Environment Waikato Technical Report 2005/55

Seasonal Variations in PM_{10} Emissions in Tokoroa 2005

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Executive Summary

Concentrations of PM_{10} (particles in the air less than 10 microns in diameter) regularly breach the ambient air quality guideline and National Environmental Standard (NES) for PM_{10} of 50 µg m^{-3} (24-hour average). The maximum measured 24-hour average PM_{10} concentration for Tokoroa was 97 µg m^{-3}. In addition to being in breach of the 24-hour average guideline for Tokoroa, annual average concentrations regularly exceed the ambient air quality guideline of 20 µg m^{-3}.

Emission inventory studies have evaluated the contribution of different sources to 24-hour average PM_{10} emissions in Tokoroa. These studies indicate the main source of daily wintertime PM_{10} in Tokoroa is domestic home heating, which contributes around 85% of the emissions. As the inventory studies have focused on the wintertime worst case emissions, it is uncertain what the relative contribution of different sources are to the annual average PM_{10} concentrations in Tokoroa.

The purpose of this study was to evaluate seasonal variations in domestic home heating emissions, to determine the impact of this source across all months of the year. A secondary objective was to evaluate seasonal variations in outdoor rubbish burning. This was done using a domestic home heating survey of home heating methods and fuels and outdoor burning for each month of the year.

Results indicated that the domestic heating contribution to daily PM_{10} emissions ranged from 28% during the summer months to 89% during the winter. Other significant contributors during the summer months were outdoor burning (35%) and motor vehicles (32%). Overall the domestic heating contribution to total annual PM_{10} emissions was around 78%.

The monthly emissions data were used in conjunction with PM_{10} concentrations observed at the Tokoroa monitoring site to provide an estimate of the relative contribution of different sources to annual average PM_{10} concentrations. Results suggested that domestic heating contributes around 69% of the annual average PM_{10} concentrations with motor vehicles, industry and outdoor burning each contributing 14%, 2% and 15%. No assessment of the contribution from Kinleith or natural sources was included in the analysis.

1 Introduction

In 2002, the Ministry for the Environment introduced an annual air quality guideline for PM_{10} of 20 µg m^{-3} in addition to the previously existing 24-hour average guideline of 50 µg m^{-3}.

In most areas of the Waikato annual average concentrations are within the annual average guideline for PM_{10}. The exception is Tokoroa. Annual average concentrations of PM_{10} in Tokoroa range from 24 to 31 µg m^{-3}.

Prior to this study, an emission inventory was carried out for Tokoroa during the winter of 2004. The purpose of that inventory was to estimate the contribution of different sources to PM_{10} concentrations and other contaminant emissions to air in Tokoroa. The focus of the inventory was daily emissions during the wintertime. The inventory found domestic home heating to be the main source of PM_{10} emissions in Tokoroa contributing 85% of the daily winter PM_{10}. Because the focus of the study was on daily wintertime emissions, the contribution of different sources to annual emissions was uncertain.

Of the different sources of emissions within Tokoroa, domestic home heating has the greatest potential for seasonal variation. This study evaluates changes in emissions from domestic home heating and outdoor rubbish burning by month of the year and combines these data with existing information on motor vehicles and industrial discharges to assess monthly variations in PM_{10} emissions in Tokoroa.

It is important to note that the analysis provides only information on the relative contribution of different sources to annual emissions and is not an indicator of the relative contribution to annual average PM_{10} concentrations. Some estimate of the latter could be made through a combination of the emissions data generated in this report and results of PM_{10} monitoring in Tokoroa, or through detailed meteorological modelling.

It is also uncertain to what extent sources not included in the inventory may contribute to annual average PM_{10} concentrations. The contribution of PM_{10} emissions from the Kinleith pulp and paper plant, located approximately five kilometres to the south-east of Tokoroa is not evaluated and natural sources of PM_{10} such as wind blown dusts are also not included in the study.

2 Methodology

The domestic heating emission inventory data was collected using a telephone survey of 300 households during May 2005. The survey was carried out by Digipol using the emission inventory survey questionnaire detailed in Appendix A. Unlike the questionnaire used for the 2004 inventory, the 2005 survey focused on seasonal variations in home heating methods. The survey also evaluated seasonal variations in outdoor rubbish burning. Emission factors were applied to the results of the survey to provide an estimate of emissions for domestic heating and outdoor burning in Tokoroa for each month of the year. Summary data for the survey and study areas are shown in Table 2.1.

Table 2-1: Home heating survey area and sample details

	Households	Sample size	Area (ha)	Sample error
Tokoroa	4451	300	1185	5.5%

Home heating methods were classified as electricity, open fires, pre 1995 wood burners, 1995-2000 wood burners, post 2000 wood burners, multi fuel burners, gas burners and oil burners.

Table 2.2 shows the emission factors used to estimate emissions from domestic home heating. Emission factors used were identical to those used for the Tokoroa 2004 air emissions inventory (Environment Waikato, 2004).

