National Air Emissions Inventory

2015

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Prepared for
Ministry for the Environment

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Revision History

No.	Date	Author	Reviewer(s)	Details
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3	29 March 2018	Jayne Metcalfe Director & Senior Air Quality Specialist		Final
4	15 June 2018	Surekha Sridhar Senior Air Quality Specialist		Minor editorial amendments to final report.

Executive summary

The Ministry for the Environment (MfE), in partnership with Statistics New Zealand, is required by law to produce regular reports on the state of the environment, including air quality. In December 2017, MfE commissioned Emission Impossible Ltd to prepare a national air emissions inventory for particulate matter less than 10 micrometres in diameter (**PM_{10}**); Particulate matter less than 2.5 micrometres in diameter (**$PM_{2.5}$**); Carbon monoxide (**CO**); Oxides of nitrogen (**NOx**) and, and Sulphur dioxide (**SO_2**).

A key objective for this inventory was to use a methodology that is timely, easily updatable and low cost. A relatively simple, top down approach has been used to achieve this objective.

This inventory has been prepared using international guidance, which ensures that the inventory is comparable and compatible with other inventories, in particular New Zealand's Greenhouse Gas Inventory (MfE, 2017).

Emissions were estimated for the base year of 2015 for all significant anthropogenic sources of PM_{10}, $PM_{2.5}$, CO, NOx and SO_2 that are included in New Zealand's Greenhouse Gas Inventory.

This national inventory builds on the results of the 2013 national emission inventory (Wilton *et al.* 2015). Estimated emissions from residential wood burning and open burning of garden waste have not been updated in this 2015 inventory because new data was not available.

Total PM_{10} emissions from anthropogenic sources in New Zealand were estimated as 46,000 tonnes per annum in 2015. Residential home heating was the biggest single source of emissions accounting for 25% of total PM_{10}. Combustion of fuels in transport were estimated to contribute 9% of all PM_{10}, while combustion of fuels in all other sectors contributed a further 21% of total PM_{10} emissions. Outdoor burning in all sectors was estimated to account for 22% of PM_{10} emissions. This comprised 3% from field burning of agricultural residues, 15% from biomass burning (which includes controlled burning and wildfires in forest and grasslands) and 4% from open burning of garden waste. Non-combustion emissions were estimated to contribute 24% of PM_{10} emissions. This comprised 13% from road dust, 5% from industrial processes, 5% from construction dust and 1% from animal housings.

Total $PM_{2.5}$ emissions from anthropogenic sources in New Zealand were estimated as 34,500 tonnes per annum in 2015. $PM_{2.5}$ emissions were predominantly from combustion sources with fuel combustion and outdoor burning in all sectors accounting for 68% and 23% of $PM_{2.5}$ emissions respectively.

Total NOx emissions from anthropogenic sources in New Zealand were estimated as 121,400 tonnes per annum in 2015. On-road vehicles were the largest single source of NOx emissions accounting for 39% of anthropogenic emissions.

Emissions estimates in this inventory are higher than previous inventories because a top-down approach has been taken. This ensures that all fuel consumption from all sectors is accounted for in the inventory.

A number of recommendations have been made to maintain and improve the accuracy of future national air pollution inventories.

Contents

1. Introduction

The Ministry for the Environment (MfE), in partnership with Statistics New Zealand, is required by law to produce regular reports on the state of the environment, including air quality. In December 2017, MfE commissioned Emission Impossible Ltd to prepare a national air emissions inventory for priority air pollutants that would be:

- Timely, easily updatable and low cost;
- Relevant to the air pollution topic in the Ministry's Air Domain reports;
- Accurate for key sources (home heating, large industrial sources and transport);
- Based on nationally representative data; and
- Accessible and comparable with other national inventories.

Accordingly, the best available data and internationally recognised methodologies were used to develop a top down national air emissions inventory. This is a simple but robust approach which represents good value for money for national domain reporting requirements.

This report details the methodology and findings and should be read in conjunction with the inventory spreadsheets. The base year for the inventory is 2015 to align with the recent greenhouse gas inventory report (MfE, 2017) with annual emissions estimated at the national level only. The pollutants, source categories and methods employed to estimate emissions are described in more detail in the following sections.

1.1. Pollutants

The inventory includes the following key pollutants:

- Particulate matter less than 10 micrometres in diameter (**PM_{10}**);
- Particulate matter less than 2.5 micrometres in diameter (**$PM_{2.5}$**);
- Carbon monoxide (**CO**);
- Oxides of nitrogen (**NOx**) and, where readily available, nitrogen dioxide (**NO_2**); and
- Sulphur dioxide (**SO_2**).

These are discussed briefly below.

1.1.1. Particulate matter

Particulate matter (PM) is a collective term used to describe small solid and/or liquid particles. They are characterised by their aerodynamic properties because these determine transport and removal process in the air and deposition sites and clearance pathways within the respiratory tract (WHO, 2006).[1]

[1] Aerodynamic diameter corresponds to the size of a unit-density sphere with the same aerodynamic characteristics as the particle of interest.

Particles less than 10 microns in size (PM_{10}) and particles less than 2.5 microns ($PM_{2.5}$) can reach the alveolar region of the lungs where inhaled gases can be absorbed by the blood. PM_{10} and $PM_{2.5}$ are therefore, the fractions of airborne dust that present the highest health risk.

Particles are emitted by both natural processes (for example sea salt, soil erosion, volcanic eruptions and pollen) and anthropogenic sources. “Primary” particles are directly emitted (e.g. coal combustion) whereas “secondary” particles are formed downwind of a source as a result of chemical reactions (for example oxidation to form acids and subsequent reaction with ammonia to form nitrates) and/or physical processes (for example nucleation-condensation and subsequent coagulation) (WHO, 2006).

This inventory addresses primary PM only – for which the two largest sources are fuel combustion and industrial processes.

1.1.2. Carbon monoxide

Carbon monoxide (CO) is an odourless, gas that, in very high concentrations, can cause adverse health effects. The primary source of CO is anthropogenic, it being formed by the incomplete combustion of fossil fuels – especially in the transport sector.

1.1.3. Oxides of nitrogen

Many chemical species of nitrogen oxide (NO_x) exist, but the air pollutant species of most interest from a health perspective is nitrogen dioxide (NO_2) (WHO, 2006). Nitrogen dioxide is a reddish brown, acidic gas with a characteristic pungent odour.

Nitrogen dioxide is also a key precursor for a range of secondary pollutants, including ozone and fine particles, which are known to be harmful to human health.

The main anthropogenic source of nitrogen dioxide is the combustion of fossil fuels, especially motor vehicles. It is also produced from making nitric acid, welding and using explosives, refining of petrol and metals, commercial manufacturing, and food manufacturing. Natural sources of other nitrogen oxides include volcanoes and bacteria.

1.1.4. Sulphur dioxide

Sulphur dioxide (SO_2) is a dense colourless gas with an unpleasant smell.

Sulphur dioxide from anthropogenic sources is produced mainly from the combustion of fossil fuels that contain sulphur, such as coal and oil. Sulphur dioxide is also produced from some industrial processes including fertiliser manufacturing, aluminium smelting and steel making.

Natural sources of sulphur dioxide include geothermal activity. In New Zealand, the largest source of sulphur dioxide is natural - White Island, which emits around 160 tonnes of sulphur dioxide per day (PAE, 2009). New Zealand’s second largest source of sulphur dioxide, the aluminium smelter at Te Wai Point, is significantly less (around 20 tonnes per day).

Sulphur dioxide can trigger asthma in certain individuals at relatively low concentrations (0.1 part per million, ppm). At higher levels (10-50 ppm) it is an eye, nose and throat irritant. Recent research has linked sulphur dioxide with serious health effects such as pre-term birth, sudden infant death syndrome and cardiovascular mortality (WHO, 2013).

Sulphur dioxide is a precursor to fine particulate formation.

In addition to sulphur dioxide, other oxides of sulphur (SOx) are emitted when fuels containing sulphur are combusted.

1.2. Source categories

This inventory includes sources delineated by the sectors listed below:

- Energy related activities
    - Fuel combustion in the energy industries
    - Fuel combustion in manufacturing and construction
    - Transport:
        - On & off-road motor vehicles
        - Aviation
        - Rail
        - Shipping
    - Residential fuel combustion (home heating)
    - Fuel combustion in commercial, agriculture, forestry and fishing
- Construction dust (fugitive emissions)
- Road dust
- Industrial process emissions (non-combustion)
- Agriculture, vegetation fires and forestry
    - Particulate from animal housings
    - Field burning of agricultural residues
    - Biomass burning
- Treatment of waste
    - Incineration of quarantine waste
    - Open burning of garden waste

1.3. Spatial resolution

The spatial resolution is for national estimates only.

1.4. Pressure, state and impacts on air quality

Ministry for the Environment and Statistics New Zealand are responsible for environmental reporting in New Zealand in accordance with the requirements of the Environmental Reporting Act 2015.

The Act divides the environment into five environmental domains, including air quality, for the purpose of reporting. The framework for environmental reporting covers:

(i) **Pressure**: the natural or human pressures that influence the state of the environment. Pressures explain why the domains are in the condition they are in.
(ii) **State**: the physical, chemical, and biological characteristics of each aspect of the environment, and how these aspects are changing over time.
(iii) **Impact**: the ecological, economic, social, and cultural consequences of changes in the state of the environment. Environmental impacts that have particular significance for Māori are covered under te ao Māori (Māori world view).

Emissions to air are an indicator of **pressure** on air quality.

A national *home heating emission inventory and other sources evaluation* was prepared for 2013 (Wilton *et al*., 2015) (referred hereafter as the *2013 national inventory*). This 2015 inventory builds on the results of the 2013 national inventory to provide an estimate of emissions from all significant anthropogenic sources of particulate, carbon monoxide, nitrogen oxides and sulphur dioxide.

This national estimate of emissions provides an indicator of pressures on air quality and will provide a benchmark to enable future tracking of trends. However, it is important to note that the relative contribution of sources to emissions at a national level does not necessarily reflect the relative contribution of sources to air pollution effects at the local level. For example, industrial emissions can be discharged through high stacks, which improve dispersion and can reduce the effect of the emission at ground level.

2. Methodology

Over the past decade there has been considerable development and harmonisation of emission inventory methodologies globally. A key driver for this has been to improve consistency between greenhouse gas emission inventories and air pollutant emission inventories.

Accordingly, this inventory has been prepared using the framework provided by the *Global Atmospheric Pollution (GAP) Forum*[2] *Air Pollutant Emission Inventory Manual* (Vallack and Rypdal, 2012), hereafter referred to as the GAP Forum Manual. This approach ensures that the national air pollution inventory is compatible and comparable with international inventories and, more specifically, the New Zealand Greenhouse Gas Inventory.

The GAP Forum Manual follows the same overall framework as the (Intergovernmental Panel on Climate Change *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006). The GAP Forum Manual methodology was developed to enable countries to develop emissions inventories in an accurate, complete, comparable, consistent and transparent manner. It generally utilises top down methods which draw mostly from national-scale data and inventory methods that are already in use for compiling greenhouse gas emissions inventories.

The GAP Forum Manual is adapted from European guidance (EEA, 2016), which describes 3 Tiers of assessment:

> **Tier 1** methodology is a "top-down" method, where emissions are estimated from readily available statistical data (aggregated activity rates such as amount of fuel use or production volumes) and default emission factors. These emission factors assume a linear relation between the statistical data and the resulting emissions. The Tier 1 default emission factors also assume an average or typical process description. This method is the simplest method, but has the highest level of uncertainty and therefore, should not be used to estimate emissions from key categories.
>
> **Tier 2** methods are typically "bottom up" methods, where emissions are estimated based on disaggregated activity data and more detailed emission factors. Tier 2 uses more specific emission factors developed on the basis of knowledge of the types of processes and specific process conditions that apply in the country for which the inventory is being developed. Tier 2 methods are more complex, will reduce the level of uncertainty, and are considered adequate for estimating emissions for key categories.
>
> **Tier 3** is defined as any methodology more detailed than Tier 2; hence there is a wide range of Tier 3 methodologies. At one end of the range there are methodologies similar to Tier 2 (i.e.

[2] The Global Atmospheric Pollution Forum is an informal partnership of governmental and non-governmental organizations supporting the sharing of information and the development of solutions to regional, hemispheric and global air pollution problems. It's founding member partner organizations include the UN Environment Programme (UNEP); the UN Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution (LRTAP); the Clean Air Initiatives for Asia and Latin America; the Air Pollution Information Network for Africa (APINA); the Inter-American Network for Atmospheric and Biospheric Studies (IANABIS) in Latin America; the Mal Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia; the Stockholm Environment Institute; and the International Union of Air Pollution Prevention and Environmental Protection Associations.

activity data x emission factor) but with a greater disaggregation of activity data and emission factors. At the other end of the range are complex, dynamic models in which the processes leading to emissions are described in great detail (e.g. vehicle emissions by vehicle class, fuel, vehicle speed and spatial location).

The methods provided in the GAP Forum Manual are generally Tier 1 (top-down) methods. Where data or methods were readily available, more advanced methods Tier 2 or Tier 3 methods have been used in this New Zealand inventory.

Emissions are typically estimated using the simple relation for each pollutant unless specified otherwise:

Emissions = Emission factor x Activity rate

An emission factor provides emissions per unit activity, for example kg NOx emitted per MJ fuel combusted. Abatement or recovery of emissions can be considered by subtracting a different, technology-specific emission factor. For example:

Emissions = Emission factor x Activity rate – Abatement/Recovery

Some methods are more complex and include more than one emission factor or type of activity data, for example in the agriculture or road transportation sector. The following sections detail the methods and assumptions used for each source.

2.1. Energy-related activities

This sector includes fuel combustion activities within the energy industries, manufacturing and construction sector, transport and other sectors such as residential, commercial, agricultural/forestry/fishing.

Emissions from fuel combustion in all sectors (excluding aviation and wood consumption for residential home heating) were estimated based on sectoral national-scale fuel consumption data from *New Zealand's Greenhouse Gas Inventory* (MfE, 2017)

The Greenhouse Gas Inventory reports aggregated fuel consumption for solid fuels, liquid fuels, gaseous fuels and biomass. Where necessary, this was split into specific fuel types according to fuel consumption data provided by Ministry of Business, Innovation and Employment *Energy in New Zealand 2017* dataset (MBIE, 2017).

Except where specified in the following sections, emission factors were calculated based on New Zealand fuel properties (calorific values and sulphur content where available) using the methodologies provided in the GAP Forum Manual. Where available, New Zealand specific emission factors were used, as described in the following sections.

Emission factors used for fuel combustion activities are summarised in Table 2-1.

Table 2-1: Emission factors for energy related activities

Sector	Sub-sector	Fuel	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO kg/TJ	NOx kg/TJ	SO_2 kg/TJ
Energy industries	Petroleum refining	Crude/feedstocks	0.04	0.04	15	142	404
	Pubic electricity and heat production	Coal	1.11	0.83	9	209	436
		Diesel	0.14	0.04	16	65	0.47
		Natural gas	0.05	0.05	39	82	0.4
		Biogas	0.20	0.17	484	131	2.8
Transport	Aviation	See Table 2-2					
	On road	Biodiesel[a]	1.35	1.35	113	390	0.46
		Diesel	1.35	1.35	113	390	0.47
		Petrol	0.21	0.21	1,309	132	0.46
		LPG	0.21	0.21	2,473	725	0.24
		Natural gas[b]	0.21	0.21	2,473	725	0.42
	Rail	Diesel	5.14	4.83	247	1209	0.46
	Domestic navigation	Fuel oil	6.2	5.6	184	1973	1725
Residential		LPG	0.32	0.31	26	51	0.24
		Coal	19.9	17.51	5,082	73.92	450
		Natural gas	0.06	0.06	26	51	0.4
		Wood	7.68	7.68	13,592	48.54	19.42
All other sectors		Petrol	0.9	0.9	66	513	0.46
		Diesel	0.87	0.87	66	513	0.46
		Fuel oil	0.8	0.8	66	513	986
		LPG	0.04	0.04	29	74	0.24
		Coal	1.11	0.83	931	173	436
		Natural gas[b]	0.04	0.04	29	74	0.4
		Biogas	0.20	0.17	484	131	2.8
		Wood	1.6	1.4	570	91	19

[a] Biodiesel emission factors were assumed to be the same as diesel emission factors.

[b] Natural gas emission factors were assumed to be the same as LPG emission factors.

2.1.1. Fuel combustion in the energy industries

Petroleum refining

The PM_{10} emission factor for the New Zealand refinery was derived from an emission reported for 1999 in *Airshed modelling for PM_{10} concentrations - Marsden point* (Wilton *et al*., 2012). The emission factor was estimated based on refinery fuel consumption for 1999 (MBIE, 2017).

The SO_2 emission factor for the New Zealand refinery was derived from the *New Zealand Sulphur Dioxide Industrial Emission Inventory – 2007* (Wilton *et al.,* 2008).

