	14
June	15	52	4	1	5	2	14
July	15	52	4	1	5	2	14
August	15	52	4	1	5	2	14
September	14	47	3	1	5	2	13
October	14	47	3	1	5	2	13
November	14	47	3	1	5	2	13
December	14	47	3	1	5	2	13
Total (kg/ year)	5309	17839	1274	212	1826	624	4969

7.2.2 Upper Hutt

In Upper Hutt, outdoor burning is estimated to emit around 88 kilograms of PM_{10} per day during the winter months. This increases to around 111 kilograms per day during the spring (Table 7.3).

As with Wainuiomata, 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 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 7.3: Seasonal variations in outdoor burning emissions in Wainuiomata

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	71	239	17	3	25	8	67
February	71	239	17	3	25	8	67
March	103	347	25	4	35	12	97
April	103	347	25	4	35	12	97
May	103	347	25	4	35	12	97
June	88	297	21	4	30	10	83
July	88	297	21	4	30	10	83
August	88	297	21	4	30	10	83
September	111	371	27	4	38	13	103
October	111	371	27	4	38	13	103
November	111	371	27	4	38	13	103
December	71	239	17	3	25	8	67
Total (kg/ year)	34097	114565	8183	1364	11729	4010	31915

8 Other sources of emissions

This inventory includes all likely major sources of PM_{10} that can be adequately estimated using inventory techniques. Other potentially significant sources of emissions not included in the inventory include dusts (PM_{10}) and sea spray. A source apportionment study for Masterton (Davy, 2005) shows that when PM_{10} emissions are high (>50 µg m^{-3}) sea spray contributes around 6% of the PM_{10} concentrations. The same study does not indicate that dust is a significant source of PM_{10} in Masterton.

Another source not included in the inventory is vegetation, which can emit VOC and NOx. Neither of these latter contaminants is likely to be an air quality concern and vegetation is unlikely to be a significant source in the predominantly urban areas.

Lawn mowers, leaf blowers and chainsaws can also contribute small amounts of particulate. Lawn mowers were included in the 1999 air emission inventory for the Wellington Region but were not found to be a significant source of PM_{10} or other contaminants (<0.1 grams per household). Based on that study, emissions of less than 1 kilogram of PM_{10} per day could be expected for both Wainuiomata and Upper Hutt during the winter months.

9 Total Emissions

9.1 Wainuiomata

Around 385 kilograms of PM_{10} are discharged to air in Wainuiomata on an average winter's day. The main source is solid fuel burning for domestic home heating, which contributes 91% of the PM_{10} (Figure 9.1). Other sources include outdoor burning (4%), transport (3%) and industry (2%).

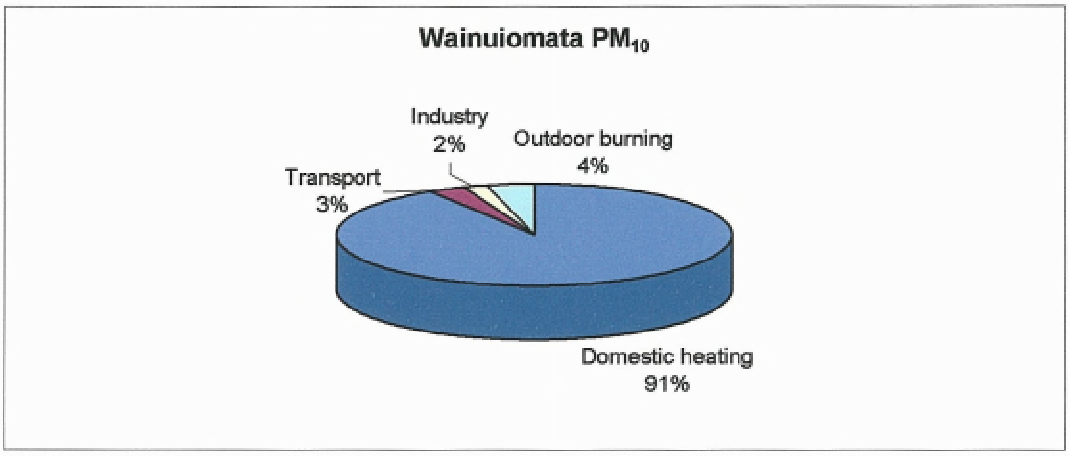

Figure 9.1: Relative contribution of sources to daily winter PM_{10} emissions in Wainuiomata

Domestic home heating is also the main source of $PM_{2.5}$, CO, VOCs and contributes about half of the CO_2 and motor vehicles are the main source of NOx and SOx in Wainuiomta (Figure 9.2).

