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PREPARED FOR

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Dargaville air emission inventory, meteorology and recommendations for monitoring - 2023

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EXECUTIVE SUMMARY

Dargaville is a rural town nestled on the banks of the Northern Wairoa River in the Kaipara District. It has a population of around 5200.

Air quality in Dargaville is not well characterised as only short term (12 monthly) particulate matter less than 10 microns in diameter (PM_{10}) monitoring has been carried out using a mobile monitor in Dargaville in 2017. A permanent monitoring for Dargaville is proposed in the near future.

The National Environmental Standard for Air Quality (NESAQ) requires that air quality monitoring take place at the location that has the highest concentrations of pollutants in an airshed. The purpose of this report is to quantify discharges to air in Dargaville, via an air emission inventory and collate this data with other information to determine the most suitable location for future monitoring. This includes investigations to establish the areas of highest emission density and evaluations of this information in conjunction with meteorological data.

The inventory includes an assessment of 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}) and the $PM_{2.5}$ subcomponent of PM_{10}, as well as carbon monoxide, nitrogen oxides and sulphur oxides.

Like most urban areas in New Zealand, the main contributor to annual and daily PM_{10} and $PM_{2.5}$ in Dargaville is domestic home heating. Outdoor burning, however, was found to be very prevalent in Dargaville and is a significant contributor to daily and annual PM_{10} and $PM_{2.5}$ emissions.

A total of 139 kilograms of PM_{10} and 134 kilograms of $PM_{2.5}$ is emitted per day from all sources during the winter. An evaluation of the spatial density in emissions found the highest emission density around an area bounded by Parore Street, State Highway 12 and Carrington Street with Dargaville High School the indicative area of the upper northern boundary.

An evaluation of meteorological data including wind speed, direction and air temperature found that the predominant wind direction under conditions conducive to elevated air pollution was easterly. St Josephs School was identified as a suitable monitoring location as it is downwind of the high emission density areas at times when conditions were likely to be most conducive to elevated concentrations. Dargaville Intermediate School may also provide an alternative location if the monitoring equipment could be located at the southern end of the school.

1 INTRODUCTION

Dargaville is a rural town nestled along the Northern Wairoa River in the Kaipara District, is home to around 5200 residents.

Air quality in Dargaville is not well characterised as only short term (12 monthly) PM_{10} monitoring has been carried out using a Beta Attenuation Monitor (BAM) in Dargaville in 2017. PM_{10} concentrations were similar to council's other permanent monitoring stations in Whangārei and Ruakākā with annual PM_{10} concentration of 12 $\mu g/m^3$. A permanent monitoring for Dargaville is proposed in the near future.

The National Environmental Standard for Air Quality (NESAQ) requires that air quality monitoring take place at the location that has the highest concentrations of pollutants in an airshed. The purpose of this report is to quantify discharges to air in Dargaville and collect data to determine the most suitable location for future monitoring. This includes investigations to establish the areas of highest emission density and evaluations of this information in conjunction with meteorological data.

An air emission inventory will assist the Regional Council in understanding the relative contributions of different sources to PM_{10} and $PM_{2.5}$ in Dargaville. This work can also form the basis of future assessments as to the most effective air quality management measures.

Emissions inventories carried out in New Zealand typically include quantification of emissions from domestic home heating, transport, industrial and commercial activities, ports and shipping, aviation and outdoor burning.

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 and sulphur oxides.

The report also includes an evaluation of meteorological data including wind speed, direction and air temperature and identification of conditions conducive to elevated air pollution with an objective of identifying locations within Dargaville suitable for monitoring that will be impacted on by high emission density areas.

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) and nitrogen oxides (NOx).

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 $PM_{2.5}$.

2.3 Selection of areas

The inventory study area for Dargaville was based on the Statistical Area Two (SA2, 2018) boundary for Dargaville which comprises of 1256 hectares and is illustrated in Figure 2.1.

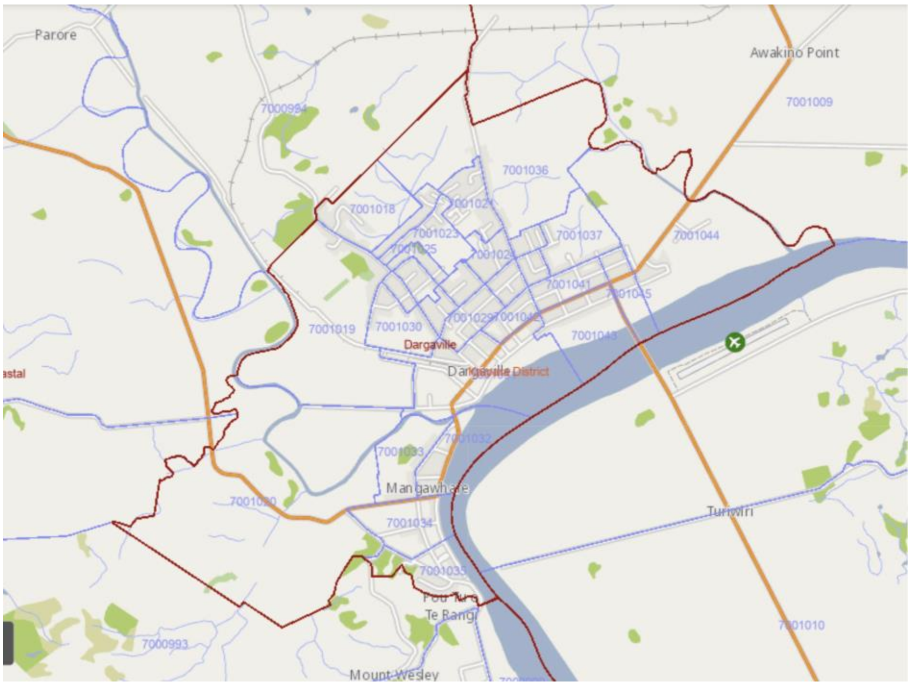

Figure 2.1: Dargaville inventory area based on the SA2 (2018) area of Dargaville (red boundary).

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 Dargaville was collected using a combination of household survey (winter 2023) and 2018 census data for heating methods (Table 3.1). The latter data were extrapolated for 2023 Dargaville household numbers using Statistics New Zealand projections for the Kaipara District. Table 3.1 shows the estimated number of households (occupied private dwellings) in Dargaville.

Table 3.1: Summary household data

	Households	Heat pump	Electric heater	Fixed gas heater	Portable gas heater	Wood burner	Pellet fire	Coal burner	Other
2018 SA2 (census)	1830	537	576	48	195	735	6	6	33
2023 SA2 (projected)	1940	569	611	51	207	779	6	6	35

Responses from the sample surveyed (100 households) were applied to the wood burning households in Dargaville to estimate the burner age distributions and fuels quantities used. A copy of the survey questionnaire is shown in Appendix A. Home heating methods were classified as; electricity, open fires, wood burners (differentiated by age), 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
Open fire - wood	7.5	7.5	55	1.2	0.2
Open fire - coal	21	18	70	4	8
Pre 2006 burners	10	10	140	0.5	0.2
Post 2006 burners	4.5	4.5	45	0.5	0.2
Pellet burners	2	2	20	0.5	0.2
Multi-fuel[1] - wood	10	10	140	0.5	0.2
Multi-fuel[1] – coal	19	17	110	1.6	8
Oil	0.3	0.22	0.6	2.2	3.8
Gas	0.03	0.03	0.18	1.3	7.56E-09

[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.

The survey includes a question on the use of wood fired cooking devices, including the frequency of use and wood volumes. Emissions from wood fired cookers are estimated using the pre 2006 wood burner emission factor. Results of emissions from domestic heating include the use of wood fired devices for cooking purposes.