Non-combustion emissions from the New Zealand refinery have not been quantified separately in this inventory because it was assumed that the measured emission factors include all refinery emissions.

Public electricity and heat production

All emission factors were default values from the GAP Forum Manual (based on New Zealand fuel properties) except as follows:

- Coal, PM_{10} 1.11g/kg was the average emission factor for industrial coal combustion from the 2013 national inventory (Wilton *et al*., 2015). The 2013 national inventory included an assessment of heat plant characteristics to develop country specific emission factors for coal boilers.
- NOx from gas combustion were default values assuming:
    - 31% of the gas consumption in public electricity and heat sector has low NOx burners[3].
    - 25% reduction in NOx from low NOx burners. This is the GAP Forum Manual default value.
    - No other NOx control assumed
- Biogas emission factors were the average of emission factors for combustion of biogas at Redvale landfill and Mangere Waste Water Treatment Plant. These emission factors were derived from the *2016 Auckland Emissions Inventory*: *Industry* (Auckland Council, 2018)

2.1.2. Fuel combustion in manufacturing and construction

All emission factors were default values from the GAP Forum Manual (based on New Zealand fuel properties) except as follows:

- Coal, PM_{10}. 1.11g/kg was the average emission factor for industrial coal combustion from the 2013 national inventory (Wilton *et al*., 2015). $PM_{2.5}$ was assumed to be 75% of PM_{10}.[4]
- Wood, PM_{10} 1.6g/kg and $PM_{2.5}$ 1.4 g/kg were the emission factor for wood boilers assumed in the 2013 national inventory (Wilton *et al*., 2015).

2.1.3. Transport

Transport sources include emissions from fuel combustion from on-road motor vehicles (includes brake and tyre wear), rail, aircraft, shipping.[5] The methods for estimating emissions from these sources are detailed below.

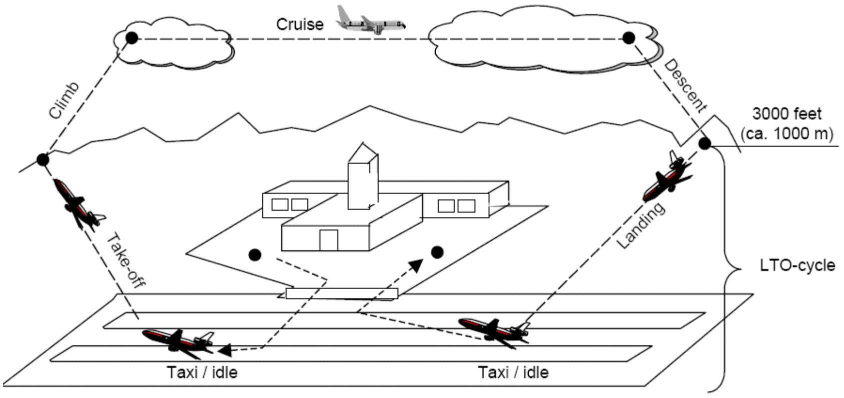
Emissions from off-road motor vehicles are not included in this sector. However, combustion emissions for all fuels are accounted for in other sectors. For example, diesel consumption in the manufacturing and construction sector will include diesel consumption in off-road construction vehicles and equipment.

[3] Based on an assessment of NZ power stations. Huntly 5 is the only power station with low NOx burners. This has a 400MW capacity accounting for up to 31% of generation capacity for gas fired power stations.
[4] Based on emission factor for Vekos boiler with multiple cyclone.
[5] Emissions from unsealed road dust are included in Section 2.1.7 Non-combustion activities.

Aviation

National-scale estimates for aviation were based on international emission factors from the European Environmental Agency (EEA, 2016). These emission factors provide an estimate of emissions per landing/take-off cycle (LTO). Annual LTO data for New Zealand domestic and international travel was obtained from Airways Ltd (Airways, 2017).

A landing/take-off cycle consists of one landing and one take-off and consists of several phases of a flight including taxi out, take-off, climb, cruise, descent, approach, landing, taxi-in and idling as shown in **Figure 2-1**.



(Source: *EEA,2016 - Emission inventory guidebook, Group 8: Other mobile sources and machinery*)

Figure 2-1: Typical phases of flight

This national emissions inventory includes flight phases (LTO cycle) up to an altitude of 915 metres (3,000 feet). Emissions from flight phases above 915 metres (climb, cruise, descent phases) do not impact on local air quality at ground level and therefore, are not included here.

Table 2-2 shows the number of LTOs per year for domestic and international flights. For this inventory, fleet weighted emission factors for domestic and international aircraft were derived from the flight schedule for one week at Auckland International Airport (see Appendix B for details). Emission factors for these aircraft are also shown in **Table 2-2**.

Table 2-2: Aircraft LTOs and emission factors

Sector	LTOs per year [a]	Emission factors [b]					
		Fuel consumption	PM_{10}	$PM_{2.5}$	CO	NOx	SO_2
		kg/LTO					
Domestic	433,594	476.19	0.03	0.03	4.33	5.98	0.40
International [c]	38,986	1,741.79	0.13	0.13	15.28	32.53	1.46

[a] LTOs are half the number of aircraft movements in 2015 and include aircraft operating under both visual flight rules (VFR) and instrument flight rules (IFR) at attended and unattended airports in New Zealand (Airways, 2017).

[b] Fleet weighted emission factors calculated from the flight schedule at Auckland International Airport. See Appendix B for details on aircraft types and number of LTOs.

On-road motor vehicles

On-road motor vehicle emissions were estimated using national fuel consumption, national vehicle kilometres travelled (VKT) data and NZ specific fuel based fleet weighted emission factors for 2015 (from Vehicle Emission Prediction Model) as follows:

- Petrol and diesel fleet weighted emission factors were obtained from the Vehicle Emission Prediction Model (VEPM 5.3) for the 2015 fleet. These were based on an average speed of 80km/hour on state highways and 40km/hr on local roads (Kuschel *et al.,* 2012). It was assumed that 49% of vehicle travel occurred on state highways and 51% of travel occurred on local roads in 2015 based on data from NZ Transport Agency (NZTA, 2018). The fleet weighted emission factors were converted to emissions per quantity of fuel (kg or TJ) to provide a top-down estimate of emissions based on national fuel consumption data for the year 2015 (from MBIE, 2017).
- Biodiesel emission factors were assumed to be the same as diesel emission factors.
- LPG emission factors were default values from the GAP Forum Manual.

Transport: Rail

All emission factors were default values from the GAP Forum Manual and based on New Zealand fuel properties (for the year 2015) from the Ministry of Business, Innovation and Employment (MBIE, 2017).

Transport: Shipping

All emission factors were default values from the GAP Forum Manual (based on international default fuel properties). In accordance with the GAP Forum Manual methodology, shipping activity data includes fuel consumed for domestic shipping only (i.e. shipping within New Zealand coastal waters). This emission estimate includes emissions from domestic shipping at sea but does not include emissions from international shipping in port or at sea.

2.1.4. Residential fuel combustion

A comprehensive national home heating inventory was prepared as part of the 2013 national inventory (Wilton *et al*., 2015). This was underpinned by household survey data to estimate average fuel consumption and burner types across New Zealand. It further utilised (2013) census data on the number of households using wood or coal for heating.

National average PM_{10} emission factors for residential wood (7.7 g/kg) and coal (19.9 g/kg) from the 2013 national inventory were used in this inventory. Other emission factors used were (Wilton *et al*, 2015*)*:

- Coal, CO (5,082 kg/TJ) and NOx (74 kg/TJ) were the multifuel burner emission factors.
- Wood, CO (11,589 kg/TJ), NOx (41 kg/TJ) were the older wood burner emission factors.
- $PM_{2.5}$ was assumed to be 100% of PM_{10} for wood and 88% of PM_{10} for coal which is consistent with 2013 national inventory (Wilton *et al*. 2015).

SO_2 from coal being directly proportional to sulphur content, was calculated using New Zealand fuel properties (MBIE, 2017). The sulphur content of wood is very low and assumed consistent with previous inventories (Wilton *et al.*, 2015).

Wood consumption for the residential sector was assumed to be 17,116 TJ per annum from the 2013 national inventory (Wilton *et al*. 2015). This is significantly higher than the 8,157 TJ per annum reported in *New Zealand's Greenhouse Gas Inventory* (MfE, 2017). The home heating inventory estimate was used in this 2015 inventory because it was based on a comprehensive and detailed assessment of fuel consumption. Wood consumption cannot be validated, for example by comparison with national sales statistics, so it is reasonable to use the survey based estimate which is likely to be more accurate.

The 2013 wood consumption estimate has not been updated for this 2015 inventory because the estimate is based on census data. It is recommended that the national home heating emissions inventory should be updated with every census.

Coal consumption for the residential sector was assumed to be 391 TJ per annum based on figures for the year 2015 in the *New Zealand's Greenhouse Gas Inventory* (MfE, 2017). This is substantially lower than the coal consumption estimated in Wilton *et al*. (2015), which was approximately 2,100 TJ per annum. The 2013 national home heating inventory reported limited data for the average household coal consumption and considered this a significant limitation of the study. Total coal consumption at a national level is based on robust data, so the *New Zealand's Greenhouse Gas Inventory* coal consumption has been used. This may underestimate the emissions from residential coal consumption at a national level. Further work is recommended to reconcile estimated residential coal consumption at a national level.

2.1.5. Commercial/institutional and Agriculture/forestry/fishing fuel combustion

All factors were default values from the GAP Forum Manual (based on New Zealand fuel properties) except as follows:

- Coal, PM_{10}. 1.11g/kg was the average emission factor for industrial coal combustion from the 2013 national inventory (Wilton *et al*., 2015). $PM_{2.5}$ was assumed to be 75% of PM_{10}.[6]
- Wood, PM_{10} 1.6g/kg and $PM_{2.5}$ 1.4 g/kg were the emission factor for wood boilers assumed in the 2013 national inventory (Wilton *et al*., 2015).

2.2. Construction dust (fugitive emissions)

There are many activities in the construction sector that result in air emissions. Fugitive particulate emissions from construction activities are mostly of mineral composition and mechanical origin, primarily with soil dust (EEA, 2016). Fugitive emissions from construction dust were calculated using the EMEP/EEA tier 1 methodology (EEA, 2016) which is based on the USEPA method. This method identifies four main types of construction:

- Residential housing, single – or two family;
- Residential housing, apartments;

[6] Based on emission factor for multicyclone Vekos boiler.

- Non-residential buildings
- Road construction

Emission factors for each type of construction are multiplied by the total area affected by the specific type of construction and the average duration of construction. The following equation outlines the US EPA approach for estimating total fugitive emissions:

$$EM_{PM_{10}} = EF_{PM_{10}} \cdot A_{affected} \cdot d \cdot (1 - CE) \cdot \left(\frac{24}{PE}\right) \cdot \left(\frac{s}{9\%}\right) \qquad \text{Equation 1}$$

Where:

EM_{PM10}	= PM_{10} emission (kg PM_{10})
EF_{PM10}	= the emission factor for this pollutant emission (kg PM_{10}/[m^2/yr])
$A_{affected}$	= area affected by construction activity (m_2)
d	= duration of construction (year)
CE	= efficiency of emission control measures
PE	= Thornthwaite precipitation-evaporation index
s	= soil silt content (%)

The Thornthwaite precipitation-evaporation index was assumed to be 64, which is the default value for a sub-humid to humid climate. The soil silt content was assumed to be 20%[7].

The total floor area (in square meters) for construction activities was derived from building consents data from Statistics New Zealand for 2015 (Statistics NZ, 2018). Only new building construction data was available. This was then converted to a total construction footprint to calculate emissions. Road construction area was estimated based on lane-km of new road construction and road reconstruction data for 2015 (NZTA 2018b). **Table 2-3** shows the data used and emission factor for each type of construction.

Table 2-3: Construction data and emission factors

Construction type	Floor area	Conversion factor: floor area to total construction footprint [a]	Estimated duration of construction[a]	Control efficiency[a]	PM_{10} emission factor[a]	$PM_{2.5}$ emission factor[a]
	(m^2)		(year)		(kg/m^2/year)	(kg/m^2/year)
Residential houses	3,971,669	1.5	0.5	0	0.086	0.01
Residential other	883,533	1.3	0.75	0	0.3	0.00
Non-residential buildings	3,354,092	1.25	0.83	0.5	1	0.1
Road construction	206,250[b]	N/A	1	0.5	2.3	0.23

[a] These are default values from EEA (2016)

[b] Calculated based on length of new road construction and road reconstruction in 2015 (NZTA) assuming an average width of 3.75m. This is the typical width of a local road lane (3.25m) + shoulder (0.5m) (www.drivingtests.co.nz)

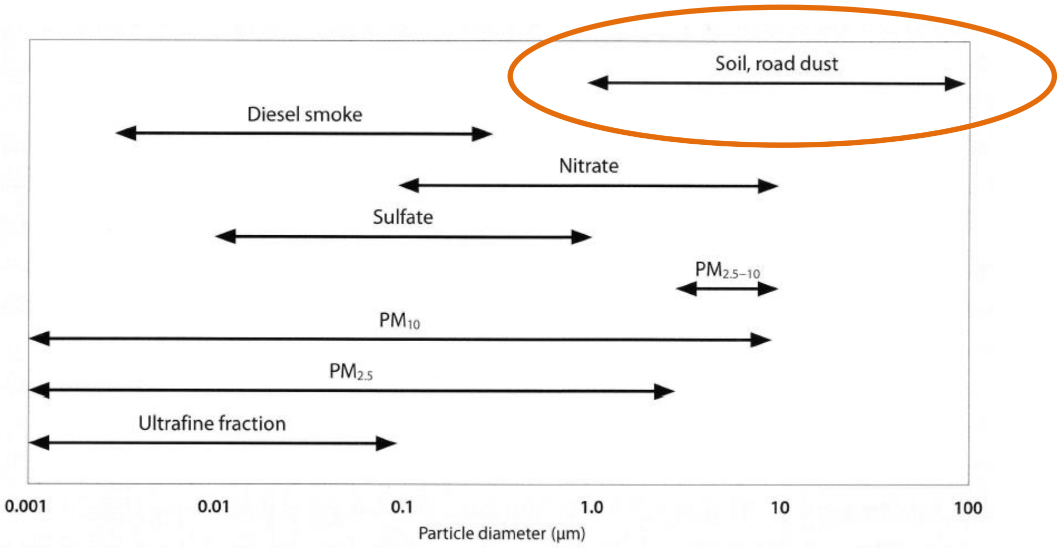
[7] There is no relevant data on the silt content of construction soils. 20% is the value that was assumed for construction in Germany (EEA, 2016).

The above approach does not address construction activities at existing buildings and is likely to underestimate total national emissions.

2.3. Road dust

Road dust is the generation and release of particulate matter into the air, mainly from the interaction between a vehicle's wheels and the road surface, both on sealed and unsealed roads. Road dust, particularly from unsealed roads can create safety and health issues for road users and those living or working near the road.

Airborne dust from roads has a range of particle sizes as shown in **Figure 2-2**. This report only focuses on PM_{10} and $PM_{2.5}$ and does not estimate road dust from coarser fractions which are largely associated with dust nuisance or amenity effects.



(Source: WHO, 2006)

Figure 2-2: Size range of airborne dust

2.3.1. Unsealed road dust

Emission factors for road dust on unsealed roads were calculated using the US EPA methodology for vehicles travelling on industrial unsealed roads (Equation 1) and public unsealed roads (Equation 2) as shown below (US EPA, 2006).[8] The calculations are based on a range of constants (shown in **Table 2-4**) and parameters to adjust for local conditions (shown in **Table 2-5**).

Equation 2

$$E = k\,(s/12)^a (W/3)^b$$

Equation 3

$$E = \frac{k\,(s/12)^a (S/30)^d}{(M/0.5)^c} - C$$

[8] Assumes light vehicles on public unsealed roads and heavy vehicles on industrial unsealed roads.

Where:

- E = size specific emission factor (g/VKT)[9]
- s = surface material silt content (%)
- W = mean vehicle weight (tons)
- M = surface material moisture content (%)
- S = mean vehicle speed (km/hr)
- C = emission factor for 1980's vehicle fleet exhaust, brake wear and tyre wear.

Subtracting exhaust, brake and tyre wear emissions (C) from unsealed roads means that emissions from these sources (i.e. exhaust, brake and tyre) are not double counted in the inventory (as they are already accounted for when calculating on-road vehicle emissions).

