Air emissions inventory – Masterton July 2008

A report prepared for Greater Wellington by Environet Ltd

Greater Wellington
Te Pane Matua Taiao

Air Emission Inventory – Masterton, July 2008

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Executive Summary

Air quality monitoring in Masterton has shown that concentrations of PM_{10} in excess of air quality guidelines and National Environmental Standards occur during the winter months. The highest measured PM_{10} concentration for Masterton was 63 µg m^{-3} and was measured during 2008. The Ministry for the Environment adopted the National Environmental Standards (NES) for air in October 2004 including an NES for PM_{10} of 50 µg m^{-3} (24-hour average).

If the NES is not met by 2013, Greater Wellington Regional Council will be unable to grant resource consents for discharges to air in non-compliant airsheds, including Masterton. In addition, between September 2005 and 2013 consents for discharges to air can only be granted if Councils can demonstrate that the granting of the consent will not impinge on the "straight-line path" to compliance.

One of the first steps in determining the required reductions in PM_{10} is to determine the quantities and sources of PM_{10} in Masterton. This emission inventory fulfils this requirement.

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

A domestic home heating survey was carried out for Masterton to determine the proportions of households using different heating methods and fuels. Results showed that using wood burners was the most common method of heating the main living area, with 66% of households using wood burners. Electricity was used by 32% of households and gas by 18% of households as the primary form of heating in their main living area. Many households used more than one method to heat the main living area of their home.

The main source of PM_{10} emissions during the winter was domestic home heating, which accounted for 94%. Outdoor burning contributed around 4%, and motor vehicles 2% of total emissions in Masterton. Industry contributes a negligible amount of PM_{10} emissions.

Contents

List of Figures

List of Tables

1 Introduction

Masterton is an urban area 79 kilometres north of Wellington and has a population of around 18000 residents. The Masterton District has a total land area of 229,500 hectares that runs from the Tararua Ranges to the Pacific Coast and from Mt Bruce to the Waingawa River (Figure 1.1).

Figure 1.1: Aerial view of Masterton Source: Google Earth

Air quality in Masterton exceeds the National Environmental Standard (NES) of 50 µg m^{-3} (24-hour average) and air quality target specified in the Greater Wellington Long Term Council Community Plan 2007 (LTCCP) of 33 µg m^{-3} (24-hour average) during the winter months.

If the NES is not met by 2013, Greater Wellington Regional Council will be unable to grant resource consents for discharges to air in non-compliant airsheds. In addition, between September 2005 and 2013 consents for discharges to air can only be granted if Councils can demonstrate that the granting of the consent will not impinge on the “straight-line path” to compliance.

The Greater Wellington Regional Council has a permanent air quality monitor situated in Masterton. Historically the main method of monitoring for PM_{10} in Masterton was the Tapered Element Oscillating Microbalance (TEOM). However, additional and alternative methods have been used. These include an FH 62 Beta Attenuation Monitor (BAM) (since June 2007) and one day in three gravimetric high volume sampling from April 2003 to March 2005. Figure 1.2 shows PM_{10} concentrations measured using the TEOM during 2007 and 2008. Based on the latter measurement method, in 2007 there were two exceedences of 50 µg m^{-3} during 2008 and none during 2007.

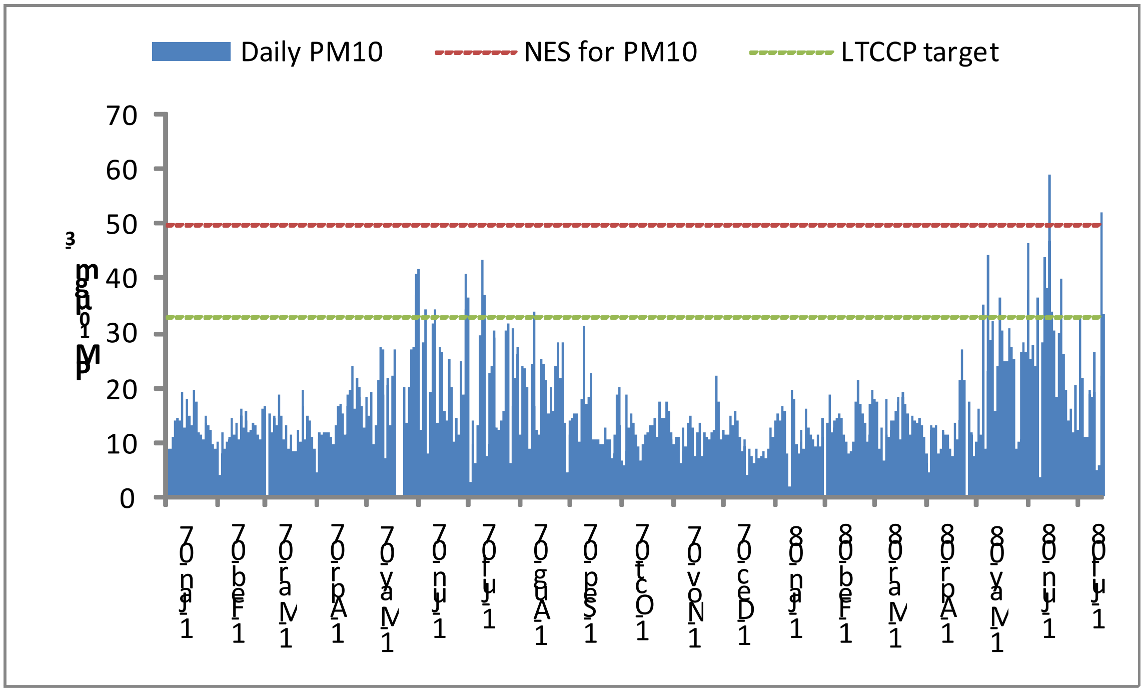

Figure 1.2: PM_{10} concentrations (24-hour average) measured using a TEOM during 2007 and 2008 in Masterton

This report details the results of an air emission inventory carried out for Masterton for 2008. The purpose of the inventory is to establish emission estimates for the contribution from domestic heating, industry, transport and outdoor burning sources of selected contaminants.

2 Inventory Design

The inventory has been designed with a focus on emissions of PM_{10}, because air quality monitoring shows this is the main issue of concern in Masterton. Concentrations of other contaminants are unlikely to exceed air quality guidelines and the NES. One exception may be the air quality guideline for benzo(a)pyrene (BaP) as concentrations of this contaminant have been found to be high in areas where PM_{10} concentrations are elevated as a result of emissions from domestic home heating. At this stage, a NES for BaP has not been proposed.