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

The most popular form of heating the main living area of homes in Dargaville is electricity with around 55% of households using that method. Of households using electricity, 53% use heat pumps. This is much lower than most urban areas of New Zealand (typically 75-80%). Wood burners are the next most common with 40% of households using them. As with other urban areas of New Zealand many households use more than one method of heating.

Trends in heating fuels from 2006 to 2018 are shown in Figure 3.1. This shows a decrease in the prevalence of most heating types and an increase of 7.5% in households that do not use fuels for heating.

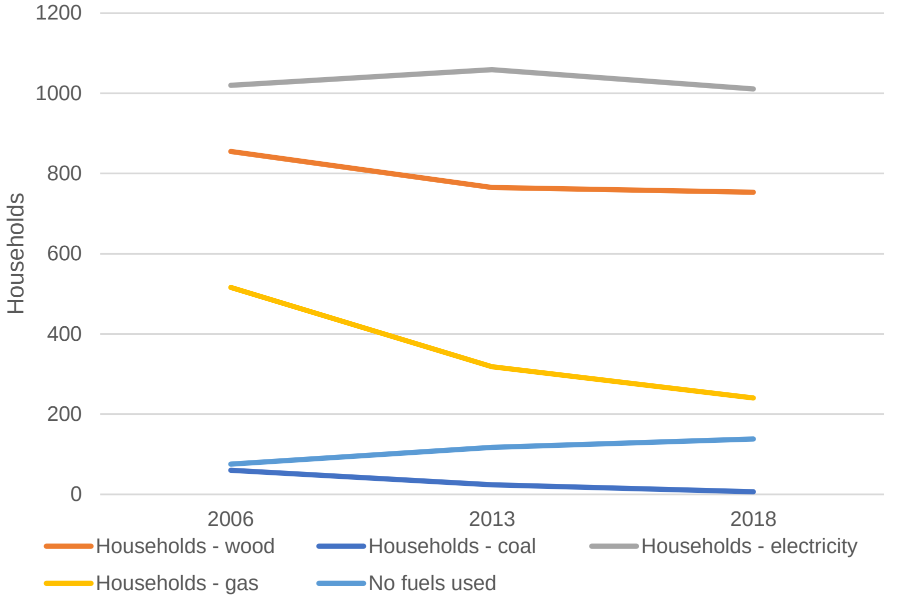

Figure 3.1: Trends in home heating fuels in Dargaville from 2006 to 2018 (NZ Stats, 2021)

Table 3.3 combines survey data with census data to provide a more detailed breakdown of heating methods.

Around 15 tonnes of wood is estimated to be burnt per typical winter's night in Dargaville for 2023.

Table 3.3: Home heating methods and fuels.

	Heating methods		Fuel Use	
	%	Households	t/day	%
Electricity	55%	1,067		
Total Gas	13%	258	0	1%
Fixed gas		51		
Portable gas		207		
Oil	3%	58	1.6	10%
Open fire	1%	15		
Open fire - wood	1%	15	0	1%
Open fire - coal	0%	0	0	0%
Total Wood burner	40%	779	13	81%
Pre 2006 wood burner	13%	260	4	27%
2006-2016 wood burner	18%	346	6	36%
Post-2016 wood burner	9%	173	3	18%
Multi-fuel burners	0%	6		
Multi-fuel burners-wood	0%	3	0.03	0%
Multi-fuel burners-coal	0%	3	0.02	0%
Pellet burners	0%	6	0.05	0%
Wood fired cookers	5%	97	1	6%
Total wood	41%	797	14	88%
Total coal	0%	3	0	0%
Total		1,940	16	

3.3 Emissions from domestic heating.

In 2023 around 90 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Dargaville. The annual PM_{10} and $PM_{2.5}$ emission was estimated at 12 tonnes per year.

Table 3.3 shows that the majority of wood burners are pre-2006 models and Figure 3.2 shows these burners contribute the largest portion (48%) of the PM_{10} emissions from domestic heating. 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 2018 contribute to 29% of domestic heating PM_{10} emissions and burners less than five years old contribute 10%. 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 burning wood contribute 2%. Multi fuel burners burning coal and pellet burners contribute less than 1% of the daily winter PM_{10} emissions.

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 115 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. Emissions during the summer months occur because of the use of wood fired cookers during these months.

[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%).

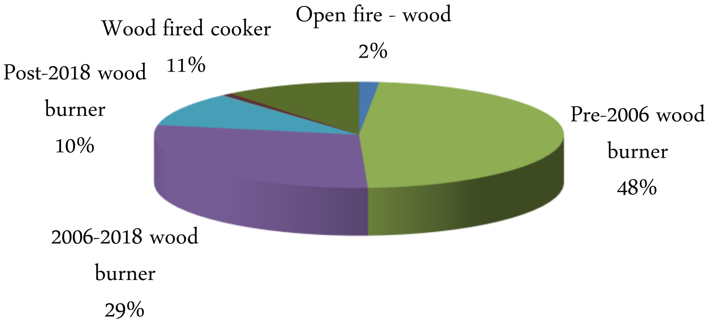

Figure 3.2: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating.

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

	Fuel Use		PM_{10}			CO			NO_x			SO_x			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																	
Open fire - wood	0.2	1%	1	1	2%	10	8	1%	0	0	2%	0	0	0%	1	1	2%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	13.0																
Pre 2006 wood burner	4.3	27%	43	34	48%	602	479	55%	2	2	19%	1	1	9%	43	34	48%
2006-2018 wood burner	5.7	36%	26	21	29%	258	205	23%	3	2	26%	1	1	12%	26	21	29%
Post 2018 wood burner	2.9	18%	9	7	10%	93	74	8%	1	1	13%	1	0	6%	9	7	10%
Pellet Burner	0.0	0%	0.1	0	0%	1	1	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel burner																	
Multi fuel– wood	0.0	0%	0	0	0%	4	3	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel – coal	0.0	0%	0	0	0%	2	2	0%	0	0	0%	0	0	2%	0	0	0%
Wood fired cooker	0.9	6%	9	7	8%	130	104	9%	0	0	4%	0	0	2%	9	7	8%
Gas	0.2	1%	0.01	0	0%	0	0	0%	0	0	3%	0	0	0%	0	0	0%
Oil	1.6	10%	0.49	0	1%	1	1	0%	4	3	32%	6	5	67%	0	0	0%
Total Wood	14.1	88%	89	71	99%	1098	875	100%	7	6	65%	3	2	31%	89	71	99%
Total Coal	0.0	0%	0.39	0	0%	2	2	0%	0	0	0%	0	0	2%	0	0	0%
Total	16		90	72		1102	877		11	9		9	7		90	72	

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

	Fuel Use		PM_{10}			CO			NO_x			SO_x			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%
Open fire																	
Open fire - wood	0.3	1%	2	2	2%	15	12	1%	0	0	2%	0	0	2	2	2%	2
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0	0	0%	0
Wood burner	16.9																
Pre 2006 wood burner	5.6	28%	56	45	49%	788	628	56%	3	2	21%	1	1	56	45	49%	56
2006-2018 wood burner	7.5	37%	34	27	29%	338	269	24%	4	3	28%	2	1	34	27	29%	34
Post 2018 wood burner	3.8	19%	12	10	11%	122	97	9%	2	1	14%	1	1	12	10	11%	12
Pellet Burner	0.0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0	0	0%	0
Multi fuel burner																	
Multi fuel– wood	0.0	0%	0.5	0	0%	7	5	0%	0	0	0%	0	0	0	0	0%	0
Multi fuel – coal	0.0	0%	0.7	1	1%	4	3	0%	0	0	0%	0	0	1	0	1%	1
Wood fired cooker	0.9	5%	9.3	7	8%	130	104	9%	0	0	4%	0	0	9	7	8%	9
Gas	0.2	1%	0	0	0%	0	0	0%	0	0	2%	0	0	0	0	0%	0
Oil	1.6	8%	0	0	0%	1	1	0%	4	3	27%	6	5	0	0	0%	0
Total Wood	18	91%	114	91	99%	1401	1115	100%	9	7	70%	4	3	114	91	99%	114
Total Coal	0	0%	1	1	1%	4	3	0%	0	0	0%	0	0	1	0	1%	1
Total	20		115	92		1406	1119		13	11		10	8	115	92		115

