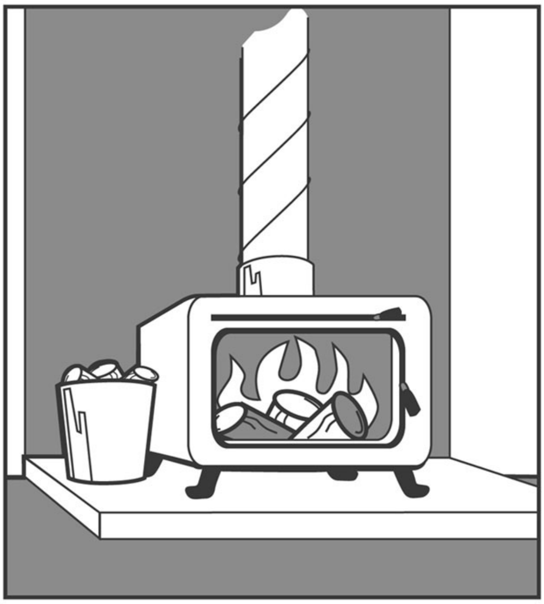
Environment Waikato Technical Report 2002/21

Hamilton, Tokoroa and Te Kuiti : Domestic Heating Emission Inventory 2001



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Executive Summary

In 1997, an emission inventory for the areas of Hamilton, Tokoroa and Te Kuiti was undertaken by Environment Waikato (Noonan, 1997). The purpose of that inventory was to quantify emissions to air and evaluate the relative significance of difference sources of those emissions. A repeat of the domestic heating emission inventory was carried out during 2001 to quantify the amount of emissions at 2001 and to allow an assessment of changes in these emissions with time. Priority was given to the assessment of domestic heating emissions, as this was found in 1997 to be the major source of suspended particulate (PM_{10}), the main contaminant of concern in these areas.

Air quality monitoring data for Hamilton, Tokoroa and Te Kuiti has found concentrations of PM_{10} of concern in the latter two areas. In Tokoroa, a maximum PM_{10} concentration of 144 $\mu g\ m^{-3}$ was recorded in 1999. This is three times the proposed national guideline (Ministry for the Environment) and Environment Waikato guideline of 50 $\mu g\ m^{-3}$ (24-hour average). Monitoring of PM_{10} in Te Kuiti during 1998 gave a maximum 24-hour average PM_{10} concentration of 47 $\mu g\ m^{-3}$. Whilst below the guideline value, this value falls within the "alert" MfE indicator category.

In areas where air quality management may be required, emission inventories can be used, in conjunction with other data, to determine the effectiveness of different management strategies in reducing emissions. Based on concentrations of PM_{10} measured in 1999 and 1997 respectively, air quality management strategies for Tokoroa and Te Kuiti should be considered.

Results of the 2001 domestic home heating survey found gas to be the most common home heating method in Hamilton with 83% of households using some form or gas heating on a typical winter's night. About one-third of the households in Hamilton use solid fuel burning for domestic home heating. Overall around 13,000 households in Hamilton use wood and around 2,000 use coal. In contrast, the main method of home heating in Tokoroa and Te Kuiti is solid fuel burning. In Tokoroa, 53% and 21% of households use woodburners and open fires respectively. Woodburner use in Te Kuiti is slightly lower at 36% and open fires are used by 24% of households. Multifuel burner use is also proportionally higher in Tokoroa and Te Kuiti than in Hamilton with 9% and 11% of households respectively using multifuel burners. The majority of solid fuel burning households use wood, although coal use in Te Kuiti is also significant with 14% of households using either a combination of wood and coal or coal alone.

About 3.6 tonnes of PM_{10} and 33 tonnes of CO are emitted from domestic home heating in Hamilton on a typical winter's day. This compares to just over one tonne of PM_{10} and less than 12 tonnes of CO in Tokoroa and less than half a tonne of PM_{10} and less than 4 tonnes of CO in Te Kuiti. Tokoroa has the highest area based PM_{10} emission rate (expressed as grams of emissions per hectare of land – g ha^{-1}) with 1615 g ha^{-1} of PM_{10}. This value is high compared to other areas e.g., 1999 data for Christchurch indicates 560 g ha^{-1}, but is slightly lower than estimates for Huntly (1747 g ha^{-1}).

Emissions from the burning of household and garden rubbish in the outdoors were also included in the emission inventory assessment. In Hamilton around 130 kilograms of PM_{10} are likely to be emitted per day as a result of outdoor rubbish burning. This compares to around 40 kilograms in Tokoroa and Te Kuiti.

A comparison of results to the 1997 emissions estimates, recalculated using 2001 emission factors, suggests PM_{10} emissions per hectare in Hamilton and Tokoroa have increased while the PM_{10} emission rate in Te Kuiti has decreased. Given this trend and the concentrations of PM_{10} measured in Tokoroa, management intervention for this area is required.

Introduction

In 1997, an emission inventory for the areas of Hamilton, Tokoroa and Te Kuiti was undertaken by Environment Waikato. The inventory was conducted in two stages. The first stage included results from domestic heating and transport; the latter stage the results of an industrial emissions assessment. Further emissions assessments for the Waikato were carried out in 1999, an assessment of biogenic emissions sources, and 2000, an assessment of domestic heating emissions in Taupo, Huntly, Matamata and Putaruru.

The purpose of this inventory, which considers domestic heating emissions in Hamilton, Tokoroa and Te Kuiti for 2001, is to quantify the amount of emissions at 2001 and to allow an assessment of changes in these emissions with time. Priority has been given to the assessment of domestic heating emissions, as this is the major source of suspended particulate (PM_{10}), the main contaminant of concern in these areas.

Suspended particulate (PM_{10}) refers to particles in the air that are less than 10 microns in diameter. These particles are sufficiently small that they can penetrate the lungs and cause adverse health impacts. Although proposed national guidelines for PM_{10} recommend a limit of 50 $\mu g\ m^{-3}$ (24-hour average), there does not appear to be a threshold below which there are no adverse effects for this contaminant. Consequently, PM_{10} has become a priority pollutant for monitoring and assessment, particularly in urban areas.

Monitoring of PM_{10} in Hamilton suggests that existing concentrations are within the 50 $\mu g\ m^{-3}$ guideline proposed by the Ministry for the Environment and included in the Waikato Regional Air Plan. However, elevated concentrations of PM_{10} have been measured in Tokoroa and Te Kuiti, and it is possible that further areas within the Waikato region experience high concentrations of contaminants from domestic space heating.

Domestic heating emission inventory data can be used to identify areas that may require air quality monitoring and contaminants that may be of concern. Inventory data can assist with prioritising areas for monitoring, particularly when used in conjunction with data on meteorological conditions. However, it is not possible to assess whether an air quality problem exists based on emissions data alone, as the extent to which emissions in any area result in air quality problems will also depend on the impact of meteorology.

An emission inventory can also be used in conjunction with other data to determine the effectiveness of different management options in reducing concentrations of contaminants. For example, prohibiting the use of open fires may be an effective management strategy in a location where open fires make a significant contribution to emissions.

1 Inventory Design

Some air quality monitoring has been carried out in the areas of Hamilton, Tokoroa and Te Kuiti. In Hamilton, measurements of NO_2, CO and PM_{10} indicate concentrations of these contaminants within guideline values. In Te Kuiti, air quality monitoring during the winter of 1997 found concentrations of PM_{10} within the Ministry for the Environments “alert” category (table 2.1). Monitoring of PM_{10} in Tokoroa during winter 1999 also found elevated PM_{10} concentrations including a maximum concentration of 144 $\mu g\ m^{-3}$, almost three times the proposed MfE guideline of 50 $\mu g\ m^{-3}$ (24-hour average) and within the “action” PM_{10} category. A report on those results (Pigott, 1999) identifies domestic heating as the most probable contributor to elevated PM_{10} in Tokoroa.

Table 2.1: Ministry for the Environment air quality indicator categories (MfE, 2000)

Category	Maximum measure value	Comment
Excellent	Less than 10% of the guideline of little concern	If maximum values are less than a tenth of the guideline, average values are likely to be much less
Good	Between 10% and 33% of the guideline peak measurements	In this range are unlikely to impact air quality
Acceptable	Between 33% and 66% of the guideline	A broad category, where maximum values might be of concern in some sensitive locations but generally at a level which does not warrant dramatic action
Alert	Between 66% and 100% of the guideline	A warning level, which can lead to exceedences if trends are not curbed
Action	More than 100% of the guideline	Exceedences of the guideline are a cause for concern and warrant action if they occur on a regular basis

The main focus of this study is therefore on wintertime emissions, as high concentrations of contaminants, in particular PM_{10} occur during the winter. This is because wood and coal burning for domestic heating occurs during the winter months and because meteorological conditions conducive to high pollution are often more prevalent during these months. Daily emissions are examined, as the PM_{10} guideline is based on a 24-hour averaging period.

1.1 Selection of sources

This report presents the results of emissions from domestic space heating. As indicated in previous inventories, domestic heating is the major source of PM_{10} emissions in Hamilton, Te Kuiti and Tokoroa. However, the industrial contribution to PM_{10} in some locations was not insignificant and a revision of transport emissions in these areas is also recommended. It is important that an emission inventory relate to a particular point in time, in this case the year 2001, because of emissions change with time. Consequently the assessment of any additional sources for this inventory will need to relate to emission rates from the year 2001.

1.2 Selection of contaminants

The previous inventory for these areas included an assessment of emissions of suspended particles (PM_{10}), carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), and carbon dioxide (CO_2).

These contaminants were selected because of their potential for adverse effects and are the main contaminants surveyed in emission inventory investigations in New Zealand. The inclusion of volatile organic compounds has been reviewed in a number of inventories conducted within New Zealand because use of these data are limited in areas where photochemical pollution is not a concern. It is recommended that these data be retained for the purpose of this inventory.

Since the advent of emission inventory studies in New Zealand, the Ministry for the Environment has released a discussion document revising ambient air quality guidelines for New Zealand. This document includes guideline values for a number of hazardous air pollutants (Table 2.2).

Table 2.2: Proposed new guideline values for Hazardous Air Pollutants (MfE, 2000)

Contaminant		Concentration	Averaging Period
Benzene Now 2010		10 µg/m^3 3.6 µg/m^3	Annual Annual
Toluene *		190 µg/m^3	Annual
Xylene *		950 µg/m^3	Annual
1,3-Butadiene		2.4 µg/m^3	Annual
Formaldehyde		15 µg/m^3	Annual
Acetaldehyde		30 µg/m^3	Annual
Benzo(a)pyrene		0.0003 µg/m^3	Annual
Mercury	inorganic organic	0.33 µg/m^3 0.13 µg/m^3	Annual Annual
Chromium	chromium VI other forms	0.0011 µg/m^3 0.11 µg/m^3	Annual Annual
Arsenic	inorganic arsine	0.0055 µg/m^3 0.055 µg/m^3	Annual Annual

Note: * The Ministry for the Environment proposes to delete the proposed guidelines for toluene and xylene.

The Ministry for the Environment (MfE) has included an interim air quality guideline for $PM_{2.5}$ in its discussion document on proposed ambient air quality guidelines (MfE, 2000). The purpose of including this particulate size fraction as an "interim" guideline is to promote monitoring and investigations into this size fraction. As the majority of the PM_{10} emissions from domestic heating are within the $PM_{2.5}$ size fraction, these data are not considered separately in this emission inventory. However, it is recommended that subsequent assessments of industry and transport include an estimate of the $PM_{2.5}$ size fraction.

Air quality monitoring of benzene by the Ministry of Health in Hamilton during the 1990s (Figure 2.1) showed concentrations of benzene close to but not exceeding the 2010 proposed guideline for benzene. A revision of the national fuel specifications for petrol and diesel should result in reductions in benzene emissions with time. However, given the proximity of the measured values to the proposed 2010 guideline, and the potential for high benzene concentrations in Te Kuiti and Tokoroa, changes in benzene emissions should be monitored.

Inclusion of benzo(a)pyrene (BAP) in the emission inventory investigations should also be considered. Monitoring of BAP in Christchurch shows concentrations well in excess of the proposed MfE annual guideline. Concentrations of BAP and PM_{10} in Christchurch are highly correlated and wood burning is thought to be the major source of both contaminants. Given these high concentrations, investigations into BAP emissions and concentrations in other areas where wood burning is a major source of elevated PM_{10} concentrations would be useful.

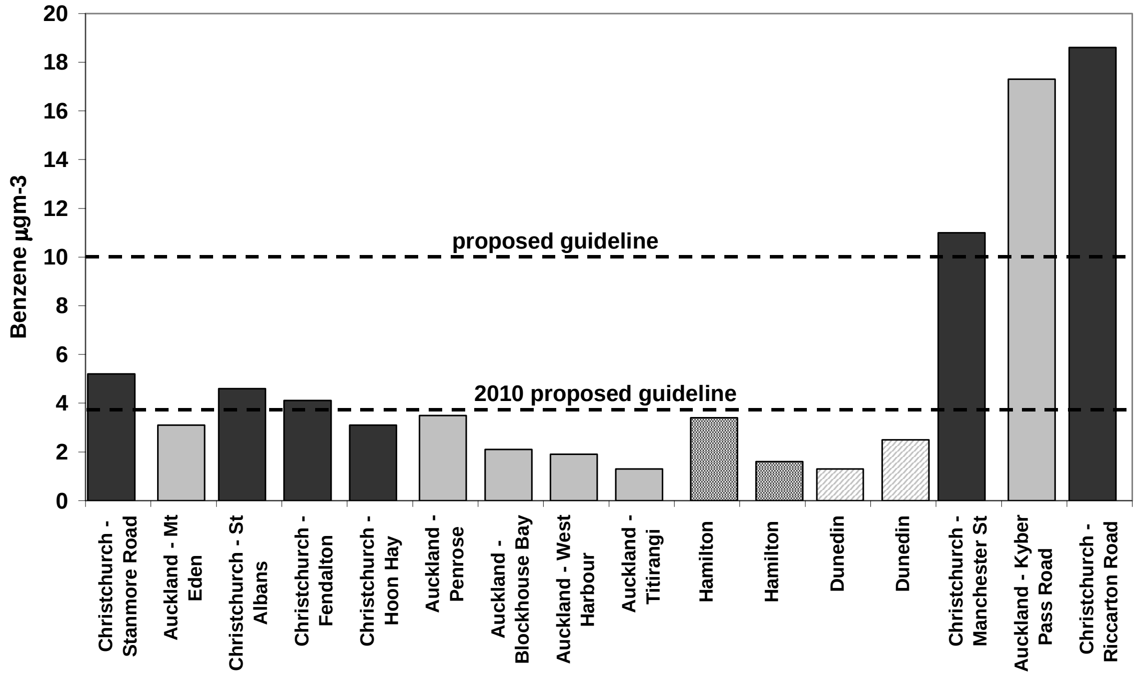


Figure 2.1: Annual average benzene concentrations measured in Christchurch, Auckland, Hamilton and Dunedin.

A major limitation in the inclusion of benzene and BAP in emission inventory investigations in New Zealand is lack of data on emission rates from local sources. Emission factors for these contaminants are therefore based on overseas data. Consequently emission estimates for these contaminants should be treated as potentially indicative of order of magnitude only.

Table 2.3 outlines the contaminants included in the 2001 domestic heating emission inventory for Hamilton, Tokoroa and Te Kuiti.

1.3 Selection of study areas

The study areas of Hamilton, Te Kuiti and Tokoroa were selected for the initial 1997 inventory because of the potential for air quality problems in these areas. The area definitions were based on a collation of census area units in accordance with the city boundary definitions. A revision of emissions inventories for these areas, based on the same area definition, will allow the assessment of trends in emissions and their potential impact on air quality.

In addition, the area of Hamilton was further segregated into seven study areas. These study areas are based on census area units as described in Table 2.4 and illustrated in Figure 2.2.

Table 2.4: Census area unit definitions for the seven Hamilton study areas

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

The areas of Te Kuiti and Tokoroa are sufficiently small not to require further spatial distribution. The Te Kuiti study area included the census area units Te Kuiti and Waipa Valley. Tokoroa included Amisfield, Aotea, Kinleith, Mangakaretu, Matarawa, Paraonui, Parkdale, Stanley Park, Strathmore and Tokoroa Central. The town boundaries and features for these areas such as rivers, roads and census area units, are illustrated in Figures 2.3 and 2.4.