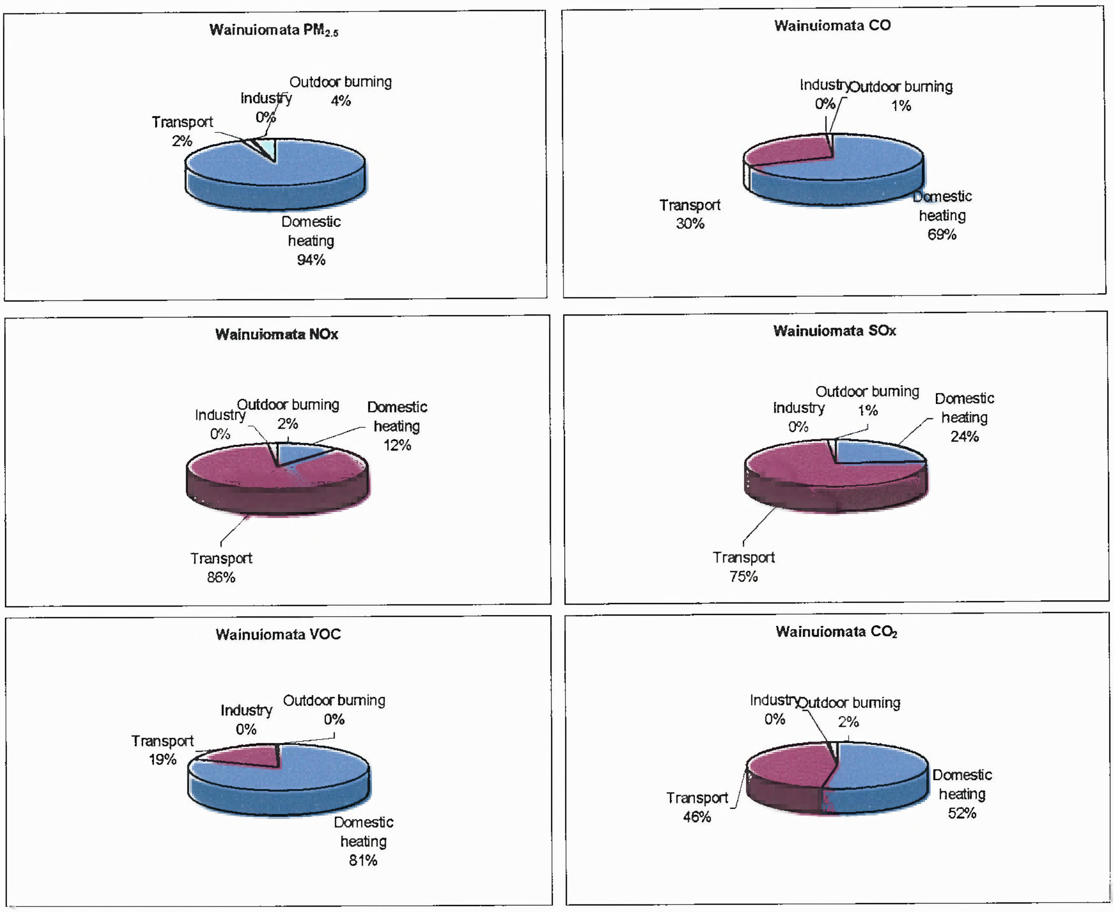

Figure 9.2: Relative contribution of sources to contaminant emissions in Wainuiomata

Table 9.2 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 9.1: Daily contaminant emissions from all sources in Wainuiomata and Upper Hutt

		PM_{10}		CO		NOx		SOx	
	km2	kg	kg/km²	kg	kg/km²	kg	kg/km²	kg	kg/km²
Upper Hutt	44	1019	23	13987	320	788	18	145	3
Wainuiomata	22	385	18	4926	228	226	10	43	2
		VOC		CO_2		$PM_{2.5}$			
	km2	kg	kg/km²	t	kg/km²	kg	kg/km²		
Upper Hutt	44	3387	77	386	9	987	23		
Wainuiomata	22	1250	58	120	6	366	17		

