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PREPARED FOR

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PREPARED BY

Emily Wilton, Environet Ltd and John Iseli, Specialist Environmental Services

www.environet.co.nz

ENVIRONET AIR QUALITY SPECIALISTS

Tauranga Air Emission Inventory 2018

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EXECUTIVE SUMMARY

An emission inventory assesses sources of discharges to air. Sources included in the 2018 Tauranga inventory are domestic heating, motor vehicles, outdoor burning, shipping and port activities, aviation, rail and industrial and commercial activities. Natural source contributions (for example sea salt and soil) are not included because the methodology to estimate emissions is less robust. The evaluation focuses on particles in the air less than 10 microns (PM_{10}), particles in the air less than 2.5 microns ($PM_{2.5}$), sulphur oxides, nitrogen oxides and carbon monoxide.

A domestic home heating and outdoor burning survey was undertaken to determine heating methods and fuels and the prevalence and characteristics of outdoor burning. Electricity was found to be the most common method of heating the main living area with 78% of households using this source in their main living area. Heat pumps were the most common electric heating option with 71% of households that use heating having these. Wood burners were used by 19% of households.

Emissions were assessed in terms of contributions to daily (winter) and annual emissions. Domestic heating (40%), industry (19%) and shipping (18%) were the main sources of annual anthropogenic PM_{10} emissions. Domestic heating also accounted for 52% of the annual average $PM_{2.5}$. Shipping and industry were also contributors to annual average $PM_{2.5}$ (22% and 9% respectively). Domestic heating was responsible for the majority of the daily winter PM_{10} and $PM_{2.5}$ contributing 70% (PM_{10}) and 78% ($PM_{2.5}$).

The main sources of SO_x emissions were shipping (around 80%) and industry (around 20%). The contribution at any given site will vary depending on the sites proximity to individual industries and the Port.

The main source of nitrogen oxides is shipping emissions from the Port which contribute 59% of the annual emissions. Motor vehicles are the other dominant contributor at 30%.

1 INTRODUCTION

Emission inventories are carried out to determine the sources of emissions in a particular area for air quality management purposes and to evaluate changes in emission sources with time. Emission inventories are used by Governments and Local Government internationally to provide an estimate of the quantities of contaminants from anthropogenic sources that are emitted into the air and the relative contribution of sources to total emissions. The sources that are included in emissions inventories in New Zealand are generally the domestic heating, motor vehicle, industrial and commercial and outdoor burning sector.

In New Zealand the main air contaminant of monitored in urban areas is PM_{10} because concentrations can exceed National Environmental Standards (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 for PM_{10} suggesting investigation into the adoption of $PM_{2.5}$ as the key indicator with priority given to an annual 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.

A 2001 Regional Air Emissions Inventory (Sinclair Knight Merz, 2003) included emissions to air in Tauranga as a part of a larger scale emissions estimation approach. That inventory found that annually transport dominated the emissions of carbon monoxide (57%) and nitrogen oxides (76%) and that industrial sources dominate the annual emissions of fine particles at 54%. The domestic sources increased during the winter to 49% and industry 39% for particulate. Regionwide, sulphur dioxide was dominated by transport emissions from shipping and two large industrial sources.

This report provides an estimate of emissions of particles (PM_{10} and $PM_{2.5}$), carbon monoxide, nitrogen oxides and sulphur oxides from domestic heating, transportation, shipping and port activities, aviation, rail, industrial and commercial activities and outdoor burning for Tauranga.

2 INVENTORY DESIGN

The key components of inventory design are selection of the study area, selection of sources and the focus/extent of investment in data collection for each, contaminants to be included, the spatial resolution (within the study area what breakdowns might be required), temporal resolution (hourly, daily or annual emissions).

2.1 Key issues

The main air quality issue for most urban areas of New Zealand is particles in the air that are typically associated with solid fuel burning for domestic home heating. In Tauranga (Figure 2.1), however, daily winter PM_{10} concentrations do not breach the NES for PM_{10} based on the Otumoetai monitoring site. A national assessment of sources of air discharges suggests a strong industry presence for both PM_{10} and SO_2 for Tauranga (Ministry for the Environment, 2014) with a dominant particulate coarse mode within the industry PM_{10} size fraction.

Key air quality issues for Tauranga, include relatively high SO_2 concentrations measured at the Mount Manganui industrial area and localized particulate issues.

2.2 Selection of contaminants

The scope of the inventory with respect to contaminants is:

- particles (PM_{10})
- fine particles ($PM_{2.5}$)
- carbon monoxide (CO)
- sulphur oxides (SOx)
- nitrogen oxides (NOx)

Emissions of PM_{10}, CO, SOx and NOx are included as these contaminants are NES contaminants because of their potential for adverse health impacts. $PM_{2.5}$ has been included in the inventory because this size fraction has significance in terms of proposed revisions to the NES for $PM_{2.5}$ (annual average).

2.3 Selection of sources

Following discussions with Council staff, it is proposed that the inventory estimate emissions from:

- Industry including small scale industrial and commercial activities.
- Domestic heating
- Motor vehicles
- Outdoor burning
- Small scale domestic sources - lawn mowing, power tool use and solvent use
- Aviation
- Shipping
- Rail

Marine aerosol emissions and other natural dusts are not well characterized using inventory techniques and are not included in the emissions assessment. Other methods such as receptor modelling and source apportionment will provide a more robust approach for these sources.

2.4 Selection of areas

The Territorial Local Authority area of Tauranga will form the basis of the Tauranga emission inventory area (Tauranga EIA). There is extensive residential development within almost all of the outlaying census area units making selection of a smaller area inappropriate. In addition, the 2018 census moves away from census area units in favour of new geographical areas referred to as statistical areas. The statistical areas are designed to fit within the existing TLA area.

The inventory area is illustrated in Figure 2.1. An additional three-kilometer radius from the harbour entry was included in the inventory area to allow for a more thorough assessment of the discharges from ocean going vessels on approach and departure from the Port.

Figure 2.1: Tauranga inventory area and TLA boundary (source Stats Maps, 2018).

2.5 Temporal distribution

The inventory is based on emission estimates for 2018. For domestic heating and outdoor burning the method includes a 2018 survey. For other sources, estimates are based on 2018 where available. For sources where 2018 data are not available, activity data are based on previous years' information adjusted for 2018 where trends are evident.

The temporal distribution of the inventory information is annual, monthly and daily basis where appropriate. Domestic heating data are presented as average and worst-case wintertime scenarios and by month of the year. Motor vehicle data are based on annualised vehicle movements as seasonal variations are not available.

No differentiation is made for weekday and weekend sources.

3 DOMESTIC HEATING

3.1 Methodology

Domestic heating methods and fuel used by households were collected using a household survey carried out by Versus during June 2018 (Appendix A). The survey method was online panel. Table 3.1 shows the number of households based on 2013 census data adjusted for projected population increases (12%) for Tauranga from 2013 to 2018 (Statistics New Zealand, 2018).

Table 3.1: Summary household, area and survey data.

	No. of Dwellings	Sample size	Area (ha)	Sample error
Tauranga EIA	53238	388	17496	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
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.

Emissions for each contaminant 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 Tauranga is electricity with around 78% of households using that method. Wood burners and gas are the next most common method with 19% and 14% of households using them respectively. The majority of the wood burners are older models installed prior to 2006. Open fires and multi fuel burners are used by less than 5% of households and none of the survey respondents reported using coal. Table 3.3 also shows that households rely on more than one method of heating their main living area during the winter months.

Around 206 tonnes of wood is burnt per typical winter's night in Tauranga.

Figure 3.1 shows the proportion of households using different electrical heating types. This shows just over 70% of households using electricity in their main living area use heat pumps.

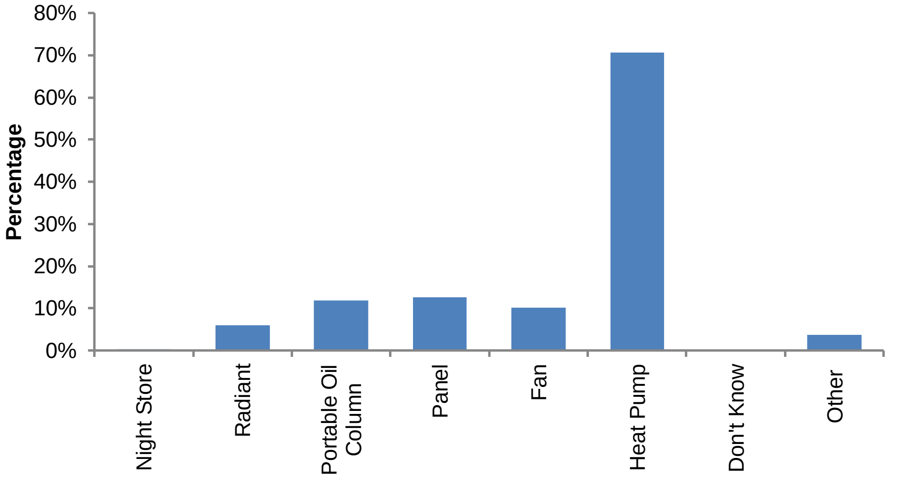

Figure 3.1: Electric heating options for Tauranga households (main living area).

Table 3.3: Home heating methods and fuels.

	Heating methods		Fuel Use	
	%	Households	t/day	%
Electricity	78%	41,575		
Total Gas	14%	7,547	7	3%
Flued gas	7%	3,551		
Unflued gas	8%	3,995		
Oil	1%	274	0.2	0%
Open fire	1%	686		
Open fire - wood	1%	686	11	5%
Open fire - coal	0%	0	0	0%
Total Woodburner	19%	9,879	172	81%
Pre 2006 wood burner	10%	5,175	90	42%
2006-2012 wood burner	5%	2,823	49	23%
Post-2012 wood burner	4%	1,882	33	15%
Multi-fuel burners	2%	1,098		
Multi-fuel burners-wood	2%	1,098	23	11%
Multi-fuel burners-coal	0%	0	0	0%
Pellet burners	1%	549		0%
Total wood	22%	11,663	206	97%
Total coal	0%	0	0	0%
Total		53,238	213	97%

3.3 Domestic heating emissions

Around 1579 kilograms of PM_{10} is discharged on a typical winter's day from domestic home heating across Tauranga.

Figure 3.2 shows that the majority (57%) 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 2012 contribute to 14% of domestic heating PM_{10} emissions and burners less than five years old contribute 9%. There is no technological difference between these latter two age categories and the differentiation is for distinguishing wood burner ages. Emissions of particulate from the use of gas and oil are negligible and not shown in Figure 3.2.