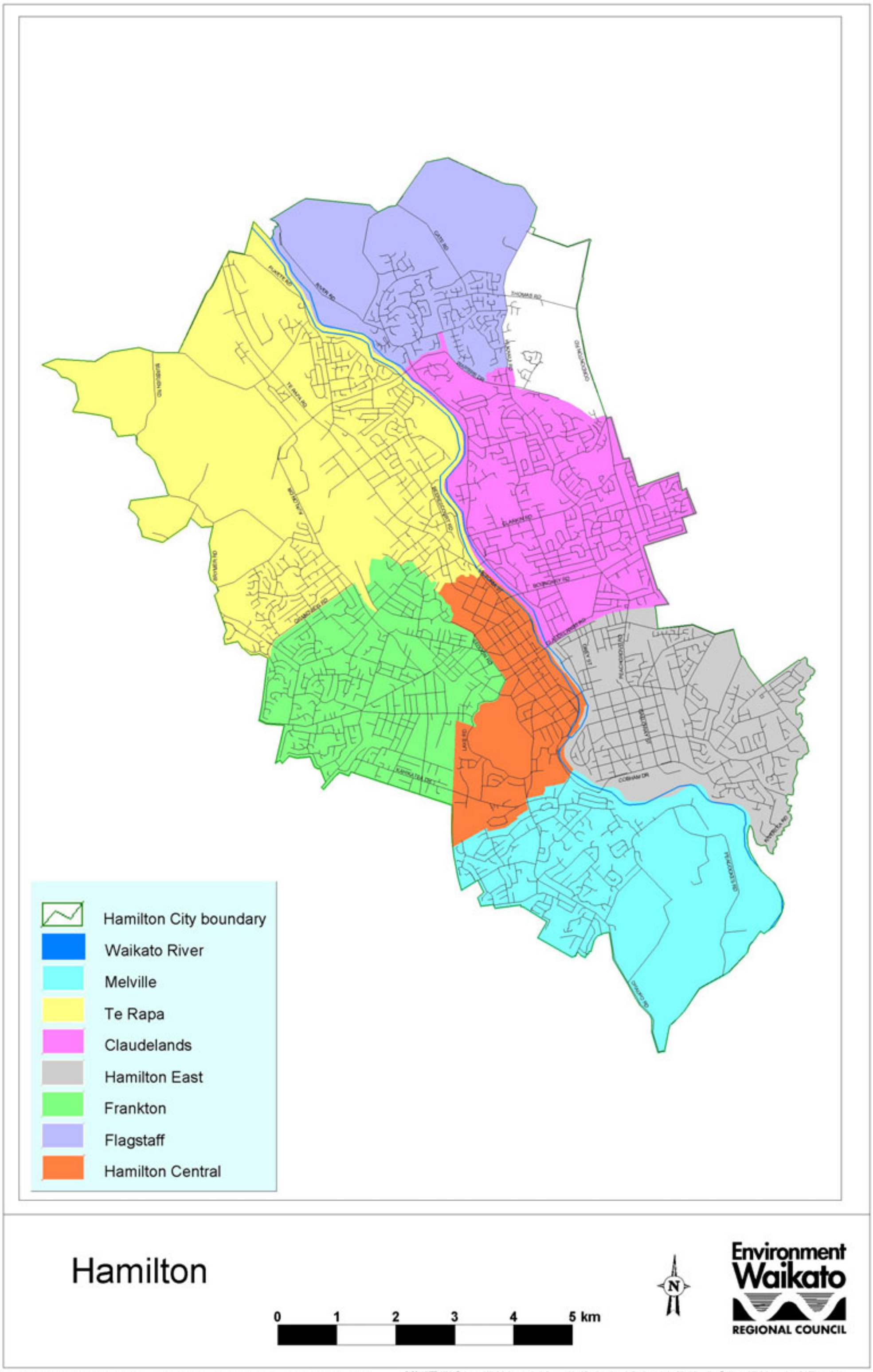


Figure 2.2: Hamilton study area

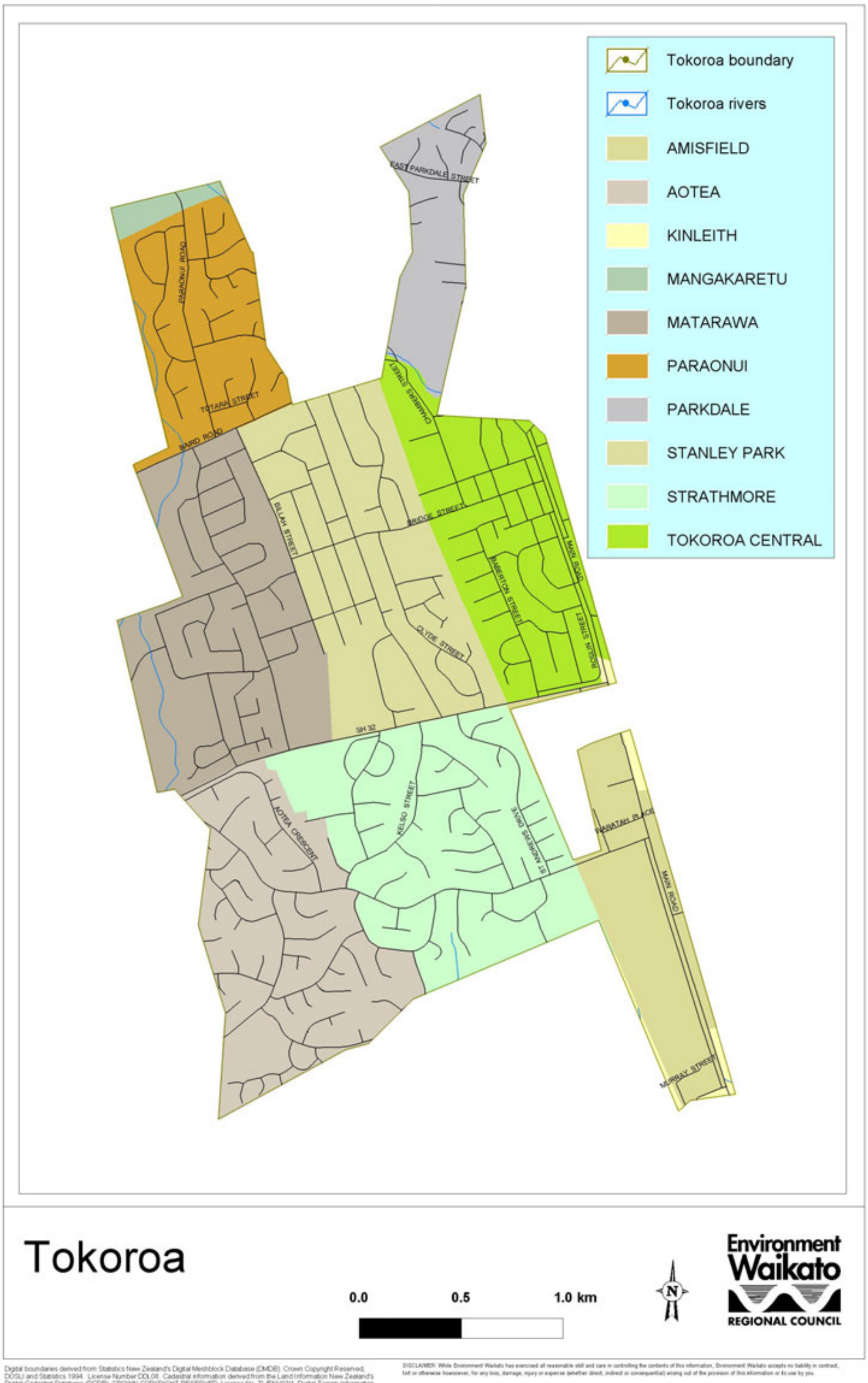


Figure 2.3: Tokoroa study area

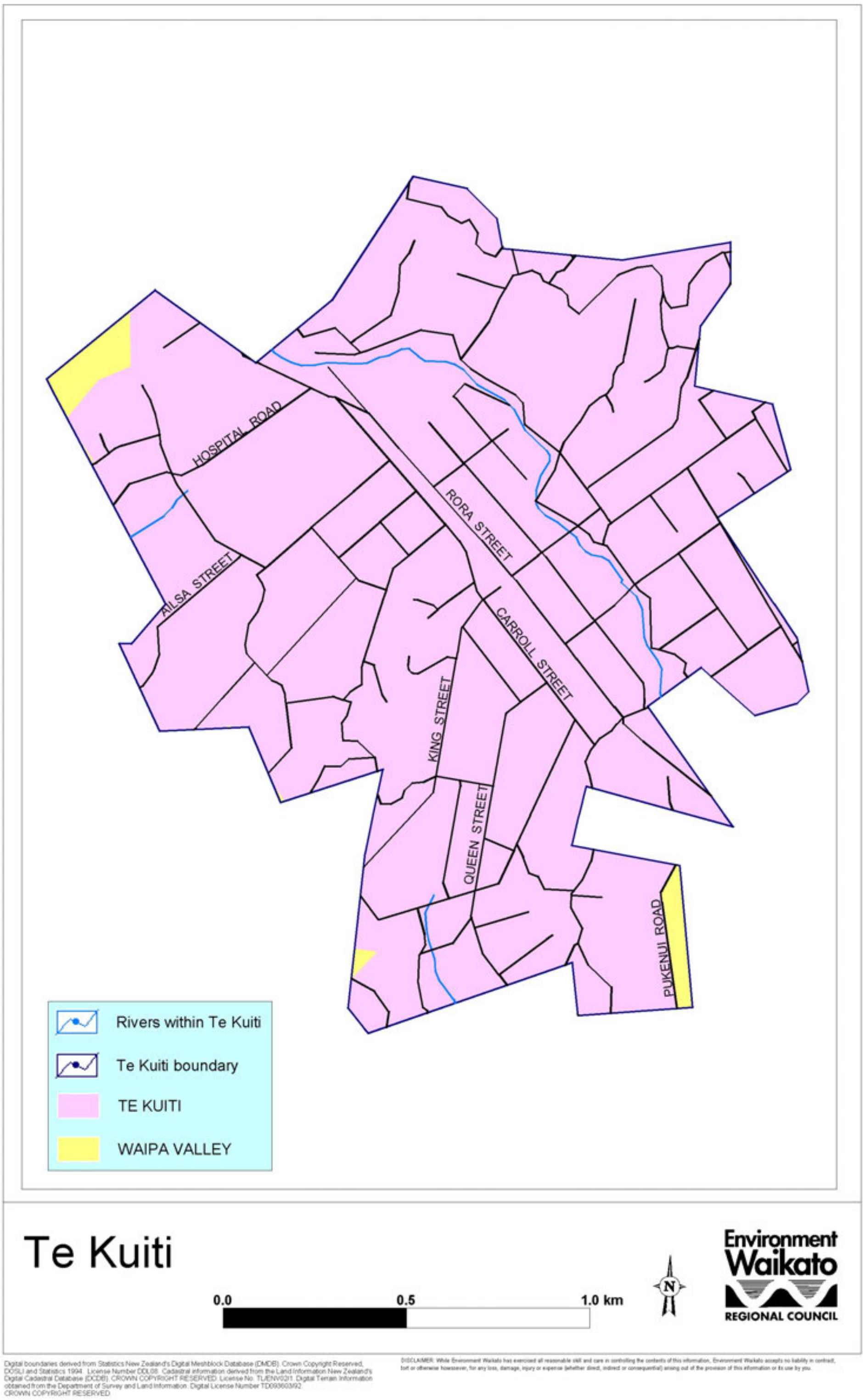


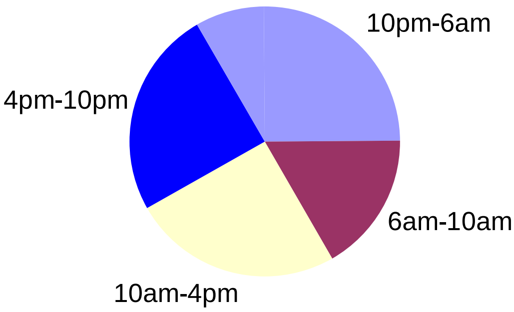
Figure 2.4: Te Kuiti study area

Table 2.3: Summary of the contaminants, guidelines and adverse effects

Contaminant	Guideline	Averaging period and source	Adverse Effect
Particulates PM_{10}	50 $\mu g/m^3$	24-hour proposed MfE (2000)	Health effects range from throat irritation, chronic cough, bronchitis, increased asthma symptoms, reduced lung function and death (Wilton, 1999).
Carbon monoxide CO	30 mg/m^3 10 mg/m^3	1 hour MfE (1994) 8 hour MfE (1994)	Health effects range from headaches and dizziness to loss of consciousness and death (MfE, 1994).
Carbon dioxide CO_2			A “greenhouse” gas that contributes to global warming.
Nitrogen dioxide NO_2	200 $\mu g/m^3$ 100 $\mu g/m^3$	1 hour proposed MfE (2000) 24 hour MfE (1994)	NO_2 increases susceptibility to asthma and bacterial infections in the lungs. NO_2 also causes reduced visibility and damages plants (MfE, 1994).
Sulphur dioxide SO_2	500 $\mu g/m^3$ 350 $\mu g/m^3$ 125 $\mu g/m^3$ 50 $\mu g/m^3$	10 min MfE (1994) 1 hour MfE (1994) 24 hour MfE (1994) Annual MfE (1994)	Causes irritation in the upper respiratory tract and can trigger bronchitis and tracheitis. At higher concentrations can cause a bronchospasm in asthmatics (MfE, 1994). The proposed revised MfE guidelines (2000) suggest the removal of the 10-minute and annual guideline values.
Volatile Organic Carbons - VOC			VOCs collectively, have typically been included in emission inventories because they are a precursor to photochemical smog.
Benzene	3.6 $\mu g\ m^{-3}$ (proposed for 2010)	Annual average	Carcinogen - Increased risk of cancer associated with long term exposure.
Benzo(a)pyrene	0.3 $ng\ m^{-3}$ (proposed)	Annual average	Carcinogen - Increased risk of cancer associated with long term exposure

1.4 Temporal distribution

Data were collected for a 24-hour period based on typical wintertime emissions. This collection time corresponds with the averaging period for PM_{10}, which is based on a 24-hour average for health assessment purposes. In addition the following temporal breakdown was included:



The purpose of these categories is to allow for an assessment of the impact of variations in meteorological conditions at different times of the day. The categories were selected based on typical high pollution incidents in other locations. It is likely that this breakdown will be appropriate for these locations.

The collection of data for different time of day breakdowns allows for subsequent assessment of the contribution of different sources to concentrations, as opposed to emissions. The latter calculation requires details on the impact of meteorological conditions on contaminant concentrations at different times of the day.

2 Domestic heating survey

Data on home heating methods and fuels for Hamilton, Tokoroa and Te Kuiti for winter 2001 were obtained via a telephone survey, conducted by DigiPol Ltd. Responses from over 1000 households in Hamilton, 165 households in Tokoroa and 155 households in Te Kuiti were used to determine typical heating methods and fuels in these areas. The survey sample errors for Hamilton, Tokoroa and Te Kuiti, assessed based on sampling for a finite population with replacement, were 3%, 7.5% and 7.5%% respectively. Table 3.1 compares sample sizes for the 1997 and 2001 surveys.

Table 3.1: Sample details for the 1997 and 2001 domestic heating survey for Hamilton, Tokoroa and Te Kuiti

Area	1997				2001			
	Households	Sample	Area ha	Sample error	Households	Sample	Area Ha	Sample error
Central	4344	51	890	14%	2427	140	628	8%
Hamilton East	7818	137	1080	8%	7791	141	1126	8%
Hospital	5820	117	960	9%	4569	146	1365	8%
Mid East	5856	166	770	8%	8973	153	1243	8%
Te Rapa	4692	101	1320	10%	4896	141	2289	8%
Upper East	3115	33	830	17%	2172	145	1420	8%
Western	5605	134	830	8%	9870	146	1349	8%
Total Hamilton	37250	739	6680	3.5%	40698	1012	9420	3%
Tokoroa	4918	105	870	9%	4854	165	763	7.5%
Te Kuiti	1596	104	420	9%	1893	155	295	7.5%

The survey collected data relating to the type of home heating methods used in the main living area on a typical winter's night. Home heating methods queried included electricity, gas (flued or unflued), oil burners, open fires, woodburners and multifuel burners. Data for woodburners was broken down to the following age categories: pre 1991, 1992-1996 and post 1997.

Data on fuel use were gathered by requiring households to estimate their daily fuel consumption. This was expressed as the number of split logs put on the fire for wood use and the number of buckets for coal use. These data were converted to weights based on average conversion rates of:

- One log = 1.4 kg
- One bucket = 9 kg

The survey aimed to eliminate some of the ambiguities of the previous 1997 survey for Hamilton and the 2000 survey for Taupo, Huntly, Matamata and Putaruru. Consequently the results of the 2001 survey will differ from the 1997 surveys for reasons other than trends in heating methods. For example, the 1997 and 2000 surveys included the question "what percentage of the following energy sources do you use to heat your main living area in winter?" This could be interpreted based on the amount of time spent using each method or the proportion of heat provided by different methods or some proportion based on cost or the amount of fuel used. In the 2001 survey, respondents were asked whether they used each heating method in their main living area on a typical winter's night. Results were recorded for each heating method.

Differences in the survey methodology between the 1997 and 2001 inventories are unlikely to have significant implications for emissions estimates.

A copy of the home heating survey used for the 2001 inventory is contained in Appendix 1.

2.1 Home heating methods

The domestic heating survey results show variability in methods of home heating across the different study areas.

Gas is the most common home heating method in Hamilton with 83% of households using some form of gas heating on a typical winter's night (Table 3.2). While the majority of these (62%) use flued gas heating, just over 10,000 households in Hamilton use unflued gas heating. Unflued gas heaters emit contaminants such as nitrogen oxides, carbon monoxide and other toxic substances into the indoor environment. This is of concern as these emissions can lead to high concentrations of these contaminants in the indoor environment.

Less than one-third of the households in Hamilton use solid fuel burning for domestic home heating. While this is low compared to areas in New Zealand where domestic heating results in air quality issues (e.g., Christchurch, Nelson, Timaru), a greater proportion of these (36%) use an open fire. The majority of households that use open fires burn wood, with about one-third of these burning both wood and coal. Less than 2% of households using open fires burn only coal.

Woodburner use in Hamilton is spread relatively evenly across the three age categories. Multifuel burners are used in the main living area by about 4% of households in Hamilton. Wood is the main fuel for these burners with about half of the multifuel burner households also using coal. Overall around 13,000 household in Hamilton use wood and around 2,000 use coal.

In contrast, the main method of home heating in Tokoroa and Te Kuiti is solid fuel burning (Table 3.2) used by about 70% and 58% of households respectively[1]. In Tokoroa, 53% and 21% of households use woodburners and open fires respectively. Woodburner use in Te Kuiti is slightly lower at 36% and open fires are used by 24% of households. Multifuel burner use is also proportionally higher in Tokoroa and Te Kuiti than in Hamilton with 9% and 11% of households respectively using multifuel burners. The majority of solid fuel burning households use wood, although coal use in Te Kuiti is also significant with 14% of households using either a combination of wood and coal or coal alone.

Around 326 tonnes of wood and 24 tonnes of coal are used for domestic heating per day in Hamilton during the winter. The dominance of wood in Hamilton is illustrated in Figure 3.1 with just less than 90% of the fuel use by weight being attributed to wood. Over half of the wood is burnt on woodburners, with open fires consuming around one third. About 2 thirds of the coal used for domestic heating in Hamilton is burnt on open fires with the remainder burnt on multifuel burners.

In contrast, the majority of coal in Tokoroa is burnt on multifuel burners and only a small proportion of both wood and coal is burnt on open fires (Figure 3.2). Te Kuiti is more similar to Hamilton in the proportions of both wood and coal burnt on open fires (Figure 3.3).

In Tokoroa, just over 110 tonnes of wood is used for home heating on a typical winter's day. This compares to 35 tonnes of wood for the smaller population of Te Kuiti. Despite differences in household numbers, Table 3.3 shows a similar amount of coal is consumed in Te Kuiti (1893 households) as in Tokoroa (4854 households).

[1] Following statistics may add to be greater than this value as some households use more than one method of solid fuel burning.