2.1 Selection of sources

The inventory includes detailed estimates of emissions from domestic heating, motor vehicles, industry and outdoor burning as these are typically the main anthropogenic sources of PM_{10} in urban areas. Natural source contributions are not typically estimated in emission inventories in New Zealand because of the uncertainties associated with the estimation methods. For Masterton, the contribution of natural sources has been estimated by Davy (2008) for high pollution days using source apportionment receptor modelling. Emissions from a number of 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 are included in the NES because of their potential for adverse health impacts. Carbon dioxide has been typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas CO_2 emissions. However, these data are now typically collected nationally and for a broader range of greenhouse gases. Estimates of CO_2 have been retained in the inventory but readers should be directed to national statistics (e.g., www.climatechange.govt.nz) should detailed data on this source be required. The finer $PM_{2.5}$ size fraction was also included, as this size fraction is also of interest from a health impacts perspective.

Volatile organic compounds are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. Ozone formation is unlikely to be a key concern for Masterton. In this report, VOC emissions have been estimated for existing sources but data on emissions from VOC specific sources (e.g., spray painting) have not been included.

2.3 Selection of areas

The Wairarapa airshed was gazetted by the Ministry for the Environment in 2005 (http://www.mfe.govt.nz/laws/standards/airsheds/index.html). Masterton is only a small part of the airshed but is the location where PM_{10} concentrations are thought to be highest.

The census area unit used are:

- Masterton Central
- Masterton West
- Masterton East
- Solway North
- Solway South
- Ngaumutawa
- Masterton Railway
- Lansdowne

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 with four time of day categories. The road network models used for estimating VKTs do not contain seasonal variations in vehicle movements. Industrial data were collected by season.

No differentiation was made for weekday and weekend sources.

3 Domestic heating

3.1 Methodology

The activity data for domestic heating was collected using a telephone survey of 335 households which were distributed across the different study areas as outlined in Table 3.1. The survey was carried out by Digipol during June 2008. The number of households within each study area was based on 2006 census data for occupied dwellings extrapolated for 2008 based on the Statistics New Zealand population projection for Masterton of zero population increase by 2021. A copy of the survey questionnaire is shown in Appendix A.

Table 3.1: Home heating survey area and sample details

	Households	Sample size	Area (km^2)	Sample error
Masterton	7116	355	18	5%

Home heating methods were classified as electricity, open fires, wood burners 10 years or older (pre 1998), wood burners 5-10 years old (1998-2003), wood burners less than 5 years old (post 2003), pellet fires, multi fuel burners, gas burners and oil burners.

Emission factors were applied to the results of the home heating survey to provide an estimate of emissions for each study area. The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. The basis for these is detailed in Appendix 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	19	15	2600	12
Pre 1998 burners	11	110	0.5	0.2	33	1600	11
1998-2003 burners	7	70	0.5	0.2	21	1600	7
Post 2003 burners	5	45	0.5	0.2	18	1600	5
Pellet burners	2	20	0.5	0.2	6	1600	2
Multi-fuel[1] - wood	13	130	0.5	0.2	39	1600	13
Multi-fuel[1] - coal	28	120	1.2	19	15	2600	16
Oil	0.3	0.6	2.2	3.8	0.25	3200	0.22
Gas	0.03	0.18	1.3	7.56E-09		2500	0.03

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

One of the assumptions underlying the emissions calculations is the average weight for a log of wood. Average log weights used for inventories in New Zealand have included 1.6 kg, 1.4 kg and more recently 1.9 kg. The latter value is based on a survey of 219 households in Christchurch during 2002 and represents the most comprehensive assessment of average fuel weight. A recent 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 of the Tokoroa population a fuel weight of 1.3 kilograms per log might be.

There is some potential for fuel size to vary by region although factors such as appliance design should limit these variations. The first three average fuel weight values noted above were 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 the householder is possible.

For this study it was assumed that the average log weight in Masterton is 1.3 kilograms. This gave an average daily fuel use rate of around 20 kilograms for households using wood burners.

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

3.2 Home heating methods

The use of wood burners was the main heating method in Masterton for 2008 with 66% of households using this method to heat their main living area. Electricity was the second most common method (32%) followed by gas (18%). Only a small proportion of Masterton residents use multi fuel burners (5%) or open fires (4%) to heat their main living area (Figure 3.1). Of the households using gas, over half used unflued gas systems. Table 3.3 shows that households rely on more than one method of heating their main living area during the winter months.

Wood is the most common fuel for households using solid fuel heating methods in Masterton with 75% of households using this fuel. About 92 tonnes of wood is burnt on an average winter's night.

Table 3.3: Home heating methods and fuels in Masterton

	Heating Methods		Fuel Use	
	%	HH	t/day	%
Electricity	32%	2,245		
Total Gas	18%	1,263	1.7	2%
Flued gas	8%	588		
Unflued gas	9%	675		
Oil	1%	80.2	0.4	0%
Open fire	4%	301		
Open fire - wood	4%	281	2	2%
Open fire - coal	1%	40	0	0%
Total Wood burner	66%	4,671	83.1	86%
Pre 1998 wood burner	19%	1,345	23.9	25%
1998-2003 wood burner	25%	1,761	31.3	32%
Post 2003 wood burner	22%	1,565	27.8	29%
Multi fuel burners	5%	361		
Multi fuel burners-wood	5%	361	7	7%
Multi fuel burners-coal	2%	160	2	2%
Pellet burners	1%	60.1	0.3	0%
Total wood	75%	5,312	92	96%
Total coal	3%	200	2	2%
Total		7,116	97	

3.3 Emissions from domestic heating

Figure 3.1 shows that the greatest amount of PM_{10} from domestic heating during the winter comes from pre 1998 wood burners (34%) and burners installed between 1998 and 2003 (28%). Multi fuel burners contribute around 18% of the PM_{10} emissions and open fires around 4%.

Estimates of wintertime contaminant emissions for different heating methods under worst-case and average scenarios are also shown in Tables 3.4 and 3.5. The emission estimates indicate the following:

- Around 886 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 (July) PM_{10} emissions are less at around 782 kilograms per day. This accounts for days when households may not be using specific home heating methods.

