OCTOBER 2019

PREPARED FOR

Otago Regional Council

PREPARED BY

Emily Wilton, Environet Ltd

www.environet.co.nz

ENVIRONET AIR QUALITY SPECIALISTS

Wanaka, Cromwell and Clyde Air Emission Inventory - 2019

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EXECUTIVE SUMMARY

The main air quality concern for urban towns in the Otago Region is concentrations of particles in the air less than 10 microns and less than 2.5 microns in diameter (PM_{10} and $PM_{2.5}$). An emission inventory was carried out in 2019 to estimate the amount of emissions of PM_{10} and $PM_{2.5}$ and other contaminants discharged to air in the towns of Wanaka, Cromwell and Clyde. These were the first emission inventory assessments to be carried out in these towns.

Sources included in the inventory were domestic heating, motor vehicles, industrial and commercial activities and outdoor burning. These are the main anthropogenic sources of air contaminants in urban areas of New Zealand. 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 estimating emissions of suspended particles (PM_{10}) 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. In Wanaka electricity and wood burning were found to be the most common methods of heating the main living area with 66 and 65% of households using these sources of heating. Open fires were used by 5% of households in Wanaka. In Cromwell and Clyde 72% of households used electricity and 56% used wood burners in their main living area. 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 all three areas accounting for between 95% and 98% of the daily winter PM_{10} and $PM_{2.5}$ emissions. Other sources included outdoor burning (4% of daily winter PM_{10}) with motor vehicles and industry having relatively minor contributions. On an average winter's night, around 310, 150 and 38 kilograms of PM_{10} are discharged in Wanaka, Cromwell and Clyde respectively. The $PM_{2.5}$ emission estimates were 36, 22 and 5 tonnes per year in Wanaka, Cromwell and Clyde.

A comparison of daily PM_{10} emissions during the winter to a 2013 estimate suggests no real change in emissions in Wanaka and Cromwell and a slight decrease in emissions in Clyde.

1 INTRODUCTION

Emission inventories assess the amount of emissions from different sources and are used for air quality management purposes and to evaluate changes in emission sources with time. 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.

The Otago Regional Council has gazetted three Air Zones for the management of air quality and in particular concentrations of PM_{10} in the Region. These are:

- Air Zone 1: Alexandra, Arrowtown, Clyde and Cromwell.
- Air Zone 2: Balclutha, Dunedin, Hawea, Kingston, Milton, Mosgiel, Naseby, Oamaru, Palmerston, Port Chalmers, Queenstown, Ranfurly, Roxburgh, Waikouaiti and Wanaka.
- Air Zone 3: The rest of Otago.

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 in Wanaka, Cromwell and Clyde. Other contaminants included in this emission inventory are carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds, carbon dioxide and benzo(a)pyrene.

Monitoring for PM_{10} has routinely been carried out in Cromwell and Clyde. In these areas, the 24-hour average concentrations of PM_{10} can exceed the 50 $\mu g/m^3$ (National Environmental Standard limit value) during the winter months. In Cromwell maximum daily PM_{10} concentrations higher than 100 $\mu g/m^3$ occur most years. In Clyde the highest 24-hour average PM_{10} concentrations are typically in the 60-70 $\mu g/m^3$ range.

Historical monitoring of PM_{10} in Wanaka suggested the town was compliant with the NES for PM_{10}. The Otago Regional Council will commence monitoring in Wanaka during 2020.

No previous air emission inventories have been carried out for Wanaka, Cromwell or Clyde.

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) and carbon dioxide (CO_2)

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 inventory study areas for each town are the census area units for Wanaka, Cromwell and Clyde and are illustrated in Figures 2.1 to 2.3. These differ to the gazetted airsheds for Wanaka and Clyde. In Wanaka the inventory area includes Albert Town and extends further to the east relative to the airshed. In Clyde the airshed includes a small number of dwellings on the west side of the Clutha River which are not included in the Clyde inventory area. The Cromwell inventory area and airshed cover the same area.

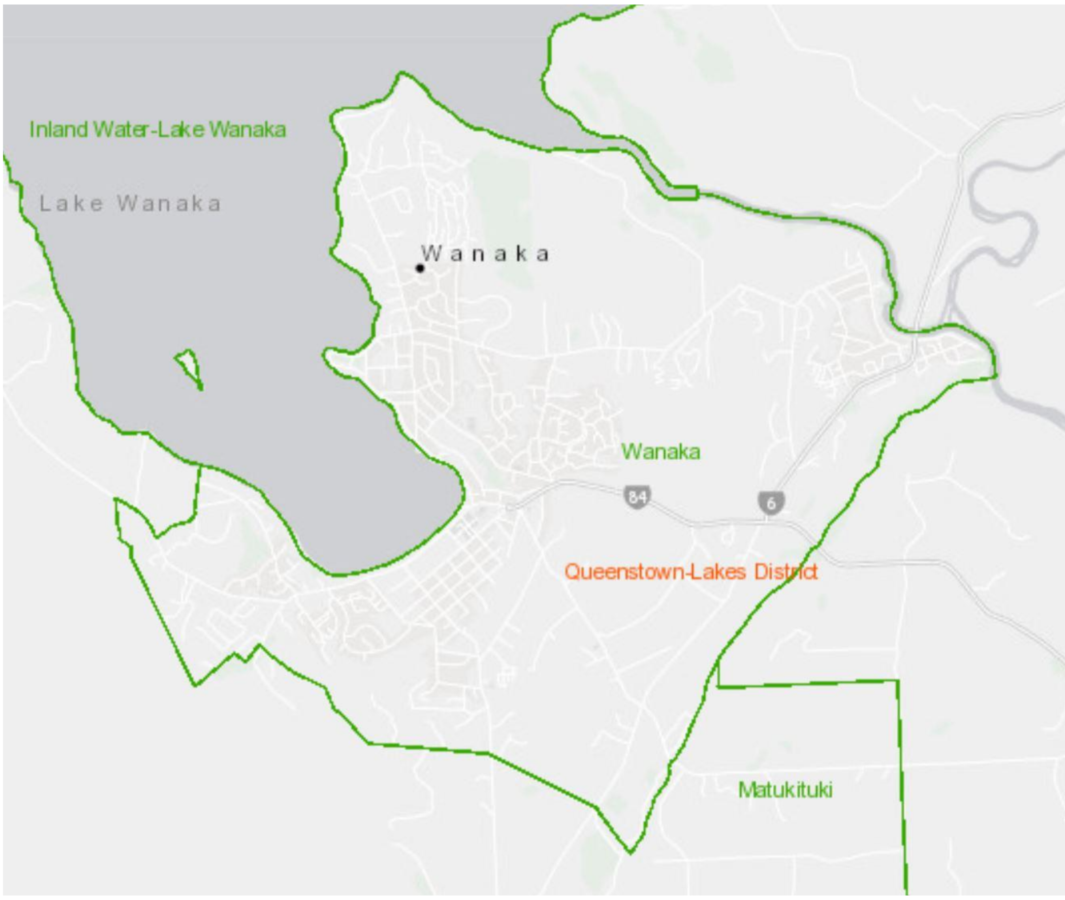

Figure 2.1: Wanaka inventory area (source StatsMaps, 2019).

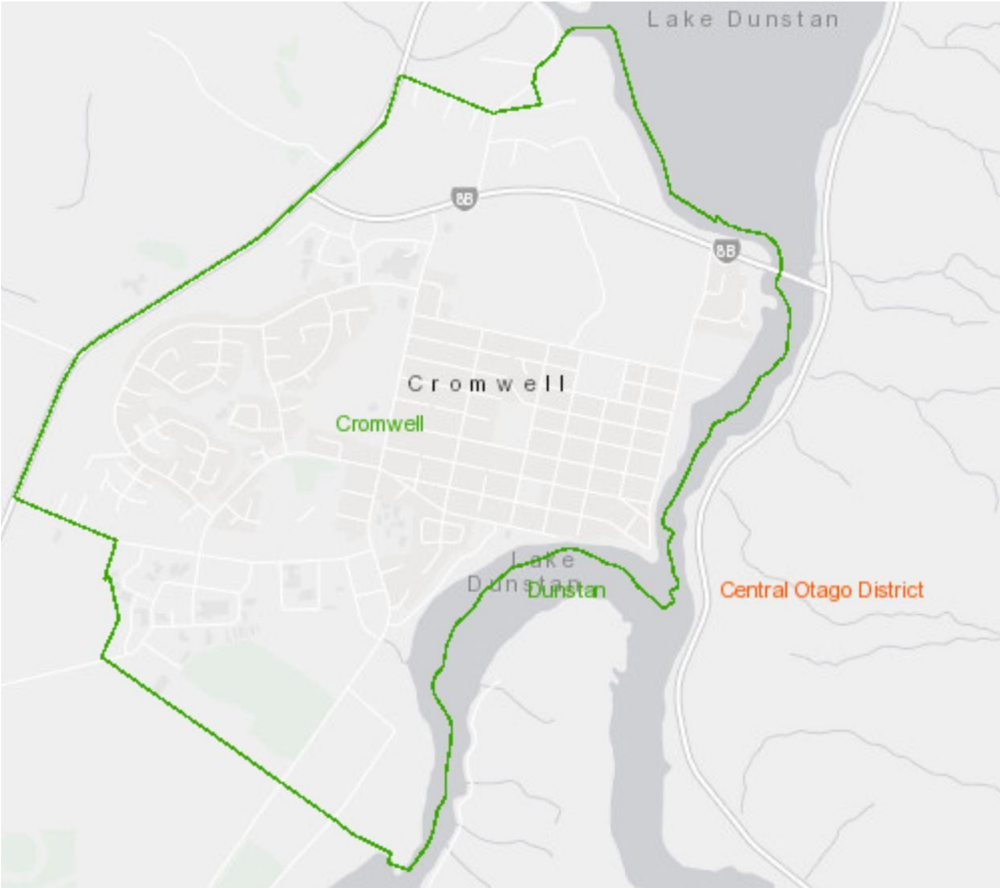

Figure 2.2: Cromwell inventory area (source StatsMaps, 2019).

Figure 2.3: Clyde inventory area (source StatsMaps, 2019).

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 Wanaka, Cromwell and Clyde 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 number of households for 2019 based on 2018 census data for occupied private dwellings (Statistics NZ, 2019). The dwelling number is based on typically occupied dwellings which will differ from the total number of dwellings particularly in areas such as Wanaka where holiday homes are prevalent. Cromwell and Clyde were surveyed together because of sample size issues.

Table 3.1: Summary household, area and survey data.

	Dwellings in Airshed	Sample size	Area (ha)	Sample error
Wanaka	3675	354	2861	<5%
Cromwell/Clyde	2679	370	761 & 322	<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	BaP g/kg
Open fire - wood	7.5	7.5	55	1.2	0.2	30	1600	0.002
Open fire - coal	21	18	70	4	8	15	2600	2.70E-06
Pre 2006 burners	10	10	140	0.5	0.2	33	1600	0.003
Post 2006 burners	4.5	4.5	45	0.5	0.2	20	1600	0.003
Pellet burners	2	2	20	0.5	0.2	20	1600	0.003
Multi-fuel[1] - wood	10	10	140	0.5	0.2	20	1600	0.002
Multi-fuel[1] – coal	19	17	110	1.6	8	15	2600	2.70E-06
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.

3.2 Home heating methods in Wanaka

The most popular forms of heating the main living area of homes in Wanaka are electricity and woodburners with around 65% of households using electricity and 66% using woodburners. Open fires and gas are used by 5% and 13% of households respectively. Table 3.3 also shows that households rely on more than one method of heating their main living area during the winter months.

