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PREPARED FOR

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Reefton Air Emission Inventory - 2019

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The main air quality concern for urban towns in New Zealand is concentrations of particles in the air less than 10 microns and less than 2.5 microns in diameter (PM_{10} and $PM_{2.5}$). In Reefton, PM_{10} concentrations exceeded the National Environmental Standard (NES) of 50 µg/m^3 from 2006 to 2016. The monitoring site was moved in October 2016. Since then concentrations of PM_{10} measured at the site have been within the NES for PM_{10}.

The purpose of this emission inventory is to evaluate emissions to air for 2019 and the contribution of different sources to these emissions. Previously air emissions inventories for Reefton were carried out in 2012 and 2005. Results of this 2019 assessment were compared to previous inventories to assess changes in emissions with time.

The 2019 inventory includes emissions from domestic heating, motor vehicles, 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.

The inventory focuses on suspended particles (PM_{10}), the main contaminant of concern in Reefton, and the $PM_{2.5}$ subcomponent of PM_{10}, as well as carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds and carbon dioxide.

A domestic home heating survey was undertaken to determine the proportions of households using different heating methods and fuels. Multi fuel burners were found to be the most common method of heating the main living area in Reefton with 62% of households using this form of heating. Electricity was also common for home heating with 44% of households using this method. A further 23% of households used wood burners. Many householders use more than one method to heat the main living area of their home.

Domestic heating was the main source of winter PM_{10} and $PM_{2.5}$ emissions in Reefton accounting for 98% of the daily winter PM_{10} and 96% of the annual PM_{10} and 98% of the daily winter $PM_{2.5}$ and 97% of an the annual $PM_{2.5}$ emissions. Other sources included outdoor burning, industry and motor vehicles at 1% of daily winter PM_{10}. On an average winter's night, around 145 kilograms of PM_{10} are discharged in Reefton.

Results suggest a slight increase in PM_{10} in Reefton from 2012 to 2019. The main cause of the increase is a reported higher daily average fuel use (18 kg/day of wood in 2012 compared with 24 kg/day in 2019). The 2019 averages are more similar to the 2005 fuel use averages. It is possible that economic or meteorological factors may have influenced fuel use in 2012. Between 2005 and 2013 emissions were estimated to have decreased by up to 44%.

1 INTRODUCTION

Emission inventories assess the amount of emissions from different sources and are used for air quality management. The sources that are included in emissions inventories in New Zealand are generally domestic home heating, transport, industrial and commercial activities, ports and shipping, aviation and outdoor burning.

In New Zealand the main air contaminant monitored in urban areas is PM_{10} as 24-hour average concentrations can exceed the National Environmental Standard (NES) in many locations in New Zealand. In 2015, a review of air quality by the Parliamentary Commissioner for the Environment highlighted issues with the current NES focus on PM_{10} suggesting investigation into the adoption of $PM_{2.5}$ as the key indicator with priority given to an annual average standard rather than a 24 hour average standard to capture the significant chronic impacts of particulate exposure. The refocus on $PM_{2.5}$ and annual average exposure is consistent with a recent WHO report (World Health Organization, 2013) which indicates that annual average $PM_{2.5}$ is the strongest indicator of health impacts.

In Reefton, the 24-hour average concentrations of PM_{10} have exceeded the 50 $\mu g/m^3$ (National Environmental Standard limit value) regularly during the winter months. Measured concentrations have reduced over time with maximum levels in the 30-40 $\mu g/m^3$ range compared with around 65-130 $\mu g/m^3$ prior to 2016.

This report primarily focuses on emissions of particles (PM_{10} and $PM_{2.5}$) from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning. Other contaminants included in this emission inventory are carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds and carbon dioxide.

Emission inventories for Reefton have been previously carried out in 2005 and 2012.

2 INVENTORY DESIGN

This emission inventory focuses on PM_{10} and $PM_{2.5}$ emissions as the main contaminants of concern in urban New Zealand. It is unlikely that concentrations of other contaminants would exceed National Environmental Standards (NES).

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 particulate 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}), fine particles ($PM_{2.5}$) carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), carbon dioxide (CO_2). The latter contaminant has been included here because of the potential issues identified below

Emissions of PM_{10}, CO, SOx and NOx are included because of their potential for adverse health impacts and the existence of National Environmental Standards for each of them. $PM_{2.5}$ has been included in the inventory because this size fraction has significance in terms of the proposed annual average NES for $PM_{2.5}$. 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 (VOCs) are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. In this report, VOC emissions have been estimated for sources already included in the inventory but data on emissions from VOC specific sources (e.g., spray painting, vegetation) has not been included. It is likely that the inventory does not capture a number of sources of VOCs.

2.3 Selection of areas

The Reefton inventory study area is the Reefton Area Unit area. This differs slightly to the Reefton airshed gazetted for air quality management purposes. Figure 2.1 shows the inventory study area and the Reefton airshed area. The inventory study area comprises the majority of the airshed area and has been retained as the study area for 2019 to enable comparison to previous inventories.

