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Air emission inventory – Te Kuiti and Putaruru 2015

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Air Emission Inventory – Te Kuiti and Putaruru 2015

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EXECUTIVE SUMMARY

Particles in the air less than 10 microns in diameter (PM_{10}) are the main air contaminant of concern in Te Kuiti and Putaruru. Prior to 2010 concentrations of PM_{10} exceeded the National Environmental Standard (NES) limit of 50 µg/m^3 at the Te Kuiti monitoring site with concentrations of up to 70 µg/m^3 being recorded and exceedences of 50 µg/m^3 occurring on 3-7 occasions per year. Since 2013, Te Kuiti has been compliant with the NES for PM_{10} (which allows for one exceedance of 50 µg/m^3 per year) with only one exceedance of 50 µg/m^3 recorded during each of 2011 and 2012 and none during 2013 and 2014. The 2012 exceedences constituted a breach of the NES because it was less than 12 months since the 2011 exceedence. In Putaruru breaches of the NES occurred in 2011 and 2014. During 2010 and 2011 only one exceedance of 50 µg/m^3 was recorded per year but with less than a year between the 2010 and 2011 exceedence a breach of the NES occurred. During 2012 and 2013 no exceedences were recorded but two exceedences during March and April 2014 constituted a further breach of the NES. Data for both sites suggest a decrease in PM_{10} emissions has occurred since monitoring commenced. The purpose of this emission inventory is to evaluate changes in emissions to air and the contribution of different sources to these emissions in Te Kuiti and Putaruru.

Sources included in the inventory are domestic heating, motor vehicle, industrial and commercial activities and outdoor burning. Natural source contributions (for example; sea salt and soil) are not included because the methodology to estimate emissions is less robust. While the evaluation focuses on PM_{10} other contaminants also evaluated include: carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds, carbon dioxide, benzene and benzo(a)pyrene.

A domestic home heating survey was undertaken to determine the proportions of households using different heating methods and fuels. The results show that electricity was the most common method of heating the main living area with 61% and 58% of households in Te Kuiti and Putaruru using it respectively. Just less than half of the households in both areas use wood burners to heat the main living area. Many households use more than one heating method.

Domestic heating is the main source of PM_{10} emissions in Te Kuiti accounting for 78% of daily winter emissions. The other main source is industry which contributes 16%. On an average winter’s night, around 212 kilograms of PM_{10} are discharged from these sources. This compares with around 231 kg/day in Te Kuiti in 2007 (after adjusting for differences in methodology) and represents a 14% reduction.

In Putaruru the domestic heating contribution was 94% with minor contributions from outdoor burning and transport. Around 131 kilograms per day of PM_{10} is discharged in Putaruru on an average winter’s day. A reduction in daily winter PM_{10} emissions of around 63% is estimated for Putaruru since 2006.

1 INTRODUCTION

The main air contaminant of concern in Te Kuiti and Putaruru is PM_{10}, particles in the air less than 10 microns in diameter. Prior to 2010 concentrations of PM_{10} exceeded the National Environmental Standard (NES) limit of 50 µg/m^3 at the Te Kuiti monitoring site with concentrations up to 70 µg/m^3 being recorded and exceedences of 50 µg/m^3 occurring on 3-7 occasions per year. Since 2013, Te Kuiti has been compliant with the NES for PM_{10} (which allows for one exceedance of 50 µg/m^3 per year) with only one exceedance of 50 µg/m^3 recorded during each of 2011 and 2012 and none during 2013 and 2014. The 2012 exceedences constituted a breach of the NES because it was less than 12 months since the 2011 exceedence. In Putaruru breaches of the NES occurred in 2011 and 2014. During 2010 and 2011 only one exceedance of 50 µg/m^3 was recorded per year but with less than a year between the 2010 and 2011 exceedence a breach of the NES occurred. During 2012 and 2013 no exceedences were recorded but two exceedences during March and April 2014 constituted a further breach of the NES. Data for both sites suggest a decrease in PM_{10} emissions has occurred since monitoring commenced.

The purpose of this emission inventory is to evaluate changes in emissions to air and the contribution of different sources to these emissions over time to evaluate the extent of any decrease in emissions, where possible.

Sources included in the assessment are domestic heating, motor vehicle, industrial and commercial and outdoor burning. Natural source contributions (for example; sea salt and soil) are not included because methodologies are less robust. This report primarily focuses on emissions of particles (PM_{10}) from these sources. Other contaminants included in this emission inventory are carbon monoxide, nitrogen oxides, sulphur oxides volatile organic compounds, carbon dioxide, benzene and benzo(a)pyrene.

A previous assessment of emissions to air for Te Kuiti was carried out in 2007 and in 2006 for Putaruru. Changes in PM_{10} emissions for both areas will be assessed although the Putaruru assessment is less robust owing to assumptions regarding changes in other sources.

2 INVENTORY DESIGN

This emission inventory focuses on PM_{10} emissions as PM_{10} has been identified as the main contaminant of concern in urban New Zealand. It is unlikely that concentrations of other contaminants are likely to exceed National Environmental Standards (NES).

No national environmental standards exist for benzo(a)pyrene (BaP). However, concentrations of this contaminant have been found to be high and in excess of ambient air quality guidelines in Christchurch. A strong correlation was found with PM_{10} concentrations, which in Christchurch occur as a result of emissions from domestic home heating, and BaP concentrations (McCauley, 2005). In Hamilton, where PM_{10} concentrations rarely exceed 50 µg/m^3 the annual average concentration for BaP was measured as 0.4 ng/m^3 for the period March 2007 to March 2008. This result was statistically indistinguishable from the annual average guideline for BaP of 0.3 ng m^{-3}. However, the results reinforce the potential for high BaP concentrations within the Waikato Region in areas that have PM_{10} concentrations that are higher than Hamilton and result from domestic home heating.

2.1 Selection of sources

Estimates of emissions from the domestic heating, motor vehicles, industry and outdoor burning sector are included in the emissions inventory. The report also discusses PM_{10} emissions from a number of other minor sources.

2.2 Selection of contaminants

The inventory included an assessment of emissions of suspended particles (PM_{10}), carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), carbon dioxide (CO_2), benzene and benzo(a)pyrene (BaP). The latter contaminant has been included here because of the potential issues identified above.

Emissions of PM_{10}, CO, SOx and NOx are included as these contaminants are NES contaminants because of their potential for adverse health impacts. Carbon dioxide has been typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas CO_2 emissions. However, these data are now generally collected nationally and for a broader range of greenhouse gases. Estimates of CO_2 have been retained in the inventory but readers should be directed to national statistics (e.g., www.climatechange.govt.nz.) should detailed data on this source be required. Volatile organic compounds are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. It is unlikely that ozone formation from emissions within Te Kuiti or Putaruru would cause ozone problems. However, ozone formation as a result of emissions from Auckland could impact on some areas of the Waikato. In this report, VOC emissions have been estimated for existing sources but data on emissions from VOC specific sources (e.g., spray painting) has not been included.

2.3 Selection of areas

Te Kuiti is located in the Waitomo District of the Waikato, situated on the floor of the valley of the Mangaokewa Stream, about 2 miles north of the entrance to the Mangaokewa Gorge. The surrounding country is undulating to hilly, and rises on the west to the Hauturu Range and on the east to the Rangitoto Range. Te Kuiti is 79 kilometres south of Hamilton by road. The Te Kuiti airshed is shown in Figure 2.1. The Te Kuiti inventory area is based on the Te Kuiti census area unit (Statistics New Zealand, 2013).