Table 2-4: Constants for emission factor calculation

	PM_{10}	**$PM_{2.5}$**		
C (g/VKT)	0.13	0.10		
Empirical constants	**Industrial roads**		**Public roads**	
	PM_{10}	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
k (g/VKT)	422.85	42.285	507.42	50.742
a	0.9	0.9	1	1
b	0.45	0.45	-	-
c	-	-	0.2	0.2
d	-	-	0.5	0.5

(Source: US EPA, 2006)

Table 2-5: Assumed parameters for emission factor calculation

Parameters	**Industrial roads**	**Public roads**	**Valid range**
Silt content % (s)[a]	18%	18%	1.8 - 35%
Vehicle weight tons (W)	9.3[b]	2.25	light: 1.5 - 3 tons; heavy: 2 - 290 tons
Soil moisture % (M)[1]	6.50%	6.50%	0.03 - 13%
Vehicle speed km/h (S)[c]	30	40	16 - 88 km/hr

[a] No local data available so a mid-range value was assumed

[b] Assumed 9.3 tonnes based on Ministry of Transport FT012 indicator for average load (tonnes) of heavy vehicles (MoT, 2018).

[c] Speeds on public roads based on the lower range of recommended driving speeds from the Motor Trade Association (MTA, 2018). Speeds on industrial roads assumed 10km/h less than public road speeds

[9] Emission factors were converted from lb/VMT (as per the US EPA methodology) to g/VKT based on: 1 lb/VMT = 281.9 g/VKT

Table 2-6 shows the derived emission factors for heavy vehicles travelling on industrial unsealed roads and light vehicles on public unsealed roads for PM_{10} and $PM_{2.5}$.

Table 2-6: Calculated emission factors

Emission factor (g/km)	PM_{10}	$PM_{2.5}$
Industrial roads	16.38	1.64
Public roads	13.38	1.25

Annual emissions were calculated at the regional level first by multiplying the emission factors with regional vehicle kilometres travelled (VKT) on unsealed roads (as some regions have more unsealed roads and vehicle traffic than others) and the number of dry days (i.e. days with less than 0.1 mm precipitation).[10] These regional estimates were then totalled to produce annual emissions for the country.

Table 2-7 shows VKT by heavy and light vehicles on unsealed roads for each region (NZTA, 2018), and the number of dry days (presented as a percentage of the total number of days in a year) for each region in 2015 used to calculate annual emissions (NIWA, 2018).

[10] This was based on data from one meteorological monitoring site used to represent each region.

Table 2-7: VKT on unsealed roads and percentage of dry days by region

2015 VKT	Unsealed roads			Dry days[3]
Authority	% Heavy vehicles[1]	Heavy vehicles[2]	Light vehicles[2]	%
Auckland Region	11.5%	4,423,514	34,209,794	69%
Bay of Plenty Region	11.5%	1,618,990	12,520,662	76%
Canterbury Region	11.5%	10,786,804	83,421,089	81%
Gisborne Region	11.5%	2,026,017	15,668,455	78%
Hawkes Bay Region	11.5%	2,205,654	17,057,699	79%
Manawatu-Wanganui Region	11.0%	2,786,083	22,541,940	72%
Marlborough-Nelson-Tasman Region	12.5%	3,278,423	22,948,958	84%
Northland Region	10.1%	9,917,098	88,271,992	73%
Otago Region	11.5%	10,753,582	83,164,166	81%
Southland Region	12.5%	6,659,023	46,613,162	54%
Taranaki Region	12.5%	646,156	4,523,095	63%
Waikato Region	11.5%	4,023,144	31,113,481	76%
Wellington Region	11.5%	1,508,584	11,666,824	72%
West Coast Region	11.5%	866,236	6,699,145	61%
Total		61,499,307	480,420,463	

[1] District council data on the proportion of heavy duty vehicles on unsealed roads was provided by six district councils. Where available, this proportion was assumed for the whole region. For regions without local data, the average of 11.5% was applied. Data was provided by Kaipara District Council, Whangarei District Council, South Taranaki District Council, Ruapehu District Council, Marlborough District Council and Southland District Council.

[2] Data for total VKT (light + heavy vehicles from: NZTA, 2018

[3] Source NIWA, 2018

2.3.2. Sealed road dust (road surface wear)

Emissions from road surface wear on sealed roads were estimated using the methodology from EMEP/EEA guidebook (EEA, 2016). Emission factors from EMEP/EEA guidebook are shown in Table 2-8. Table 2-9 shows 2015 VKT by vehicle class on sealed roads.

Table 2-8: Emission factors from road surface wear

	Emission factor (g/km)	
Vehicle category	PM_{10}	$PM_{2.5}$
Two-wheel vehicles	0.003	0.002
Passenger vehicles	0.008	0.004
Light-duty trucks	0.008	0.004
Heavy-duty trucks	0.038	0.021

(Source: EEA, 2016)

Table 2-9: VKT by vehicle class on sealed roads

Vehicle category	VKT (2015)[1] billions
Light passenger	32.3
Light commercial[2]	7.2
Truck	2.8
Bus	0.3
Motorcycle	0.4
Total	42.9

[1] Total VKT by vehicle class (MOT, 2018b), was multiplied by 98.7%. This was the proportion of total VKT on sealed roads was 98.7% for every vehicle class (NZTA, 2018b)

2.4. Industrial processes

This sector addresses emissions from industrial processes that are not from fuel combustion (as these are already covered under energy related activities and would double count emissions). In accordance with the GAP Forum Manual, the industrial processes included are:

- Mineral products;
- The chemical industry;
- Metals production;
- Pulp and paper industries;

This inventory includes all industrial processes that are listed as sources of PM, CO, NO_X or SO_2 in the GAP Forum Manual, and are included in *New Zealand's Greenhouse Gas Inventory*. Typically, industrial processes that are not included in *New Zealand's Greenhouse Gas Inventory* do not occur in New Zealand or are not significant internationally. However, we note that whilst this inventory captures the most significant sources of non-combustion industrial emissions in New Zealand, the following industries with significant discharges to air are not included:

- Non-combustion emissions from production of fibreboard and particle board
- Non-combustion emissions from production of milk powder

It is recommended that these sources should be included in future inventories because they are known to be significant industrial sources of particulate in New Zealand.

Emissions from industrial processes were estimated from national-scale activity data from *New Zealand's Greenhouse Gas Inventory* (MfE, 2017) where available.

The top-down method is simpler than the detailed bottom up approach taken for the 2013 national inventory (Wilton *et al.*, 2015). This means that the results may be less precise. However, the top-down methodology has the following advantages:

- It will provide emission estimates that are complete (for sectors where data activity is available);
- It will provide emissions estimates that are accessible (i.e. will not rely on confidential data); and
- Data are directly comparable with international inventories.

New Zealand specific emission factors were used where available. For activities where New Zealand specific emission factors were not readily available, Tier 2 emission factors (or abatement factors) from the European guidance (EEA, 2016) were used. These were used in preference to the GAP forum default values, which are generally for uncontrolled processes (with no emission control technology). Uncontrolled emission factors are not generally applicable in New Zealand, where most industrial processes have a reasonable level of emissions control.

The sources of activity data and emission factor for each industrial process are summarised in **Table 2-10**. The activity data and emission factors are summarised in **Table 2-11**.

Table 2-10: Source of activity data and emission factors for industrial process emissions

Process	Activity data	Emission factors[11]
Cement	Minerals.usgs.gov	SO_2 is a New Zealand emission factor reported in *New Zealand's Greenhouse Gas Inventory* (MfE, 2017). All other pollutants are EMEP/EEA 2016 Tier 1 factors. Abatement factors are for an older plant with ESP on the main stack and fabric filters for moderate control of fugitive sources.
Lime	MfE, 2017	SO_2 is a New Zealand emission factor reported in *New Zealand's Greenhouse Gas Inventory* (MfE, 2017). All other pollutants are EMEP/EEA 2016 Tier 2 factors for lime production with typical emission controls.
Glass	No data[12]	PM_{10}, $PM_{2.5}$ and SO_2 emissions are the sum of emissions from O-I glass[13] and Tasman insulation from the *Auckland air emissions inventory 2016: industry* (Auckland Council 2018).
Asphalt for road paving	MfE, 2017	EMEP/EEA 2016 Tier 1 factors with abatement factors for drum mix hot mix plant with venturi/wet scrubber.

[11] Abatement factors have been selected based on "typical" or moderate emission controls specified in the EMEP/EEA 2016 Manual. A specific assessment of New Zealand emission control technology has not been undertaken.
[12] New Zealand's Greenhouse Gas Inventory (MfE, 2017) states that there are two companies making glass in New Zealand. O-I glass makes container glass and Tasman Insulation makes smaller amounts of glass for insulation.
[13] The Auckland inventory reports emissions for a base year of 2016. However, 2015 emissions of PM_{10} and $PM_{2.5}$ were reported for O-I glass and these were significantly different to 2016 emissions. The total PM_{10} and $PM_{2.5}$ reported here is the sum of 2015 emissions from O-I glass and 2016 emissions from Tasman Insulation.

Process	Activity data	Emission factors[11]
Asphalt roofing	MfE, 2017	EMEP/EEA 2016 Tier 1 factors[14].
Ammonia	MfE, 2017	EMEP/EEA Tier 1 factors[15].
Urea	Approximate figure reported by manufacturer[16]	Uncontrolled emission factors are Tier 2 factors from EMEP/EEA for manufacture of Urea. Abatement factors are for an average age plant with ESP or wet scrubber and some capture of fugitive emissions (EMEP/EEA).
Superphosphate	MfE, 2017	SO_2 emission factor is an average factor reported for 3 New Zealand sites[17]. Uncontrolled PM emission factors are Tier 2 factors from EMEP/EEA for manufacture of phosphate fertilisers. Abatement factors are for an average age plant with ESP or wet scrubber and some capture of fugitive emissions (EMEP/EEA).
Steel	UN Industrial Commodity Yearbook[18].	All emissions are from the *Auckland air emissions inventory 2016: industry* (Auckland Council 2018).
Aluminium	MfE, 2017	SO_2 and PM_{10} emission factors were derived from monitoring data[19] All other emission factors are uncontrolled EMEP/EEA Tier 1 factors.
Lead recycling	MfE, 2017	EMEP/EEA Tier 2 emission factors for secondary lead production with average emission controls
Pulp and paper	Stats NZ Infoshare	EMEP/EEA Tier 2 factors for Kraft process with typical emission controls (scrubber and electrostatic precipitator).

[14] Asphalt roofing is a very small source of emissions so the Tier 1 factors were considered adequate. Note that the EMEP/EEA Tier 1 factors are the same as the GAP forum default values.
[15] EMEP/EEA Tier 1 and Tier 2 emission factors for NOx emissions from ammonia production are the same, and are similar for CO. Ammonia production is not a significant source of emissions so Tier 1 factors were considered adequte. Note that the EMEP/EEA Tier 1 factors are the same as the GAP forum default values.
[16] https://www.productivity.govt.nz/sites/default/files/sub-low-emissions-34-ballance-agri-nutrients-limited-662Kb.pdf
[17] Ravensdown Operations Environmental Report 2014-2015
[18] The yearbook reports pig iron production for 2014
[19] New Zealand Aluminium Smelters Limited, Quarterly Resource Consent Report, Quarter 3 2017. Provided by Environment Southland

Table 2-11: Activity data and emission factors for industrial processes

Subsector	Process	Activity rate (kilotonnes per year)		Uncontrolled emission factors		Control efficiency assumed		Emission factors				
				PM_{10}	$PM_{2.5}$	$PM_{2.5}$ to PM_{10}	> $PM_{2.5}$	PM_{10}	$PM_{2.5}$	CO	NOx	SO_2
				kg/tonne		%		kg/tonne				
Mineral products	Cement production	1,200	Product	0.222	0.124	34%	40%	0.139	0.074			0.65
	Lime production	246		N/A (factors are for a controlled process)				0.2	0.03			0.5
	Glass			N/A (emissions are site specific)				N/A - total PM_{10}, $PM_{2.5}$ and SO_2 emissions are from the Auckland inventory (Auckland Council, 2018)				
	Asphalt roofing production	0.3		0.4	0.08	nil	nil	0.4	0.08			
	Asphalt for road paving	201		3	0.4	99.7%	99.7%	0.009	0.001			
Production of chemicals	Ammonia	137								0.1	1	
	Urea	265		1.2	0.9	81%	76%	0.273	0.216			
	Superphosphate	1,918		0.24	0.18	81%	76%	0.055	0.043			0.95
Metal industries	Steel production	697		N/A (factors are site specific)				0.36	0.34	3.16	2.45	1.34
	Aluminium production	333		N/A (factors are site specific)				2.0	1.7	120	1	17.1
	Lead recycling	9		N/A (factors are for a controlled process)				0.016	0.008			5
Pulp and paper	Kraft pulping	1,438	Dried pulp	N/A (factors are for a controlled process)				0.8	0.6	0	1	2

2.5. Agriculture, vegetation fires and forestry

This section includes:

- Particulate emissions from animal housings
- Emissions from burning of agricultural crop residues, and
- Emissions from vegetation fires resulting from changes in land use, forestry management practices or by accident.

Other potential sources of agricultural particulate emissions, such as particulate from tillage of soils and application of fertilisers are not included in the GAP Forum manual and were not included in this inventory. Emissions from combustion of fuels in farm machinery are captured in the energy sector (Section 2.1.6).

2.5.1. Animal housings

Emissions were based on Tier 1 emission factors from the EEA guidebook (EEA, 2016) and activity data (animal numbers) from *New Zealand's Greenhouse Gas Inventory* (MfE, 2017) and Statistics NZ for 2015. Activity data and emission factors are summarised in **Table 2-12**.

New Zealand's Greenhouse Gas Inventory (MfE, 2017) states that; dairy cattle, non-dairy cattle (beef), sheep and deer are largely grazed outside all year round, and intensive housing of major ruminant livestock species is not practised in New Zealand. On this basis, it was assumed that pigs and chickens are the only animals that are housed in New Zealand. The proportion of chickens that are free range and pigs that are housed outdoors was estimated based on available data as follows:

- 70% of sows and pigs were housed (MPI, 2012)
- 90% of laying hens were housed (MAF, 2011)
- 97% of broilers were housed (MAF, 2011)

Table 2-12: Activity data and emission factors for animal housing

	Activity rate	Time spent inside animal housing[20]	PM_{10} emission factor	$PM_{2.5}$ emission factor
Animal	**(thousands of animals)**	**(%)**	**(kg PM_{10} per animal per year)**	**(kg $PM_{2.5}$ per animal per year)**
Sows	56	100%	0.17	0.01
Fattening pigs	131	100%	0.14	0.006
Laying hens	3,107	100%	0.04	0.003
Broilers	15,368	100%	0.02	0.002

[20] No data was available on the proportion of time spent inside animal housings so 100% was assumed.

2.5.2. Field burning of agricultural residues and biomass burning

Emissions from burning (field burning of agricultural residues, biomass burning) were based on activity data from *New Zealand's Greenhouse Gas Inventory* (MfE, 2017). Emission factors were default emission factors from the GAP Forum Manual. Biomass burning includes emissions from controlled burning as well as wildfires. Emission factors and activity data are summarised in Table 2-13.

Table 2-13: Activity data and emission factors for field burning of agricultural residues and biomass burning

Crop/vegetation type	Activity rate	Emission factors				
		PM_{10}	$PM_{2.5}$	CO	NOx	SO_2
	Total biomass burned (kt dry matter)	kg/tonne biomass burned				
Field burning of agricultural residues[21]	256.39	5.7	5.4	66.7	2.4	0.5
Biomass burning: forest land[22]	281.60	17.6	13	107	4.6	1
Biomass burning: grasslands[23]	240.69	8.3	5.4	65	6	0.35

2.6. Treatment and disposal of waste

This section includes emissions from disposal of waste by incineration and open burning.

2.6.1. Waste incineration

New Zealand's Greenhouse Gas Inventory reports no incineration of waste in New Zealand except for the incineration of a small quantity of quarantine waste (MfE, 2017).

Emissions were estimated based the amount of estimated quarantine waste (only) as reported in the *New Zealand's Greenhouse Gas Inventory*, and default emission factors from the GAP Forum Manual.[24] Activity data and emission factors assumed are summarised in Table 2-14.

Table 2-14: Activity data and emission factors waste incineration

Process	Activity rate	Emission factors				
		PM_{10}	$PM_{2.5}$	CO	NOx	SO_2
	kt waste (wet weight)	kg/tonne				
Incineration municipal solid waste (quarantine waste)	5.35	0.007	0.004	0.07	0.87	0.047

[21] GAP Forum Manual default values for wheat
[22] Gap Forum Manual defaults for other (non-eucalypt) forests
[23] Gap Forum Manual defaults for temperate grasslands
[24] Gap Forum manual default for modern plant with emission controls

2.6.2. Open burning of waste

New Zealand's Greenhouse Gas Inventory states that there may be some open burning of waste, but that no information is available to confirm whether this occurs or the extent of the practice (MfE, 2017). The 2013 national inventory (Wilton et al. 2015) includes an estimate of emissions from open burning of garden waste. The quantity of waste disposed of by open burning was estimated in the 2013 national inventory based on the results of a household survey undertaken in 2014, as well as regional council emission inventory data where available.