Table 2-2: Emission factors for domestic heating methods

	PM_{10} g/kg	CO g/kg	NOx g/kg	SO_2 g/kg	VOC g/kg	CO_2 g/kg	Benzene g/kg	$PM_{2.5}$ g/kg
Open fire - wood	10	100	1.6	0.2	30	1600	0.97	10
Open fire - coal	21	80	4	5.0	15	2600	0.00065	21
Pre 1995 wood burner	11	110	0.5	0.2	33	1600	0.97	11
1995-2000 wood burner	7	70	0.5	0.2	21	1600	0.97	7
Post 2000 wood burner	6	60	0.5	0.2	18	1600	0.97	6
Multi fuel[1] – wood	13	130	0.5	0.2	39	1600	0.97	13
Multi fuel[1] – coal	28	120	1.2	3.0	15	2600	0.00065	28
Pellet burner	2	20	0.5	0.2	6	1600	0.97	2
Oil	0.3	0.6	2.2	3.8	0.25	3200	2.160E-05	0.219
Gas	0.03	0.18	1.3	7.56E-09		2500	2.13E-03	0.03

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

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

Equation 2.1 **CE (g/day) = EF (g/kg) * FB (kg/day)**

Where:

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

The 2004 survey evaluated only daily worst-case PM_{10} emissions and relied on the assumption that all households would use a particular heating method on any given night. In addition to collecting information relating to worst-case emissions, the 2005 survey evaluated average daily emissions by adjusting daily fuel use by the average number of days per week each household used their heating method.

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

The main assumptions underlying the emissions calculations are as follows:

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

There are uncertainties in both the estimates of fuel use and the emission factors used to estimate emissions from solid fuel burning. Fuel use uncertainties include the ability

of householders to accurately estimate their daily fuel consumption, the conversion of pieces of wood to kilograms of fuel and in the case of small subgroups of appliance types, for example open fires, the applicability of the average fuel use of the small number of respondents in the sample size to the rest of the population of that burner category.

The uncertainty surrounding emission factors for domestic home heating is also high. Emission factors used are based on results of laboratory simulations of real life operation, rather than emissions from “in situ” measurements and burners operated by householders in real life. Further studies on real life emissions from domestic wood burners are being carried out during 2005. Emission factors used in this report are based on current best available information, which does not include the results of 2005 real life emission testing.

3 Home heating methods

Home heating methods and fuels used in Tokoroa for 2005 are shown in Table 3.1. Wood burners were the main heating method with 58% of households using this method. Gas use was also common with 35% of households using gas to heat the main living area of their home. Results for 2004 were 53% for wood burners and 40% for gas. Differences are likely to reflect variations relating to the sample error (5.5% for 2005 and 5% for 2004) rather than changes in home heating methods in the past year. Other notable variations in survey results include a drop in the proportion of households with open fires, with the 2005 survey indicating 4% of households using open fires, compared to the 12% suggested by the 2004 survey. Given the respective sample errors, it is likely that the proportion of households with open fires is around 7-9%.

The proportions of households using wood and coal for the 2005 survey was similar to 2004, although the estimated quantities of fuel used per day for 2005 were around 9 tonnes higher.

Table 3-1: Home heating methods and fuels in Tokoroa

	Heating methods		Fuel Use (average)	
	%	HH	t/day	%
Electricity	25%	1,098		
Total Gas	35%	1,558	1	1%
Flued gas	17%	748	-	0%
Unflued gas	18%	810	-	0%
Oil	1%	30	0.1	0%
Open fire	4%	163	-	0%
Open fire - wood	3%	148	3	4%
Open fire – coal	1%	30	1	1%
Total Wood burner	58%	2,596	69	87%
Pre 1995 wood burner	25%	1,110	29	55%
1995-2000 wood burner	16%	698	18	18%
Post 2000 wood burner	18%	788	21	14%
Multi fuel burners	6%	252	-	0%
Multi fuel burners-wood	6%	252	4	5%
Multi fuel burners-coal	3%	119	1	1%
Pellet burners	1%	30	0.2	0%
Total wood	67%	2,997	75	96%
Total coal	3%	148	2	2%
Total		4,451	78	0%

Seasonal variations in home heating methods and fuel use are shown in Table 3.2.

Table 3-2: Seasonal variations in home heating methods and fuel use in Tokoroa:

Percentage of houses using this method that use it during each month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Gas	0%	0%	1%	14%	75%	91%	91%	78%	41%	13%	3%	1%
Open fire	0%	0%	10%	10%	90%	90%	90%	80%	50%	20%	0%	0%
Wood burner	1%	1%	2%	21%	79%	94%	95%	91%	59%	21%	6%	2%
Pellet burner	0%	0%	0%	50%	100%	100%	100%	100%	100%	50%	50%	0%
Multi fuel	6%	6%	6%	24%	82%	88%	94%	88%	59%	35%	18%	6%
Oil	0%	0%	0%	0%	50%	100%	100%	100%	50%	0%	0%	0%
Average number of days per week house is heated (by those that actually use heat during that month)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Gas			4	5	5	6	6	6	5	4	2	1
Open fire			7	7	6	6	6	6	7	7		
Wood burner	5	5	5	6	6	6	6	6	6	6	6	5
Pellet burner				7	7	7	7	7	7	7	7	
Multi fuel	7	7	7	7	5	6	6	6	6	6	7	7
Oil					7	5	5	5	7			
Daily fuel use (tonnes)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Gas	-	-	-	0	1	1	1	1	0	0	0	0
Open fire wood	-	-	-	-	2	3	3	3	5	2	-	-
Open fire coal	-	-	-	-	0	1	1	1	0	-	-	-
Wood burner	2	2	2	19	52	67	69	65	48	22	12	2
Multi fuel wood	1	1	1	1	3	4	4	4	5	4	3	1
Multi fuel coal	-	-	-	-	1	1	1	1	1	0	0	-