Tables 3.4 and 3.5 show the estimates of emissions for different heating methods under average and worst-case scenarios respectively. Emissions are shown in kilograms per day (kg/day) and in grams per hectare (g/ha). 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 1834 kilograms of PM_{10} is likely to be emitted.

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

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

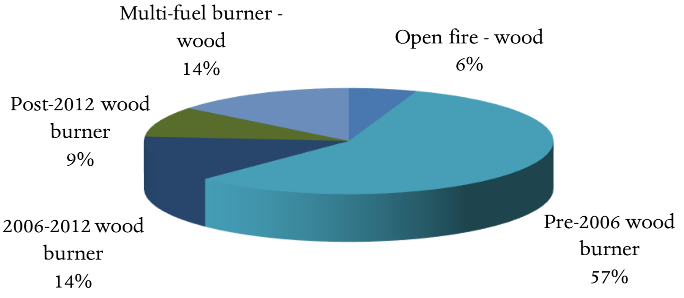

Figure 3.2: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating.

Table 3.4: Tauranga 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	11.4	5%	85	5	5%	624	36	3%	14	1	11%	2	0	5%	85	5	5%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	171.6																
Pre 2006 wood burner	89.9	42%	899	51	57%	12586	719	63%	45	3	37%	18	1	43%	899	51	57%
2006-2012 wood burner	49.0	23%	221	13	14%	2207	126	11%	25	1	20%	10	1	23%	221	13	14%
Post 2012 wood burner	32.7	15%	147	8	9%	1471	84	7%	16	1	14%	7	0	16%	147	8	9%
Pellet Burner	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	22.6	11%	226	13	14%	3170	181	16%	11	1	9%	5	0	11%	226	13	14%
Multi fuel – coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Gas	6.9	3%	0.21	0	0%	1	0	0%	9	1	7%	0	0	0%	0	0	0%
Oil	0.2	0%	0.06	0	0%	0	0	0%	0	0	0%	1	0	2%	0	0	0%
Total Wood	205.6	97%	1578	90	100%	20058	1146	100%	111	6	92%	41	2	98%	1578	90	100%
Total Coal	0.0	0%	0.00	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total	213		1579	90		20060	1147		120	7		42	2		1579	90	

Table 3.5: Tauranga 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	13.7	6%	103	6	6%	753	43	3%	16	1	12%	3	0	6%	103	6	6%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	200.5																
Pre 2006 wood burner	105.0	43%	1050	60	57%	14707	841	63%	53	3	38%	21	1	43%	1050	60	57%
2006-2012 wood burner	57.3	23%	258	15	14%	2578	147	11%	29	2	21%	11	1	24%	258	15	14%
Post 2012 wood burner	38.2	16%	172	10	9%	1719	98	7%	19	1	14%	8	0	16%	172	10	9%
Pellet Burner	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel burner																	
Multi fuel– wood	25.0	10%	250	14	14%	3504	200	15%	13	1	9%	5	0	10%	250	14	14%
Multi fuel – coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Gas	6.9	3%	0	0	0%	1	0	0%	9	1	6%	0	0	0%	0	0	0%
Oil	0.2	0%	0	0	0%	0	0	0%	0	0	0%	1	0	2%	0	0	0%
Total Wood	239	97%	1833	105	100%	23262	1330	100%	129	7	93%	48	3	98%	1833	105	100%
Total Coal	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total	246		1834	105		23263	1330		139	8		49	3		1834	105	

Table 3.6: Total annual and monthly variations in contaminant emissions from domestic heating.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	$PM_{2.5}$ kg/day
January	0	0	0	0	0
February	0	0	0	0	0
March	11	146	1	0	11
April	90	1185	15	2	90
May	734	9432	59	19	734
June	1424	18110	100	37	1424
July	1579	20059	120	41	1579
August	1302	16546	100	34	1302
September	392	5073	35	10	392
October	123	1574	8	3	123
November	13	167	1	0	13
December	0	0	0	0	0
	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Total domestic heating	174	2217	13	5	174

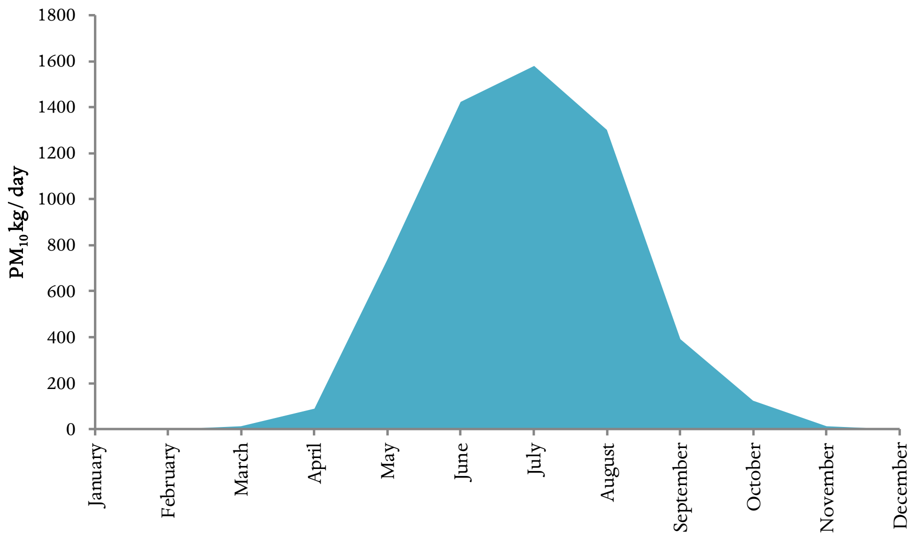

Figure 3.3: Monthly variations in PM_{10} emissions from domestic heating.

3.4 Other domestic sources of emissions

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. Pacific Air and Environment (1999) indicated around 0.07 grams of PM_{10} are emitted per household per day. However, this source is very dated and has been re-evaluated for this work. Appendix C outlines an updated assessment of potential emissions from small domestic appliances such as lawn mowers, chain saws and leaf blowers. This indicates a range of 0.7-3kg/day for Tauranga or 0.0012 to 0.05 g/household/day.

3.5 Uncertainty

The emission estimates include a range of uncertainties. The uncertainty has been quantified based on the statistical approach outlined in Appendix D. Because of some limitations in the assumptions underpinning this approach the resulting calculation has been categorised as either low (less than 20%), medium (20-40%) or high (more than 40%).

The uncertainties associated with the input variables for domestic heating include the emission factors for each appliance type, the fuel quantities used and the number of households using different heating methods. The sampling uncertainty for the household survey of 5% was used for the latter variable (assuming no systemic bias) and expert judgement for emission factors (30%) and fuel quantities (25%).

Motor vehicle emissions include tailpipe emissions as well as particulate emissions from brake and tyre wear and resuspended road dusts from on-road vehicles. Emissions from other non-road transportation methods including shipping and port activities, rail and aviation are included in section seven. Dust emissions from unpaved roads are not included in the inventory for Tauranga. The emissions from domestic home heating were estimated to have a medium level of uncertainty based on the above assessment.

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 5.3) developed by Auckland Council. Emission factors for PM_{10}, $PM_{2.5}$, CO and NOx for this study have been based on VEPM 5.3. Default settings were used for all variables except for the temperature data, average speed and the vehicle fleet profile which was based on Tauranga vehicle registration data for the year ending May 2018 (Table 4.1). This data was selected over the default national fleet profile as it was more consistent with vehicle model run data provided by Tauranga City Council (TCC). Temperature data were based on an average winter temperature for Tauranga of 15 degrees provided by Bay of Plenty Regional Council. The average vehicle speed data was based on data provided by TCC. 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 (10ppm) and the assumption of 100% conversion to SOx. The g/km emission factor was estimated using VEPM 5.3 using the fuel consumption per VKT for the parameters described above.

The number of vehicle kilometres travelled (VKT) for the Tauranga EIA was estimated using the New Zealand Transport Authority VKT data for 2017 which indicates just less than 2 million VKT per day (Table 4.3).

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 two different approaches. The approach outlined in Davy & Xie, (2014) uses a tracer component method (TCM) to separate exhaust and non-exhaust emissions from the entire source profile for motor vehicles in Auckland by using chemical markers. They estimated 18% of the total $PM_{2.5}$ and 30% of the total PM_{10} emissions were non-tailpipe. They found the VEPM estimates for brake and tyre wear underestimated total non-tailpipe emissions. These ratios were used to estimate non-tailpipe PM_{10} and $PM_{2.5}$ emissions from motor vehicles with the resulting PM_{10} separated into brake and tyre wear using the amounts estimated from VEPM and the remainder classified as road dust.

The alternative method was that specified in the EMEP/EEA air pollutant emission inventory guidebook (2016). The emission factors from this method are shown in Table 4.4.

Table 4.1: Vehicle registrations for the year ending May 2018.

	Petrol	Diesel	Hybrid/electric	LPG	Other	Total
Cars	84,923	7,564	668	11	2	93,168
LCV	3,820	10,787	3	10	0	14,620
Bus	124	485	1			610
HCV		5,516				5,516
Miscellaneous	2024	830		40	6	2,900
Motorcycle	4,509					4,509
Total	95400	25182		61	8	121,323

Table 4.2: Emission factors for Tauranga vehicle fleet (2018).

	CO g/VKT	PM_{10} g/VKT	PM brake & tyre g/VKT	NOx g/VKT	NO_2 g/VKT	$PM_{2.5}$ g/VKT	$PM_{2.5}$ brake & tyre g/VKT
Tauranga	2.1	0.019	0.010	0.546	0.070	0.019	0.005

Table 4.3: VKT daily and annual .

	Total VKT per day	Annual VKT
Tauranga	1912329	698000000

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

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

Table 4.4: 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	0.018
PM_{10} size fraction	0.5
$PM_{2.5}$ size fraction	0.27

4.2 Motor vehicle emissions

Around 72 kilograms per day of PM_{10} are estimated to be emitted from motor vehicles daily in Tauranga. The emission estimates for road dust from the EMEP/EEA emission factors and the Davy & Xie, (2014) approach gave extremely close estimates for PM_{10} (within 1%) and close estimates for $PM_{2.5}$ (14% difference with the EMEP/ EEA method being higher). Notwithstanding the closeness of the two methods in our view the uncertainty with the emission estimate would still be high. The Davy & Xie, (2014) based emission estimates are reported in the table below because they more closely represent New Zealand conditions.

Around 50% of the PM_{10} and 66% of the $PM_{2.5}$ from motor vehicles is estimated to occur as a result of the tailpipe emissions with the remainder estimated from brake and tyre wear and road dust (Figure 4.1). Table 4.5 shows the daily and annual estimates of emissions from motor vehicles in Tauranga.