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

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	$PM_{2.5}$ kg/day
January	3	41	1	1	3
February	3	41	1	1	3
March	3	41	1	1	3
April	16	208	2	3	16
May	40	499	4	4	40
June	82	1013	8	6	82
July	90	1100	9	7	90
August	85	1043	9	6	85
September	38	473	5	4	38
October	17	218	3	3	17
November	3	41	1	1	3
December	0	0	0	0	0
Total (tonnes/year)	12	144	1	1.1	12

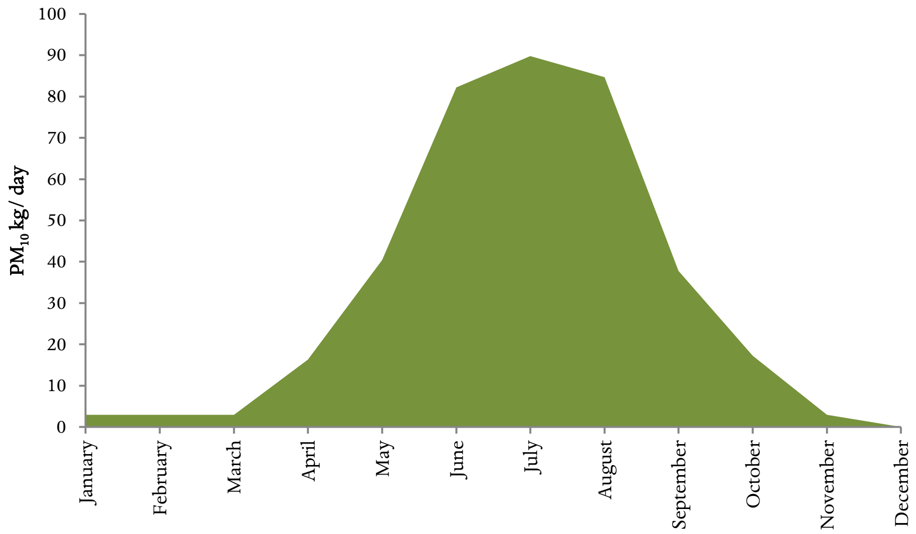

Figure 3.3: Monthly variations in PM_{10} emissions from domestic heating and cooking.

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 (Table 4.1). Temperature data were based on an average winter temperature for Dargaville of 13 degrees and 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 Dargaville area was estimated using the New Zealand Transport Authority VKT data for the Kaipara District for 2021 with the proportion of this occurring within Dargaville based on the relationship between the 2013 VKT in Dargaville relative to the Kaipara District (5%). The 2013 data were the only VKT data able to be sourced at the SA2 level.

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 European Environment Authority (EEA) air pollutant emission inventory guidebook (Table 4.2).

Table 4.1: Emission factors for the NZ vehicle fleet profile 2023 from VEPM (6.0).

CO g/VKT	PM_{10} g/VKT	PM brake & tyre g/VKT	NOx g/VKT	CO_2 g/VKT	$PM_{2.5}$ g/VKT	$PM_{2.5}$ brake & tyre g/VKT
1.24	0.018	0.021	0.616	0.127	0.018	0.012

Table 4.2: Road dust TSP emissions (EEA, 2016).

	TSP g/VKT
Two wheeled vehicles	0.00
Passenger car	0.01
Light duty trucks	0.01
Heavy duty trucks	0.01
Weighted vehicle fleet factor	0.020
	Size fraction g/VKT
PM_{10} size fraction	0.010
$PM_{2.5}$ size fraction	0.005

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 two kilograms per day of PM_{10} and $PM_{2.5}$ are estimated to be emitted from motor vehicles daily in Dargaville (Table 4.3) and around one tonne per year of PM_{10} and $PM_{2.5}$ (Table 4.4). Around 40% of the PM_{10} from motor vehicles is estimated to occur as a result of the wearing of brakes and tyres and 22% from resuspended road dust.

Table 4.3: Summary of daily motor vehicle emissions

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	kg	g/ha	kg		kg	g/ha	kg	g/ha		
Tailpipe	0.8	0.6	53	42	26	21	0.0	0.04	1.2	0.9
Brake and tyre	0.9	0.7							0.5	0.4
Road dust	0.4	0.3							0.2	0.2
Total	2.1	1.7	53	42.4	26	21.0	0	0.04	1.9	1.5

Table 4.4: Summary of annual motor vehicle emissions

PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
1	19	10	0	1

5 INDUSTRIAL AND COMMERCIAL

5.1 Methodology

Information on activities discharging to air in Dargaville were provided by Northland Regional Council. A range of industry types including combustion processes, materials handling and abrasive blasting activities were included in the evaluation.

The selection of industries for inclusion in this inventory was based on potential for PM_{10} and $PM_{2.5}$ emissions. Industrial activities such as waste transfer, sewage and spray painting, which discharge primarily odours and VOCs were not included in the assessment.

For some industries included in the assessment, site specific emissions data was available from the resource consent application or stack testing results. 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.

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

The emission factors used to estimate the quantity of emissions discharged are shown in Table 5.1. These use information such as the United States Environmental Protection Authority Air Pollution 42 database (referred to as AP 42). 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.

AP 42 Chapter	AP 42 Source Category Code	Discharge Type	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	$PM_{2.5}$ g/kg
11.12	SCC 3-05-011-04,-21,23	Aggregate handling - concrete production	0.0017				0.0005
13.2.6	SCC 3-09-002-04	Abrasive blasting - garnet	0.69				
	Wilton and Baynes (2009) for PM and AP 42 for others	Pellet boiler	0.8	6.8	0.8	0.0	0.7

5.2 Industrial and commercial emissions

Table 5.2 shows the estimated emissions to air from industrial and commercial activities in Dargaville. Around 12 kilograms of PM_{10} is estimated to be discharged to air per winter's day and around four tonnes of PM_{10} and 2.6 tonnes of $PM_{2.5}$ are emitted per year from industrial activities.

Table 5.2: Industrial and commercial daily and annual emissions in Dargaville

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
Daily	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Industrial & commercial activities	12	9	58	46	6	5	0.3	0.3	7	6
	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
Annual	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha
Industrial & commercial activities	4.4	3.5	21.4	17.1	2.4	1.9	0.1	0.1	2.6	2.1

6 OUTDOOR BURNING

Outdoor burning of green wastes or household material can contribute to PM_{10} and $PM_{2.5}$ 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.

6.1 Methodology

Outdoor burning emissions for Dargaville were estimated for the winter months based on data collected during the 2023 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 2.7 m^3 (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. The emission factor for SOx is 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 35 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average in Dargaville. Survey responses for Dargaville indicated a greater prevalence of outdoor burning than many other areas of New Zealand.

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. 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 density.

Table 6.2: Outdoor burning (garden waste) emission estimates for Dargaville.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	$PM_{2.5}$ kg/day
Summer (Dec-Feb)	10	54	4	1	10
Autumn (Mar-May)	19	100	7	1	19
Winter (June-Aug)	35	184	13	2	35
Spring (Sept-Nov)	24	126	9	1	24
	PM_{10} tonnes/ year	CO tonnes/ year	NOx tonnes/ year	SOx tonnes/ year	$PM_{2.5}$ tonnes/ year
Annual emissions	8	42	3	1	8

6.3 Brazier, pizza oven and wood fired barbeque emissions

The prevalence of burning in braziers, pizza ovens and outdoor barbeques in Dargaville was relatively low. Less than one kilogram of PM_{10} and $PM_{2.5}$ from braziers, pizza ovens and outdoor barbeques could be expected per day during the winter months from these sources Dargaville (Table 6.3).