Around 46 tonnes of wood was burnt per typical winter's night in Wanaka during 2019.

Figure 3.1 shows the proportion of households using different electrical heating types. This shows around 75% of households using electricity in their main living area use heat pumps.

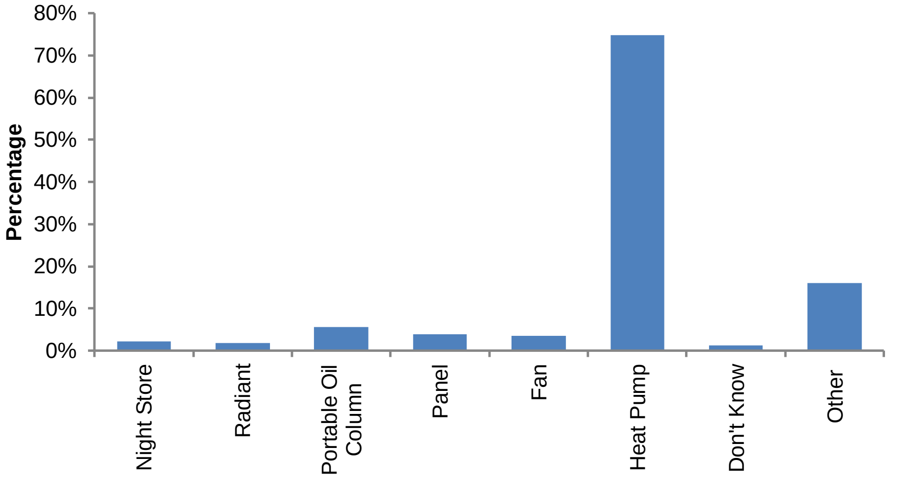

Figure 3.1: Electric heating options for Wanaka households (main living area).

Table 3.3: Home heating methods and fuels.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	65%	2,398		
Total Gas	13%	467	0.4	1%
Flued gas	10%	383		
Unflued gas	2%	84		
Oil	3%	125	0.1	0%
Open fire	5%	187		
Open fire - wood	5%	187	2	5%
Open fire - coal	0%	10	0.1	0%
Total Wood burner	66%	2,408	44	92%
Pre 2006 wood burner	21%	785	14	30%
2006-2013 wood burner	27%	987	18	38%
Post-2013 wood burner	17%	637	12	24%
Multi-fuel burners	1.1%	42		
Multi-fuel burners-wood	0.6%	21	0.4	1%
Multi-fuel burners-coal	0.6%	21	0.1	0%
Pellet burners	1%	21	0.1	0%
Total wood	71%	2,616	46	98%
Total coal	1%	31	0.2	0.4%
Total		3,675	47	100%

3.3 Emissions from domestic heating.

In 2019 around 300 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Wanaka. The annual $PM_{2.5}$ emission was estimated at 36 tonnes per year.

Figure 3.2 shows that the largest portion (47%) of the PM_{10} emissions are from pre-2006 wood burners. The NES design criteria for wood burners was mandatory for new installations on properties less than 2 hectares from September 2005. Wood burners installed during the years 2006 to 2013 contribute to 27% of domestic heating PM_{10} emissions and burners less than five years old contribute 17%. Burners in these two age categories represent the same technology (the same emission factors are used) and segregations just represent burners age distributions. Open fires contribute around 7% of daily winter PM_{10} emissions in Wanaka.

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 328 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 May, June and July.

[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%).

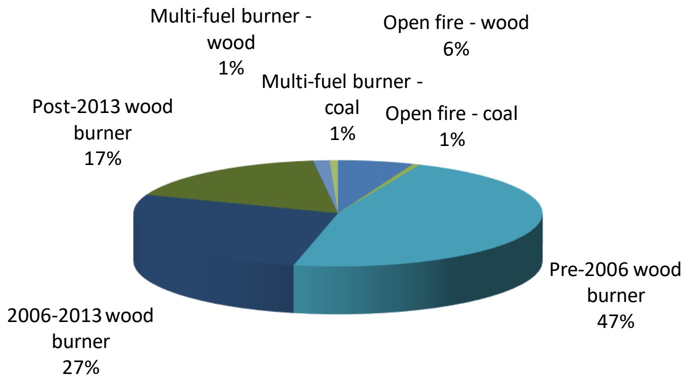

Figure 3.2: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Wanaka.

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

	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	2.4	5%	18	6	6%	131	46	4%	3	1	11%	0	0	4%	72	25	6%	4	1	5%	18	6	6%
Open fire - coal	0.1	0%	2	1	1%	6	2	0%	0	0	1%	1	0	6%	1	0	0%	0	0	0%	2	1	1%
Wood burner	43.7																						
Pre 2006 wood burner	14.2	30%	142	50	47%	1989	695	57%	7	2	27%	3	1	25%	469	164	41%	23	8	30%	142	50	47%
2006-2013 wood burner	17.9	38%	80	28	27%	804	281	23%	9	3	34%	4	1	32%	357	125	31%	29	10	38%	80	28	27%
Post 2013 wood burner	11.5	24%	52	18	17%	519	181	15%	6	2	22%	2	1	21%	230	81	20%	18	6	24%	52	18	17%
Pellet Burner	0.1	0%	0.1	0	0%	1	0	0%	0	0	0%	0	0	0%	1	0	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.4	1%	4	1	1%	54	19	2%	0	0	1%	0	0	1%	8	3	1%	1	0	1%	4	1	1%
Multi fuel – coal	0.1	0%	2	1	1%	12	4	0%	0	0	1%	1	0	8%	2	1	0%	0	0	0%	2	1	1%
Gas	0.4	1%	0.01	0	0%	0	0	0%	1	0	2%	0	0	0%	0	0	0%	1	0	1%	0	0	0%
Oil	0.1	0%	0.03	0	0%	0	0	0%	0	0	1%	0	0	3%	0	0	0%	0	0	0%	0	0	0%
Total Wood	46.4	98%	296.26	104	99%	3499	1223	99%	25	9	95%	9	3	83%	1137	398	100%	74	26	98%	296	104	99%
Total Coal	0.2	0%	3.80	1	1%	18	6	0%	1	0	2%	2	1	14%	3	1	0%	0	0	1%	3	1	1%
Total	47		300	105		3516	1229		26	9		11	4		1140	399		76	27		300	105	

Table 3.5: Wanaka 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	3.5	7%	26	9	8%	191	67	5%	4	1	14%	1	0	6%	104	36	8%	6	2	7%	26	9	8%
Open fire - coal	0.1	0%	3	1	1%	9	3	0%	0	0	2%	1	0	8%	2	1	0%	0	0	0%	2	1	1%
Wood burner	46.2																						
Pre 2006 wood burner	15.1	30%	151	53	46%	2110	738	56%	8	3	26%	3	1	24%	497	174	40%	24	8	29%	151	53	46%
2006-2013 wood burner	18.9	37%	85	30	26%	853	298	22%	9	3	33%	4	1	30%	379	132	31%	30	11	37%	85	30	26%
Post 2013 wood burner	12.2	24%	55	19	17%	550	192	14%	6	2	21%	2	1	20%	244	85	20%	20	7	24%	55	19	17%
Pellet Burner	0.1	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.5	1%	5	2	2%	72	25	2%	0	0	1%	0	0	1%	10	4	1%	1	0	1%	5	2	2%
Multi fuel – coal	0.1	0%	3	1	1%	15	5	0%	0	0	1%	1	0	9%	2	1	0%	0	0	0%	2	1	1%
Gas	0.4	1%	0	0	0%	0	0	0%	1	0	2%	0	0	0%	0	0	0%	1	0	1%	0	0	0%
Oil	0.1	0%	0	0	0%	0	0	0%	0	0	1%	0	0	3%	0	0	0%	0	0	0%	0	0	0%
Total Wood	50	98%	322	113	98%	3777	1320	99%	28	10	95%	10	4	80%	1237	432	100%	80	28	98%	322	113	99%
Total Coal	0	1%	5	2	2%	24	8	1%	1	0	2%	2	1	17%	4	1	0%	1	0	1%	5	2	1%
Total	51		328	115		3801	1329		29	10		13	4		1241	434		83	29		327	114	

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

	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	1	7	0	0	2	0	1
February	0	1	0	0	0	0	0
March	2	29	0	0	9	1	2
April	25	298	3	1	96	7	25
May	262	3064	23	9	997	66	261
June	297	3485	25	11	1132	74	297
July	300	3516	26	11	1140	76	300
August	210	2469	18	8	788	53	209
September	54	641	5	2	206	15	54
October	12	139	1	0	43	3	12
November	3	32	0	0	10	1	3
December	0	4	0	0	1	0	0
Total (kg/year)	35744	419798	3095	1281	135747	9075	35692

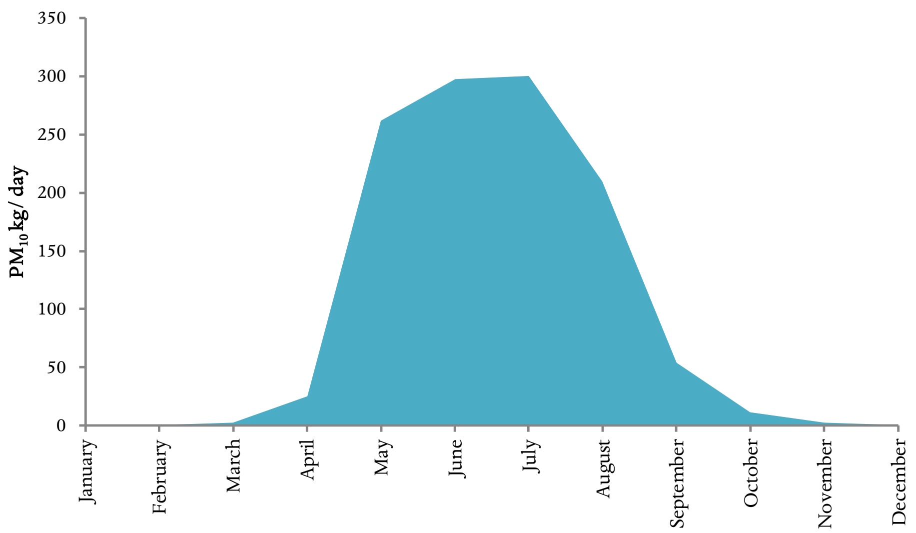

Figure 3.3: Monthly variations in PM_{10} emissions from domestic heating in Wanaka.

3.4 Home heating methods in Cromwell

The most popular form of heating the main living area of homes in Cromwell is electricity with around 72% of households using this method. Wood burners are the next most prevalent heating method with 56% of households using a wood burner in their main living area. Gas is used by 12% of households and 8% of households use oil. Table 3.7 also shows that households rely on more than one method of heating their main living area during the winter months.

Around 26 tonnes of wood was burnt per typical winter's night in Cromwell during 2019.

Figure 3.4 shows the proportion of households using different electrical heating types. This shows around 88% of households using electricity in their main living area use heat pumps.