Table 4.5: Summary of daily motor vehicle emissions (kg/day)

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	36.1	2.1	3968	227	1045	60	0.8	0.05	36.1	2.1
Brake and tyre	18.8	1.1							10.3	0.6
Road dust	17	1.0							8	0.5
Total	72	4.1	3968	227	1045	60	1	0.05	54	3.1

Table 4.6: Summary of daily motor vehicle emissions (tonnes/year)

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	tonnes	kg/ha	tonnes	kg/ha	tonnes	kg/ha	tonnes	kg/ha	tonnes	kg/ha
Tailpipe	13	0.8	1448	83	381	22	0.3	.02	13	1
Brake and tyre	7	0.4							4	0
Road dust	6	0.4							3	0
Total	26	1.5							20	1

Figure 4.1: Motor vehicle PM_{10} (left) and $PM_{2.5}$ (right) emissions by source.

4.3 Uncertainty

There are several areas of uncertainty around the emissions estimates from motor vehicles. The fleet weighted average emission factors contain assumptions around average speeds, cold starts and the distribution of diesel and petrol vehicles as well as the allocation of vehicles to different engine capacity or weight classes. The NZTA VKT data provide another source of potential uncertainty.

The authors of VEPM provide an expert judgement on the uncertainty being in the range of 20-100% depending on the make-up of the fleet being investigated. In particular it notes that *"It is anticipated that if the fleet consisted entirely of European vehicles uncertainty would be close to 20%. Conversely, if the fleet was predominantly of Japanese origin with a high proportion of HDVs then the uncertainty could be as high as 100%"* (EFRU, 2008).

An estimate of the uncertainty of the PM_{10} motor vehicle tailpipe emissions was made based on the following uncertainties: fleet weighted average emissions – exhaust 40% and brake and tyre wear 60% and VKT estimates 20%. Road dust PM_{10} estimates were assumed to contain an uncertainty of 50%.

The emissions for motor vehicle exhaust, brake and tyre wear emissions and road dust were estimated to have a medium level of uncertainty based on the above assessment.

5 INDUSTRIAL AND COMMERCIAL ACTIVITIES

5.1 Methodology

5.1.1 Sources and approach

Industrial and commercial activities to be included in the inventory were identified by searching a range of databases and through the Council's resource consent database.

Information on activities with resource consents for discharges to air in Tauranga were provided by the Bay of Plenty Regional Council. These included a range of surface coating activities, landfills, combustion activities, cement processing, fertiliser production and chemical industries. A range of other databases were examined and additional industrial and commercial activities were identified.

Surface coating activities (e.g., spray painters) were the most predominant consented industrial activity. The main discharge from surface coatings is volatile organic compounds (VOC) which is a contaminant not included in the inventory. Particle emissions may occur if coatings are applied using spray guns in an uncontrolled environment. However, they are not typically included in emission inventory assessments as they are comparatively small in relation to those from other sources (Environment Australia, 1999).

The general approach was to identify activities discharging to air and collect site specific information relevant to the discharge type (activity data) as well as information on seasonal variability and hours of operation where relevant.

An alternative approach to assessing emissions from the storage and handling of stock feed material/ grains/ palm kernel imported through the Port was adopted, however. Information on the quantities was available through the Port and suppliers were of the view that the majority (~80%) of this was transported to stores within the Tauranga area. Those supplying the product did not hold resource consents and databases available did not distinguish storage of products that might discharge to air from storage of other products. Consequently, emissions for this source were estimated for the handling of these materials based on a top down approach using the Port cargo data and the assumption that around 80% of the material was stored locally.

5.1.2 Emission estimates

For industries for which relatively recent site-specific emissions data were available from compliance testing or the resource consent application, emissions were estimated based on equation 5.1.

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

Where site specific emissions data were not available, emissions were estimated using activity data and emission factor information, as indicated in Equation 5.2. Activity data from industry includes information such as the quantities of fuel used, or in the case of non-combustion activities, materials used or produced. Activity data was collected by direct contact with industry, using data from the resource consents or compliance monitoring or a combination of these methods.

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

The emission factors used to estimate the quantity of emissions discharged are shown in Table 5.1. Site specific information was available for a number of sources. The emissions factors used are from the USEPA AP42 database[2] with the exception of the animal cremation factors which are from (EEA, 2016). In addition, AP 42 database was used to assess the proportion of PM_{10} emissions that were likely to be $PM_{2.5}$ for a range

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

of sources. Fugitive dust emissions from industrial and commercial activities were generally 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
1.1	1-03-013-02	Waste oil combustion	1.40	0.7	2.7	7.8	1.31
9.9.1	3-02-005-55	Grain unloading – shipping	0.019				0.0025
9.9.1	3-02-005-30	Grain handling - general	0.017				0.0028
9.9.1	3-02-008-16	Grain processing – pellet cooler	0.0375				0.0062
9.9.1	3-02-005-51	Grain unloading - truck	0.0295				0.005
9.9.1	3-02-005-52	Grain unloading – hopper truck	0.0039				0.00065
11.2	3-05-011-17	Cement supplement handling controlled	0.0024				
11.12	3-05-011-04,-21,23	Aggregate loading/ unloading uncontrolled	0.0017				0.0005
11.2	3-05-011-07	Cement handling controlled	0.00017				
13.2.6	3-09-002-04	Abrasive blasting – garnet fabric filter	0.69				0.069
			kg/m^3	kg/m^3	kg/m^3	kg/m^3	kg/m^3
1.4	1-01-006-02	Natural gas boilers	0.0001	0.0006	0.0016	0.0000	0.0001
Source							
5.c.1.b	(EEA, 2016)	Crematorium – animal (kg per tonne of material cremated)	0.6				0.5
(Wilton & Baynes, 2010)		Coal boiler – underfeed stoker	2	5.5	4.8	19*	1.2

For 1% Sulphur content but adjusted for S content percentage where available

5.2 Small scale activities - methodology

An additional assessment of PM_{10} and $PM_{2.5}$ discharges from small scale industry is included in this report based on the methodology described in the Bay of Plenty Regional Council Rotorua Air Emission Inventory (Iremonger & Graham, 2007). The methodology used for this assessment as per Iremonger & Graham, 2005 was to sort small scale activities into category groupings and to apply an across the board hourly emission rate for each activity in each category. The groupings and emission rates from that study and applied here were:

Facilities with highest potential for PM emissions (assumed to emit 0.1 kg/hr)

Joinery factories, heavy engineering, panel beaters, light metal fabrication, metal finishers (powder coating), bakeries, bone/stone/wood grinding or carving.

Facilities with lower potential for PM emissions (0.02 kg/hr)

Light vehicle workshops, printing works, packaging manufacturers, tanneries, paint and other solvents, metal finishers/ electroplating, appliance repairs.

Facilities with very little potential for PM_{10} emissions (no emissions)

Retail facilities, car dealers, food and beverage facilities. **Facilities with the potential for yard emissions (0.1 kg/day)**

Wreckers, scrap metal dealers, waste management, timber yards.

The assignment of these emission factors to these groupings was made by Graham, (2006) and reported in Iremonger & Graham, (2007) based on the emission test data reported in Appendix B. It is noted that these factors will be TSP and the main size fractions of interest are PM_{10} and $PM_{2.5}$. To estimate emissions by size data on size fraction distributions from AP 42 (Appendix B.2, table B2.2 mechanically generated sources for aggregate/ unprocessed ores) were adopted. This indicated PM_{10} at around 51% of TSP and $PM_{2.5}$ at 15% of TSP.

Iremonger & Graham, (2007) note a very high degree of uncertainty in the method to the point of it providing only an indication for the purposes of assessing whether further evaluation is required. We concur with this view because of the very small number of test results available for the different discharge types, no specificity of method associated with the test results (e.g., controlled or uncontrolled) and some significant variations in test results for seemingly the same discharge type (e.g., the two results for spray painting are 0.03 kg/hr and 0.14 kg/hr). In addition, these test data are extrapolated to other industry to provide rough groupings and we have applied an across the board size distribution allocation that does not take into account the different particulate formation processes.

Small scale industrial and commercial activities were identified based on a Regional Council audit database which included around 380 activities. The activity types were compared to those described in Graham (2006) and those consistent with the categories listed were included based on the emission rates specified. Activities not specified in the existing emission categorisation were generally assumed to fall into the "no likely emission" category except in instances where additional information indicated otherwise (e.g., a number of "yard emissions" activities were identified based on comments provided in the audit). A total of 181 small scale industrial and commercial activities were included in the assessment. It is noted that the audit database did not cover all of Tauranga and may underestimate the total number of small scale operators. No additional databases were able to be sourced.

5.3 Industrial and commercial emissions

Table 5.2 shows the estimated emissions to air from industrial and commercial activities in Tauranga. For SOx, 231 tonnes is estimated to be discharged per year and the daily winter discharge is around 617 kg/day for July (month typically used to represent winter). The highest daily average emissions for 2018 occurred during September, however (795 kg/day). Figure 5.1 shows seasonal variations in total industrial and commercial SO_2 emissions as well as the contribution from two key industrial activities (with respect to SO_2 emissions).

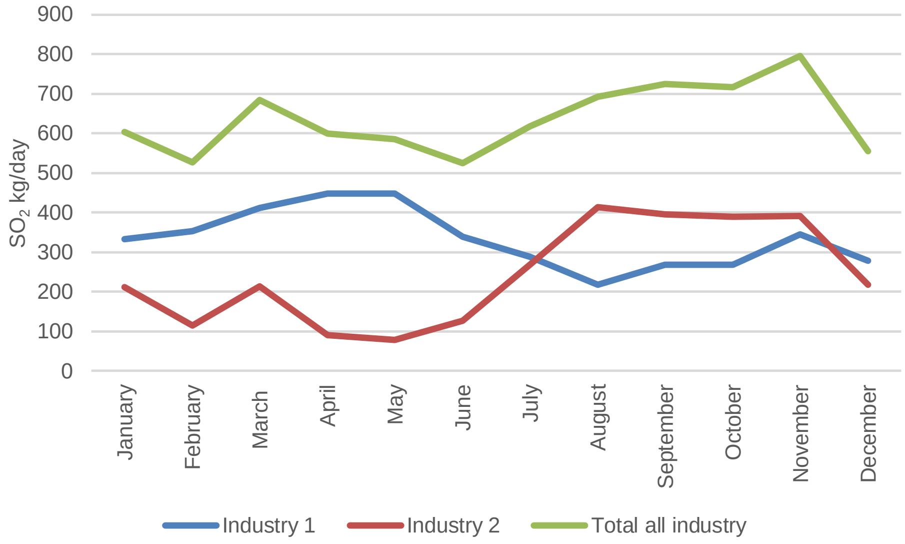

Figure 5.1: Seasonal variations in SO_2 emissions from industrial and commercial activities and the contribution of two key industrial activities to total SO_2 emissions from this sector.