Table 9.2: Monthly variations in daily PM_{10} emissions in Wainuiomata

	Domestic Heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	
January	0	0%	14	43%	7	21%	12	36%	32
February	0	0%	14	43%	7	21%	12	36%	32
March	3	8%	15	41%	7	18%	12	33%	36
April	11	24%	15	34%	7	15%	12	27%	44
May	248	88%	15	5%	7	2%	12	4%	281
June	334	91%	15	4%	7	2%	12	3%	368
July	351	91%	15	4%	7	2%	12	3%	385
August	269	89%	15	5%	7	2%	12	4%	302
September	75	70%	14	13%	7	6%	12	11%	108
October	8	19%	14	35%	7	17%	12	29%	40
November	1	4%	14	41%	7	20%	12	35%	34
December	0	0%	14	43%	7	21%	12	36%	32
Total kg year	39843		5309		2433		4292		

9.2 Upper Hutt

Just over one tonne of PM_{10} is discharged to air in Upper Hutt on an average winter's day. Domestic home heating is the main source contributing 87% of the daily winter time PM_{10} (Figure 9.3). Other sources include outdoor burning and transport which contribute 9% and 4% respectively. The industrial contribution to PM_{10} emissions in Upper Hutt is negligible and less than 1% of the total PM_{10}.

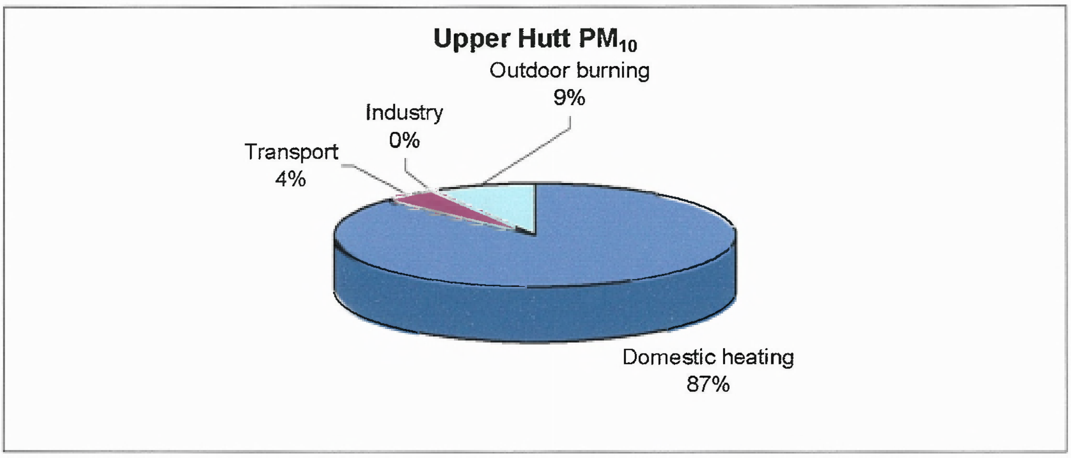

Figure 9.3: Relative contribution of sources to daily winter PM_{10} emissions in Upper Hutt

Domestic home heating is also the main source of CO, $PM_{2.5}$ and VOCs and contributes about half of the CO_2 in Upper Hutt. Motor vehicles are the main source of NOx and SOx (Figure 9.4).