Table 6.3: Brazier, pizza oven and wood fired barbeque emission estimates for Dargaville.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	$PM_{2.5}$ kg/day
Summer (Dec-Feb)	1.7	8.8	0.6	0.1	1.7
Autumn (Mar-May)	0.6	3.2	0.2	0.0	0.6
Winter (June-Aug)	0.2	1.1	0.1	0.0	0.2
Spring (Sept-Nov)	0.6	3.1	0.2	0.0	0.6
	PM_{10} tonnes/ year	CO tonnes/ year	NOx tonnes/ year	SOx tonnes/ year	$PM_{2.5}$ tonnes/ year
Annual emissions	0.3	1.5	0.1	0.0	0.3

6.4 Total emissions from outdoor burning

Table 6.4 shows the combined outdoor garden waste burning and burning of wood in braziers, pizza ovens and wood fired barbeques in Dargaville for 2023 by season and per year. Around 35 kilograms per day (winter) and around eight tonnes per year of PM_{10} and $PM_{2.5}$ are estimated from burning in the outdoors.

Table 6.4: Total outdoor burning emission estimates for Dargaville.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	$PM_{2.5}$ kg/day
Summer (Dec-Feb)	12	63	5	0.8	12
Autumn (Mar-May)	20	104	7	1.2	20
Winter (June-Aug)	35	185	13	2.2	35
Spring (Sept-Nov)	25	129	9	1.5	25
	PM_{10} tonnes/ year	CO tonnes/ year	NOx tonnes/ year	SOx tonnes/ year	$PM_{2.5}$ tonnes/ year
Annual emissions	8	44	3	0.5	8

7 OTHER SOURCES OF EMISSIONS

This inventory includes all likely major sources of PM_{10} and $PM_{2.5}$ 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 0.1 kilograms of PM_{10} per day from these sources.

8 TOTAL EMISSIONS

The total PM_{10} and $PM_{2.5}$ discharged to air in Dargaville on an average winter's day was estimated at 139 and 134 kilograms respectively. Figure 8.1 shows domestic heating is the main sources of both daily and annual PM_{10}. Domestic heating is also the main source of both daily and annual $PM_{2.5}$ emissions in Dargaville contributing around 67% and 50% respectively (Figure 8.2). Outdoor burning is also a significant contributor to PM_{10} and $PM_{2.5}$ emissions in Dargaville and is responsible for 36% of the annual $PM_{2.5}$ emissions.

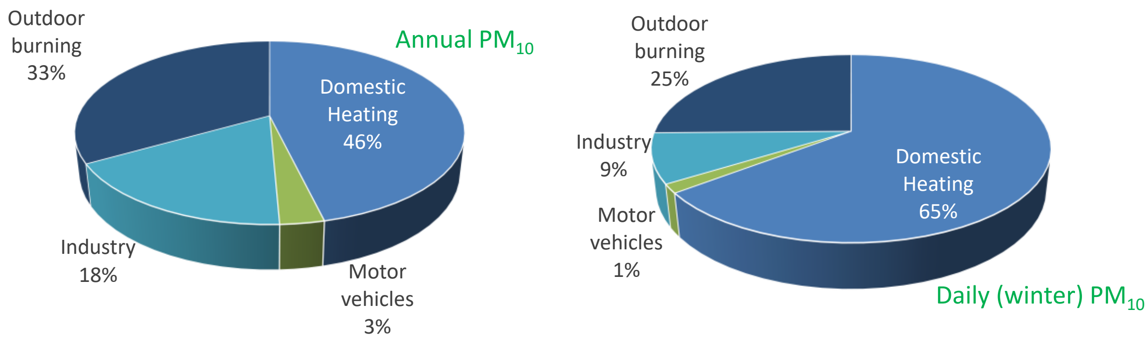

Figure 8.1: Relative contribution of sources to daily winter and annual PM_{10} emissions in Dargaville.

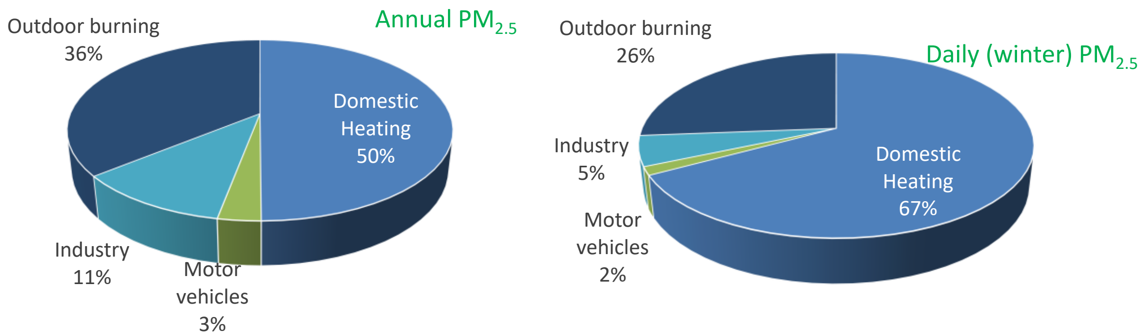

Figure 8.2: Relative contribution of sources to daily winter and annual $PM_{2.5}$ emissions in Dargaville.

Domestic heating is the main source of CO and SOx in Dargaville. Motor vehicles is the main source of NO_x emissions (Figure 8.3).

Tables 8.1 and 8.2 show daily and annual contaminant emissions by source. Seasonal variations in contaminants emissions are shown in Tables 8.3 to 8.7.