- The majority (96%) of the wintertime domestic 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 3.2 and 3.3. Table 3.6 shows seasonal variations in contaminant emissions. The majority of the annual PM_{10} from domestic home heating occurs during the months June, July and August (Figure 3.4).

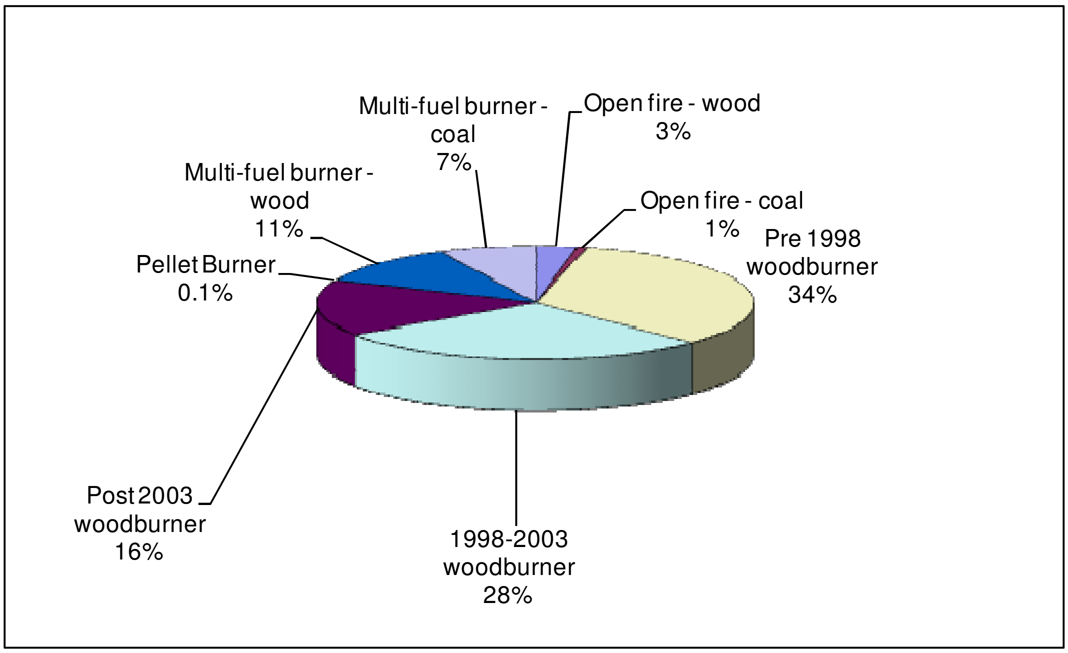

Figure 3.1: Relative contribution of different heating methods to average daily PM_{10} (July) from domestic heating in Masterton