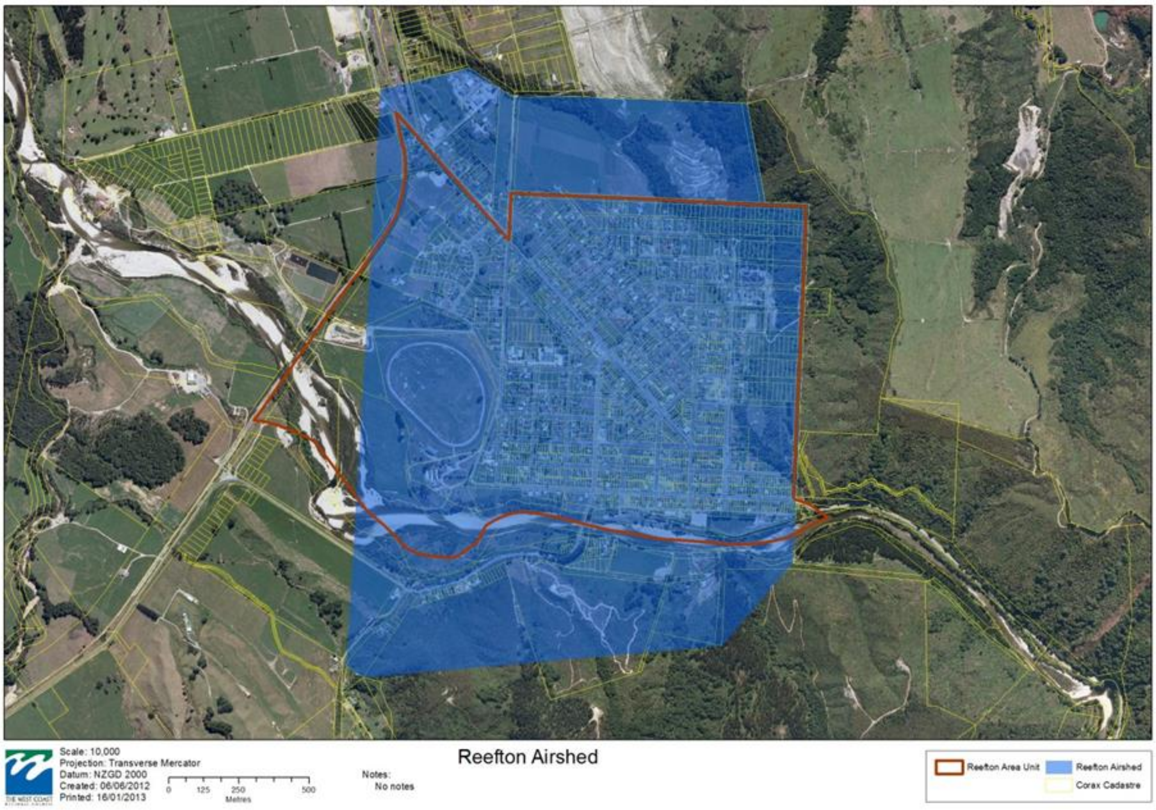

Figure 2.1: Reefton Airshed (source West Coast Regional Council).

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.

3 DOMESTIC HEATING

3.1 Methodology

Information on domestic heating methods and fuel used by households in Reefton was collected using a household survey carried out by Versus during winter 2019 (Appendix A). A combined approach was used to gather information which included both a telephone survey and an online survey. Table 3.1 shows the estimated number of households for 2019 based on 2018 census household data for Reefton.

Table 3.1: Summary household, area and survey data.

	Dwellings in Airshed	Sample size	Area (ha)	Sample error
Reefton	453	101	201	8.5%

Home heating methods were classified as; electricity, open fires, wood burners, pellet fires, multi fuel burners, gas burners and oil burners. Emission factors were applied to these data 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	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SO_2 g/kg	VOC g/kg	CO_2 g/kg
Open fire - wood	7.5	7.5	55	1.2	0.2	30	1600
Open fire - coal	21	18	70	4	8	15	2600
Pre 2006 burners	10	10	140	0.5	0.2	33	1600
Post 2006 burners	4.5	4.5	45	0.5	0.2	20	1600
Pellet burners	2	2	20	0.5	0.2	20	1600
Multi-fuel[1] - wood	10	10	140	0.5	0.2	20	1600
Multi-fuel[1] – coal	19	17	110	1.6	8	15	2600
Oil	0.3	0.22	0.6	2.2	3.8	0.25	3200
Gas	0.03	0.03	0.18	1.3	7.56E-09		2500

[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. This was converted into average daily fuel consumption based on an average log weight of 1.6 kg per piece of wood and integrating seasonal and weekly usage rates. The value of 1.6 kg/log was selected as the mid-point of the range found from different New Zealand evaluations (Wilton & Bluett, 2012, Wilton, Smith, Dey, & Webley, 2006, Metcalfe, Sridhar, & Wickham, 2013). The log weight recommended for this work (1.6 kg/ piece) is the midpoint and average of the range of values.

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 Reefton

The most popular form of heating the main living area of homes in Reefton is multi fuel burners with around 62% of households using that method. Electricity is the next most common method with 44% of households using electric heating options. Wood burners are used by 23% of households. Table 3.3 also shows that households rely on more than one method of heating their main living area during the winter months.