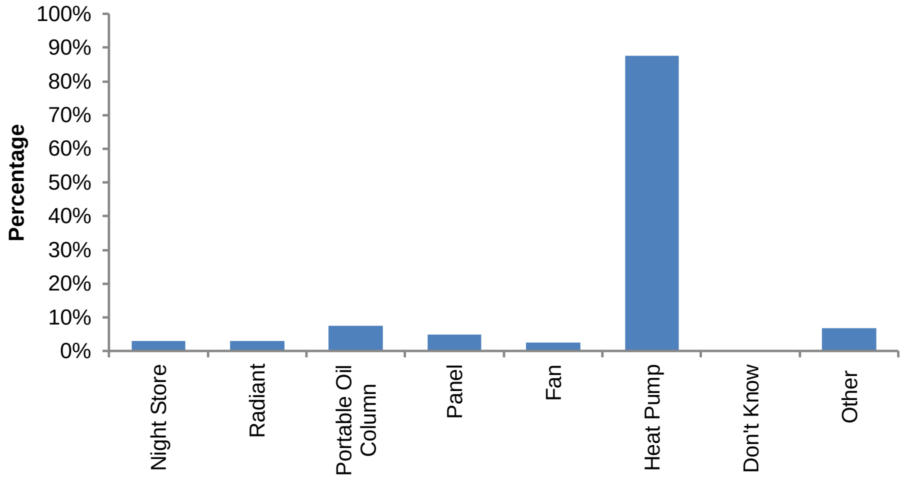

Figure 3.4: Electric heating options for Cromwell households (main living area).

Table 3.7: Home heating methods and fuels in Cromwell.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	72%	1,549		
Total Gas	12%	254	0.2	1%
Flued gas	11%	225		
Unflued gas	1%	30		
Oil	8%	173	0.1	0%
Open fire	1%	17		
Open fire - wood	1%	17	0.3	1%
Open fire - coal	0%	0	0	0%
Total Wood burner	56%	1,202	25	95%
Pre 2006 wood burner	8%	167	3	13%
2006-2013 wood burner	23%	501	10	40%
Post-2013 wood burner	25%	534	11	42%
Multi-fuel burners	2%	46		
Multi-fuel burners-wood	1%	17	0.3	1%
Multi-fuel burners-coal	1%	29	0.2	1%
Pellet burners	1%	29	0.2	1%
Total wood	58%	1,237	26	98%
Total coal	1%	29	0	1%
Total		2,139	26	100%

3.5 Emissions from domestic heating in Cromwell

In 2019 around 141 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Cromwell. The annual $PM_{2.5}$ emission was estimated at 18 tonnes per year.

Figure 3.5 shows that the largest portion (33%) of the PM_{10} emissions are from 2006-2013 wood burners. The NES design criteria for wood burners was mandatory for new installations on properties less than 2 hectares from September 2005. Wood burners installed prior to 2006 contribute to 25% of domestic heating PM_{10} emissions and burners less than five years old contribute 35%.

Tables 3.8 and 3.9 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[2]. Under the worst-case scenario that all households are using a burner on any given night around 148 kilograms of PM_{10} is likely to be emitted.

The seasonal variation in contaminant emissions is shown in Table 3.10. Figure 3.6 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during May, June, July and August.

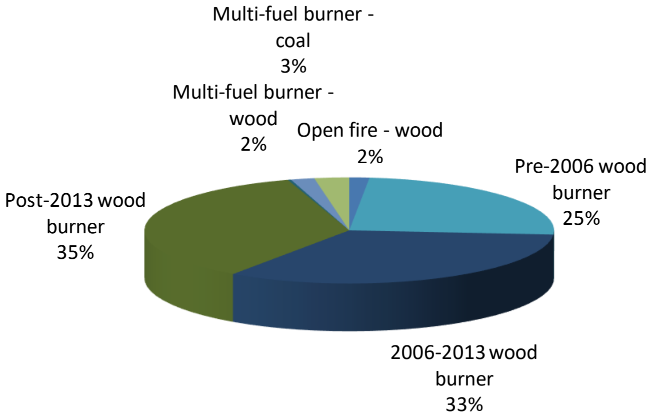

Figure 3.5: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Cromwell.

[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%).

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

	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	0.3	1%	2	3	2%	16	22	1%	0	0	3%	0	0	1%	9	12	2%	0	1	1%	2	3	2%
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%
Wood burner	25.3																						
Pre 2006 wood burner	3.5	13%	35	46	25%	487	640	32%	2	2	12%	1	1	10%	115	151	20%	6	7	13%	35	46	25%
2006-2013 wood burner	10.5	40%	47	62	33%	471	619	31%	5	7	37%	2	3	29%	209	275	37%	17	22	39%	47	62	33%
Post 2013 wood burner	11.2	42%	50	66	36%	502	660	33%	6	7	40%	2	3	31%	223	293	39%	18	23	42%	50	66	36%
Pellet Burner	0.2	1%	0.4	0	0%	4	5	0%	0	0	1%	0	0	0%	4	5	1%	0	0	1%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.3	1%	3	3	2%	37	48	2%	0	0	1%	0	0	1%	5	7	1%	0	1	1%	3	3	2%
Multi fuel – coal	0.2	1%	4	5	3%	22	30	1%	0	0	2%	2	2	22%	3	4	1%	1	1	1%	3	4	2%
Gas	0.2	1%	0.01	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	1	1	1%	0	0	0%
Oil	0.1	0%	0.04	0	0%	0	0	0%	0	0	2%	0	1	7%	0	0	0%	0	1	1%	0	0	0%
Total Wood	25.9	98%	137.40	181	97%	1518	1995	99%	13	17	93%	5	7	71%	565	743	99%	41	54	96%	137	181	98%
Total Coal	0.2	1%	3.88	5	3%	22	30	1%	0	0	2%	2	2	22%	3	4	1%	1	1	1%	3	4	2%
Total	26		141	186		1540	2024		14	18		7	10		568	747		43	56		141	185	

Table 3.9: Cromwell 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	0.3	1%	2	3	2%	18	24	1%	0	1	3%	0	0	1%	10	13	2%	1	1	1%	2	3	2%
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%
Wood burner	26.3																						
Pre 2006 wood burner	3.6	13%	36	48	25%	510	670	32%	2	2	12%	1	1	10%	120	158	20%	6	8	13%	36	48	25%
2006-2013 wood burner	11.0	40%	49	65	33%	493	648	31%	5	7	37%	2	3	29%	219	288	37%	18	23	39%	49	65	33%
Post 2013 wood burner	11.7	42%	53	69	36%	525	690	33%	6	8	40%	2	3	31%	233	307	39%	19	25	42%	53	69	36%
Pellet Burner	0.2	1%	0	1	0%	4	5	0%	0	0	1%	0	0	1%	4	5	1%	0	0	1%	0	1	0%
Multi fuel burner																							
Multi fuel– wood	0.3	1%	3	4	2%	38	49	2%	0	0	1%	0	0	1%	5	7	1%	0	1	1%	3	4	2%
Multi fuel – coal	0.2	1%	4	5	3%	23	30	1%	0	0	2%	2	2	22%	3	4	1%	1	1	1%	3	5	2%
Gas	0.2	1%	0	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	1	1	1%	0	0	0%
Oil	0.1	0%	0	0	0%	0	0	0%	0	0	2%	0	1	6%	0	0	0%	0	1	1%	0	0	0%
Total Wood	27	98%	144	189	97%	1587	2086	99%	14	18	94%	5	7	72%	592	778	99%	43	57	97%	144	189	98%
Total Coal	0	1%	4	5	3%	23	30	1%	0	0	2%	2	2	22%	3	4	1%	1	1	1%	3	5	2%
Total	28		148	194		1610	2116		15	19		8	10		595	782		45	59		147	194	

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

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	1	12	0	0	5	0	1
April	13	138	2	0	52	4	13
May	111	1214	11	5	450	34	111
June	137	1493	13	7	551	41	137
July	141	1540	14	7	568	42	141
August	128	1395	12	6	513	38	127
September	43	473	4	2	178	14	43
October	16	181	2	1	68	5	16
November	2	23	0	0	9	1	2
December	0	2	0	0	1	0	0
Total (kg/year)	18159	198520	1775	846	73451	5503	18109

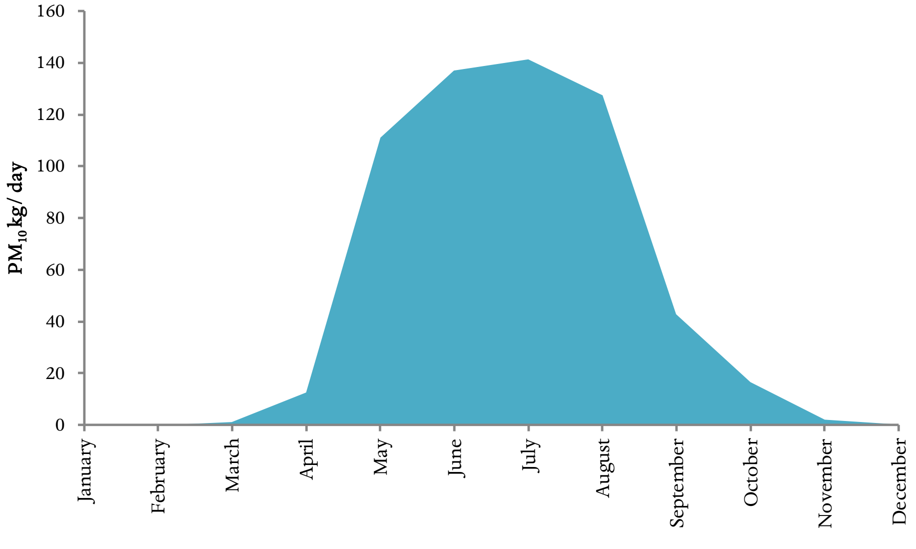

Figure 3.6: Monthly variations in PM_{10} emissions from domestic heating in Cromwell

3.6 Home heating methods in Clyde

The most common forms of heating the main living areas of homes in Clyde are electricity and woodburners with 72% and 56% of homes using these methods. Gas and oil are also used by a small proportion of households (12% and 8% respectively). Table 3.11 also shows that households rely on more than one method of heating their main living area during the winter months.

Around 6 tonnes of wood was burnt per typical winter's night in Clyde during 2019.

Figure 3.7 shows the proportion of households using different electrical heating types. This shows around 88% of households using electricity in their main living area use heat pumps.

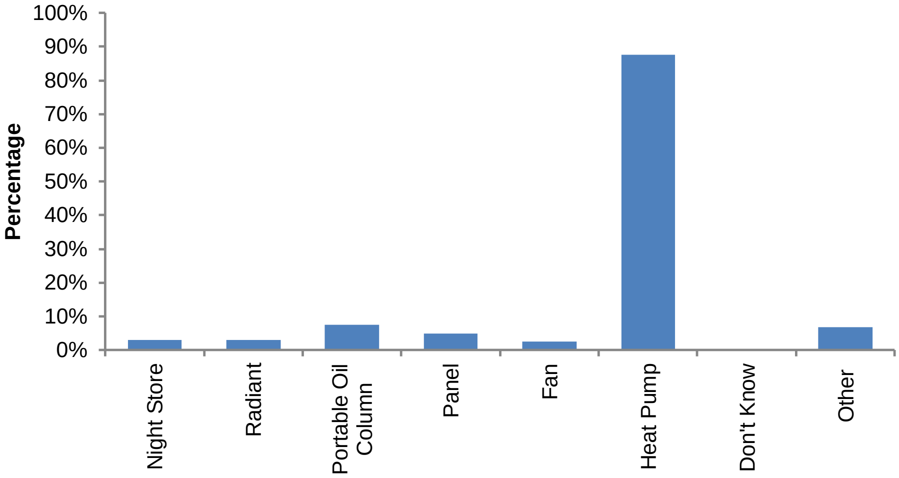

Figure 3.7: Electric heating options for Clyde households (main living area).