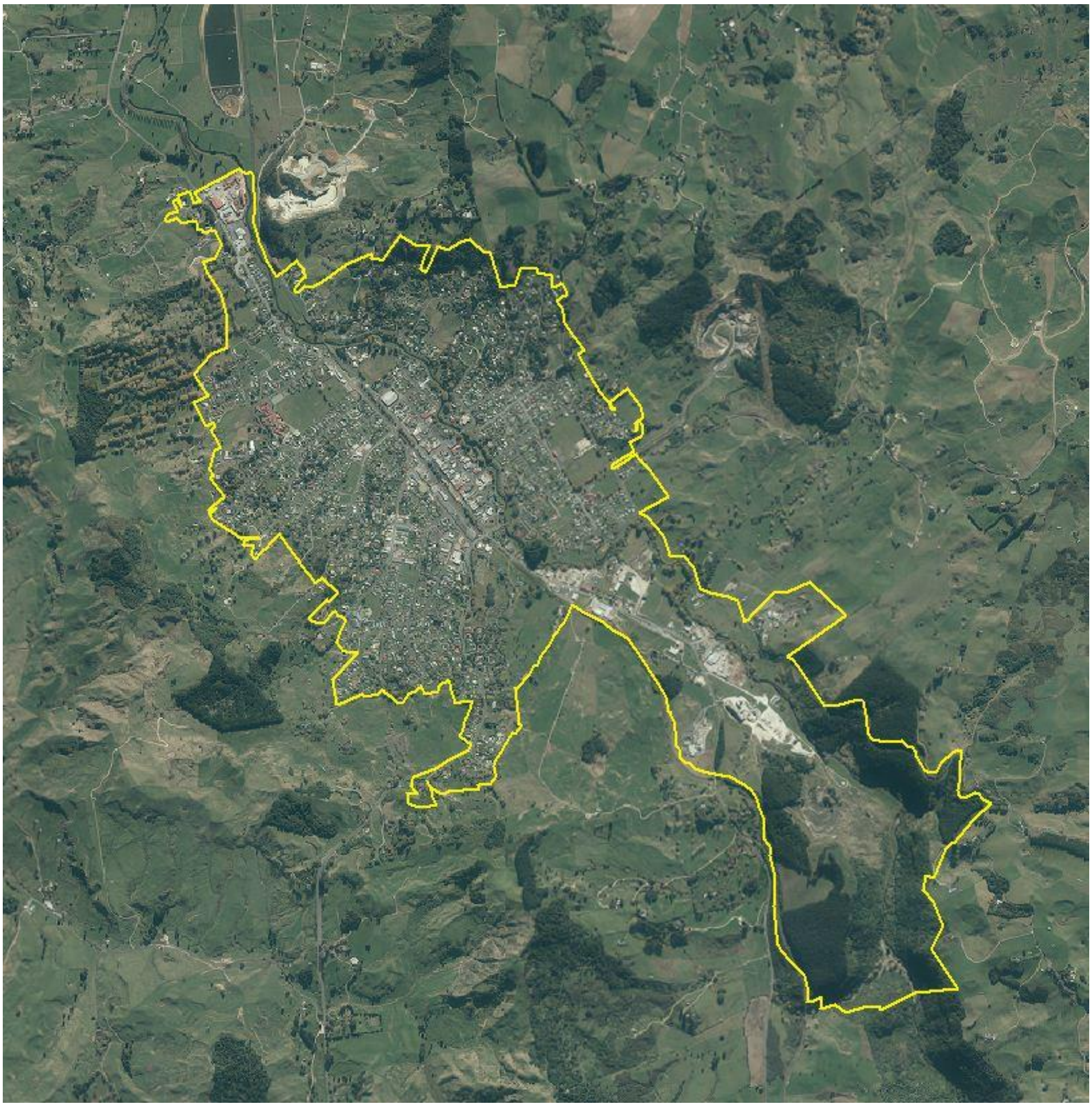

Figure 2.1: Te Kuiti Airshed (source Waikato Regional Council).

Putaruru is a small town in the Waikato region of New Zealand's North Island. It is on the Oraka River 65 kilometres south-east of Hamilton. Figure 2.2 shows the Putaruru Airshed boundary.

Figure 2.2: Putaruru Airshed (source Waikato Regional Council).

2.4 Temporal distribution

Data were collected based on daily data with some seasonal variations. Domestic heating data were collected based on average and worst-case wintertime scenarios and by month of the year. Motor vehicle data were collected for an average day as models do not contain seasonal variations in vehicle movements. Industrial data were collected by season as was outdoor burning data.

No differentiation was made for weekday and weekend sources. Limited time of day breakdowns were obtained for the data.

3 DOMESTIC HEATING

3.1 Methodology

Domestic heating methods and fuel used by households in Te Kuiti and Putaruru were collected using a household survey carried out by Digipol Limited during May and June 2015 (Appendix A). Table 3.1 shows the number of households based on 2013 census data for the Airshed area and survey details.

Table 3.1: Summary household, area and survey data for the Te Kuiti and Putaruru Airsheds.

	Households by census area unit 2013	Sample size	Area (ha)	Sample error
Te Kuiti	1581	305	557	5%
Putaruru	1521	305	430	5%

Home heating methods were classified as; electricity, open fires, wood burners 10 years or older (pre 2006), wood burners five to 10 years old (2006-2010), wood burners less than five years old (post 2010), pellet fires, multi fuel burners, gas burners and oil burners. The 2006-2010 and post 2010 wood burner categories would contain wood burners meeting the NES design criteria.

Emission factors were applied to the results of the home heating survey to provide an estimate of emissions for each study area. The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. The basis for these is detailed in Appendix B.

Table 3.2: Emission factors for domestic heating methods.

	PM_{10} g/kg	CO g/kg	NOx g/kg	SO_2 g/kg	VOC g/kg	CO_2 g/kg	Benzene g/kg	BaP g/kg
Open fire - wood	7.5	55	1.2	0.2	30	1600	0.97	0.002
Open fire - coal	21	70	4	8	15	2600	0.00065	2.70E-06
Pre 2006 burners	10	140	0.5	0.2	33	1600	0.97	0.003
Post 2005 burners	4.5	45	0.5	0.2	20	1600	0.97	0.003
Pellet burners	2	20	0.5	0.2	20	1600	0.97	0.003
Multi-fuel[1] - wood	10	140	0.5	0.2	20	1600	0.97	0.002
Multi-fuel[1] – coal	19	110	1.6	8	15	2600	0.97	2.70E-06
Oil	0.3	0.6	2.2	3.8	0.25	3200	0.00065	
Gas	0.03	0.18	1.3	7.6E-09	0.2	2500	2.16E-05	

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

The average weight for a log of wood is one of the assumptions required for this inventory to convert householder's estimates of fuel use in logs per evening to a mass measurement required for estimating emissions. Average log weights used for inventories in New Zealand have included 1.6 kilograms, 1.4 kilograms and more recently, 1.9 kilograms. The latter value is based on a survey of 219 households in Christchurch during 2002 and represents the most comprehensive assessment of average fuel weight. A recent burner emission testing programme carried out in Tokoroa during 2005 gave an average log weight of 1.3 kilograms. The sample size (pieces of wood weighed) for this study was 845. These were spread across only 12 households so it is uncertain how representative of the Tokoroa population a fuel weight of 1.3 kilograms per log might be. More recently a similar study was carried out in Nelson, Rotorua and Taumaranui. Results of fuel use from that study indicated an average fuel weight of 1.7 kilograms per log. The previous inventory for Te Kuiti ((Wilton & Baynes, 2007)) used 1.3 kg. However, based on an evaluation of all sources of information it is recommended that a value of 1.6 kg be used for this inventory.

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

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

Where:

CE = contaminant emission

EF = emission factor

FB = fuel burnt

The main assumptions underlying the emissions calculations are as follows:

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

3.2 Home heating methods in Te Kuiti

The most popular form of heating the main living area of homes in Te Kuiti is electricity with 61% of households using that method. Wood burners are also popular with 46% of households using them. Around 11% of households used gas for home heating and 5% use open fires. Table 3.3 also shows that households rely on more than one method of heating their main living area during the winter months.

Around 22 tonnes of wood is burnt per typical winter's night in Te Kuiti and 0.3 tonnes of coal. In 2007 the amount of wood used on average per night was around 17 tonnes[1] and around 1.2 tonnes of coal was used per night.

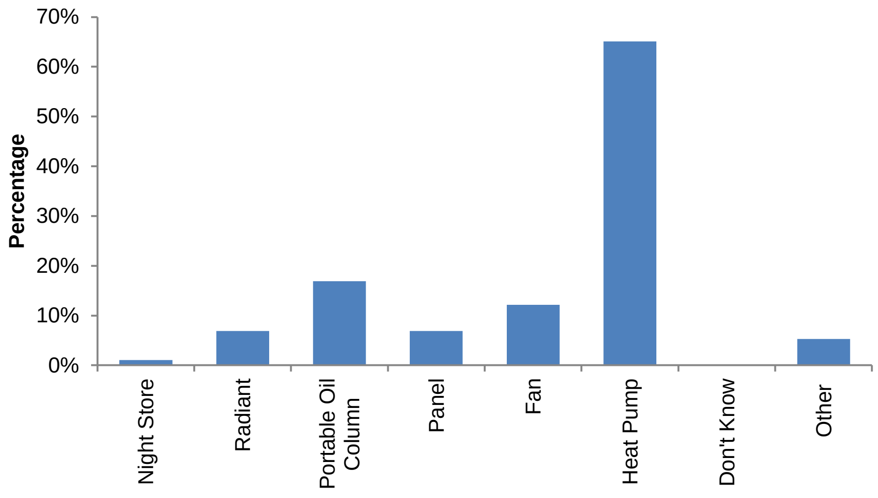

Figure 3.1: Electric heating options for Te Kuiti households (main living area).

[1] Adjusting for differences in assumptions regarding the average weight of a log of wood, i.e., multiplying by 1.6/1.3.

Table 3.3: Home heating methods and fuels in Te Kuiti.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	61%	970		
Total Gas	11%	175	0.04	0%
Flued gas	5%	76		
Unflued gas	6%	99		
Oil	0%	0	0	0%
Open fire	5%	82		
Open fire - wood	5%	82	1.9	8%
Open fire - coal	1%	15	0.1	1%
Total Woodburner	46%	729	20.2	89%
Pre 2006	21%	338	9.4	41%
2006-2010 wood burner	11%	169	4.7	21%
Post-2010 wood burner	14%	222	6.1	27%
Multi-fuel burners	3%	46		
Multi-fuel burners-wood	0.6%	10	0.3	1%
Multi-fuel burners-coal	1%	15	0.2	1%
Pellet burners	0%	0		0%
Total wood	52%	821	22	98%
Total coal	2%	31	0	1%
Total		1,581	23	100%

3.3 Home heating methods in Putaruru

Table 3.4 shows electricity is the main heating method in Putaruru and is used by 58% of households to heat their main living area. Heat pumps were the most common type of electric heating method being used by 60% of households using electricity (Figure 3.2). Wood burners are also a popular heating method in Putaruru with 47% of households opting for these devices. Around 17% of households used gas for home heating. Table 3.4 also shows that households rely on more than one method of heating their main living area during the winter months.

Around 17 tonnes of wood is burnt per typical winter's night in Putaruru and less than one tonne of coal.