For this 2015 inventory, emissions from open burning of waste were assumed to be unchanged from the 2013 national inventory (Wilton et al. 2015). There is no new information to update this estimate, and it is reasonable to assume that the amount of waste being disposed of by open burning did not significantly change between 2013 and 2015.

Table 2-15 shows the emission factors and activity data used to estimate emissions from open burning of waste.

Table 2-15: Activity data and emission factors for open burning of waste

Process	Activity rate	Emission factors				
		PM_{10}	$PM_{2.5}$	CO	NOx	SO_2
	kt waste	kg/tonne				
Open burning of garden waste	205	8.0	8.0	42.0	3.0	0.5

2.7. Large point sources

Large point sources were not included separately in this inventory as these emissions are expected to be captured in the other sectors (energy and industry). A more detailed (accurate) assessment of industrial emissions from large point sources could be undertaken based on resource consent information held by regional councils. However, this would be labour intensive because there is currently no mechanism in place to regularly collect, collate and update industrial emissions data.

It is recommended that the Ministry should investigate potential options to improve accessibility and quality of industrial emissions data.

3. Results

Results from the emissions inventory are presented here for each pollutant. Full results are provided in Appendix A.

3.1. PM_{10}

Total PM_{10} emissions from anthropogenic sources in New Zealand were estimated as 46,000 tonnes per annum in 2015.

Figure 3-1 shows estimated PM_{10} emissions by sector and **Figure 3-2** shows a breakdown on emissions from the energy sector. The energy sector accounts for 54% of all PM_{10} emissions. Outdoor burning in all sectors was estimated to account for 22% of PM_{10} emissions. This comprised 3% from field burning of agricultural residues, 15% from biomass burning (which includes controlled burning and wildfires in forest and grasslands) and 4% from open burning of garden waste. Non-combustion emissions were estimated to contribute 24% of PM_{10} emissions. This comprised 13% from road dust, 5% from industrial processes, 5% from construction dust and 1% from animal housings.

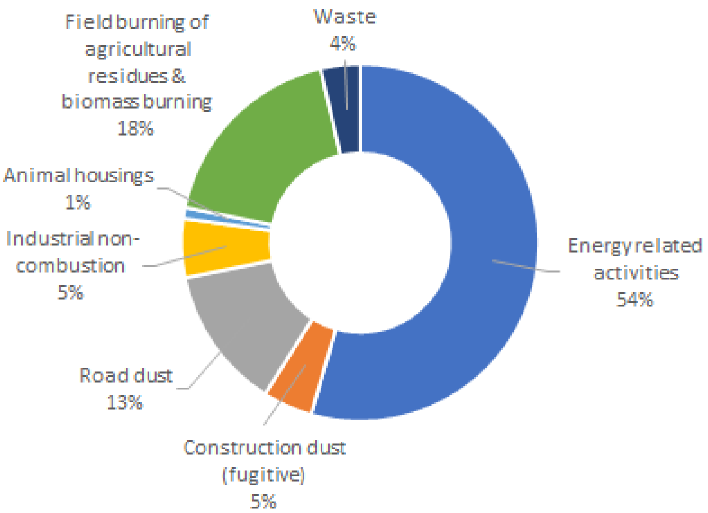


Figure 3-1: PM_{10} emissions by sector

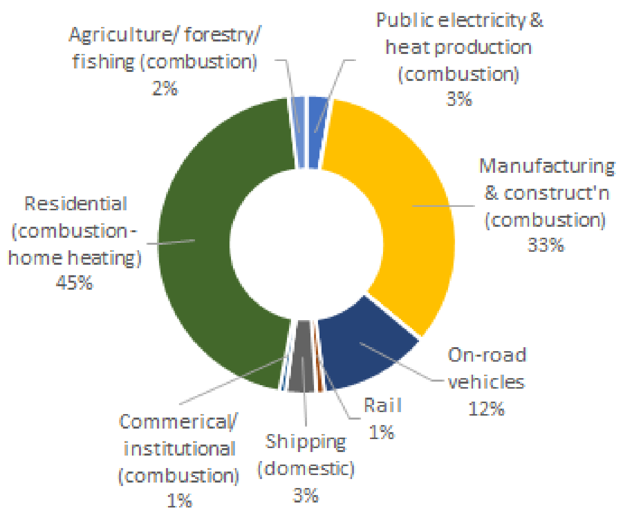


Figure 3-2: Breakdown of PM_{10} emissions from energy related activities*

* Sub-sectors with emissions <1% are not shown on this chart. These include: Manufacture of solid fuels & other energy industries (combustion), petroleum refining (combustion, domestic & international aviation and pipeline transport (combustion).

Detailed emissions by source are illustrated in **Figure 3-3**. Residential home heating was the biggest single source of emissions accounting for 25% of total PM_{10}. Combustion of fuels in transport accounts for approximately 9% of all PM_{10}, while combustion of fuels in all other sectors (public electricity and heat production, petroleum refining, manufacture of solid fuels and other energy industries, manufacturing and construction, commercial/ institutional & agriculture/forestry/fishing) accounts for a further 21% of total PM_{10} emissions.

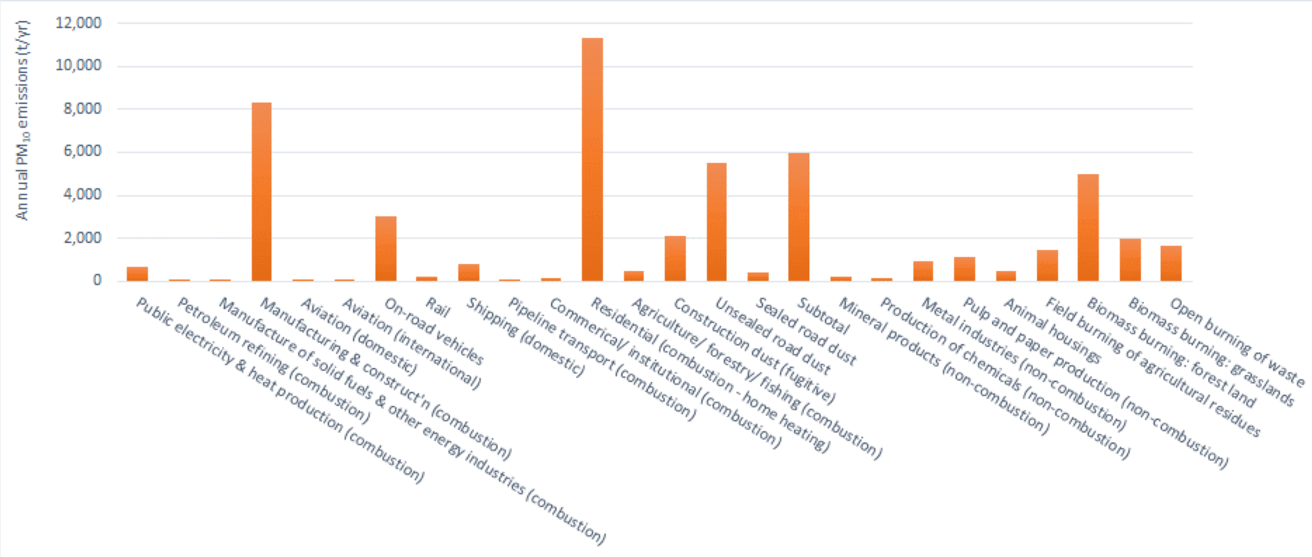


Figure 3-3: PM$_{10}$ emissions by source for 2015 (t/yr)

Figure 3-4 shows PM$_{10}$ emissions by fuel for the energy sector. This illustrates that wood combustion is a significant source of PM$_{10}$ in New Zealand.

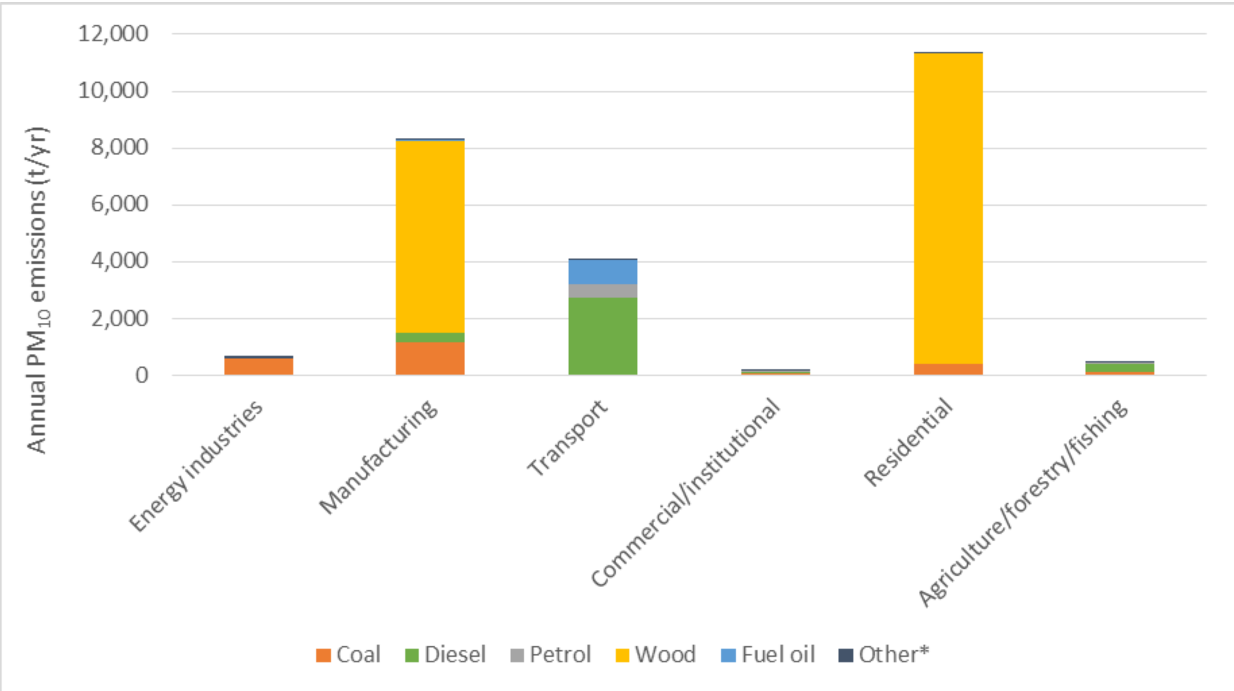
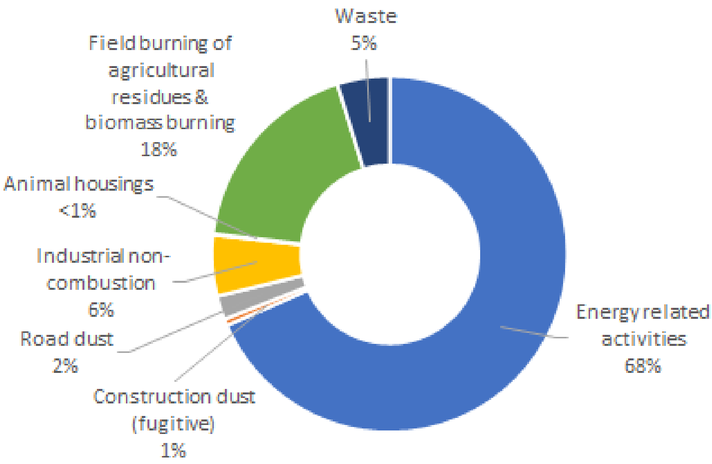


Figure 3-4: PM$_{10}$ emissions by fuel type for fuel combustion from the energy sector

3.2. PM$_{2.5}$

Total PM$_{2.5}$ emissions from anthropogenic sources in New Zealand were estimated as 34,500 tonnes per annum in 2015.

Figure 3-5 shows estimated $PM_{2.5}$ emissions by sector and **Figure 3-6** shows a breakdown of energy sector emissions. $PM_{2.5}$ emissions were primarily from combustion sources. Combustion of fuels in the energy sector energy sector was estimated to account for 68% of all $PM_{2.5}$ emissions. Outdoor burning (including field burning of agricultural residues, biomass burning and open burning of waste) was estimated to contribute 23% of national $PM_{2.5}$ emissions in 2015.



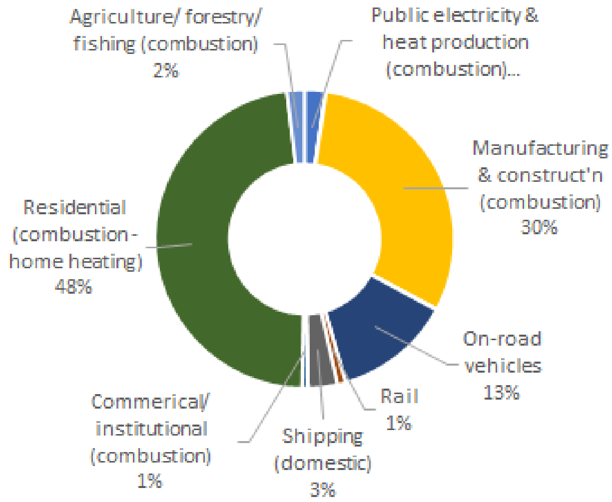


Figure 3-5: $PM_{2.5}$ emissions by sector for 2015

Figure 3-6: Breakdown of $PM_{2.5}$ emissions from energy related activities

* Sub-sectors with emissions <1% are not shown on this chart. These include: Manufacture of solid fuels & other energy industries (combustion), petroleum refining (combustion, domestic & international aviation and pipeline transport (combustion).

Detailed emissions by source are illustrated in **Figure 3-7**. Residential home heating was the biggest single source of emissions accounting for 33% of total $PM_{2.5}$ in New Zealand in 2015.

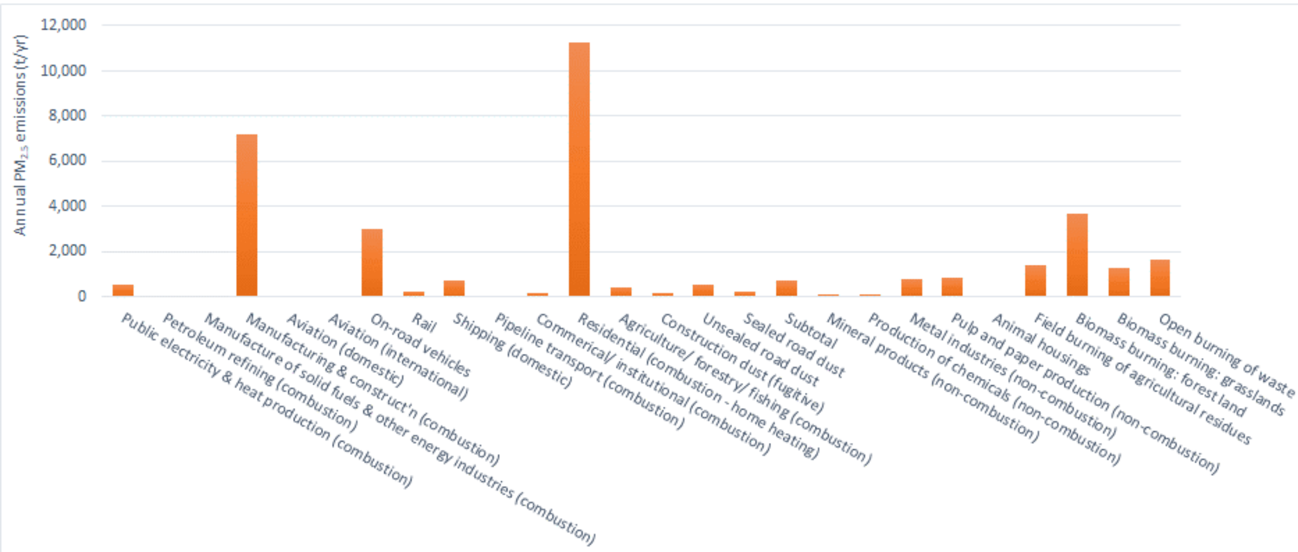


Figure 3-7: $PM_{2.5}$ emissions by source for 2015 (t/yr)

3.3. Carbon monoxide (CO)

Total CO emissions from anthropogenic sources in New Zealand were estimated as 531,500 tonnes per annum in 2015.

Figure 3-8 shows estimated CO emissions by sector and **Figure 3-9** shows a breakdown of energy sector emissions.