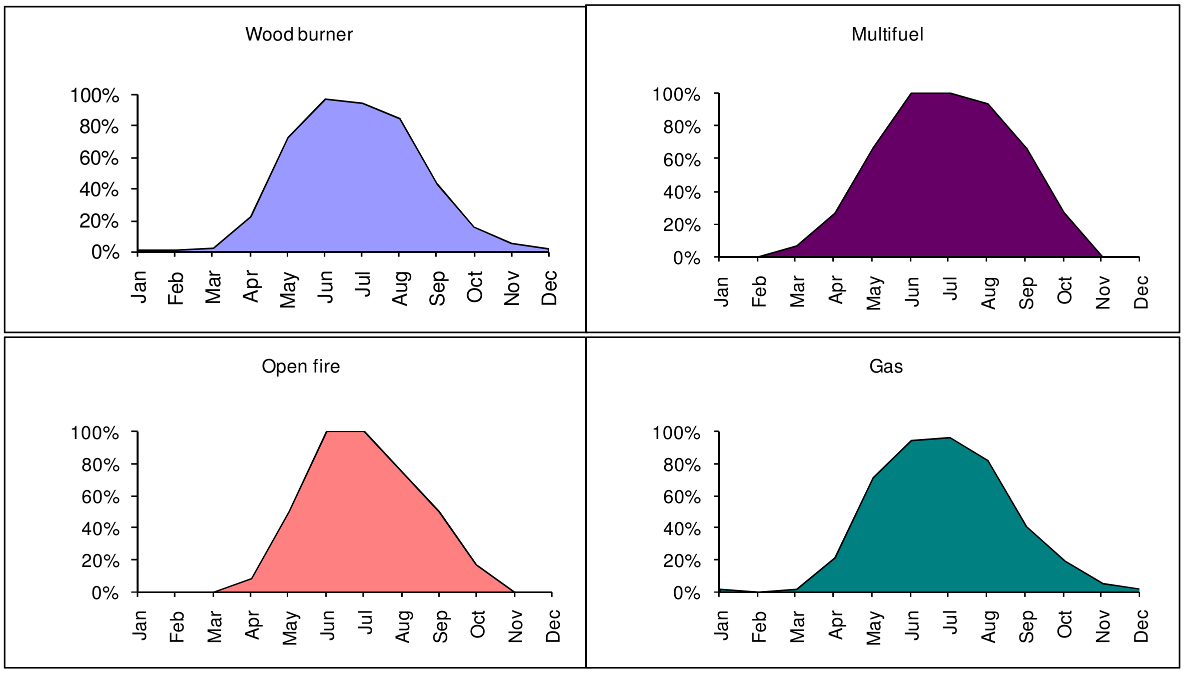

Figure 3.2: Monthly variations in appliance use in Masterton

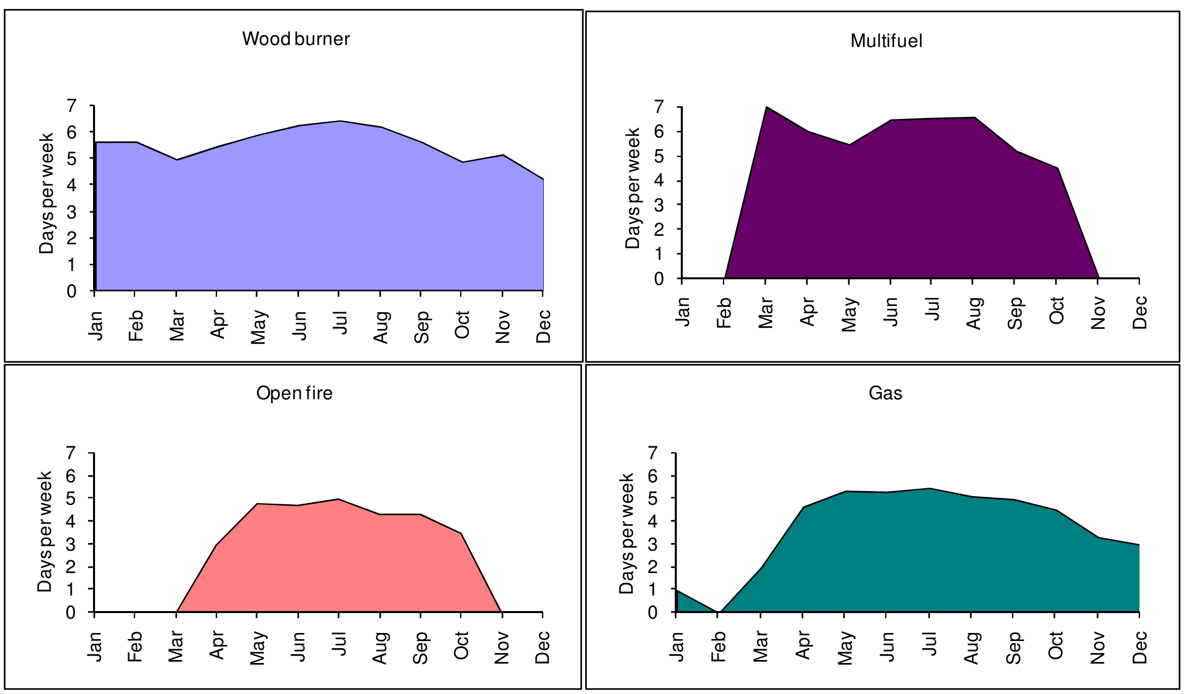

Figure 3.3: Average number of days per week appliances are used in Masterton per month

Table 3.4: Masterton 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	kg/km^2	%	kg	kg/km^2	%	kg	kg/km^2	%	kg	kg/km^2	%	kg	kg/km^2	%	t	tonnes $/km^2$	%	kg	kg/km^2	%
Open fire																							
Open fire - wood	3.3	3%	33	2	4%	334	19	4%	5	0	8%	1	0	1%	100	6	4%	5	0	3%	33	2	4%
Open fire - coal	0.4	0%	8	0	1%	29	2	0%	1	0	2%	7	0	10%	5	0	0%	1	0	1%	4	0	1%
Wood burner																							
Pre 1998 wood burner	27.2	25%	299	17	34%	2987	166	35%	14	1	21%	5	0	8%	896	50	34%	43	2	24%	299	17	35%
1998-2003 wood burner	35.5	32%	249	14	28%	2488	138	29%	18	1	28%	7	0	10%	747	41	28%	57	3	31%	249	14	29%
Post 2003 wood burner	31.6	29%	142	8	16%	1422	79	17%	16	1	25%	6	0	9%	569	32	22%	51	3	28%	142	8	17%
Pellet Burner	0.3	0%	1	0	0%	6	0	0%	0	0	0%	0	0	0%	2	0	0%	1	0	0%	1	0	0%
Multi fuel burner																							
Multi fuel burner – wood	7.2	7%	94	5	11%	939	52	11%	4	0	6%	1	0	2%	282	16	11%	12	1	6%	94	5	11%
Multi fuel burner – coal	2.2	2%	61	3	7%	260	14	3%	3	0	4%	41	2	58%	32	2	1%	6	0	3%	35	2	4%
Gas	2.2	2%	0	0	0%	0	0	0%	3	0	4%	0	0	0%	0	0	0%	5	0	3%	0	0	0%
Oil	1	0%	0	0	0%	0	0	0%	1	0	2%	2	0	3%	0	0	0%	2	0	1%	0	0	0%
Total Wood	105	95%	818	45	92%	8177	454	97%	56	3	88%	21	1	30%	2595	144	99%	168	9	92%	818	45	95%
Total Coal	3	2%	68	4	8%	289	16	3%	4	0	6%	48	3	68%	38	2	1%	7	0	4%	39	2	5%
Total	110		886	49		8466	470		64	4		71	4		2633	146		182	10		857	48	

Table 3.5: Masterton 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	kg/km^2	%	kg	kg/km^2	%	kg	kg/km^2	%	kg	kg/km^2	%	kg	kg/km^2	%	t	tonnes/km^2	%	kg	kg/km2	%
Open fire																							
Open fire - wood	2.4	2%	24	1	3%	239	13	3%	4	0	7%	0	0	1%	72	4	3%	4	0	2%	24	1	3%
Open fire - coal	0.3	0%	5	0	1%	21	1	0%	1	0	2%	5	0	8%	4	0	0%	1	0	0%	3	0	0%
Wood burner																							
Pre 1998 wood burner	23.9	25%	263	15	34%	2631	146	35%	12	1	22%	5	0	8%	789	44	34%	38	2	24%	263	15	35%
1998-2003 wood burner	31.3	32%	219	12	28%	2192	122	29%	16	1	28%	6	0	10%	658	37	28%	50	3	31%	219	12	29%
Post 2003 wood burner	27.8	29%	125	7	16%	1253	70	17%	14	1	25%	6	0	9%	501	28	22%	45	2	28%	125	7	17%
Pellet Burner	0.3	0%	0.6	0	0%	6	0	0%	0	0	0%	0	0	0%	2	0	0%	1	0	0%	1	0	0%
Multi fuel burner																							
Multi fuel burner – wood	6.7	7%	88	5	11%	876	49	12%	3	0	6%	1	0	2%	263	15	11%	11	1	7%	88	5	12%
Multi fuel burner – coal	2.0	2%	57	3	7%	242	13	3%	2	0	4%	38	2	61%	30	2	1%	5	0	3%	32	2	4%
Gas	1.7	2%	0	0	0%	0	0	0%	2	0	4%	0	0	0%	0	0	0%	4	0	3%	0	0	0%
Oil	0.4	0%	0	0	0%	0	0	0%	1	0	2%	1	0	2%	0	0	0%	1	0	1%	0	0	0%
Total Wood	92.5	96%	720	40	92%	7197	400	96%	49	3	88%	19	1	29%	2284	127	99%	148	8	93%	720	40	95%
Total Coal	2.3	2%	62	3	8%	263	15	4%	3	0	6%	43	2	68%	34	2	1%	6	0	4%	35	2	5%
Total	97		782	43		7461	414		55	3		63	4		2319	129		159	9		755	42	