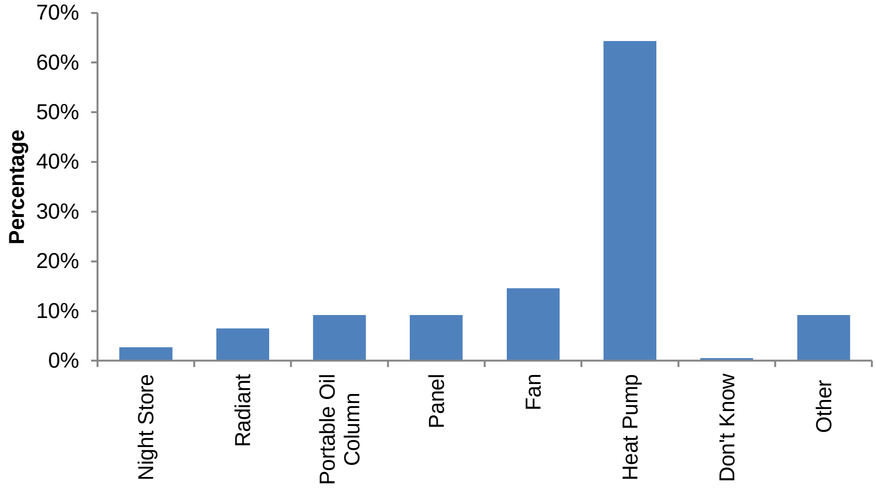

Figure 3.2: Electric heating options for Putaruru households (main living area).

Table 3.4: Home heating methods and fuels in Putaruru.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	58%	879		
Total Gas	17%	252	0.0	0%
Flued gas	11%	173		
Unflued gas	5%	79		
Oil	1%	14	0.0	0%
Open fire	1%	14		
Open fire - wood	1%	14	0.2	1%
Open fire - coal	0%	0	0.0	0%
Total Woodburner	47%	718	16.5	97%
Pre 2006	23%	346	8.0	47%
2006-2010 wood burner	12%	183	4.2	25%
Post-2010 wood burner	12%	189	4.3	25%
Multi-fuel burners	2%	24		
Multi-fuel burners-wood	1%	10	0.2	1%
Multi-fuel burners-coal	1%	10	0.1	1%
Pellet burners	1%	14	0.0	0.0%
Total wood	49%	741	17	99%
Total coal	1%	10	0.1	1%
Total		1,521	17	

3.4 Emissions from domestic heating in Te Kuiti

Around 165 kilograms of PM_{10} is discharged on a typical winter's day from domestic home heating in Te Kuiti. Just over half of the PM_{10} emissions are from pre 2005 wood burners (Figure 3.3). Wood burners installed during the years 2006 to 2010 contribute to 13% of domestic heating PM_{10} emissions and burners less than five years old contribute 17%. Open fires contribute 10% and multi fuel burners less than 5%.

Tables 3.5 and 3.6 show the estimates of emissions for different heating methods under average and worst-case scenarios. Days when households may not be using specific home heating methods are accounted for in the daily winter average emissions[2]. When all households are using a burner on any given night around 195 kilograms of PM_{10} is likely to be emitted.

Figures 3.4 and 3.5 show the monthly variation in appliance use and average days per week used. The seasonal variation in contaminant emissions is shown in Table 3.7. Figure 3.6 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during June, July and August.

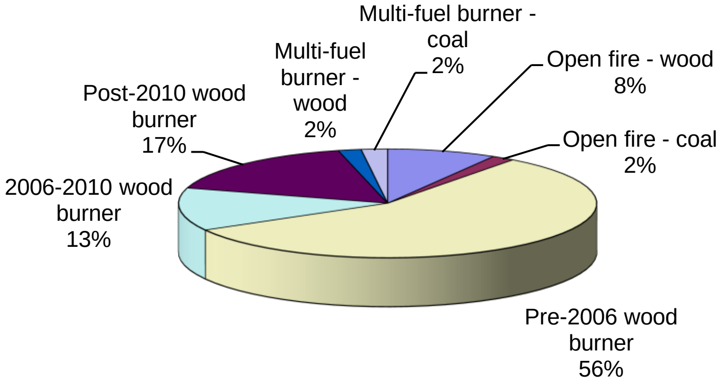

Figure 3.3: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Te Kuiti.

2 Total fuel use per day is adjusted by the average number of days per week wood burners are used (e.g.,6/7) and the proportion of wood burners that are used during July (e.g.,95%).

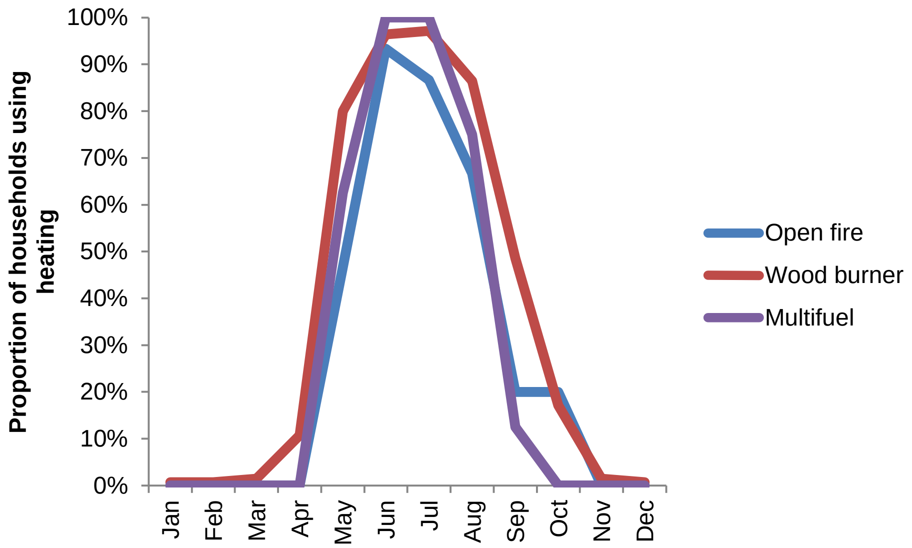

Figure 3.4: Monthly variations in appliance use in Te Kuiti.

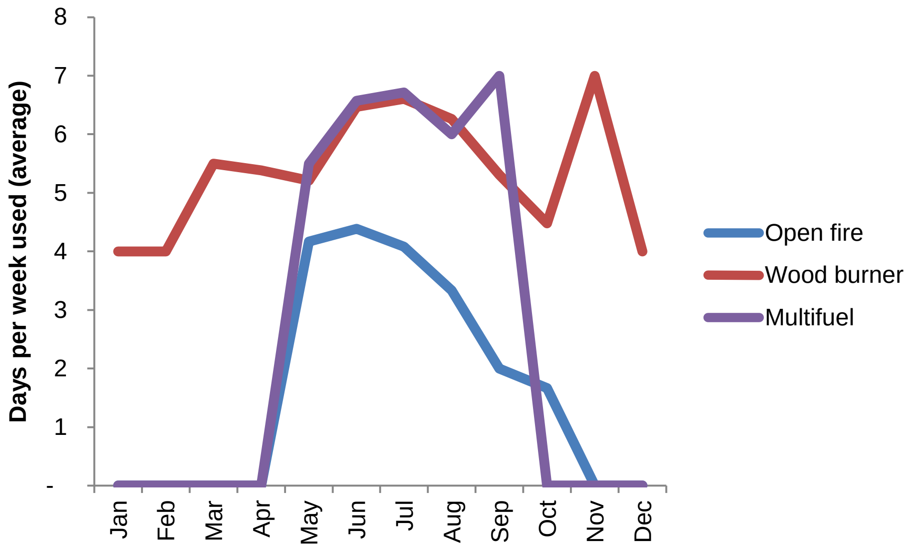

Figure 3.5: Average number of days per week appliances are used in Te Kuiti.

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

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			BaP		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	1.9	8%	14	25	8%	103	184	5%	2	4	17%	0	1	5%	56	101	9%	3	5	8%	2	3	8%	0.00	0.01	6%
Open fire - coal	0.1	1%	3	5	2%	10	18	0%	1	1	4%	1	2	16%	2	4	0%	0	1	1%	0	0	0%	0.00	0.00	0%
Wood burner	20.2																									
Pre 2006 wood burner	9.4	41%	94	168	57%	1310	2352	67%	5	8	35%	2	3	27%	309	554	52%	15	27	41%	9	16	42%	0.03	0.05	43%
2006-2010 wood burner	4.7	21%	21	38	13%	211	378	11%	2	4	18%	1	2	13%	94	168	16%	7	13	20%	5	8	21%	0.01	0.03	22%
Post 2010 wood burner	6.1	27%	28	50	17%	276	495	14%	3	6	23%	1	2	18%	123	220	21%	10	18	27%	6	11	27%	0.02	0.03	28%
Pellet Burner	0.0	0%	0.0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.00	0.00	0%
Multi fuel burner																										
Multi fuel– wood	0.3	1%	3	5	2%	41	74	2%	0	0	1%	0	0	1%	6	11	1%	0	1	1%	0	1	1%	0.00	0.00	1%
Multi fuel – coal	0.2	1%	3	6	2%	19	35	1%	0	1	2%	1	3	20%	3	5	0%	0	1	1%	0	0	0%	0.00	0.00	0%
Gas	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	0.00	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%	0.00	0.00	0%
Total Wood	22.3	98%	159	286	96%	1940	3484	99%	12	22	93%	4	8	64%	587	1054	99%	36	64	97%	22	39	100%	0.06	0.12	100%
Total Coal	0.3	1%	6	11	4%	29	53	1%	1	2	6%	3	5	36%	5	9	1%	1	1	2%	0	0	0%	0.0	0.0	0%
Total	23		165	297		1970	3536		13	24		7	13		592	1062		37	66		22	39		0.1	0.1	