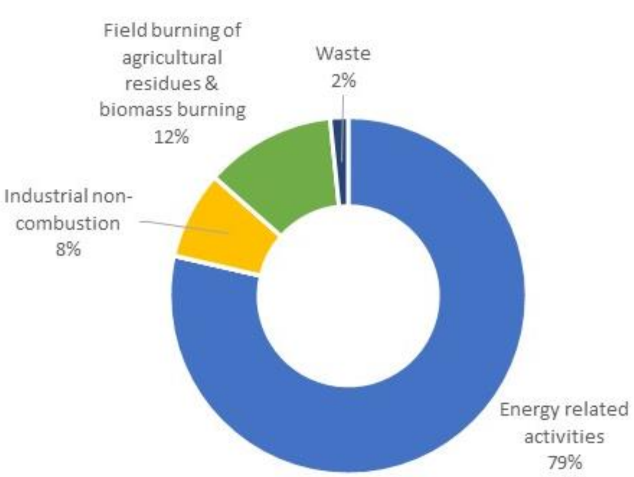


Figure 3-8: CO emissions by sector for 2015⁺

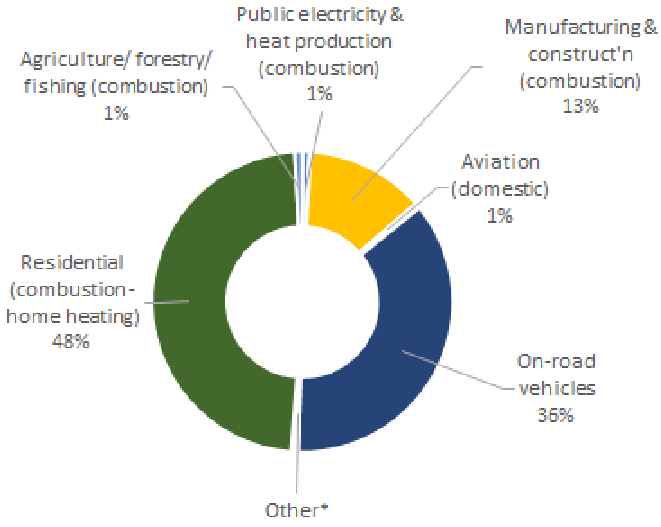


Figure 3-9: Breakdown of CO emissions from energy related activities

⁺ Note, due to rounding, this chart does not add up to 100%.

* Sub-sectors with emissions <1% are labelled as 'other' on the chart. These include: Manufacture of solid fuels & other energy industries (combustion), petroleum refining (combustion), international aviation, pipeline transport (combustion), rail, domestic shipping and commercial/institutional (combustion).

CO emissions are predominantly from combustion. The energy sector was estimated to account for 79% of all CO emissions in 2015. Outdoor burning (including field burning of agricultural residues, biomass burning and open burning of waste) was estimated to contribute 13% of national CO emissions in 2015. The only non-combustion source of CO was metal industries (manufacture of iron and aluminium) which accounted for 8% of emissions in 2015.

Figure 3-10 shows estimated emissions by source. This shows that residential home heating and on-road motor vehicles were the most significant sources of CO accounting for 38% and 28% of total emissions respectively.

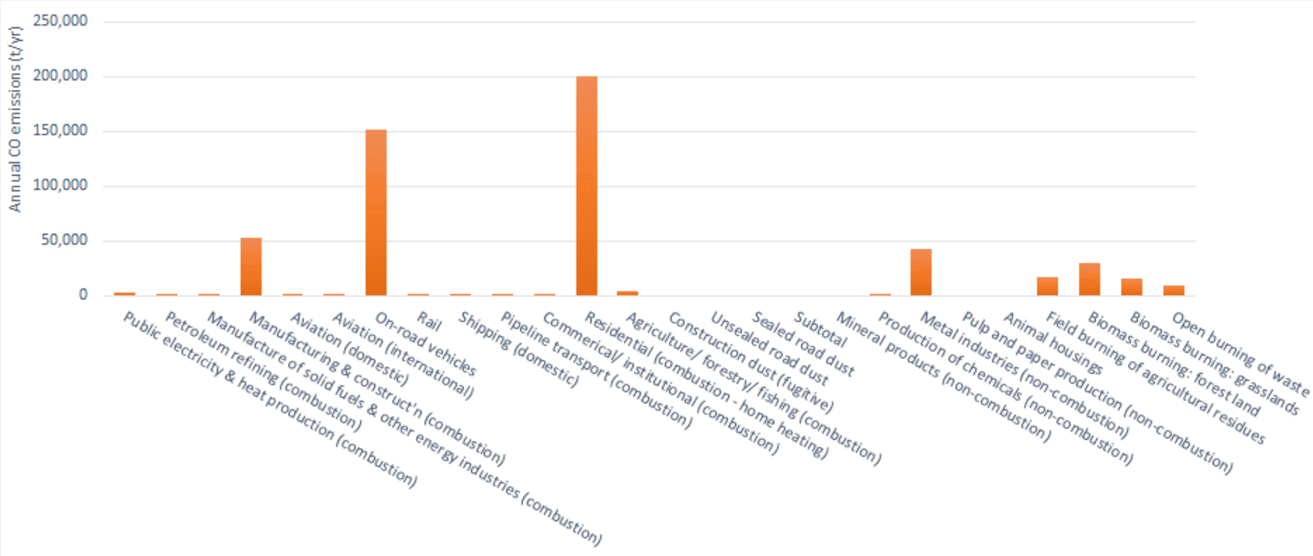


Figure 3-10: CO emissions by source for 2015 (t/yr)

3.4. Nitrogen oxides (NOx)

Total NOx emissions from anthropogenic sources in New Zealand were estimated as 121,400 tonnes per annum in 2015.

Figure 3-11 shows estimated NOx emissions by sector. This shows that 94% of NOx emissions were from combustion of fuels in the energy sector. **Figure 3-12** shows a breakdown of energy sector emissions.

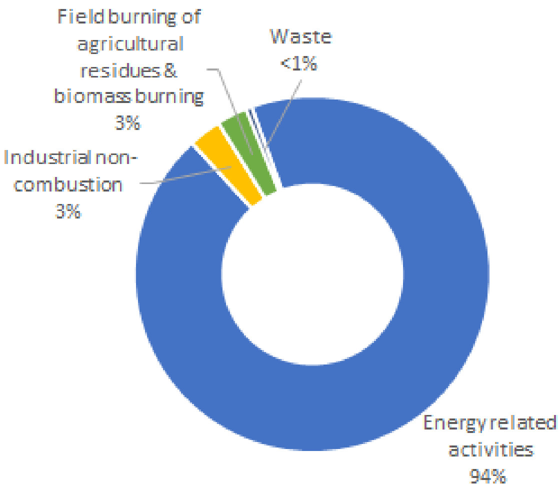


Figure 3-11: NOx emissions by sector for 2015

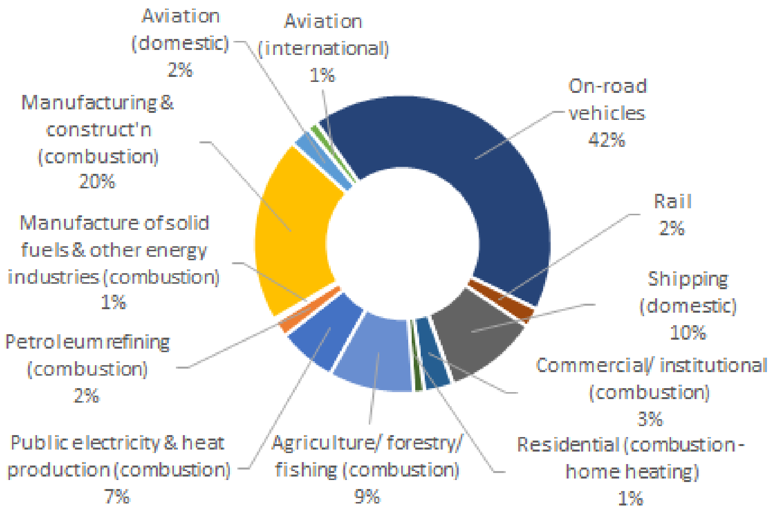


Figure 3-12: Breakdown of NOx emissions from energy related activities*

* Sub-sectors with emissions <1% are not shown on the chart. This includes: pipeline transport (combustion)

Figure 3-13 summarises emissions by source. On-road vehicles were the largest single source of NOx emissions accounting for 39% of total emissions in 2015.

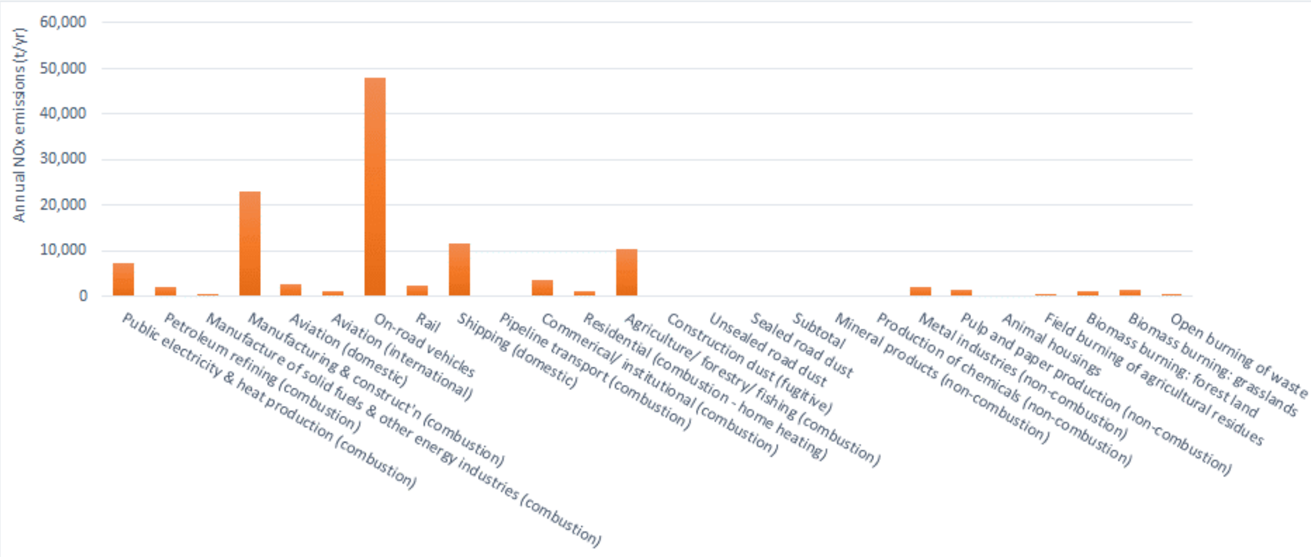


Figure 3-13: NOx emissions by source for 2015 (t/yr)

3.5. Sulphur dioxide (SO_2)

Total SO_2 emissions from anthropogenic sources in New Zealand were estimated as 49,900 tonnes per annum in 2015.

Figure 3-14 shows estimated SO_2 emissions by sector. This shows combustion of fuels in the energy sector and industrial non-combustion emissions were the main sources of SO_2, accounting for 74% and 25% of emissions respectively. **Figure 3-15** shows a breakdown of energy sector emissions.

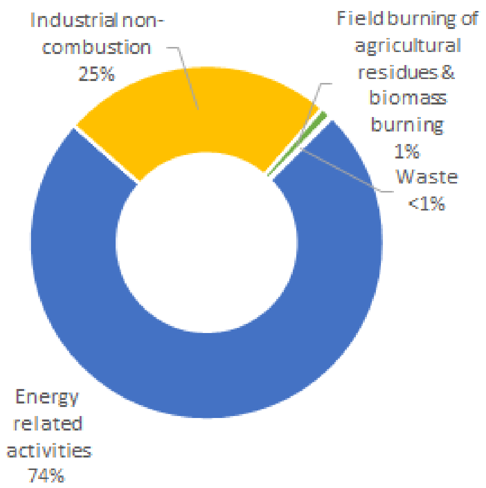


Figure 3-14: SO_2 emissions by sector for 2015

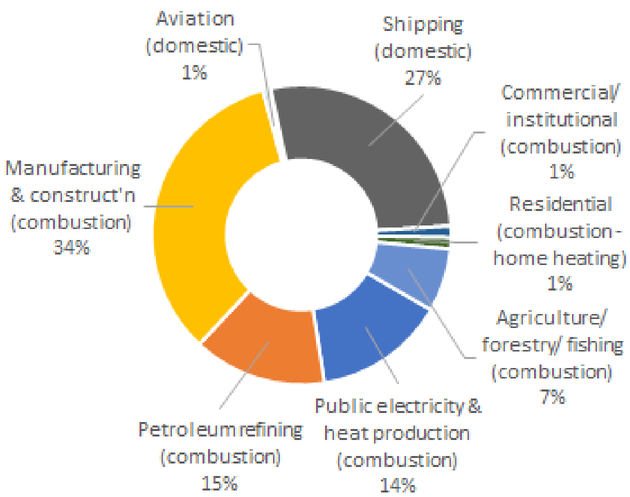


Figure 3-15: Breakdown of SO_2 emissions from energy related activities*

* Sub-sectors with emissions <1% are not shown on the chart. These include manufacture of solid fuels & other energy industries (combustion), international aviation, on-road vehicles & rail.

Figure 3-16 shows emissions by source. This shows that SO_2 emissions were dominated by industrial combustion and non-combustion sources. Domestic shipping was also significant, accounting for an estimated 20% of total SO_2 emissions in 2015.

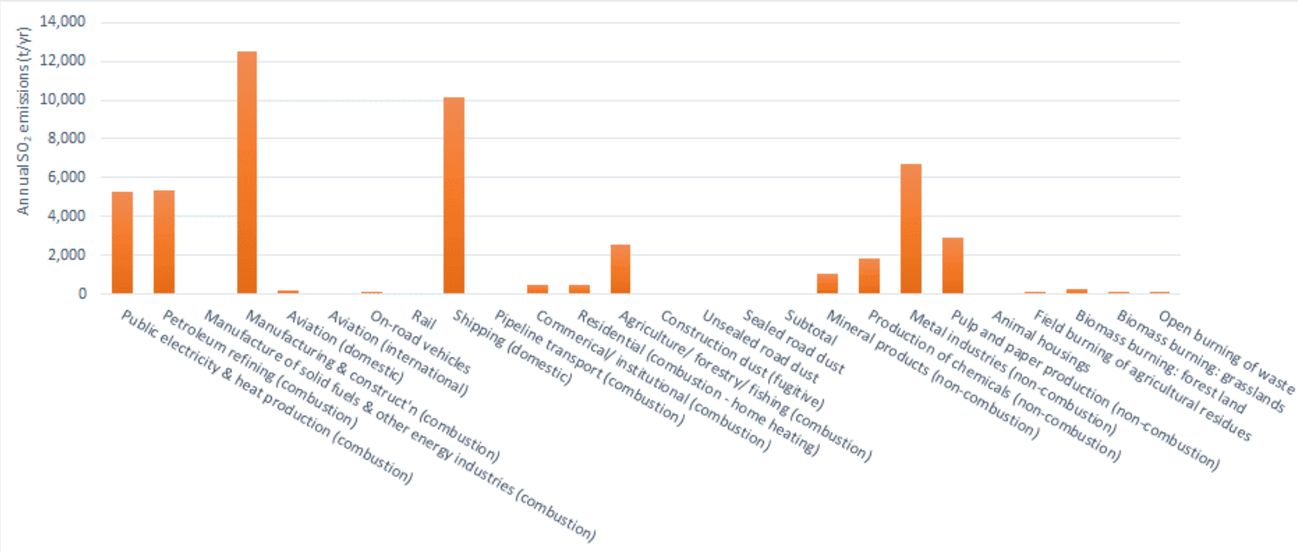


Figure 3-16: **SO_2 emissions by source for 2015 (t/yr)**

Combustion emissions of SO_2 are directly proportional to the sulphur content of fuel. **Figure 3-17** shows a breakdown of energy sector emissions by fuel. This shows that emissions of SO_2 from combustion were dominated by combustion of coal, fuel oil (predominantly in shipping) and crude oil (in the energy industries).

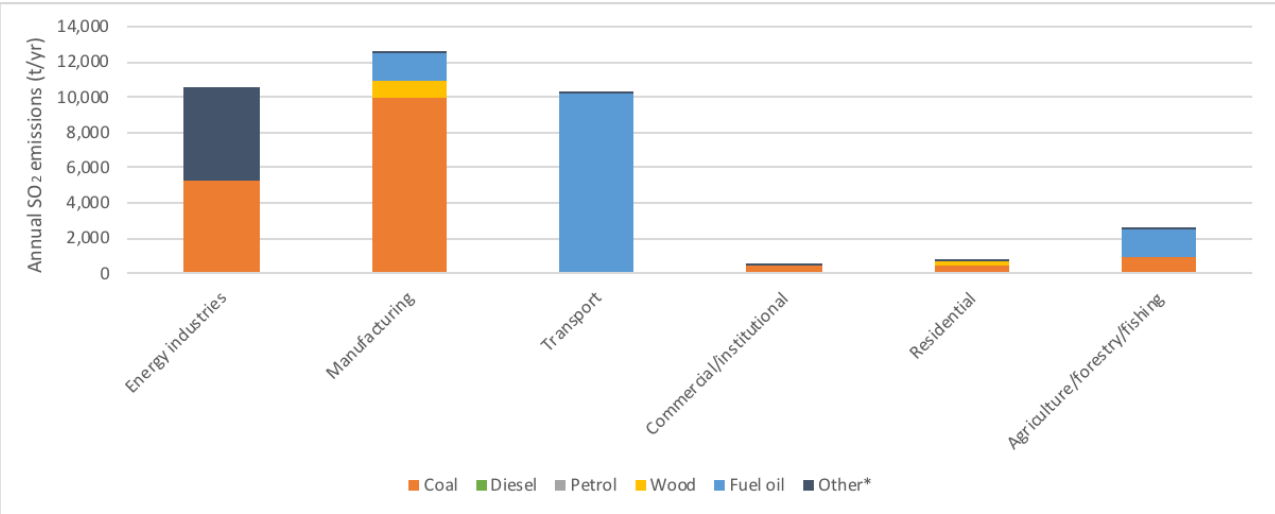


Figure 3-17: **SO_2 emissions by fuel type for fuel combustion from the energy sector**

3.6. Uncertainty

A quantitative assessment of uncertainty was not undertaken for this inventory.