Daily fuel use (kg)/ total number of households that heat with that method												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Gas	-	-	-	0.0	0.6	0.7	0.6	0.5	0.2	0.0	0.0	0.0
Open fire wood	-	-	-	-	10.9	17.7	17.7	17.7	34.8	12.7	-	-
Open fire coal	-	-	-	-	2.6	18.0	18.0	18.0	3.0	-	-	-
Wood burner	0.7	0.7	0.9	7.2	20.1	25.8	26.5	25.0	18.3	8.3	4.6	0.8
Multi fuel wood	5.7	5.7	5.7	5.7	12.4	16.1	15.5	15.7	20.4	15.7	12.8	5.7
Multi fuel coal	-	-	-	-	4.8	8.7	8.7	8.7	6.0	3.0	3.0	-

4 Emissions from domestic heating

Table 4.1 outlines the emissions estimates for Tokoroa for 2005 for a worst-case scenario, which assumes all households are using their specified heating methods on any given night. The average case scenario is presented in Table 4.2, which takes into account the average number of days per week each heating method is used during July.

For the worst-case scenario around 0.8 tonnes of PM_{10} are emitted per day during the winter months. This decreases to around 0.7 tonnes per day for the average case scenario. The daily estimated PM_{10} for 2004 for the worst-case scenario was 0.6 tonnes. The difference occurs because of the slightly higher average fuel use reported for 2005 and because a greater proportion of wood burners were estimated to be in the older (greater than 10 years) category. The ability of householders to estimate the age of a burner is limited and these data are likely to contain a high degree of uncertainty.

Figure 4.1 shows the relative contribution of different sources to PM_{10} emissions on an average winter's day for Tokoroa. The greatest amount of PM_{10} from domestic home heating emissions occurs as a result of the burning of wood on older pre 1995 wood burners.

Monthly variations in appliance use and average days per week used are shown in Figures 4.2 and 4.3. These show that only a small proportion of houses heat their homes using solid fuel burning during the months October to March. Households using wood burners during the non-winter months typically burn on an average of five days per week during the non-winter months. The impact of seasonal variations in home heating on air emissions is shown in Table 4.3 and Figure 4.4.

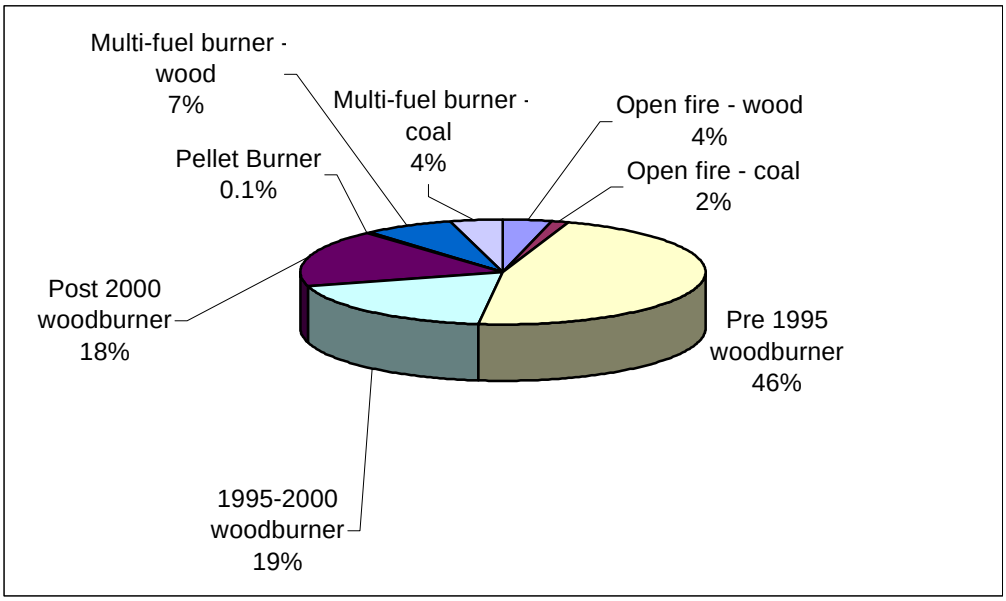

Figure 4-1: Relative contribution of different heating methods to average daily wintertime PM10 from domestic heating in Tokoroa