Around 84 tonnes of PM_{10} and 31 tonnes of $PM_{2.5}$ is estimated to be discharged to air per year in Tauranga. The average daily amount during winter is 175 kg/day and 76 kg/day for PM_{10} and $PM_{2.5}$ respectively (Table 5.2).

Table 5.2: Industrial and commercial emissions in Tauranga.

	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Industrial & commercial activities	175	10	96	6	166	9	617	35	76	4
	PM_{10}		CO		NOx		SOx		$PM_{2.5}$	
	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha	t/year	kg/ha
Industrial & commercial activities	77	4	30	2	59	3	231	13	30	2

5.4 Small scale activity emissions

The total estimated emissions from small scale industrial and commercial activities comprising industry for which emission factors are not readily available was 28 kilograms PM_{10} per day and 7.5 tonnes per year. The $PM_{2.5}$ estimates are 8 kilograms per day and 2 tonnes per year. The estimates were based on the assumption that discharges would occur for six hours a day and five days per week at the rates specified for each location.

5.5 Uncertainty

The uncertainty for the industrial and commercial emissions was estimated for PM_{10} and SO_2 based on the kg/day emissions for the months of July (PM_{10}) and June (SO_2).

For each contaminant the key industrial contributors were identified, and uncertainty estimates calculated for each source based on the quality of information available for each variable. For example, the SO_2 emission estimates for the larger SO_2 emitters were based on continuous monitoring at the source and will contain lower uncertainty than for other emission estimation methods.

The uncertainties used were 15% for continuous emission sampling, 40%- 50% for emission factors depending on AP42 rating and activity data ranging from 10% (Port Shipping Data) to 30% depending on the source of the information. The remaining smaller contributors were collated and allocated an emission uncertainty estimate of 40%.

The SO_2 and PM_{10} uncertainties were estimated to be low (less than 20%).

The small-scale activity emissions have been treated as a separate source for the purposes of assessing uncertainty. The uncertainty has been estimated to be high based on expert judgement.

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 Proposed Bay of Plenty Regional Air Plan bans outdoor burning within 100 metres of a neighbouring dwelling house unless for recreational/ cultural purposes (Rule AQR 9) or if the activity meets requirements of rules 7 and 8 which provide for fire fighting and emergency disposal of diseased carcasses and vegetation. The plan has been notified and therefore a resource consent would have been required for outdoor burning during 2018. Notwithstanding this, the source has been included in the inventory because of the time it takes for changes to become public knowledge. The estimates below are likely to represent outdoor burning emissions for 2018 but it is likely that decreases in this source will occur in the near future if the plan becomes operative with the outdoor burning rules in their current form.

6.1 Methodology

Outdoor burning emissions for Tauranga were estimated for all seasons based on data collected during the 2018 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[3] and using the emission factors in Table 6.1 with an average fire size of 0.7 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 factors selected are based on a combination of refuse (AP42 table 2.5.1), weeds and prunings (table 2.5.5). 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. AP42 emission factors were selected in preference to European Environment Agency air pollution emission inventory guidebook (EEA, 2016) tier one assessment emission factors as the latter are based on tree slash for two species and tree pruning for two species only.

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

Source AP 42	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SOx g/kg
Tables 2.5- 1 and 2.5-5	8	8	42	3	0.5

[3] 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 87 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average in Tauranga. Survey responses for Tauranga indicated a greater prevalence of outdoor burning during the winter months than other seasons of the year.

It should be noted, however, that there are a number of uncertainties relating to the calculations. In particular it is assumed that burning is carried out evenly throughout 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 emission estimates for Tauranga.

	PM_{10} kg/ day	CO kg/ day	NOx kg/ day	SOx kg/ day	$PM_{2.5}$ kg/day
Summer (Dec-Feb)	42	223	16	3	42
Autumn (Mar-May)	58	305	22	4	58
Winter (June-Aug)	87	457	33	5	87
Spring (Sept-Nov)	51	268	19	3	51
	PM_{10} tonnes/ year	CO tonnes/ year	NOx tonnes/ year	SOx tonnes/ year	$PM_{2.5}$ tonnes/ year
Annual emissions	22	115	8	1	22

6.3 Uncertainty

The key areas of uncertainty regarding emissions estimates from outdoor burning are the quantities of material burnt per day and the emission factors. The uncertainty around the quantities has been estimated at around 80% because of potential errors in householder estimates of quantities burnt and the potential for burning not to be spread evenly across the seasons (i.e., more emissions on some days and less on others). The uncertainty around emission factors of 50% was assumed.

The combined uncertainty around outdoor burning emissions was estimated to be high (around 50-100%).

7 AVIATION, SHIPPING, PORT AND RAIL

Non-road transportation sources of emissions in Tauranga include emissions from shipping and other port activities, rail and aviation emissions. Shipping emissions within the inventory area occur as a result of ocean-going vessels approaching and leaving the Port, manoeuvring whilst berthing and as a result of the use of auxiliary engines and boilers whilst docking. Harbour vessels including tugs, coast guard and recreational boats also contribute to shipping emissions, but to a lesser extent (e.g., Peeters, 2018).

In addition, the loading and unloading of cargo at the Port results in discharges to air (PM_{10} and $PM_{2.5}$) as a result of the handling of materials that generate fine dusts. Cargo handling equipment and trucks visiting the Port emit products of combustion including all contaminants considered in this inventory (PM_{10}, CO, NOx, SOx and $PM_{2.5}$). Other sources of PM_{10} and $PM_{2.5}$ include open storage of material, brake and tyre wear and use of paved and unpaved roads.

The use of diesel engines in rail is typically only a minor contributor to urban air pollution in New Zealand.

Emissions from the landing and take-off of aircraft may be included in an emission inventory as a portion of these parts of the flight path occur within the lower atmosphere and contribute to urban air quality. The Tauranga airport is a small regional airport which has a low volume of commercial flights and relatively small aircraft.

7.1 Methodology

7.1.1 Shipping

The methodology for assessing emissions from shipping was taken from the USEPA “Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories (ICF International, 2009). That report details three approaches for ocean going vessels: a detailed inventory, a mid tier assessment and a port matching process.

Emissions from ocean going vessels that call at a Port vary depending on vessel size and the time spent at different speeds. A call refers to one entrance and one clearance of a vessel from the Port Authority area. A shift refers to a movement within the Port Authority Area as vessels may move from berth to berth during a call. Hotelling is the time spent stationary at Port during which it uses its auxiliary engine for power. Activity data for shipping includes the number of calls for different vessel sizes, the average number of shifts and the time spent in Port. Speeds are broken down into cruise speed (94% of maximum speed), reduced speed (harbour reduced speed zone – 9-12 knots in most areas) and manoeuvre speed (typically 3-8 knots).

For the purposes of assessing the contribution of shipping and port activities to the Tauranga air emission inventory the shipping discharge was limited to emissions assessed at a reduced speed within the harbour area as well as a three kilometre radius from the harbour entry.

Emissions from ocean going vessels were calculated using equation 7.1 which was applied to both the main propulsion engine and the auxiliary engine using the load factor assumptions from Table 7.2.

Equation 7.1 $E = P \times LF \times A \times EF$

Where:

E = Emissions (grams)

P = Maximum continuous rating power (kW)

LF = Load Factor (percent of vessels total power)

A = Activity (hours)

EF = Emission Factor (g/kWh)

A mid-tier assessment approach was undertaken using information on the number of calls by ship type and using the average power rating and load factors for the vessel type.

Data on the number of calls for different vessel types, travel speeds and the time in Port was obtained from the Port of Tauranga (pers comm, Rowan Johnston, 2018). Vessels classified as miscellaneous were assumed to have the same average rating and loadings as the general cargo vessels.

Emission factors for shipping were taken from ICF International, (2009) and are shown in Table 7.1. Emission factors are considered constant down to loads of 20% and increase for lower loads. Low load adjustment factors from ICF International (Table 2-15, 2009) were used when loads were estimated at less than 20%. ICF International, (2009) indicates that most ocean-going vessels operate their main propulsion engines on residual oil (RO)/ heavy fuel oil (HFO). Load factors are 83% for ships at cruise speed and for lower speeds are calculated using propeller law as per Equation 7.2. The maximum speed per vessel type was calculated using equations developed for the Port of Auckland Inventory (table 4, Peeters, 2018).

Equation 7.2: Load Factor = $(\text{Average speed}/\text{Maximum speed})^3$

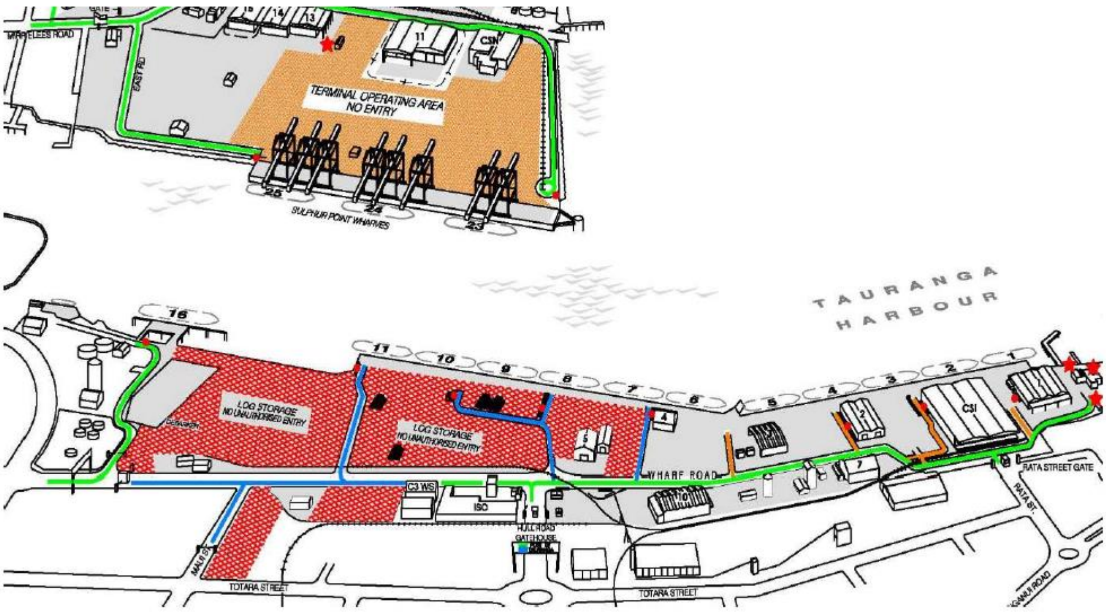

Figure 7.1: Tauranga Harbour and shipping berths at the Port (source Port of Tauranga).