Table 3.6: Te Kuiti winter daily domestic heating emissions by appliance type (worst case).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			BaP		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	Kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	3.7	14%	28	50	14%	203	365	9%	4	8	26%	1	1	8%	111	199	16%	6	11	14%	4	6	14%	0.0	0.0	10%
Open fire - coal	0.3	1%	6	10	3%	19	35	1%	1	2	6%	2	4	25%	4	7	1%	1	1	2%	0	0	0%	0.0	0.0	0%
Wood burner	22.0																									
Pre 2006 wood burner	10.2	38%	102	183	52%	1429	2566	64%	5	9	30%	2	4	23%	337	605	48%	16	29	38%	10	18	39%	0.0	0.1	41%
2006-2010 wood burner	5.1	19%	23	41	12%	230	412	10%	3	5	15%	1	2	11%	102	183	15%	8	15	19%	5	9	20%	0.0	0.0	21%
Post 2010 wood burner	6.7	25%	30	54	15%	301	540	13%	3	6	20%	1	2	15%	134	240	19%	11	19	25%	6	12	26%	0.0	0.0	27%
Pellet Burner	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.0	0.0	0%
Multi fuel burner																										
Multi fuel– wood	0.3	1%	3	5	2%	43	77	2%	0	0	1%	0	0	1%	6	11	1%	0	1	1%	0	1	1%	0.0	0.0	1%
Multi fuel – coal	0.2	1%	4	6	2%	20	36	1%	0	1	2%	1	3	17%	3	5	0%	0	1	1%	0	0	0%	0.0	0.0	0%
Gas	0.1	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.0	0.0	0%
Oil	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.0	0.0	0%
Total Wood	26	98%	186	334	95%	2206	3960	98%	16	28	91%	5	9	58%	690	1238	99%	42	75	97%	25	45	100%	0.1	0.1	100%
Total Coal	0	2%	9	17	5%	40	71	2%	1	3	8%	4	7	42%	7	12	1%	1	2	3%	0	0	0%	0.0	0.0	0%
Total	27		195	351		2245	4031		17	31		9	16		697	1251		43	77		25	45		0.1	0.1	

Table 3.7: Monthly variations in contaminant emissions from domestic heating in Te Kuiti.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	Benzene kg/day	BaP kg/day
January	0	6	0	0	2	0	0	0.0
February	0	6	0	0	2	0	0	0.0
March	1	17	0	0	5	0	0	0.0
April	10	127	1	0	37	2	1	0.0
May	105	1260	8	4	377	23	14	0.0
June	164	1936	14	7	586	36	21	0.1
July	165	1970	13	7	592	37	22	0.1
August	135	1627	11	5	485	30	18	0.1
September	46	579	3	1	170	10	6	0.0
October	14	174	1	0	52	3	2	0.0
November	2	22	0	0	6	0	0	0.0
December	0	6	0	0	2	0	0	0.0
Total (kg/year)	19745	236987	1571	789	71001	4391	2606	8

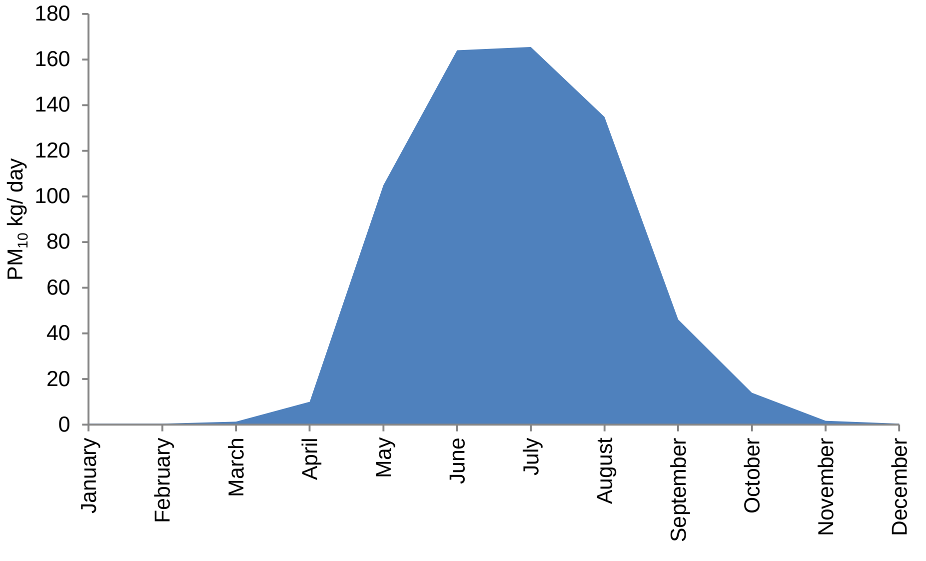

Figure 3.6: Monthly variations in PM_{10} emissions from domestic heating in Te Kuiti as a proportion of annual emissions.

3.5 Emissions from domestic heating in Putaruru

Around 64% of the daily PM_{10} emissions from domestic heating in Putaruru during the winter are from pre 2005 wood burners (Figure 3.7). Wood burners installed during the years 2006 to 2010 contribute to 15% of domestic heating PM_{10} emissions and burners less than five years old contribute 16%. Multi fuel burners and open fires collectively contribute 5% of winter time PM_{10} from domestic heating.

Table 3.8 and 3.9 shows the estimates of emissions for different heating methods under average and worst-case scenarios. Average daily wintertime PM_{10} emissions are around 124 kilograms per day. Days when households may not be using specific home heating methods are accounted for in this method[3]. Under the worst-case scenario around 143 kilograms of PM_{10} are discharged from all households using solid fuel burners on a particular night.

Figures 3.8 and 3.9 show the monthly variation in appliance use and average days per week used. The seasonal variation in contaminant emissions is shown in Table 3.10. Figure 3.10 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during June, July and August.

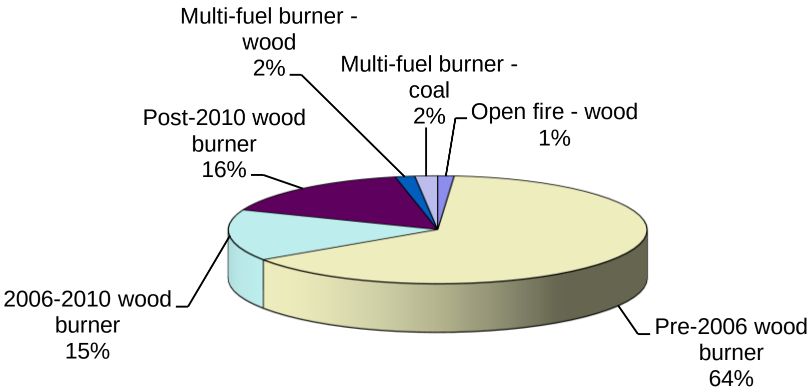

Figure 3.7: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Putaruru.

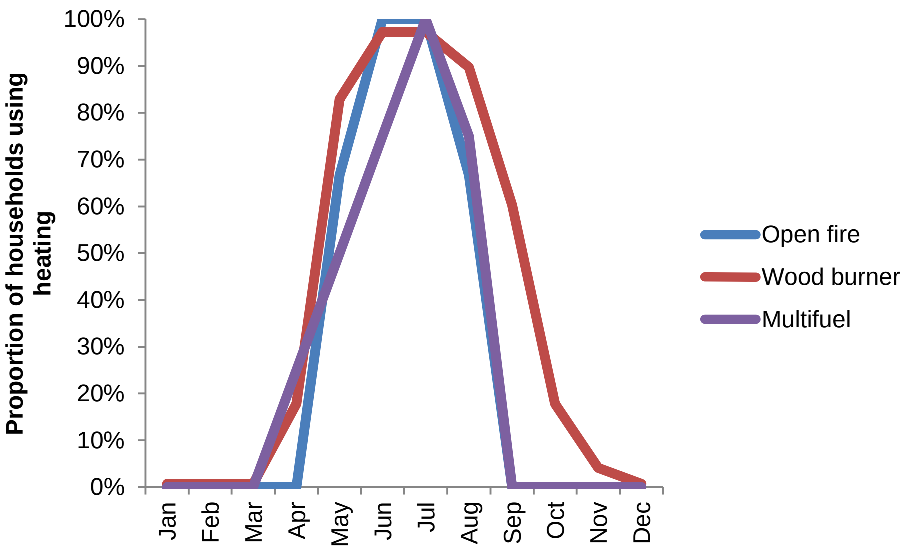

Figure 3.8: Monthly variations in appliance use in Putaruru.

[3] Total fuel use per day is adjusted by the average number of days per week wood burners are used (e.g.,6/7) and the proportion of wood burners that are used during July (e.g.,95%).

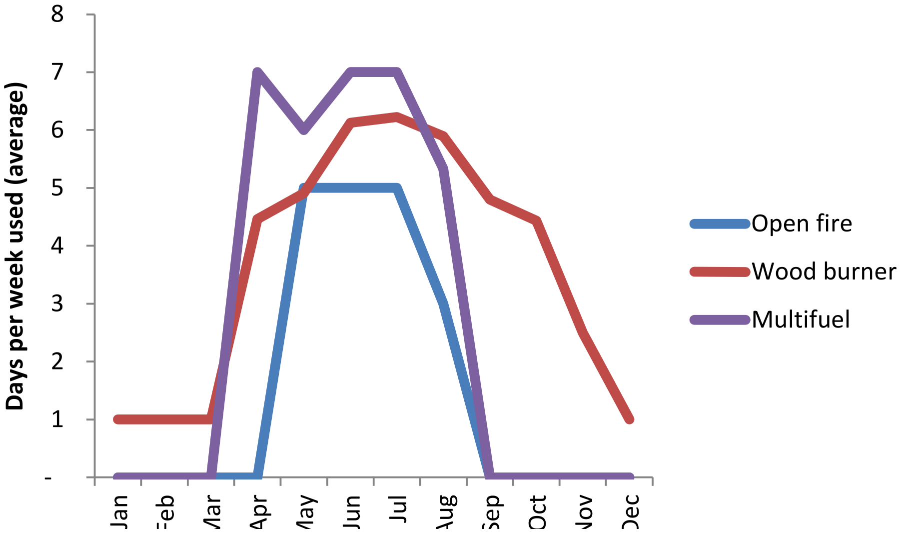

Figure 3.9: Average number of days per week appliances are used in Putaruru.