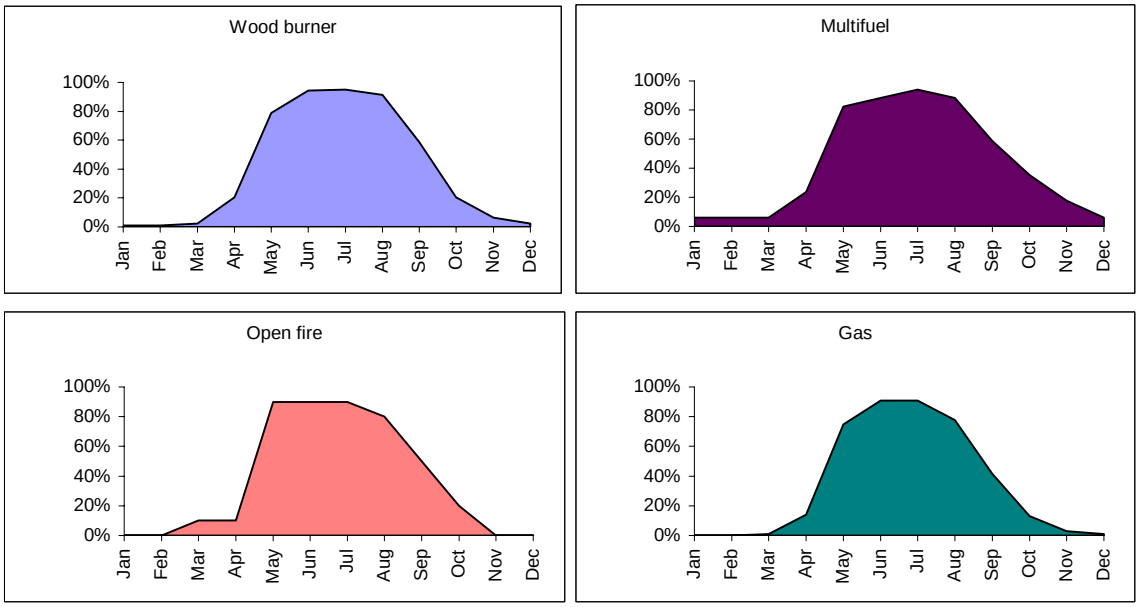

Figure 4-2: Monthly variations in appliance use in Tokoroa. Y-axis shows percentage of households that use a particular appliance, if it is available in the house.

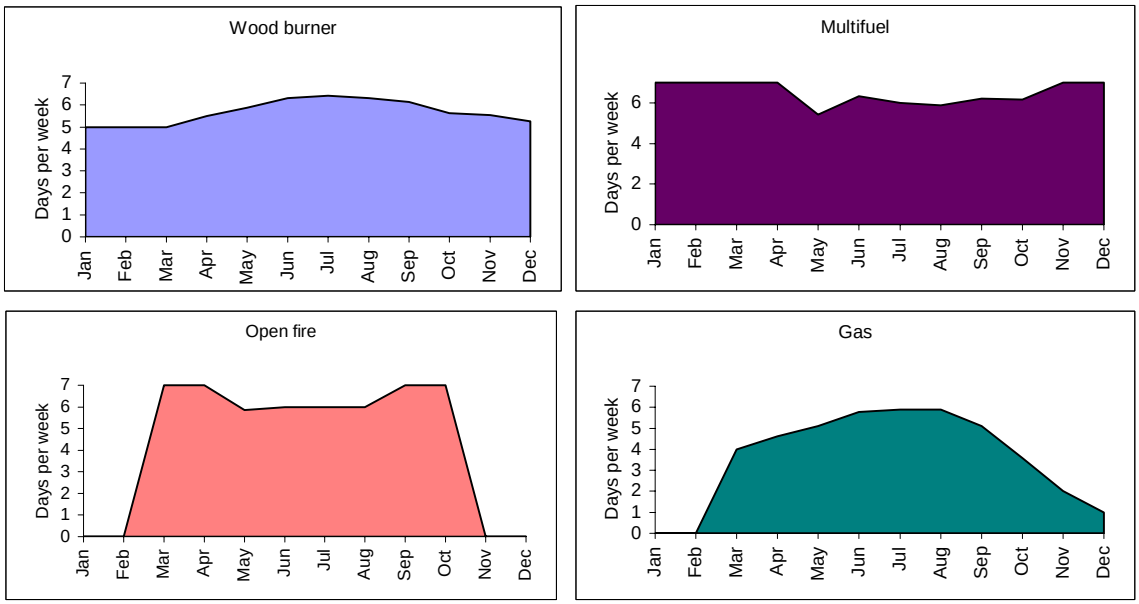

Figure 4-3: Average number of days per week appliances are used in Tokoroa per month

Table 4-1: Tokoroa worst-case winter daily domestic heating emissions by appliance type