Table 3.11: Home heating methods and fuels in Clyde.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	72%	391		
Total Gas	12%	64	0.1	1%
Flued gas	11%	57		
Unflued gas	1%	7		
Oil	8%	44	0.03	0%
Open fire	1%	4		
Open fire - wood	1%	4	0.1	1%
Open fire - coal	0%	0	0	0%
Total Wood burner	56%	304	6	96%
Pre 2006 wood burner	8%	42	1	13%
2006-2013 wood burner	23%	127	3	40%
Post-2013 wood burner	25%	135	3	42%
Multi-fuel burners	2%	12		
Multi-fuel burners-wood	1%	4	0.1	1%
Multi-fuel burners-coal	1%	7	0.1	1%
Pellet burners	1%	7	0.01	0%
Total wood	58%	312	6	98%
Total coal	1%	7	0.1	1%
Total		540	7	100%

3.7 Emissions from domestic heating in Clyde

Around 36 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Clyde. The annual $PM_{2.5}$ emission was estimated at 4.5 tonnes per year.

Figure 3.8 shows that the largest portion (33%) of the PM_{10} emissions are from 2006-2013 wood burners. The NES design criteria for wood burners was mandatory for new installations on properties less than 2 hectares from September 2005. Wood burners installed prior to 2006 contribute to 25% of domestic heating PM_{10} emissions and burners less than five years old contribute 36%.

Tables 3.12 and 3.13 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[3]. Under the worst-case scenario that all households are using a burner on any given night around 37 kilograms of PM_{10} is likely to be emitted.

The seasonal variation in contaminant emissions is shown in Table 3.14. Figure 3.9 indicates that the majority of the annual PM_{10} emissions from domestic home heating occur during May, June, July and August.

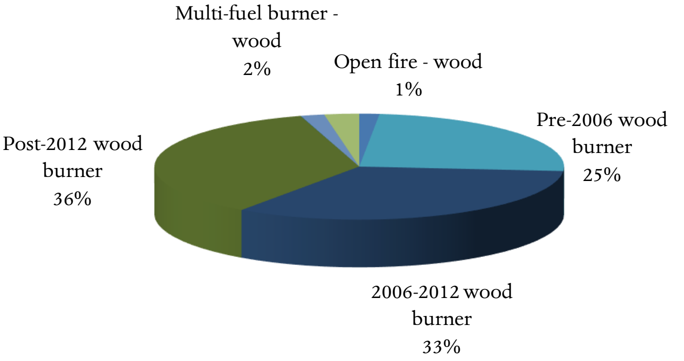

Figure 3.8: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Clyde.

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[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%).

Table 3.12: Clyde winter daily domestic heating emissions by appliance type (winter average).

	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	0.1	1%	1	2	2%	4	13	1%	0	0	3%	0	0	1%	2	7	2%	0	0	1%	1	2	2%
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%
Wood burner	6.3																						
Pre 2006 wood burner	0.9	13%	9	27	25%	122	380	32%	0	1	12%	0	1	10%	29	90	20%	1	4	13%	9	27	25%
2006-2013 wood burner	2.6	40%	12	37	34%	119	370	31%	1	4	38%	1	2	29%	53	165	37%	4	13	39%	12	37	34%
Post 2013 wood burner	2.8	42%	13	39	36%	127	394	33%	1	4	40%	1	2	31%	56	175	40%	5	14	42%	13	39	36%
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%
Multi fuel burner																							
Multi fuel– wood	0.1	1%	1	2	2%	9	29	2%	0	0	1%	0	0	1%	1	4	1%	0	0	1%	1	2	2%
Multi fuel – coal	0.1	1%	1	3	3%	6	18	1%	0	0	2%	0	1	23%	1	2	1%	0	0	1%	1	3	2%
Gas	0.1	1%	0.00	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	0	0	1%	0	0	0%
Oil	0.0	0%	0.01	0	0%	0	0	0%	0	0	2%	0	0	7%	0	0	0%	0	0	1%	0	0	0%
Total Wood	6.5	98%	34.58	107	97%	382	1186	99%	3	10	93%	1	4	71%	142	441	99%	10	32	96%	35	107	98%
Total Coal	0.1	1%	0.98	3	3%	6	18	1%	0	0	2%	0	1	23%	1	2	1%	0	0	1%	1	3	2%
Total	7		36	110		388	1204		4	11		2	6		143	443		11	33		35	110	

Table 3.13: Clyde 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	0.1	1%	1	2	2%	5	14	1%	0	0	3%	0	0	1%	2	8	2%	0	0	1%	1	2	2%
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%
Wood burner	6.6																						
Pre 2006 wood burner	0.9	13%	9	28	25%	128	397	31%	0	1	12%	0	1	10%	30	94	20%	1	5	13%	9	28	25%
2006-2013 wood burner	2.8	40%	12	39	33%	125	387	31%	1	4	37%	1	2	29%	55	172	37%	4	14	39%	12	39	34%
Post 2013 wood burner	2.9	42%	13	41	36%	133	412	33%	1	5	40%	1	2	31%	59	183	39%	5	15	42%	13	41	36%
Pellet Burner	0.0	1%	0	0	0%	1	3	0%	0	0	1%	0	0	1%	1	3	1%	0	0	1%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.1	1%	1	2	2%	9	29	2%	0	0	1%	0	0	1%	1	4	1%	0	0	1%	1	2	2%
Multi fuel – coal	0.1	1%	1	3	3%	6	18	1%	0	0	2%	0	1	22%	1	2	1%	0	0	1%	1	3	2%
Gas	0.1	1%	0	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	0	0	1%	0	0	0%
Oil	0.0	0%	0	0	0%	0	0	0%	0	0	2%	0	0	6%	0	0	0%	0	0	1%	0	0	0%
Total Wood	7	98%	36	113	97%	400	1243	99%	3	11	94%	1	4	72%	149	464	99%	11	34	97%	36	113	98%
Total Coal	0	1%	1	3	3%	6	18	1%	0	0	2%	0	1	22%	1	2	1%	0	0	1%	1	3	2%
Total	7		37	116		406	1261		4	12		2	6		150	466		11	35		37	115	

Table 3.14: Monthly variations in contaminant emissions from domestic heating in Clyde.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	0	3	0	0	1	0	0
April	3	35	0	0	13	1	3
May	28	306	3	1	114	9	28
June	35	376	3	2	139	10	34
July	36	388	3	2	143	11	36
August	32	352	3	2	129	10	32
September	11	119	1	0	45	3	11
October	4	46	0	0	17	1	4
November	1	6	0	0	2	0	1
December	0	1	0	0	0	0	0
Total (kg/year)	4581	50052	448	214	18534	1389	4568

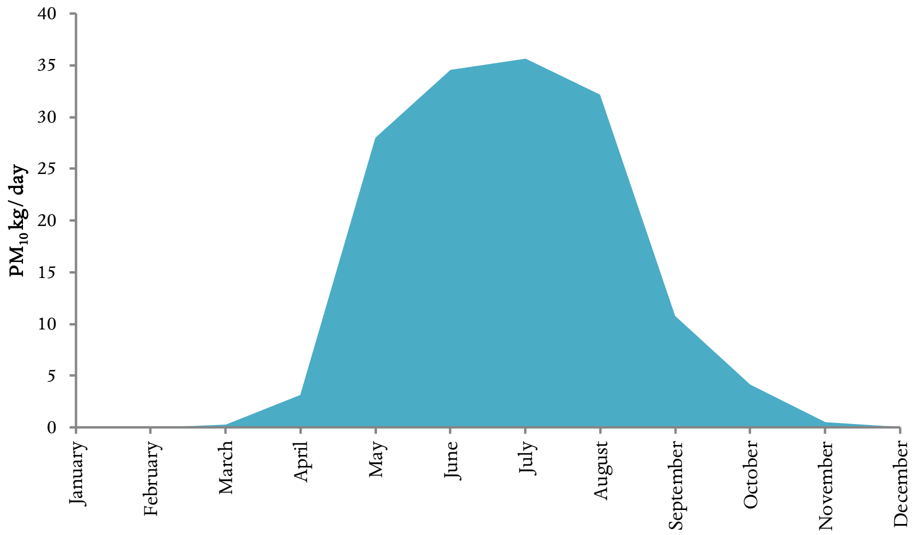

Figure 3.9: Monthly variations in PM_{10} emissions from domestic heating in Clyde

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 Queenstown Lakes District (Wanaka) and Central Otago District (Cromwell and Clyde) vehicle registration data for the year ending July 2019 (Table 4.1). Temperature data were based on an average winter temperature of 3.6 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.

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).

The number of vehicle kilometres travelled (VKT) for the airshed was estimated using the New Zealand Transport Authority VKT data for 2017 for Queenstown Lakes and Central Otago areas multiplied by an estimate of the proportion of VKT for the District within each inventory area. The latter estimate was based on NZTA 2013 data (available by CAU). The estimated VKT for each urban area are shown in Table 4.3.

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

QLDC	Petrol	Diesel	Hybrid	Plug in Hybrid	Electric	LPG	Other	Total
Cars	26,482	5,288	245	39	94	2	3	32,153
LCV	1,554	4,902	1	0	2	0	1	6,460
Bus	109	514	0	0	0	1	0	624
HCV		2,438			5			2,443
Miscellaneous	601	464	2	0	16	9	2	1,094
Motorcycle	1,578							1,578
Total	30324	13606	248	39	117	12	6	44,352
Central Otago District	Petrol	Diesel	Hybrid	Plug in Hybrid	Electric	LPG	Other	Total
	14,645	2,659	73	20	30	5	2	17,434
Cars	1,103	4,052	0	0	2	1	0	5,158
LCV	29	174	0	0	0	0	0	203
Bus		1,947			5			1,952
HCV	308	851	0	1	9	5	3	1,177
Miscellaneous	1,071							1,071
Motorcycle	17156	9683	73	21	46	11	5	26,995
Total	14,645	2,659	73	20	30	5	2	17,434

Table 4.2: Emission factors for the Queenstown Lakes and Central Otago vehicle fleets (2019).

Area	CO g/VKT	CO_2 g/VKT	VOC g/VKT	NOx g/VKT	PM_{10} g/VKT	$PM_{2.5}$ g/VKT	PM brake & tyre g/VKT	$PM_{2.5}$ brake & tyre g/VKT
Wanaka	2.38	230	0.21	0.70	0.030	0.030	0.021	0.019
Cromwell/Clyde	2.32	238	0.20	0.80	0.034	0.034	0.02	0.01

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	0.02
PM_{10} size fraction	0.5
$PM_{2.5}$ size fraction	0.27

Table 4.4: VKT estimates for 2019.

	VKT
Wanaka	51775
Cromwell	13306
Clyde	4390

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

Tables 4.4 to 4.6 show the estimated contaminant emissions from motor vehicles for Wanaka, Cromwell and Clyde for 2019. The daily PM_{10} emissions range from 3.2 kilograms per day in Wanaka down to less than 0.5 kilograms per day for Clyde. In Wanaka around 50% of the PM_{10} from motor vehicles are estimated to occur as a result of tailpipe emissions with 35% brake and tyre wear and 15% resuspended road dust. Distributions are similar for Cromwell and Clyde (51% tailpipe).