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

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			BaP		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	0.2	1%	2	4	1%	11	27	1%	0	1	3%	0	0	1%	6	14	1%	0	1	1%	0	0	1%	0.0	0.0	1%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.0	0.0	0%
Wood burner	16.5	97%																								
Pre 2006 wood burner	8.0	47%	80	185	64%	1113	2589	72%	4	9	45%	2	4	37%	262	610	59%	13	30	46%	8	18	47%	0.0	0.1	47%
2006-2010 wood burner	4.2	25%	19	44	15%	190	441	12%	2	5	24%	1	2	20%	84	196	19%	7	16	25%	4	10	25%	0.0	0.0	25%
Post 2010 wood burner	4.3	25%	20	45	16%	195	454	13%	2	5	25%	1	2	20%	87	202	19%	7	16	25%	4	10	26%	0.0	0.0	26%
Pellet Burner	0.0	0%	0.0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.0	0.0	0%
Multi fuel burner																										
Multi fuel– wood	0.2	1%	2	4	2%	26	61	2%	0	0	1%	0	0	1%	4	9	1%	0	1	1%	0	0	1%	0.0	0.0	1%
Multi fuel – coal	0.1	1%	2	5	2%	13	29	1%	0	0	2%	1	2	21%	2	4	0%	0	1	1%	0	0	0%	0.0	0.0	0%
Gas	0.0	0%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.0	0.0	0%
Oil	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.0	0.0	0%
Total Wood	16.9	99%	121	282	98%	1536	3571	99%	9	20	97%	3	8	78%	443	1031	100%	27	63	98%	16	38	100%	0.1	0.1	100%
Total Coal	0.1	1%	2	5	2%	13	29	1%	0	0	2%	1	2	21%	2	4	0%	0	1	1%	0	0	0%	0.0	0.0	0%
Total	17		124	287		1548	3600		9	21		4	10		445	1035		27	64		16	38		0.1	0.1	

Table 3.9: Putaruru winter daily domestic heating emissions by appliance type (worst case).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			Benzene			BaP		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	Kg	g/ha	%	T	kg/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																										
Open fire - wood	0.3	1%	2	5	2%	16	37	1%	0	1	3%	0	0	1%	9	20	2%	0	1	1%	0	1	1%	0.00	0.00	1%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.00	0.00	0%
Wood burner	19.1	97%																								
Pre 2006 wood burner	9.2	47%	92	214	64%	1287	2993	72%	5	11	45%	2	4	38%	303	705	59%	15	34	46%	9	21	47%	0.03	0.06	47%
2006-2010 wood burner	4.9	25%	22	51	15%	219	510	12%	2	6	24%	1	2	20%	97	227	19%	8	18	25%	5	11	25%	0.01	0.03	25%
Post 2010 wood burner	5.0	25%	23	52	16%	226	525	13%	3	6	24%	1	2	21%	100	233	19%	8	19	25%	5	11	26%	0.02	0.03	26%
Pellet Burner	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.00	0.00	0%
Multi fuel burner																										
Multi fuel– wood	0.2	1%	2	4	1%	26	61	1%	0	0	1%	0	0	1%	4	9	1%	0	1	1%	0	0	1%	0.00	0.00	1%
Multi fuel – coal	0.1	1%	2	5	2%	13	29	1%	0	0	2%	1	2	19%	2	4	0%	0	1	1%	0	0	0%	0.00	0.00	0%
Gas	0.1	0%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0.00	0.00	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%	0.00	0.00	0%
Total Wood	20	99%	140	327	98%	1774	4125	99%	10	23	97%	4	9	81%	514	1194	100%	31	73	99%	19	44	100%	0.06	0.14	100%
Total Coal	0	1%	2	5	2%	13	29	1%	0	0	2%	1	2	19%	2	4	0%	0	1	1%	0	0	0%	0.00	0.00	0%
Total	20		143	332		1786	4154		10	24		5	11		515	1198		32	74		19	44		0.1	0.1	

Table 3.10: Monthly variations in contaminant emissions from domestic heating in Putaruru.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	Benzene kg/day	BaP kg/day
January	0	1	0	0	0	0	0	0.00
February	0	1	0	0	0	0	0	0.00
March	0	1	0	0	0	0	0	0.00
April	12	154	1	0	45	3	2	0.01
May	82	1030	6	3	298	18	11	0.03
June	121	1514	9	4	437	27	16	0.05
July	124	1548	9	4	445	27	16	0.05
August	106	1335	8	3	384	24	14	0.04
September	44	562	3	1	163	10	6	0.02
October	12	154	1	0	44	3	2	0.01
November	2	20	0	0	6	0	0	0.00
December	0	1	0	0	0	0	0	0.00
Total (kg/year)	15409	193770	1098	503	55857	3435	2059	6

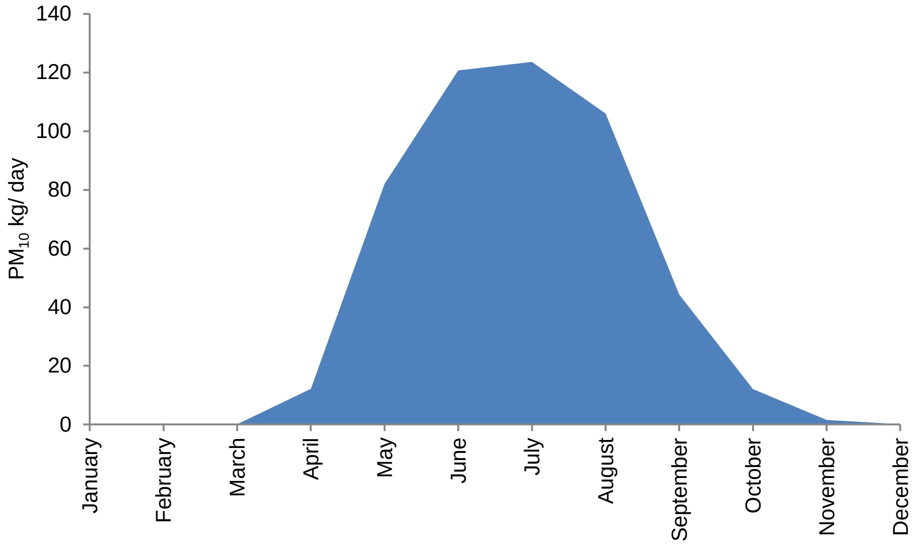

Figure 3.10: Monthly variations in PM_{10} emissions from domestic heating in Putaruru as a proportion of annual emissions.

4 MOTOR VEHICLES

4.1 Methodology

Motor vehicle emissions to air include tailpipe emissions of a range of contaminants and particulate emissions occurring as a result of the wear of brakes and tyres. Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) and the application of emission factors to these data.

Historically the emission factors used for motor vehicle emissions assessments in New Zealand were taken from the New Zealand Traffic Emission Rates (NZTER) database using local vehicle fleet profiles derived from motor vehicle registrations. The NZTER database was developed by the Ministry of Transport (MOT) based on measured emission rates from actual vehicle emissions tests on New Zealand vehicles under various road and traffic conditions. However, assumptions underpinning the model were not documented. As a result, the Auckland Regional Council developed the Vehicle Emission Prediction Model (VEPM 5.0). Emission factors for PM_{10}, CO, NOx, VOCs and CO_2 for this study have been based on VEPM 5.0. Default settings were used for all variables except for the temperature data and the vehicle fleet profile which was based on Waitomo District and South Waikato District vehicle registration data for the year ending 31 May 2015 (Table 4.1) for Te Kuiti and Putaruru respectively. Temperature data were based on the annual average temperatures of 15 degrees and 11 degrees Te Kuiti and Putaruru respectively. Resulting emission factors are shown in Table 4.2.

Emission factors for SOx were estimated for diesel vehicles based on the sulphur content of the fuel (0.01%) and the assumption of 100% conversion to SOx. Total VKT for diesel vehicles were estimated based on the proportion of diesels in the vehicle fleet.

No emission factor data for BaP are available for motor vehicle emissions in New Zealand.

The number of vehicle kilometres travelled (VKT) for the airshed was estimated using the New Zealand Transport Authority VKT data for 2013 available at the census area unit level. No CAU data for VKT were available for 2014. Table 4.3 shows the estimated VKTs distributed by time of day splits from the Taupo transport model as no road network models were available for Te Kuiti or Puatruru.

Table 4.1: Vehicle registrations in South Waikato and Putaruru for the year ending March 2015.

Te Kuiti	Petrol	Diesel	LPG	Other	Total
Cars	18,909	2,631	6	0	21,546
LCV	1,363	3,172	4	0	4,539
Bus	53	184			237
HCV		2,203			2,203
Miscellaneous	414	358	7	0	779
Motorcycle	1,046				1,046
Putaruru	**Petrol**	**Diesel**	**LPG**	**Other**	**Total**
Cars	18,909	2,631	6	0	21,546
LCV	1,363	3,172	4	0	4,539
Bus	53	184			237
HCV		2,203			2,203
Miscellaneous	414	358	7	0	779
Motorcycle	1,046				1,046
Total	21785	8548	17	0	30,350

Table 4.2: Emission factors for Te Kuiti and Putaruru vehicle fleet (2015).