Emissions from vessels whilst stationary at Port also need to be assessed as the auxiliary engines are used during this time to provide power to the ship unless cold ironing (connection of ships to land based power) is adopted. No cold ironing is carried out at the Tauranga Port. The load factors used to assess auxiliary emissions whilst stationary at Port (referred to as hoteling) are shown in Table 7.2 along with the average power rating of auxiliary engines for different vessels. Time spent hoteling was calculated using the average time in Port less the approach and manoeuvring times (shown in Table 7.3).

In addition to use of auxiliary to provide power at Port many vessels operate a boiler when the main engines are shut down to heat residual oil to make it fluid enough to use in diesel engines and to provide hot water. Table 7.3 (from (ICF International, 2009) shows the auxiliary boiler energy default kW ratings for different vessels. Emissions from the boilers have been calculated using the steam turbine emission factors (Table 7.1) as specified in ICF International (2009), the boiler energy ratings (kW) and the time in mode (hours hoteling). The exception is the tankers which are unlikely to contain onboard boilers owing to the likely smaller size of these vessels at the Tauranga Port(Peeters, 2018). The Port of Auckland inventory notes that the smaller tankers used there tend to use hydraulic pumps powered by the auxiliary engines and uses the auxiliary engine manoeuvring power for the emission estimates (Peeters, 2018).

Emissions from recreational vessels and harbour vessels were not included in the assessment. For the Auckland inventory harbour and recreational vessels only comprised a small proportion of the emissions.

Table 7.1: Emission factors for shipping (ICF International, 2009)

	Fuel + S content	PM_{10} g/kWh	CO g/kWh	SOx g/kWh	NOx* g/kWh	$PM_{2.5}$ g/kWh
Slow speed diesel	RO 2.7%	1.42	1.4	10.29	18.1	1.31
	MDO 1%	0.45	1.4	3.62	17	0.42
	MGO 0.5%	0.31	1.4	1.81	17	0.28
	MGO 0.1%	0.19	1.4	0.36	17	0.17
Medium speed diesel	RO 2.7%	1.43	1.1	11.24	14	1.32
	MDO 1%	0.47	1.1	3.97	13.2	0.43
	MGO 0.5%	0.31	1.1	1.98	13.2	0.29
	MGO 0.1%	0.19	1.1	0.40	13.2	0.17
Gas turbine	RO 2.7%	1.47	0.2	16.1	6.1	1.35
	MDO 1%	0.58	0.2	5.67	5.7	0.53
	MGO 0.5%	0.35	0.2	2.83	5.7	0.32
	MGO 0.1%	0.17	0.2	0.57	5.7	0.15
Steam turbine	RO 2.7%	1.47	0.2	16.1	2.1	1.35
	MDO 1%	0.58	0.2	5.67	2.0	0.53
	MGO 0.5%	0.35	0.2	2.83	2.0	0.32
	MGO 0.1%	0.17	0.2	0.57	2.0	0.15
Auxiliary Engine	RO 2.7%	1.44	1.1	11.98	14.7	1.32
	MDO 1%	0.49	1.1	4.24	13.9	0.45
	MGO 0.5%	0.32	1.1	2.12	13.9	0.29
	MGO 0.1%	0.18	1.1	0.42	13.9	0.17

* ICF International, (2009) indicates that an adjustment factor of 0.8 can be applied to NOx emissions for a 2015 assessment to take into account international standards relating to NOx emissions from shipping.

RO = residual oil, MGO = marine gas oil, MDO marine diesel oil

Table 7.2: Average engine power, speeds, load factors and boiler energy defaults (ICF International, 2009)

Ship Type	Average propulsion engine (kW)	Average Auxiliary Engines			Boiler Energy default – hotel (kW)	LF (Aux hoteling)	LF (Aux reduced speed)	LF (Aux cruise)	LF (Aux manoeuvre)	Cruise speed (knots)
		Number	Power each (kW)	Total Power						
Bulk carrier	8000	2.9	612	1776	371	0.1	0.30	0.15	0.45	14.5
Container ship	30900	3.6	1889	6800	109	0.19	0.27	0.17	0.45	21.6
Cruise ship	39600	4.7	2340	11000	506	0.64	0.25	0.13	0.48	20.9
General cargo	9300	2.9	612	1776	1000	0.22	0.80	0.80	0.80	15.2
Roll on roll off	11000	2.9	983	2850	106	0.26	0.27	0.17	0.45	16.8
Reefer	9600	4	975	3900	109	0.32	0.30	0.15	0.45	19.5
Tanker	9400	2.7	735	1985	464	0.26	0.34	0.20	0.67	14.8

Table 7.3: Activity data for shipping (pers comm, Rowan Johnstone, Port of Tauranga, 2018)

Classification	No of calls call/year	Days in Port days/year
Bulk carrier	493	1611
Container ship	873	644
Cruise ship	83	41
General cargo	90	179
Roll on roll off	12	4
Tanker	136	166
Miscellaneous	21	57

7.1.2 Cargo Handling

Loading and unloading of bulk dry materials can result in dust emissions including particles in the PM_{10} and $PM_{2.5}$ size fractions. Emissions from cargo loading and unloading were estimated using 2018 product quantities provided by the Port of Tauranga (pers comm, Rowan Johnston, 2018) and AP42 emission factors (Table 7.4). Emission estimates were made for palm kernel, cement, clinker and other bulk grains. Where product-specific emission factors were not available, emission factors from other products were used. For palm kernel, a grain-based emission factor was used. The common grains used in developing the emission factors were wheat, corn, oat, rice soyabean and sorghum. The particles within these bulk products will have size distributions to palm kernel and as a result the emission factor may underestimate PM_{10} and $PM_{2.5}$ emissions.

Loading and unloading of the ships and associated emissions are estimated as cargo handling emissions. The unloading of bulk cargo from these trucks to storage facilities at destinations within Tauranga, including locations within the Port of Tauranga, have been included in the industrial and commercial emissions assessment.

Table 7.4: Activity data and emission factors for cargo handling.

Product	Quantity tonnes	AP42 description	SIC	PM_{10} kg/tonne product	$PM_{2.5}$ kg/tonne product
Palm kernel	1,004,000	9.9.1 grain unloading - shipping	SCC 3-02-005-55	0.019	0.0025
Cement – clinker	134,000	11.19.2 – truck loading crushed stone	SCC 3-05-020-32	0.0001	n/a
Cement	89,000	11.12.4 - loading/ unloading	SCC 3-05-011-07	0.0002	0.0002
Other grains/ dry bulk product	523,000	9.9.1 grain unloading - shipping	SCC 3-02-005-55	0.019	0.0025
Logs	6,382,000	AP42 memorandum		0.000145 /drop	0.000044 /drop
				Tonne/ha/year	
Log storage	29 hectares	AP 42 memorandum		0.04	

7.1.3 Trucks and off-road vehicles

Around 1700 heavy vehicles deliver or collect goods from the Port each day. Emissions from these vehicles include exhaust emissions, brake and tyre wear and resuspended road dusts from paved and unpaved surfaces. Exhaust and brake and tyre wear emissions from trucks were estimated using emission factors from Table 7.5 and VKT estimated based on the number of trucks per day and average distances travelled within the port of two kilometres for trucks visiting Sulphur Point (25,000 per month for 2018) and 1.6 kilometres for all other trucks (30,000 per month) (pers comm, Rowan Johnston 2018).

Emissions from off road vehicles (e.g., cargo handling equipment) include exhaust emissions and emissions from brake and tyre wear. Exhaust emissions were estimated using Regional diesel use data for motive power stationary (non-transport) from the EECA energy database as this category includes diesel consumption at the Port (pers comm Hien Dang, EECA 2018) and emission factors from EEA (2016) (Table 7.5) Emissions from brake and tyre wear for off road vehicles were calculated using VFPM brake and tyre emission factors (heavy vehicle fleet average) with VKT estimated from the off-road diesel consumption and the fuel consumption rate for heavy vehicles (kilometres per year = litres per year divided by litres per kilometre).

Table 7.5: Emission factors for diesel consumption by trucks and off road vehicles

		PM_{10}	CO	SOx*	NOx	$PM_{2.5}$
		g/litre	g/litre	g/litre	g/litre	g/litre
Off road vehicles	EEA, (2016) category 1.A.2.g.vii	2.5	13.0	39.3	0.2*	2.5
		g/VKT	g/VKT	g/VKT	g/VKT	g/VKT
Heavy truck road dust	EEA, (2016)	0.04				0.00216
Brake and tyre	(Jones, Graham, Elder, & Raine, 2011)	0.0145				0.0096

* based on sulphur content of diesel

The resuspension of PM_{10} and $PM_{2.5}$ from the movement of trucks and other port equipment on roads around the Port has been estimated using emission factors from EEA (2016). Activity data for trucks was obtained from the Port (vehicles per day x average distance travelled) and for the cargo handling equipment an estimate of VKT was made based on fuel consumption rates for heavy vehicles (VFPM) and fuel use estimates. The method for assessing road dust emissions from cargo handling equipment contains a high degree of uncertainty[4] and is likely to overestimate road dust emissions from this source.

7.1.1 Aviation

The Tauranga Airport operates a small number of commercial scheduled flights and is also used for general aviation. The number of take/off landing cycles per year typically ranges from around 50,000 to 70,000 with around 20% being scheduled flights. The main types of commercial aircraft used at the airport are the smaller turboprop aircraft (e.g., Bombardier Dash 8 and ATR72-500s). Aircraft emissions from turbo prop engines are relatively low for all contaminants and particularly PM_{10} and $PM_{2.5}$. Table 7.6 from EEA (2016) compares the Bombardier Dash 8 emissions to larger aircraft type. Emissions from this source will be minimal owing to the types of aircraft frequenting the airport.

An estimate of aircraft emissions from Tauranga airport was made based on the 2017 TLOs and emission factors for the Bombardier Dash 8.

Table 7.6: Emission factors for aircraft take off and landing cycles (source EEA, 2016).