Table 3.6: Monthly variations in contaminant emissions from domestic heating in Masterton

	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	0	5	0	0	1	0	0
April	72	718	4	2	225	13	72
May	400	3824	28	30	1196	84	387
June	775	7380	55	63	2296	158	747
July	782	7455	56	68	2317	160	755
August	576	5467	39	48	1695	116	554
September	198	1946	17	13	616	45	195
October	28	284	2	1	90	6	28
November	0	4	0	0	1	0	0
December	0	0	0	0	0	0	0
Total (kg/ year)	86707	829517	6139	6917	258458	17848	83906

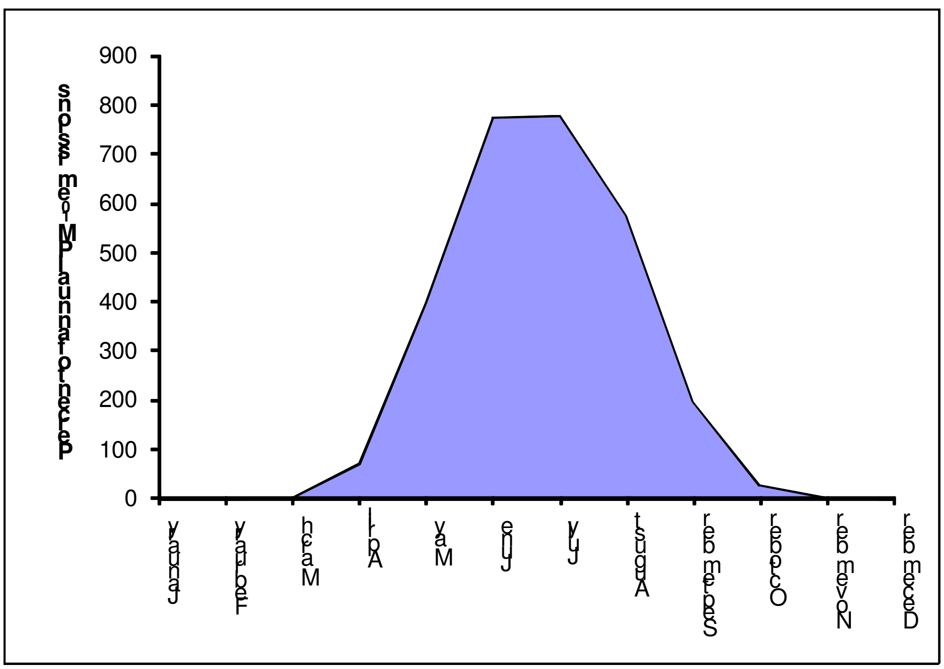

Figure 3.4: Proportion of annual PM_{10} emissions from domestic heating in Masterton by month of year

4 Motor vehicles

Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) under different levels of congestion, and the application of emission factors to these data. Some VKT data were available from a road network model for Masterton. However, this included only a small proportion of the Masterton Road network so an alternative methodology was used to estimate total VKTs for Masterton. These were estimated using the average of the ratio of VKTs to households for the areas of Wainuiomata (ratio of 27 VKT per household per day) and Upper Hutt (ratio of 51 VKTs per household per day. The existing road network modelling was used to apportion the VKTs by time of day and level of congestion.

The 2006 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 based on a vehicle fleet profile derived from motor vehicle registrations for the Wellington area (Table 4.1). The NZTER database was developed by the Ministry of Transport (MOT) based on measured emissions rates from actual vehicle emissions tests on New Zealand vehicles under various road/traffic conditions. Emission rates for SOx and CO_2 are not included in the NZTER database and were selected based on emission rates derived by the Fuel and Energy Group for the national vehicle fleet profile.

The emission factors for $PM_{2.5}$ were based on estimates of PM_{10} emissions using data from the British Columbia Lower Fraser Valley adjusted for the Wellington vehicle fleet profile. This indicated that around 56% of the PM_{10} tailpipe emissions would be in the $PM_{2.5}$ size fraction. In addition to tailpipe emissions, PM_{10} from the wearing of brakes and tyres were also included in the emissions assessments. Emission factors for PM_{10} and $PM_{2.5}$ from these sources were also derived from the British Columbia Lower Fraser Valley data adjusted for the Wellington vehicle fleet profile. However, 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} from the wearing of tyre and brakes should be treated as indicative only.

Table 4.1: Vehicle registrations in Masterton

	Petrol	**Diesel**	**LPG**	**Other**	**Total**
Cars	224,090	12,902	125	16	237,133
LCV	15332	10985	11	2	26,330
MCV	416	3370			3,786
Bus		1566			1,566
Heavy truck	114	2902			3,016
Motorcycle	5,201				5,201
Total	245,153	31,725	136	18	277,032
Total - percentage	88%	11%	0%	0%	

For the purpose of assessing emissions from motor vehicles, VKTs are typically differentiated into three different driving conditions called Levels Of Service (LOS) and a fourth category representing emissions under cold running conditions. The LOS categories include free flow conditions (LOS category A-B), interrupted flow conditions (LOS category C-D) and congested flow conditions (LOS category E-F). The number of VKTs occurring under different LOS is usually determined on a road network model by the number of vehicles on a particular road relative to the capacity of the road. The road network model for Masterton was used to assign LOS to the total VKTs. This may slightly overestimate congestion because the road network model exists for the main roads only and these are likely to experience more congestion than more suburban areas.

Table 4.2 shows the estimated number of VKTs under different LOS categories for Masterton for 2006, 2008 (interpolated) 2016 and 2026. The VKT data are based on the VKT to household ratios for Wainuiomata and Upper Hutt and utilise the road network model outputs for Masterton for time of day and LOS and percentage increase from 2006 to 2016. The 2008 data are based on an interpolation between 2006 and 2016. The majority of the VKTs occur under free flowing (A-B) and interrupted (C-D) conditions with no VKTs occurring under congested (E-F) conditions until after 2016.