Driving Conditions	CO g/VKT	CO_2 g/VKT	VOC g/VKT	NOx g/VKT	PM_{10} g/VKT	PM brake & tyre g/VKT	Benzene g/VKT
Te Kuiti	3.02	246	0.20	0.73	0.03	0.01	0.01
Putaruru	3.69	237	0.23	0.62	0.03	0.01	0.01

Table 4.3: VKT by time of day for Te Kuiti and Putaruru.

	Total VKT	Time of day			
		6am-10am	10am-4pm	4pm-10pm	10pm-6am
Te Kuiti	31247	6059	12884	10427	1878
Putaruru	41944	8133	17295	13996	2520

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

Emissions (g) = Emission Rate (g/VKT) * VKT

4.2 Motor vehicle emissions

Less than two kilograms per day of PM_{10} are estimated to occur from motor vehicle emissions in Te Kuiti and Putaruru. Around 24% of the PM_{10} from motor vehicles is estimated to occur as a result of the wearing of brakes and tyres. Table 4.4 shows the daily estimates of emissions of other contaminants in Te Kuiti and Putaruru.

Table 4.4: Summary of daily motor vehicle emissions

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Te Kuiti	557	1.3	2	94	170	23	41	0.1	0.2
Putaruru	430	1.5	3	155	360	26	61	0.1	0.3
		VOC		CO_2		Benzene			
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha		
Te Kuiti	557	6	11	8	14	0.3	1		
Putaruru	430	9	22	10	23	0.4	1		

5 INDUSTRIAL AND COMMERCIAL

5.1 Methodology

Information on activities discharging to air in Te Kuiti and Putaruru were provided by the Waikato Regional Council.

Schools were also surveyed by phone or email to determine the source of their heating. The results showed that only one school used a coal boiler in Te Kuiti and two in Putaruru. Emissions from gas and diesel boilers were not included in the inventory as the PM_{10} emissions from them are negligible for small to medium size boilers. Three industrial and commercial premises and one school were included in the inventory for Te Kuiti and two schools for Putaruru.

The selection of industries for inclusion in this inventory was based on potential for PM_{10} emissions. Industrial activities such as spray painting or dry cleaning operations, which discharge primarily VOCs were not included in the assessment.

For most industries included in the assessment, site specific emissions data was available from the resource consent application. Emissions were estimated based on equation 5.1.

Equation 5.1 Emissions (kg/day) = Emission rate (kg/hr) x hrs per day (hrs)

Where site specific emissions data were not available (for example for contaminants other than PM_{10}), emissions were estimated using activity data and emission factor information, as indicated in Equation 5.2. Activity data from industry includes information such as the quantities of fuel used, or in the case of non-combustion activities, materials used or produced. Activity data were collected using data provided by Waikato Regional Council staff.

Equation 5.2 Emissions (kg) = Emission factor (kg/tonne) x Fuel use (tonnes)

The emission factors used to estimate the quantity of emissions discharged are shown in Table 5.1. The coal fired boiler emission factors for PM_{10} are based on New Zealand specific emission factors as described in Wilton et. al. 2007. Other emission factors are from the USEPA AP42 database[4].

Fugitive dust emissions from industrial and commercial activities were not included in the inventory assessment because of difficulties in quantifying the emissions.

Table 5.1: Emission factors for industrial discharges.

	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg	Benzene g/kg	BaP g/kg
Coal boiler (bagfilter)	0.47	3.0	3.8	18 x S*	0.1	2400	0.00	0.00
Coal underfeed	2	5.5	4.8	18 x S*	0.1	2400	0.00	0.00
Wood fired boilers	1.6	6.8	0.8	0.04	0.1	1069	0.00	0.00

* where S is the sulphur content of the fuel

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

5.2 Industrial and commercial emissions

Table 5.2 shows the estimated emissions to air from industrial and commercial activities in Te Kuiti and Putaruru. Around 34 kilograms is estimated to be discharged to air per winter's day in Te Kuiti and less than 1 kilogram of PM_{10} in Putaruru (Table 5.2). The Te Kuiti industrial emissions assessment is lower than the 47 kilograms per day estimated in 2007 largely owing to a reduction in emissions from the installation of emission control equipment at the limeworks.

Table 5.2: Summary of industrial emissions (daily winter) in Te Kuiti and Putaruru.

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Te Kuiti	557	34	61	366	657	270	485	605	1086
Putaruru	430	0	1	1	3	1	2	0	0
		VOC		CO_2		Benzene		BaP	
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha	kg	g/ha
Te Kuiti	557	8	14	187	336	0.47	1	0.00	0.0
Putaruru	430	0	0	0	1	0.00	0	0.00	0.0

6 OUTDOOR BURNING

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

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

6.1 Methodology

Outdoor burning emissions for Te Kuiti and Putaruru were estimated for the winter months based on data collected during the 2015 domestic home heating survey. The survey showed 21% of households in Te Kuiti and 14% in Putaruru burnt rubbish in the outdoors during the winter. On average there are around 12 fires per day during winter in Te Kuiti and six per day in Putaruru. Emissions were calculated based on the assumption of an average weight of material per burn of 75 kilograms and using the emission factors in Table 6.1 with an average fire size of 1 m^3. Emission factors of benzene and BaP were based on wood burning for domestic heating and are indicative only. Emissions of these contaminants will be largely influenced by the material burnt, in particular the inclusion of household rubbish and plastics.

Estimates of PM_{10} and other emissions are detailed in sections 6.2 to 6.4. It should be noted, however, that there are a number of uncertainties relating to the calculations. In particular it is assumed that burning is carried out evenly throughout the winter, whereas in reality it is highly probable that a disproportionate amount of burning is carried out during weekend days. Thus on some days no PM_{10} from outdoor burning may occur and on other days it might be many times the amount estimated in this assessment.

Table 6.1: Outdoor burning emission factors (AP42, 2002).

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

6.2 Outdoor burning emissions

Around 13 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average in Te Kuiti and around six kilograms per day in Putaruru. The greatest amount of burning in Te Kuiti occurs during the autumn months whereas in Putaruru it occurs during the winter.

Table 6.2: Outdoor burning emission estimates for Te Kuiti.

	PM10 kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	VOC kg/ day	CO2 t/ day	Benzene	BaP kg/day
Summer (Dec-Feb)	9	32	2	0	3	1	0	0
Autumn (Mar-May)	13	42	3	1	4	1	1	0
Winter (June-Aug)	12	39	3	0	4	1	0	0
Spring (Sept-Nov)	10	35	2	0	4	1	0	0

Table 6.3: Outdoor burning emission estimates for Putaruru.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	VOC kg/ day	CO_2 t/ day	Benzene kg/day	BaP kg/day
Summer (Dec-Feb)	3	12	1	0	1	0	0	0
Autumn (Mar-May)	4	15	1	0	2	1	0	0
Winter (June-Aug)	6	20	1	0	2	1	0	0
Spring (Sept-Nov)	5	16	1	0	2	1	0	0

7 OTHER SOURCES OF EMISSIONS

This inventory includes all likely major sources of PM_{10} that can be adequately estimated using inventory techniques. Other sources of emissions not included in the inventory that may contribute to measured PM_{10} concentrations at some times during the year include dusts (a portion of which occur in the PM_{10} size fraction) and sea spray. These sources are not typically included because the methodology used to estimate the emissions is less robust.

Lawn mowers, leaf blowers and chainsaws can also contribute small amounts of particulate. These are not typically included in emission inventory studies owing to the relatively small contribution, particularly in areas where solid fuel burning is a common method of home heating. Based on data for other areas, PM_{10} emissions from lawn mowing in all areas are likely to be less than one kilogram per day[5].

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

8 TOTAL EMISSIONS

8.1 Te Kuiti

In Te Kuiti around 212 kilograms of PM_{10} is discharged to air on an average winter's day. This compares with an estimated 246 kilograms per day for 2007 (after taking into account differences in methods) indicating a reduction in emissions of around 14% since 2007. Figure 8.1 shows that domestic home heating is the main source of PM_{10} emissions contributing 78% of the daily wintertime emissions. Industry contributes 16%, outdoor burning 5% and transport around 1% of the total wintertime PM_{10} emissions.

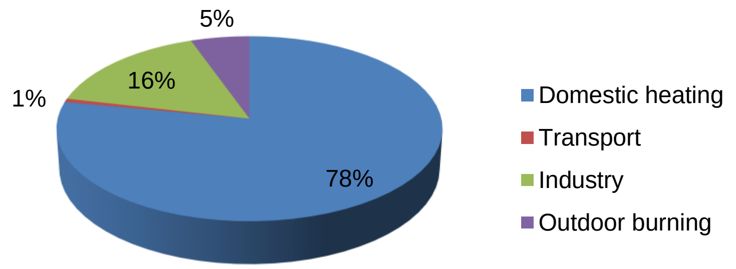

Figure 8.1: Relative contribution of sources to daily winter PM_{10} emissions in Te Kuiti.

The estimated reduction in PM_{10} emissions in Te Kuiti from 2007 to 2015 is illustrated in Figure 8.2.

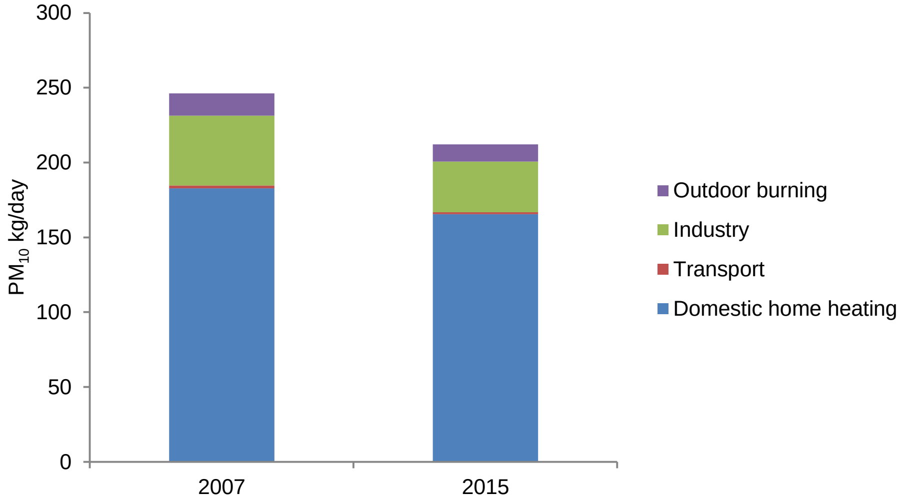

Figure 8.2: Comparison of estimated changes in PM_{10} emissions in Te Kuiti from 2007 to 2015.