Around 6.8 tonnes of wood and 4.4 tonnes of coal was burnt per typical winter's night in Reefton during 2019. In 2012 the amount of wood and coal used on average per night was around 4.2 and 3.6 tonnes respectively.

Figure 3.1 shows the proportion of households using different electrical heating types. This shows around 64% of households using electricity in their main living area use heat pumps.

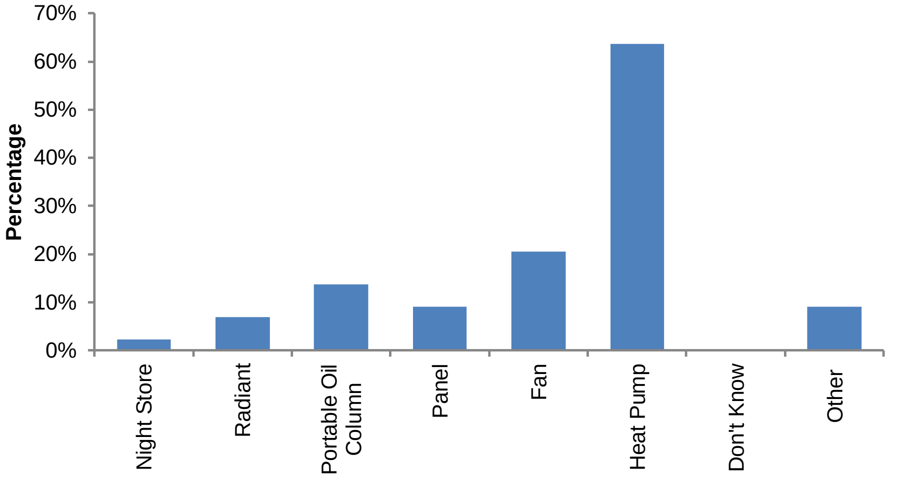

Figure 3.1: Electric heating options for Reefton households (main living area).

Table 3.3: Home heating methods and fuels.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	44%	197		
Total Gas	2%	9	0	0%
Flued gas	0%	0		
Unflued gas	2%	9		
Oil	2%	9	0.01	0%
Open fire	4%	18		
Open fire - wood	3%	13	0.1	1%
Open fire - coal	3%	13	0.2	1%
Total Wood burner	23%	103	2	22%
Pre 2006 wood burner	6%	27	1	6%
2006-2013 wood burner	10%	45	1	10%
Post-2013 wood burner	7%	31	1	7%
Multi-fuel burners	62%	283		
Multi-fuel burners-wood	42%	188	4	37%
Multi-fuel burners-coal	57%	260	4	38%
Pellet burners	1%	4	0.04	0%
Total wood	67%	305	6.8	61%
Total coal	60%	274	4.4	39%
Total		453	11	100%

3.3 Emissions from domestic heating.

In 2019 around 141 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Reefton. The annual $PM_{2.5}$ emission was estimated at 22 tonnes per year.

Figure 3.2 shows that the largest portion (57%) of the PM_{10} emissions are from multi fuel burners burning coal. The NES design criteria for wood burners was mandatory for new installations on properties less than 2 hectares from September 2005. However, the emission criteria relating to these burners does not apply to multi fuel burners. Wood burners installed prior to 2006 contribute 5% and wood burners installed post 2006 also contribute 5% of the daily winter PM_{10}.

Tables 3.4 and 3.5 show the estimates of emissions for different heating methods under average and worst-case scenarios respectively. Days when households may not be using specific home heating methods are accounted for in the daily winter average emissions[1]. Under the worst-case scenario that all households are using a burner on any given night around 149 kilograms of PM_{10} is likely to be emitted.

The seasonal variation in contaminant emissions is shown in Table 3.6. Figure 3.3 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during June, July and August.

[1] 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%).

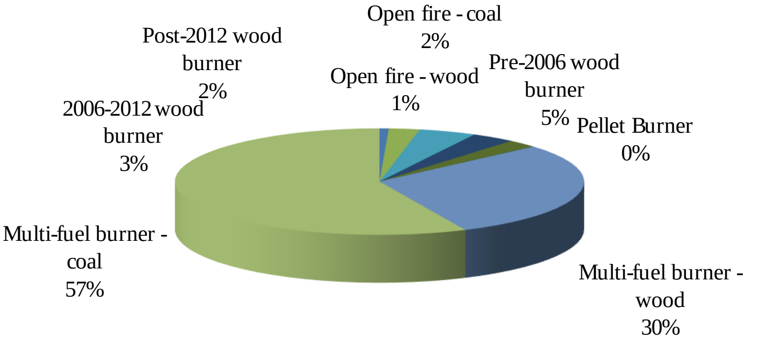

Figure 3.2: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating.