Table 4.5: Summary of daily motor vehicle emissions in Wanaka

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	1.6	0.5	123	43	36	13	0.0	0.01
Brake and tyre	1.1	0.4						
Road dust	0.5	0.2						
Total	3.2	1.1	123	43.1	36	12.7	0	0.01
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	t	kg/ha	kg	g/ha		
Tailpipe	11	4	12	4	1.0	0		
Brake and tyre					0.3	0		
Road dust					0.3	0		
Total	11	4	0	0	1.5	1		

Table 4.6: Summary of daily motor vehicle emissions in Cromwell

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	0.4	0.6	31	41	11	14	0.0	0.01
Brake and tyre	0.3	0.4						
Road dust	0.1	0.2						
Total	0.9	1.1	31	40.6	11	14.0	0	0.01
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	t	kg/ha	kg	g/ha		
Tailpipe	3	4	3	4	0.3	0.4		
Brake and tyre	0	0	0	0	0.07	0.1		
Road dust	0	0	0	0	0.07	0.1		
Total	3	4	3	4	0.4	0.6		

Table 4.7: Summary of daily motor vehicle emissions in Clyde

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	0.1	0.5	10	32	4	11	0.0	0.01
Brake and tyre	0.1	0.3						
Road dust	0.0	0.1						
Total	0.3	0.9	10	31.7	4	10.9	0	0.01
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	t	kg/ha	kg	g/ha		
Tailpipe	0.9	3	1	3	0.1	0.3		
Brake and tyre					0.02	0.1		
Road dust					0.02	0.1		
Total	0.9	2.8	0	0.0	0.1	0.4		

5 INDUSTRIAL AND COMMERCIAL

5.1 Methodology

Information on consented activities discharging to air in Wanaka, Cromwell and Clyde was provided by the Otago Regional Council. The selection of industries for inclusion in this inventory was based on potential for PM_{10} emissions. Industrial activities such as spray painting or drycleaning operations, which discharge primarily VOCs were not included in the assessment. A number of the consented discharges were for odour or other contaminants not included in the inventory.

In the Otago airsheds only boilers with heat outputs greater than 1 MW require resource consent. To capture smaller scale boilers schools, hospitals and recreation centres were also contacted. In Wanaka, Mount Aspiring College was the only school operating with a coal boiler, although it was noted that the boiler would be replaced with two wood chip boilers before winter 2020. In Cromwell, the high school boiler ran on coal during 2019 but wood chips would be the fuel source for 2020. The primary school used heat pumps as did Clyde primary school. Emissions from gas and diesel small scale boilers were not included in the inventory as the PM_{10} emissions from them are relatively minor.

Emissions were estimated based on equation 5.1 or equation 5.2 depending on the availability of site specific emissions data. 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.

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

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}	CO	NOx	SOx	VOC	CO_2	$PM_{2.5}$
Underfeed stoker	2	5.5	4.8	19.0	0.1	2400	1.2
Wood boiler	1.6	6.8	0.8	0.04	0.1	1069	1.4
Open fire	7.5	55	1.2	0.2	30	1600	7.5
Concrete batching	0.003						
Cement loading	0.00017						0.00017
Aggregate loading	0.0017						0.0005
LPG boiler	0.1	1	1.8	0.0	0.1	1716	0.1

5.2 Industrial and commercial emissions

Tables 5.2 and 5.3 show the estimated emissions to air from industrial and commercial activities in Wanaka, Cromwell and Clyde for daily winter and annual emission estimates.

Table 5.2: Summary of emissions from industrial and commercial activities (daily winter) in Wanaka, Cromwell and Clyde.

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Wanaka	2861	2.1	0.7	11.9	4.2	2.1	0.7	1.6	0.6
Cromwell	761	1.1	1.5	2.0	2.6	1.7	2.3	3.4	4.5
Clyde	322	0	0	0	0	0	0	0	0
		VOC		CO_2		$PM_{2.5}$			
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha		
Wanaka	2861	5.2	1.8	1.3	0.5	1.8	0.6		
Cromwell	761	0.0	0.0	0.9	1.1	0.5	0.6		
Clyde	322	0	0	0	0	0	0		

Table 5.3: Summary of emissions from industrial and commercial activities (annual) in Wanaka, Cromwell and Clyde.

	PM_{10}	CO	NOx	SOx	VOC	CO_2	$PM_{2.5}$
	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes
Wanaka	0.4	2.2	0.5	0.3	1.0	221	0.3
Cromwell	0.17	0.20	0.24	0.34	0.00	86.40	0.06
Clyde	0	0	0	0	0	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 Otago Regional Plan permits outdoor burning of in Airzone 2 (Wanaka) all year around subject to conditions and in Airzone 1 (Clyde and Cromwell) during the non-winter months.

6.1 Methodology

Outdoor burning emissions for Wanaka, Cromwell and Clyde were estimated based on data collected during the 2019 domestic home heating survey.

Emissions were calculated based on the assumption of an average weight of material per burn of 159 kilograms per cubic metre of material[4] and using the emission factors in Table 6.1. 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	BaP g/kg
Outdoor burning	8	8	42	2	0.5	1470	0.002

[4] 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 5, 7 and 2 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average in Wanaka, Cromwell and Clyde respective.

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 each season, 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.

Wanaka	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)	2	10	1	0	1	0	2
Autumn (Mar-May)	2	11	1	0	1	0	2
Winter (June-Aug)	5	24	2	0	2	1	5
Spring (Sept-Nov)	2	9	1	0	1	0	2
Cromwell	**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)	2	11	1	0	1	0	2
Autumn (Mar-May)	9	48	3	1	5	2	9
Winter (June-Aug)	7	35	3	0	3	1	7
Spring (Sept-Nov)	3	13	1	0	1	0	3
Clyde	**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)	0.5	3	0.2	0.0	0.3	0.1	0.5
Autumn (Mar-May)	2	12	1	0	1	0	2
Winter (June-Aug)	2	9	1	0	1	0	2
Spring (Sept-Nov)	1	3	0.2	0.0	0.3	0.1	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 0.3 kilograms of PM_{10} per day in each area from these sources.

8 TOTAL EMISSIONS

8.1 Wanaka

Around 310 kilograms of PM_{10} was discharged to air in Wanaka on an average winter's day for 2019. Domestic home heating is the main source of PM_{10} emissions in all areas contributing 97% of the daily wintertime emissions and 93% of the annual PM_{10} emissions. Outdoor burning, motor vehicles and industrial and commercial activities each contribute 1% of the daily PM_{10} and 1-3% of the annual emissions.

The relative contributions to daily winter and annual average $PM_{2.5}$ are similar as for PM_{10} with domestic heating contributing 97% and 95% respectively (Figure 8.2).

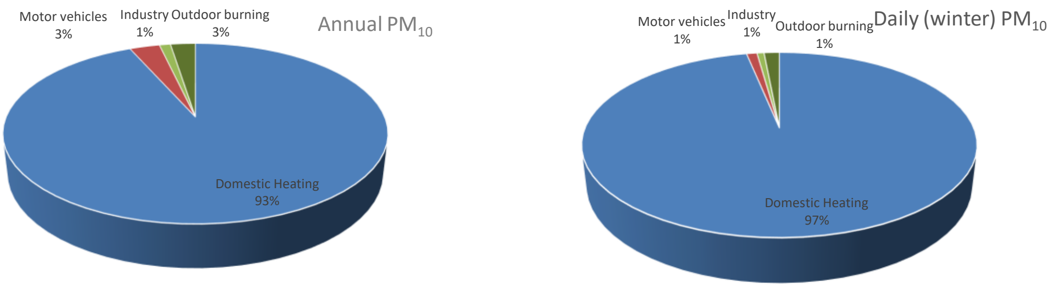

Figure 8.1: Relative contribution of sources to daily winter and annual PM_{10} emissions in Wanaka.

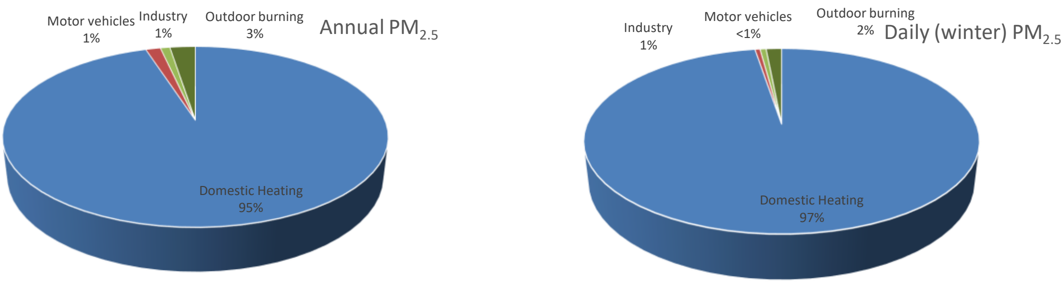

Figure 8.2: Relative contribution of sources to daily winter and annual $PM_{2.5}$ emissions in Wanaka.

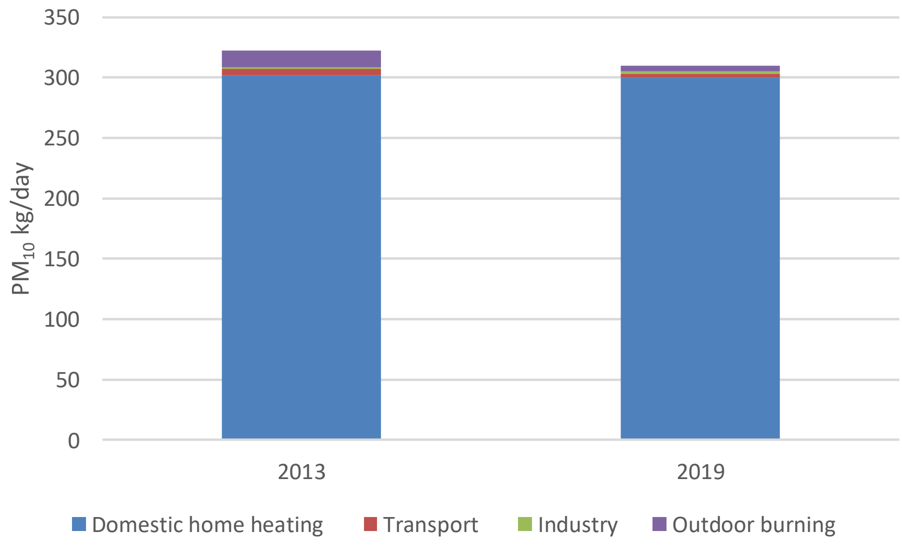

Figure 8.3: Daily winter PM_{10} emissions in Wanaka in 2013 and 2019.

Figure 8.3 compares daily PM_{10} emissions in Wanaka to the 2013 emission estimates from the national emission inventory carried out by the Ministry for the Environment, (2014). The latter was based on a region wide surveying of homes for heating methods (excluding Airzone 1 towns) and integration of census data for wood use to determine local emission rates. The 2013 method has high uncertainty and trend estimates are indicative only .

Domestic home heating is also the main source of CO, SOx, VOCs and CO_2. Motor vehicles are the main source of NOx in Wanaka (Figure 8.4).

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 motor vehicles 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.