	Fuel Use		PM10			CO			NOx			SOx			VOC			CO2			PM2.5			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	3.6	4%	36	31	4%	362	305	5%	6	5	11%	1	1	3%	109	92	5%	6	5	4%	36	31	5%	4	3	4%
Open fire - coal	0.5	1%	11	9	1%	43	36	1%	2	2	4%	3	2	11%	8	7	0%	1	1	1%	6	5	1%	0	0	0%
Wood burner																										
Pre 1990 wood burner	33.7	37%	371	313	46%	3707	3128	47%	17	14	32%	7	6	29%	1112	938	48%	54	45	36%	371	313	47%	33	28	38%
1991-1995 wood burner	21.2	23%	148	125	18%	1484	1252	19%	11	9	20%	4	4	18%	445	376	19%	34	29	23%	148	125	19%	21	17	24%
1996-2000 wood burner	23.9	26%	143	121	18%	1435	1211	18%	12	10	23%	5	4	20%	430	363	19%	38	32	26%	143	121	18%	23	20	27%
Pellet Burner	0.2	0%	0	0	0%	5	4	0%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel burner																										
Multi fuel burner – wood	5.1	6%	67	56	8%	667	563	9%	3	2	5%	1	1	4%	200	169	9%	8	7	6%	67	56	8%	5	4	6%
Multi fuel burner – coal	1.1	1%	30	25	4%	128	108	2%	1	1	2%	3	3	14%	16	14	1%	3	2	2%	17	14	2%	0	0	0%
Gas	1.3	1%	0	0	0%	0	0	0%	2	1	3%	0	0	0%	0	0	0%	3	3	2%	0	0	0%	0	0	0%
Oil	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	88	97%	766	646	95%	7659	6463	98%	48	40	90%	18	15	75%	2298	1939	99%	140	119	95%	766	646	97%	85	72	100%
Total Coal	2	2%	41	35	5%	171	144	2%	3	3	6%	6	5	25%	24	20	1%	4	4	3%	23	20	3%	0	0	0%
Total	91		807	681		7830	6608		53	45		23	20		2322	1959		148	125		789	666		85	72	

Table 4-2: Tokoroa average winter daily domestic heating emissions by appliance type (July)

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$			Benzene		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	t	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	2.6	3%	26	22	4%	263	222	4%	4	4	9%	1	0	2%	79	67	4%	4	4	3%	26	22	4%	3	2	3%
Open fire - coal	0.5	1%	11	9	2%	43	36	1%	2	2	5%	3	2	13%	8	7	0%	1	1	1%	6	5	1%	0	0	0%
Wood burner																										
Pre 1990 wood burner	29.4	38%	323	273	46%	3232	2727	48%	15	12	32%	6	5	28%	969	818	49%	47	40	37%	323	273	48%	28	24	39%
1991-1995 wood burner	18.5	24%	129	109	19%	1294	1092	19%	9	8	20%	4	3	17%	388	327	20%	30	25	23%	129	109	19%	18	15	24%
1996-2000 wood burner	20.8	27%	125	106	18%	1251	1056	19%	10	9	23%	4	4	20%	375	317	19%	33	28	26%	125	106	18%	20	17	28%
Pellet Burner	0.2	0%	0.5	0	0%	5	4	0%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel burner																										
Multi fuel burner – wood	3.9	5%	51	43	7%	510	430	8%	2	2	4%	1	1	4%	153	129	8%	6	5	5%	51	43	8%	4	3	5%
Multi fuel burner – coal	1.0	1%	29	24	4%	124	104	2%	1	1	3%	3	3	15%	15	13	1%	3	2	2%	16	14	2%	0	0	0%
Gas	1.0	1%	0	0	0%	0	0	0%	1	1	3%	0	0	0%	0	0	0%	2	2	2%	0	0	0%	0	0	0%
Oil	0.1	0%	0	0	0%	0	0	0%	0	0	1%	0	0	2%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	75.5	97%	655	553	94%	6554	5531	98%	41	34	89%	15	13	71%	1966	1659	99%	121	102	95%	655	553	97%	73	62	100%
Total Coal	1.6	2%	40	34	6%	166	140	2%	3	3	7%	6	5	27%	23	20	1%	4	3	3%	23	19	3%	0	0	0%
Total	78		696	587		6720	5671		46	38		21	18		1990	1679		128	108		678	572		73	62	

Table 4-3: Monthly variations in domestic heating emissions in Tokoroa

	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	35	346	2	1	104	5	35
February	35	346	2	1	104	5	35
March	39	390	2	1	117	6	39
April	176	1760	10	4	528	32	176
May	514	5040	33	14	1499	96	507
June	684	6604	45	21	1955	125	667
July	696	6720	46	21	1990	128	678
August	664	6409	43	21	1896	121	647
September	541	5281	37	14	1568	96	531
October	261	2556	16	7	759	45	257
November	153	1476	8	4	435	26	149
December	36	355	2	1	107	6	36
Total (kg/ year)	117159	1139604	7477	3323	338120	21136	114795