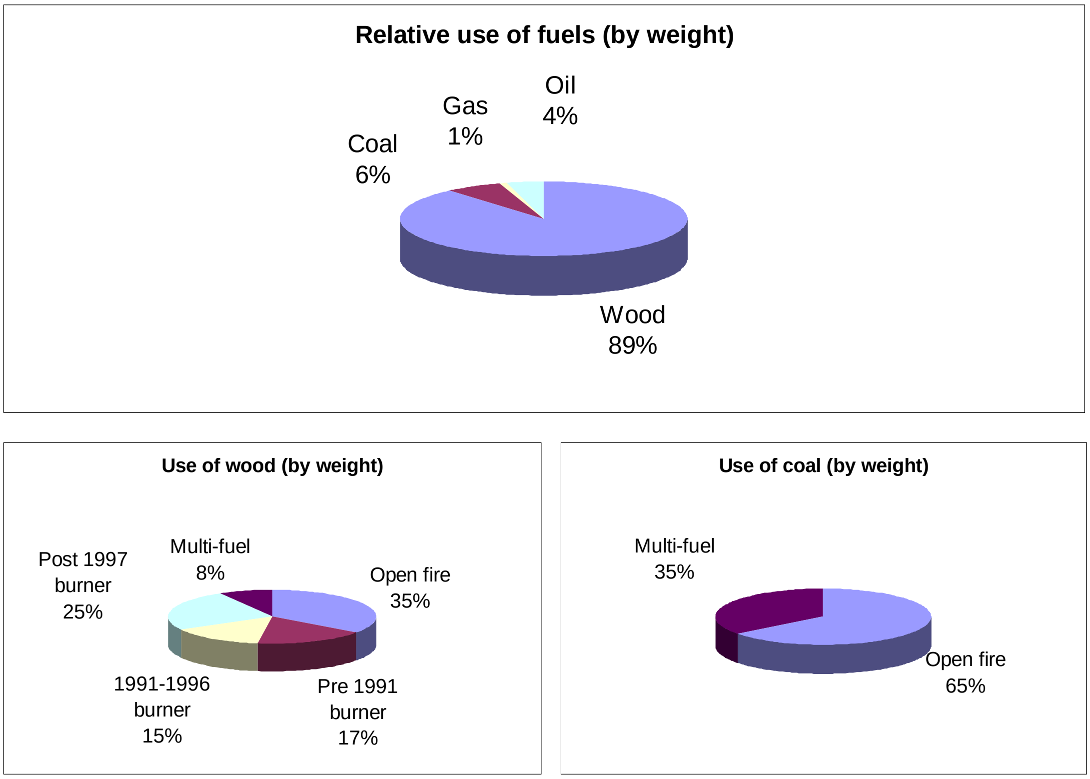


Figure 3.1: Fuel use for domestic heating in Hamilton

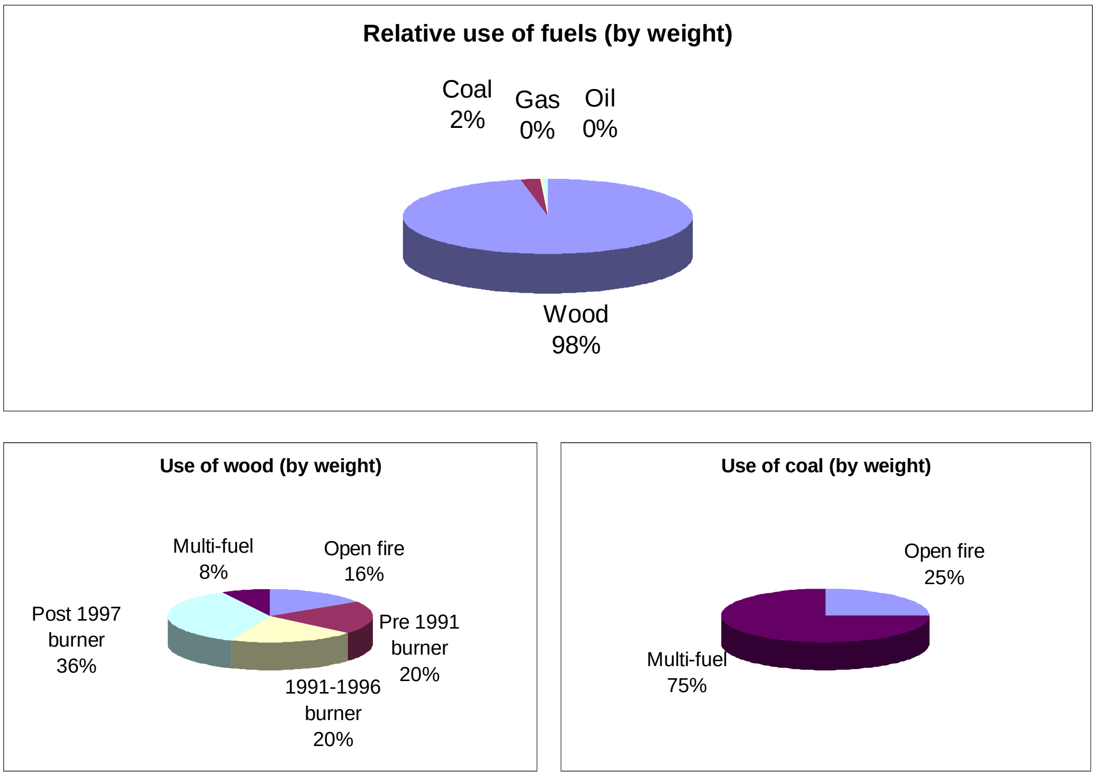


Figure 3.2: Fuel use for domestic heating in Tokoroa

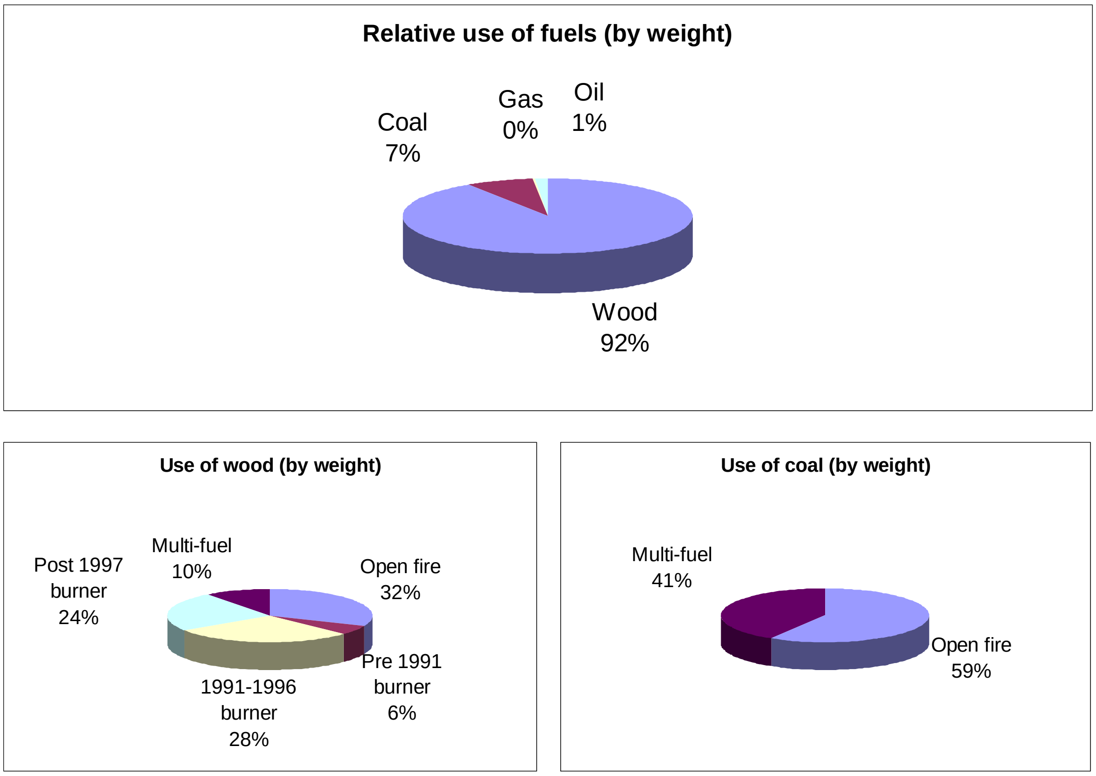


Figure 3.3: Fuel use for domestic heating in Te Kuiti

Table 3.2 Methods of domestic heating across all study areas

	Hamilton[2]		Centre (CBD-Lake)		Hamilton East		Hospital (Melville)		Mid East (Claudlands)		Te Rapa		Upper East (Flagstaff)		Western (Frankton)		Tokoroa		Te Kuiti	
	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH
Electricity	33	13281	28	676	33	2597	25	1127	27	2463	29	1424	25	539	21	2096	21	1030	30	574
Total Gas	83	33627	63	1526	57	4420	66	3004	67	6041	71	3472	73	1588	73	7233	41	2000	39	745
Flued gas	51	20956	39	936	35	2763	40	1815	47	4223	46	2257	52	1123	41	4056	18	883	12	220
Unflued gas	27	10903	21	503	19	1492	23	1033	15	1349	20	972	17	374	29	2907	22	1059	26	501
Oil	5	1994	4	87	4	276	3	125	8	704	2	104	3	60	2	203	2	88	4	73
Open fire	12	4696	9	225	14	1105	9	407	10	880	7	347	6	120	7	676	21	1030	24	452
Total woodburners	17	6924	6	156	16	1216	16	720	10	880	11	556	3	60	17	1690	53	2559	36	684
Pre 1991 woodburners	6	2479	4	104	5	405	5	240	5	406	3	159	2	40	6	563	13	632	6	105
1991-1996 woodburners	5	1880	1	17	3	270	4	200	2	203	2	119	0	0	6	563	14	698	16	303
Post 1997 woodburners	6	2564	1	35	7	540	6	280	3	271	6	278	1	20	6	563	25	1230	15	276
Multifuel burners	4	1576	4	87	4	276	3	156	3	293	4	174	1	15	3	270	9	441	11	208
Open fire - wood	11	4620	9	225	13	1050	9	407	10	880	7	347	6	120	7	676	21	1000	23	440
Open fire - coal	4	1429	3	69	3	221	2	94	5	411	1	69	3	60	2	203	2	88	7	134
Multifuel burners-wood	4	1576	4	87	4	276	3	156	3	293	4	174	1	15	3	270	9	441	11	208
Multifuel burners-coal	2	701	3	69	0	0	3	125	2	176	2	104	0	0	1	135	4	177	6	122
Total wood[1]	32	13120	19	468	33	2542	28	1283	23	2053	22	1076	9	195	27	2637	82	4001	70	1331
Total coal[1]	5	2130	6	139	3	221	5	219	7	586	4	174	3	60	3	338	5	265	14	256

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

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

Table 3.3: Fuel use by appliance type for Hamilton, Tokoroa and Te Kuiti

	Hamilton		Centre (CBD-Lake)		Hamilton East		Hospital (Melville)		Mid East (Claudlands)		Te Rapa		Upper East (Flagstaff)		Western (Frankton)		Tokoroa		Te Kuiti	
	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%	T day^{-1}	%
Open fire	130	35	8.7	53	22.3	37	16.2	35	23.7	37	5.7	20	5.4	76	24.4	34	21.3	16	14.0	33
Open fire - wood	114	31	8.2	50	20.3	33	14.8	32	20.0	31	5.1	18	5.0	70	21.4	30	20.5	15	12.2	28
Open fire - coal	15	4	0.5	3	2.0	3	1.4	3	3.7	6	0.6	2	0.4	6	3.0	4	0.8	1	1.9	4
Total Woodburner	185	50	3.6	22	32.0	53	24.0	52	26.3	41	16.8	59	0.9	12	40.0	56	99.8	74	22.6	53
Pre 1991 woodburner	56	15	1.9	12	8.8	14	6.8	15	9.8	15	5.0	18	0.4	5	11.3	16	26.4	20	2.3	5
1991-1996 woodburner	48	13	0.1	1	8.8	15	5.0	11	7.2	11	3.4	12	0.0	0	11.1	15	26.0	19	10.9	26
Post 1997 woodburner	81	22	1.5	9	14.4	24	12.3	27	9.4	15	8.4	0	0.5	7	17.6	24	47.4	35	9.3	22
Multifuel burner	35	10	3.4	20	3.7	6	4.3	9	8.4	13	4.8	17	0.3	4	5.1	7	12.7	9	5.3	12
Multifuel burner-wood	27	7	2.3	14	3.7	6	2.8	6	6.3	10	2.9	10	0.3	4	3.9	5	10.3	8	4.0	9
Multifuel burner-coal	8	2	1.0	6	0.0	0	1.5	3	2.1	3	1.9	7	0.0	0	1.2	2	2.4	2	1.3	3
Gas	4	1	0.2	1	0.8	1	0.3	1	0.5	1	0.3	1	0.1	1	0.8	1	0.5	0	0.2	0
Oil	15	4	0.7	4	2.1	3	0.9	2	5.3	8	0.8	3	0.5	6	1.5	2	0.7	0	0.6	1
Total Wood	326	88	14.1	86	56.0	92	41.6	91	52.7	82	24.8	87	6.1	87	65.3	91	130.5	97	38.7	91
Total Coal	24	6	1.5	9	2.0	3	2.9	6	5.8	9	2.5	9	0.4	6	4.3	6	3.2	2	3.2	7
Total	368		16.4		60.9		45.8		64.3		28.3		7.1		71.9		134.8		42.6	

3 Domestic heating emissions

3.1 Method used to calculate emissions

Assessing emissions from domestic heating involves the collection of data on home heating methods and fuel use, referred to as activity data, and the application of emission factors to these data.

As detailed in the previous section, data on home heating methods and fuel use were obtained through a domestic heating survey of the study areas. The total quantity of each type of fuel burnt on each type of appliance was used to calculate the emissions from that appliance and fuel type. Because the use of electricity does not result in any discharges to air, no emissions from that source are included. The generation of electricity using combustion does result in discharges to air, however, for the purpose of an emission inventory these are treated as an industrial point source discharge.

Emissions for each appliance type, for each contaminant and for each time period were calculated, based on the following equations:

*CE (g/day) = EF (g/kg) * FB (kg/day)* ***(Equation 4.1)***

where

CE = contaminant emission
EF = emission factor
FB = fuel burnt

*CE (g/time period) = EF (g/kg) * FB (kg/time period)* ***(Equation 4.2)***

where:

CE = contaminant emissions per time period
EF = emission factor

$$\text{FB (kg/time period)} = \frac{\text{no. of hours in time period}}{\text{24hrs}} * \text{total daily fuel use}$$

The amount of fuel burnt on each type of appliance was determined using the domestic heating survey outlined in the previous section.

The emission factors used for the 2001 emission inventory for Hamilton, Tokoroa and Te Kuiti are shown in Table 4.1. For open fires, multifuel burners, gas and oil burners, these are based on the Christchurch 1999 emission factors, the basis for which is detailed in Wilton (2001). The woodburner emission rates were derived based on an examination of the types of solid fuel burners reported for the different age categories in the emission inventory survey. These are consistent with emission factors derived for same age category appliances for Nelson and Timaru but dissimilar to Christchurch for the post 1997 appliances. This is because regulations in Christchurch restrict the installation of solid fuel burners to burners meeting an emission criterion of 1.5 grams of particulate per kilogram of fuel burnt.

Emission factors for benzene, BaP and dioxins were from the Timaru 2001 emission inventory (Wilton, 2001), which were selected based on data from overseas studies. Because of the limited data available, particular care should be taken in interpreting results for these contaminants. For dioxins, emission factors used were selected based on the Ministry for the Environment's dioxin assessment (MfE, 2000). However, recent studies of wood burning emissions in Canada (Environment Canada, 2000) suggest that these factors may overestimate dioxins from this source.

The emission factors are also different to those used in the 1997 Hamilton, Te Kuiti and Tokoroa emission inventory (Table 4.2). Those factors were based on the 1996 Christchurch emission inventory. While these emission factors were used widely throughout New Zealand, they did not take into account the additional regulations relating to solid fuel burning emissions in Christchurch. Variations in emission factors for open fires and coal burners between 1996 and 1999 are based on an evaluation of results of more recent testing of these appliances described in Wilton (2001).

It should be noted however, that emission test data for the derivation of emission factors applicable to New Zealand domestic heating appliances and fuels are limited and existing emission factors are indicative only.

Table 4.1: Emission factors used for 2001 emission inventory for Hamilton, Tokoroa and Te Kuiti

	PM_{10} g/kg	CO g/kg	Nox g/kg	SO_2 g/kg	VOC	CO_2 g/kg	Benzene g/kg	BaP g/kg	Dioxins µg/I TEQ tonne	$PM_{2.5}$ g/kg
Open fire - wood	10	100	1.6	0.2	30	1600	0.97	0.002	15	10
Open fire - coal	21	80	4	5.0	15	2600	0.00065	2.7E-06	7.5	12
Wood burner -pre 1991	13	130	0.5	0.2	39	1600	0.97	0.003	2	13
Wood burner - 91-96	7	70	0.5	0.2	21	1800	0.97	0.003	2	7
Wood burner - 1997 +	6	60	0.5	0.2	15	1800	0.97	0.003	2	6
Multifuel – wood	13	130	0.5	0.2	39	1600	0.97	0.002	2	13
Multifuel - coal[1]	28	120	1.2	3.0	15	2600	0.00065	2.7E-06	7.5	12
Oil	0.59	0.6	2.2	3.8	0.25	3200	2.16E-05		0.35	0.43
Gas	0.04	0.18	1.3	7.6E-09	0.2	2500	2.13E-03			0.04

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

Table 4.2: Emission factors used for the 1997 emission inventory for Hamilton, Tokoroa and Te Kuiti

	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg
Gas burner	0.1	0.4	2	0.01	0.2	2500
Oil burner	1.3	0.6	2.2	3.8	0.25	3200
Open fire – wood	15	120	1.6	0.2	30	1700
Open fire – coal	33	60	1.5	18	15	2800
Old (10yr +) burner - wood	12.8	104	1.4	0.2	26	1700
Newer (< 10 yr) burner -wood	6.4	51	0.7	0.2	13	1700
Enclosed coal burner - wood	14.3	114	1.6	0.2	29	1700
Enclosed coal burner - coal	31	57	1.4	18	14	2800
Multifuel burner - wood	6.4	51	0.7	0.2	13	1700
Multifuel burner - coal	14.3	26	0.6	18	6	2800
Potbelly - wood	14.3	114	1.6	0.2	31	1700
Potbelly - coal	31.5	57	1.4	18	14	2800

3.2 Total domestic heating emissions

A summary of total contaminant emissions for Hamilton, Tokoroa and Te Kuiti is shown in Table 4.3. A breakdown for the different areas within Hamilton is also given. Note however, that results for these areas do not equal the total for Hamilton as weighting to account for differences in numbers of respondents for different areas was required.