Table 4.2: VKT by LOS and time of day in Masterton for 2006 and 2016

	Total VKT	VKT Level of Service			Time of day			
		A-B	C-D	E-F	7am-9am	9am-4pm	4pm-6pm	6pm-7am
2006	194,943	100339	94604	0	28510	85566	30730	50136
2008	199,187	100459	98728	0	29043	87577	31350	51217
2016	216,163	90238	104705	0	31133	95687	33806	55537
2026	244,982	86654	92720	15570	34719	109536	37644	63083

The emission factors for each contaminant under the different degrees of congestion are shown in Table 4.3. These are based on the assumption that 17% of the VKTs occur under cold start conditions and are based on 2006 and 2021 conditions.

Table 4.3: Emission factors for Masterton based on a suburban driving regime -2006 and 2021

Driving Conditions	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
2006							
Congested – E-F	15.0	476	2.1	1.2	0.28	0.08	0.04
Interrupted – C-D	11.8	406	1.6	1.1	0.23	0.05	0.03
Free flow - A-B	9.5	366	1.5	1.0	0.22	0.04	0.03
2021							
Congested – E-F	12.8	476	0.8	0.8	0.28	0.03	0.02
Interrupted – C-D	4.6	406	1.0	0.7	0.24	0.02	0.01
Free flow - A-B	4.2	366	0.9	0.7	0.22	0.02	0.01

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) = A-B Emission Rate (g/VKT) * VKT (A-B) + C-D Emission Rate (g/VKT) * VKT (C-D) + E-F Emission Rate (g/VKT) * VKT (E-F)

In addition, PM_{10} and $PM_{2.5}$ emissions from brake and tyre wear were calculated as follows:

Emissions (g) = total VKT * Emission rate (g/VKT)

Emissions were calculated for 2006 and 2021 using emission factors suitable for each year and VKT estimates from Table 4.2, with 2021 VKTs interpolated using the 2016 and 2026 VKTs. Emissions for 2008 were interpolated using the 2006 and 2021 emission estimates.

4.1 Motor vehicle emissions

Emission estimates for motor vehicles in Masterton include 12 kilograms of PM_{10} per day. 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 Masterton include around 1.9 tonnes of CO, 203 kilograms of NOx and 45 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 109 tonnes of CO within the main urban area.

Table 4.4 shows emissions from motor vehicles in Masterton by weight and kilograms per square metre respectively

Table 4.4: Summary of daily motor vehicle emissions in Masterton

	PM_{10}		CO		NOx		Sox	
Km2	kg	kg/km2	kg	kg/km2	kg	kg/km2	kg	kg/km2
18	12	0.7	1941	108	203	11	45	2.5
	VOC		**CO_2**		**$PM_{2.5}$**			
Km2	kg	kg/km2	t	tonnes/km2	kg	kg/km2		
18	295	16	77	4.3	6.2	0.3		

5 Industrial and Commercial

5.1 Methodology

The selection of industries for inclusion in this 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.

A list of resource consents were supplied by Greater Wellington Regional Council. Google Earth was used to check the location of each industry and determine if it was in the study area. Three industries were identified and surveyed by telephone. Twenty one schools in the Masterton area were surveyed by telephone, of those, six schools were identified that had coal fired boilers or wood burners and were within the study area. Data were collected for winter, autumn, spring and summer.

The methodology used to estimate emissions from these activities involved the collection of data relating to the process (e.g. abrasive blasting) - referred to as activity data - and the application of emission factors to these data. A large proportion of the industrial activities discharging to air involve combustion processes. The activity data required for abrasive blasting processes is the quantity of fuel burnt.

Combustion emissions were estimated using emission factor data as indicated in Equation 5.1.

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

The emission factors used to estimate the quantity of emissions discharged are shown in Table 5.1. The coal fired boiler emission factors for PM_{10} are based on CRL Energy Ltd emission factors. Emission factors for $PM_{2.5}$ are based on the USEPA AP42 database[1] particle size distribution factors, as are emission factors for CO, NOx and SOx. The VOC and CO_2 are based on factors derived by NIWA for the Christchurch 1996 emission inventory (NIWA, 1998). Gas emission factors are based on AP-42 for a small boiler.

Table 5.1: Emission factors for industrial discharges

	PM_{10} g/kg	**CO** g/kg	**NOx** g/kg	**SOx** g/kg	**VOC** g/kg	**CO_2** g/kg	**$PM_{2.5}$** g/kg
Underfeed stokers	3.1	5.5	4.8	13.5	0.1	2400	3.1
Abrasive Blasting	0.69						
Crematorium	0.035		.1			78	

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

5.2 Industrial and commercial emissions

Discharges from three industrial and commercial activities were included in the assessment. These included abrasive blasting, crematorium and a cement factory. Six schools that use coal or have wood burners were included in the assessment.

Around 2.2 kilograms of PM_{10} on an average winter day are discharged to air from industrial and commercial activities in Masterton. (Table 5.2) The main source of these emissions is schools that contribute around 1.7 kilograms of PM_{10} on an average winter day.

Table 5.2: Summary of daily industrial emissions in Masterton

	PM_{10}		CO		NOx		SOx	
Km2	kg	kg/km^2	kg	kg/km^2	kg	kg/km^2	kg	kg/km^2
18	2.2	0.1	9.3	0.5	2.8	0.2	3.2	0.2
	VOC		**CO_2**		**$PM_{2.5}$**			
Km2	kg	kg/km^2	t	tonnes/km^2	kg	kg/km^2		
18	1.9	0.1	1.5	0.1	1.8	0.1		

6 Outdoor burning

The Regional Air Quality Management Plan for the Greater Wellington Region permits outdoor burning. Potential adverse effects from outdoor burning are controlled through Section 29 of the Health Act (1956) as well as advocacy and education work undertaken by the Greater Wellington Regional Council.

Outdoor burning emissions for the winter months were estimated for Masterton based on data collected for the 2008 Masterton domestic home heating emission survey. The survey showed 14% of households in Masterton burnt rubbish in the outdoors during the winter. These households burnt an average of around four fires per winter per household. 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 across and an estimated average weight of 75 kg/m^3.

Emissions from domestic outdoor burning have been estimated using the emission factors shown in Table 6.1.

Table 6.1: Outdoor burning emission factors (source AP-42)

	$PM_{2.5}$ g/kg	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg
Outdoor burning	8	8	42	3	0.5	4	1470

Outdoor burning emission estimates for Masterton (Table 6.2) indicate that around 35 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months. Outdoor burning also produces around 182 kilograms of carbon monoxide and around 6 tonnes of carbon dioxide per day during winter.