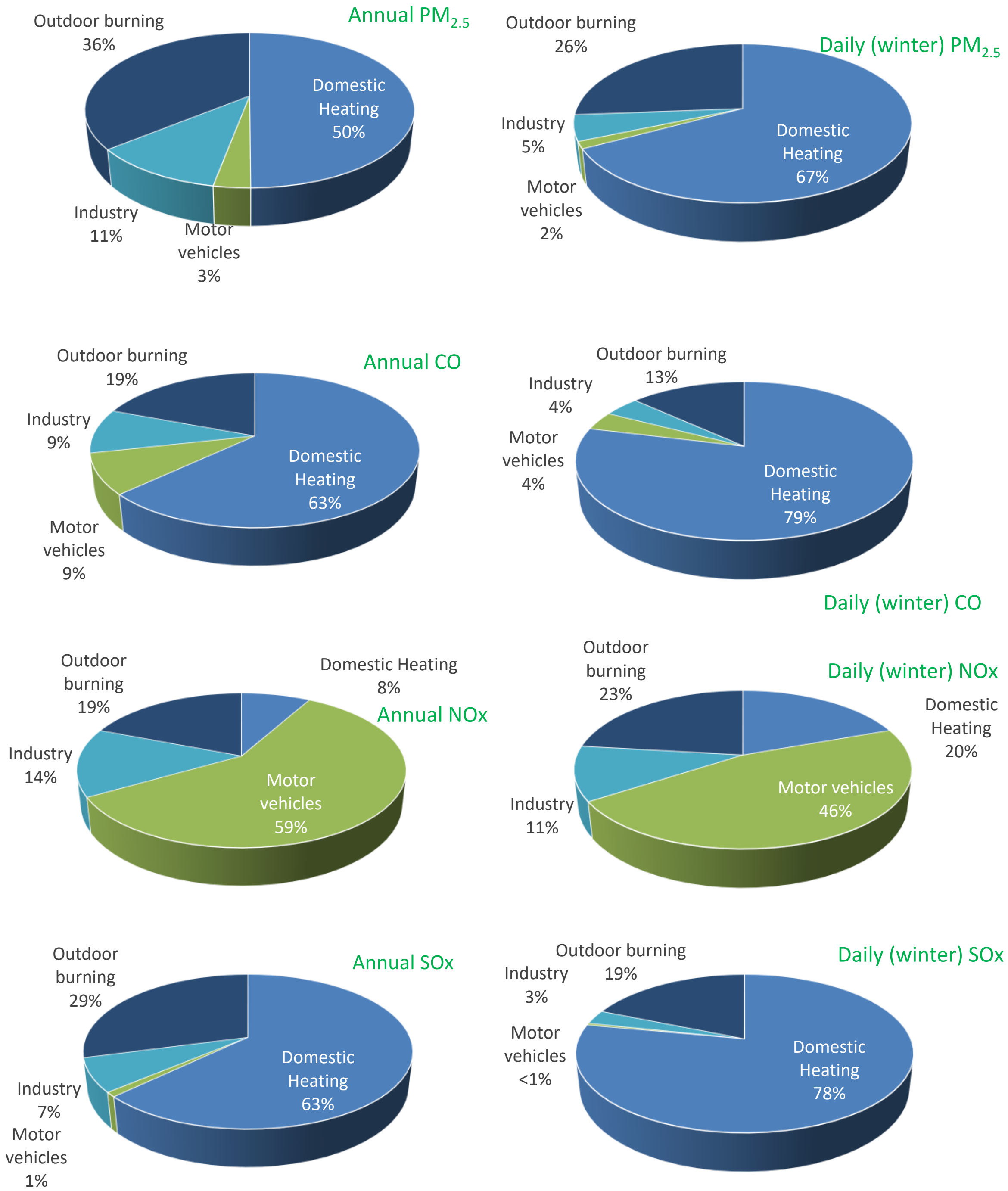

Figure 8.3: Relative contribution of sources to daily winter and annual contaminant emissions in Dargaville.

Table 8.1: Annual average emissions in Dargaville by source and contaminant (tonnes/year)

	PM_{10} tonnes/year	CO tonnes/year	Nox tonnes/year	Sox tonnes/year	$PM_{2.5}$ tonnes/year
Domestic Heating	12	144	1	1	12
Motor vehicles	1	19	10	0	1
Industry	4	21	2	0	3
Outdoor burning	8	44	3	1	8
Total	25	229	16	2	23

Table 8.2: Daily (winter) average emissions in Dargaville by source and contaminant (kg/day)

	PM_{10} kg/day	CO kg/day	Nox kg/day	Sox kg/day	$PM_{2.5}$ kg/day
Domestic Heating	90	1100	9	7	90
Motor vehicles	2	53	26	0	2
Industry	12	58	6	0	7
Outdoor burning	35	185	13	2	35
Total	139	1396	55	9	134

Table 8.3: Monthly variations in PM_{10} emissions in Dargaville by source (kg/day)

	Domestic Heating kg/day	Motor vehicles kg/day	Industry kg/day	Outdoor burning kg/day	Total kg/day
January	3	2	12	12	29
February	3	2	13	12	30
March	3	2	12	20	37
April	16	2	12	20	50
May	40	2	12	20	74
June	82	2	12	35	132
July	90	2	12	35	139
August	85	2	12	35	134
September	38	2	12	25	77
October	17	2	12	25	56
November	3	2	12	25	42
December	0	2	12	12	26

Table 8.4: Monthly variations in CO emissions in Dargaville by source (kg/day)

	Domestic Heating kg/day	Motor vehicles kg/day	Industry kg/day	Outdoor burning kg/day	Total kg/day
January	41	53	58	63	215
February	41	53	64	63	221
March	41	53	58	104	255
April	208	53	60	104	425
May	499	53	58	104	714
June	1013	53	60	185	1310
July	1100	53	58	185	1396
August	1043	53	58	185	1338
September	473	53	60	129	714
October	218	53	58	129	458
November	41	53	60	129	283
December	0	53	58	63	174

Table 8.5: Monthly variations in NOx emissions in Dargaville by source (kg/day)

	Domestic Heating kg/day	Motor vehicles kg/day	Industry kg/day	Outdoor burning kg/day	Total kg/day
January	1	26	6	5	38
February	1	26	7	5	39
March	1	26	6	7	41
April	2	26	7	7	43
May	4	26	6	7	45
June	8	26	7	13	55
July	9	26	6	13	55
August	9	26	6	13	55
September	5	26	7	9	47
October	3	26	6	9	45
November	1	26	7	9	43
December	0	26	6	5	37

Table 8.6: Monthly variations in SOx emissions in Dargaville by source (kg/day)

	Domestic Heating kg/day	Motor vehicles kg/day	Industry kg/day	Outdoor burning kg/day	Total kg/day
January	1	0.05	0.3	1	2
February	1	0.05	0.4	1	2
March	1	0.05	0.3	1	3
April	3	0.05	0.4	1	4
May	4	0.05	0.3	1	5
June	6	0.05	0.4	2	9
July	7	0.05	0.3	2	9
August	6	0.05	0.3	2	9
September	4	0.05	0.4	2	6
October	3	0.05	0.3	2	5
November	1	0.05	0.4	2	3
December	0	0.05	0.3	1	1

Table 8.7: Monthly variations in $PM_{2.5}$ emissions in Dargaville by source (kg/day)

	Domestic Heating kg/day	Motor vehicles kg/day	Industry kg/day	Outdoor burning kg/day	Total kg/day
January	3	2	7	12	24
February	3	2	7	12	24
March	3	2	7	20	32
April	16	2	7	20	45
May	40	2	7	20	69
June	82	2	7	35	126
July	90	2	7	35	134
August	85	2	7	35	129
September	38	2	7	25	71
October	17	2	7	25	51
November	3	2	7	25	37
December	0	2	7	12	21

9 SPATIAL VARIABILITY IN PM_{10} AND $PM_{2.5}$ EMISSIONS

Figures 9.1 to 9.4 show the spatial variability in PM_{10} and $PM_{2.5}$ emission density across Dargaville in as kilograms per square kilometer per day (winter (June, July and August)) and tonnes per square kilometer per year. The geographical basis is the 2018 SA1 Statistical Area Units. Emission densities are dominated by the domestic home heating emission distribution.