Table 3.4: Reefton winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use t/day	%	PM_{10} kg	g/ha	%	CO kg	g/ha	%	NO_x kg	g/ha	%	SO_x kg	g/ha	%	VOC kg	g/ha	%	CO_2 T	kg/ha	%	$PM_{2.5}$ kg	g/ha	%
Open fire																							
Open fire - wood	0.1	1%	1	5	1%	8	37	1%	0	1	1%	0	0	0%	4	20	2%	0	1	1%	1	5	1%
Open fire - coal	0.2	1%	3	17	2%	12	57	1%	1	3	6%	1	7	4%	2	12	1%	0	2	2%	3	15	2%
Wood burner	2.5																						
Pre 2006 wood burner	0.6	6%	6	32	5%	90	447	7%	0	2	3%	0	1	0%	21	105	10%	1	5	5%	6	32	5%
2006-2013 wood burner	1.1	10%	5	24	3%	49	243	4%	1	3	5%	0	1	1%	22	108	10%	2	9	8%	5	24	4%
Post 2013 wood burner	0.8	7%	3	17	2%	34	169	3%	0	2	3%	0	1	0%	15	75	7%	1	6	5%	3	17	3%
Pellet Burner	0.0	0%	0.1	0	0%	1	4	0%	0	0	0%	0	0	0%	1	4	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	4.2	37%	42	208	30%	584	2907	47%	2	10	19%	1	4	2%	83	415	39%	7	33	30%	42	208	32%
Multi fuel – coal	4.2	38%	80	400	57%	466	2316	37%	7	34	62%	34	168	93%	63	316	30%	11	55	49%	71	352	54%
Gas	0.0	0%	0.00	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Oil	0.0	0%	0.00	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	6.8	61%	57.53	286	41%	765	3807	62%	4	17	32%	1	7	4%	146	728	69%	11	54	49%	58	286	44%
Total Coal	4.4	39%	83.87	417	59%	477	2374	38%	7	37	68%	35	175	96%	66	328	31%	11	57	51%	74	367	56%
Total	11		141	704		1242	6180		11	55		37	182		212	1056		22	111		131	653	

Table 3.5: Reefton winter daily domestic heating emissions by appliance type (worst case).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	0.2	2%	2	8	1%	11	55	1%	0	1	2%	0	0	0%	6	30	3%	0	2	1%	2	8	1%
Open fire - coal	0.2	2%	5	25	3%	17	84	1%	1	5	8%	2	10	5%	4	18	2%	1	3	3%	4	22	3%
Wood burner	2.7																						
Pre 2006 wood burner	0.7	6%	7	35	5%	97	484	7%	0	2	3%	0	1	0%	23	114	10%	1	6	5%	7	35	5%
2006-2013 wood burner	1.2	10%	5	26	4%	53	264	4%	1	3	5%	0	1	1%	24	117	10%	2	9	8%	5	26	4%
Post 2013 wood burner	0.8	7%	4	18	2%	37	183	3%	0	2	3%	0	1	0%	16	82	7%	1	7	6%	4	18	3%
Pellet Burner	0.0	0%	0	0	0%	1	4	0%	0	0	0%	0	0	0%	1	4	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	4.3	36%	43	215	29%	604	3004	46%	2	11	18%	1	4	2%	86	429	38%	7	34	29%	43	215	31%
Multi fuel – coal	4.4	37%	83	413	56%	481	2394	37%	7	35	60%	35	174	91%	66	326	29%	11	57	48%	73	364	53%
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%
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%
Total Wood	7	61%	61	302	41%	803	3994	62%	4	19	32%	1	7	4%	156	776	69%	12	58	49%	61	302	44%
Total Coal	5	39%	88	439	59%	498	2478	38%	8	40	68%	37	184	96%	69	344	31%	12	60	51%	78	386	56%
Total	12		149	740		1301	6472		12	58		38	191		225	1120		24	118		138	688	

Table 3.6: Monthly variations in contaminant emissions from domestic heating in Reefton.

	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	9	80	1	3	12	1	9
February	9	80	1	3	12	1	9
March	23	186	2	7	29	3	21
April	42	349	3	12	55	6	39
May	104	912	8	28	151	16	97
June	140	1224	11	36	208	22	130
July	141	1242	11	37	212	22	131
August	136	1197	11	35	204	22	127
September	77	651	6	21	104	12	71
October	50	430	4	14	66	8	46
November	22	183	2	6	27	3	20
December	13	109	1	4	17	2	12
Total (kg/year)	23457	203276	1814	6258	33582	3647	21726

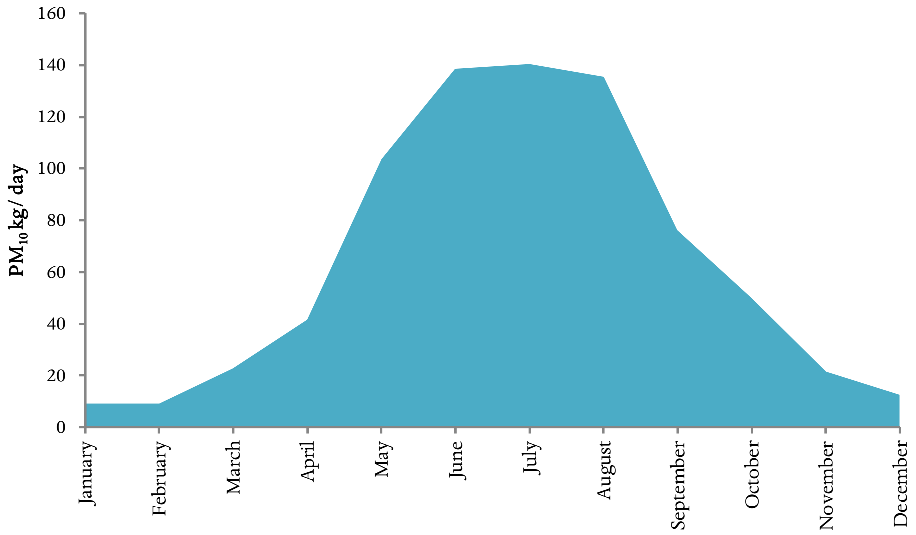

Figure 3.3: Monthly variations in PM_{10} emissions from domestic heating.