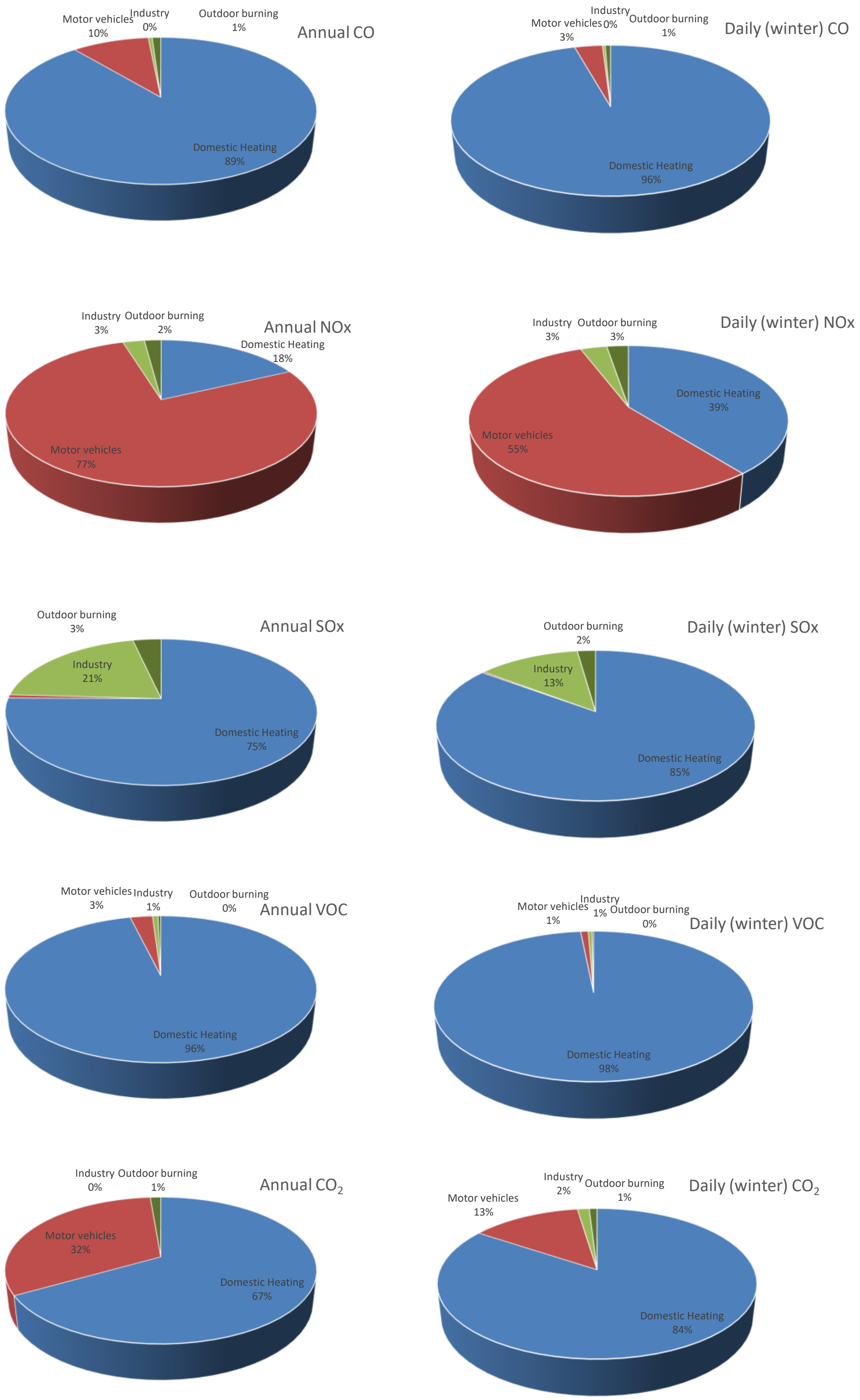

Figure 8.4: Relative contribution of sources to daily winter contaminant emissions in Wanaka

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

	Domestic heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	1	10%	2	33%	0	3%	3	53%	6
February	0	2%	2	36%	0	4%	3	59%	5
March	2	27%	2	24%	1	13%	3	36%	9
April	25	79%	2	7%	1	4%	3	10%	31
May	262	98%	2	1%	1	0%	3	1%	268
June	297	97%	5	2%	2	1%	3	1%	307
July	300	97%	5	1%	2	1%	3	1%	310
August	210	95%	5	2%	2	1%	3	1%	220
September	54	90%	2	3%	1	2%	3	5%	60
October	12	66%	2	10%	1	6%	3	18%	18
November	3	30%	2	20%	1	13%	3	36%	9
December	0	6%	2	35%	0	3%	3	56%	6
Total kg year	35744	93%	956	2%	424	1%	1152	3%	38275

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

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	300	105	3516	1229	26	9	11	4
Transport	3	1	123	43	36	13	0	0
Industry	2.1	0.7	11.9	4.2	2.1	0.7	1.6	0.6
Outdoor burning	5	2	24	9	2	1	0	0
Total	310	108	3676	1285	66	23	13	5
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	tonnes	kg/ha	kg	g/ha		
Domestic home heating	1140	399	76	27	300	105		
Transport	11	4	12	4	2	1		
Industry	5.2	1.8	1.3	0.5	1.8	0.6		
Outdoor burning	2	1	1	0	5	2		
Total	1158	405	90	32	308	108		

8.2 Cromwell

Around 150 kilograms of PM_{10} was discharged to air in Cromwell on an average winter's day for 2019. Domestic home heating is the main source of PM_{10} emissions in all areas contributing 94% of the daily wintertime emissions and 88% of the annual PM_{10} emissions. Outdoor burning contributes 4% of the daily PM_{10} and 9% of the annual emissions (Figure 8.5).

The relative contributions to daily winter and annual average $PM_{2.5}$ are similar as for PM_{10} with domestic heating contributing 95% and 90% respectively (Figure 8.6).

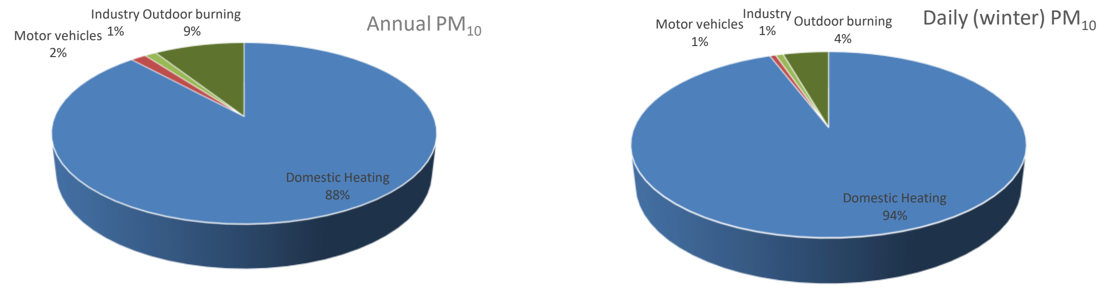

Figure 8.5: Relative contribution of sources to daily winter and annual PM_{10} emissions in Cromwell.

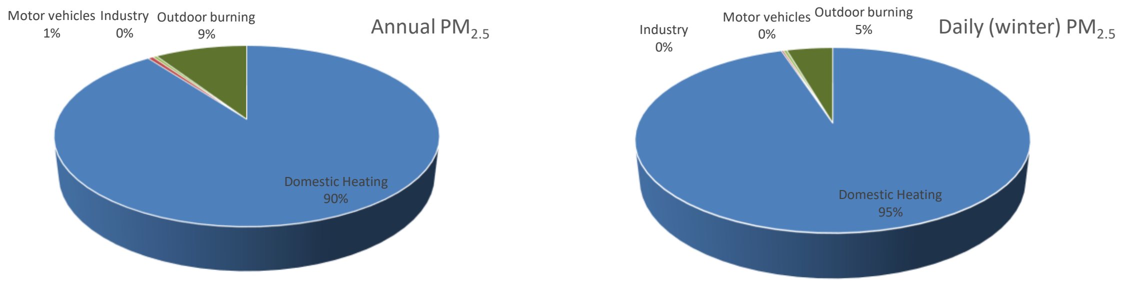

Figure 8.6: Relative contribution of sources to daily winter and annual $PM_{2.5}$ emissions in Cromwell.

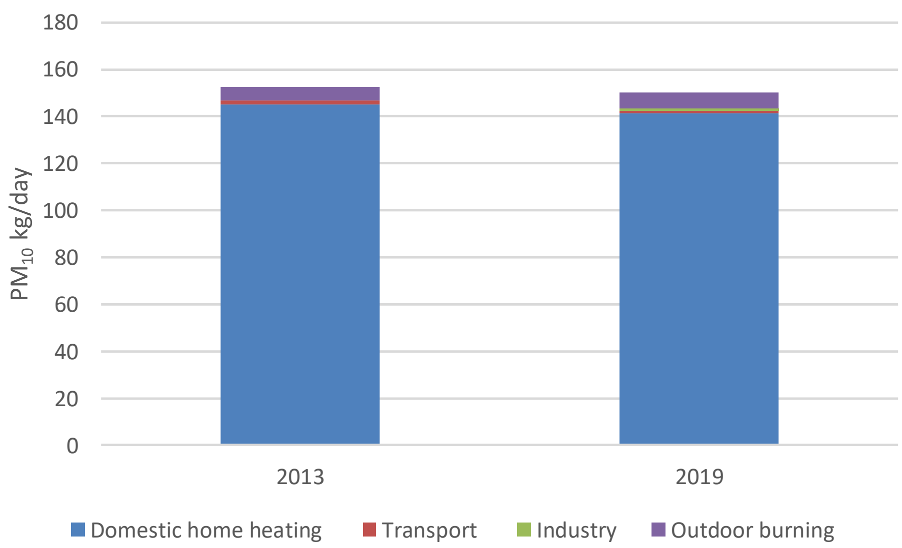

Figure 8.7: Daily winter PM_{10} emissions in Wanaka in 2013 and 2019.

Figure 8.7 compares daily PM_{10} emissions in Cromwell to the 2013 emission estimates from the national emission inventory carried out by the Ministry for the Environment, (2014). The latter was based on airzone wide surveying of homes for heating methods (Arrowtown, Alexandra, Cromwell, Clyde) and integration of census data for wood use to determine local emission rates. No trend in emissions is observed relative to 2013.

Domestic home heating is also the main source of daily winter CO, SOx, VOCs and CO_2. Motor vehicles are the main source of annual NOx in Cromwell (Figure 8.8).

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.