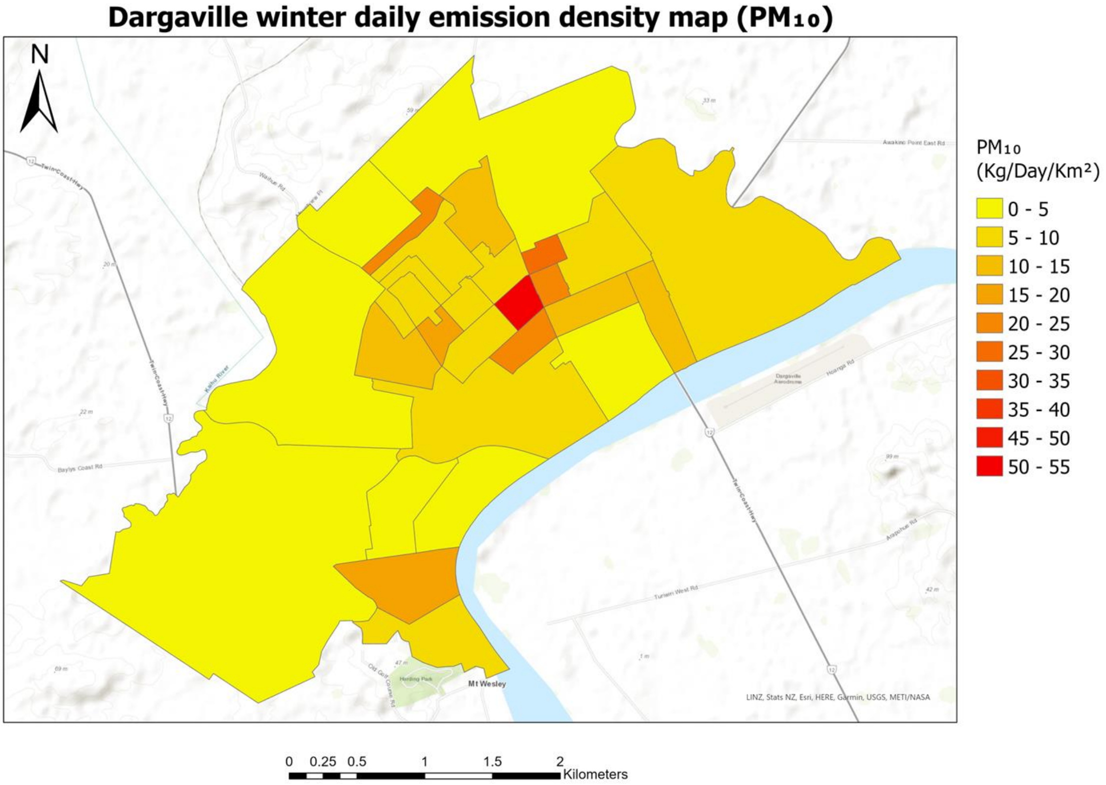

Figure 9.1: PM_{10} emission density (kg/day winter per km^2) in Dargaville

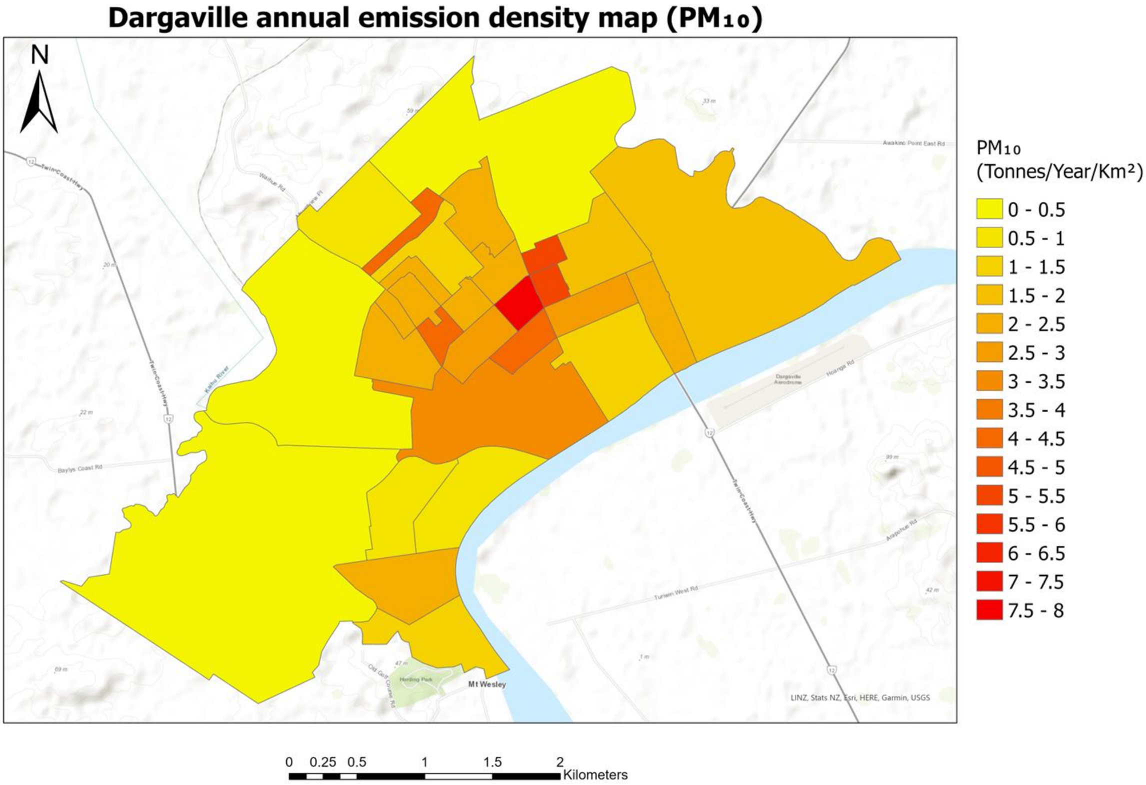

Figure 9.2: PM_{10} emission density (tonnes/year/km^2) in Dargaville

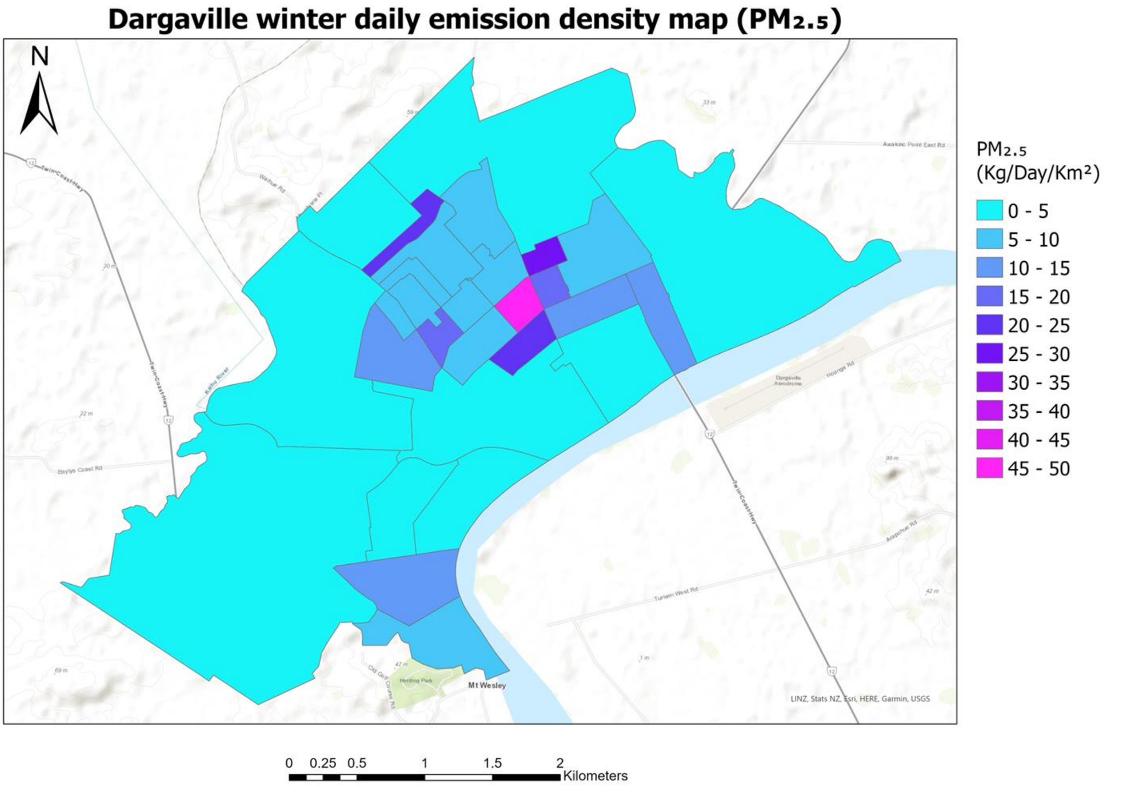

Figure 9.3: $PM_{2.5}$ emission density (kg/day winter per km^2) in Dargaville

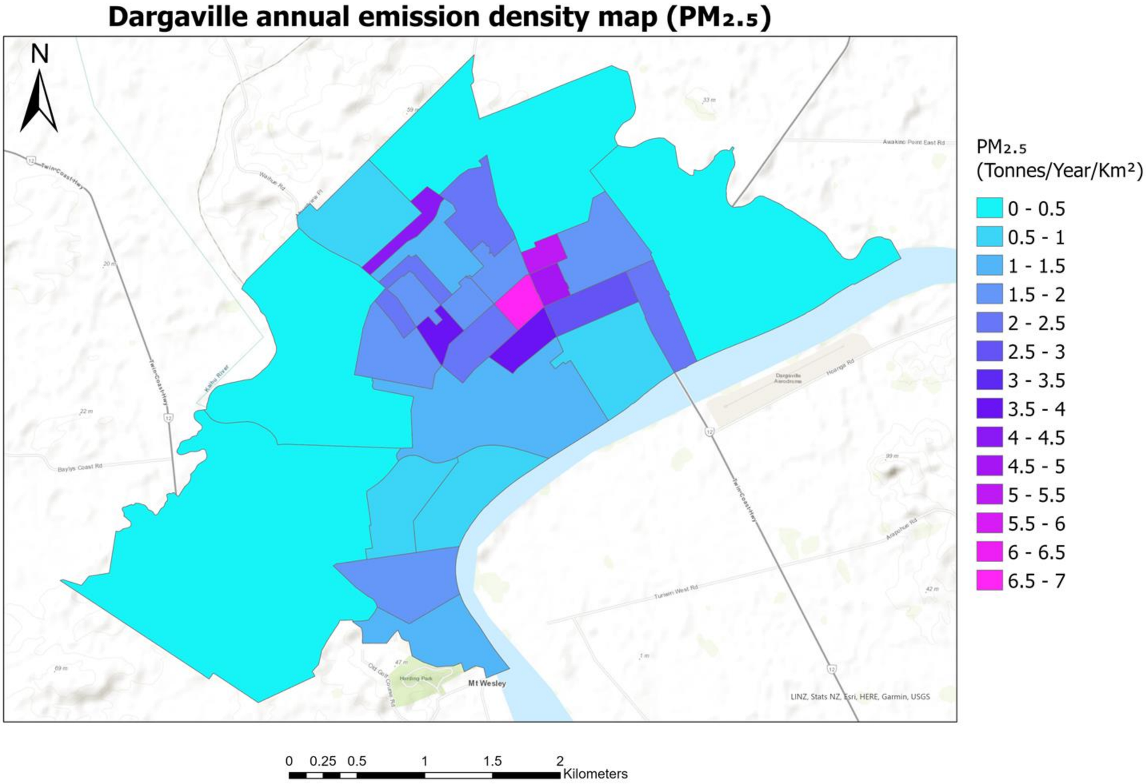

Figure 9.4: $PM_{2.5}$ emission density (tonnes/year/km^2) in Dargaville

10 AIR QUALITY MONITORING RECOMMENDATIONS FOR DARGAVILLE

Key factors influencing the location of an air quality monitoring station, sited in accordance with the NES for PM_{10} include the meteorology and emission density. These variables considered in conjunction with each other provide an indication of the direction of travel of the highest density emissions. This section considers the emission density maps illustrated in Section 9 and the meteorology of Dargaville to identify locations where high PM_{10} and $PM_{2.5}$ concentrations are likely to occur.

10.1 Meteorology in Dargaville

Northland Regional Council staff obtained meteorological data for Dargaville from the NIWA climate station (site ID 53987) for the period 2018 to 2022. Figure 10.1 show the predominant and less frequent wind directions in Dargaville by wind strength and separated by day and night. During the daytime, winds from the westerly