However, an approximate assessment was made based on expert judgement and guidance provided in the EMEP/EEA guidebook. The guidebook suggests default uncertainty ranges for activity data and emission factors as shown in **Table 3-1** and **Table 3-2**.

Table 3-1: EMEP/EEA 2016 indicative error ranges for uncertainty analysis

Data source	Error range	Remarks
National (official) statistics	-	The official statistics of a country will, in principle, be assumed to be 'fixed' data, with no uncertainty. In fact, however, for energy data an indication of the uncertainties could be derived from the entry under 'statistical differences', representing the mismatch between production and consumption.
An update of last year's statistics using gross economic growth factors	0-2%	The economic system of a country will probably not shift more than a few per cent between successive years. Hence, if an update of last year's data is used, an uncertainty of a few per cent seems reasonable
IEA energy statistics	OECD 2-3%	The International Energy Agency (IEA) publishes national energy statistics for many countries. For the Organisation for Economic Co-operation and Development (OECD) countries these statistics will ideally be equal to the official energy statistics. For other countries the uncertainties could be expected to be in the order of 5 to 10 % (educated guess).
UN databases	5-10%	These data might have a similar uncertainty as the ones provided by IEA.
Default values, other sectors and data sources	30-100%	

(Source: EEA, 2016)

Table 3-2: Default error ranges associated with emission factors

Rating	Descriptions	Typical error range
A	An estimate based on a large number of measurements made at a large number of facilities that fully represent this sector	10 to 30%
B	An estimate based on a large number of measurements made at a large number of facilities that represent a large part of the sector	20 to 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 to 200%
D	An estimate based on single measurements, or an engineering calculation derived from a number of relevant facts	100 to 300%
E	An estimate based on an engineering calculation derived from assumptions only	Order of magnitude

(Source: EEA, 2016)

An approximate assessment of uncertainty in estimated PM_{10} emissions is provided in **Table 3-3** for key sources in this inventory.

Table 3-3: Indicative uncertainty assessment for key sources of PM_{10} in this inventory

Source	activity data	approximate uncertainty
Residential combustion (home heating)	Assessment is based on a comprehensive Tier 3 assessment (Wilton et al 2015).	25%
Transport – on road vehicles	On-road vehicle assessment based on national fuel consumption statistics and country specific Tier 3 emission factors from VEPM.	25%
Transport - other	Other sources in the transport sector are based on national fuel consumption statistics and international default emission factors.	100%
Energy sector - other	Combustion emissions are based on national fuel consumption statistics and a combination of New Zealand emission factors where available and international default emission factors.	30-100%
Industry – non combustion	Industrial emissions are based on annual activity data from *New Zealand's Greenhouse Gas Inventory* and UN databases. Emission factors are a combination of New Zealand specific emission factors where available, and international default emission factors.	30-100%
Unsealed road dust	Emissions are based on international emission factor equations and very limited data about the characteristics of New Zealand roads or the vehicles using them. Uncertainty is estimated as approximately 300% based on the default error ranges shown in Table 3-2.	300%

Source	activity data	approximate uncertainty
Sealed road dust	Emission factors are highly uncertain and based on limited information (EEA, 2016). Uncertainty is estimated as approximately 300% based on the default error ranges shown in Table 3-2.	300%
Field burning of agricultural residues and biomass burning	*New Zealand's Greenhouse Gas Inventory* estimates the uncertainty in activity data as ±30%. The uncertainty in default emission factors is estimated as 25% (EMEP/EEA 2016).	50%
Open burning of waste	Emissions were based on international emissions factors and activity data were based on the results of surveys. It is assumed that the uncertainty in open burning emissions is similar to the uncertainty for agricultural residues and biomass burning.	50%

3.7. Comparison with previous inventory

This inventory builds on the results of the previous *2013 Home heating emission inventory and other sources evaluation* (Wilton *et al* 2015). This updated inventory includes all significant anthropogenic sources of particulate, carbon monoxide, nitrogen oxides and sulphur dioxide. In general, this inventory uses top down methodology which is simpler than the detailed bottom up approach taken for the 2013 national inventory. This means that (for some sources) the results will be less precise. However, the top-down methodology has the advantage that it will provide emission estimates that are complete (for sectors where data activity is available), accessible (i.e. will not rely on confidential data) and directly comparable with international inventories.

Emission estimates from sources that are directly comparable are shown in **Table 3-4**. This shows that, emissions estimates in this inventory are higher than previous inventories because a top-down approach has been taken based on national fuel consumption statistics. This ensures that all fuel consumption from all sectors is accounted for in the inventory.

Table 3-4: Comparison of estimated emissions between the 2013 national inventory and this inventory

Source	2013 inventory* (t/yr)	This inventory (t/yr)	Notes
Residential (domestic heating) - wood	10,900	10,900	Residential wood burning emissions were estimated in this inventory based on the emission factors and fuel consumption estimated in Wilton *et al* 2015.
Residential (domestic heating) coal	2,231	428	Residential coal burning emissions were estimated in this inventory based on the emission factors from Wilton *et al* 2015 and fuel consumption from *New Zealand's Greenhouse Gas Inventory* (MfE, 2017). The coal consumption estimate (for the year 2015) from the GHG

Source	2013 inventory* (t/yr)	This inventory (t/yr)	Notes
			inventory is an order of magnitude lower than the estimated coal consumption (for the year 2013) in Wilton *et al*. (2015).
Industry	6,142	11,496[25]	This inventory uses a top-down methodology which is simpler than the detailed bottom up approach taken for the 2013 national inventory. This means that (for some sources) the results will be less precise. However, the top-down methodology has the advantage that it will provide emission estimates that are complete. For example, this updated inventory accounts for emissions from combustion of any diesel that is not accounted for in on-road transport. Off-road vehicles and equipment were not included in the previous inventory, so the majority of non-road diesel consumption was not accounted for. A detailed comparison of sources was not possible because *inter alia* the detailed industrial emissions inventory from the 2013 national inventory is not readily available.
On-road motor vehicles	1,900	3,006	On-road motor vehicle emissions were estimated in this inventory based on robust national fuel consumption data. The previous inventory was based on estimated VKT. Using VKT underestimates fuel consumption (and therefore emissions) because VEPM is known to underestimate fuel consumption, especially for diesel vehicles (Metcalfe & Sridhar, 2018). Emission factors used in this inventory were from VEPM 5.3 which has been updated since the previous (Wilton *et al* 2015) inventory. Emission factors are higher in VEPM 5.3 compared with the previous version (Metcalfe and Sridhar, 2017).
Outdoor burning	1,643	10,058	Previous (Wilton *et al.,* 2015) inventory included an estimate of household outdoor burning of green waste only. This inventory includes the 2013 estimate (1,643 tonnes per annum from outdoor burning of green waste) as well as emissions from burning of crop residue and biomass based on activity data compiled for New Zealand's Greenhouse Gas Inventory (MfE, 2017). Burning of crop residues and biomass burning was not included in the previous inventory.

[25] This includes emissions from combustion in energy industries, combustion in manufacturing and construction and non-combustion industrial emissions.

4. Conclusions and recommendations

This 2015 national emissions inventory has been prepared using a methodology that is:

- Timely, easily updatable and low cost;
- Relevant to the air pollution topic in the Ministry's Air Domain reports;
- Accurate for key sources (home heating, large industrial sources and transport);
- Based on nationally representative data to permit trends to be assessed; and
- Accessible and comparable with other national inventories.

However, some further work is recommended to ensure that the accuracy and relevance of future inventories is maintained. These recommendations are outlined in the following sections.

Fuel combustion

Combustion of fuels in the industrial and commercial sectors (energy industries, manufacturing and construction, commercial/institutional, agriculture/forestry/fishing) accounts for approximately 21% of national PM_{10} emissions (9,700 tonnes per year). This estimate includes all fuel combusted in these sectors but excludes on-road transport.

PM_{10} and $PM_{2.5}$ emission factors assumed for wood and coal boilers are New Zealand specific factors that have been developed based on data from EECA's heat plant database as well as available emission test results. These emission factors are a valuable resource for New Zealand and potentially provide a good benchmark for estimation of emissions. However, the base data are not publicly accessible and the emission estimates from the database are not regularly updated. The lack of accessibility means we cannot interrogate the underlying assumptions and limits the credibility of the data. **It is recommended that EECA or the Ministry develop a publicly accessible database of heat plant data and emission tests to facilitate regular update of heat plant emission factors and improve data integrity.**

PM_{10} emissions from wood combustion in the manufacturing industries and construction sector were estimated as approximately 15% of annual PM_{10} emissions from all sources (6,700 tonnes per annum). However, this estimate is based on an emission factor that *should be used with caution owing to the small number of wood boilers included in the study* (Wilton & Barnes, 2010). **Further work is recommended to improve wood boiler emission factors given the estimated significance of emissions from wood combustion.**

Residential (home heating)

Emissions from home heating are a key source of particulate pollution in New Zealand, especially in urban areas. This national inventory incorporates the results of the comprehensive assessment of home heating emissions undertaken for the 2013 home heating emission inventory (Wilton *et al* 2015). For future national air emissions inventories, trends in the number of households using wood and coal for home heating will be available from census. However, further work will be required to update average emission factors. For example, average emission factors are expected to reduce due to replacement of older wood burners with new NES compliant low emission wood burners. **It is**

recommended that the national home heating emissions inventory should be maintained and updated with every census.

Emissions from residential consumption of coal were estimated in this inventory based on coal consumption figures reported in New Zealand's Greenhouse Gas Inventory. This is substantially lower than the coal consumption estimated for the 2013 national inventory evaluation (Wilton *et al*., 2015) and may underestimate emissions from this sector. **Further work is recommended to reconcile residential coal consumption estimates at a national level.**

Transport: Domestic shipping

Emissions from domestic shipping are estimated based on fuel consumption reported in *New Zealand's Greenhouse Gas Inventory* (MfE, 2017). This includes emissions from domestic shipping at sea but does not include any emissions from international shipping. This may not provide a good estimate of emissions that are likely to impact local air quality in and around New Zealand towns and cities. **Further work is recommended to estimate emissions from international ship movement data.**

Industrial

Industrial emissions are an important source of particulate for local air quality in some locations. This inventory includes a simple top-down assessment of industrial (non-combustion) emissions. This inventory includes most major industrial sources of pollution in New Zealand with the notable exception of:

- **(i) dairy processing (especially milk powder manufacturing); and**
- **(ii) manufacture of particle board and fibre board and other wood processing;**

It is recommended that these sources be included in the next inventory.

A more detailed (accurate) assessment of industrial emissions from large point sources could be undertaken based on resource consent information held by regional councils. However, this is typically very labour intensive because there is currently no mechanism in place to regularly collect, collate and update industrial emissions data.

We recommend that **the Ministry should investigate potential options to improve accessibility and quality of industrial emissions data.** One option is to implement an OECD recommendation to *establish a pollutant release and transfer register (PRTR) to collect, and facilitate the public's access to, information on environmental impacts of private companies* (OECD, 2017). The Australian NPI is an example of a PRTR, which puts the onus on emitters to quantify and report their emissions on an annual basis. Once established, this would substantially reduce the cost and effort required to maintain comprehensive inventories of industrial emissions across local and central government.

Waste

This national inventory incorporates estimated emissions from open burning of garden waste from the 2013 national inventory (Wilton *et al* 2015). The quantity of waste disposed of by open burning was estimated in the 2013 national inventory based on the results of a household survey undertaken in 2014, as well as regional council emission inventory data where available.

New Zealand's Greenhouse Gas Inventory does not include emissions from open burning of waste. The report states that there may be some open burning of waste, but that no information is available to confirm whether this occurs or the extent of the practice (MfE, 2017). This is inconsistent with the 2013 national inventory (Wilton *et al.,* 2015). **It is recommended that further work is undertaken to reconcile the estimated quantity of waste disposed of by open burning at a national level.**

It is recommended that the estimation of emissions from open burning of waste should be regularly updated. This is likely to require household surveys (including collation of surveys undertaken for regional council emission inventories).

Non-combustion activities

Emissions of particulate from unsealed roads and construction are estimated based on international emissions factors. Previous research in New Zealand has recommended further work to improve the estimation of road dust emissions in New Zealand (Bluett *et al.*, 2017).

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Appendix A: Annual emissions summary

Table A-1: Annual emissions for 2015 from each source (t/yr)

Activity	Sector	Sub sector	Emissions				
			PM_{10}	$PM_{2.5}$	CO	NOx	SO_2
			tonnes/annum				
Energy related activities	**Fuel combustion in energy industries**	Public electricity and heat production	679	525	3,251	7,270	5,257
		Petroleum refining	14	14	257	2,026	5,336
		Manufacture of solid fuels and other energy industries	6	6	169	435	2
	Fuel combustion in manufacturing and construction		8,339	7,201	53,277	22,954	12,518
	Transport	Aviation (domestic)	12	12	1,875	2,595	173
		Aviation (international)	5	5	596	1,268	57
		On-road vehicles	3,006	3,006	151,271	47,843	90
		Rail	223	210	491	2,402	1
		Shipping (domestic)	828	748	1,089	11,564	10,114
		Other (pipeline transport)	1	1	18	46	0
	Other sectors	Commercial/ institutional	165	150	1,584	3,550	450
		Residential	11,341	11,289	200,613	1,292	463
		Agriculture/ forestry/ fishing	479	452	3,302	10,537	2,516
		Subtotal	25,096	23,617	417,791	113,782	36,977
Construction dust	**Construction dust (fugitive)**	Construction dust (fugitive)	2,076	208			
Road dust	**Unsealed road dust**		5,537	522			
	Sealed road dust		414	223			
		Subtotal	5,951	746			

Activity	Sector	Sub sector	Emissions				
			PM_{10}	$PM_{2.5}$	CO	NOx	SO_2
			tonnes/annum				
Industrial non-combustion	Mineral products		232	109	0	0	1,007
	Production of chemicals		177	140	14	137	1,822
	Metal industries		899	793	42,187	2,031	6,667
	Pulp and paper production		1,150	863	0	1,438	2,876
		Subtotal	2,459	1,905	42,201	3,606	12,372
Agriculture	Animal housings		460	41			
Field burning of agricultural residues & biomass burning	Field burning of agricultural residues		1,461	1,385	17,101	615	128
	Biomass burning: forest land		4,956	3,661	30,131	1,295	282
	Biomass burning: grasslands		1,998	1,300	15,645	1,444	84
		Subtotal	8,415	6,345	62,877	3,355	494
Waste	Incineration of quarantine waste		0	0	0	5	0
	Open burning of waste		1,643	1,643	8,625	616	103
		Subtotal	1,643	1,643	8,625	621	103
		Total	46,099	34,504	531,493	121,364	49,946

Table A-2: Fuel consumption, fuel calorific values and emission factors used by source