Manufacturer and aircraft	Model[3]	Engine type	Engine ID[4]	Fuel burn (kg)	PM TOTAL kg/LTO	CO kg/LTO	NOx kg/LTO	SOx kg/LTO
Airbus A320 – 100/200	A320 233	Jet	3CM026	816.7	0.07	8.25	11.28	0.69
Boeing 777-200LR	B777 300ER	Jet	7GE099	3090.84	0.21	47.54	69.79	2.6
B777 300ER	B777 300ER	Jet	7GE099	3090.84	0.21	47.54	69.79	2.6
Boeing 787-8	B787 800	Jet	11GE136	1592.36	0.09	14.51	17.15	1.34
Boeing 787-9	B787 900	Jet	12RR055	1726.66	0.1	6.8	34.52	1.45
Convair CV-580	L188PF	Turboprop	Turboprop	856.47	0	0	0.88	0.72
De Havilland Canada DHC-8-300 Dash 8 / 8Q	DHC8 314Q	Turboprop	Turboprop	242.08	0	1.54	2.33	0.2
McDonnell Douglas MD11	MD11ER F	Jet	2GE049	2627.91	0.17	18.28	38.17	2.21
Saab SF340A/B	SF340A	Turboprop	Turboprop	145.06	0	0.95	0.89	0.12
Fairchild (Swearingen) SA26 / SA226	SA 226TC METRO II	Turboprop	Turboprop	86.48	0	1.23	0.62	0.07

[4] The fuel consumption rates for cargo handling equipment may vary significantly to those for heavy vehicles and some of the diesel will be used in equipment that does not cause movement on roads.

7.1.2 Rail

The KiwiRail rail network for Tauranga is for freight only with a southern link from Kawerau and a northern link from Waharoa Junction and includes a number of branches within the port area (Figure 7.2). KiwiRail operates New Zealand DL class (diesel-electric) locomotives.

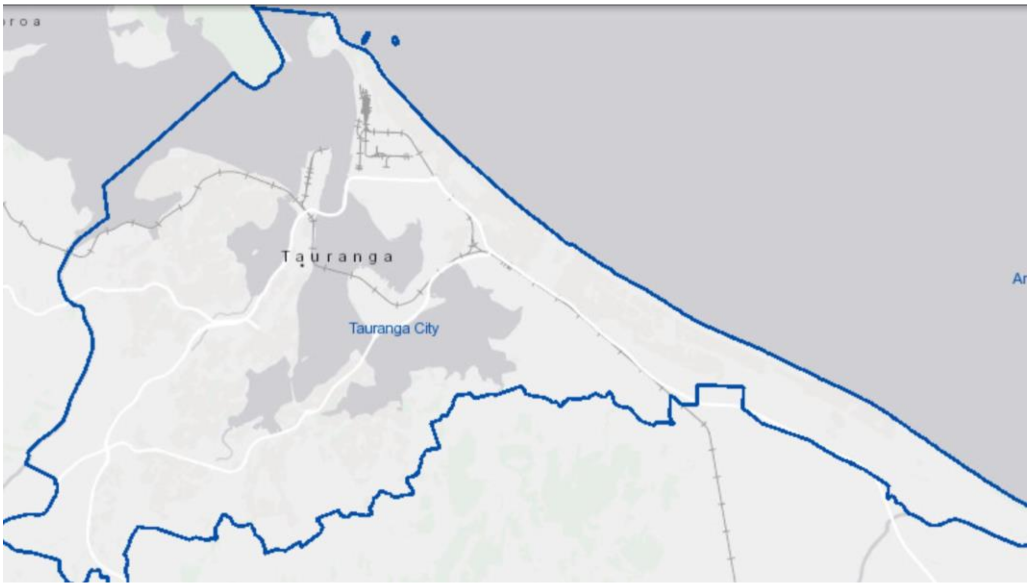

Figure 7.2: Tauranga rail network (source Stats Maps, 2018)

Emissions from rail are calculated using emission factors and fuel consumption as follows:

Emissions = fuel consumption (tonnes of diesel per day) x emission factor (kg pollutant/ tonne of diesel)

The fuel consumption for the area within the Tauranga City boundary was estimated using data on the gross tonne kilometres (GTK) within the TCC boundary. Diesel consumption was estimated by multiplying the GTK by the average diesel consumption rate per GTK across the national rail network (litres per GTK).

Data provided by KiwiRail indicates around 110,000,000 Gross Tonne kilometres (GTKs) occur across the Tauranga area (Table 7.7) assuming around 3% of the links for G8 and G11 occur within Tauranga. The diesel consumption rate per GTK was provided by KiwiRail (pers com J, Jones, 2018) as 5.7 litres per 1000 GTK (average for New Zealand rail fleet).

Emission factors for rail are shown in Table 7.8 and are from the European Inventory Guidebook (EEA/EMEP, 2016).

Table 7.7: Gross Tonne Kilometers (GTKs) for Rail Links into and out of Tauranga.

Train Segment Code	Train Segment Name	GTK's
G8	Waharoa Jnctn - Tauranga	484,322,874
G9	Tauranga - Mt Mng Link	26,960,484
G10	Mt Mng Link - Mt Maunganui	59,762,630
G11	Mt Mng Link - Kawerau	402,908,333

Table 7.8: Emission factors for rail (source EEA, 2016).

	PM_{10} kg/tonne fuel	CO kg/tonne fuel	SOx* kg/tonne fuel	NOx kg/tonne fuel	$PM_{2.5}$ kg/tonne fuel
Line-haul rail	1.2	18	0.02	63	1.1
Upper CI (95%)	3	21		93	3
Lower CI (95%)	0.45	5		29	0.42

*SOx emissions calculated based on the sulphur content of diesel in New Zealand

7.2 Aviation, shipping, rail and port emissions

Table 7.9 shows the estimated emissions from shipping, cargo handling, off road vehicles, aviation and rail. Shipping is the largest non-road transport contributor to air emissions with around 766 tonnes of SO_2 and 83 tonnes of PM_{10} discharged per year. Table 7.11 shows total shipping emissions by vessel type and Tables 7.12 to 7.14 show emission for approach/ departure, hoteling and auxiliary boilers by ship type. The majority of emissions occur whilst at berth as a result of running of auxiliary engines for providing power to the ship. The use of boilers on board the ship also contributes to the emissions. The breakdown of auxiliary hoteling emissions by vessel type (Table 7.13) indicates that container ships are the largest contributors to discharges to air whilst hoteling, significantly greater than emissions from cruise ships.

Table 7.9: Aviation, rail, shipping and port emissions in kilograms per day (winter) and tonnes per year

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	$PM_{2.5}$ kg/day
Port Activities					
- shipping	209	148	1918	1870	192
- cargo handling	115	0	0	0	27
- trucks/ off road vehicles - exhaust	29	157	472	0	29
- trucks/ off road vehicles - brake & tyre wear	0.4				0.2
- trucks/ off road vehicles – road dust	1.1				0.1
Total Port	355	305	2390	1870	248
Aviation	0	52	79	7	0
Rail	2	26	91	0	2
Total non-road transportation	357	383	2561	1877	250
	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Port Activities					
- shipping	83	59	766	745	77
- cargo handling	43	0	0	0	10
- trucks/ off road vehicles - exhaust	11	57	172	0	11
- trucks/ off road vehicles - brake & tyre wear	0.1				0.3
- trucks/ off road vehicles – road dust	0.4				0.1
Total Port	138	116	938	745	98
Aviation	0	19	29	2	0
Rail	0.6	10	33	0	1
Total other-transportation	138	145	1000	748	98

Table 7.10: Shipping emissions by ship type

	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Bulk carrier	14.3	8.9	115.2	131.9	13.1
Container ship	43.1	31.4	407.4	379.3	39.5
Cruise ship	9.8	8.3	108.4	83.9	9.0
General cargo	2.9	2.2	28.9	25.3	2.6
Roll on roll off	0.1	0.1	1.6	1.2	0.1
Reefer	5.9	4.2	54.1	53.4	5.4
Tanker	6.7	3.3	41.4	64.8	6.1
Miscellaneous	0.7	0.7	8.6	5.5	0.6
Total	83	59	766	745	77

Table 7.11: Shipping emissions in transit by vessels type – cruise/ reduced speed and manoeuvring

	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Bulk carrier	1.5	1.2	15.3	11.4	1.3
Container ship	10.1	8.4	109.0	78.3	9.3
Cruise ship	0.8	0.6	8.1	6.5	0.7
General cargo	0.4	0.3	3.8	2.8	0.3
Roll on roll off	0.1	0.0	0.5	0.4	0.0
Reefer	0.1	0.1	1.0	0.8	0.1
Tanker	0.6	0.5	6.6	4.8	0.6
Miscellaneous	0.1	0.1	0.9	0.7	0.1
Total	14	11	145	106	13

Table 7.12: Auxiliary hoteling emissions by vessel type

	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Bulk carrier	7.1	7.0	91.8	57.8	6.5
Container ship	21.8	21.5	282.3	178.0	19.9
Cruise ship	7.6	7.5	98.2	61.9	6.9
General cargo	1.9	1.8	24.1	15.2	1.7
Roll on roll off	0.1	0.1	1.0	0.7	0.1
Reefer	3.9	3.8	50.4	31.8	3.6
Tanker	2.3	2.2	29.4	18.5	2.1
Miscellaneous	0.6	0.6	7.7	4.9	0.5
Total	45	44	585	369	41

Table 7.13: Boiler emissions by vessel type

	PM_{10} tonnes/year	CO tonnes/year	NOx tonnes/year	SOx tonnes/year	$PM_{2.5}$ tonnes/year
Bulk carrier	5.7	0.8	8.2	62.7	5.3
Container ship	11.2	1.5	16.0	123.0	10.3
Cruise ship	1.4	0.2	2.0	15.5	1.3
General cargo	0.7	0.1	1.0	7.3	0.6
Roll on roll off	0.0	0.0	0.0	0.2	0.0
Reefer	1.9	0.3	2.7	20.9	1.7
Tanker	3.8	0.5	5.4	41.5	3.5
Miscellaneous	0.0	0.0	0.0	0.0	0.0
Total	25	3	35	271	23

Table 7.14: Seasonal variability in emissions from ocean going vessels

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	$PM_{2.5}$ kg/day
January	261	186	2414	2332	240
February	187	131	1703	1673	171
March	230	162	2095	2056	211
April	224	159	2065	2003	206
May	224	159	2066	2001	206
June	233	166	2151	2080	214
July	209	148	1918	1870	192
August	209	147	1910	1872	192
September	195	138	1792	1738	179
October	224	158	2043	1999	205
November	208	148	1912	1852	191
December	287	203	2626	2568	263

7.3 Uncertainty

The uncertainties were assessed for shipping and cargo handling as the key contributors to emissions from the non-road transportation.

There are a number of uncertainties in the calculations of emissions from shipping. The mid-tier methodology assumes average kW ratings based on ship classifications rather than using individual vessel data. Emission factors, load assumptions and speed assumptions are other sources of uncertainty. A comparison to the Port of Auckland emission inventory, which used a detailed ship methodology, indicates the estimates are in the right range. In that inventory there were 2480 calls compared with 1708 for Tauranga with 3333 days in Port compared with 3690 for Tauranga.