direction are the strongest and occur with a high frequency. The north-east wind direction also occurs with a high frequency but includes a greater proportion of wind speeds in the 2- 4 ms^{-1} category. During the night the wind is most commonly from the northerly direction and typically wind speeds are less than 4 ms^{-1}. Higher night-time winds occur from a westerly and south westerly direction.

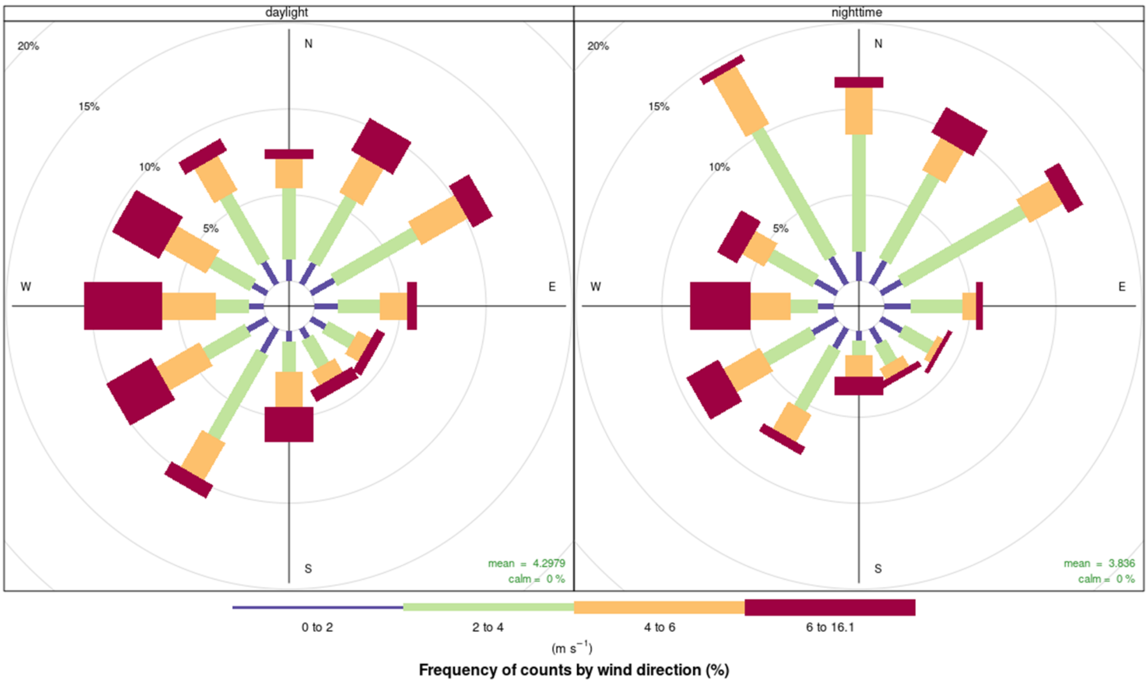

Figure 10.1: Wind direction frequency by daytime and night time in Dargaville

A key meteorological variable impacting on air quality and the selection of a suitable monitoring site is identifying the wind direction on days when dispersion is limited by low wind speeds. In New Zealand meteorological conditions most conducive to elevated concentrations typically occur during the winter months when temperature inversions coincide with higher emissions from domestic home heating.

Figure 10.2 shows that during the winter months lowest wind speeds occur during the evening and early hours of the morning, most typically when the wind is blowing from an easterly direction. Lower wind speeds are more typical generally during the autumn in Dargaville. However, Figure 10.3 shows that the winds are lowest in the winter from mid night to 6am on average. In both seasons the easterly wind direction is most significant in terms of the low wind speeds.