Table 4.4 shows the total emissions of each contaminant expressed in units of mass of pollutant per hectare. This is an area adjusted emission loading that shows the impact of factors such as types of heating methods and housing density in different areas. This shows the effect of the predominance of the use of gas and subsequent reduction in solid fuel use in Hamilton, with a lower g ha^{-1} emission rate than in Tokoroa or Te Kuiti.

Another way of presenting results, which provides an indicator of the relative cleanliness of home heating methods in each area, is grams of emissions per household. For example, Table 4.5 shows that, overall, home heating methods used in Te Kuiti and Tokoroa are more polluting than those used in Hamilton. Within Hamilton, the upper East area shows the lowest emission rate reflecting the prevalence of non-solid fuel heating methods in this newly developed area.

Table 4.3: Domestic heating emissions (kg) in each study area

	PM_{10} kg	CO kg	NOx kg	SOx kg	VOC kg	CO_2 tonnes	Benzene kg	BaP kg	Dioxin grams
Hamilton	3600	32605	397	223	9228	665.567	316	1	2
Centre	187	1635	21	11	460	29	14	0.03	0.15
Hamilton East	716	6891	89	32	2007	134	70	0.18	0.63
Hospital	453	4101	47	23	1149	81	40	0.11	0.30
Mid East	627	5716	78	55	1609	121	51	0.13	0.41
Te Rapa	294	2557	25	17	697	52	24	0.07	0.13
Upper East	70	648	11	5	189	13	6	0.01	0.08
Western	693	6334	74	38	1795	128	63	0.17	0.44
Tokoroa	1232	11829	96	40	3349	235	127	0.36	0.55
Te Kuiti	412	3667	43	23	1028	77	38	0.10	0.26

Table 4.4: Domestic heating emissions per hectare in each study area

	PM_{10} g ha^{-1}	CO g ha^{-1}	NOx g ha^{-1}	SOx g ha^{-1}	VOC g ha^{-1}	CO_2 kg ha^{-1}	Benzene g ha^{-1}	BaP µg ha^{-1}	Dioxin µg ha^{-1}
Hamilton	382	3461	42	24	980	70.652	34	89	0.2
Centre	297	2602	33	17	732	47	22	51	0.2
Hamilton East	636	6121	79	29	1782	119	62	156	0.6
Hospital	332	3004	34	17	842	60	30	79	0.2
Mid East	505	4600	63	45	1295	97	41	106	0.3
Te Rapa	129	1117	11	7	304	23	11	29	0.1
Upper East	50	456	8	3	133	9	4	9	0.1
Western	514	4695	55	28	1330	95	47	126	0.3
Tokoroa	1615	15513	126	52	4393	308	166	473	0.7
Te Kuiti	1399	12440	147	78	3486	260	127	339	0.9

Table 4.5: Domestic heating emissions per household in each study area

	PM_{10} g/hh	CO g/hh	NOx g/hh	SOx g/hh	VOC g/hh	CO_2 kg/hh	Benzene g/hh	BaP µg/hh	Dioxin µg/hh
Hamilton	88	801	10	5	227	16	8	21	0.06
Centre	77	674	9	4	190	12	6	13	0.06
Hamilton East	92	885	11	4	258	17	9	23	0.08
Hospital	99	898	10	5	252	18	9	23	0.07
Mid East	70	637	9	6	179	13	6	15	0.05
Te Rapa	60	522	5	3	142	11	5	14	0.03
Upper East	32	298	5	2	87	6	3	6	0.04
Western	70	642	8	4	182	13	6	17	0.04
Tokoroa	254	2437	20	8	690	48	26	74	0.11
Te Kuiti	218	1937	23	12	543	40	20	53	0.14

Emissions of PM_{10} in Hamilton, Tokoroa and Te Kuiti, expressed as total kilograms, grams per hectare and grams per household are shown in Figure 4.1. While total PM_{10} emissions in Hamilton are much greater than in Tokoroa or Te Kuiti, the emission rate per area of land and per household are greater in Tokoroa and Te Kuiti. The latter variables show a higher density of emissions and are a better indicator of the potential for air quality problems. However, the prevalence of meteorological conditions conducive to high pollution is also a predominant factor in determining the potential for elevated pollution levels.

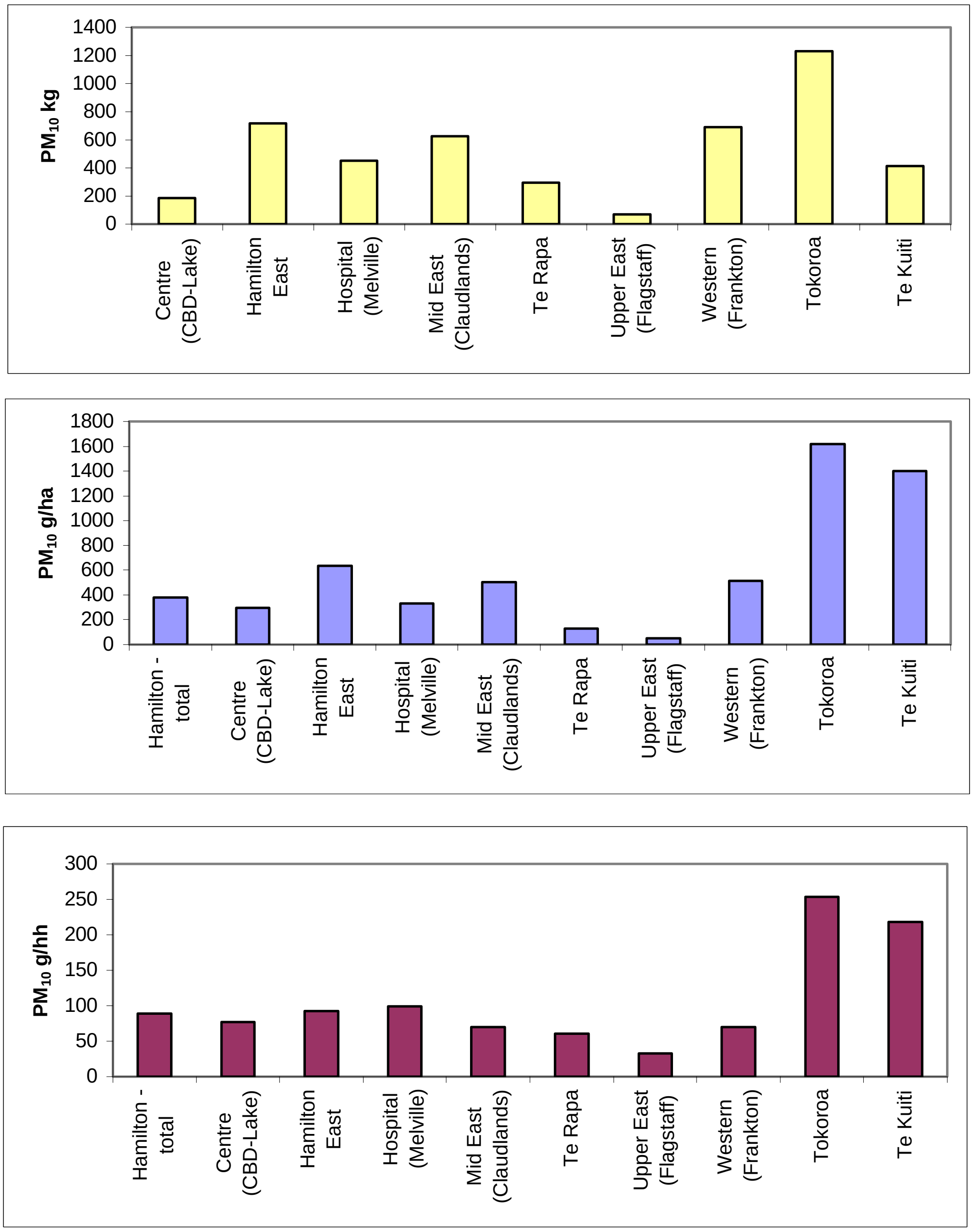


Figure 4.1: PM_{10} emissions in Hamilton, Tokoroa and Te Kuiti

3.3 Domestic heating emissions in Hamilton

About 3.6 tonnes of PM_{10} and 33 tonnes of CO are estimated to be emitted from domestic home heating in Hamilton on a typical winter's day. Although the total CO emissions are ten times greater than the PM_{10} emissions, this is not an indicator of potential impact as guideline values for CO are orders of magnitude greater than for PM_{10} e.g., they are expressed in units of mg m^{-3} compared to $\mu g\ m^{-3}$ for PM_{10}. Of the hazardous air pollutants (see Section 2.2 for definition), benzene emissions are highest with around 300 kilograms emitted from domestic heating per day, compared to less than 1 kilogram of benzo(a)pyrene and 2 grams of dioxins. Caution should be taken in using these results, however, owing to uncertainties in emission factors.

With the exception of SOx, burning of wood is the main contributor to emissions of all contaminants included in the study (Figure 4. 2). The burning of oil contributes 25%, 8% and 7% of the SOx, NOx and CO_2 emissions respectively despite only 4% of homes in Hamilton using this form of heating. Coal burning contributes 46% of the SOx emissions and less than 20% to emissions of other contaminants.

Figure 4.3 shows contaminant emissions for different methods of home heating. Open fires burning wood and pre 1991 burners are the greatest contributors to PM_{10}, CO, benzene and VOC emissions. Open fires burning coal are a major contributor to SOx emissions. Emissions of NOx stem largely from both wood and coal burnt on open fires.

Within Hamilton, the areas of Hamilton East, Mid East and Western have the highest emission rate per hectare of land. Emission rates per household are highest in Hamilton East, Hospital and Hamilton Centre. Te Rapa and Upper East have the lowest emission rates. In the case of Te Rapa this reflects the overall lower housing density in this area whereas the lower emission rate in Upper East is a reflection of the preference for non-solid fuel heating methods because of the more recently built homes.

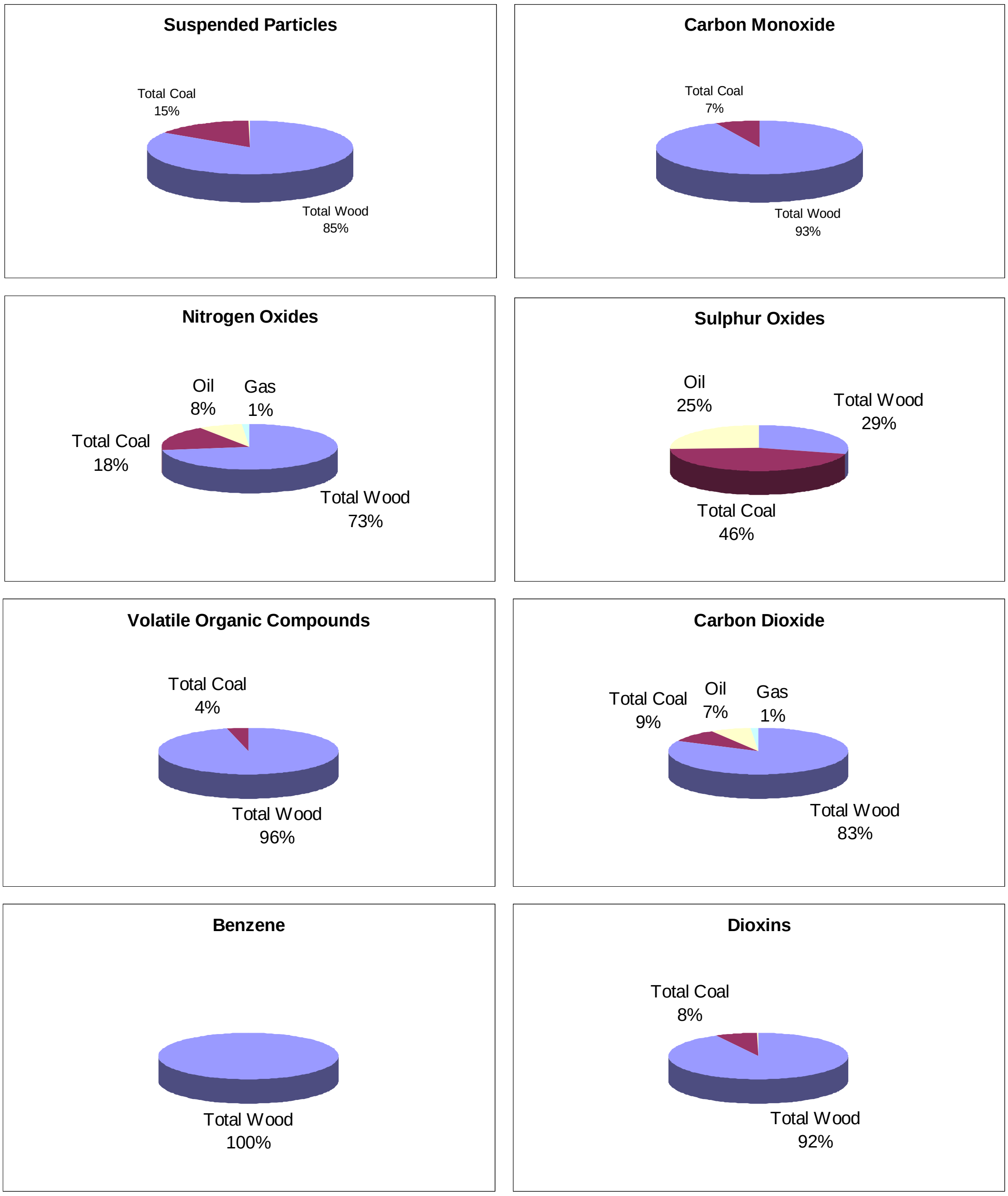


Figure 4.2: Contribution of fuels to contaminant emissions in Hamilton

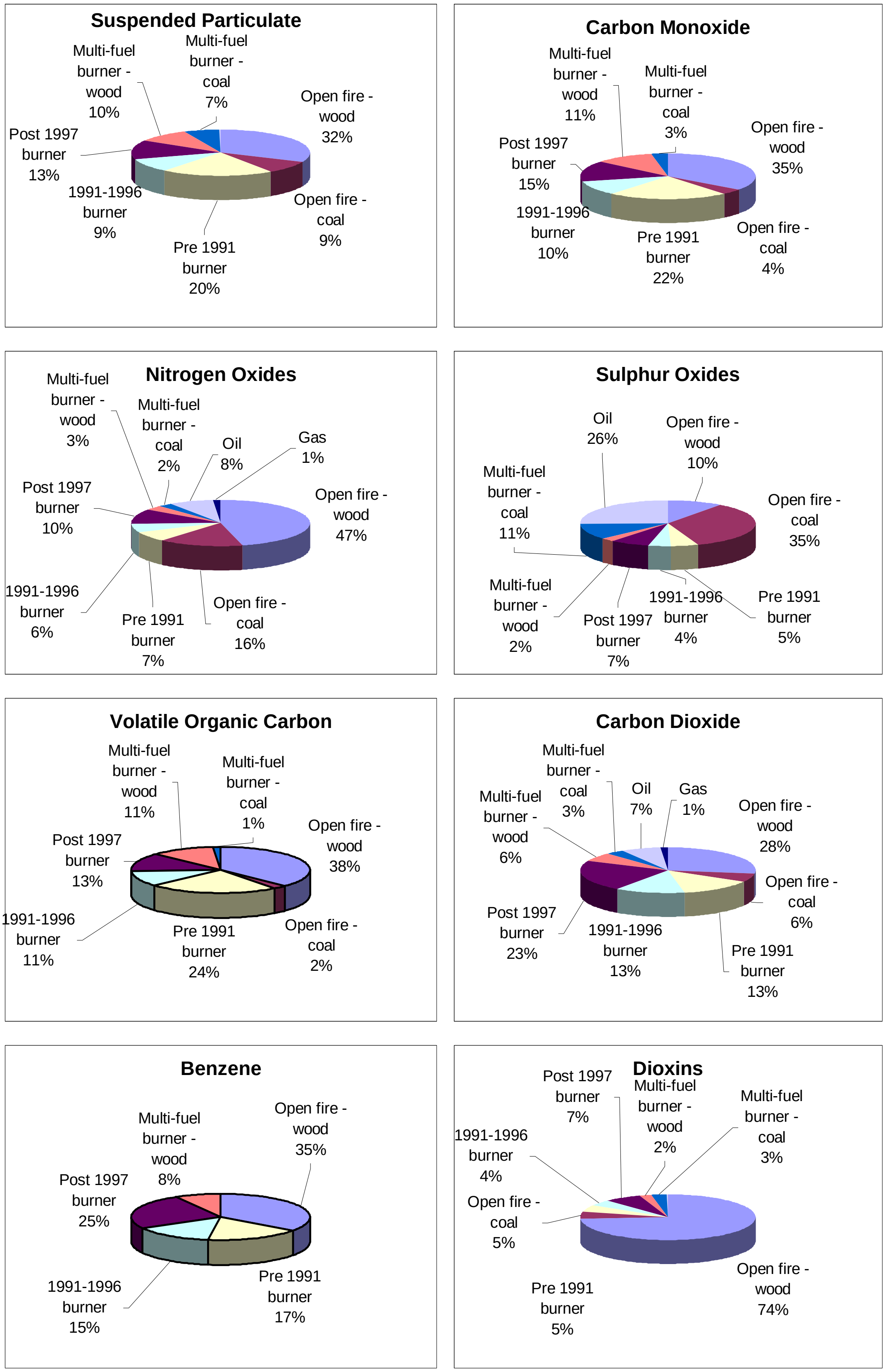


Figure 4.3: Contribution of different heating methods to contaminant emissions in Hamilton