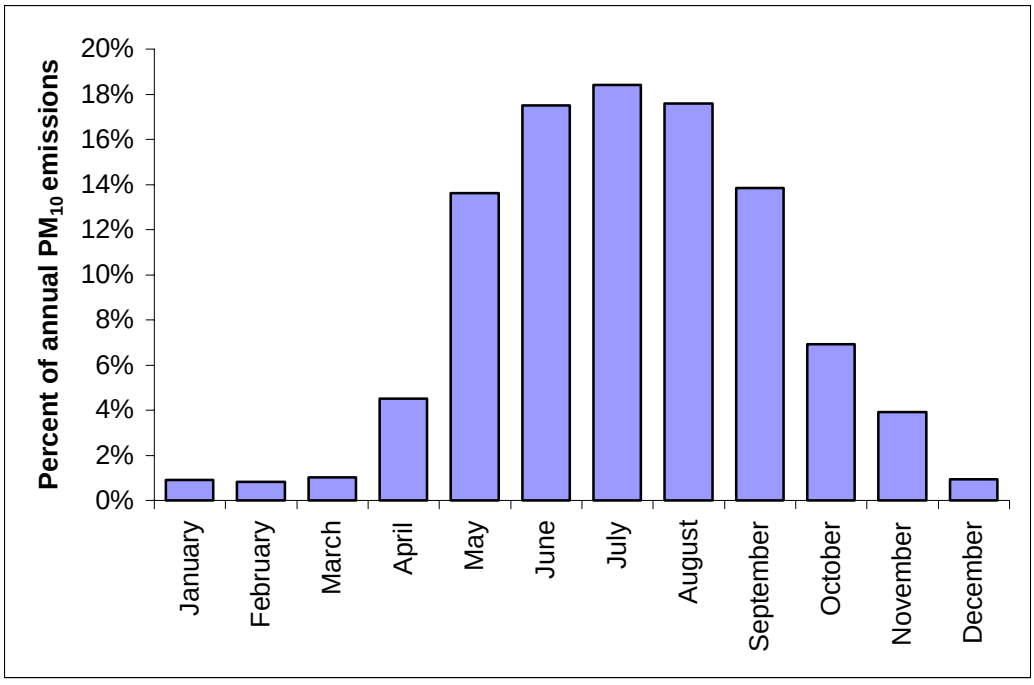

Figure 4-4: Figure 4.4: Proportion of annual PM10 emissions that occur during each month of the year

5 Outdoor Burning

Around 42 kilograms per day of PM_{10} is emitted from outdoor burning in Tokoroa during the winter months (Table 5.1). Seasonal variations in emissions from outdoor burning are minimal with around 45 kilograms per day being emitted during spring and summer. Figure 5.1 shows the proportion of annual PM_{10} from outdoor burning that occurs during different months of the year.

Table 5-1: Daily emissions from outdoor burning in Tokoroa by month

Outdoor burning	PM_{10}	CO	NOx	SOx	VOC	CO_2	$PM_{2.5}$	Benzene
	kg	kg	kg	kg	kg	t	kg	kg
January	45	150	11	2	15	5	42	2
February	45	150	11	2	15	5	42	2
March	42	141	10	2	14	5	39	2
April	42	141	10	2	14	5	39	2
May	42	141	10	2	14	5	39	2
June	42	142	10	2	15	5	40	2
July	42	142	10	2	15	5	40	2
August	42	142	10	2	15	5	40	2
September	45	150	11	2	15	5	42	2
October	45	150	11	2	15	5	42	2
November	45	150	11	2	15	5	42	2
December	45	150	11	2	15	5	42	2
Total (kg/ year)	15835	53205	3800	633	5447	1862	14821	633

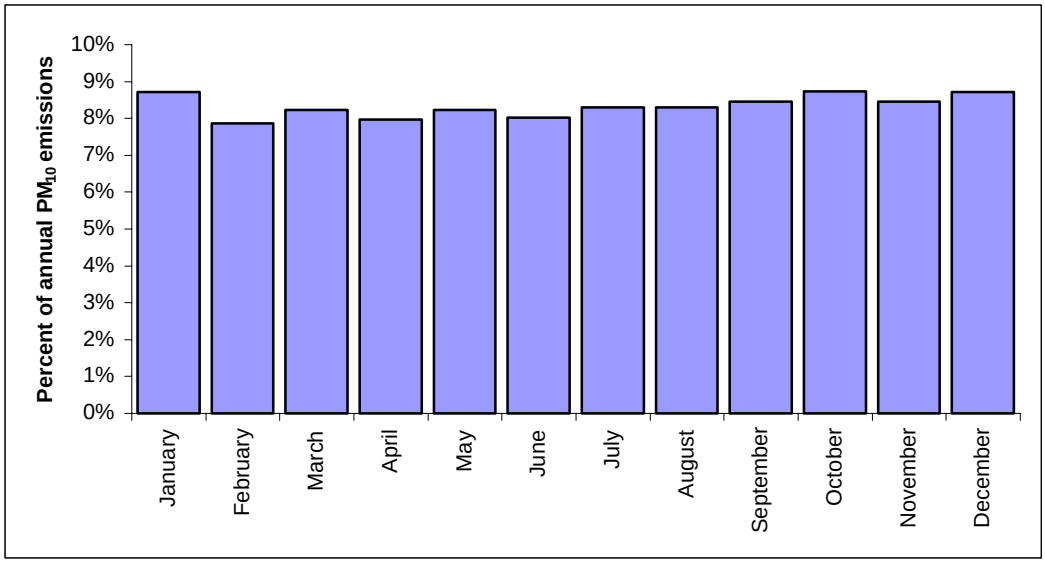

Figure 5-1: Proportion of annual PM10 from outdoor burning in Tokoroa by month

6 Seasonal contributions – all sources

Motor vehicle and industrial/ commercial emission estimates from the 2004 inventory were combined with domestic heating and outdoor burning emission estimates from this study to evaluate the seasonal variation of relative source contributions to PM_{10} emissions in Tokoroa. In addition, data were used to estimate the relative contribution of different sources to annual PM_{10} emissions. All estimates were based on the assumption of no significant seasonal variations in motor vehicle and industrial emissions.