Domestic home heating is also the main source of daily winter benzene CO, VOCs and industry is the main source of daily winter NOx, SOx and CO_2 in Te Kuiti (Figure 8.3).

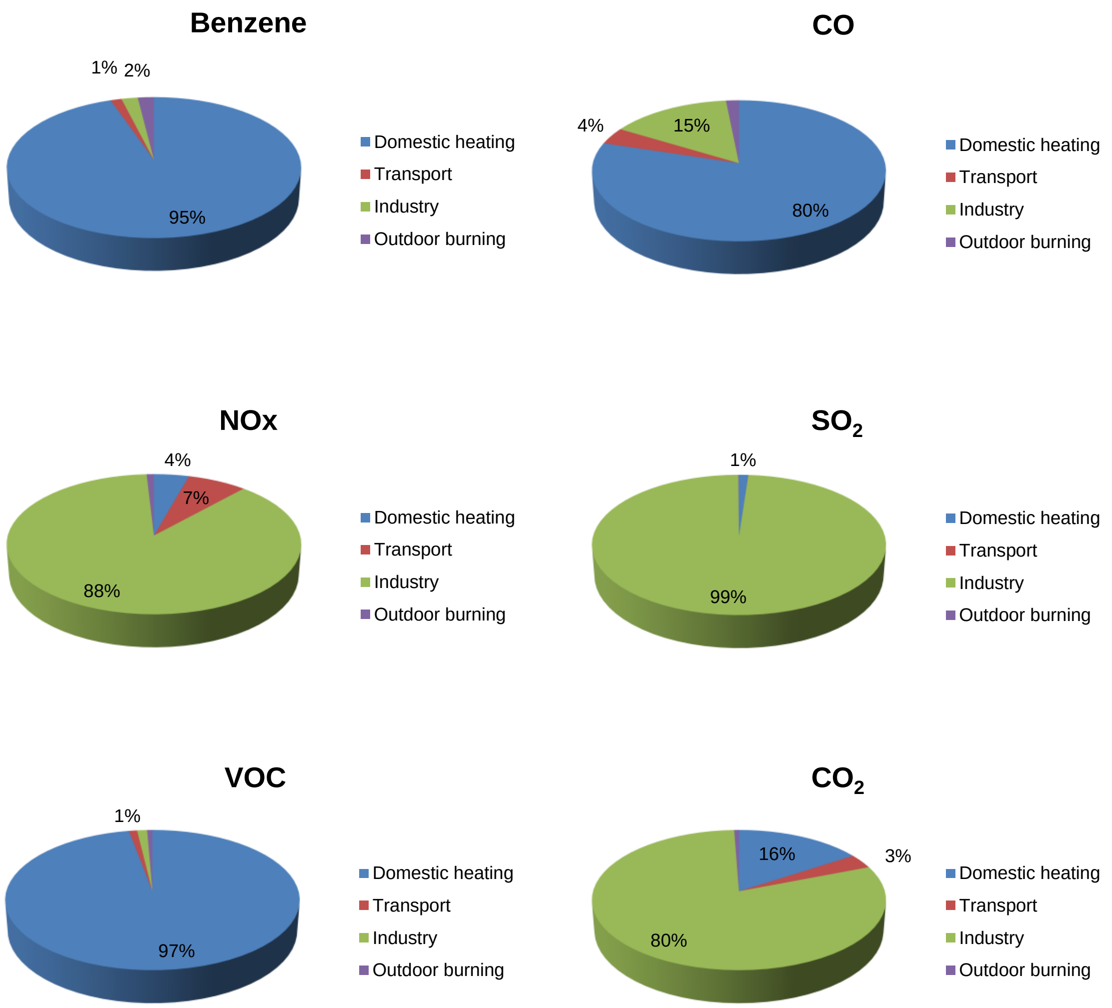

Figure 8.3: Relative contribution of sources to contaminant emissions Te Kuiti

Table 8.1 shows seasonal variations in PM_{10} emissions. Although domestic home heating is the dominant source of PM_{10} emissions during the winter months, during the summer, industry is the main source of PM_{10} emissions. Daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) are shown in Table 8.2.

Table 8.1: Monthly variations in daily PM_{10} emissions in Te Kuiti.

	Domestic Heating		Outdoor Burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	1%	9	21%	34	75%	1	3%	45
February	0	1%	9	21%	34	75%	1	3%	45
March	1	3%	13	25%	34	69%	1	3%	49
April	10	17%	13	22%	34	59%	1	2%	58
May	105	69%	13	8%	34	22%	1	1%	153
June	164	78%	12	6%	34	16%	1	1%	211
July	165	78%	12	5%	34	16%	1	1%	212
August	135	74%	12	6%	34	19%	1	1%	182
September	46	50%	10	11%	34	37%	1	1%	92
October	14	24%	10	17%	34	57%	1	2%	60
November	2	4%	10	22%	34	72%	1	3%	47
December	0	1%	9	21%	34	75%	1	3%	45
Total kg year	19745		4010		12352		481		

Table 8.2: Daily contaminant emissions from all sources in Te Kuiti (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	165	297	1970	3536	13	24	7	13
Transport	1	2	94	170	23	41	0	0
Industry	34	61	366	657	270	485	605	1086
Outdoor burning			0					
Total	212	381	2469	4433	309	555	612	1100
	VOC		CO_2		Benzene		BaP	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	592	1062	37	66	22	40	0.1	0.1
Transport	6	11	8	14	0	1		
Industry	8	14	187	336	0	1	0.001	0.0
Outdoor burning	4	7	1	2	0	1	0	0.0
Total	605	1087	232	416	23	42	0.1	0.1

8.2 Putaruru

Around 131 kilograms of PM_{10} is discharged to air in Putaruru on an average winter's day. Figure 8.4 shows that domestic home heating is the main source of PM_{10} emissions contributing 94% of the daily wintertime emissions. Outdoor burning contributes 5%, motor vehicles 1% and industry has a negligible contribution to total wintertime PM_{10} emissions.

A previous emissions inventory for Putaruru found 354 kilograms per day during winter (Smith & Wilton, 2006). However a reasonable proportion of this (136 kg/day) was from industry no longer operating in 2015. Around 205 kilograms of PM_{10} was discharged per day from domestic heating compared with 124 kg/day in 2015. A reduction in PM_{10} of around 63% in total emissions is estimated to have occurred from 2006 to 2015. The reduction in domestic heating emissions over this time is around 40%.

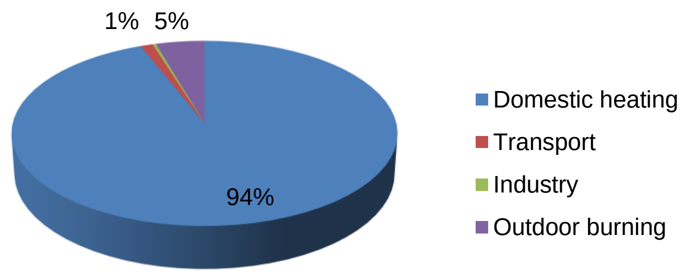

Figure 8.4: Relative contribution of sources to daily winter PM_{10} emissions in Putaruru.

Domestic home heating is also the main source of benzene CO, SOx, VOCs and CO_2 and motor vehicles is the main source of NOx (Figure 8.5).