Sector	Sub sector	Fuel	Fuel consumption (TJ)	Fuel calorific value (Gross) MJ/kg	Emission factors				
					PM_{10} g/kg	$PM_{2.5}$ g/kg	CO kg/TJ	NOx kg/TJ	SO_2 kg/TJ
Energy industries	a. Public electricity and heat production	Diesel	13.45	45.79	0.139	0.035	16	65	0.47
		Coal: TOTAL	11,994.56						
		Coal: bituminous	629.55	29.59	1.11	0.8325	8.7	209	436
		Coal: sub-bituminous	11,233.77	21.64	1.11	0.8325	8.7	209	436
		Coal: lignite	131.24	15.26	1.11	0.8325	8.7	209	436
		Natural gas	54,676.16	41.30	0.05	0.05	39.00	82.10	0.40
		Biogas	2,092.97	41.30	0.20	0.17	484.34	130.52	2.80
	b. Petroleum refining	Crude oil	13,204.51	45.78	0.04	0.04	15	142	404.03
		Natural gas	2,043.23	41.30	0.04	0.04	29	74	0.4
	c. Manufacture of solid fuels and other energy industries	Diesel	13.00	45.79	0.867	0.867	66	513	0.46
		Natural gas	5,785.82	41.3	0.04	0.04	29	74	0.4
Manufacturing industries and construction		Liquid fuels: TOTAL	19,304.94						
		Petrol	1,407.62	46.99	0.895	0.895	66	513	0.46
		Diesel	16,234.19	45.79	0.87	1	66	513	0
		Fuel oil	1,582.52	43.91	0.804	0.804	66	513	986
		LPG	80.61	49.51	0.037	0.037	29	74	0.24
		Coal: TOTAL	22,841.73						
		Coal: bituminous	4,784.87	29.59	1.11	0.8325	931	173	436
		Coal: sub-bituminous	14,391.70	21.64	1.11	0.8325	931	173	436
		Coal: lignite	3,665.16	15.26	1.11	0.8325	931	173	436
		Natural gas	60,926.30	41.30	0.04	0.04	29	74	0.4
		Wood	50,829.55	12.08	1.6	1.4	570	91	19
Transport	a. Aviation	Domestic: LTO	8,946.07	43.33	(See Table B-1)				
		Domestic: Cruise	3,453.12	43.33	n/a				
		International: LTO	2,942.17	43.33	See Table B-2)				
		International: Cruise	37,414.50	43.33	n/a				
	b. Road transportation	Liquid fuels: TOTAL	193,327.42						
		Petrol	107,444.85	46.99	0.21	0.21	1309.10	131.93	0.46
		Diesel	85,520.30	45.79	1.35	1.35	112.77	389.83	0
		LPG	362.27	49.51	0.21	0.21	2473.00	725.00	0.24
		Natural gas	24.57	41.30	0.21	0.21	2473.00	725.00	0.42
		Biodiesel	126.04	45.79	1.35	1.35	112.77	389.83	0.46
	c. Railways	Diesel	1,986.85	45.79	5.14	4.83	247	1209	0.46
	d. Domestic Navigation	Fuel oil	5,860.03	43.91	6.2	5.6	184	1973	1725
		Coal: bituminous	11.47	29.59	1.11	0.8325	931	173	436
	e. Other transportation *(pipeline transport)*	Natural gas	627.37	41.3	0.04	0.04	29	74	0.4

Sector	Sub sector	Fuel	Fuel consumption (TJ)	Fuel calorific value (Gross) MJ/kg	Emission factors				
					PM_{10} g/kg	$PM_{2.5}$ g/kg	CO kg/TJ	NOx kg/TJ	SO_2 kg/TJ
Other sectors	a. Commercial/institutional	Liquid fuels: TOTAL	6,267.86						
		Petrol	317.18	46.99	0.895	0.895	66	513	0.46
		Diesel	4,621.56	45.79	0.87	1	66	513	0
		Fuel oil	9.00	43.91	0.804	0.804	66	513	986
		LPG	1,320.12	49.51	0.037	0.037	29	74	0.24
		Coal: TOTAL	996.82						
		Coal: bituminous	30.33	29.59	1.11	0.83	931.00	173.00	436
		Coal: sub-bituminous	522.08	21.64	1.11	0.83	931.00	173.00	436
		Coal: lignite	444.42	15.26	1.11	0.83	931.00	173.00	436
		Natural gas	8,869.43	41.30	0.04	0.04	29	74	0.4
		Biogas	1,159.16	41.30	0.04	0.04	29.00	74.00	0.40
	b. Residential	Liquid fuels: TOTAL	3,132.10						
		Diesel	105.51	45.79	0.867	0.867	66	513	0.46
		LPG	3,026.59	49.51	0.32	0.31	26	51	0.24
		Coal: TOTAL	391.59						
		Coal: bituminous	8.27	29.59	19.90	17.51	5082.30	73.92	450
		Coal: sub-bituminous	201.75	21.64	19.90	17.51	5082.30	73.92	450
		Coal: lignite	181.56	15.26	19.90	17.51	5082.30	73.92	450
		Natural gas	6,782.92	41.30	0.061	0.061	26	51	0.4
		Wood	17,115.68	12.08	8	8	11589	41	17
	c. Agriculture/forestry/fishing	Liquid fuels: TOTAL	19,663.25						
		Petrol	1,433.74	46.99	0.895	0.895	66	513	0.46
		Diesel	16,535.51	45.79	0.87	1	66	513	0
		Fuel oil	1,611.89	43.91	0.804	0.804	66	513	986
		LPG	82.11	49.51	0.037	0.037	29	74	0.24
		Coal: TOTAL	2,104.36						
		Coal: bituminous	113.00	29.59	1.11	0.83	931.00	173.00	436
		Coal: sub-bituminous	1,959.06	21.64	1.11	0.83	931.00	173.00	436
		Coal: lignite	32.30	15.26	1.11	0.8325	931	173	436
		Natural gas	1,647.07	41.3	0.04	0.04	29	74	0.4

Appendix B: Emission factors by aircraft type for domestic and international flights

Table B-1: Emission factors and number of LTOs (for one week) by aircraft type for domestic flights at Auckland International Airport (EEA, 2016)

IATA Code	ICAO Code	Manufacturer & aircraft	Type of model	Engine type	Engine ID	No. engines	LTO emission factors						No. of LTOs
							Fuel consumption (kg)	PM_{10} (kg)	$PM_{2.5}$ (kg)	CO (kg)	NOx (kg)	SO_2 (kg)	
76F	n/a	Boeing 767 all Freighter models	B767 200	Jet	1GE012	2	1,462.66	0.16	0.16	14.80	23.76	1.23	2
320	A320	Airbus A320-100/200	A320 233	Jet	3CM026	2	816.17	0.07	0.07	8.25	11.28	0.69	860
AT7	AT72	Aerospatiale/Alenia ATR 72	ATR72 212 F	Turboprop	Turboprop	2	242.76	0.00	0.00	1.54	2.34	0.20	1
ATR	AT75	Aerospatiale/Alenia ATR 72-500	ATR72 212 F	Turboprop	Turboprop	2	242.76	0.00	0.00	1.54	2.34	0.20	369
ATR	AT76	Aerospatiale/Alenia ATR 72-600	ATR72 212 F	Turboprop	Turboprop	2	242.76	0.00	0.00	1.54	2.34	0.20	29
738	B738	Boeing 737-800 (winglets)	B737 800	Jet	8CM051	2	881.10	0.07	0.07	7.07	12.30	0.74	1
763	B763	Boeing 767-300 pax	B767 300	Jet	12PW101	2	1,729.93	0.16	0.16	29.65	26.67	1.45	4
CV5	CVLT	Convair CV-580 pax	L188PF	Turboprop	Turboprop	4	856.47	0.00	0.00	0.00	0.88	0.72	3
DH3	DH8C	De Havilland Canada DHC-8-300 Dash 8 / 8Q	DHC8 314Q	Turboprop	Turboprop	2	242.08	0.00	0.00	1.54	2.33	0.20	721
SF3	SF34	Saab SF340A/B	SF340A	Turboprop	Turboprop	2	145.06	0.00	0.00	0.95	0.89	0.12	55
SF3	SF34	Saab SF340A/B	SF340A	Turboprop	Turboprop	2	145.06	0.00	0.00	0.95	0.89	0.12	18
SWM	n/a	Fairchild (Swearingen) SA26 / SA226 / SA227 Metro / Merlin / Expediter	SA 226TC METRO II	Turboprop	Turboprop	2	86.48	0.00	0.00	1.23	0.62	0.07	38

Table B-2: Emission factors and number of LTOs (for one week) by aircraft type for international flights at Auckland International Airport (EEA, 2016)

IATA Code	ICAO Code	Manufacturer & aircraft	Type of model	Engine type	Engine ID	No. engines	LTO emission factors						No. of LTOs
							Fuel consumption (kg)	PM_{10} (kg)	$PM_{2.5}$ (kg)	CO (kg)	NOx (kg)	SO_2 (kg)	
73H	B738	Boeing 737-800 (winglets)	B737 800	Jet	8CM051	2	881.10	0.07	0.07	7.07	12.30	0.74	30
74F	B744	Boeing 747 all Freighter models	B747 400	Jet	2GE045	4	3,319.68	0.21	0.21	25.27	44.45	2.79	2
74Y	n/a	Boeing 747-400 Freighter	B747 400	Jet	2GE045	4	3,319.68	0.21	0.21	25.27	44.45	2.79	3
75F	B752	Boeing 757 Freighter	B757 200	Jet	5RR038	2	1,362.60	0.16	0.16	12.25	14.98	1.14	4
76F	n/a	Boeing 767 all Freighter models	B767 200	Jet	1GE012	2	1,462.66	0.16	0.16	14.80	23.76	1.23	2
320	A320	Airbus A320-100/200	A320 233	Jet	3CM026	2	816.17	0.07	0.07	8.25	11.28	0.69	189
330	A330	Airbus A330 all models	A330 201	Jet	14RR071	2	2,168.08	0.16	0.16	21.19	35.32	1.82	3
332	A332	Airbus A330-200	A330 201	Jet	14RR071	2	2,168.08	0.16	0.16	21.19	35.32	1.82	91
333	A333	Airbus A330-300	A330 322	Jet	14RR071	2	2,168.08	0.16	0.16	21.19	35.32	1.82	35
343	A343	Airbus A340-300	A340 313	Jet	2CM015	2	2,019.89	0.50	0.50	25.23	34.81	1.70	6
359	A359	Airbus A350-900	A350 941	Jet	14RR075	2	2,137.98	0.16	0.16	19.55	40.49	1.80	16
388	A388	Airbus A380-800	A380 842	Jet	8RR046	4	4,142.40	0.25	0.25	29.62	67.26	3.48	41
737	B737	Boeing 737 all pax models	B737 75R	Jet	3CM032	2	824.65	0.07	0.07	8.00	10.30	0.69	10
738	B738	Boeing 737-800 (winglets)	B737 800	Jet	8CM051	2	881.10	0.07	0.07	7.07	12.30	0.74	203
744	B744	Boeing 747 all Freighter models	B747 400	Jet	2GE045	4	3,319.68	0.21	0.21	25.27	44.45	2.79	9
75F	B752	Boeing 757 Freighter	B757 200	Jet	5RR038	2	1,362.60	0.16	0.16	12.25	14.98	1.14	9
763	B763	Boeing 767-300 pax	B767 300	Jet	12PW101	2	1,729.93	0.16	0.16	29.65	26.67	1.45	6
772	B772	Boeing 777-200 pax	B777 200	Jet	8GE100	2	2,406.41	0.16	0.16	12.31	61.24	2.02	109
777	B777	Boeing 777 all pax models	B777 300ER	Jet	7GE099	2	3,090.84	0.21	0.21	47.54	69.79	2.60	1
		Manufacturer & aircraft	T y p e	E n g i	E n g i	N o	**LTO emission factors**						N o

IATA Code	ICAO Code						Fuel consumption (kg)	PM_{10} (kg)	$PM_{2.5}$ (kg)	CO (kg)	NOx (kg)	SO_2 (kg)	
77L	B77L	Boeing 777-200LR	B777 300ER	Jet	7GE099	2	3,090.84	0.21	0.21	47.54	69.79	2.60	15
77W	B77W	Boeing 777 300ER	B777 300ER	Jet	7GE099	2	3,090.84	0.21	0.21	47.54	69.79	2.60	85
788	B788	Boeing 787-8	B787 800	Jet	11GE136	2	1,592.36	0.09	0.09	14.51	17.15	1.34	4
789	B789	Boeing 787-9	B787 900	Jet	12RR055	2	1,726.66	0.10	0.10	6.80	34.52	1.45	151
M11	MD11	McDonnell Douglas MD11 pax	MD11ER F	Jet	2GE049	2	2,627.91	0.17	0.17	18.28	38.17	2.21	1

Appendix C: Data & assumptions

Units

Further to the GAP Forum Manual, the SI system of units has been employed for this inventory. The basic unit of weight is the gram (g) and the basic unit of energy is the joule (J). Units of greater magnitude are denoted by the following multiple prefixes.

P	peta	10^{15}
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}

Thus one kilogram (kg) equals one thousand (10^3) grams, one megagram (Mg) equals 10^6 grams and a petajoule (PJ) equals 10^{15} joules. A common SI alternative to the Mg is the ”metric tonne” (t), also equal to 10^6 grams, and this is used throughout the inventory.

Conversion factors are provided in **Table C-1** (energy) and **Table C-2** (mass).

Table C-1: Energy conversion factors

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	Multiply by:				
Terra Joules (TJ)	1	238.8	2.388×10^{-5}	947.8	0.2778
Giga calories (Gcal)	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mega tonnes oil equivalent (Mtoe)	4.1868×10^{-4}	10^{7}	1	3.968×10^{7}	11,630
Mega British thermal units (MBtu)	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
Giga Watt hours (GWh)	3.6	860	8.6×10^{-5}	3412	1

Table C-2: Mass conversion factors

To:	kg	t	lt	st	lb
From:	Multiply by:				
Kilogramme (kg)	1	0.001	9.84×10^{-4}	1.102×10^{-3}	2.2046
Tonne (t)	1,000	1	0.984	1.1023	2,204.6
Long ton (lt)	1,016	1.016	1	1.120	2,240.0
Short ton (st)	907.2	0.9072	0.893	1	2,000
Pound (lb)	0.454	4.54×10^{-4}	4.46×10^{-4}	5.0×10^{-4}	1

Fuel categories and properties

As defined by the international Energy Agency (IEA) in their Statistics and Balances databases. Presented in the order in which they are listed in the energy worksheets of the Forum Manual.

Coal

Sulphur content of 0.6% was assumed for all types of coal. This was the average sulphur content of coal reported in the NZ SO_2 Industrial Emissions Inventory (Wilton et al 2008).

Bituminous coal & anthracite

Bituminous coal is used for steam raising and space heating purposes and includes all anthracite coals and bituminous coals. Its average gross calorific value is 29.59 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

Sub-bituminous coal

Sub-bituminous coal is a non-agglomerating coal used for steam raising and space heating and has an average gross calorific value of 21.64 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

Lignite/brown coal

Lignite/brown coal is a non-agglomerating coal with an average gross calorific value of 15.26 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

Natural gas

Natural gas comprises gases, occurring in underground deposits, whether liquefied or gaseous, consisting mainly of methane. It includes both "non-associated" gas originating from fields producing only hydrocarbons in gaseous form, and "associated" gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas). Production is measured after extraction of natural gas liquid (NGL) and sulphur, and excludes re-injected gas, quantities vented or flared. It includes gas consumed by gas processing plants and gas transported by pipeline.

The gross calorific values for New Zealand natural gas is assumed to be 41.3 MJ/m^3, which is the value for processed Kapuni and McKee gas (Ministry of Business, Innovation & Employment, 2017).

Crude oil

Crude oil is a mineral oil consisting of a mixture of hydrocarbons of natural origin, being yellow to black in colour, of variable density and viscosity. It also includes lease condensate (separator liquids) which are recovered from gaseous hydrocarbons in lease separation facilities.

The gross calorific value of crude oil is assumed to be 45.5 MJ/kg which is the average of the top ten crudes used at the New Zealand Refinery (Ministry of Business, Innovation & Employment, 2017).

Natural gas liquids (NGL)

NGLs are the liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. These are those portions of natural gas which are recovered as liquids in separators, field facilities, or gas processing plants. NGLs include but are not limited to ethane, propane, butane, pentane, natural gasoline and condensate.

The net average calorific value for (Kapuni, Kupe and Maui) condensates is 43.83 MJ/kg (Ministry of Business, Innovation & Employment, 2012).

Liquefied petroleum gases (LPG)

These are the light hydrocarbons fraction of the paraffin series, derived from refinery processes, crude oil stabilisation plants and natural gas processing plants comprising propane (C_3H_8) and butane (C_4H_{10}) or a combination of the two. They are normally liquefied under pressure for transportation and storage.

The average gross calorific value of New Zealand LPG is 49.51 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

Petrol

This is light hydrocarbon oil for use in internal combustion engines such as motor vehicles, excluding aircraft. Petrol is distilled between 35°C and 215°C and is used as a fuel for land based spark ignition engines. Petrol may include additives, oxygenates and octane enhancers. New Zealand motor vehicle fuel no longer includes lead compounds such as TEL (Tetraethyl lead) and TML (tetramethyl lead).

The gross calorific values of regular and premium unleaded fuel in New Zealand are 46.99MJ/kg (regular) and 46.92 MJ/kg (premium) respectively (Ministry of Business, Innovation & Employment, 2017).

The sulphur content of petrol was assumed to be 10ppm, which is the regulated maximum.

Aviation gasoline (Av gas)

The average gross calorific value of New Zealand aviation gasoline is 47.3 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

Sulphur content of 0.08% sulphur was assumed for aviation gasoline (EEA, 2016).

NB: Jet fuel (used in jet turbines) is not aviation gasoline (used in piston aircraft).

Gasoline type jet fuel (Jet kerosene)

This includes all light hydrocarbon oils for use in aviation turbine power units. They distil between 100°C and 250°C. It is obtained by blending kerosene and gasoline or naphtha in such a way that the aromatic content does not exceed 25 percent in volume. Additives can be included to improve fuel stability and combustibility.