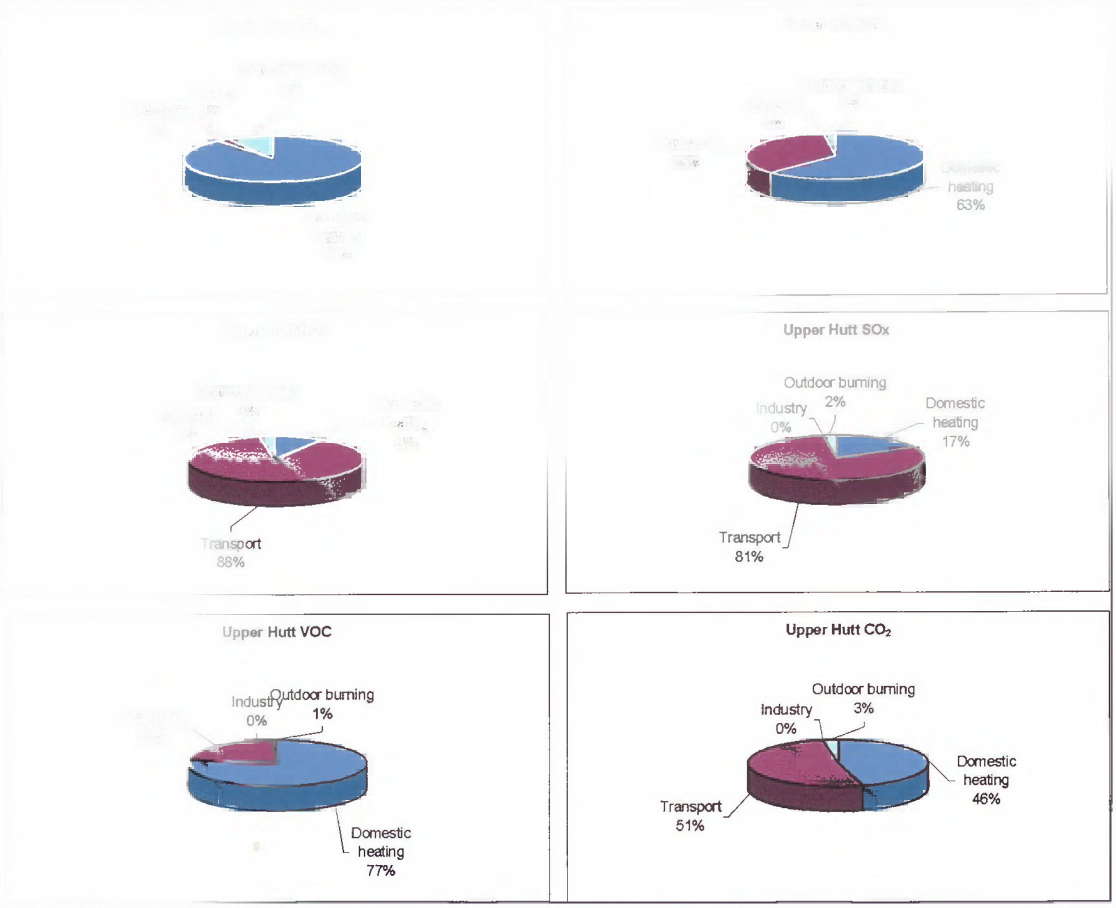

Figure 9.2: Relative contribution of sources to contaminant emissions in Upper Hutt

Daily wintertime emissions of PM_{10} and other contaminants (kg/day and kg/day/km^2) are shown in Table 9.2. Table 9.3 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 9.3: Monthly variations in daily PM_{10} emissions in Upper Hutt

	Domestic Heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	
January	0	0%	71	62%	0	0%	43	38%	115
February	0	0%	71	62%	0	0%	43	38%	115
March	2	1%	103	69%	0	0%	43	29%	149
April	65	31%	103	49%	0	0%	43	20%	212
May	657	82%	103	13%	0	0%	43	5%	804
June	880	87%	88	9%	0	0%	43	4%	1012
July	887	87%	88	9%	0	0%	43	4%	1019
August	774	85%	88	10%	0	0%	43	5%	906
September	389	72%	111	20%	0	0%	43	8%	543
October	32	17%	111	59%	0	0%	43	23%	186
November	0	0%	111	72%	0	0%	43	28%	154
December	0	0%	71	62%	0	0%	43	38%	115
Total kg year	112947		34097		172		15763		

9.3 Uncertainty

As with any emission inventory investigation, a number of uncertainties exist because of the methodology applied. In particular, the use of average emission factors, estimates of quantities of fuel burnt, variations in traffic flows or industrial activities can influence emissions. Notwithstanding these areas of uncertainty, emission inventory investigations are a useful tool and are used throughout the world for assessing sources of emissions and as a basis for determining appropriate management options.

An estimate of the uncertainty associated with the emission estimates for Upper Hutt was made using the formulae described in Topping (1971) and the following assumptions regarding the uncertainty around input variables:

Domestic heating emission factors, ± 50%
Domestic heating fuel weight, ± 30%
Survey sample error, ± 5%
Transport emission estimates, ±40%
Industrial emission estimates, ±40%

The total uncertainty was calculated to be ± 28% with the main variables influencing this value being the emission factors for domestic heating and quantity of fuel burnt for domestic home heating. A similar level of uncertainty would be estimated for Wainuiomata for the above assumptions.

References

Dasch, J. M. 1982: Particulate and Gaseous Emissions from Wood Burning Fireplaces, Environ. Sci. and Technol., Vol. 16, No 10, pg 639-645.

Davy, P., Trompetter, W. J., Markwitz, A., Weatherburn, D. C., 2005, Elemental analysis and source apportionment of ambient particulate matter at Masterton, New Zealand. 2005 Biopixe conference, Wellington New Zealand 17-21 January 2005.

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

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

Gimson, N., & Fisher, G., 1997, The Relationship Between Emissions to Air and Measured Ambient Air Concentrations of Contaminants in Christchurch, Report U97(67), Environment Canterbury.

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

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

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

Ministry of Transport, 1998, Vehicle fleet emission control strategy – final report. Ministry of Transport.