Table 4.6: Domestic heating emissions in Hamilton

Hamilton	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	g ha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	129.5	35%	1463	155	41%	12648	1343	39%	244	26	61%	99	11	44%	3657	388	40%	222	24	33%	111	12	35%	1829	0.19	79%
Open fire - wood	114.3	31%	1143	121	32%	11430	1213	35%	183	19	46%	23	2	10%	3429	364	37%	183	19	27%	111	12	35%	1714	0.18	74%
Open fire - coal	15.2	4%	320	34	9%	1218	129	4%	61	6	15%	76	8	34%	228	24	2%	40	4	6%	0	0	0%	114	0.01	5%
Total woodburner	184.7	50%	1547	164	43%	15470	1642	47%	92	10	23%	37	4	17%	4399	467	48%	321	34	48%	179	19	57%	369	0.04	16%
Pre 1991 woodburner	55.8	15%	726	77	20%	7260	771	22%	28	3	7%	11	1	5%	2178	231	24%	89	9	13%	54	6	17%	112	0.01	5%
1991-1996 woodburner	48.1	13%	337	36	9%	3368	357	10%	24	3	6%	10	1	4%	1010	107	11%	87	9	13%	47	5	15%	96	0.01	4%
Post 1997 woodburner	80.7	22%	484	51	13%	4843	514	15%	40	4	10%	16	2	7%	1211	129	13%	145	15	22%	78	8	25%	161	0.02	7%
Multifuel burner	35.1	10%	582	62	16%	4478	475	14%	23	2	6%	30	3	14%	1168	124	13%	65	7	10%	26	3	8%	116	0.01	5%
Multifuel burner-wood	26.7	7%	347	37	10%	3475	369	11%	13	1	3%	5	1	2%	1042	111	11%	43	5	6%	26	3	8%	53	0.01	2%
Multi-fuel burner-coal	8.4	2%	234	25	7%	1003	107	3%	10	1	2%	25	3	11%	125	13	1%	22	2	3%	0	0	0%	63	0.01	3%
Gas	3.8	1%	0.2	0	0%	0.7	0	0%	5	1	1%	0	0	0%	1	0	0%	9	1	1%	0.0	0	0%	0	0.00	0%
Oil	15.0	4%	8.8	1	0%	9.0	1	0%	33	3	8%	57	6	25%	4	0	0%	48	5	7%	0.0	0	0%	5	0.00	0%
Total Wood	325.7	88%	3037	322	84%	30374	3224	93%	289	31	73%	65	7	29%	8870	942	96%	547	58	82%	316	34	100 %	2137	0.23	92%
Total Coal	23.6	6%	554	59	15%	2221	236	7%	71	7	18%	101	11	45%	354	38	4%	61	7	9%	0	0	0%	177	0.02	8%
Total	368.0		3600	382		32605	3461		397	42		223	24		9228	980		666	71		316	34		2319	0.25	

Table 4.7: Domestic heating emissions in City Centre

Centre	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	8.7	53%	92	146	49%	858	1365	52%	15	24	72%	4	6	37%	253	403	55%	14	23	49%	8	13	58%	127	0.20	86%
Open fire - wood	8.2	50%	82	131	44%	820	1305	50%	13	21	63%	2	3	15%	246	392	54%	13	21	45%	8	13	58%	123	0.20	84%
Open fire - coal	0.5	3%	10	16	5%	37	60	2%	2	3	9%	2	4	22%	7	11	2%	1	2	4%	0	0	0%	4	0.01	2%
Total woodburner	3.6	22%	10	16	5%	101	161	6%	1	1	4%	0	1	3%	26	41	6%	3	5	10%	2	3	12%	3	0.01	2%
Pre 1991 woodburner	1.9	12%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0.00	0%
1991-1996 woodburner	0.1	1%	1	1	0%	8	14	1%	0	0	0%	0	0	0%	3	4	1%	0	0	1%	0	0	1%	0	0.00	0%
Post 1997 woodburner	1.5	9%	9	15	5%	92	147	6%	1	1	4%	0	0	3%	23	37	5%	3	4	9%	1	2	11%	3	0.00	2%
Multifuel burner	3.4	20%	59	94	32%	427	679	26%	2	4	11%	4	6	33%	106	169	23%	6	10	22%	2	4	16%	12	0.02	9%
Multifuel burner-wood	2.3	14%	30	48	16%	302	481	18%	1	2	6%	0	1	4%	91	144	20%	4	6	13%	2	4	16%	5	0.01	3%
Multifuel burner-coal	1.0	6%	29	46	16%	125	199	8%	1	2	6%	3	5	29%	16	25	3%	3	4	9%	0	0	0%	8	0.01	5%
Gas	0.2	1%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	1	1%	0	0	0%	0	0.00	0%
Oil	0.7	4%	0	1	0%	0	1	0%	1	2	7%	2	4	23%	0	0	0%	2	3	7%	0	0	0%	0	0.00	0%
Total Wood	14.1	86%	147	234	79%	1473	2343	90%	16	26	77%	3	4	26%	437	696	95%	23	36	78%	14	22	100%	135	0.21	92%
Total Coal	1.5	9%	39	62	21%	162	258	10%	3	5	15%	5	9	51%	23	36	5%	4	6	13%	0	0	0%	11	0.02	8%
Total	16.4		187	297		1635	2602		21	33		11	17		460	732		29	47		14	22		146	0.23	

Table 4.8: Domestic heating emissions in Hamilton East

Hamilton East	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	22.3	37%	404	359	56%	3781	3358	55%	66	59	74%	17	15	53%	1116	992	56%	63	56	47%	35	31	50%	558	0.50	89%
Open fire - wood	20.3	33%	362	322	51%	3622	3217	53%	58	51	65%	7	6	22%	1087	965	54%	58	51	43%	35	31	50%	543	0.48	86%
Open fire - coal	2.0	3%	42	37	6%	159	141	2%	8	7	9%	10	9	31%	30	27	1%	5	5	4%	0	0	0%	15	0.01	2%
Total woodburner	32.0	53%	263	233	37%	2628	2334	38%	16	14	18%	6	6	20%	745	662	37%	56	50	42%	31	28	45%	64	0.06	10%
Pre 1991 woodburner	8.8	14%	115	102	16%	1146	1018	17%	4	4	5%	2	2	5%	344	305	17%	14	13	11%	9	8	12%	18	0.02	3%
1991-1996 woodburner	8.8	15%	62	55	9%	619	549	9%	4	4	5%	2	2	5%	186	165	9%	16	14	12%	9	8	12%	18	0.02	3%
Post 1997 woodburner	14.4	24%	86	77	12%	863	767	13%	7	6	8%	3	3	9%	216	192	11%	26	23	19%	14	12	20%	29	0.03	5%
Multifuel burner	3.7	6%	48	43	7%	481	427	7%	2	2	2%	1	1	2%	144	128	7%	6	5	4%	4	3	5%	7	0.01	1%
Multifuel burner-wood	3.7	6%	48	43	7%	481	427	7%	2	2	2%	1	1	2%	144	128	7%	6	5	4%	4	3	5%	7	0.01	1%
Multifuel 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%	0	0.00	0%
Gas	0.8	1%	0	0	0%	0	0	0%	1	1	1%	0	0	0%	0	0	0%	2	2	1%	0	0	0%	0	0.00	0%
Oil	2.1	3%	1	1	0%	1	1	0%	5	4	5%	8	7	24%	1	0	0%	7	6	5%	0	0	0%	1	0.00	0%
Total Wood	56.0	92%	673	598	94%	6731	5979	98%	76	67	85%	14	13	45%	1976	1755	98%	120	106	90%	70	62	100%	615	0.55	98%
Total Coal	2.0	3%	42	37	6%	159	141	2%	8	7	9%	10	9	31%	30	27	1%	5	5	4%	0	0	0%	15	0.01	2%
Total	60.9		716	636		6891	6121		89	79		32	29		2007	1782		134	119		70	62		630	0.56	

Table 4.9: Domestic heating emissions in the Hospital area

Hospital	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	16.2	35%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0.00	0%
Open fire - wood	14.8	32%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0.00	0%
Open fire - coal	1.4	3%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0.00	0%
Total woodburner	24.0	52%	196	144	43%	1964	1439	48%	12	9	26%	5	4	20%	552	405	48%	42	31	51%	23	17	58%	48	0.04	16%
Pre 1991 woodburner	6.8	15%	88	64	19%	878	643	21%	3	2	7%	1	1	6%	263	193	23%	11	8	13%	7	5	16%	14	0.01	5%
1991-1996 woodburner	5.0	11%	35	25	8%	348	255	8%	2	2	5%	1	1	4%	104	76	9%	9	7	11%	5	4	12%	10	0.01	3%
Post 1997 woodburner	12.3	27%	74	54	16%	738	541	18%	6	5	13%	2	2	10%	185	135	16%	22	16	27%	12	9	30%	25	0.02	8%
Multifuel burner	4.3	9%	78	57	17%	543	397	13%	3	2	7%	5	4	22%	131	96	11%	8	6	10%	3	2	7%	17	0.01	6%
Multifuel burner-wood	2.8	6%	36	27	8%	362	265	9%	1	1	3%	1	0	2%	109	80	9%	4	3	5%	3	2	7%	6	0.00	2%
Multifuel burner-coal	1.5	3%	42	31	9%	180	132	4%	2	1	4%	5	3	19%	23	17	2%	4	3	5%	0	0	0%	11	0.01	4%
Gas	0.3	1%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	1	1	1%	0	0	0%	0	0.00	0%
Oil	0.9	2%	1	0	0%	1	0	0%	2	2	4%	4	3	15%	0	0	0%	3	2	4%	0	0	0%	0	0.00	0%
Total Wood	41.6	91%	381	279	84%	3807	2789	93%	37	27	79%	8	6	36%	1105	810	96%	70	51	86%	40	30	100%	276	0.20	93%
Total Coal	2.9	6%	72	52	16%	293	215	7%	7	5	16%	12	8	49%	44	32	4%	8	6	9%	0	0	0%	22	0.02	7%
Total	45.8		453	332		4101	3004		47	34		23	17		1149	842		81	60		40	30		298	0.22	

Table 4.10: Domestic heating emissions in the Mid East

Mid East	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	23.7	37%	249	200	40%	2300	1851	40%	47	38	60%	22	18	41%	657	528	41%	42	34	34%	19	16	38%	328	0.26	80%
Open fire - wood	20.0	31%	177	143	28%	2004	1613	35%	32	26	41%	4	3	7%	601	484	37%	32	26	27%	19	16	38%	301	0.24	73%
Open fire - coal	3.7	6%	72	58	11%	296	238	5%	15	12	19%	18	15	33%	55	45	3%	10	8	8%	0	0	0%	28	0.02	7%
Total woodburner	26.3	41%	234	188	37%	2336	1880	41%	13	11	17%	5	4	10%	673	541	42%	45	37	38%	26	21	50%	53	0.04	13%
Pre 1991 woodburner	9.8	15%	127	102	20%	1270	1022	22%	5	4	6%	2	2	4%	381	307	24%	16	13	13%	9	8	19%	20	0.02	5%
1991-1996 woodburner	7.2	11%	50	40	8%	502	404	9%	4	3	5%	1	1	3%	150	121	9%	13	10	11%	7	6	14%	14	0.01	3%
Post 1997 woodburner	9.4	15%	56	45	9%	564	454	10%	5	4	6%	2	2	3%	141	114	9%	17	14	14%	9	7	18%	19	0.02	5%
Multifuel burner	8.4	13%	141	114	23%	1077	867	19%	6	5	7%	8	6	14%	279	224	17%	16	13	13%	6	5	12%	29	0.02	7%
Multifuel burner-wood	6.3	10%	82	66	13%	824	663	14%	3	3	4%	1	1	2%	247	199	15%	10	8	8%	6	5	12%	13	0.01	3%
Multifuel burner-coal	2.1	3%	59	48	9%	253	204	4%	2	2	3%	6	5	11%	32	25	2%	5	4	5%	0	0	0%	16	0.01	4%
Gas	0.5	1%	0	0	0%	0	0	0%	1	1	1%	0	0	0%	0	0	0%	1	1	1%	0	0	0%	0	0.00	0%
Oil	5.3	8%	3	3	0%	3	3	0%	12	9	15%	20	16	36%	1	1	0%	17	14	14%	0	0	0%	2	0.00	0%
Total Wood	52.7	82%	493	397	79%	5164	4156	90%	48	39	62%	11	8	19%	1521	1224	95%	88	71	72%	51	41	100%	366	0.29	89%
Total Coal	5.8	9%	131	105	21%	549	442	10%	17	14	22%	25	20	45%	87	70	5%	15	12	12%	0	0	0%	44	0.04	11%
Total	64.3		627	505		5716	4600		78	63		55	45		1609	1295		121	97		51	41		411	0.33	

Table 4.11: Domestic heating emissions in Te Rapa

Te Rapa	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	5.7	20%	64	28	22%	560	245	22%	11	5	43%	4	2	25%	163	71	23%	10	4	19%	5	2	21%	81	0.04	60%
Open fire - wood	5.1	18%	51	22	17%	510	223	20%	8	4	33%	1	0	6%	153	67	22%	8	4	16%	5	2	21%	77	0.03	57%
Open fire - coal	0.6	2%	13	6	4%	50	22	2%	3	1	10%	3	1	19%	9	4	1%	2	1	3%	0	0	0%	5	0.00	3%
Total woodburner	16.8	59%	139	61	47%	1391	608	54%	8	4	34%	3	1	20%	392	171	56%	29	13	56%	16	7	68%	34	0.01	25%
Pre 1991 woodburner	5.0	18%	65	29	22%	654	286	26%	3	1	10%	1	0	6%	196	86	28%	8	4	16%	5	2	20%	10	0.00	7%
1991-1996 woodburner	3.4	12%	24	10	8%	236	103	9%	2	1	7%	1	0	4%	71	31	10%	6	3	12%	3	1	14%	7	0.00	5%
Post 1997 woodburner	8.4	0%	50	0	0%	501	0	0%	4	0	0%	2	0	0%	125	0	0%	15	0	0%	8	0	0%	17	0.00	0%
Multifuel burner	4.8	17%	90	40	31%	605	264	24%	4	2	15%	6	3	37%	142	62	20%	10	4	18%	3	1	12%	20	0.01	15%
Multifuel burner-wood	2.9	10%	38	17	13%	380	166	15%	1	1	6%	1	0	4%	114	50	16%	5	2	9%	3	1	12%	6	0.00	4%
Multifuel burner-coal	1.9	7%	53	23	18%	225	98	9%	2	1	9%	6	2	34%	28	12	4%	5	2	9%	0	0	0%	14	0.01	10%
Gas	0.3	1%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	1	0	1%	0	0	0%	0	0.00	0%
Oil	0.8	3%	0	0	0%	0	0	0%	2	1	7%	3	1	18%	0	0	0%	3	1	5%	0	0	0%	0	0.00	0%
Total Wood	24.8	87%	228	100	78%	2281	996	89%	18	8	73%	5	2	30%	659	288	95%	42	18	81%	24	10	100%	116	0.05	86%
Total Coal	2.5	9%	66	29	22%	275	120	11%	5	2	19%	9	4	52%	38	16	5%	7	3	13%	0	0	0%	19	0.01	14%
Total	28.3		294	129		2557	1117		25	11		17	7		697	304		52	23		24	11		135	0.06	

Table 4.12: Domestic heating emissions in the Upper East

Upper East	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	5.4	76%	8	6	12%	32	23	5%	2	1	14%	2	1	41%	6	4	3%	1	1	8%	0	0	0%	3	0.00	4%
Open fire - wood	5.0	70%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0.00	0%
Open fire - coal	0.4	6%	8	6	12%	32	23	5%	2	1	14%	2	1	41%	6	4	3%	1	1	8%	0	0	0%	3	0.00	4%
Total woodburner	0.9	12%	8	6	11%	79	55	12%	0	0	4%	0	0	3%	22	16	12%	1	1	12%	1	1	14%	2	0.00	2%
Pre 1991 woodburner	0.4	5%	5	3	7%	50	35	8%	0	0	2%	0	0	2%	15	10	8%	1	0	5%	0	0	6%	1	0.00	1%
1991-1996 woodburner	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0.00	0%
Post 1997 woodburner	0.5	7%	3	2	4%	29	20	4%	0	0	2%	0	0	2%	7	5	4%	1	1	7%	0	0	8%	1	0.00	1%
Multifuel burner	0.3	4%	4	3	6%	39	27	6%	0	0	1%	0	0	1%	12	8	6%	0	0	4%	0	0	5%	1	0.00	1%
Multifuel burner-wood	0.3	4%	4	3	6%	39	27	6%	0	0	1%	0	0	1%	12	8	6%	0	0	4%	0	0	5%	1	0.00	1%
Multifuel 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%	0	0.00	0%
Gas	0.1	1%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0.00	0%
Oil	0.5	6%	0	0	0%	0	0	0%	1	1	9%	2	1	34%	0	0	0%	1	1	11%	0	0	0%	0	0.00	0%
Total Wood	6.1	87%	62	43	88%	615	433	95%	9	6	76%	1	1	25%	183	129	97%	10	7	79%	6	4	100%	77	0.05	96%
Total Coal	0.4	6%	8	6	12%	32	23	5%	2	1	14%	2	1	41%	6	4	3%	1	1	8%	0	0	0%	3	0.00	4%
Total	7.1		70	50		648	456		11	8		5	3		189	133		13	9		6	4		80	0.06	

Table 4.13: Domestic heating emissions in Western

Western	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	24.4	34%	64	47	9%	243	180	4%	12	9	16%	15	11	40%	46	34	3%	8	6	6%	0	0	0%	23	0.02	5%
Open fire - wood	21.4	30%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0.00	0%
Open fire - coal	3.0	4%	64	47	9%	243	180	4%	12	9	16%	15	11	40%	46	34	3%	8	6	6%	0	0	0%	23	0.02	5%
Total woodburner	40.0	56%	330	244	48%	3297	2444	52%	20	15	27%	8	6	21%	936	694	52%	70	52	54%	39	29	61%	80	0.06	18%
Pre 1991 woodburner	11.3	16%	146	108	21%	1463	1084	23%	6	4	8%	2	2	6%	439	325	24%	18	13	14%	11	8	17%	23	0.02	5%
1991-1996 woodburner	11.1	15%	78	58	11%	778	577	12%	6	4	7%	2	2	6%	233	173	13%	20	15	16%	11	8	17%	22	0.02	5%
Post 1997 woodburner	17.6	24%	106	78	15%	1056	783	17%	9	7	12%	4	3	9%	264	196	15%	32	23	25%	17	13	27%	35	0.03	8%
Multifuel burner	5.1	7%	85	63	12%	656	486	10%	3	3	5%	4	3	12%	171	127	10%	9	7	7%	4	3	6%	17	0.01	4%
Multifuel burner-wood	3.9	5%	51	38	7%	510	378	8%	2	1	3%	1	1	2%	153	113	9%	6	5	5%	4	3	6%	8	0.01	2%
Multifuel burner-coal	1.2	2%	34	25	5%	146	108	2%	1	1	2%	4	3	10%	18	14	1%	3	2	2%	0	0	0%	9	0.01	2%
Gas	0.8	1%	0	0	0%	0	0	0%	1	1	1%	0	0	0%	0	0	0%	2	2	2%	0	0	0%	0	0.00	0%
Oil	1.5	2%	1	1	0%	1	1	0%	3	2	5%	6	4	15%	0	0	0%	5	4	4%	0	0	0%	1	0.00	0%
Total Wood	65.3	91%	594	441	86%	5944	4405	94%	56	42	76%	13	10	35%	1730	1282	96%	110	82	86%	63	47	100%	408	0.30	93%
Total Coal	4.3	6%	98	73	14%	389	289	6%	14	10	18%	19	14	50%	64	47	4%	11	8	9%	0	0	0%	32	0.02	7%
Total	71.9		693	514		6334	4695		74	55		38	28		1795	1330		128	95		63	47		441	0.33	

3.4 Domestic heating emissions in Tokoroa

Emissions from domestic heating result in just over 1 tonne of PM_{10} and less than 12 tonnes of CO discharged to air on a typical winter's night in Tokoroa (Table 4.14). As indicated previously, the potential for impact from PM_{10} is greater as health effects occur at much lower concentrations than for CO. The majority of the PM_{10} emissions come from the burning of wood on woodburners. In particular, older (pre 1991) burners contribute 30% of the PM_{10} emissions.