The average gross calorific value of New Zealand jet fuel is 46.29 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

Sulphur content of 0.05% was assumed for jet kerosene (GAP Forum Manual default value)

Diesel

Diesel includes heavy gas oils. Gas oils are obtained from the lowest fraction from atmospheric distillation of crude oil, while heavy gas oils are obtained by vacuum re-distillation of the residual from atmospheric distillation. Gas/diesel oil distils between 180°C and 380°C. Several grades are available depending on uses: diesel oil for diesel compression ignition (cars, trucks, marine, etc.), light heating oil for industrial and commercial uses, and other gas oil including heavy gas oils which distil between 380°C and 540°C and which are used as petrochemical feedstocks.

The average gross calorific values of New Zealand automotive diesel is 45.79 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

The sulphur content of diesel was assumed to be 10ppm, which is the regulated maximum.

Fuel oil

This heading defines oils that make up the distillation residue. It comprises all residual fuel oils, including those obtained by blending.

The sulphur content of fuel oil for all combustion except shipping was assumed to be 2%. This was the average sulphur content of fuel oil reported in the NZ SO_2 Industrial Emissions Inventory (Wilton et al 2008). The gross calorific value of fuel oil for all combustion except shipping was assumed to be the light fuel oil value of 43.91 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

Fuel oil for shipping

The gross calorific value of fuel oil for shipping was assumed to be the bunker fuel value of 42.67 MJ/kg (Ministry of Business, Innovation & Employment, 2017).

The sulphur content of marine fuel oil was assumed to be 3.5%. This is the current global limit established by the IMO (http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/FAQ_2020_English.pdf).

Biomass

Biomass is defined as any plant matter used directly as fuel or converted into other forms before combustion. Included are wood, vegetal waste (including wood waste and crops used for energy production), animal materials/wastes, sulphite lyes, also known as "black liquor" (an alkaline spent liquor from the digesters in the production of sulphate or soda pulp during the manufacture of paper where the energy content derives from the lignin removed from the wood pulp) and other solid biomass.

The average net calorific value of New Zealand fuel wood is 10.3 MJ/kg (Ministry of Business, Innovation & Employment, 2012).

Biogas

Biomass gases are derived principally from the anaerobic fermentation of biomass and solid wastes and combusted to produce heat and/or power. Included in this category are landfill gas and sludge gas (sewage gas and gas from animal slurries).

Default calorific values were used to estimate emissions from biogas combustion.

Liquid biomass

Liquid biomass includes bio-additives such as ethanol. Default calorific values were used to estimate emissions from liquid biofuels combustion.

Default sulphur ash retention

Assumed sulphur retention in ash factors from the GAP Forum Manual are provided in **Table C-3**.

Table C-3: Default sulphur ash retention factors

Fuel	Sectors	Sulphur retention in ash (%)
Hard coal (i.e. bituminous, anthracite)	Power generation and Industry Transport and Other Sectors (Commercial/Institutional, Residential and Agriculture/Forestry/Fishing)	5 22.5
Brown coal (sub-bituminous/ lignite)	All sectors	25
Solid biomass	All sectors	Negligible
Liquid and gaseous fuels	All sectors	0

Appendix D: Source estimate metadata

Title	**Fuel production**
Source	National air emissions inventory - 2015
Description	Annual emissions generated from the production of fuel at refineries in New Zealand.
Variables	Refinery fuel consumption for 1999 (TJ/yr) Emission factors
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal, 2012)
Limitations to data & analysis	Fugitive and non-combustion emissions not quantified. Emission factors: • PM_{10} emission factor derived from an emission reported for 1999 (Wilton *et al*., 2012) • SO_2 emission factor derived from the *New Zealand Sulphur Dioxide Industrial Emission Inventory – 2007* (Wilton *et al.* 2008)
Changes to time series	
References	Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York. Wilton *et al*. (2008) *New Zealand Sulphur Dioxide Industrial Emission Inventory - 2007*. Report prepared by Emily Wilton, Melanie Baynes and John Iseli. Wilton *et al*. (2012) *Airshed modelling for PM_{10} concentrations - Marsden point.* Prepared for Northland Regional Council by Environet Ltd and University of Canterbury.

<table>
<tr><td>Title</td><td>Public electricity and heat production</td></tr>
<tr><td>Source</td><td>National air emissions inventory - 2015</td></tr>
<tr><td>Description</td><td>Annual emissions generated from electricity and heat production in New Zealand</td></tr>
<tr><td>Variables</td><td>Fuel consumption (TJ/yr)
Emission factors (g/kg)</td></tr>
<tr><td>Coverage</td><td>National</td></tr>
<tr><td>Methodology (collection & analyses)</td><td>GAP Forum Manual (Vallack & Rypdal (2012)</td></tr>
<tr><td>Limitations to data & analysis</td><td>Emission factors (based on NZ fuel properties):
Coal PM_{10} is the average emission factor for industrial coal combustion from the NZ 2013 national inventory (Wilton et al., 2015)
NOx from gas combustion default values based on:
31% gas consumption in public electricity and heat sector has low NOx burners.
25% reduction in NOx from low NOx burners (Vallack & Rypdal (2012)
No other NOx control assumed.</td></tr>
<tr><td>Changes to time series</td><td></td></tr>
<tr><td>References</td><td>Ministry for the Environment (MfE) (2017). New Zealand’s Greenhouse Gas Inventory 1990-2015. Wellington. May.

Vallack & Rypdal (2012). The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual. Version 5.0. Stockholm Environment Institute. York University of York.

Wilton et al. (2015). Home heating emission inventory and other sources evaluation. Prepared for Ministry for the Environment and Statistics NZ by Environet Ltd and Golders Associates.</td></tr>
</table>

Title	**Other sectors – Fuel combustion in manufacturing and construction**
Source	National air emissions inventory - 2015
Description	Annual emissions generated from electricity and heat production in New Zealand
Variables	Fuel consumption (TJ/yr) Emission factors – based on NZ fuel properties (g/kg)
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal (2012)
Limitations to data & analysis	Emission factors (based on NZ fuel properties): • Coal, PM_{10} average emission factor for industrial coal combustion from the NZ 2013 national inventory (Wilton *et al*., 2015). • $PM_{2.5}$ was assumed to be 75% of PM_{10} (based emission factor for Vekos boiler with multiple cyclone). • Wood, PM_{10} and $PM_{2.5}$ emission factor for wood boilers assumed in the NZ 2013 national inventory (Wilton *et al*., 2015).
Changes to time series	
References	Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York. Wilton *et al*. (2015). *Home heating emission inventory and other sources evaluation*. Prepared for Ministry for the Environment and Statistics NZ by Environet Ltd and Golders Associates.

Title	**Transport - Aviation**
Source	National air emissions inventory – 2015
Description	Emissions from aircraft movements across all airports (attended and unattended) in New Zealand.
Variables	Aircraft movements (annual) Fuel consumption (TJ) Emission factors in kg/LTO
Coverage	National
Methodology (collection & analyses)	Tier 1 EMEP/EEA methodology (EEA, 2016) for aircraft emissions.
Limitations to data & analysis	Emissions are only estimated for aircraft movements below 915 m in altitude. Without a detailed analysis of aircraft operating at each airport in New Zealand, the following assumptions were made: • Fleet weighted emission factors calculated for domestic and international flights based on a week's schedule at Auckland International Airport.
Changes to time series	
References	Airways (2017). *1703-Movement-Stats-by-Year*. Spreadsheet prepared by Airways Corporation Ltd. EEA (2016). *Air pollutant emission inventory guidebook – 2016*. European Environment Agency Report No 21/2016 Ministry of Business, Innovation & Employment (MBIE) (2017). *Energy in New Zealand 2017: 2016 Calendar Year Edition.* Wellington.

Title	**Transport – On-road motor vehicles**
Source	National air emissions inventory - 2015
Description	Emissions generated from on-road motor vehicles in New Zealand
Variables	Fuel consumption (TJ/yr) Emission factors: Petrol and diesel – fleet weighted emission factors from VEPM 5.3 (Metcalfe & Sridhar, 2017)
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal (2012)
Limitations to data & analysis	Assumed average speed of 80km/hour on state highways and 40km/hr on local roads. Assumed 49% of vehicle travel occurred on state highways and 51% of travel occurred on local roads (NZTA, 2018) Emission factors: • Biodiesel emission factors assumed the same as diesel emission factors (from VEPM 5.3). • LPG emission factors were default values from the GAP Forum Manual (Vallack & Rypdal (2012)
Changes to time series	
References	Metcalfe & Sridhar (2017). *VEPM 5.3 Vehicle Emission Prediction Model Update: technical report*. Report for New Zealand Transport Agency prepared by Emission Impossible Ltd. Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. NZTA (2018). *Vehicle Kilometres Travelled Trend for New Zealand*. Website accessed 31 Jan 2018. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York.

Title	**Transport – Off-road, rail & shipping**
Source	National air emissions inventory - 2015
Description	Emissions from off-road vehicles, railway locomotives and shipping within New Zealand
Variables	Fuel consumption (TJ/yr) Emission factors (g/kg)
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal (2012)
Limitations to data & analysis	Estimates are dependent upon the accuracy of reported fuel consumption for these activities. Emission factors (Vallack & Rypdal, 2012): • rail based on NZ fuel properties • shipping based on international fuel properties
Changes to time series	
References	Ministry of Business, Innovation & Employment (MBIE), (2017). *Energy in New Zealand 2017: 2016 Calendar Year Edition.* Wellington. Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York.

Title	**Other sectors: Residential**
Source	National air emissions inventory - 2015
Description	Emissions from residential home heating in New Zealand.
Variables	Wood consumption for 2013(TJ/yr) (Wilton *et al*. 2015) Coal consumption 2015 (TJ/yr) (MfE, 2017) Emission factors (g/kg)
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal (2012)
Limitations to data & analysis	Emission factors: • Average PM_{10} emission factors for residential wood and coal from the 2013 inventory (Wilton *et al*., 2015) • Coal, CO and NOx were the multifuel burner emission factors (Wilton *et al*., 2015). • Coal, SO_2 was the GAP Forum Manual default value based on New Zealand fuel properties. (Vallack & Rypdal, 2012; MBIE, 2017) • Wood, CO, NOx and SO_2 were the older wood burner emission factors (Wilton et al 2015). • $PM_{2.5}$ was assumed to be 100% of PM_{10} for wood and 88% of PM_{10} for coal.
Changes to time series	
References	Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Ministry of Business, Innovation & Employment (MBIE), (2017). *Energy in New Zealand 2017: 2016 Calendar Year Edition.* Wellington. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York. Wilton *et al*. (2015). *Home heating emission inventory and other sources evaluation*. Prepared for Ministry for the Environment and Statistics NZ by Environet Ltd and Golders Associates.

Title	**Other sectors: commercial/institutional and Agriculture/forestry/fishing**
Source	National air emissions inventory - 2015
Description	Annual emissions from commercial/institutional and agriculture/forestry/fishing activities in New Zealand.
Variables	Fuel consumption (TJ/yr) Emission factors (g/kg)
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal (2012)
Limitations to data & analysis	Emission factors: Default values from the GAP Forum Manual (based on New Zealand fuel properties) except as follows: • Coal, PM_{10} assumed average emission factor for industrial coal combustion (Wilton *et al*., 2015). • $PM_{2.5}$ was assumed to be 75% of PM_{10} (based on emission factor for Vekos boiler with multiple cyclone). • Wood, PM_{10} and $PM_{2.5}$ emission factor for wood boilers assumed in the NZ 2013 national inventory (Wilton *et al*., 2015).
Changes to time series	
References	Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York. Ministry of Business, Innovation & Employment (MBIE), (2017). *Energy in New Zealand 2017: 2016 Calendar Year Edition.* Wellington. Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Wilton *et al*. (2015). *Home heating emission inventory and other sources evaluation*. Prepared for Ministry for the Environment and Statistics NZ by Environet Ltd and Golders Associates.

Title	**Construction dust (fugitive emissions)**
Source	National air emissions inventory - 2015
Description	Annual fugitive emissions from new building and road construction activities in New Zealand.
Variables	Floor area (m2) Lane km of road construction and reconstruction Conversion factor from floor area to total construction footprint Duration of construction (year) Control efficiency Emission factors (kg/m2/yr)) Silt content (%) Soil moisture content (%)
Coverage	National
Methodology (collection & analyses)	EMEP/EEA Tier 1 methodology
Limitations to data & analysis	Emissions estimates are sensitive to percentage of silt content and soil moisture content. There is no New Zealand specific data for these variables.
Changes to time series	
References	EEA (2016). *Air pollutant emission inventory guidebook – 2016*. European Environment Agency Report No 21/2016 NZTA (2018b). *New and Improved Roads Trend for New Zealand.* Website accessed 5 Mar 2018.

Title	**Unsealed road dust**
Source	National air emissions inventory - 2015
Description	Road dust is the generation and release of particulate matter into the air, mainly from the interaction between a vehicle's wheels and the road surface.
Variables	Vehicle kilometres travelled (VKT) Number of annual dry days Speed (kms)
Coverage	Regional and national
Methodology (collection & analyses)	US EPA methodology (US EPA, 2006)
Limitations to data & analysis	The following assumptions were made: • Proportion of heavy vehicles travelling on unsealed local roads based on local council data where available. The local council data was assumed to apply to the whole region. For regions without local council data, the average of all data was assumed (11.5%) • Heavy vehicle weight assumed to be 9.3t based on Ministry of Transport's FT012 indicator for *Average load (tonnes) of heavy vehicles* for 2015. • Dry days assumed as days with <1mm of rainfall recorded at each site. • One site's rainfall record from each region used to represent the region.
Changes to time series	
References	MoT (2018). *Freight and the transport industry: Road freight efficiency - FT012 Average load (tonnes) of heavy vehicles* [Website: Accessed 13 Feb 2018] NIWA (2018). *CliFlo database*. [Database: Accessed 12 Feb 2018] NZTA (2018). *Vehicle kilometres travelled trend for New Zealand* [Website: Accessed 31 Jan 2018] US EPA (2006). *AP42 Miscellaneous Sources, Unpaved roads (section 13.2.2).* Research Triangle Park, NC: Office of Air Quality Planning & Standards, US Environmental Protection Agency.

Title	**Sealed road dust**
Source	National air emissions inventory - 2015
Description	An estimate of particulate emissions from sealed road abrasion.
Variables	Vehicle kilometres travelled (VKT) by vehicle class
Coverage	National
Methodology (collection & analyses)	EMEP/EEA methodology (EEA, 2016)
Limitations to data & analysis	
Changes to time series	
References	MOT (2018b)

Title	**Industrial processes**
Source	National air emissions inventory - 2015
Description	Annual emissions from industrial processes that generate by-product emissions that are not from fuel combustion
Variables	Process activity data (MfE, 2017) Emission factors (European guidance or NZ specific) – see Table 2-8 of report for specific source references
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal (2012)
Limitations to data & analysis	
Changes to time series	
References	EEA (2016). *Air pollutant emission inventory guidebook – 2016*. European Environment Agency Report No 21/2016 Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York.

Title	**Agriculture**
Source	National air emissions inventory - 2015
Description	Annual particulate emissions from animal housing.
Variables	Number of animals housed (MfE, 2017) • Housing of chickens (Statistics NZ) Emission factors (Vallack & Rypdal, 2012)
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal, 2012)
Limitations to data & analysis	No New Zealand based data for animal housing except chickens. Assumptions made as follows: • 1% of beef cattle are housed, • 0% of dairy cattle are housed, • 100% of sows and pigs are housed, • 80% of hens and broilers are housed.
Changes to time series	
References	EEA (2016). *Air pollutant emission inventory guidebook – 2016*. European Environment Agency Report No 21/2016 Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York. Statistics NZ

Title	**Field burning of agricultural residues and biomass burning**
Source	National air emissions inventory - 2015
Description	Annual emissions from burning agricultural residues and biomass burning
Variables	Total biomass burning (kt dry matter) (MfE, 2017) Emission factors
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal , 2012)
Limitations to data & analysis	
Changes to time series	
References	Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York.

Title	**Treatment and disposal of waste**
Source	National air emissions inventory - 2015
Description	Annual emissions from the incineration of medical, quarantine, hazardous waste and sewage sludge. Annual emissions from open burning of garden waste.
Variables	Amount of quarantine waste (MfE, 2017), Amount of waste disposed of by open burning (Wilton *et al*, 2015) Emission factors (GAP manual)
Coverage	National
Methodology (collection & analyses)	GAP Forum Manual (Vallack & Rypdal, 2012)
Limitations to data & analysis	
Changes to time series	
References	Ministry for the Environment (MfE) (2017). *New Zealand's Greenhouse Gas Inventory 1990-2015*. Wellington. May. Vallack & Rypdal (2012). *The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual.* Version 5.0. Stockholm Environment Institute. York University of York.