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.

Emission factors for motor vehicles are determined using the Vehicle Emission Prediction Model (VEPM 6.0). Emission factors for PM_{10}, $PM_{2.5}$, CO, NOx, VOCs and CO_2 for this study have been based on VEPM 6.0. Default settings were used for all variables except for the temperature data, and the vehicle fleet profile which was based on Buller District vehicle registration data for the year ending July 2019 (Table 4.1). Temperature data were based on an average winter temperature for Reefton of 6.8 degrees and an average speed the default setting of 50 km/hr was assumed. 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.

The number of vehicle kilometres travelled (VKT) for the airshed was estimated using the New Zealand Transport Authority VKT data for 2017 for Buller District urban areas multiplied by an estimate of the proportion of urban area VKT for the District within Reefton. The latter estimate was based on NZTA 2013 data (available by CAU).

In addition to estimates of tailpipe emissions and brake and tyre emissions using VEPM an estimate of the non-tailpipe emissions (including brake and tyre wear and re-suspended road dusts) was made using the emissions factors in the EMEP/EEA air pollutant emission inventory guidebook (Table 4.4).

Table 4.1: Vehicle registrations for the year ending July 2019.

Buller District	Petrol	Diesel	Hybrid	Plug in Hybrid	Electric	LPG	Other	Total
Cars	6,191	1,224	21	3	1	6	1	7,447
LCV	480	1,465	0	0	0	0	0	1,945
Bus	11	97	0	0	0	0	0	108
HCV		734			0			734
Miscellaneous	190	257	0	0	3	1	0	451
Motorcycle	577							577
Total	7449	3777	21	3	4	7	1	11,262

Table 4.2: Emission factors for the Buller District vehicle fleet (2019).

CO	PM_{10}	PM brake & tyre	NOx	NO_2	$PM_{2.5}$	$PM_{2.5}$ brake & tyre
g/VKT	g/VKT	g/VKT	g/VKT	g/VKT	g/VKT	g/VKT
2.2	0.031	0.022	0.765	0.140	0.031	0.012

Table 4.3: Road dust TSP emissions (from EMEP/EEA guidebook, EEA, 2016).

	TSP g/KVT
Two wheeled vehicles	0.01
Passenger car	0.02
Light duty trucks	0.02
Heavy duty trucks	0.08
Weighted vehicle fleet factor	0.019
PM_{10} size fraction	0.5
$PM_{2.5}$ size fraction	0.27

Emissions were calculated by multiplying the appropriate average emission factor by the VKT:

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

4.2 Motor vehicle emissions

Around one kilograms per day of PM_{10} are estimated to be emitted from motor vehicles daily in Reefton (Table 4.4). Around 26% of the PM_{10} from motor vehicles is estimated to occur as a result of the wearing of brakes and tyres and 13% from resuspended road dust.

Table 4.4: Summary of daily motor vehicle emissions

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	0.2	1.2	17	82	6	29	0.0	0.03
Brake and tyre	0.2	0.8						
Road dust	0.1	0.4						
Total	0.5	2.4	17	82.1	6	28.7	0	0.03
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	t	kg/ha	kg	g/ha		
Tailpipe	1	7	2	9	0.1	0.4		
Brake and tyre	0	0	0	0	0.0	0.2		
Road dust	0	0	0	0	0.0	0.2		
Total	1.5	7	0	0	0.1	0.4		

5 INDUSTRIAL AND COMMERCIAL

5.1 Methodology

Information on activities discharging to air in Reefton were obtained from information provided by the West Coast Regional Council and surveying. The main industry types are combustion for heating of schools, hospitals and other commercial activities.

The selection of industries for inclusion in this inventory was based on potential for PM_{10} emissions. Industrial activities such as spray painting, 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 was collected through contacting industry by phone or email.

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. 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	$PM_{2.5}$ g/kg
Coal – underfeed boiler	2	5.5	4.8	19.0	0.1	2400	1.2
Domestic scale multi fuel burner	19	110	1.6	8	15	2600	16.7

5.2 Industrial and commercial emissions

Table 5.2 shows the estimated emissions to air from industrial and commercial activities in Reefton. Just less than two kilograms of PM_{10} is estimated to be discharged to air per winter's day in Reefton (Table 5.2).

Table 5.2: Summary of industrial emissions (daily winter) in Reefton.

	PM_{10}		CO		NOx		SOx	
Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
201	1.7	9	6	32	3	15	5	27
	VOC		CO_2		$PM_{2.5}$			
Hectares	kg	g/ha	t	kg/ha	kg	g/ha		
201	0.4	2	2	8	1.2	6		

Table 5.3: Summary of industrial annual emissions in Reefton.