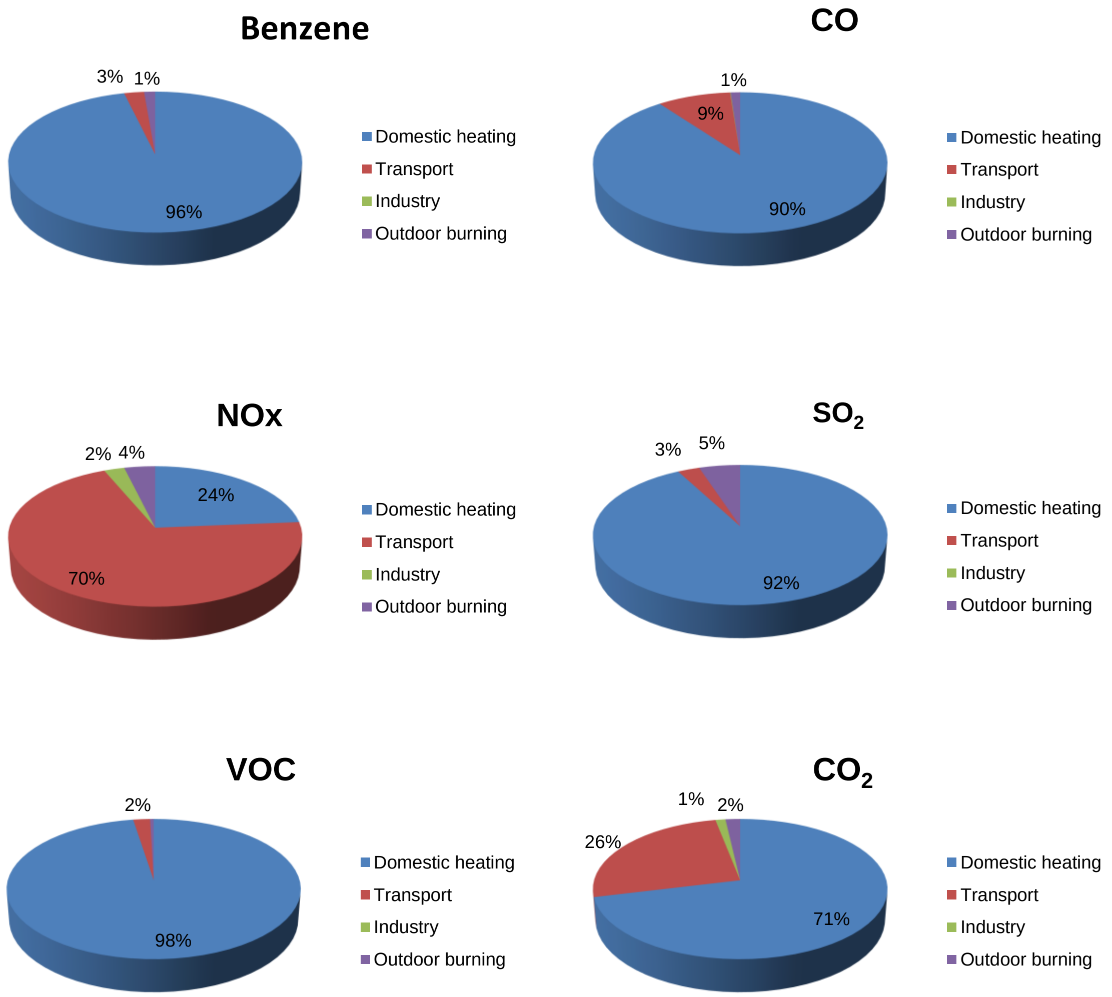

Figure 8.5: Relative contribution of sources to contaminant emissions in Putaruru

Table 8.3 shows seasonal variations in PM_{10} emissions. Although domestic home heating is the dominant source of PM_{10} emissions during the winter months, during the summer, outdoor burning is the main source of PM_{10} emissions. Daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) are shown in Table 8.4.

Table 8.3: Monthly variations in daily PM_{10} emissions in Putaruru.

	Domestic Heating		Outdoor Burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	2%	3	68%	0.0	0%	2	30%	5
February	0	2%	3	68%	0.0	0%	2	30%	5
March	0	2%	4	71%	0.2	3%	2	24%	6
April	12	66%	4	24%	0.2	1%	2	8%	18
May	82	93%	4	5%	0.2	0%	2	2%	88
June	121	94%	6	5%	0.4	0%	2	1%	129
July	124	94%	6	5%	0.4	0%	2	1%	131
August	106	93%	6	5%	0.4	0%	2	1%	114
September	44	87%	5	9%	0.2	0%	2	3%	51
October	12	66%	5	25%	0.2	1%	2	8%	18
November	2	20%	5	59%	0.2	3%	2	19%	8
December	0	2%	3	68%	0.0	0%	2	30%	5
Total kg year	15409		1691		74		548		

Table 8.4: Daily contaminant emissions from all sources in Putaruru (winter average).

	PM_{10}		CO		NOx		SOx	
	Kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	124	287	1548	3600	9	21	4	10
Transport	2	3	155	360	26	61	0	0
Industry	0	1	1	3	1	2	0	0
Outdoor burning	6	14	20	47	1	3	0	1
Total	131	306	1724	4009	37	87	5	11
	VOC		CO_2		Benzene		BaP	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	445	1035	27	64	17	39	0.05	0.1
Transport	9	22	10	23	0.4	1.0		
Industry	0	0	0	1	0.0	0.0	0.0	0.0
Outdoor burning	2	5	1	2	0.2	0.6	0.0	0.0
Total	457	1062	39	90	17	40	0.05	0.1

REFERENCES

Bluett, J., Smith, J., Wilton, E., & Mallet, T. (2009). Real world emission testing of domestic wood burners. Presented at the 19th International Clean Air and Environment Conference, Perth.

Smith, J., Bluett, J., Wilton, E., & Mallet, T. (2009). In home testing of particulate emissions from NES compliant woodburners: Nelson, Rotorua and Taumaranui 2007. NIWA report number CHC2008-092.

Smith, J., & Wilton, E. (2006). Air Emission Inventory - Matamata, Putaruru and Waihi 2006.

Smithson, J. (2011). *Inventory of emissions to air in Christchurch 2009*. Environment Canterbury Report R11/17.

Stern, C. H., Jaasma, D. R., Shelton, J. W., & Satterfield, G. (1992). Parametric Study of Fireplace Particulate Matter and Carbon Monoxide Emissions. *Journal of the Air & Waste Management Association*, *42*(6), 777–783. http://doi.org/10.1080/10473289.1992.10467029

Wilton, E. (2014). Nelson Air Emission Inventory - 2014. Nelson City Council Technical Report.

Wilton, E., & Baynes, M. (2007). Air emission inventory for Te Kuiti & Tokoroa 2007. Environment Waikato Report TR 2008/02.

APPENDIX A: HOME HEATING QUESTIONNAIRE

1. Good morning / afternoon/evening - Is this a home or business number?(- terminate if business)

Hi, I'm _________from DigiPoll and I am calling on behalf of the Environment Waikato

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

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

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

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

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

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

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

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

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

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

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

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

(f) What size gas bottle do you use?

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

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

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

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

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

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

(d) How old is your log burner?

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

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

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

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

(i) What proportion would be bought?

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

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

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

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

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

(d) How old is your multi fuel burner?

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

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

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

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

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

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

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

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

(m) What proportion would be bought?

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

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

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

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

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

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

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

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

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

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

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

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

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

(l) What proportion would be bought?

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

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

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

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

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

(d) How old is your pellet burner?

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

(e) and what model is your pellet burner?

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

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

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

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

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

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

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

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

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

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

9. Does you home have insulation?

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

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

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

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

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

D3 With which ethnic group do you most closely relate?

Interviewer: tick gender.

D4 How many people live at your address?

D5 Do you own your home or rent it?

D6 Approximately how old is your home?

D7 How many bedrooms does your home have?

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

APPENDIX B: EMISSION FACTORS FOR DOMESTIC HEATING.

Emission factors were based on the review of New Zealand emission rates carried out by Wilton et al., (2015) for the Ministry for the Environments air quality indicators programme. This review evaluated emission factors used by different agencies in New Zealand and where relevant compared these to overseas emission factors and information. Preference was given to New Zealand based data where available including real life testing of pre 1994 and NES compliant wood burners (Wilton & Smith, 2006; Smith, et. al., 2008) and burners meeting the NES design criteria for wood burners (Bluett, Smith, Wilton, & Mallet, 2009; Smith, Bluett, Wilton, & Mallet, 2009).

The PM_{10} open fire emission factor was reduced in the review relative to previous factors. Some very limited New Zealand testing was done on open fires during the late 1990s. Two tests gave emissions of around 7.2 and 7.6 g/kg which at the time was a lot lower than the proposed AP42 emission factors (http://www.rumford.com/ap42firepl.pdf) for open fires and the factors used in New Zealand at the time (15 g/kg). An evaluation of emission factors for the 1999 Christchurch emission inventory revised the open fire emission factor down from 15 g/kg to 10 g/kg based on the testing of Stern, Jaasma, Shelton, & Satterfield, (1992) in conjunction with the results observed for New Zealand (as reported in Wilton, 2014). The proposed AP42 emission factors (11.1 g/kg dry) now suggest that the open fire emission factor may be lower still and closer to the result of the limited testing carried out in New Zealand. Consequently a factor of 7.5 g/kg for PM_{10} (wet weight) is proposed to be used for open fires in New Zealand based on the likelihood of the Stern et al., (1992) data being dry weight (indicating a lower emission factor), the data supporting a proposed revised AP 42 factor and the results of the New Zealand testing being around this value. It is proposed that other contaminant emissions for open fires be based on the proposed AP42 emission factors adjusted for wet weight.

The emission factor for wood use on a multi fuel burner was also reduced from 13 g/kg (used in down to the same value as the pre 2004 wood burner emission factor (10 g/kg). The basis for this was that there was no evidence to suggest that multi fuel burners burning wood will produce more emissions than an older wood burner burning wood.

Emission factors for coal use on a multi fuel burner are based on limited data, mostly local testing. Smithson, (2011) combines these data with some further local testing to give a lower emission factor for coal use on multi fuel burners. While these additional data have not been viewed, and it uncertain whether bituminous and subbituminous coals are considered, the value used by Smithson has been selected. The Smithson, (2011) values for coal burning on a multi fuel burner have also been used for PM_{10}, CO and NOx as it is our view that many of the more polluting older coal burner (such as the Juno) will have been replaced over time with more modern coal burners.

No revision to the coal open fire particulate emission factor was proposed as two evaluations (Smithson, (2011) and Wilton 2002) resulted in the same emission factor using different studies. Emissions of sulphur oxides will vary depending on the sulphur content of the fuel, which will vary by location. A value of 8 g/kg is proposed for SOx based on an assumed average sulphur content of 0.5 g/kg and relationships described in AP42 for handfed coal fired boilers (15.5 x sulphur content).

An emission factor of 0.5 g/kg was proposed for NOx from wood burners based on the AP42 data because the non-catalytic burner measurements were below the detection limit but the catalytic converter estimates (and conventional burner estimates) weren't. This value is half of the catalytic burner NOx estimate.

A ratio of 14 x PM_{10} values was used for CO emission estimates as per the AP42 emissions table for wood stoves. This is selected without reference to any New Zealand data owing to the latter not being in any publically available form.