The hoteling PM_{10} estimates for Auckland for ocean going vessels were 38 tonnes per year compared with 45 tonnes for Tauranga and the boiler emissions for Auckland were estimated at 15 tonnes/year compared with 21 tonnes/year for Tauranga. Hoteling and boiler emissions are primarily influenced by days in port as well as vessel type with cruise ships and container ships giving rise to greater emissions. Comparison of at sea emissions was not made because of the larger distances included in the Port of Auckland assessment. The uncertainty for shipping was estimated at low to medium based on estimated uncertainties of 40% emission factors, 30% load factors, 40% kW ratings and 30% average speeds.

Cargo handling emission estimates collectively had individual source estimates and collective emission estimates with a high level of uncertainty. The assessment was based on activity data uncertainty of 20% and emission factor uncertainties ranging from 40% to 100%.

8 TOTAL EMISSIONS

The total PM_{10} and $PM_{2.5}$ emissions per year for Tauranga for 2018 was 443 and 337 tonnes respectively. Domestic heating, industry and shipping were all significant contributors to annual PM_{10} while domestic heating was the dominant source of daily winter PM_{10} (Tables 8.1 and 8.2). Seasonal variations in PM_{10} emissions are shown in Table 8.3. This suggests the main sources of summer time anthropogenic PM_{10} are industry and shipping. As neither source decreases significantly during the autumn and spring, when PM_{10} concentrations decrease (see section 1), sources of elevated summer concentrations are unclear. It is possible that natural source contributions (not assessed in the inventory) increase during the summer months or that meteorological conditions during spring and autumn are less conducive to elevated concentrations.

The main source of annual and winter $PM_{2.5}$ is domestic home heating (Figure 8.2). Shipping is also a significant contributor to annual emissions with a 23% contribution, while industry, outdoor burning and motor vehicles contribute 9%,6% and 6% respectively.

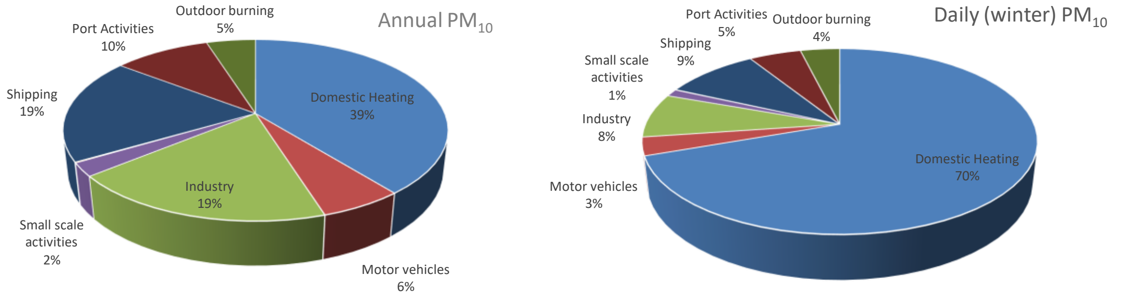

Figure 8.1: Relative contribution of sources to annual PM_{10} and daily winter PM_{10} emissions in Tauranga.

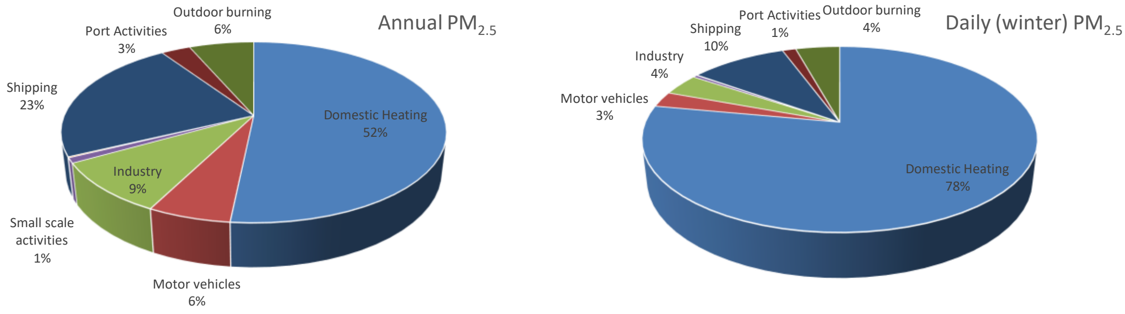

Figure 8.2: Relative contribution of sources to annual $PM_{2.5}$ and daily winter $PM_{2.5}$ in Tauranga.

Figures 8.3 and 8.4 show domestic heating is the main source of CO and NOx emissions in Tauranga.

The main source of SOx emissions is shipping with industry contributing around 24% of the total emissions (Figure 8.5), although it is noted that industrial emissions have halved since 2014, reducing the relative contribution of this source. The main SOx source from shipping is the use of high sulphur fuels (residual oil/ heavy fuel oil) in auxiliary engines and boilers whilst at berth. Container ships contribute the most of all ocean going vessels, accounting for around half of the emissions.

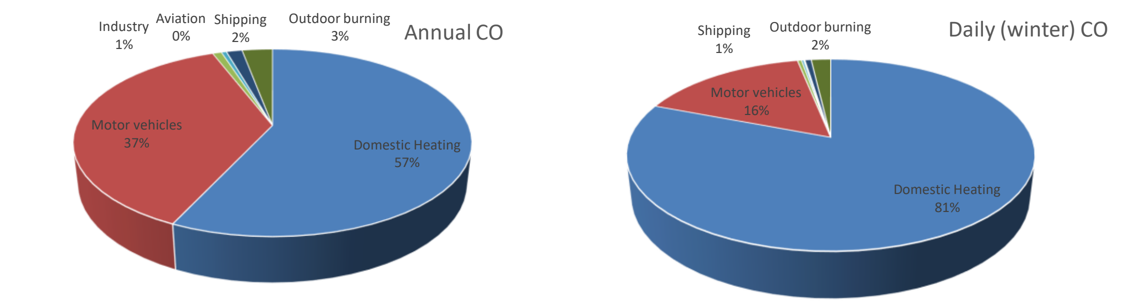

Figure 8.3: Relative contribution of sources to daily winter and annual average CO, emissions in Tauranga for 2018

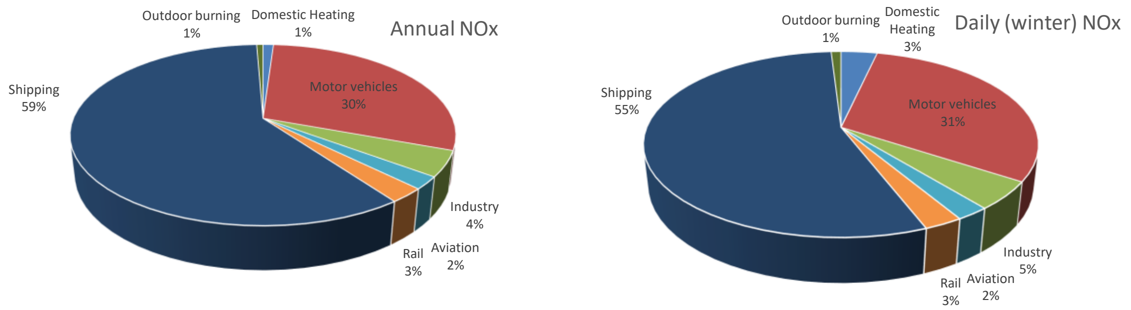

Figure 8.4: Relative contribution of sources to annual (left) and daily winter (right) NOx emissions in Tauranga.

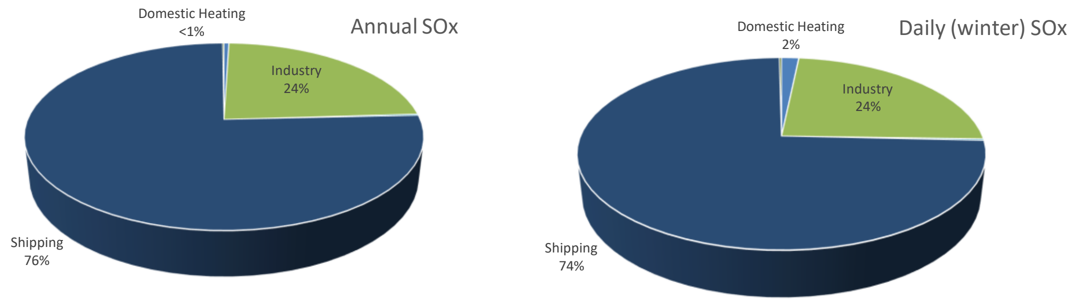

Figure 8.5: Relative contribution of sources to daily winter and annual average SOx, emissions in Tauranga for 2018

Table 8.1: Annual average emissions 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	174	2217	13	5	174
Motor vehicles	26	1448	381	0	20
Industry	84	33	59	232	31
Small scale activities	11				3
Aviation	0	19	29	2	0
Rail	1	1	33	0	1
Shipping	83	59	766	745	77
Port Activities	43	0	0	0	10
Outdoor burning	22	115	8	1	22
Total	443	3892	1289	986	337

Table 8.2: Daily (winter) average emissions 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	1579	20059	120	41	1579
Motor vehicles	72	3968	1045	1	54
Industry	175	96	166	617	77
Small scale activities	29			0	8
Aviation	0	52	79	7	0
Rail	2	2	91	0	2
Shipping	209	148	1870	1918	192
Port Activities	115	0	0	0	27
Outdoor burning	87	457	33	5	87
Total	2268	24783	3403	2590	2025

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

	Domestic Heating kg/day	Motor vehicles kg/day	Industry kg/day	Small scale activities kg/day	Aviation kg/day	Rail kg/day	Shipping kg/day	Port Activities kg/day	Outdoor burning kg/day	Total kg/day
January	0	72	245	29	0	2	261	115	42	766
February	0	72	262	29	0	2	187	128	42	721
March	11	72	245	29	0	2	230	115	58	762
April	90	72	250	29	0	2	224	119	58	844
May	734	72	245	29	0	2	224	115	58	1479
June	1424	72	178	29	0	2	233	119	87	2144
July	1579	72	175	29	0	2	209	115	87	2268
August	1302	72	175	29	0	2	209	115	87	1991
September	392	72	250	29	0	2	195	119	51	1110
October	123	72	245	29	0	2	224	115	51	860
November	13	72	250	29	0	2	208	119	51	744
December	0	72	245	29	0	2	287	115	42	792