PM_{10} t/year	CO t/year	NOx t/year	SOx t/year	VOC t/year	CO_2 t/year	$PM_{2.5}$ t/year
0.5	2	0.89	1	0	457	0.3

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 or because of the contribution of these emissions to ambient air quality. Outdoor burning includes any burning in a drum, incinerator or open air on residential properties in the study area.

6.1 Methodology

Outdoor burning emissions for Reefton were estimated for the winter months based on data collected during the 2019 household survey.

Emissions were calculated based on the assumption of an average weight of material per burn of 159 kilograms per cubic metre of material[2] and using the emission factors in Table 6.1 with an average fire size of 0.9 m3 (size based on survey responses). The AP42 emission factor database includes estimates for a wide range of materials including different tree species, weeds, leaves, vines and other agricultural material. Emission factors for SOx are based on residential wood burning in the absence of emission factors for these contaminants within the AP42 database for outdoor burning. In comparison the European Environment Agency air pollution emission inventory guidebook (EEA, 2016) tier one assessment emission factors are based on tree slash for two species and tree pruning for two species only.

Table 6.1: Outdoor burning emission factors (AP42).

	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SOx g/kg	CO_2 g/kg
Outdoor burning	8	8	42	2	0.5	1470

[2] Based on the average of low and medium densities for garden vegetation from (Victorian EPA, 2016)

6.2 Outdoor burning emissions

Table 6.2 shows that around one kilogram of PM_{10} from outdoor burning could be expected per day during the winter months on average in Reefton.

It should be noted, 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 on days more suitable for burning. 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. In addition, the emission factors vary by a factor of three for different materials being burnt. Outdoor burning emissions include a higher degree of uncertainty relative to domestic heating, motor vehicles and industry owing to uncertainties in the distribution of burning and potential variabilities in material type and density.

Table 6.2: Outdoor burning emission estimates for Reefton.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	VOC kg/ day	CO_2 t/ day	$PM_{2.5}$ kg/day
Summer (Dec-Feb)	1	6	0	0	1	0	1
Autumn (Mar-May)	1	6	0	0	1	0	1
Winter (June-Aug)	1	5	0	0	0	0	1
Spring (Sept-Nov)	1	6	0	0	1	0	1

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 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. Historically a Pacific Air and Environment (1999) figure of around 0.07 grams of PM_{10} per household per day has been used. This was re-evaluated with more recent information in Wilton (2019). This indicated a range of 0.0012 to 0.05 g/household/day and results in an estimate of less than 0.03 kilograms of PM_{10} per day from these sources.

8 TOTAL EMISSIONS

The total PM_{10} that was discharged to air in Reefton on an average winter's day was estimated at 144 kilograms for 2019. Domestic home heating is the main source of PM_{10} emissions contributing 98% of the daily wintertime emissions and 96% of the annual PM_{10} emissions. Outdoor burning and industry each contribute less than 2% of the daily PM_{10} and annual emissions with motor vehicles contributing the remainder.

The relative contributions to daily winter and annual average $PM_{2.5}$ are similar as for PM_{10} with domestic heating contributing 98% and 97% respectively (Figure 8.2).

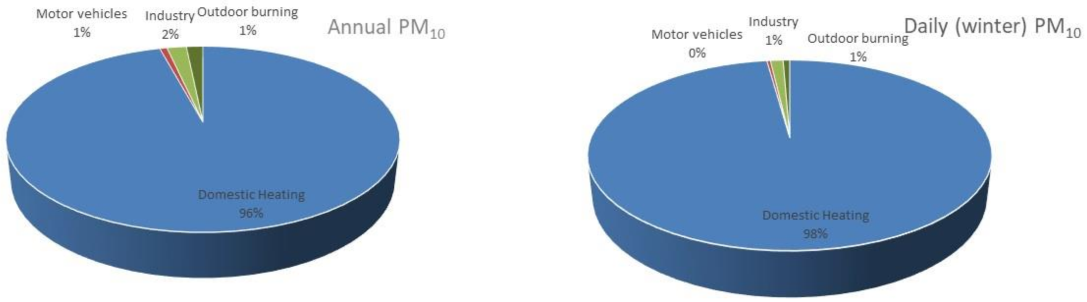

Figure 8.1: Relative contribution of sources to daily winter and annual PM_{10} emissions in Reefton.

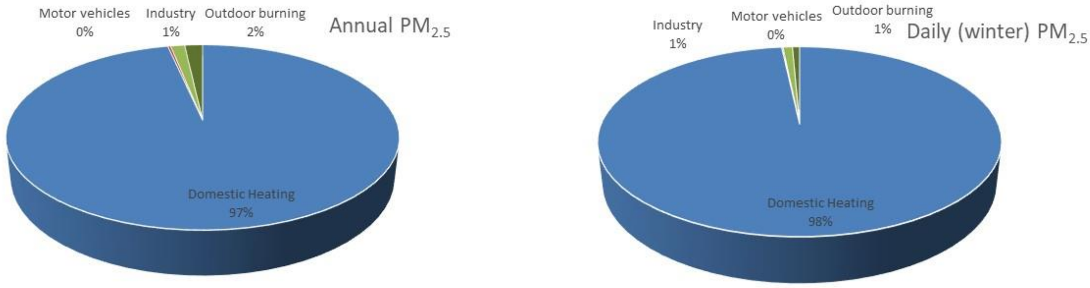

Figure 8.2: Relative contribution of sources to daily winter and annual $PM_{2.5}$ emissions in Reefton.