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

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

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

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

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 Greater Wellington Regional Council
May I please speak to an adult in your household who knows about your home heating systems? We are currently undertaking a survey in your area on methods of home heating. We wish to know what you use to heat your main living area during a typical year. The survey will take about 5 minutes. Is it a good time to talk to you now?

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

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

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

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

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

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

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

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

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

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

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

(f) What size gas bottle do you use?

(f.2) How many times in a winter would you refill your x kg gas bottle? Interviewer: Winter is defined as May to August inclusive.
4. (a) Do you use a log burner in your MAIN living area during a typical year? (This is a fully enclosed burner but does not include multi fuel burner i.e., those that burn coal) *(If No then question 5)*

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

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

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

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

(d) How old is your log burner?
(e) In a typical year, how many pieces of wood do you use on an average winters day? Interviewers note : winter is defined as May to August inclusive.
(f) ask only If they used their log burner during non winter months How many pieces of wood do you use per day during the other months? Interviewers note : winter is defined as May to August inclusive.
(g) In a typical year, how much wood would you use per year on your log burner? (record wood use in cubic metres - note 1 cord equals 3.6 cubic meters of loosely piled blocks, one trailer equals about 1.65 cubic metres without cage, or 2.2 with cage)
(h) Do you buy wood for your log burner, or do you receive it free of charge?
(i) What proportion would be bought?
5. (a) Do you use an enclosed burner which burns coal as well as wood – i.e., a multi fuel burner in your MAIN living area during a typical year? (This includes incinerators, pot belly stoves, McKay space heaters etc but does not include open fires.) *(If No then question 6)*

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

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

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

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

(d) How old is your multi fuel burner?

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

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

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

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

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

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

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

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

(m) What proportion would be bought?

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

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

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

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

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

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

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

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

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

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

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

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

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

(l) What proportion would be bought?

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

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

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

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

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

(d) How old is your pellet burner?

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

(e) and what model is your pellet burner?

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

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

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

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

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

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

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

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

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

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

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

How many days would you burn rubbish outdoors during

a) winter (June, July, August)

b) spring (September, October, November)

c) summer (December, January, February)

d) autumn (March, April, May)
How much garden waste or rubbish would you burn each session. We are looking for cubic metres, or number of wheelbarrows full per fire.

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

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

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

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

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

D3 With which ethnic group do you most closely relate?

Interviewer: tick gender.

How many people live at your address?

Do you own your home or rent it?

D5 What is your employment status:

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

Appendix B: Emission factors for domestic heating.

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

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

Emission factors for the post 1995 wood burner categories were based on data collected in Nelson on burner types in different age categories. Gas and oil emission factors were based on factors derived by Angie Scott (pers comm., 2004) based on more recent testing of these appliances.

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

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

Appendix C: Additional information on industrial emissions

Consent Holder	Discharge Activity	PM_{10} kg day (winter)	Notes:
Gee and Hickton Ltd	Cremator.	0.07	Average use of 3 hours per day.
Ministry Of Education	Three natural gas-fired boilers.	0.00	
Ministry Of Education	Two natural gas-fired boilers.	0.00	
Eurocell Sawmilling Ltd	Natural gas-fired boiler.	0.01	
South Pacific Tyres	Manufacture of tyres.	0.04	Emission rates from actual test data used – documented on consent files.
Ministry Of Education	Two natural gas-fired boilers.	0.00	
Vita New Zealand Ltd	Manufacture of foam and associated processes.		Consent examined. Not a significant source of PM_{10} or other key contaminants.
Ministry Of Education	Natural gas-fired boiler	0.00	
Ministry Of Education	Two natural gas-fired boilers.	0.00	
Winstone Aggregates	Quarry, mobile crushing and screening equipment	4.94	600,000 tonnes per year processed.
Allied Milburn Ltd	Discharge of cement dust.	1.72	60,000 tonnes per year.
NZ Pastoral Agriculture Research Institute	2 small waste incinerators.	0.32	
Ministry Of Education	3 natural gas-fired boilers.	0.00	
Ministry Of Education	Natural gas-fired school boilers.	0.00	
Serco Project Engineering Ltd.	Abrasive blasting.	0.02	8 tonnes per year.
Ministry Of Education	Natural gas-fired boiler.	0.00	
Ministry Of Education	Two natural gas-fired boilers.	0.00	
Ministry Of Education	Natural gas-fired boiler	0.00	
Ministry Of Education	Two natural gas-fired boilers.	0.00	

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