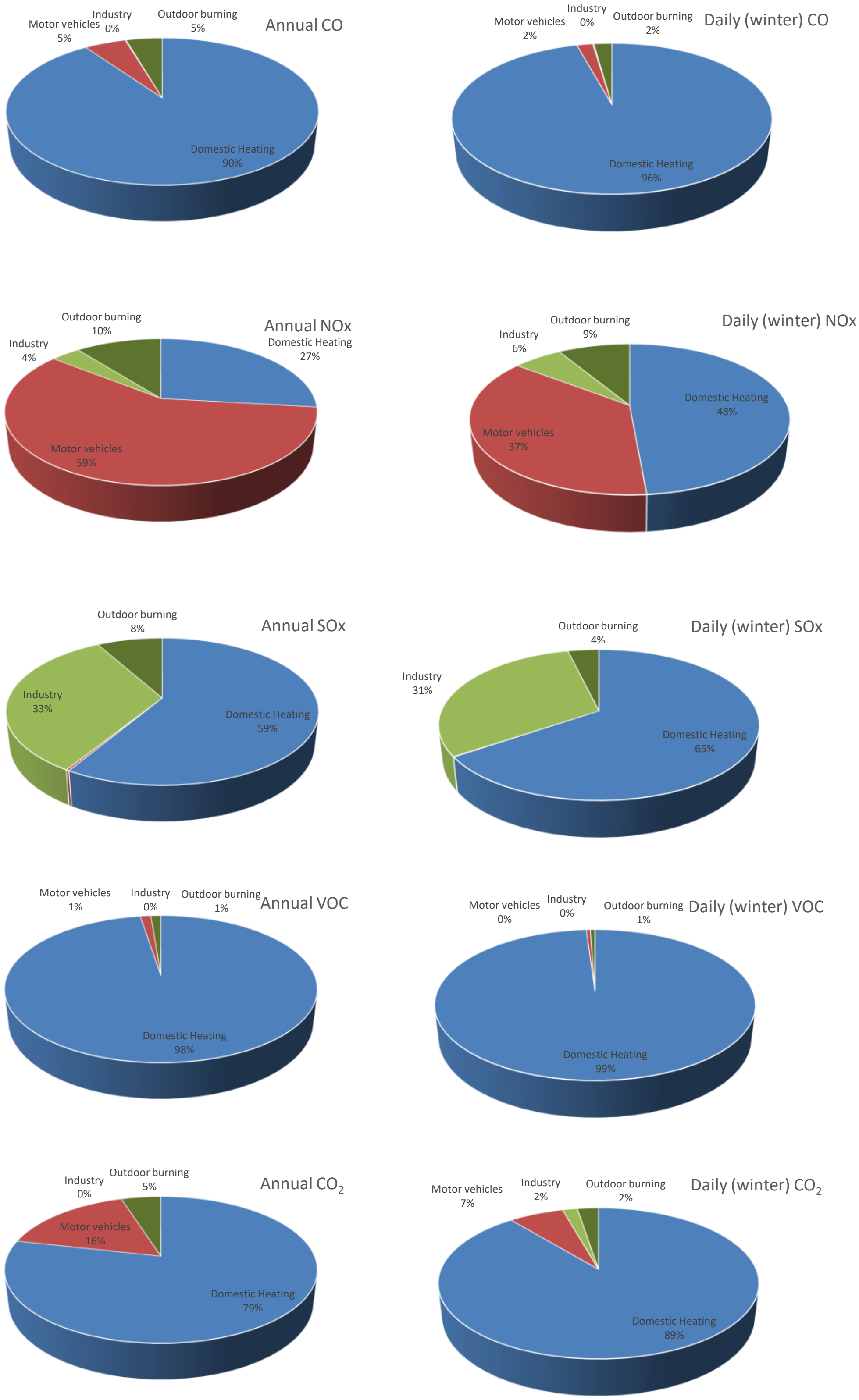

Figure 8.8: Relative contribution of sources to daily winter contaminant emissions in Cromwell

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

	Domestic heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	0%	2	62%	0	12%	1	27%	3
February	0	0%	2	61%	0	12%	1	26%	3
March	1	9%	9	78%	1	6%	1	7%	12
April	13	54%	9	39%	1	3%	1	4%	23
May	111	91%	9	8%	1	1%	1	1%	122
June	137	94%	7	5%	1	1%	1	1%	146
July	141	94%	7	4%	1	1%	1	1%	150
August	128	94%	7	5%	1	1%	1	1%	136
September	43	91%	3	5%	1	1%	1	2%	47
October	16	80%	3	12%	1	3%	1	4%	20
November	2	34%	3	41%	1	11%	1	14%	6
December	0	6%	2	58%	0	11%	1	25%	3
Total kg year	18159	88%	1868	9%	243	1%	318	2%	20588

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

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	141	186	1540	2024	14	18	7	10
Transport	1	1	31	41	11	14	0	0
Industry	1.1	1.5	2.0	2.6	1.7	2.3	3.4	4.5
Outdoor burning	7	9	35	46	3	3	0	1
Total	150	197	1608	2114	29	38	11	15
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	tonnes	kg/ha	kg	g/ha		
Domestic home heating	568	747	43	56	141	185		
Transport	3	4	3	4	0	0		
Industry	0.0	0.0	0.9	1.1	0.5	0.6		
Outdoor burning	3	4	1	2	7	9		
Total	575	755	48	63	148	195		

8.3 Clyde

Around 38 kilograms of PM_{10} was discharged to air in Clyde on an average winter's day for 2019. Domestic home heating is the main source of PM_{10} emissions in all areas contributing 95% of the daily wintertime emissions and 89% of the annual PM_{10} emissions (Figure 8.9). Outdoor burning, motor vehicles and industrial and commercial activities each contribute 1% of the daily PM_{10} and 0-3% of the annual emissions.

The relative contributions to daily winter and annual average $PM_{2.5}$ are similar as for PM_{10} with domestic heating contributing 95% and 90% respectively (Figure 8.10).

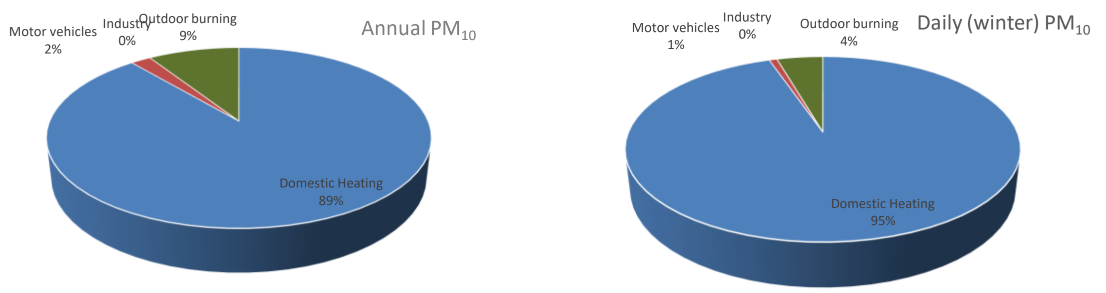

Figure 8.9: Relative contribution of sources to daily winter and annual PM_{10} emissions in Clyde.

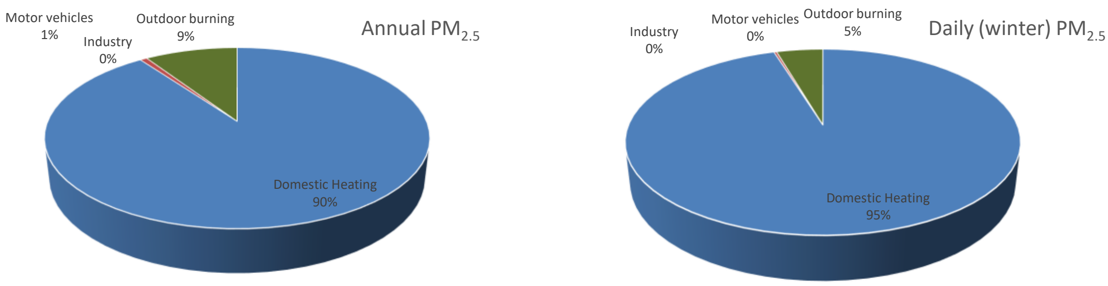

Figure 8.10: Relative contribution of sources to daily winter and annual $PM_{2.5}$ emissions in Clyde.

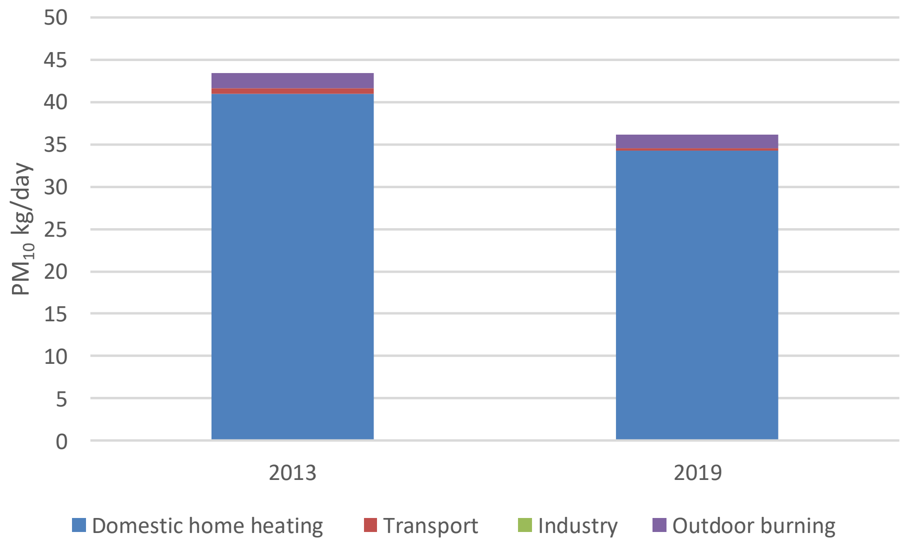

Figure 8.11: Daily winter PM_{10} emissions in Clyde in 2013 and 2019.

Figure 8.11 compares daily PM_{10} emissions in Wanaka to the 2013 emission estimates from the national emission inventory carried out by the Ministry for the Environment, (2014). The latter was based on an airzone wide surveying of homes for heating methods and integration of census data for wood use to determine local emission rates. A reduction in emission of around 13% relative to 2013 is estimated but contains a high degree of uncertainty because of the less robust emission estimate approach for 2013.

Domestic home heating is also the main source of daily winter CO, SOx, VOCs and CO_2. Motor vehicles are the main source of NOx in Clyde (Figure 8.12).

Table 8.5 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 8.6.

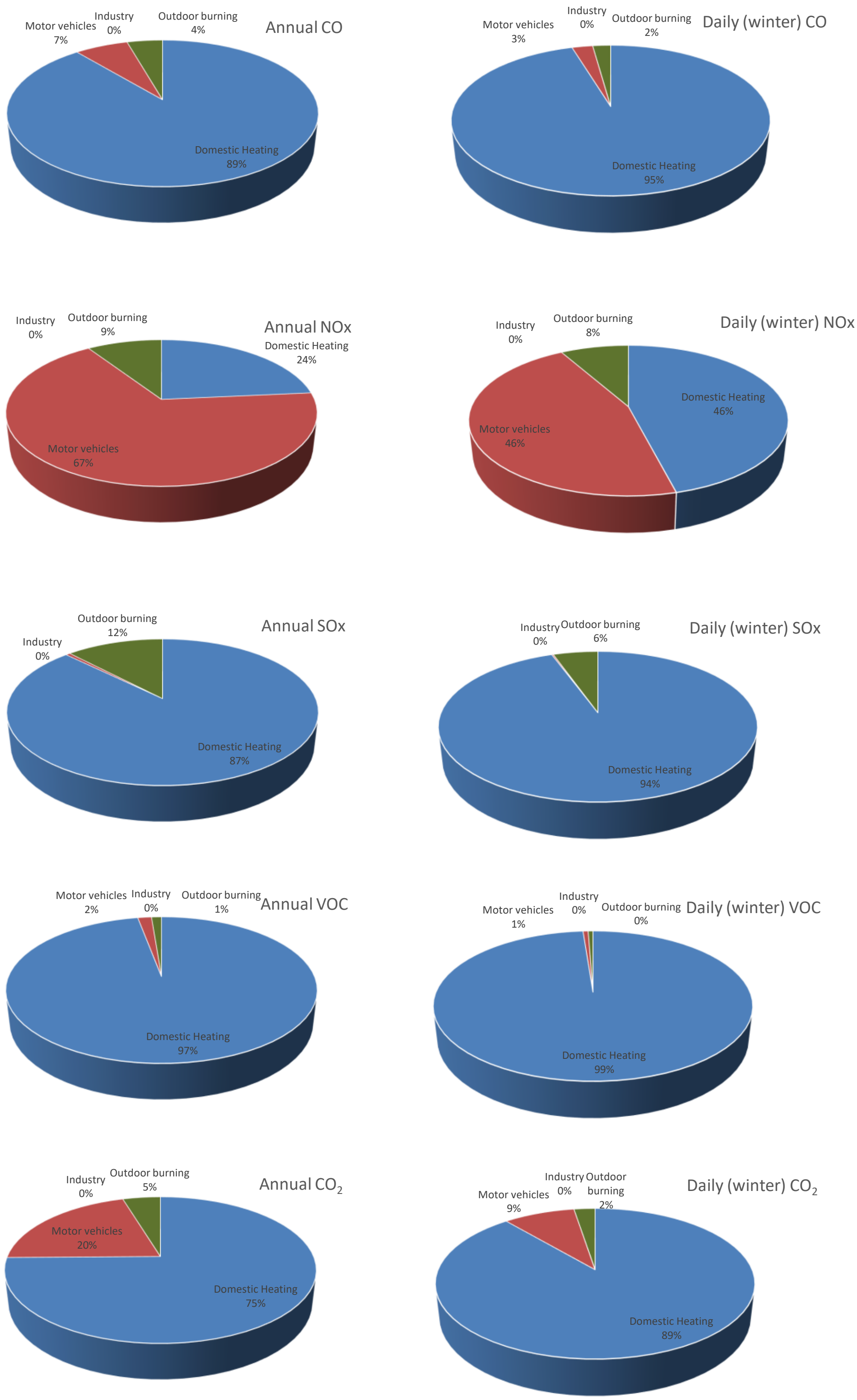

Figure 8.12: Relative contribution of sources to daily winter contaminant emissions in Clyde

Table 8.5: Monthly variations in daily PM_{10} emissions in Clyde.