Previous inventories were carried out in 2005 and 2012. In 2005 the daily winter estimate for PM_{10} was 293 kilograms per day and in 2012 it was 122 kg/day although it is likely that the dwelling numbers for 2012 were underestimated. Figure 8.3 shows that the trends in daily winter PM_{10} emissions in Reefton from 2005 to 2019 after adjusting 2012 dwelling numbers to be equivalent to the 2013 census result. Results suggest a small (7%) increase in PM_{10} in Reefton from 2012 to 2019. The main cause of the increase is a reported higher daily average fuel use in 2019 relative to 2012. The 2019 fuel use averages are more similar to those in 2005. It is possible that economic or meteorological factors may have influenced fuel use in 2012.

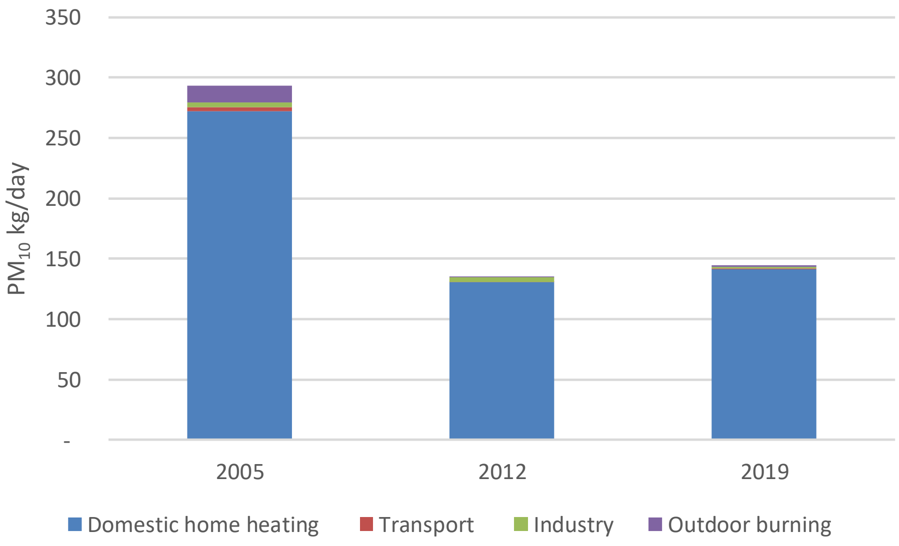

Figure 8.3: Daily winter PM_{10} emissions in Reefton in 2005, 2012 and 2019.

Domestic home heating is also the main source of daily winter SOx, CO_2, CO and VOC and motor vehicles are the main source of daily winter NOx (Figure 8.4).

Table 8.1 shows seasonal variations in PM_{10} emissions. Domestic heating is the main source of daily PM_{10} during all seasons. Daily wintertime emissions of PM_{10} and other contaminants (kg/day and g/day/ha) are shown in Table 8.2.