Table 6.1 shows average daily mass emissions of PM_{10} from various sources in Tokoroa by month of year. Significant monthly variations in emission rates are a

consequence of variable domestic home heating emissions. Industrial emission estimates are for the Tokoroa area only and do not include contributions that might originate from the Kinleith pulp and paper plant located approximately 5 kilometres to the south-east.

Table 6.2 shows the relative contribution of different sources to PM_{10} emissions by month of the year. During the summer months, domestic heating, outdoor burning and motor vehicles are the main contributors to PM_{10} emissions. Overall, domestic home heating contributes around 79% of the annual PM_{10} emissions in Tokoroa (Figure 6.1). It is important to note that this is not necessarily an estimate of the relative contribution of different sources to annual average PM_{10} concentrations because the ambient PM_{10} concentrations are also affected by seasonal variations in meteorological conditions.

Table 6-1: Monthly variations in daily PM10 emissions in Tokoroa

	Domestic Heating kg/day	Outdoor burning kg/day	Industry kg/day	Motor vehicles kg/day	Total
January	35	45	6	40	125
February	35	45	6	40	125
March	39	42	6	40	127
April	176	42	6	40	264
May	514	42	6	40	602
June	684	42	6	40	772
July	696	42	6	40	784
August	664	42	6	40	753
September	541	45	6	40	631
October	261	45	6	40	352
November	153	45	6	40	244
December	36	45	6	40	126
Total kg year	117159	15835	2190	14600	149784

Table 6-2: Relative contribution of sources to monthly and annual PM10 emissions in Tokoroa:

	Domestic Heating	Outdoor burning	Industry	Motor vehicles
January	28%	36%	5%	32%
February	28%	36%	5%	32%
March	31%	33%	5%	31%
April	67%	16%	2%	15%
May	85%	7%	1%	7%
June	89%	5%	1%	5%
July	89%	5%	1%	5%
August	88%	6%	1%	5%
September	86%	7%	1%	6%
October	74%	13%	2%	11%
November	63%	18%	2%	16%
December	28%	35%	5%	32%
Total contribution (annual)	78%	11%	1%	10%

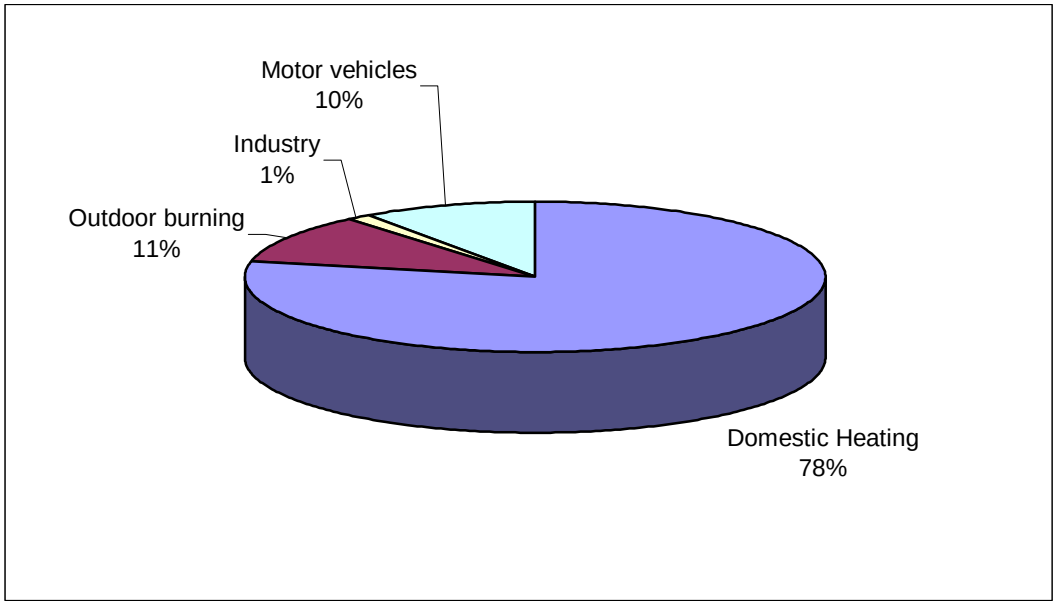

Figure 6-2: Relative contribution of sources to annual PM10 emissions in Tokoroa

7 Source contribution to annual average PM_{10} concentrations

An estimate of the contribution of these different sources to annual average PM_{10} concentrations can be made using a combination of daily PM_{10} concentrations and the seasonal data on the estimated proportion of emissions coming from each source (i.e., Table 6.2). This analysis indicates that domestic heating contributed around 69% of the annual average PM_{10} concentrations for 2004, with outdoor rubbish burning contributing 15%, motor vehicles 14% and industry 2% if it is assumed that Kinleith does not contribute at all to annual average PM_{10} concentrations in Tokoroa (Figure 7.1).