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

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	0	3968	89	0	52	2	186	0	223	4520
February	0	3968	91	0	52	2	131	0	223	4467
March	146	3968	90	0	52	2	162	0	305	4724
April	1185	3968	90	0	52	2	159	0	305	5762
May	9432	3968	90	0	52	2	159	0	305	14008
June	18110	3968	97	0	52	2	166	0	457	22852
July	20059	3968	96	0	52	2	148	0	457	24783
August	16546	3968	96	0	52	2	147	0	457	21269
September	5073	3968	91	0	52	2	138	0	268	9592
October	1574	3968	90	0	52	2	158	0	268	6112
November	167	3968	90	0	52	2	148	0	268	4695
December	0	3968	89	0	52	2	203	0	223	4536

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

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	0	1045	157	0	79	91	2414	0	16	3802
February	0	1045	161	0	79	91	1703	0	16	3094
March	1	1045	158	0	79	91	2095	0	22	3491
April	15	1045	159	0	79	91	2065	0	22	3475
May	59	1045	158	0	79	91	2066	0	22	3519
June	100	1045	166	0	79	91	2151	0	33	3665
July	120	1045	166	0	79	91	1918	0	33	3451
August	100	1045	166	0	79	91	1910	0	33	3423
September	35	1045	160	0	79	91	1792	0	19	3221
October	8	1045	158	0	79	91	2043	0	19	3443
November	1	1045	159	0	79	91	1912	0	19	3305
December	0	1045	157	0	79	91	2626	0	16	4014

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

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	0	1	603	0	7	0	2332	0	3	2945
February	0	1	527	0	7	0	1673	0	3	2210
March	0	1	684	0	7	0	2056	0	4	2752
April	2	1	599	0	7	0	2003	0	4	2615
May	19	1	586	0	7	0	2001	0	4	2617
June	37	1	526	0	7	0	2080	0	5	2656
July	41	1	617	0	7	0	1870	0	5	2542
August	34	1	692	0	7	0	1872	0	5	2611
September	10	1	725	0	7	0	1738	0	3	2484
October	3	1	717	0	7	0	1999	0	3	2730
November	0	1	795	0	7	0	1852	0	3	2659
December	0	1	554	0	7	0	2568	0	3	3133

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

	Domestic Heating	Motor vehicles	Industry	Small scale activities	Aviation	Rail	Shipping	Port Activities	Outdoor burning	Total
	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day	kg/day
January	0	54	87	8	0	2	240	27	42	460
February	0	54	91	8	0	2	171	29	42	399
March	11	54	87	8	0	2	211	27	58	459
April	90	54	89	8	0	2	206	27	58	534
May	734	54	87	8	0	2	206	27	58	1176
June	1424	54	77	8	0	2	214	27	87	1894
July	1579	54	76	8	0	2	192	27	87	2025
August	1302	54	76	8	0	2	192	27	87	1748
September	392	54	89	8	0	2	179	27	51	802
October	123	54	87	8	0	2	205	27	51	557
November	13	54	89	8	0	2	191	27	51	435
December	0	54	87	8	0	2	263	27	42	484

8.1 Uncertainty

The uncertainty for the total PM_{10} emission estimate was assessed by combining the individual source uncertainties addition as per Appendix C. The total uncertainty for the inventory PM_{10} emission estimate is low to medium (around 20%).

REFERENCES

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

California Air Resources Board. (2017). 2017 Off-Road Diesel Emission Factor Update for NOx and PM. Carb. Retrieved from https://www.arb.ca.gov/msei/ordiesel/ordas_ef_fcf_2017.pdf

Davy, P., & Xie, S. (2014). Improving estimates of non-exhaust particulate matter emissions from motor vehicles. *Air Quality and Climate Change*, *48*(1).

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

EFRU. (2008). Development of a vehicle emissions prediction model. Energy and Fuels Research Unit, Auckland University. Retrieved from www.air.nzta.govt.nz

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. DustConf. Retrieved from http://www.dustconf.com/CLIENT/DUSTCONF/UPLOAD/S4/EHRLICH_.PDF

Environment Australia. (1999). Emissions Estimation Technique Manual for Aggregated Emissions from Motor Vehicle Refinishing. Environment Australia. Retrieved from http://www.npi.gov.au/resource/emission-estimation-technique-manual-aggregated-emissions-motor-vehicle-refinishing

Graham, B. (2006). Light industry/Commercial Sources of PM10, Analysis performed for Environment Bay of Plenty. Unpublished report for Bay of Plenty Regional Council.

ICF International. (2009). Current methodologies in preparing mobile source port-related emission inventories. U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/moves/current-methodologies-preparing-mobile-source-port-related-emission-inventories-final-report

Iremonger, S., & Graham, B. (2007). Rotorua Air Emissions Inventory 2005. Retrieved from https://www.boprc.govt.nz/media/523535/0702_rotorua-air-emissions-inventory-2005_final.pdf

Jones, K., Graham, M., Elder, S., & Raine, R. (2011). Vehicle Emissions Prediction Model (VEPM) Version 5.0 Development and User Information Report. UniServices.

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. (2002). Ambient Air Quality Guidelines – 2002. Ministry for Environment.

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

Peeters, S. (2018). Auckland Air Emission Inventory Sea Transport 2016. Auckland Council Technical Report 2018/017.

Sinclair Knight Merz. (2003). Bay of Plenty Regional Air Emission Inventory. Bay of Plenty Regional Council.

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. Victorian EPA. 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. (1998). An investigation into management options towards reducing suspended particulate concentration in the Christchurch Air Shed. Lincoln University.

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

Wilton, E., & Baynes, M. (2010). Improving PM10 Emission Factors from Industrial Boilers in New Zealand - Stage 2. Report prepared for the Foundation of Research, Science and Technology.

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.

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APPENDIX A: HOME HEATING QUESTIONNAIRE

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

(d) 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) How old is your log burner?

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

(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?

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

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) 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?

(n) 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?

(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?

(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 ?

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

9. 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?

APPENDIX B: EMISSION FACTORS FOR DOMESTIC HEATING.

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

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

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

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

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

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

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

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

APPENDIX C: ESTIMATING EMISSIONS FROM LAWN MOWERS

An update of the emission estimate for lawn mowers has been made as a check that this source is not a significant contributor to urban PM_{10} and $PM_{2.5}$. Fuel consumption for Tauranga was estimated based on a range of household use rates and fuel consumptions. At the higher end of the scale it was assumed that there was one mower per household and an annual fuel consumption rate of 20 litres per year (this is about 26 mows per year of an average section size of 800m^2). At the lower end of the scale it was assumed that there was one mower per 1.5 households and only 10 litres per year fuel consumption. Emission factors from Table C1 were used and the assumption of an 80:20 ratio of two stroke to four stroke engines.

Table C1: Emission factors for lawn mowers (EEA, 2016)

Contaminant	2 stroke kg/tonne	4 stroke kg/tonne
CO	620793	770368
NO_X	2765	7117
PM_{10}	3762	157
SO_2	100	100

The PM_{10} emissions ranged from 0.056 grams per household per day (3kg/day for Tauranga) for the higher end fuel consumption rates and 0.012 g/hh/day (0.7 kg/day for Tauranga). This assessment confirms previous historical evaluations that emissions from lawn mowers are not significant contributors to urban PM_{10}.

APPENDIX D: ASSESSMENT OF UNCERTAINTY

Statistical methods can be used to quantify the uncertainty associated with the emission estimates. Typically, this involves the collating of base uncertainties on variables in the emission calculation (e.g., emission factors or activity data) although EMEP/EEA also give the option of a more sophisticated stochastic simulation (Monte Carlo) analysis.

The uncertainties on variables may have been quantitatively determined (through testing) or based on expert judgement. A 95% confidence interval is used.

Formulae given in the EMEP/EEA guidebook (EEA, 2016) for carrying out a tier one statistical assessment of uncertainty are shown below. These gave the same uncertainty estimates as the equations used previously by the author (e.g., Wilton, 1998) and detailed in Topping, (1971).

Tier one statistical uncertainty from EMEP/EEA guidebook

Calculation of uncertainty when quantities are combined by adding:

$$U_{total} = \frac{\sqrt{(U_1 \times x_1)^2 + (U_2 \times x_2)^2 + \cdots + (U_n \times x_n)^2}}{x_1 + x_1 + \cdots + x_n}$$

Where:

x_i are the quantities.

U_i are the percentage uncertainties associated with the quantities (half the 95% confidence interval). And

U_{total} is the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e. mean) and expressed as a percentage).

Calculation of uncertainty when quantities are combined by multiplication

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

U_i are the percentage uncertainties associated with the quantities (half the 95% confidence interval). and

U_{total} is the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage)

These rules are based on the assumptions that variables are uncorrelated with a standard deviation of less than about 30% of the mean. The guidebook recognises that in practice these assumptions are often not valid, but states that under these circumstances the rules may still be used to obtain an approximate result.

Statistical uncertainty estimates

Where quantitative uncertainty data were not available uncertainty was estimated using the following table from in EEA (2016) as guidance.

Rating	Description	Typical Range
A	An estimate base on a large number of measurements made at a large number of facilities that fully represent this sector.	10-30%

B	An estimate based on a number of measurements made at a large number of facilities that represent a large part of the sector	20-60%
C	An estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts.	50-200%
D	An estimate based on single measurement, or an engineering calculation derived from a number of relevant facts.	100-300%
E	An estimate based on an engineering calculation derived from assumptions only.	Order of magnitude

APPENDIX E: EMISSION TEST DATA SMALL SCALE ACTIVITIES

The following tables summaries the test data used by Graham (2006) to derive emission estimates for small scale activities.

Industry type	kg/hr
timber & joinery, good control	0.07, 0.07
timber & joinery, poor control	1.8, 3.6
spray painting	0.14, 0.03
abrasive blasting	0.05, 0.04
metal fabrication, etc	0.04, 0.07, 0.14, 0.01
printing	0.05
packaging	0.36, 0.72
coffee roasting	0.11
coffee drying	1.37
bakeries	0.04
tyre retreads	0.01
sand dryer	1.08
concrete plant	0.11
roofing tiles	0.02
coal-fired boiler	2.16

Facilities with the highest potential for PM emissions:	assigned a rate of 0.1 kg/hr
Heavy engineering/maintenance Joinery factories Panel beaters Light metal fabrication	Metal finishers – powder coating Bakeries Stone/bone/wood grinding or carving
Facilities with lower potential for PM emissions:	assigned a rate of 0.02 kg/hr
Light vehicle workshops Printing works Packaging manufacturers Tanneries (small specialty products)	Paint and other solvents Metal finishers – electroplating Appliance repairs
Facilities with very little potential for PM emissions:	assigned a rate of 0.0 kg/hr
Abattoirs	Photographic developing/printing
Facilities with the potential for 'yard' emissions:	assigned a rate of 0.1 kg/hr
Wreckers Scrap metal dealers	Waste management Timber yards