	Domestic heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	0%	1	64%	0	0%	0	36%	1
February	0	0%	1	64%	0	0%	0	36%	1
March	0	9%	2	81%	0	0%	0	10%	3
April	3	55%	2	40%	0	0%	0	5%	6
May	28	91%	2	8%	0	0%	0	1%	31
June	35	95%	2	5%	0	0%	0	1%	37
July	36	95%	2	4%	0	0%	0	1%	38
August	32	94%	2	5%	0	0%	0	1%	34
September	11	92%	1	5%	0	0%	0	2%	12
October	4	82%	1	12%	0	0%	0	6%	5
November	1	36%	1	44%	0	0%	0	20%	1
December	0	6%	1	60%	0	0%	0	34%	1
Total kg year	4581	89%	472	9%	0	0%	105	2%	5157

Table 8.6: Daily contaminant emissions from all sources in Clyde (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	36	110	388	1204	4	11	2	6
Transport	0	1	10	32	4	11	0	0
Industry	0	0	0	0	0	0	0	0
Outdoor burning	2	5	9	27	1	2	0	0
Total	38	117	407	1263	8	24	2	6
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	tonnes	kg/ha	kg	g/ha		
Domestic home heating	143	443	11	33	35	110		
Transport	1	3	1	3	0	0		
Industry	0	0	0	0	0	0		
Outdoor burning	1	3	0	1	2	5		
Total	144	448	12	38	37	116		

REFERENCES

Bluett, J., Smith, J., Wilton, E., & Mallet, T. (2009, September 8). *Real world emission testing of domestic wood burners*. Presented at the 19th International Clean Air and Environment Conference, Perth.

EEA. (2016). *Air pollutant emission invenotry guidebook - 2016*. European Environment Agency Report 21/2016.

Ehrlich, N., & Kalkoff, W. (2007). *Determining PM-emission fractions (PM10, PM2.5, PM1.0) from small-scale combustion units and domestic stoves using different types of fuels including bio fuels like wood pellets and energy grain*. Retrieved from http://www.dustconf.com/CLIENT/DUSTCONF/UPLOAD/S4/EHRLICH_.PDF

Metcalfe, J., Sridhar, S., & Wickham, L. (2013). *Domestic fire emissions 2012: options for meeting the national environmental standard for PM10.* Auckland Council technical report, TR 2013/022.

Ministry for the Environment. (2014). *2014 Air Domain Report*. Retrieved from http://mfe.govt.nz/environmental-reporting/air/air-domain-report-2014/about-report/purpose-scope.html

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.

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. https://doi.org/10.1080/10473289.1992.10467029

Victorian EPA. (2016). *Waste Materials Density Data*. Retrieved from http://www.epa.vic.gov.au/business-and-industry/lower-your-impact/~/media/Files/bus/EREP/docs/wastematerials-densities-data.pdf

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

Wilton, E. (2019). *Tauranga Air Emission Inventory - 2018*. Retrieved from https://www.boprc.govt.nz/environment/air/air-pollution/

Wilton, E., & Bluett, J. (2012). *Factors influencing particulate emissions from NES compliant woodburners in Nelson, Rotorua and Taumarunui 2007*. NIWA Client Report 2012- 013.

Wilton, E., Smith, J., Dey, K., & Webley, W. (2006). Real life testing of woodburner emissions. *Clean Air and Environmental Quality*, *40*(4), 43–47.

World Health Organization. (2013). *Review of evidence on health aspects of air pollution - REVIHAAP*. World Health Organization.

APPENDIX A: HOME HEATING QUESTIONNAIRE

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

Hi, I'm _________from and I am calling from _____ on behalf of

Can you please confirm you live in Wanaka (or Clyde/ Cromwell).

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 5-7 minutes depending on your answers. Is it a good time to talk to you now?

1. (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). Off the top of your head approximately how much would you spend, on average, per month during the winter, on electricity for space heating?

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

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

(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) Off the top of your head approximately how much would you spend, on average, per month during the winter, on gas for space heating?

3. (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) During the winter what times of the day do you use your wood burner (tick all that apply)

- ☐ 6am - 11am
- ☐ 11am - 4pm
- ☐ 5pm - 10pm
- ☐ 10pm - 6am

e) Approximately what time during the evening would you put your last load on the fire.

(f) How old is your log burner?

12 yrs+
5- 12 yrs old
Less than five years old
Don't know/refused

(g) 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.

(h) 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.

(i) 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)

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

(k) What proportion would be bought?

l) If you placed your hand on your burner first thing in the morning (e.g., 6am-7am) after having used it the night before would it be?

- ☐ Cold to touch (no feeling of leftover heat)
- ☐ Warm to touch (if you held your hand there for a bit it would warm them up)
- ☐ Hot to touch (too hot to hold a hand on for more than a few seconds)

4. (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 5)*

(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) 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

(f) 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?

(g) 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

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

(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 multi fuel burner during non winter months How much coal do you use per day during the other months?

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

(l) What proportion would be bought?

(m) Off the top of your head approximately how much would you spend, on average, per month during the winter, on wood and coal for space heating?

5. (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 6)*

(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?

(m) Off the top of your head approximately how much would you spend, on average, per month during the winter, on wood and coal for space heating?

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

(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?

(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?

(i) Off the top of your head approximately how much would you spend, on average, per month during the winter, on pellets for space heating?

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

(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 ?

8. a) Do you use a wood fuelled cooking appliance during a typical year? (This is an appliance primarily used for cooking includes an oven and hot plate) Interviewers-pot belley stoves, chip heaters or wood burners are not wood fired cookers

b) Which months of the year do you use your wood fueled cooker?

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

☐ (c) How many days per week would you use your wood fueled cooker?

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

d) how old is your wood fired cooker

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

8. Does your home have insulation?

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

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

(If 3 skip to Demographics)

a) How many days would you burn waste or garden rubbish outdoors during winter? Interviewer note: Winter is defined as June, July and August.

b) How many days would you burn waste or garden rubbish outdoors during Spring? Interviewer note: Spring is defined as September to November.

c) How many days would you burn waste or garden rubbish outdoors during Summer? Interviewer note: Summer is defined as December to February.

d) How many days would you burn waste or garden rubbish outdoors during Autumn? Interviewer note: Autumn is defined as March to May.

(e) How many cubic metres of garden waste or other material would be burnt per fire on average.

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?

D8 How long have you lived in this house

1	1 – 2 years
2	3 – 5 years
3	6 -7 years
4	8 – 9 years

5	10 – 14 years
6	15 – 20 years
7	20+ years
98	Don't know/Refused

D9 How would you rate the level of warmth in your home during winter

1	Too cold
2	Adequate
3	Warm
98	Don't know/ refused

D10. If used wood for heating - Do you check the moisture content of your wood

1	Yes
2	No
97	Refused/not sure

D11. If yes to D11 – How do you evaluate the moisture content?

1	Visual inspection for cracks
2	Moisture meter
90	Other specify
98	Don't know/Refused

D12. Can you tell me the household annual income – if boarder refer to personal income

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 publicly available form.

APPENDIX C – ANALYSIS OF ADDITIONAL INFORMATION

Table 1 shows that proportion of firewood burnt on wood burners that is bought versus self-collected for the four urban areas. Table 2 shows the amount of insulation in dwellings in Wanaka, Cromwell and Clyde. The prevalence of double glazing is high with 76% of dwellings in Wanaka and 65% in Cromwell and Clyde having double glazing. The majority of dwellings have ceiling and wall insulation.

Table 0.1:: Proportion of wood used on wood burners that is bought and self-collected

Firewood	Wanaka	Cromwell/ Clyde
Bought	79%	68%
Self-collected	21%	32%

Table 0.2:: Prevalence of household insulation by type

Household insulation	Wanaka		Cromwell		Clyde	
	Households	%	Households	%	Households	%
Ceiling	3198	96%	1882	96%	499	96%
Underfloor	1849	55%	833	42%	221	42%
Wall	2963	89%	1601	82%	424	82%
Cylinder wrap	1085	32%	530	27%	141	27%
Double glazing	2538	76%	1283	65%	340	65%
None	47	1%	5	0%	1	0%
Don't know	38	1%	48	2%	13	2%
Other	208	6%	186	9%	49	9%

Table 0.3:: Do you check the moisture content of your wood and if so how?

	Wanaka	Cromwell/ Clyde
Proportion that check wood	39%	40%
Visual inspection	18%	25%
Moisture meter	23%	9%
Other specify	60%	66%
Don't know/Refused	0%	0%

Around 40% of households that reported that they check the moisture content of the wood (Table 3). The most common response in the “other” category, was that they purchased the wood dry from the supplier or that they seasoned the wood themselves by keeping it for year or more before using. A number of households also measured the weight of the wood as a method of checking the moisture content.

Tables 4 to 6 summarise level of warmth, age of dwelling and length of time in a dwelling. Only 7% of households in Wanaka and 6% of households in Cromwell and Clyde reported their home warmth as being inadequate.

Table 0.4: How would you rate the level of warmth in your home during winter?

	Wanaka Households	Arrowtown Households	Milton Households
Too cold	123	53	14
Adequate	670	318	84
Warm	1038	573	152
Unsure/ refused	0	0	0

Table 0.5: How old is your dwelling?

	Wanaka %	Cromwell %	Clyde %
10 years or less	31%	25%	25%
11 - 20 years	31%	28%	28%
21 - 40 years	25%	25%	25%
41 + years	12%	20%	20%
Refused/not sure	1%	3%	3%

Table 0.6: How long have you lived in this dwelling

	Wanaka	Cromwell/ Clyde
1 - 2 years	21%	10%
3 - 5 years	16%	16%
6 -7 years	10%	8%
8 - 9 years	6%	3%
10 - 14 years	16%	22%
15- 20 years	16%	21%
20+ years	16%	20%
Don't know/Refused	<1%	1%