Table 6.2: Estimated daily emissions from outdoor rubbish burning in Masterton

	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
Summer (Dec-Feb)	54	283	20	3	27	10	54
Autumn (Mar-May)	52	274	20	3	26	10	52
Winter (June-Aug)	35	182	13	2	17	6	35
Spring (Sept-Nov)	61	319	23	4	30	11	61

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

7 Other sources of emissions

This inventory includes all likely major sources of PM_{10} that can be adequately estimated using inventory techniques. Some minor sources not included in the include dusts (PM_{10}) and sea spray. Estimates of the contribution to PM_{10} concentrations from these sources have been evaluated using receptor modelling by Davy (2008). Results of that study found that around 4% of PM_{10} on average on high pollution days originated from sea spray and 12% from soil.

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 5 kilograms per day.

8 Total emissions

Around 831 kilograms of PM_{10} is discharged to air in Masterton on an average winter's day. Domestic home heating is the main source contributing 94% of the daily wintertime PM_{10} (Figure 8.1). Other sources include outdoor burning 4% and, transport 2%. The industry contribution is negligible. A source appointment study by Davy (2008) of high pollution days in Masterton suggests that around 4% of PM_{10} concentrations originate from sea spray and 12% from soil. These sources have not been included in the inventory and should be considered in any subsequent air quality management strategies.

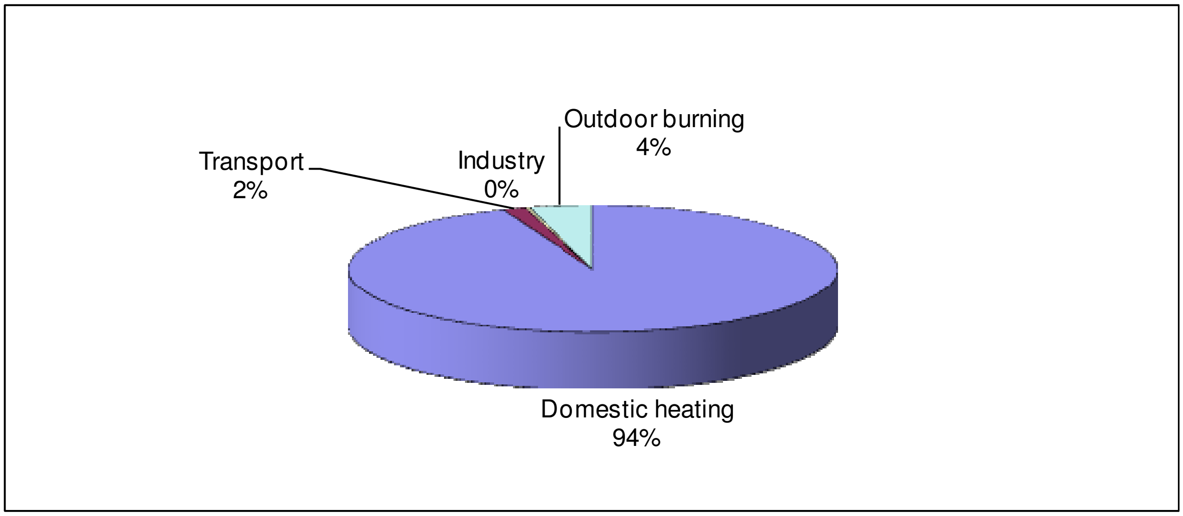

Figure 8.1: Relative contribution of sources to daily winter PM_{10} emissions in Masterton

Domestic home heating is also the main source of CO, CO_2, SO_x, VOC and $PM_{2.5}$ in Masterton. Motor vehicles are the main source of NOx (Figure 8.2).

Daily wintertime emissions of PM_{10} and other contaminants (kg/day and kg/day/km^2) are shown in Table 8.1. 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.