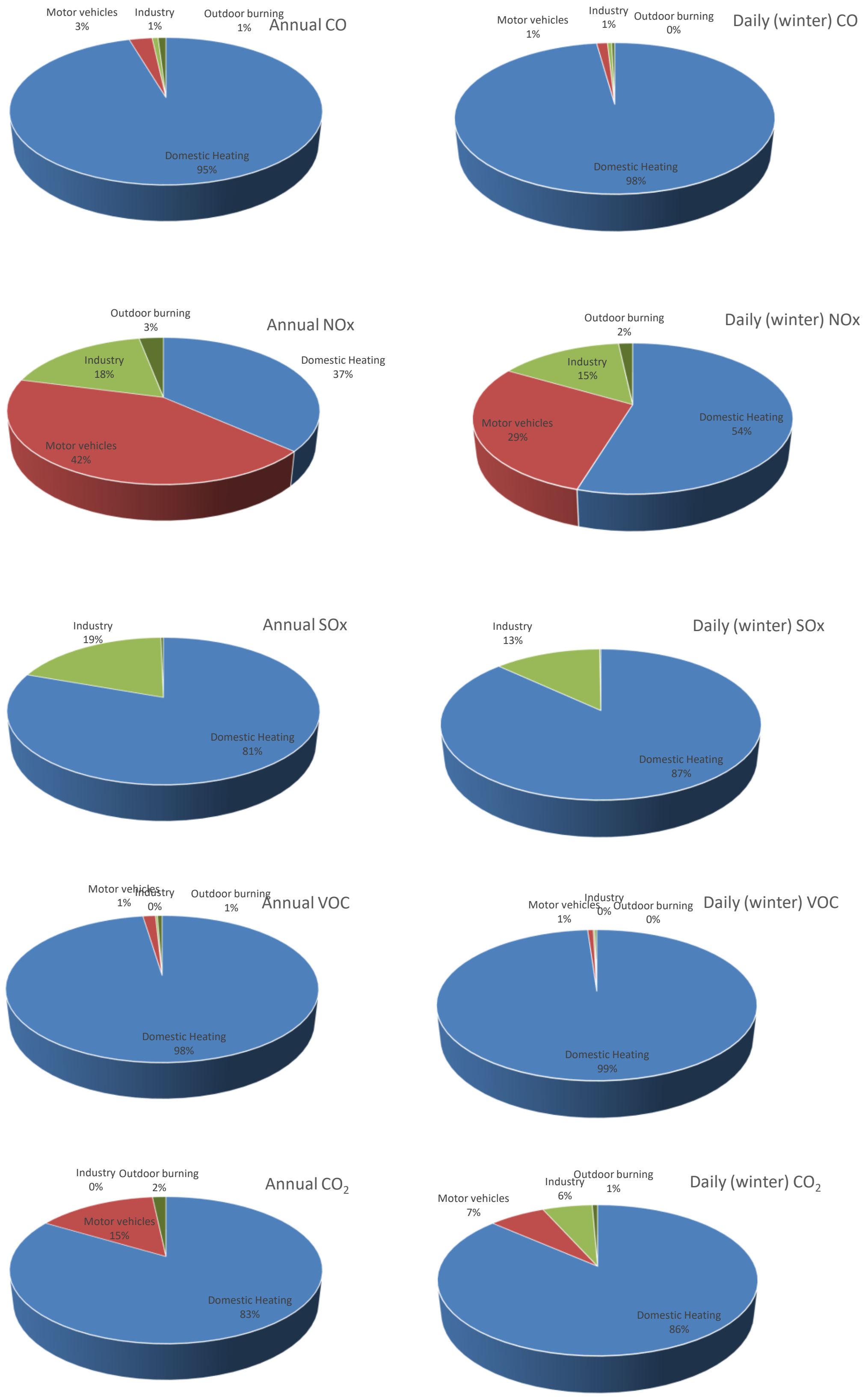

Figure 8.4: Relative contribution of sources to daily winter contaminant emissions in Reefton

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

	Domestic Heating		Outdoor Burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	9	78%	1.2	10%	1.0	8%	0.5	4%	12
February	9	77%	1.2	10%	1.1	9%	0.5	4%	12
March	23	90%	1.1	4%	1.0	4%	0.5	2%	26
April	42	94%	1.1	2%	1.1	2%	0.5	1%	45
May	104	98%	1.1	1%	1.0	1%	0.5	0%	107
June	140	98%	0.9	1%	1.8	1%	0.5	0%	143
July	141	98%	0.9	1%	1.7	1%	0.5	0%	145
August	136	98%	0.9	1%	1.7	1%	0.5	0%	140
September	77	96%	1.1	1%	1.3	2%	0.5	1%	80
October	50	95%	1.1	2%	1.2	2%	0.5	1%	53
November	22	88%	1.1	5%	1.3	5%	0.5	2%	24
December	13	83%	1.2	8%	1.0	6%	0.5	3%	15
Total kg year	23457	96%	395	2%	463	2%	173	1%	24487

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

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	141	704	1242	6180	11	55	37	182
Transport	0.5	2.4	16.5	82.1	5.8	28.7	0.0	0.0
Industry	1.7	9	6	32	3	15	5	27
Outdoor burning	1	5	5	24	0	2	0	0
Total	145	719	1270	6318	20	100	42	209
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	tonnes	kg/ha	kg	g/ha		
Domestic home heating	212	1056	22	111	131	653		
Transport	1	7	2	9	0.2	0.8		
Industry	0.4	2	2	8	1.2	6		
Outdoor burning	0.5	2	0.2	1	1	5		
Total	215	1068	26	129	134	665		

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APPENDIX A: HOME HEATING QUESTIONNAIRE

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?

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?

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).

Emission factors for $PM_{2.5}$ are based on 100% of the particulate from wood burning being in the $PM_{2.5}$ size fraction and 88% of the PM_{10} from domestic coal burning. The $PM_{2.5}$ component of PM_{10} is typically expressed as a proportion. The AP42 wood stove and open fire proportion is based on 1998 data and given as 93% of the PM_{10} being $PM_{2.5}$ (http://www.epa.gov/ttnchie1/efdocs/rwc_pm25.pdf). Smithson, (2011) uses a proportion of 97% which is more consistent with current scientific understanding that virtually all the particulate from wood burning in New Zealand is less than 2.5 microns in diameter (Perry Davy, pers comm, 2014). Literature review of the proportion of PM_{10} that was $PM_{2.5}$ returns minimal information for domestic scale wood use. The technical advisory group to the Ministry for the Environment (2014) air quality indicators project on emissions advised their preference for a value of 100% and we have opted for this value for subsequent work because information is indicative of a value nearing 100%. Further investigations into this may be warranted in the future given the focus towards $PM_{2.5}$. A value of 88% from Ehrlich & Kalkoff, (2007) was used for the proportion of PM_{10} in the $PM_{2.5}$ size fraction for small scale coal burning.

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.