Wood burning is also the main contributor to emissions of all contaminants included in the study (Figure 4.4). Coal burning contributes 28% of the SOx emissions and less than 10% to emissions of other contaminants. Oil burning contributes 6% of the SOx emissions and less than 2% of all other contaminant emissions.

Figure 4.5 shows contaminant emissions for different methods of home heating. Wood burners are the main contributors to emissions of all contaminants, although multifuel burners burning coal contribute about 18% of the SOx emissions. Open fires burning wood are also a major contributor to NOx emissions from domestic heating in Tokoroa.

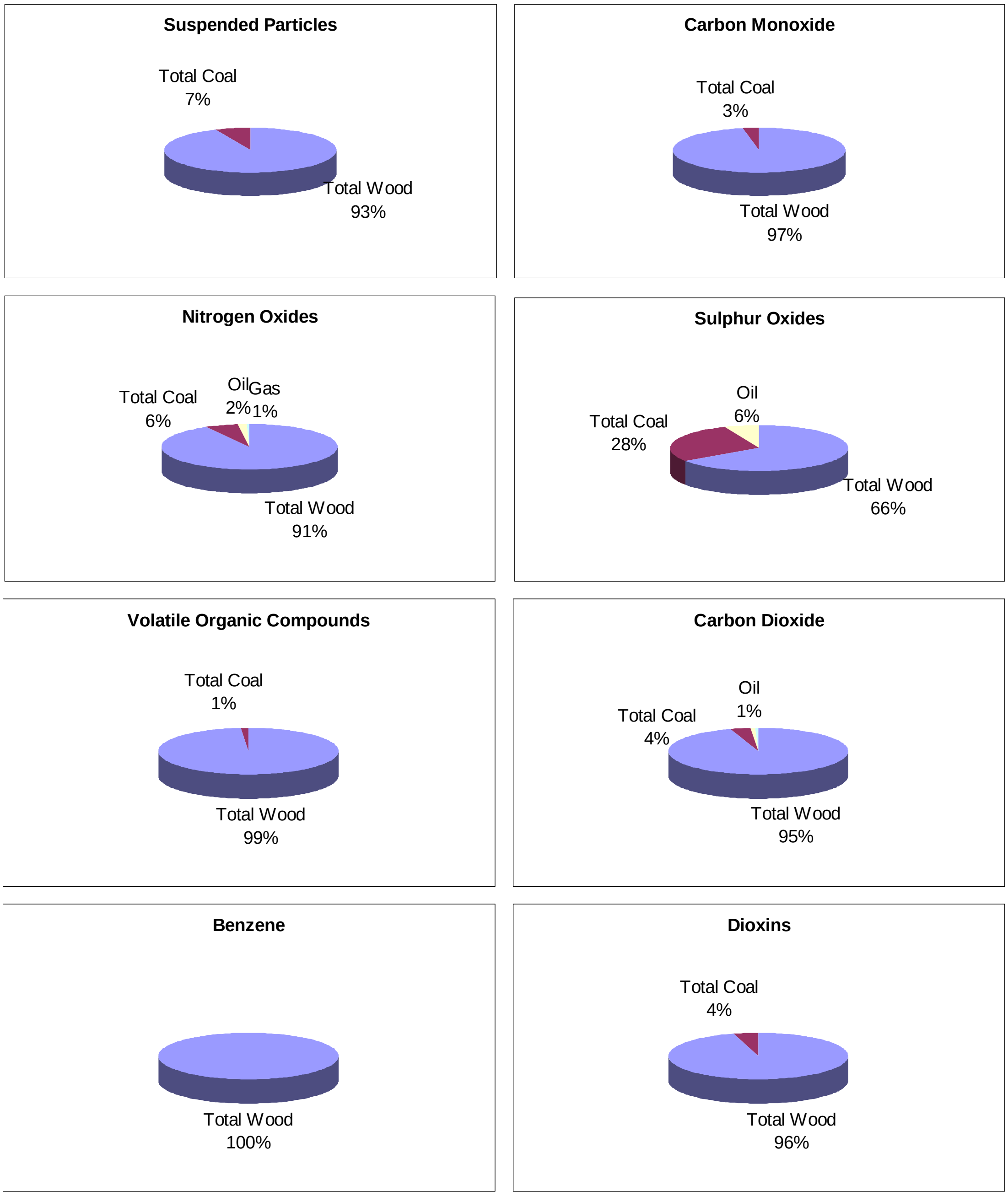


Figure 4.4: Contribution of fuels to contaminant emissions in Tokoroa

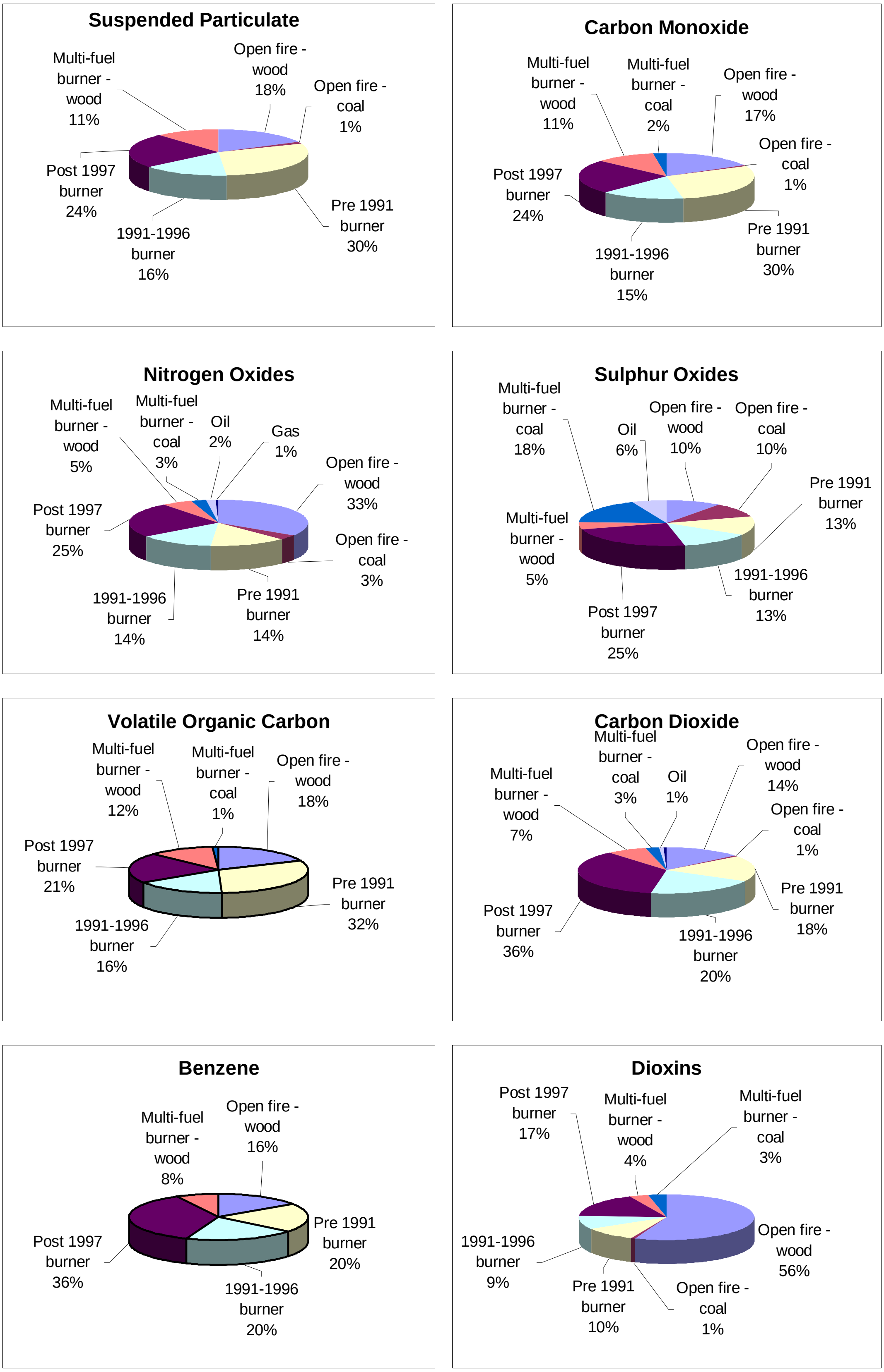


Figure 4.5: Contribution of heating methods to contaminant emissions in Tokoroa

Table 4.14: Domestic heating emissions in Tokoroa

Tokoroa	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	T	kgha^{-1}	%	kg	gha^{-1}	%	ug	ugha^{-1}	%
Open fire	21.3	16%	221	290	18%	2111	2769	18%	36	47	38%	8	11	20%	626	821	19%	35	46	15%	20	26	16%	313	0.41	57%
Open fire - wood	20.5	15%	205	269	17%	2048	2686	17%	33	43	34%	4	5	10%	614	806	18%	33	43	14%	20	26	16%	307	0.40	56%
Open fire - coal	0.8	1%	17	22	1%	64	83	1%	3	4	3%	4	5	10%	12	16	0%	2	3	1%	0	0	0%	6	0.01	1%
Total woodburner	99.8	74%	810	1062	66%	8095	10616	68%	50	65	52%	20	26	50%	2286	2999	68%	174	229	74%	97	127	76%	200	0.26	36%
Pre 1991 woodburner	26.4	20%	344	451	28%	3436	4506	29%	13	17	14%	5	7	13%	1031	1352	31%	42	55	18%	26	34	20%	53	0.07	10%
1991-1996 woodburner	26.0	19%	182	238	15%	1818	2384	15%	13	17	14%	5	7	13%	545	715	16%	47	61	20%	25	33	20%	52	0.07	9%
Post 1997 woodburner	47.4	35%	284	373	23%	2841	3726	24%	24	31	25%	9	12	24%	710	931	21%	85	112	36%	46	60	36%	95	0.12	17%
Multifuel burner	12.7	9%	200	263	16%	1622	2127	14%	8	10	8%	9	12	23%	436	572	13%	23	30	10%	10	13	8%	38	0.05	7%
Multifuel burner-wood	10.3	8%	134	175	11%	1336	1752	11%	5	7	5%	2	3	5%	401	526	12%	16	22	7%	10	13	8%	21	0.03	4%
Multifuel burner-coal	2.4	2%	67	88	5%	286	375	2%	3	4	3%	7	9	18%	36	47	1%	6	8	3%	0	0	0%	18	0.02	3%
Gas	0.5	0%	0	0	0%	0	0	0%	1	1	1%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0.00	0%
Oil	0.7	0%	0	1	0%	0	1	0%	1	2	2%	3	3	6%	0	0	0%	2	3	1%	0	0	0%	0	0.00	0%
Total Wood	130.5	97%	1148	1505	93%	11479	15054	97%	88	115	92%	26	34	66%	3302	4330	99%	223	293	95%	127	166	100%	527	0.69	96%
Total Coal	3.2	2%	83	109	7%	349	458	3%	6	8	6%	11	15	28%	48	63	1%	8	11	4%	0	0	0%	24	0.03	4%
Total	134.8		1232	1615		11829	15513		96	126		40	52		3349	4393		235	308		127	166		551	0.72	

3.5 Domestic heating emissions in Te Kuiti

Less than half a tonne of PM_{10} and less than 4 tonnes of CO are discharged to air on a typical winter's night in Te Kuiti (Table 4.15). While less in total quantity than in Hamilton and Tokoroa, the amount of emissions per household and per hectare is greatest in Te Kuiti. This is a reflection of the predominance of solid fuel burning for domestic home heating and the greater proportion of households in Te Kuiti using coal (14%).

With the exception of SOx, wood burning is the main contributor to emissions of all contaminants included in the study (Figure 4.6). Coal burning contributes the majority of the SOx emissions, 21% of the NOx emissions, 18% of the PM_{10} and less than 15% to emissions of other contaminants. About half of the PM_{10} emissions from coal burning are from the use of multifuel burners with the remainder from open fires. Oil burning contributes 9% of the SOx emissions, 3% of the NOx and 2% of the CO_2.

Open fires and burners less than 10 years old each account for around one-third of the PM_{10} emissions in Te Kuiti. (Figure 4.7). The lower proportion of emissions from pre 1991 burners in Te Kuiti reflects a more modern age profile of burners in Te Kuiti, compared to both Hamilton and Tokoroa.