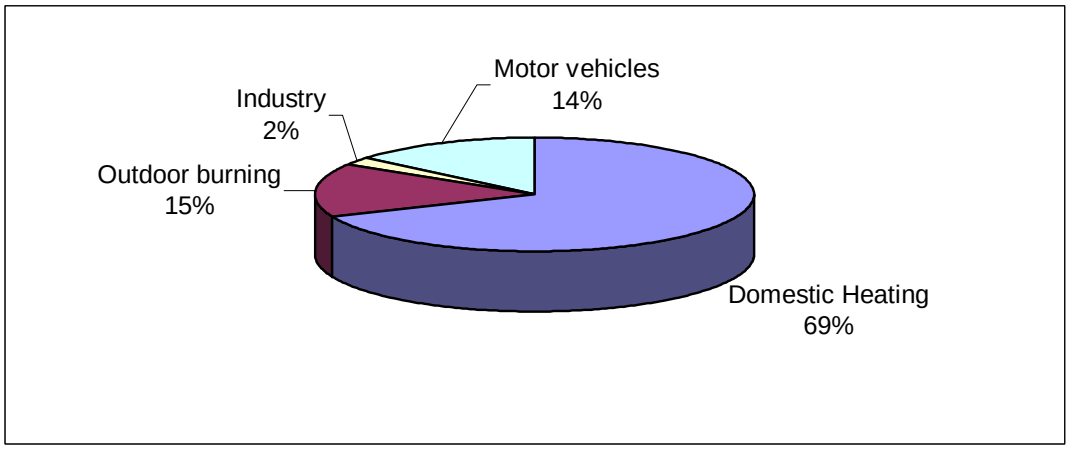

Figure 7-1: Estimated contribution to 2004 annual average PM10 concentrations in Tokoroa

Note this is a fairly simple methodology that does not take into account the impact of daily variations in meteorological conditions. In particular, on days when meteorological conditions are most conducive to elevated pollution, temperature

inversion and low wind speeds occur during the evening and early morning periods and result in higher concentrations. Predominant sources during these periods are therefore likely to have a greater impact on 24-hour average PM_{10} concentrations.

The impact of daily variations in meteorological conditions on the relative contribution of different sources to PM_{10} concentrations has been examined in Christchurch (Foster, 1998) based on a box model developed by Gimson & Fisher (1997). In Christchurch this effect resulted in an increase in the domestic heating contribution to 24-hour average PM_{10} concentrations from 82% to 90%. However, this relationship for Christchurch only applies to days of worst-case meteorological conditions. It would seem likely that the impact on annual average PM_{10} concentrations in Tokoroa would be to increase the domestic home heating component by a few percentage points.

The other more significant uncertainty is the contribution of Kinleith to annual average PM_{10} concentrations. While previous studies (e.g., Wilton, 2004b) suggest that the contribution is likely to be minimal on days of high pollution, the potential for contribution to annual average concentrations has not been evaluated.

8 Conclusions

This study examined seasonal variations in domestic home heating emissions, to determine the impact of this source across all months of the year. A secondary objective was to evaluate seasonal variations in outdoor rubbish burning. Both objectives were achieved using a domestic home heating survey of home heating methods and fuels and outdoor burning for each month of the year, combined with existing emission factor data.

Results indicated that the domestic heating contribution to daily PM_{10} emissions ranged from 28% during the summer months to 89% during the winter. Other significant contributors during the summer months were outdoor burning (35%) and motor vehicles (32%). Overall the domestic heating contribution to total annual PM_{10} emissions was around 78%.

To estimate the impact of different sources on annual average PM_{10} concentrations, the proportion of daily PM_{10} concentrations from each source were evaluated based on the monthly emissions data. Results suggested that domestic heating contributes around 69% of the annual average PM_{10} concentrations with motor vehicles, industry and outdoor burning each contributing 14%, 2% and 15%. No assessment of the contribution from Kinleith or natural sources was included in the analysis.

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

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

2b. Do you use any other heating system in your main living area in a typical year? *(If yes then question 3 otherwise Q9)*

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

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

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

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

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

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

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

(f) What size gas bottle do you use?

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

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

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

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

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

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

(d) How old is your log burner?

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

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

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

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

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

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

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

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

(d) How old is your multi fuel burner?

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

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

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

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

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

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

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

during the other months?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(d) How old is your pellet burner?

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

(e) and what model is your pellet burner?

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

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

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

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

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

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

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

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

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

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

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

How many days would you burn rubbish outdoors during

a) winter (June, July, August)

b) spring (September, October, November)

c) summer (December, January, February)

d) autumn (March, April, May)

How much garden waste or rubbish would you burn each session. We are looking for cubic metres, or number of wheelbarrows full per fire.

10. Does you home have insulation?

- Ceiling
- Under floor
- Wall
- Cylinder wrap
- Double glazing
- None
- Don't know
- Other

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

d1. Would you mind telling me in what year you were born ?

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

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

D3 With which ethnic group do you most closely relate?

Interviewer: tick gender.

How many people live at your address?

Do you own your home or rent it?

D5 What is your employment status:

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