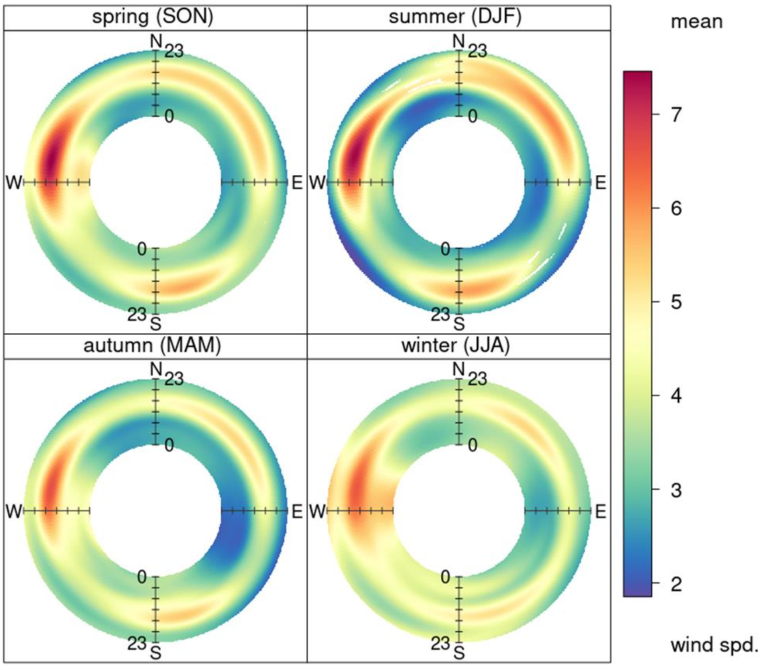

Figure 10.2: Wind speed and direction by season and time of day in Dargaville

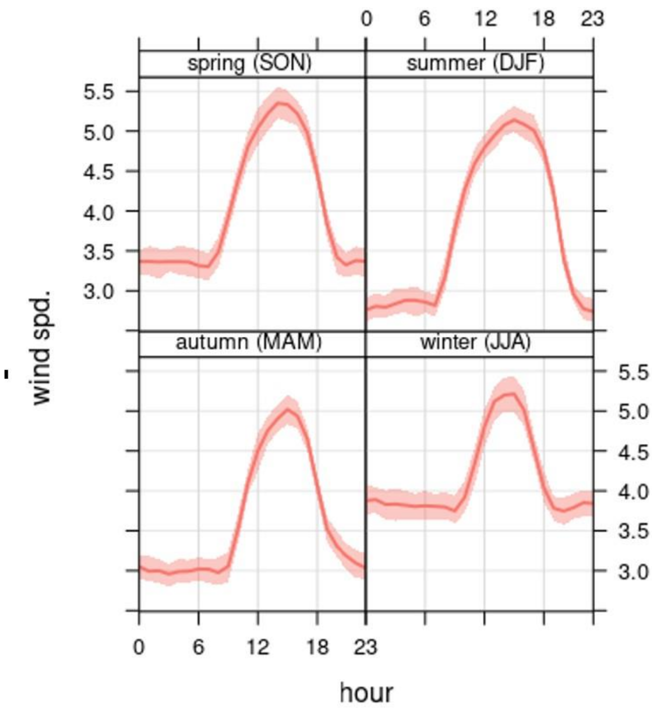

Figure 10.3: Wind speed (ms^{-1}) by season and time of day in Dargaville

Figure 10.4 shows that low temperatures coincide with very low wind speeds predominantly during the night time but also with some daytime prevalence in Dargaville. Colder temperatures under higher wind speeds also occur when the wind direction is from the south during both daytime and night-time in Dargaville.

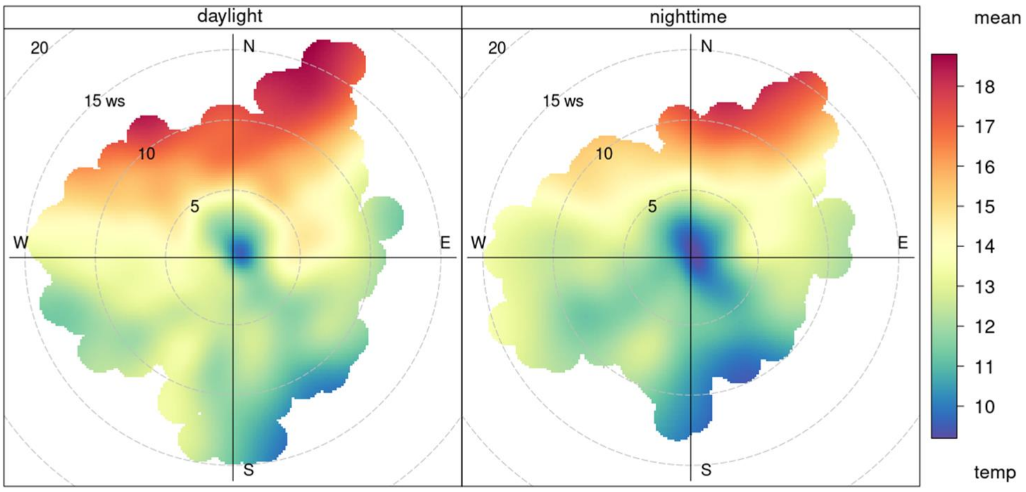

Figure 10.4: Temperature by wind speed (ms^{-1}) and wind direction in Dargaville

10.2 Potential locations for siting an air quality monitoring station in Dargaville

The most suitable location for a monitoring site to capture the worst case PM_{10} and $PM_{2.5}$ concentrations in Dargaville is likely to be areas in the west side of the urban area bounded by Parore Street, State Highway 12 and Carrington Street with Dargaville Highschool forming the upper northern boundary.

St Josephs school is located on the west of Dargaville and is downwind of the high emission density areas when the meteorological conditions are most likely to be conducive to elevated particulate. School grounds represent good locations for monitoring sites because of the open space and distance from point source discharges. This appears to be the most likely location of a suitable monitoring site in Dargaville. An alternative location would be Dargaville Intermediate school at the southern most end of the grounds.

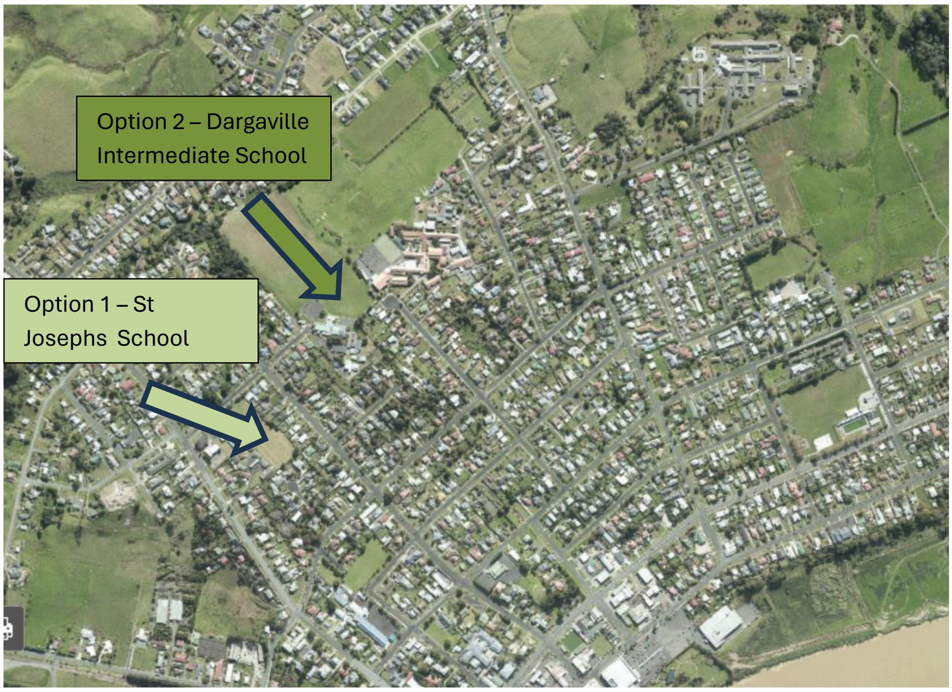

Figure 10.5: Locations for air quality monitoring sites in Dargaville

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APPENDIX A: HOME HEATING QUESTIONNAIRE

Good morning / afternoon/evening, I'm _________ calling from Symphony Research on behalf of the Northland Regional Council.
We are currently undertaking a survey in your area on methods of home heating. Can you please confirm you live in Dargaville
May I please speak to an adult in your household who knows about your home heating systems?
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). Do you use any other heating system in your main living area in a typical year? (If yes then question 3 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 4)
(b) Is it flued or unflued gas heating? If necessary: (A flued gas heating appliance will have an external vent or chimney)

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) 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?

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 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?

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 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?

6. (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?

7. 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.

8. Does your 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 et al., 2009; Smith et al., 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 NO_x 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 SO_x 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.