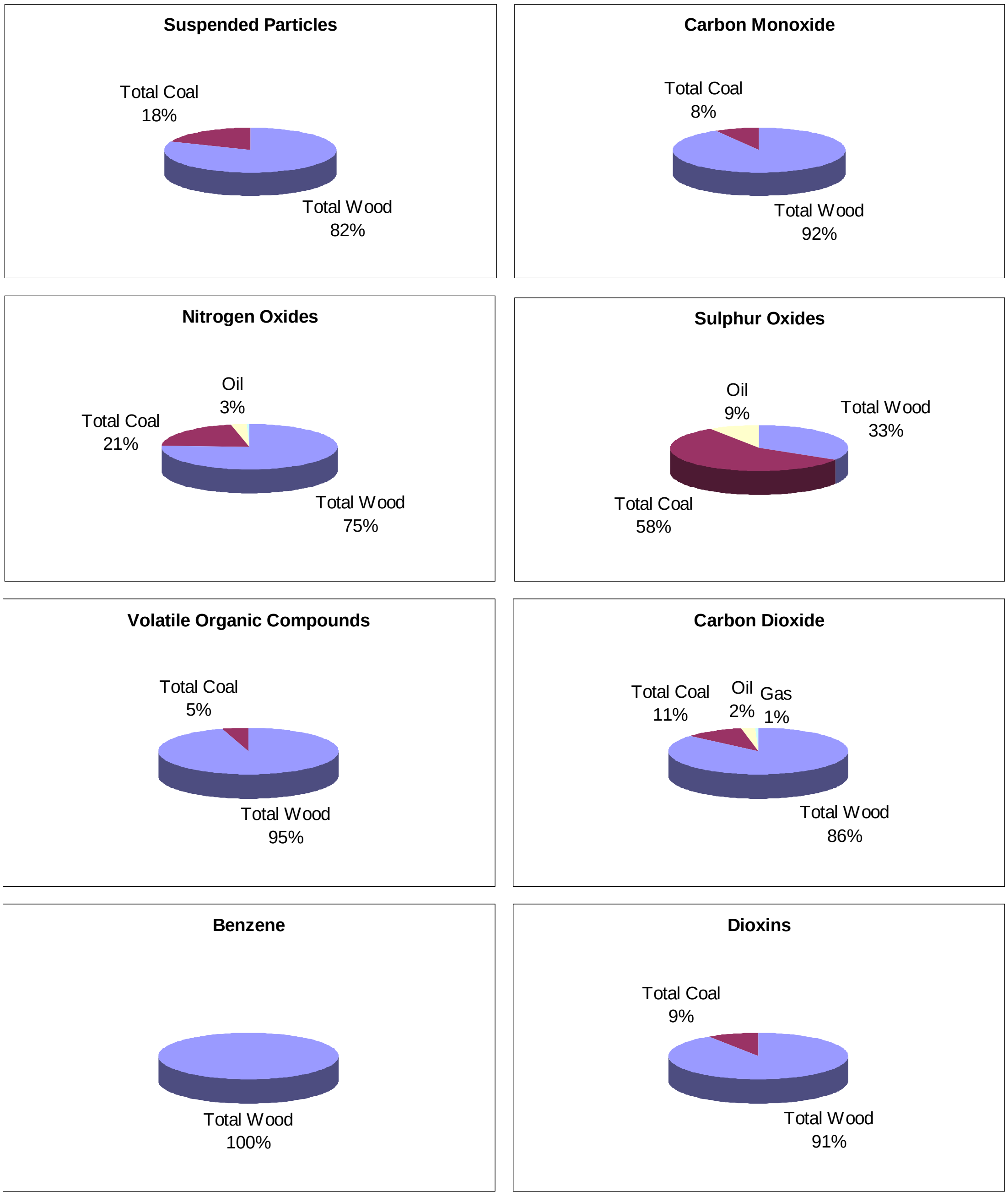


Figure 4.6: Contribution of different fuels to contaminant emissions in Te Kuiti

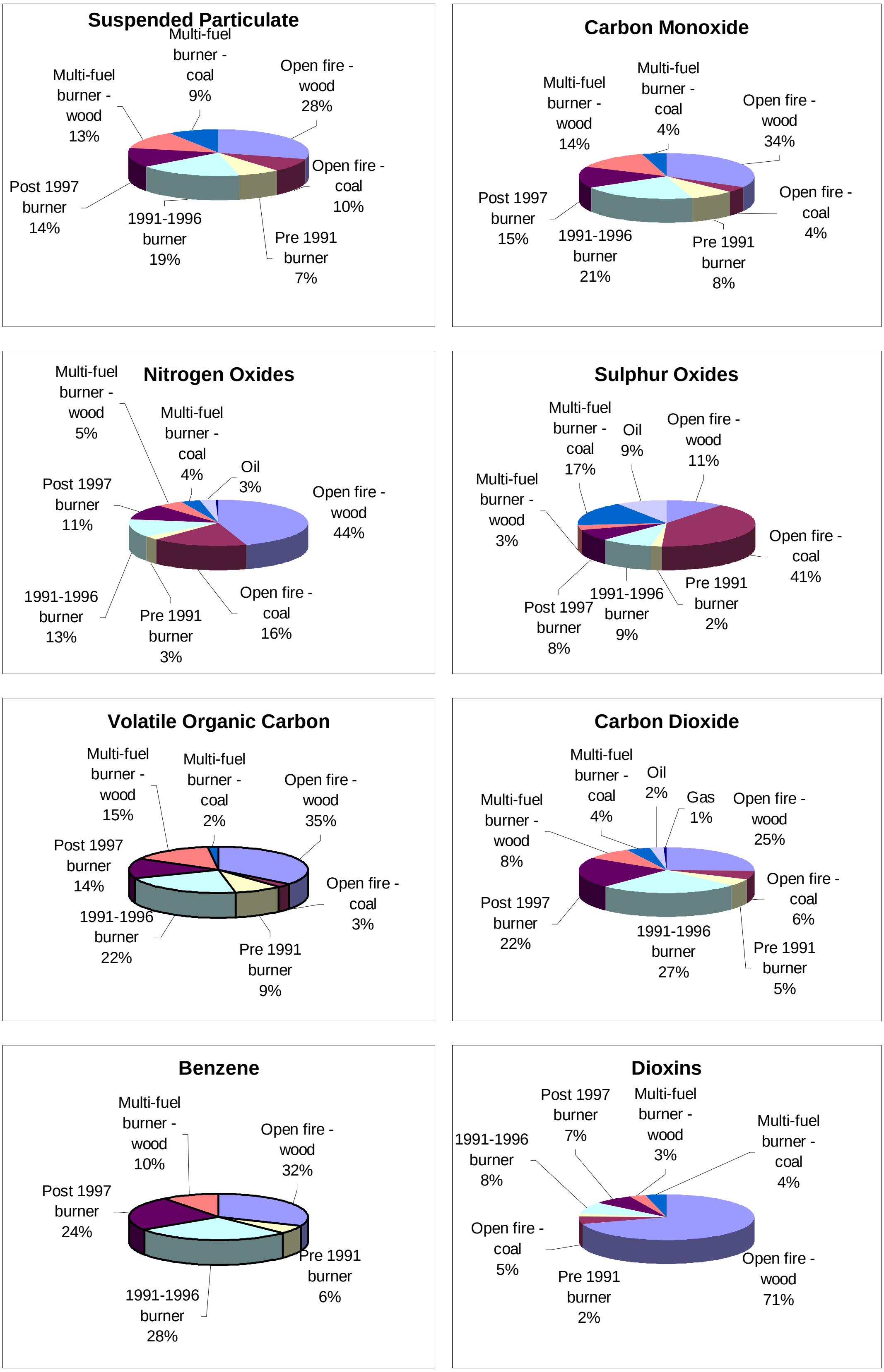


Figure 4.7: Contribution of different heating methods to contaminant emissions in Te Kuiti

Table 4.15: Domestic heating emissions in Te Kuiti

Te Kuiti	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			Dioxin		
	T day^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	kg	gha^{-1}	%	t	$kgha^{-1}$	%	kg	gha^{-1}	%	ug	$ugha^{-1}$	%
Open fire	14.0	33	161	545	39	1365	4629	37	27	91	62	12	40	51	393	1332	38	24	82	32	12	40	31	196	0.67	76
Open fire - wood	12.2	28	122	412	29	1215	4122	33	19	66	45	2	8	11	365	1237	35	19	66	25	12	40	31	182	0.62	70
Open fire - coal	1.9	4	39	133	10	149	507	4	7	25	17	9	32	40	28	95	3	5	16	6	0	0	0	14	0.05	5
Total woodburner	22.6	53	163	552	39	1626	5516	44	11	38	26	5	15	20	460	1560	45	40	136	53	22	74	58	45	0.15	17
Pre 1991 woodburner	2.3	5	30	102	7	300	1019	8	1	4	3	0	2	2	90	306	9	4	13	5	2	8	6	5	0.02	2
1991-1996 woodburner	10.9	26	77	260	19	765	2596	21	5	19	13	2	7	9	230	779	22	20	67	26	11	36	28	22	0.07	8
Post 1997 woodburner	9.3	22	56	190	14	561	1902	15	5	16	11	2	6	8	140	475	14	17	57	22	9	31	24	19	0.06	7
Multifuel burner	5.3	12	89	301	22	676	2293	18	4	12	8	5	16	21	175	594	17	10	33	13	4	13	10	18	0.06	7
Multifuel burner-wood	4.0	9	52	176	13	518	1756	14	2	7	5	1	3	3	155	527	15	6	22	8	4	13	10	8	0.03	3
Multifuel burner-coal	1.3	3	37	125	9	158	537	4	2	5	4	4	13	17	20	67	2	3	12	4	0	0	0	10	0.03	4
Gas	0.2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2	1	0	0	0	0	0.00	0
Oil	0.6	1	0	1	0	0	1	0	1	4	3	2	7	9	0	0	0	2	6	2	0	0	0	0	0.00	0
Total Wood	38.7	91	336	1139	81	3359	11395	92	33	111	76	8	26	33	980	3323	95	66	224	86	38	127	100	235	0.80	91
Total Coal	3.2	7	76	258	18	308	1044	8	9	31	21	13	45	57	48	162	5	8	28	11	0	0	0	24	0.08	9
Total	42.6		412	1399		3667	12440		43	147		23	78		1028	3486		77	260		38	127		260	0.88	

3.6 Domestic heating emissions by time of day

About 2 thirds of the domestic heating PM_{10} emissions in Hamilton occur during the evening, 4pm to 10pm period (Figure 4.8). The remaining emissions are spread across the other three time periods. The 15% attributed to the night time period may be an underestimate of the contribution during this time. This is because overnight burning practices often result in the stoking up of the fire and the turning down of the air flow, allowing a slow burn throughout the night. The increased PM_{10} emissions associated with this type of operation are not factored into the emission inventory assessments because of difficulties in quantifying the impact of these operational factors.

In Tokoroa and Te Kuiti around 50% of the PM_{10} emissions occur during the evening, 4pm to 10pm period. In these areas daytime operation of burners is more common than in Hamilton, resulting in a slightly greater proportion of emissions occurring between 10am and 4pm.

Emissions of other contaminants follow the same general time of day distributions as PM_{10} (Tables 4.16- 4.18).

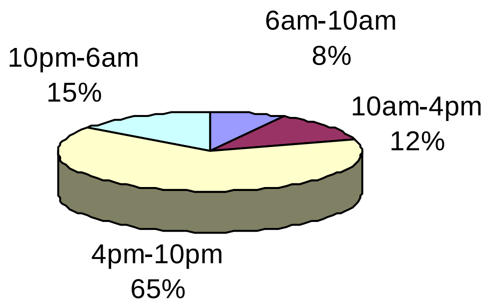


Figure 4.8: PM_{10} emissions by time of day in Hamilton

Table 4.16: Hamilton emissions by time of day

Hamilton	Suspended Particulate					Carbon monoxide					Nitrogen oxides					Sulphur oxides				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	NOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	SOx (kg)
Open fire - wood	77	126	764	176	1143	771	1264	7638	1757	11430	12	20	122	28	183	2	3	15	4	23
Open fire - coal	8	22	215	73	320	32	86	820	280	1218	2	4	41	14	61	2	5	51	17	76
Pre 1991 burner	66	87	473	100	726	662	868	4727	1003	7260	3	3	18	4	28	1	1	7	2	11
1991-1996 burner	32	42	218	44	337	322	417	2184	445	3368	2	3	16	3	24	1	1	6	1	10
Post 1997 burner	48	63	305	68	484	479	632	3053	678	4843	4	5	25	6	40	2	2	10	2	16
Multifuel burner - wood	24	51	238	34	347	239	508	2383	345	3475	1	2	9	1	13	0	1	4	1	5
Multifuel burner - coal	29	43	117	45	234	124	184	501	194	1003	1	2	5	2	10	3	5	13	5	25
Total Wood	247	369	1998	423	3037	2473	3689	19985	4228	30374	22	34	191	42	289	5	8	43	9	65
Total Coal	37	65	332	119	554	156	270	1321	474	2221	3	6	46	16	71	5	10	64	22	101
Oil	0.5	0.3	4.9	3.1	9	0	0	5	3	9	2	1	18	12	33	3	2	32	20	57
Gas	0.0	0.0	0.1	0.0	0	0	0	0	0	1	1	1	3	0	5	0	0	0	0	0
Total	285	435	2336	545	3600	2630	3959	21311	4705	32605	28	42	258	70	397	13	20	138	52	223

Hamilton	Volatile Organic Compounds					Carbon dioxide					Benzene					Dioxins				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO_2 (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Benzene (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Dioxin (µg)
Open fire - wood	231	379	2291	527	3429	12	20	122	28	183	7	12	74	17	111	116	190	1146	264	1714
Open fire - coal	6	16	154	52	228	1	3	27	9	40	0	0	0	0	0	3	8	77	26	114
Pre 1991 burner	199	260	1418	301	2178	8	11	58	12	89	5	6	35	7	54	10	13	73	15	112
1991-1996 burner	97	125	655	133	1010	8	11	56	11	87	4	6	30	6	47	9	12	62	13	96
Post 1997 burner	120	158	763	170	1211	14	19	92	20	145	8	10	49	11	78	16	21	102	23	161
Multifuel burner - wood	72	152	715	103	1042	3	6	29	4	43	2	4	18	3	26	4	8	37	5	53
Multifuel burner - coal	16	23	63	24	125	3	4	11	4	22	0	0	0	0	0	8	12	31	12	63
Total Wood	718	1075	5843	1234	8870	46	67	357	76	547	26	39	207	44	316	155	244	1419	320	2137
Total Coal	22	39	216	77	354	4	7	38	13	61	0	0	0	0	0	11	20	108	38	177
Oil	0	0	2	1	4	2	2	27	17	48	0	0	0	0	0	0	0	3	2	5
Gas	0	0	0	0	1	2	1	5	1	9	0	0	0	0	0	0	0	0	0	0
Total	740	1114	6062	1313	9228	54	77	427	108	666	26	39	207	44	316	166	263	1530	360	2319

Table 4.17: Tokoroa emissions by time of day

Tokoroa	Suspended Particulate					Carbon monoxide					Nitrogen oxides					Sulphur oxides				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	NOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	SOx (kg)
Open fire - wood	31	37	85	52	205	307	367	855	519	2048	5	6	14	8	33	1	1	2	1	4
Open fire - coal	4	6	3	4	17	14	22	12	16	64	1	1	1	1	3	1	1	1	1	4
Pre 1991 burner	47	67	163	66	344	472	669	1633	661	3436	2	3	6	3	13	1	1	3	1	5
1991-1996 burner	25	35	86	35	182	250	354	864	350	1818	2	3	6	2	13	1	1	2	1	5
Post 1997 burner	39	55	135	55	284	390	553	1350	547	2841	3	5	11	5	24	1	2	5	2	9
Multifuel burner - wood	20	16	82	16	134	199	156	825	156	1336	1	1	3	1	5	0	0	1	0	2
Multifuel burner - coal	2	11	48	5	67	11	48	207	21	286	0	0	2	0	3	0	1	5	1	7
Total Wood	162	210	553	223	1148	1619	2100	5527	2232	11479	13	16	41	18	88	4	5	12	5	26
Total Coal	6	17	51	9	83	25	69	218	37	349	1	2	3	1	6	1	3	6	2	11
Oil	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	3
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Total	168	227	604	232	1232	1644	2170	5746	2269	11829	14	18	44	20	96	5	8	19	8	40

Tokoroa	Volatile Organic Compounds					Carbon dioxide					Benzene					Dioxins				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO_2 (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Benzene (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Dioxin (μg)
Open fire - wood	92	110	256	156	614	5	6	14	8	33	3	4	8	5	20	46	55	128	78	307
Open fire - coal	3	4	2	3	12	0	1	0	1	2	0	0	0	0	0	1	2	1	1	6
Pre 1991 burner	142	201	490	198	1031	6	8	20	8	42	4	5	12	5	26	7	10	25	10	53
1991-1996 burner	75	106	259	105	545	6	9	22	9	47	3	5	12	5	25	7	10	25	10	52
Post 1997 burner	98	138	338	137	710	12	17	41	16	85	6	9	22	9	46	13	18	45	18	95
Multifuel burner - wood	60	47	247	47	401	2	2	10	2	16	1	1	6	1	10	3	2	13	2	21
Multifuel burner - coal	1	6	26	3	36	0	1	4	0	6	0	0	0	0	0	1	3	13	1	18
Total Wood	466	602	1591	642	3302	31	42	107	44	223	18	24	60	25	127	77	96	236	119	527
Total Coal	4	10	28	6	48	1	2	5	1	8	0	0	0	0	0	2	5	14	3	24
Oil	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0
Gas	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Total	470	613	1619	648	3349	33	44	113	46	235	18	24	60	25	127	79	101	250	121	551

Table 4.18: Te Kuiti emissions by time of day

Te Kuiti	Suspended Particulate					Carbon monoxide					Nitrogen oxides					Sulphur oxides				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	PM_{10} (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	NOx (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	SOx (kg)
Open fire - wood	7	22	73	20	122	68	219	730	198	1215	1	3	12	3	19	0	0	1	0	2
Open fire - coal	4	10	18	7	39	16	37	69	28	149	1	2	3	1	7	1	2	4	2	9
Pre 1991 burner	3	5	17	5	30	31	49	168	52	300	0	0	1	0	1	0	0	0	0	0
1991-1996 burner	8	13	43	13	77	78	125	429	133	765	1	1	3	1	5	0	0	1	0	2
Post 1997 burner	6	9	31	10	56	57	92	314	97	561	0	1	3	1	5	0	0	1	0	2
Multifuel burner - wood	9	9	21	12	52	93	89	213	123	518	0	0	1	0	2	0	0	0	0	1
Multifuel burner - coal	6	8	19	5	37	24	33	81	21	158	0	0	1	0	2	1	1	2	1	4
Total Wood	33	57	186	60	336	328	573	1855	603	3359	3	6	19	6	33	1	1	4	1	8
Total Coal	10	17	37	12	76	39	70	150	49	308	1	2	4	2	9	2	3	6	2	13
Oil	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	2
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	43	75	223	73	412	367	643	2006	652	3667	4	8	24	7	43	3	5	12	4	23

Te Kuiti	Volatile Organic Compounds					Carbon dioxide					Benzene					Dioxins				
	6am-10am	10am-4pm	4pm-10pm	10pm-6am	VOC (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	CO_2 (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Benzene (kg)	6am-10am	10am-4pm	4pm-10pm	10pm-6am	Dioxin (µg)
Open fire - wood	20	66	219	60	365	1	3	12	3	19	1	2	7	2	12	10	33	110	30	182
Open fire - coal	3	7	13	5	28	1	1	2	1	5	0	0	0	0	0	1	3	6	3	14
Pre 1991 burner	9	15	51	16	90	0	1	2	1	4	0	0	1	0	2	0	1	3	1	5
1991-1996 burner	23	38	129	40	230	2	3	11	3	20	1	2	6	2	11	2	4	12	4	22
Post 1997 burner	14	23	79	24	140	2	3	9	3	17	1	1	5	2	9	2	3	10	3	19
Multifuel burner - wood	28	27	64	37	155	1	1	3	2	6	1	1	2	1	4	1	1	3	2	8
Multifuel burner - coal	3	4	10	3	20	1	1	2	0	3	0	0	0	0	0	1	2	5	1	10
Total Wood	95	167	541	176	980	6	11	37	12	66	4	6	21	7	38	16	42	138	39	235
Total Coal	6	11	23	8	48	1	2	4	1	8	0	0	0	0	0	3	5	12	4	24
Oil	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	101	178	564	184	1028	8	13	42	13	77	4	6	21	7	38	19	47	150	43	260

4 Comparison to 1997 domestic heating inventory

An assessment of emissions from domestic home heating was carried out for Hamilton, Tokoroa and Te Kuiti for the winter of 1997. Around 4 tonnes of PM_{10} were estimated for Hamilton per night compared to just under 1 tonne in Tokoroa and 0.6 tonnes in Te Kuiti. Solid fuel burning was a predominant home heating method in both Tokoroa and Te Kuiti, with about 50% of households burning wood or coal compared to less than 20% in Hamilton (Noonan, 1997).

A similar assessment carried out for the areas of Taupo, Huntly, Matamata and Putaruru in 2000 found 50-60% of households used solid fuel burning for domestic home heating. Less than half a tonne of PM_{10} was estimated for Taupo, Matamata and Putaruru compared to 0.8 tonnes per night in Huntly. The use of coal in the latter area was much greater with 23% of households relying on that fuel compared to less than 5% in other areas.

Table 5.1 compares data on the study areas for the 1997, 2000 and 2001 emission inventories. This shows an increase in the study area for the 2001 inventory in both size and number of households. The geographical areas of Tokoroa and Te Kuiti included in the inventories for 2001 are slightly smaller in size than in 1997. However, an increase in household numbers for Te Kuiti indicates a higher housing density for this area in 2001.

Differences in the study areas make any comparisons in heating methods and emissions between the 2 years difficult. Another source of variation between the two inventories is the questionnaire used to assess home heating methods and fuels, which was modified for the 2001 emissions inventory to overcome some limitations in the interpretation in the 1997 and 2000 surveys. In particular, in the 1997 and 2000 surveys households were asked “what percentage of the following energy sources do you use to heat your main living area in winter?”. Because of the potential for ambiguity in the interpretation of this question, the 2001 inventory asked households “Do you use an….[e.g., open fire] in your main living area on a typical winter’s night?”. Consequently a comparison of results for the different surveys will be influenced by methodology, particularly differences in study areas.