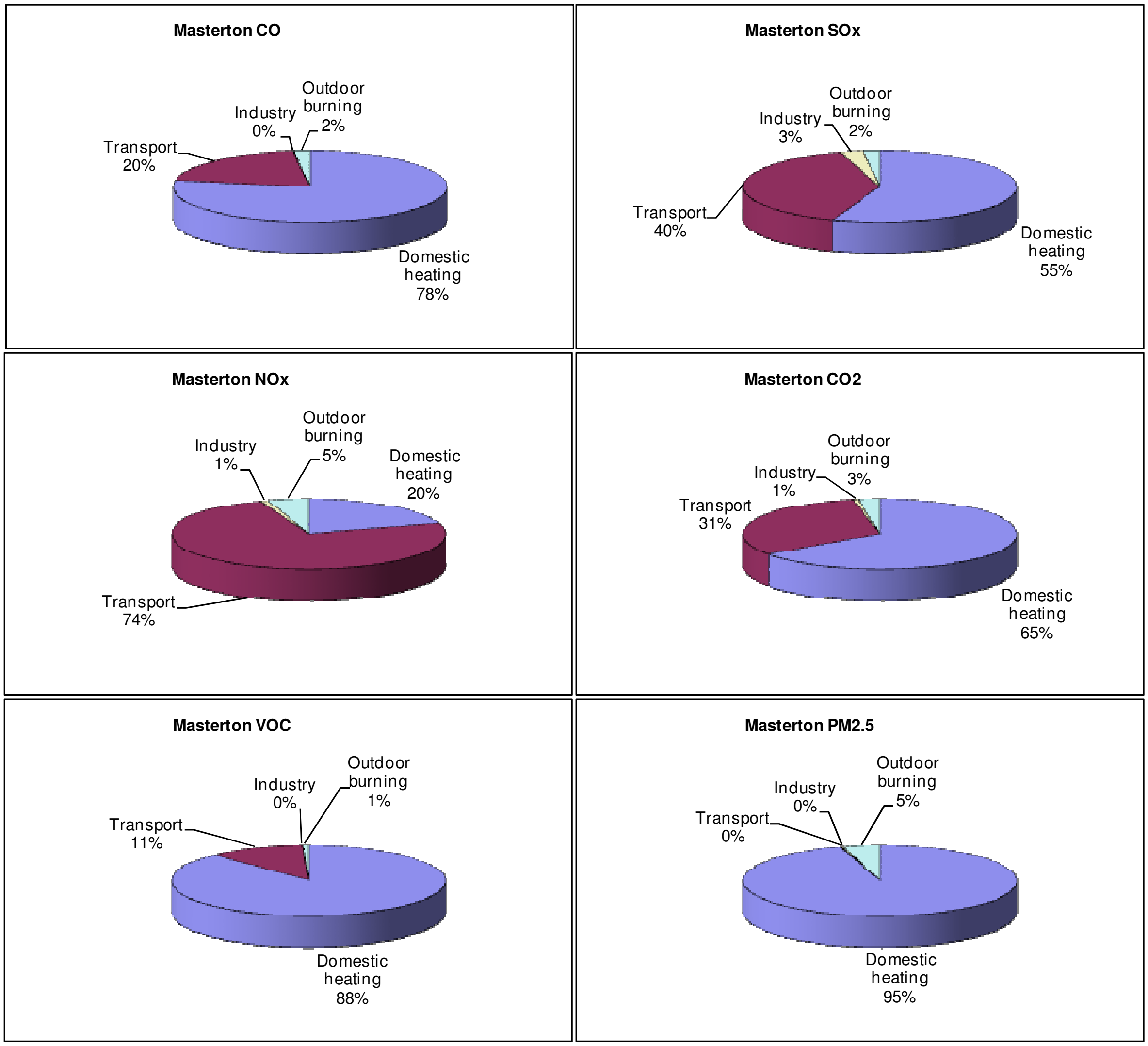

Figure 8.2: Relative contribution of sources to contaminant emissions in Masterton

Table 8.1: Daily contaminant emissions from all sources

		PM_{10}		CO		NOx		SOx	
	Km^2	kg	kg/km2	kg	kg/km2	kg	kg/km2	kg	kg/km2
Masterton	18	831	46	9593	533	275	15	114	6
		VOC		CO_2		$PM_{2.5}$			
	Km^2	kg	kg/km2	t	tonnes/km2	kg	kg/km2		
Masterton	18	2632	146	244	14	798	44		

Table 8.2: Monthly variations in daily PM_{10} emissions in Masterton

	Domestic Heating		Outdoor Burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	
January	0	0%	54	79%	2	3%	12	18%	68
February	0	0%	54	79%	2	3%	12	18%	68
March	0	1%	52	77%	3	4%	12	18%	68
April	72	52%	52	38%	3	2%	12	9%	139
May	400	86%	52	11%	3	1%	12	3%	467
June	775	94%	35	4%	2	0%	12	1%	824
July	782	94%	35	4%	2	0%	12	1%	831
August	576	92%	35	6%	2	0%	12	2%	625
September	198	73%	61	22%	2	1%	12	5%	273
October	28	27%	61	59%	2	2%	12	12%	103
November	0	1%	61	81%	2	2%	12	16%	75
December	0	0%	54	80%	1	2%	12	18%	67
Total kg year	86707		18376		807		4483		

8.1 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 Masterton was made using the formulae described in Topping (1971) and the following assumptions regarding the uncertainty around input variables:

- Domestic heating emission factors, ± 30%
- Domestic heating fuel weight, ± 30%
- Survey sample error, ± 5%
- Transport emission estimates, ±100%
- Industrial emission estimates, ±40%

The total uncertainty was calculated to be ± 20% with the main variables influencing this value being the emission factors for domestic heating and quantity of fuel burnt for domestic home heating.

9 Spatial Distribution in PM_{10} emissions

Estimates of the PM_{10} emission densities by census area unit (CAU) were made based on the results of the 2008 air emission inventory and census home heating data. The number of households using wood within each CAU as a proportion of total households using wood in the Masterton study area was used to distribute emissions. PM_{10} emission densities in kilograms per square kilometre per winter's day are shown in Figure 9.1.

Masterton urban area - PM_{10} emissions kg/km^2/day (July 2008)

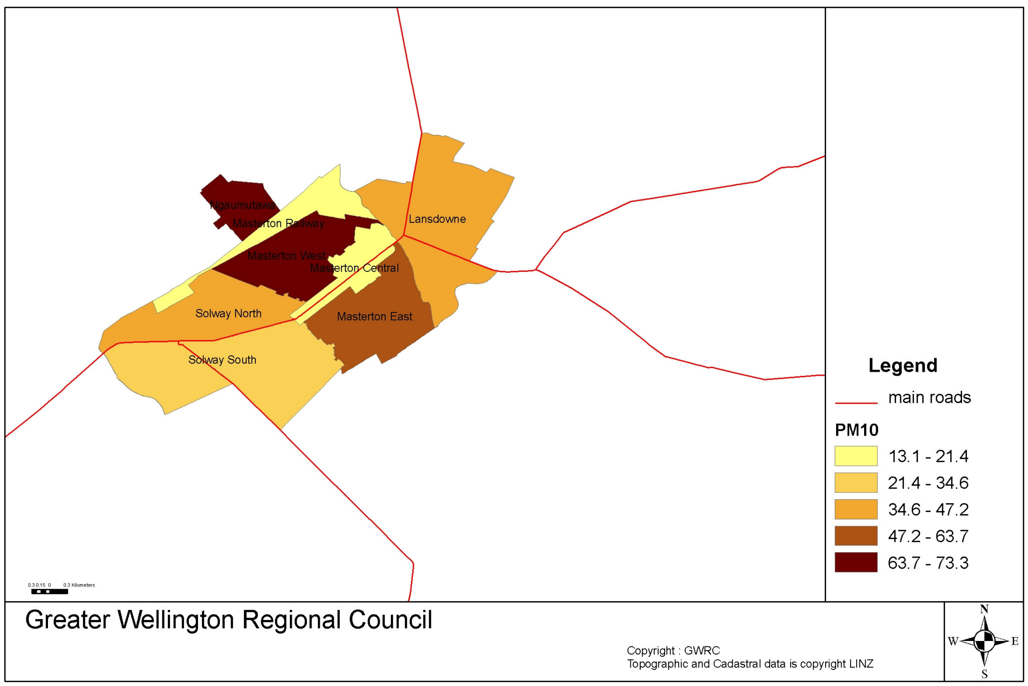

Figure 9.1: Distribution of PM_{10} emissions (kg/km^2) across Masterton

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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 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. 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.

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?

D8 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.

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

Domestic heating emission factors for CO, NOx, SOx and CO_2 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.

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