Table 5.2 compares the results of the domestic heating survey for Hamilton, Tokoroa and Te Kuiti for 1997 and 2001. The proportions of households using different heating methods in Hamilton are very similar in 1997 to 2001. The main exception is an increase in the use of gas heating in 2001. This increase is not reflected in the results for Tokoroa or Te Kuiti. Results for the latter two areas suggest a slight increase in the proportion of households using solid fuel burners in Tokoroa and a decrease in Te Kuiti. However, the extent to which these differences occur as a result of variation in study area is uncertain.

Tables 5.3-5.5 compare 1997 and 2001 PM_{10} emissions in Hamilton, Tokoroa and Te Kuiti. The 1997 emissions estimates have been recalculated using the updated emission factors from the 2001 inventory. Because of differences in the sizes of each area a direct comparison of PM_{10} mass emissions is less meaningful than the grams per hectare (g ha^{-1}) outputs. This suggests an increase in the PM_{10} emission rate per hectare in Hamilton and Tokoroa and a decrease in the PM_{10} emission rate in Te Kuiti.

Table 5.1: Housing densities within Hamilton, Tokoroa, Te Kuiti, Taupo, Huntly, Matamata and Putaruru study areas for 1997, 2000 and 2001

	Number of Households HH 1997/2000	Study Area Size Ha 1997/2000	Housing Density HH/Ha 1997/2000	Number of Households HH 2001	Study Area Size Ha 2001	Housing Density HH/Ha 2001
Hamilton	37250	6680	5.6	40698	9420	4.3
Tokoroa	4918	870	5.7	4854	763	6.4
Te Kuiti	1596	420	4	1893	295	6.4
Taupo	6973	810	8.6			
Huntly	2354	492	4.8			
Matamata	2297	315	7.3			
Putaruru	1405	313	4.5			

Table 5.2: Comparison of 1997 and 2001 emission inventory survey results for Hamilton, Tokoroa and Te Kuiti

	Hamilton 1997		Hamilton 2001		Tokoroa 1997		Tokoroa 2001		Te Kuiti 1997		Te Kuiti 2001	
	%	HH	%	HH	%	HH	%	HH	%	HH	%	HH
Electricity	34%	12522	33%	13281	32%	1592	21%	1030	42%	675	30%	574
Total Gas	69%	25517	83%	33627	47%	2295	41%	2000	40%	645	39%	745
Oil	1%	467	5%	1994	1%	47	2%	88	4%	61	4%	73
Open fire	14%	5083	12%	4696	17%	843	21%	1030	19%	307	24%	452
Total Woodburner	19%	7024	17%	6924	54%	2670	53%	2559	49%	783	36%	684
Multifuel burners	6%	2238	4%	1576	2%	94	9%	441	29%	460	11%	208
Total wood	36%	13244	32%	13120	71%	3513	82%	4001	89%	1427	70%	1331
Total coal	3%	1101	5%	2130	2%	94	5%	265	9%	138	14%	256

Table 5.3: Comparison of 1997 and 2001 fuel use and PM_{10} emissions for Hamilton

	1997 Fuel Use		1997 PM_{10}			2001 Fuel use		2001 PM_{10}		
	T day^{-1}	%	kg	g ha^{-1}	%	T day^{-1}	%	kg	g ha^{-1}	%
Open fire	120.8	39%	1343	143	39%	129.5	35%	1463	155	41%
Open fire - wood	108.5	35%	1085	115	31%	114.3	31%	1143	121	32%
Open fire - coal	12.3	4%	258	27	7%	15.2	4%	320	34	9%
Total Woodburner	138.7	44%	1514	161	44%	184.7	50%	1547	164	43%
Multifuel burner	30.9	10%	597	63	17%	35.1	10%	582	62	16%
Multifuel burner - wood	17.8	6%	232	25	7%	26.7	7%	347	37	10%
Multifuel burner - coal	13.1	4%	366	39	11%	8.4	2%	234	25	7%
Gas	21.4	7%	0.9	0	0%	3.8	1%	0.2	0	0%
Oil	1.0	0%	0.6	0	0%	15.0	4%	8.8	1	0%
Total Wood	265.0	85%	2830	300	82%	325.7	88%	3037	322	84%
Total Coal	25.4	8%	624	66	18%	23.6	6%	554	59	15%
Total	312.7		3456	367		368.0		3600	382	

Table 5.4: Comparison of 1997 and 2001 fuel use and PM_{10} emissions for Tokoroa

	1997 Fuel Use		1997 PM_{10}			2001 Fuel use		2001 PM_{10}		
	T day^{-1}	%	kg	g ha^{-1}	%	T day^{-1}	%	kg	g ha^{-1}	%
Open fire	12.9	14%	140	183	14%	21.3	16%	221	290	18%
Open fire - wood	12.0	13%	120	157	12%	20.5	15%	205	269	17%
Open fire - coal	0.9	1%	20	26	2%	0.8	1%	17	22	1%
Total Woodburner	72.8	80%	813	1067	81%	99.8	74%	810	1062	66%
Multifuel burner	2.6	3%	48	63	5%	12.7	9%	200	263	16%
Multifuel burner - wood	1.7	2%	22	29	2%	10.3	8%	134	175	11%
Multifuel burner - coal	0.9	1%	26	34	3%	2.4	2%	67	88	5%
Gas	2.1	2%	0	0	0%	0.5	0%	0	0	0%
Oil	0.1	0%	0	0	0%	0.7	0%	0	1	0%
Total Wood	86.5	96%	955	1253	95%	130.5	97%	1148	1505	93%
Total Coal	1.9	2%	46	60	5%	3.2	2%	83	109	7%
Total	90.5		1001	1313		134.8		1232	1615	

Table 5.5: Comparison of 1997 and 2001 fuel use and PM_{10} emissions for Te Kuiti

	1997 Fuel Use		1997 PM_{10}			2001 Fuel use		2001 PM_{10}		
	T day^{-1}	%	kg	g ha^{-1}	%	T day^{-1}	%	kg	g ha^{-1}	%
Open fire	8.3	16%	86	293	15%	14.0	33%	161	545	39%
Open fire - wood	8.1	16%	81	273	14%	12.2	28%	122	412	29%
Open fire - coal	0.3	1%	6	20	1%	1.9	4%	39	133	10%
Total Woodburner	30.7	60%	317	1076	54%	22.6	53%	163	552	39%
Multifuel burner	11.7	23%	188	638	32%	5.3	12%	89	301	22%
Multifuel burner - wood	9.3	18%	121	409	20%	4.0	9%	52	176	13%
Multifuel burner - coal	2.4	5%	67	229	11%	1.3	3%	37	125	9%
Gas	0.7	1%	0	0	0%	0.2	0%	0	0	0%
Oil	0.1	0%	0	0	0%	0.6	1%	0	1	0%
Total Wood	48.0	93%	518	1758	88%	38.7	91%	336	1139	81%
Total Coal	2.7	5%	73	248	12%	3.2	7%	76	258	18%
Total	51.5		592	2007		42.6		412	1399	

5 Comparison to other areas

Table 6.1 compares emissions in Hamilton, Tokoroa and Te Kuiti to those estimated for Huntly, Taupo, Matamata and Putaruru for 2000. The highest area adjusted emission rates (g ha^{-1}), occur in Huntly (1747 g ha^{-1} of PM_{10} and SOx at 1255 g ha^{-1}) and Tokoroa (1615 g ha^{-1} PM_{10} and 15513 g ha^{-1} for CO). These emissions and those from Te Kuiti (1399 g ha^{-1} for PM_{10}) and Matamata (1147 g ha^{-1} for PM_{10}) are high compared to locations outside of the Waikato with air quality problems. For example, PM_{10}, CO and SOx emissions from domestic heating in Christchurch in 1999 were 560 g ha^{-1}, 3535 g ha^{-1} and 461 g ha^{-1} respectively (Wilton, 2001). In Christchurch, meteorological conditions restrict the dispersion of these emissions on many occasions during the winter. This results in guidelines exceedences for both PM_{10} and CO. The extent to which emissions of these contaminants will result in guideline exceedences in these Waikato locations will depend on meteorological conditions.

Table 6.1: Comparison of 2001 Hamilton, Te Kuiti and Tokoroa emissions to Taupo, Huntly, Matamata and Putaruru 2000 emissions

	PM_{10}		CO		NOx		SOx		VOC		CO_2	
	kg	**g ha^{-1}**	**kg**	**g ha^{-1}**	**kg**	**g ha^{-1}**	**kg**	**g ha^{-1}**	**kg**	**g ha^{-1}**	**kg**	**g ha^{-1}**
Taupo - 2000	409	505	3235	3993	68	84	16	20	809	999	76208	94083
Huntly - 2000	860	1747	2331	4737	67	136	618	1255	600	1219	93228	189488
Matamata - 2000	361	1147	2640	8382	46	145	58	183	622	1976	52804	167633
Putaruru - 2000	175	560	1487	4750	23	73	26	83	306	976	29735	95001
Hamilton - 2001	3600	382	32605	3461	397	42	223	24	9228	980	666567	70652
Tokoroa - 2001	1232	1615	11829	15513	96	126	40	52	3349	4393	234999	308195
Te Kuiti - 2001	412	1399	3667	12440	43	147	23	78	1028	3486	76532	259605

6 Outdoor burning emissions

Outdoor burning includes the burning of household or garden wastes outside in a drum, incinerator or open air.

The frequency and size of outdoor rubbish fires in Hamilton, Tokoroa and Te Kuiti was assessed through the domestic heating survey questionnaire. Households were asked whether or not they carried out outdoor burning of rubbish during the winter months and if so how often and how much waste was burnt. Emissions from outdoor burning were then estimated by applying emission factors to data (Table 7.1). Emission factors are from AP-42 based on the assumption that 60% of the material burnt is garden waste and 40% is household waste.

Table 7.1: Outdoor burning emission factors

	$PM_{2.5}$ g/kg	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg	Benzene g/kg
Garden rubbish	8	8	42	3	0.5	4	1470	0.0
Household rubbish	17	19	42	3	0.5	4.3	1470	1.2
Emission factor	12	12	42	3	0.5	4	1470	0.5

The survey found Hamilton had the least number of burns at 0.3 per household. This increased to 0.6 burns per household in Tokoroa and 1.5 burns per household in Te Kuiti. Estimated emissions from outdoor burning are presented in Table 7.2. These are based on an average fire weight of 100 kg for Hamilton and 150 kg in Tokoroa and Te Kuiti.

Table 7.2: Estimated daily emissions from outdoor burning in Hamilton, Tokoroa and Te Kuiti

	PM_{10} kg	CO kg	NOx kg	SO_2 kg	VOC kg	CO_2 kg	Benzene kg
Hamilton	130	435	31	5	44	15236	5
Tokoroa	44	149	11	2	15	5221	2
Te Kuiti	43	144	10	2	15	5057	2

7 Conclusion

The quantities of emissions to air from domestic heating are high in many of the small Waikato towns. In particular, Tokoroa, Huntly, Te Kuiti and Matamata all show elevated PM_{10} emission rates relative to the sizes of the urban areas.

A comparison of the emissions data for Tokoroa to a previous inventory carried out in 1997 suggests an increase in the use of solid fuel burning for domestic heating and a consequent increase in PM_{10} emissions in this area. Results of air quality monitoring in Tokoroa also indicate PM_{10} concentrations in excess of guideline values occur during the winter months. Management intervention is required in this area.

Further monitoring is required in other areas such as Matamata and Huntly to determine the impact of these emission rates on existing air quality. The extent to which management intervention in these areas may be required will depend on the outcomes of the monitoring.

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Appendix 1: Home heating survey questionnaire

Q1.1	(A) HELLO, I'm....[name]....from DigiPoll in Hamilton. We are conducting a very brief survey on behalf of Environment Waikato about home heating. May I speak to a person who owns, or is responsible, for your house? We are currently undertaking a survey in your area…
AREA	(A)
Q2	Open Fire 2a Do you use an open fire (this includes a visor fireplace) in your main living area on a typical Winter's day or night?
Q3.1	Morning? (6am - 10am)
Q3.2	Day time? (10am - 4pm)
Q3.3	Evening? (4pm - 10pm)
Q3.4	Overnight? (10pm - 6am)
Q3.5	Don't Know
Q4	2c Do you use wood on your open fire?
Q5.2	2d How many pieces of wood (logs) would you use on an average Winter's day? Don't Know - type zero
Q6	2e Do you buy your wood from a wood merchant or collect it yourself or do both?
Q7.2	If the answer to Question 2e is Both, please ask 2e.1 What % would be bought? Don't Know - type zero
Q8	2f Do you use coal on your open fire?
Q9.2	2g How many buckets of coal would you use on an average Winter's day? Don't Know - type zero
Q10	2h What type of coal do you use:
Q11	Electrical Heating 3a Do you use any type of electrical heating in your main living area on a typical Winter's day or night?
Q12.1	Morning? (6am - 10am)
Q12.2	Day time? (10am - 4pm)
Q12.3	Evening? (4pm - 10pm)
Q12.4	Overnight? (10pm - 6am)
Q12.5	Don't Know
Q13	Gas Heating 4a Do you use any type of gas heating in your main living area on a typical Winter's day or night?
Q14	4b Is your gas heating ...
Q15.1	Morning? (6am - 10am)
Q15.2	Day time? (10am - 4pm)
Q15.3	Evening? (4pm - 10pm)
Q15.4	Overnight? (10pm - 6am)
Q15.5	Don't Know
Q16	4d.1 Could you please tell me what size of gas bottle do you use? If more than one of the same size - tick here, if different sizes - use the next question 4d.3
Q17.2	4d.2 How many times in a winter would you refill it? If an answer is given to you on a weekly basis multiply the response by 12 Interviewer: Remember that there are 12 weeks or 3 months in a winter if the answer is given as per week or per month basis D
Q18	4d.3 Could you please tell me what second size of gas bottle do you use?
Q19.2	4d.4 How many times in a winter would you refill it? If an answer is given you on a weekly basis multiply the response by 12 Interviewer: Remember that there are

	12 weeks or 3 months in a winter if the answer is given as per week or per month basis D
Q20	Log Burner 5a Do you use a log burner in your main living area on a typical Winter's day or night? We do not mean a multifuel burner which also burns coal.
Q21	5b How old is your log burner?
Q22	5c.1 What make is your log burner?
Q22.2	(A)
Q23	5c.2 What model is your log burner?
Q24.1	(A)
Q25.1	Morning? (6am - 10am)
Q25.2	Day time? (10am - 4pm)
Q25.3	Evening? (4pm - 10pm)
Q25.4	Overnight? (10pm - 6am)
Q25.5	Don't Know
Q26.2	5e How many pieces of wood (logs) would you use on an average Winter's day? Don't Know - type zero
Q27	5f Do you buy your wood from a wood merchant or collect it yourself or do both?
Q28.2	If the answer to Question 5f is Both, please ask 5f.1 What % would be bought? Don't Know - type zero
Q29	Multi Fuel Burner 6a Do you use a burner which burns coal as well as wood, that is a multifuel burner, in your main living area on a typical Winter's day or night? This includes incinerators, potbelly stoves, McKay space heaters etc.
Q30	6b How old is your multifuel burner?
Q31	6c.1 What make is your multifuel burner?
Q31.2	(A)
Q32	6c.2 What model is your multifuel burner?
Q33.1	(A)
Q34.1	(A) 6c.3 What type of multifuel burner is it?
Q35.1	Morning? (6am - 10am)
Q35.2	Day time? (10am - 4pm)
Q35.3	Evening? (4pm - 10pm)
Q35.4	Overnight? (10pm - 6am)
Q35.5	Don't Know
Q36.2	6e How many pieces of wood (logs) would you use on an average Winter's day? Don't Know - type zero
Q37	6f Do you buy your wood from a wood merchant or collect it yourself or do both?
Q38.2	If the answer to Question 6f is Both, please ask 6f.1 What % would be bought? Don't Know - type zero
Q39	6g Do you use coal on your multifuel burner?
Q40.2	6h How many buckets of coal would you use on an average Winter's day? Don't Know - type zero
Q41	6i What type of coal do you use:
Q42	Oil Fired Heating System 7a Do you use an oil fired heating system in your main living area on a typical Winter's day or night?
Q43.1	Morning? (6am - 10am)
Q43.2	Day time? (10am - 4pm)
Q43.3	Evening? (4pm - 10pm)
Q43.4	Overnight? (10pm - 6am)
Q43.5	Don't Know
Q44	7c.1 Could you please tell me what size of oil container you use? Is it the small size 200 Litre or the large size 500 Litre?
Q44.2	(A)

Q45.2	7c.2 How many times in a winter would you refill it? If an answer is given you on a weekly basis multiply the response by 12 Interviewer: Remember that there are 12 weeks or 3 months in a winter if the answers is given as per week or per month basis D
Q46	Outside burning 8a Do you burn rubbish or garden waste outside in an incinerator or rubbish bin?
Q47	8b How frequently during Winter would you burn waste or garden rubbish outdoors? (That is, during the months of June, July and August)
Q48	8c How much garden waste or rubbish would you burn each session? We are looking for cubic metres or number of wheelbarrows full, per fire. Tick Cubic Metre or wheel barrow
Q49.2	
Q50.2	
Q51	DEMOGRAPHICS Now we need some demographic information to make it sure that we have a good cross-cut of the population.
Q52	Which of the following best describes your household?
Q52.2	(A)
Q53.1	How many people live at your address? TYPE ZERO FOR REFUSAL
Q54.13	AGE GROUP
Q54.14	AGE GROUP
Q54.15	AGE GROUP
Q54.16	AGE GROUP
Q54.17	AGE GROUP
Q54.18	AGE GROUP
Q54.19	AGE GROUP
Q54.20	AGE GROUP
Q54.21	AGE GROUP
Q54.22	AGE GROUP
Q54.23	AGE GROUP
Q54.24	AGE GROUP
Q55	Do you own your home or rent it?
Q56	How old is the dwelling you live in?
Q57	What ethnic group do you mainly identify to?
Q57.2	(A)
Q58	What is your employment status:
Q59	3.9 And finally, would you estimate your total combined household income before tax to be over or under $40,000 per year? DON'T click, Continue to ask: