Auckland Air Emissions Inventory 2016 Industry

Paul Crimmins

August 2018 Technical Report 2018/019

Auckland Council
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Resource Consents

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Executive summary

Periodically, the quantities of air pollutants discharged into air throughout the Auckland region are estimated through comprehensive emission inventories. For the 2016 emission inventory, the main source categories have been separately considered for future inclusion in a summary report.

This report updates previous inventories to estimate the quantities of various air pollutants emitted in 2016 from consented industrial point sources (predominantly chimney stacks).

Industry is commonly associated with discharges of contaminants into air. In 2006 industrial point sources contributed 15 per cent (476 tonnes) of Auckland's total anthropogenic fine particulate emissions (Xie, et al., 2014).

This update demonstrates that closures and upgrades to consented industries throughout Auckland have greatly reduced these emissions. Industrial point sources are estimated to have discharged 302 tonnes of fine particulate matter less than 10µm in diameter (PM_{10}) in 2016, 34 per cent reduction in estimated industrial emissions over a decade. This reduction however did not achieve the targeted 50 per cent reduction of PM_{10} emissions from 2006 levels, as set by the Auckland Plan (Auckland Council, 2012).

Notable industrial discharges that ceased between 2006 and 2016 include Auckland's two thermal power stations, the Pacific Steel smelting facility, and the New Lynn brickworks. These industries collectively represented 1055 tonnes of nitrogen oxide (NO_x) emissions in 2006, a third of Auckland's total emissions that were estimated to occur at that time.

Numerous other consented industries have implemented major air pollution controls since 2006, resulting in significant declines, particularly for PM_{10} emissions. For example, the O-I Glass smelter in Penrose upgraded the emission control system of its glass furnaces in 2012 to reduce PM_{10} emissions from an estimated 40 tonnes in 2006 to four tonnes in 2016.

Compared to other international cities, there are few significant heavy industrial activities in the Auckland urban area. Reticulated natural gas is the dominant method of generating heat and energy for Auckland's industries. The only industrial site that consumes significant quantities of coal is NZ Steel at Glenbrook, near to the southern boundary of the Auckland region, approximately 40km to the south of the Auckland CBD. NZ Steel is the largest industrial emitter of all common air pollutants in the Auckland region, with its emissions of fine particulates estimated to account for 80 per cent of all point source mass emissions from Auckland's consented industrial sites. Within the Auckland urban boundary, industry is estimated to have emitted 47.6 tonnes of PM_{10} and 775 tonnes of NO_x in 2016.

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1.0 Introduction

1.1 Emission inventories

Emission inventories quantify the amounts of air pollutants discharged by various sources over a specific time period within a geographical area. They are a key tool for air quality management, as they assist to identify key sources of air pollutants for the prioritisation and tracking of improvement policies.

This emission inventory details emissions from consented industrial point sources in 2016 (calendar year). It follows previous studies undertaken for 2011 (Grange & Xie, 2015), 2009, and 2006 (Kevern, et al., 2009).

These previous studies were iterative updates, utilising the same quantification methodologies and tools. Generally minor changes to emissions of air pollutants from consented industrial point sources were estimated to have occurred between the iterations.

The most recent complete Auckland Air Emissions Inventory (for all pollutants discharged by all anthropogenic sources) was completed for 2006 (Xie, et al., 2014). In the 2006 inventory, consented industrial point source emissions were estimated to comprise 15% of the total particulate matter discharged across the region (approximately 476 tonnes of the 3170 tonnes total). The contribution of industrial point source emissions to other total air pollutant emissions varied between 2% (carbon monoxide) and 52% (carbon dioxide).

The previous industrial emission inventories utilised a complex workbook of multiple spreadsheets. Due to its initial complexity and multiple edits and additions since it was first created in 2006, the workbook was considered to be unwieldy when completing the 2011 update (Grange & Xie, 2015). This 2016 update has created a new database in accordance with the recommendations of the 2011 update.

1.2 Industry in Auckland

Compared to other global cities, Auckland has a small industrial economic sector. The effects of the global financial crisis and other economic and efficiency factors have reduced this base, with a number of industries closing or shifting production outside of the region over the past decade (Infometrics, 2009).

The remaining industries are generally centred around key industrial hubs, most notably Penrose/Otahuhu/Onehunga, East Tamaki, Wiri and the Rosebank Peninsula. These industrial areas are within the urban limits, as defined by the Rural

Urban Boundary of the Auckland Unitary Plan (Operative in Part, AUP(OP)), Auckland Council, 2016).

Auckland's single most significant industrial site – in terms of manufacturing volumes, employment and air emissions – is the Bluescope New Zealand Steel Ltd (NZ Steel) steel mill. This site is located outside of the Rural Urban Boundary in rural Glenbrook, near to the region's southern boundary.

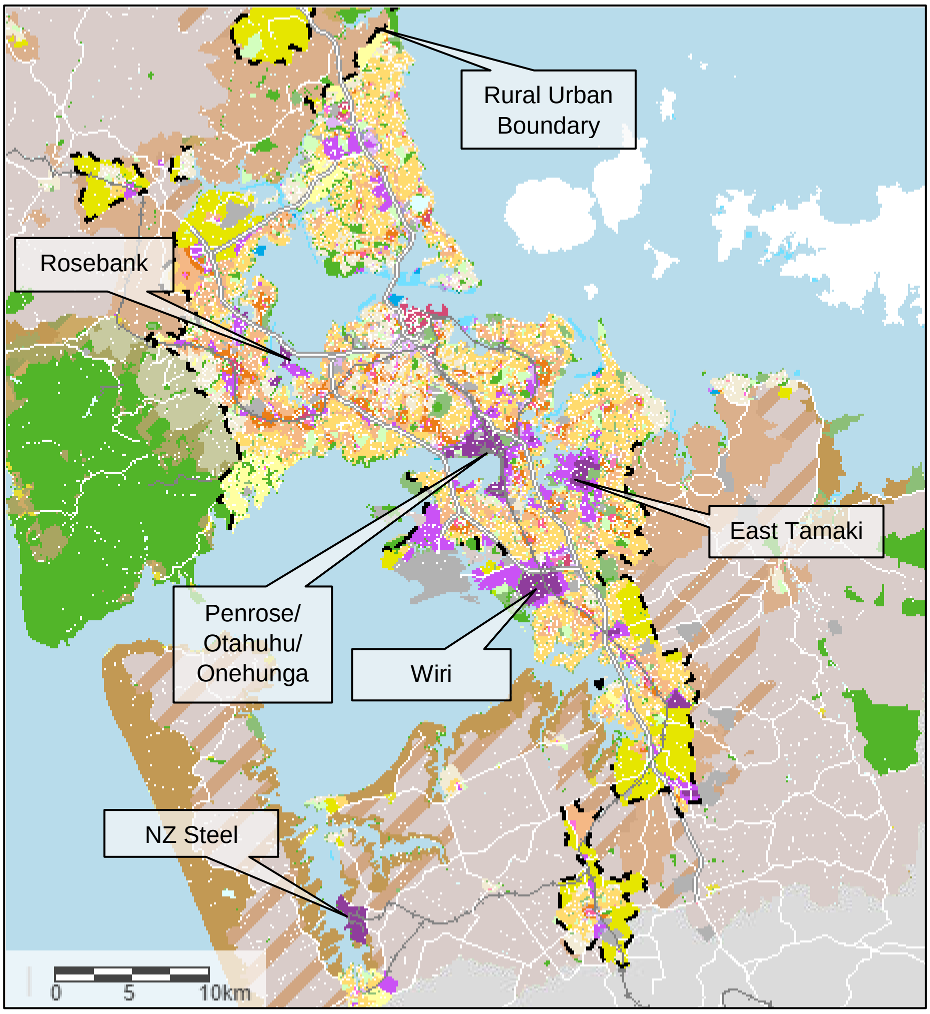

Figure 1: Map of Auckland's significant industrial areas (in purple) with Rural Urban Boundary in black dashed line

1.3 Considered air pollutants and emission sources

This emission inventory calculates discharges of a number of common air pollutants from point sources at consented industrial facilities. Point sources are typically chimney stacks, but vents have also been included where the emissions were able to be quantified. Air pollutant emissions from stacks can be accurately quantified by source emission testing methods set by the US Environmental Protection Agency

(US EPA) or by estimating emissions from combustion sources through emission factors.

The air pollutants considered are:

- particulate matter, categorised by size fractions:
    - Total Suspended Particulate (TSP), all airborne particulate matter captured on a filter, typically up to 100µm in diameter
    - fine particulate matter less than 10µm in aerodynamic diameter (PM_{10})
    - fine particulate matter less than 2.5µm in aerodynamic diameter ($PM_{2.5}$)
- nitrogen oxides (NO_x), as nitrogen dioxide (NO_2)
- sulphur dioxide (SO_2)
- carbon monoxide (CO)
- carbon dioxide (CO_2)
- volatile organic compounds (VOCs), any non-methane hydrocarbon compound with a vapour pressure less than 0.27kPa at 25°C.

A brief discussion of the emerging air pollutant black carbon (BC) is also contained within the discussion of particulate emissions.

1.4 Excluded air pollutants and emission sources

Previous industrial air emission inventories for Auckland attempted to quantify the discharges of specific types of VOCs. This made the database unnecessarily complex, particularly as the majority of industrial sites report VOC discharges as total VOCs. This emission inventory does not include information on the particular species of VOCs emitted; rather, the total VOCs discharges quantified for this inventory were standardised to the molecular weight of the common solvent toluene (92.1 g/mol).

Specific contaminants such as metals, acids and certain process gases have not been included. Metals are a constituent part of particulate matter and are not specifically quantified. Many sites require consent for potential odour discharges; only a few of these discharges which occur as odorous VOCs from point sources are included. Some industrial sites discharge uncommon contaminants, which are not quantified or reported.

Only sites that held resource consent for air discharges in 2016 are included in this inventory. The Auckland Unitary Plan (Operative in Part) (AUP(OP)) (Auckland Council, 2016) requires industries with notable air discharges to obtain a resource consent under 168 activity specific rules (see Activity Table E14.4.1 of the AUP(OP)).

The AUP(OP) air discharge rules include a number of Permitted Activity thresholds. Sites that comply with these thresholds are not required to obtain resource consent and are therefore not included in this inventory. These small sources were also excluded from earlier iterations of the inventory as they were a Permitted Activity under the previous Auckland Regional Plan (Air, Land, Water) (2004). Notably, this includes the following small combustion sources.

- Natural gas or liquid petroleum gas fired boilers or engines with a gross heat release of up to 22MW.
- Diesel or fuel oil boilers (and previously existing engines) with a gross heat release of up to 10MW.
- Previously existing wood or coal-fired boilers with a gross heat release of up to 5MW and appropriate emission controls.

Such small-scale heat generating combustion sources are ubiquitous throughout Auckland's industries and it is not possible to accurately quantify their resulting emissions in the absence of information regarding their size and number at unconsented industrial sites. However, it is noted that reticulated natural gas is widely available throughout Auckland and is the predominant fuel source for industries of all scales; coal, wood and diesel are uncommon fuels in stationary engines and boilers.

Abrasive blasting, spray painting, aggregate handling, wood and metal working are other common industrial activities that discharge some air pollutants but are typically considered to be permitted activities under the AUP(OP) rules. A specific rule of the AUP(OP) notes that air discharges from mobile sources, including mobile machinery on industrial sites, are a permitted activity. Therefore, these air pollutant sources are not included in this inventory despite their industrial nature.

Only stationary point sources with measurable emissions are included in this inventory. Emissions not discharged through a point source are referred to as 'fugitive'. These include dust emissions from unpaved surfaces and aggregate handling, and VOC emissions from solvent uses where active extraction to a stack does not occur (such as the drying of solvent-based paints at ambient temperatures or the filling of fuel storage tanks).

Fugitive VOC emissions are sometimes estimated by industrial sites by mass-balance measurements (the mass of solvents imported less those exported as liquid waste). However, these calculations commonly appear to over-state emissions when compared to source testing results and information is not available to apply this methodology for all industrial sites. Therefore, only measured point source VOCs discharges are included, typically those which arise from the drying of solvent coatings within an oven with extraction to an emission control system and stacks.

Other excluded sources are baghouses that do not have a stack. The particulate emissions from these types of filtration systems cannot be tested for quantification and were also excluded from previous inventories for this reason. Such filter systems are commonly employed at concrete batching facilities, of which there are more than 30 throughout the Auckland region. Therefore, all concrete batching facilities are excluded from the inventory as fugitive dust sources only.

Of the 345 consented sites included in the database, 198 (57%) do not have any point source air pollution sources and therefore do not contribute to the calculated industrial discharges. Many of these sites are consented due to odour concerns, such as 36 intensive poultry farms, 12 refuse transfer stations, and 20 wastewater treatment facilities (except for the largest two that combust biogas).

2.0 Methodology

This emission inventory quantifies emissions of various air pollutants from consented industrial point sources in the Auckland region. The data for each site were collated by members of Auckland Council's Air Quality Consents and Compliance Team, Natural Resources and Specialist Input, Resource Consents, in early 2017. The Air Quality Team had familiarity with each site's air discharges from previous assessments of environmental effects for consenting and on-going liaisons as part of undertaking consent compliance audits. The methods generally follow those of previous industrial inventories completed for Auckland (Grange & Xie, 2015), except where noted below.

2.1 Industrial emissions database

The industrial emissions inventory is held in an Excel spreadsheet database. Although other database systems could have provided a more elegant solution (as recommended by the 2011 update), the use of an Excel workbook was chosen due to its widespread availability and familiarity for users.

2.1.1 Structure of database

The database is contained in a table listing all 345 currently active air discharge consents with metadata and the emissions of various air pollutants (in tonnes/year) for each site. These emissions data are updated from three calculation spreadsheets.

The data detailed for each consent are:

- file reference (prior to digitisation in July 2017, all sites applying for an air discharge consent were assigned a numbered hard-copy file into which the various consent renewals, changes and compliance information was placed)
- site name and consent holder
- consent number (of the current or most-recent air discharge consent), and granted and expiry dates of this consent
- consent status (active or expired)
- site address, NZTM co-ordinates and a code for whether the site is within or outside of the Rural Urban Boundary of the AUP(OP)
- site purpose, both free text and assigned to specific primary and secondary source categories (Figure 2)

- air emission sources (free text) and notes regarding fugitive emissions and the frequency of any stack testing required
- date of last emissions update with free-text notes
- the combined combustion capacity on site (MW)
- point-source emissions (tonnes/year) of TSP, PM_{10}, $PM_{2.5}$, NOx (as NO_2), SO_2, CO, CO_2 and VOCs.

The calculation spreadsheets are titled 'Stack Emissions', 'Site Emissions' and 'Uncertainties'. The Stack Emissions spreadsheet is the main data entry point for users of the database. It lists all sites, arranged by file number, with multiple lines for each point source on each site so that the air pollution emissions are calculated for each.

Operational data (the number of hours the discharge occurs) is calculated by entering the typical operating hours, days and months of each discharge point. Free text and categorised columns enable users to detail the information source for the operational data.

Other columns in the Stack Emissions spreadsheet calculate the annual discharges of air pollutants based on the operational data and stack testing results and/or combustion capacity. The source of the emissions information is entered and a confidence rating applied.

The Site Emissions spreadsheet is a pivot table which auto-sums each site's total air pollutant emissions and combustion capacity across all sources. These data then feed into the main summary spreadsheet.

Uncertainty is calculated in a separate spreadsheet, based upon the Stack Emissions data and calculation methodologies recommended by the EEA (2016).

Emission factors and other 'back-end' calculation data and lists are contained in a hidden spreadsheet titled 'Emission Factors'.

2.1.2 Changes to structure of database from previous emission inventories

This iteration of the Auckland Industrial Emission Database has completely re-written the previous complex design, first created in 2006 by Rhys Kevern of URS Ltd. The original database contained 11 spreadsheets and required the user to enter data in multiple locations, often repeating the same data before manually editing calculations for each source. The original database was also in a poor state, with many entries colour coded and annotated without a clear system. Consents that had been replaced or surrendered were not removed from the database, but remained within an ever-growing list. The poor state and convoluted design of the original database was noted as a major limitation in the 2011 update (Grange & Xie, 2015).

2.2 Information sources

To calculate emissions from each source it is necessary to know the operating hours (duration of discharge) and the rate of air pollutant discharges.

2.2.1 Operational data

Operating hours are a common weak point for emission inventories (EEA, 2016). The previous iterations of the industrial emission inventory typically assumed continuous discharges in the absence of any other data. However, this update had the added advantage of direct communication with consent holders through the Air Quality Team's compliance inspection role, so that the annual operating hours are more accurately estimated for all sources.

Operating hours were most typically obtained from an Assessment of Environmental Effects (AEE) report supplied as part of an application for resource consent. Where details were considered to be outdated or unclear, the operating hours were input based on recent conversations with site managers as part of routine consent compliance inspection visits.

2.2.2 Air pollutant discharge rates

The rate of air pollutant discharges was calculated by differing methods for each source depending on available information and type of discharge. Preferentially, stack testing results were used to determine the typical volume flow of air from the stack (in Nm^3 per hour, where Nm^3 is the cubic metres of air at standard conditions: 0°C and 101.25 kPa) and the concentration of an air pollutant within that air stream (in mg/Nm^3). Stack testing is typically undertaken in accordance with US EPA prescribed methods, which require at least three samples to be taken. The average flow rates and air pollutant concentration results from the sampling rounds were multiplied to calculate typical air pollutant discharges (in g/s). This average measured instantaneous discharge rate was then multiplied by the annual operating hours to estimate an annual discharge (in tonnes/yr).

Where available for a point source, the most-recent stack testing information was used. 131 sources (35%) had stack testing information available and submitted in accordance with conditions of consent. The majority of these sources had a requirement for annual testing so that tests undertaken in 2016 were available.

Where more-frequent testing was undertaken, an average of the two (or more) 2016 testing rounds was used.

Where stack testing results were not available for a non-combustion source and/or pollutant, source emissions were estimated from assessment of environmental effects (AEE) reports, emission control manufacturer's information and by emission factors (for combustion sources). AEEs are received as part of applications for consent and often seek to quantify air pollutant discharges for input into air dispersion models or other assessment methods. It is common that applicant's select a 'worst-case' emission rate to assess the maximum likely potential effects of a discharge when preparing an AEE. However, many AEEs also include data regarding typical discharges, and therefore, these AEEs provided reasonable information to estimate average annual emissions for a further 60% of sources.

For approximately 5% of sources, where stack testing or AEE information was not available, discharges were estimated from the consented emission rate limits.

An alternate method was used for combustion sources and air pollutants in the absence of stack testing data, which only required the user to enter the combustion fuel type and gross heat-generating capacity of the source for air pollutant emissions to be calculated.

2.2.3 Emission factors

The calculation of combustion emissions relied upon emission factors. Emission factors published within the US EPA AP-42 database (2004) were used for most combustion types. These emission factors were based upon stack tests undertaken at similar combustion sources. They estimate the discharges of air pollutants per quantity of fuel consumed.

The majority of these emission factors were the same as those used in previous iterations of the industrial emission inventory. However, some important changes were made for the calculation of particulate matter in this inventory. The particulate discharge rates recommended by the US EPA AP-42 database for gaseous fuels are widely considered to be unrealistically high (Olson & Corio, 2014). In 2012, Roy Huntley of the US EPA recommended new emission factors approximately 95% lower than those of AP-42 for the nation-wide USA emission inventory after analysing a further tranche of stack testing results for gaseous fuel combustion sources (Olson & Corio, 2014). This inventory uses Huntley's (2012) recommended TSP, PM_{10} and $PM_{2.5}$ discharge rates for natural gas combustion sources instead of the US EPA AP-42 (2004) values that had been used in previous Auckland emission inventories.

Particulate discharges were also amended for landfill gas and biogas combustion engines. The US EPA AP-42 database (2004) values for these discharges were also considered to be unrealistically high and were based on few tests under combustion conditions that may differ from those at Auckland's landfills and two major wastewater treatment plants.

Extensive testing for particulates has been undertaken at Redvale Landfill, which currently operates 12 landfill gas engines, each generating approximately 1MW of electricity. Redvale's 2010 air discharge consent application assumed a maximum realistic TSP discharge of 30 mg/m^3 for these units, in accordance with the manufacturer's specifications (Tonkin & Taylor, 2010). Testing undertaken at Redvale since 2009 has shown that actual TSP discharges are typically less than half this assumed value, meaning that emissions from landfill gas and biogas engines lacking TSP testing data (and therefore rely on a nominal 30 mg/m^3 emission factor), are likely to be over-stated, although not to the extent that would occur had the international AP-42 values (2008) been used.

Emission factors (amount of air pollutant emitted as a function of gross heat release in kg/MW) used in this inventory and references to their source documents are shown in Appendix A

2.2.4 Particulate size fractions

For Auckland's industrial particulate sources, stack testing is most often undertaken in accordance with US EPA Method 5 (1987), which measures all particulate matter regardless of size as Total Suspended Particulate (TSP). Where only TSP discharge information was available, PM_{10} and $PM_{2.5}$ discharges were pro-rated according to size fraction speciation information for various sources (Appendix A) from the US EPA SPECIATE database (2014).

Over the past five years, size fraction speciated particulate testing has become more common for Auckland's industrial sources, using in-stack cyclone testing apparatus in accordance with US EPA Method 201A (US EPA, 2010). This testing for size-differentiated $PM_{2.5}$, PM_{10} and $>PM_{10}$ reports filterable particulate. Testing for condensable $PM_{2.5}$ in accordance with US EPA Method 202 has not been undertaken at any industrial site in Auckland. Where size fraction speciated particulate measurements were available for a source, these were preferentially used to calculate PM_{10} and $PM_{2.5}$ discharges.

2.3 Confidence ratings

Confidence ratings were applied to both the operational data and emissions data, according to the source of the information and its likely reliability (Table 1)

Table 1: Confidence ratings and error range for operational and emission data

Confidence rating	Error rating
A – Stack Testing (post 2010)	±10%
B – AEE (post 2010)	±20%
C – Stack Testing (pre 2010)	±20%
D – AEE (pre 2010)	±50%
E – US EPA emission factors	As reported in AP-42 (US EPA, 2004)
F – Consent limit	±100%
G – Estimate (user judgement)	±100%

The majority of emissions were quantified using recent (post 2010) data from stack tests or assessment of environmental effects (AEE) reports, received as part of applications for consent. Of the 370 sources, 289 were informed by these high-quality data sources.

Entering operational data required a greater degree of user judgement as many applications did not specify typical operating hours and conservatively assumed continuous operation to assess the worst-case potential effects. Approximately 70% of the emission sources specified operational hours, typically stated within the AEE reports. An additional 30% of sources required the operational hours to be estimated. Auckland Council's Air Quality Team were well-placed to estimate a site's typical operating hours, as they were in frequent contact with consented sites for compliance inspections.

2.4 Calculation of uncertainties

Uncertainties for each air pollutant emission are reported in general accordance with the methodology recommended by the European Environment Agency (EEA) Air Pollutant Emission Inventory Guidebook (EEA, 2016).

The level of uncertainty calculated in the Emission Inventory Database for each stack source used a semi-quantitative methodology. Using the above confidence ratings, categorised error ranges were applied to the operating hours and stack test results (Table 1). These error values were based on the default uncertainty ranges recommended by section 5 of the EEA Emission Inventory Guidebook (2016).

The emission factors used to calculate emissions from some combustion sources have reported confidence intervals (US EPA, 2004). Where the emissions of a pollutant were calculated by multiplying the combustion capacity of a source (in MW) by an emission factor, the combustion capacity was assumed to be accurate (no uncertainty) and published uncertainties specific to each emission factor applied.

The level of uncertainty for each air pollutant discharged by each source listed in the inventory database was calculated by adapting the EEA (2016) recommendation (Equation 1). This equation accounts for the uncertainties associated with the annual operational hours of a source and the stack testing result or emission factors applied to determine the instantaneous emission rate.

$$\boldsymbol{U_{source}} = \sqrt{\boldsymbol{U_{op}^2} + \boldsymbol{U_{ER}^2}} \qquad \textbf{Equation 1}$$

Where:

U_{source} is the total percentage uncertainty of annual air pollutant emissions from a source

U_{op} is the percentage uncertainty of the annual operating hours determined for an air emission source, assigned as a percentage according to the categories in Table 1.

U_{ER} is the percentage uncertainty of the emission rate determined for an air emission source, determined from either the categorised confidence ratings for stack testing results or by reference to published levels of uncertainty for emission factors

The total levels of uncertainty for the cumulative annual air pollutant emissions were calculated in accordance with EEA (2016) recommendation (Equation 2).

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

Where:

U_{total} is the percentage uncertainty of the total estimated annual air pollutant emissions

x_i are the quantities of annual air pollutant emissions from each source

U_i are the percentage uncertainties associated with the quantities of air pollutant emissions from each source (U_{source})

This inventory calculates and reports the level of uncertainty for consented industrial point source emissions only.

2.5 Categorisation of industries

The sites were categorised according to activity type (Figure 2).

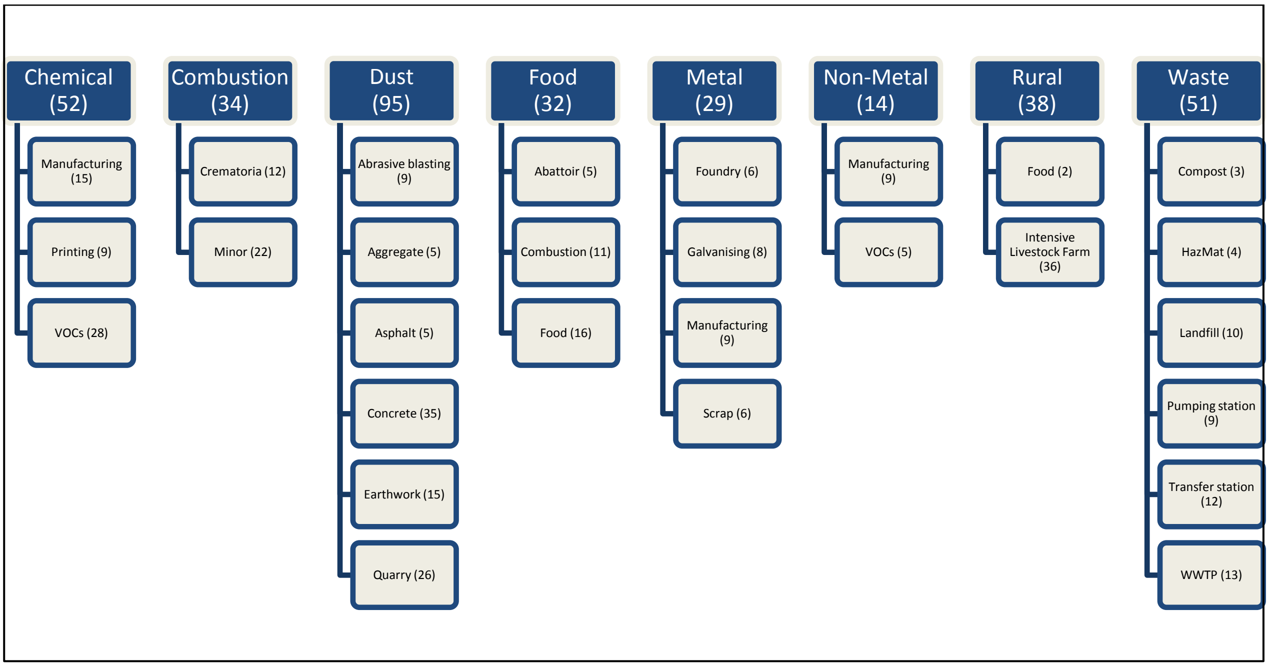

Figure 2: Primary and secondary categories of industrial sites (including number of consented sites within the database)

3.0 Results and discussion

Industry in Auckland discharges a range of air pollutants, primarily as a result of combustion processes. Discharges of particulate matter and some process gases also occur as a result of manufacturing processes, such as grinding and milling materials. Only consented point sources are included in this emission inventory; fugitive emissions and emissions from sites which do not require an air discharge consent are not captured in this inventory.

3.1 Total industrial emissions

The industrial air pollutants estimated for this inventory include all criteria air pollutants under the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NESAQ) with the exception of ozone, and additionally calculated emissions of TSP, $PM_{2.5}$, CO_2 and VOCs. The majority of point source industrial air pollutant discharges occur outside the Auckland urban area, defined by the AUP(OP)'s Rural Urban Boundary.

Table 2: Air pollutant emissions from all consented industrial point sources

Contaminant	2016 Auckland regional emissions (tonnes)	2016 Auckland urban emissions (tonnes)	Regional emissions uncertainty (%)
TSP	356.2	70.1	9
PM_{10}	301.9	47.6	14
$PM_{2.5}$	274.7	35.2	15
NO_x	2,606.2	775.1	16
SO_2	1,042.7	114.1	24
CO	3,110.4	412.7	25
CO_2	2,343,923	536,740	24
VOCs	480.5	479.9	47

One site, NZ Steel, dominates discharges of all contaminants except VOCs. NZ Steel's discharges are located outside of the urban area, approximately 40km to the south of the Auckland CBD, at Glenbrook in Franklin (see section 3.4.1).

Discharges of air pollutants from industry have the greatest impact when there are substantial populations living or working near to the discharges. For this reason, the total air pollutant discharges from industries within the Auckland urban area are also assessed (Table 2).

Most sites with point-source discharges are located within the Rural Urban Boundary, predominantly in Auckland's historic industrial areas such as Penrose, Otahuhu, Wiri, East Tamaki, and Rosebank. Eight consented air discharge point sources are located outside the Rural Urban Boundary, notably including NZ Steel and the operational municipal landfills (Redvale and Whitford).

3.1.1 Particulate matter

Respirable particulate matter (PM_{10} and $PM_{2.5}$) is the key air quality management focus in Auckland and throughout New Zealand, owing to its significant human health effects and relatively high ambient concentrations, which sometimes approach or exceed health-based assessment criteria (Kuschel, et al., 2012). Industrial emissions of PM_{10} and $PM_{2.5}$ make important contributions to the overall ambient concentrations in specific locations. Davy et al. (2016) found that 7% of PM_{10} measured at the Penrose monitoring site between 2006 and 2013 was attributable to industrial processes.

$PM_{2.5}$ is the finest size fraction of particulate matter commonly measured. It is receiving increasing regulatory attention as more is understood about its significant effects on human health (Pope & Dockery, 2006). Accordingly, this inventory has aimed to determine $PM_{2.5}$ emissions from industrial point sources as accurately as possible. Size fraction speciation calculations were used to make reasonable estimates (albeit with higher levels of uncertainty) of the $PM_{2.5}$ content of discharges measured only as TSP (Table 2).

An increasing number of sites are now undertaking stack testing for size differentiated particulates in accordance with US EPA Method 201A. Air discharge consents that have been recently granted are more likely to include conditions that require specific tests for filterable PM_{10} and $PM_{2.5}$ rather than relying on TSP testing and size-fraction assumptions (as with older consents). However, no consents yet specify testing for 'condensable' component of $PM_{2.5}$ (using US EPA Method 202). It is noted that Method 202 is unsuitable for some sources (such as moist discharges or narrow stacks) and that its applicability is currently under review by the US EPA

(2016). Consented industrial point sources discharged 356.2 tonnes of total particulate matter (TSP) in 2016. 85% of this TSP was PM_{10} (301.9 tonnes) and 77% was $PM_{2.5}$ (274.7 tonnes), reflecting the dominance of combustion emissions to industrial stack discharges. The level of uncertainty calculated for particulate matter discharges largely reflects that calculated for NZ Steel's discharges, that varied between 9% for TSP and 18% for $PM_{2.5}$. A greater level of uncertainty was calculated for the smaller size fractions as the majority of sites only reported TSP discharges, with size fractions estimated from published data.

This emission inventory does not include fugitive sources. For TSP and PM_{10} particularly, these fugitive sources include emissions of dust from unsealed surfaces and aggregate handling as occurs at consented quarries and concrete batching facilities as well as at numerous other construction and earthworks sites that do not require air discharge consents. Davy et al. (2016) found that the portion of PM_{10} identified as 'crustal matter' (typically 1-2 µg/m³ or 8% of total PM_{10}) at all five monitoring sites across the Auckland urban area display a clear weekly variation, with greater crustal PM_{10} concentrations on weekdays when industrial and construction activities are more widespread. This variance indicates that fugitive dust emissions from industrial sites are likely to be significant and may even outweigh those from stack sources on a mass basis.

Black carbon (BC) is a specific particulate contaminant that has been found to impact human health and contribute to climate change (Janssen, et al., 2011; Bond, et al., 2013). BC is generated by incomplete combustion processes and exists as complex ultra-fine soot particles. Combustion of diesel, coal and biomass are the key global sources of BC (Bond, et al., 2013). Relatively clean burning fuels such as natural gas and petrol result in negligible BC emissions.

As the majority of industrial combustion processes in the Auckland region use natural gas, BC emissions from these industrial sites are assumed to be negligible. NZ Steel's large-scale combustion of coal is considered to be the only significant industrial source of BC in Auckland. Previously, this site was estimated to discharge approximately 2.7 tonnes of BC per year (Crimmins, 2017).

3.1.2 Nitrogen oxides

The combustion of any fuel generates a range of nitrogen oxides (NO_x), as nitrogen in the air is oxidised in the combustion process. For industrial combustion processes, the majority of NO_x is emitted as nitrogen oxide (NO), which is generally considered not to be harmful to human health or the environment at typical ambient concentrations. However, over time in the presence of sunlight, atmospheric ozone and/or organic compounds, NO is oxidised to the hazardous air pollutant nitrogen dioxide (NO_2). Monitoring data suggests that this conversion process is limited in Auckland so that not all NO_x becomes NO_2 within the urban boundary (Metcalfe, et al., 2014). However, to maintain compatibility with other aspects of the emission inventory and earlier inventories, nitrogen oxide emissions are reported as total NO_x.

The majority of NO_x emission data were calculated from emission factors based on the combustion capacity at each site. Some larger combustion sources such as O-I Glass, NZ Steel and Redvale Landfill undertake routine stack testing for NO_x utilising US EPA Method 7E (instrumental analyser). Where available, these stack testing results were used in preference to emission factors.

AP-42 (US EPA, 2017) assigns a 'B' confidence rating to the emissions of NO_x from natural gas combustion sources. As per the semi-quantitative methodology for determining uncertainty detailed in section 2.4, this emission factor was categorised as having a 20% uncertainty rating. The total uncertainty rating of industrial NO_x emissions was calculated as 16%.

It is notable that discharges of NO_x and other combustion contaminants from a greater range of combustion processes became Permitted Activities under the AUP(OP) than was the case under the rules of the former Auckland Council Regional Plan (Air, Land and Water). However, as at 2016, all had retained their air discharge consents and are thus included within this inventory. Greenlane Hospital, which raises 10MW of heat from natural gas boilers to discharge an estimated 6.1 tonnes of NO_x per year, is an example of a site with discharges that are now considered to be a Permitted Activity under Rule E14.4.1(A51) of the AUP(OP). It is estimated that a further six air discharge consents could be surrendered for the same reason. These now permitted 'combustion only' activities represented combined estimated annual discharges of 34 tonnes of NO_x, 41,000 tonnes of CO_2 and 0.15 tonnes of $PM_{2.5}$.

3.1.3 Sulphur dioxide

Industrial emissions of SO_2 in Auckland are dominated by the region's only large-scale coal consumer, NZ Steel. The most recent National SO_2 Emission Inventory estimated that the approximate 0.8 million tonnes/year of coal consumed as part of the steel making process at NZ Steel emitted 922 tonnes of SO_2 in 2007 (Wilton, et al., 2008). No update to this figure was available, with recent stack testing results not providing an adequate site-wide estimate of total SO_2 emissions.

The only other significant SO_2 source in the region is the O-I Glass smelter, which discharges SO_2 as a result of colouring agents added to the glass furnaces for specific batches. Based on two stack tests undertaken in 2016, it is estimated that 104.6 tonnes of SO_2 were discharged from O-I Glass in 2016.

The combined total of all other industrial point source SO_2 discharges is 11.1 tonnes/year, predominantly from starch manufacturing, asphalt production and the combustion of biogas as occurs at landfills and the region's two major wastewater treatment plants. The absence of SO_2 discharges is largely a result of the dominance of natural gas as fuel for industrial combustion processes, which has a negligible sulphur content.

An uncertainty of 24% was calculated for SO_2 emissions, mostly as a result of the uncertainties assigned to NZ Steel's discharges.

3.1.4 Other combustion gases (CO and CO_2)

Discharges of CO and CO_2 are largely dependent on the quantity and type of fuel consumed. Fuel use is approximated by the emission inventory as the total gross heat release of combustion appliances at each site, measured in MWh, multiplied by the annual operating hours.

The majority of combustion processes occurring at Auckland's industrial sites use reticulated natural gas supplied from Taranaki. Natural gas emits less CO_2 per MW of heat raised than many other fuels. NZ Steel raises the largest quantity of heat on a single site and is reliant on CO_2 intensive coal as part of the steel making process. As a result, this site is estimated to account for 76% of the CO_2 discharged from all of Auckland's consented industrial sites.

Uncertainties of 25% and 24% were calculated for regional CO and CO_2 emissions, respectively.

3.1.5 Volatile organic compounds

VOCs are most commonly emitted by industrial processes as a result of the evaporation of solvents used in printing and painting operations as well as from storage tank filling.

Where VOCs are emitted from painting operations drying at ambient temperatures without active extraction to stacks, emissions are sometimes calculated by industries using a theoretical mass balance approach. This assumes that 100% of the solvent content applied is emitted as VOCs, so that a site's total VOCs emissions are equal to the quantity of solvents brought onto site, less that which is exported as liquid waste.

This approach is likely to over-state VOCs emissions, as a portion of the solvent remains bound within the coated product. Some emission inventories seek to estimate entire life-cycle industrial VOC emissions (including from consumer product use) (European Solvents VOC Co-ordination Group, 2015). However, these wider VOC emissions are considered outside the scope of this industrial emissions inventory, which focuses on point source discharges at Auckland's consented industrial sites. Data regarding the volumes of solvents which are imported to or manufactured in Auckland are not available, nor their volatility (rates of evaporation). Therefore, only point source VOC discharges from printers and coating operations have been included in this industrial emission inventory.

It is also noted that there are other significant fugitive sources of VOCs not captured by this inventory, arising from tank filling displacement and evaporative losses such as those that occur at the numerous petrol stations throughout the Auckland region. These VOC discharges are outside the scope of point-source industrial emissions.

An uncertainty of 47% was calculated for included VOCs discharges; however, the information sources are considered to have a lower reliability than is reflected by this rating. Only 42 point sources from 32 sites with specific emissions data were included in this inventory. The actual industrial VOCs emissions are therefore likely to be higher than those reported.

3.2 Trends in estimated total industrial emissions

The overall emissions estimated by this inventory are less than those estimated by previous updates undertaken for 2006 and 2009 (Kevern, et al., 2009) and 2011 (Grange & Xie, 2015). This is primarily a result of site closures that have occurred since 2011, which accounted for an estimated decrease of 40 tonnes of $PM_{2.5}$ and 1765 tonnes of NO_x from the 2011 estimates (An uncalculated level of emissions and uncertainty regarding the total air pollutant discharges from all industrial activities is present due to the absence of accounting of air discharges from unconsented activities and fugitive sources in all iterations of the industrial emission inventory. The absence of these sources means that total industrial air pollutant emissions within Auckland in 2016 are higher than those reported.

Table 3).

Some individual sites have also greatly reduced air pollutant emissions over time as a result of upgrades to emission control equipment (Figure 3). The large-scale manufacturing processes at O-I Glass is indicative of this overall improving trend (see section 3.4.2).

Air discharge consents may only be granted for a maximum 35-year duration. However, owing to the requirement for a precautionary approach when assessing the actual and potential effects of an air discharge, Auckland Council has typically granted air discharge consents for much shorter durations, typically 10-15 years. These short durations mean that sites must periodically renew the consents, by re-assessing the effects of the discharges and demonstrating that emission controls meet a requirement for the 'best practicable option.'

As more is understood regarding the health effects of hazardous air pollutants and urban intensification brings sensitive residential receptors closer to industrial sites, the tolerance for industrial air discharges decreases. This 'sinking lid' means that industrial sites usually reduce air discharges over time even without an explicit regulatory directive. All of these factors have led to an apparent decline in air pollutant discharges from consented industrial point sources across Auckland in the decade prior to 2016 (Figures Figure 3Figure 4).

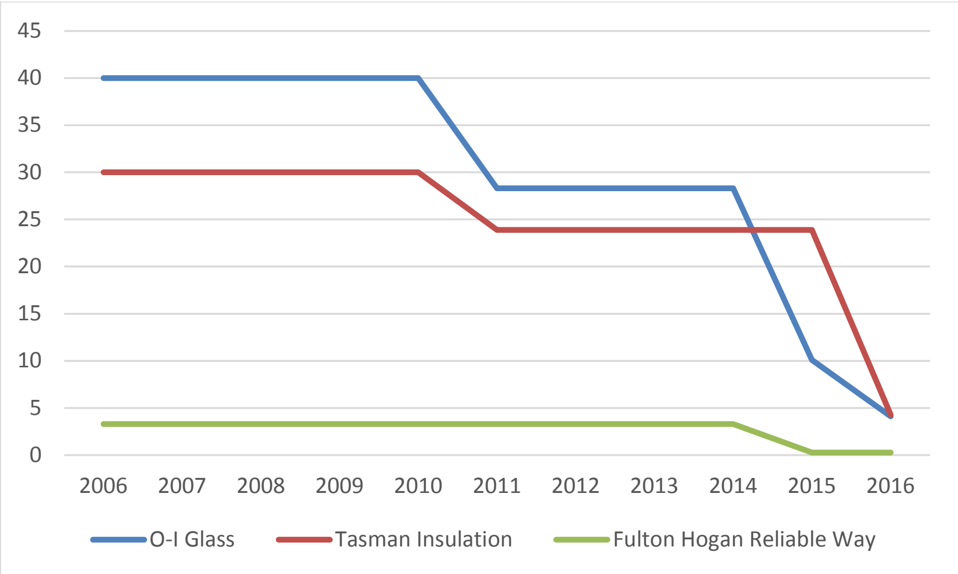

Figure 3: Decreasing estimated PM_{10} emissions at three industrial sites

The improvements in industrial emissions are countered to a degree by an increase at some other sites in line with production. The landfills and Mangere Wastewater Treatment Plant generate electricity by combusting biogas generated by the biological treatment of wastes received at the sites. As this biogas production increases with increasing cumulative waste volume at the landfills and increasing wastewater inflows at the treatment plants, it is expected that discharges of particulates, combustion gases and SO_2 at these sites will increase correspondingly.

While it is apparent that site closures and improvements in emission controls have resulted in a decrease of industrial point source emissions in Auckland over the past decade, it is difficult to accurately quantify the trends in actual industrial emissions given the limitations of each of the inventories. However, the emissions for most pollutants estimated by each inventory can be compared to illustrate the estimated impacts of site closures and upgrades undertaken over the past decade. Trends in estimated VOC emissions are not reported as the previous iterations of the industrial emission inventory applied a different methodology for estimating these discharges.

An uncalculated level of emissions and uncertainty regarding the total air pollutant discharges from all industrial activities is present due to the absence of accounting of air discharges from unconsented activities and fugitive sources in all iterations of the industrial emission inventory. The absence of these sources means that total industrial air pollutant emissions within Auckland in 2016 are higher than those reported.

Table 3: Notable industrial sites that ceased emissions between 2011 and 2016

Site type	Suburb	Date closed	2011 PM_{10} estimate (t)	2011 NOx estimate (t)	2011 VOCs estimate (t)
Power station	Southdown	Dec 2015	21.6[A]	1,222.6[B]	0
Steel mill	Favona	Sep 2015	9.4	103.1	0
Foundry	Wiri	2011	4.1	6.2	0.1
Scrap metal	Onehunga	2014	1.2	0	0
Power station	Otahuhu	Sep 2015	1.2	416.7	0
Printing	New Lynn	May 2012	0.9	12.1	760.7[C]
Bricks	New Lynn	Jun 2015	0.8[D]	11.0	0
Building products	Papakura	Gradual wind-down from 2010	0.0	0.1	286.6
Foam	Avondale	2013	0	0	330.8
Total			**39.2**	**1,772**	**1,378.1**

Notes:

A: PM_{10} emissions assumed continuous operation of all three generators on site using potentially erroneously high results obtained in one sampling round in April 2010. Other sampling undertaken in September 2010 showed much lower PM_{10} discharges, in line with testing undertaken at other natural gas thermal power stations. A thorough analysis for a consent renewal for the Southdown power station estimated 4.1 tonnes of PM_{10} was emitted by the site in 2012.

B: NO_x emissions assumed continuous operation of all three generators on site using potentially erroneously high results obtained in one sampling round in April 2010. The potentially inaccuracy of estimated NO_x emissions is demonstrated by comparing the Southdown and the larger Otahuhu power stations (Southdown 2011 fuel consumption was 3.75 million TJ, Otahuhu was 13.93 million TJ).

C: VOCs emissions for this flexible printing operation were estimated using a mass balance approach and from the consent discharge limits; these approaches have not been used for this update.

D: This PM_{10} estimate appears low; stack tests undertaken in other years indicate that PM_{10} emissions from brick manufacturing were more likely to be in the range of 3 to 4 tonnes/year.

The estimated air pollutant discharges from industrial point sources have generally declined since 2006 within the Auckland region. CO and SO_2 are estimated to have increased, although these are considered to be a result of improved information sources for this inventory (particularly for NZ Steel's discharges). At a regional level, it is estimated that PM_{10} discharges from industrial point sources have decreased by 34% between 2006 and 2016. This reduction did not meet the 50% target for this period set by the 2012 Auckland Plan.

Focussing on emissions within the Auckland urban area, the estimated emissions of all air pollutants from industrial point sources in 2016 have more than halved when compared to those that were estimated for 2006. Point source industrial PM_{10} discharges within the urban area were estimated to be 264.3 tonnes in 2006, and are estimated to have fallen to 47.6 tonnes in 2016, an 82% decrease. Similarly significant decreases are estimated to have occurred for industrial emissions within the Auckland urban area over this period for TSP (80%), $PM_{2.5}$ (86%), NO_2 (61%), CO (83%), CO_2 (79%), and SO_2 (75%).

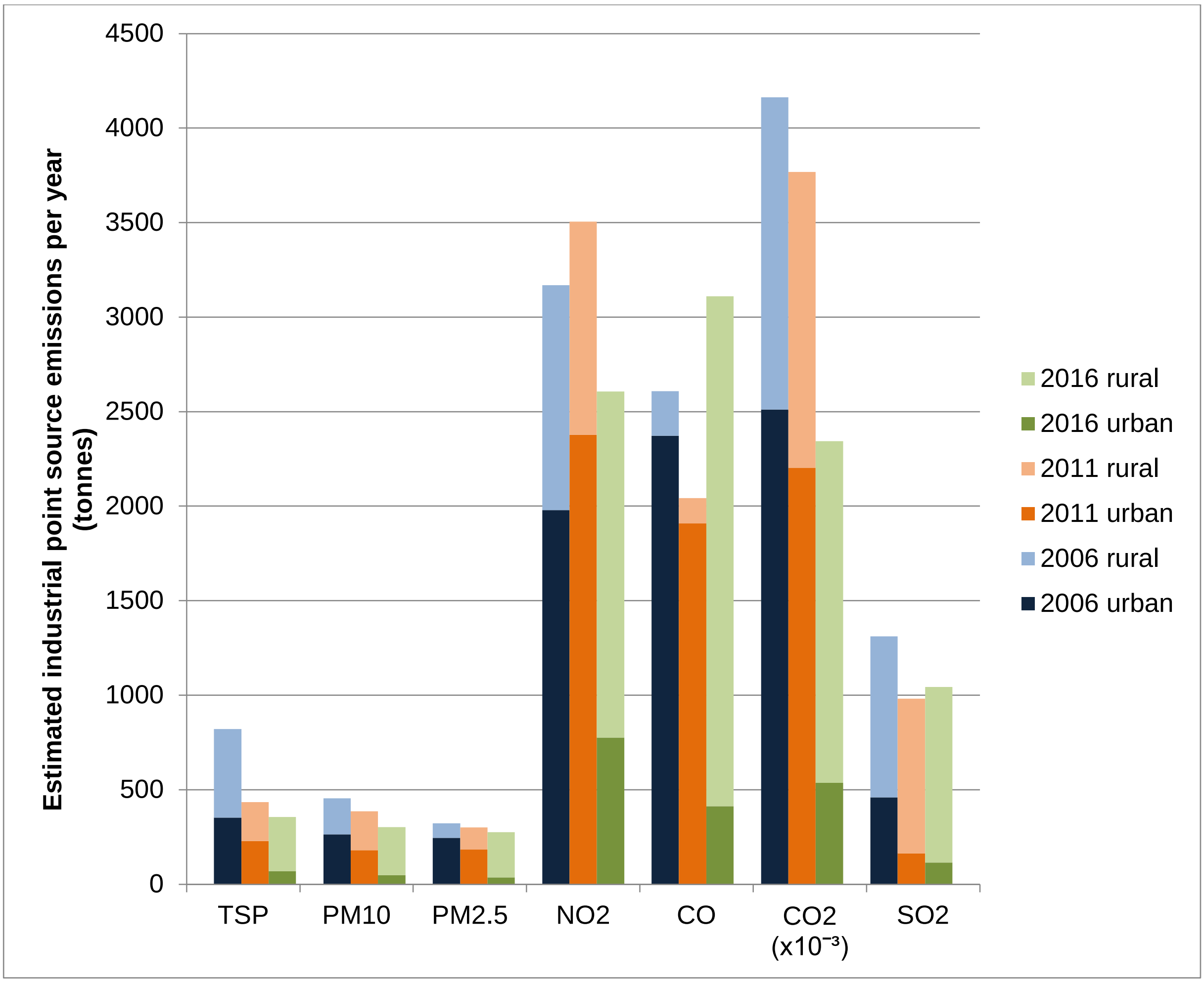

Figure 4: Comparison of estimated 2006, 2011 and 2016 air pollutant discharges from Auckland's rural and urban industrial point sources

3.3 Emissions by industrial category

All air pollutants aside from VOCs are dominated by the 'Metal > Foundry' category, which includes the emissions from NZ Steel. The emissions profile of this specific site is further discussed in section 3.4.1. A number of industry categories do not have any point source emissions as these are consented for odour or fugitive dust discharges only (see Appendix B).

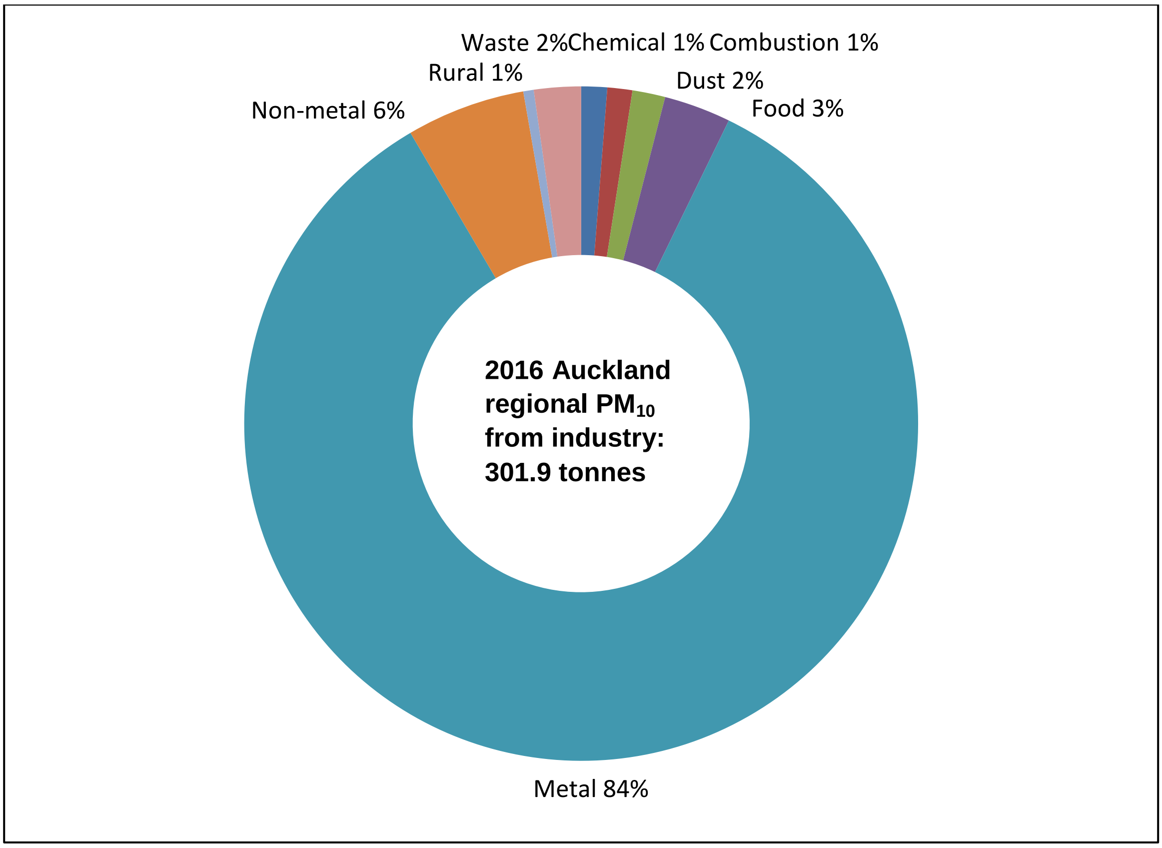

Figure 5: Proportional emissions of PM_{10} by primary industrial category (Auckland region)

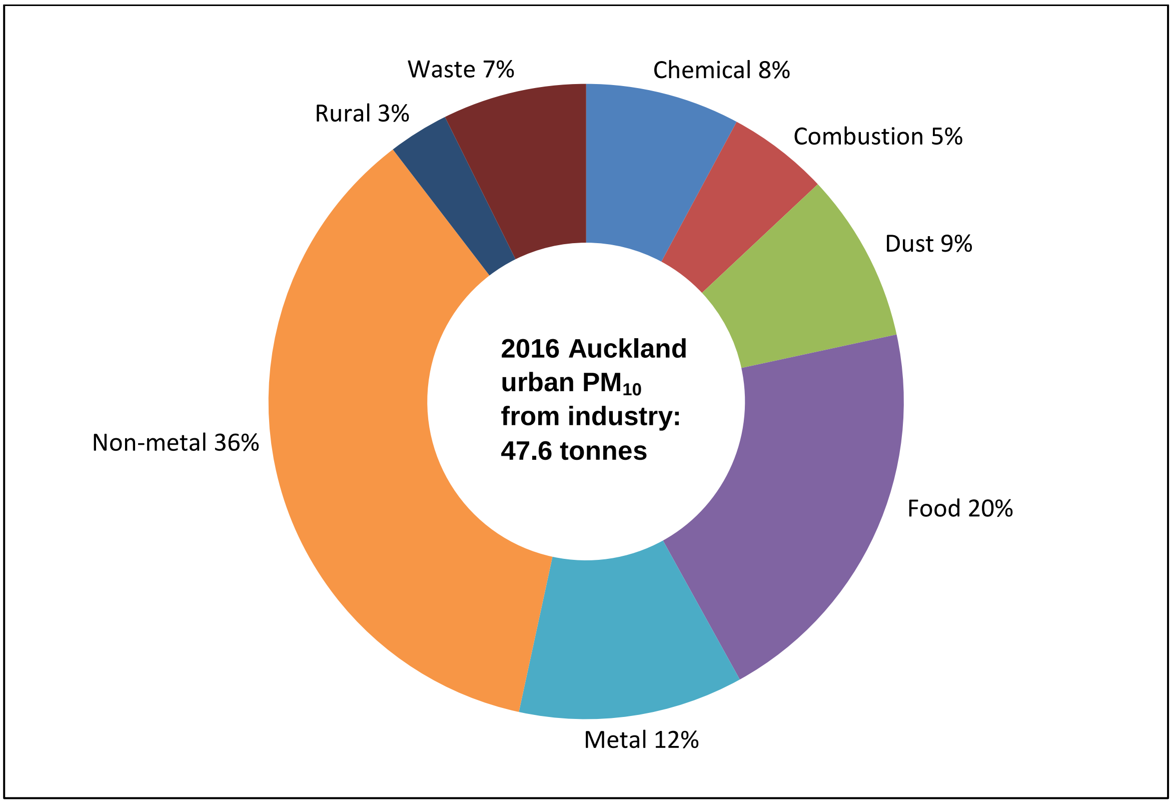

Figure 6: Proportional emissions of PM_{10} by primary industrial category (Auckland urban area)

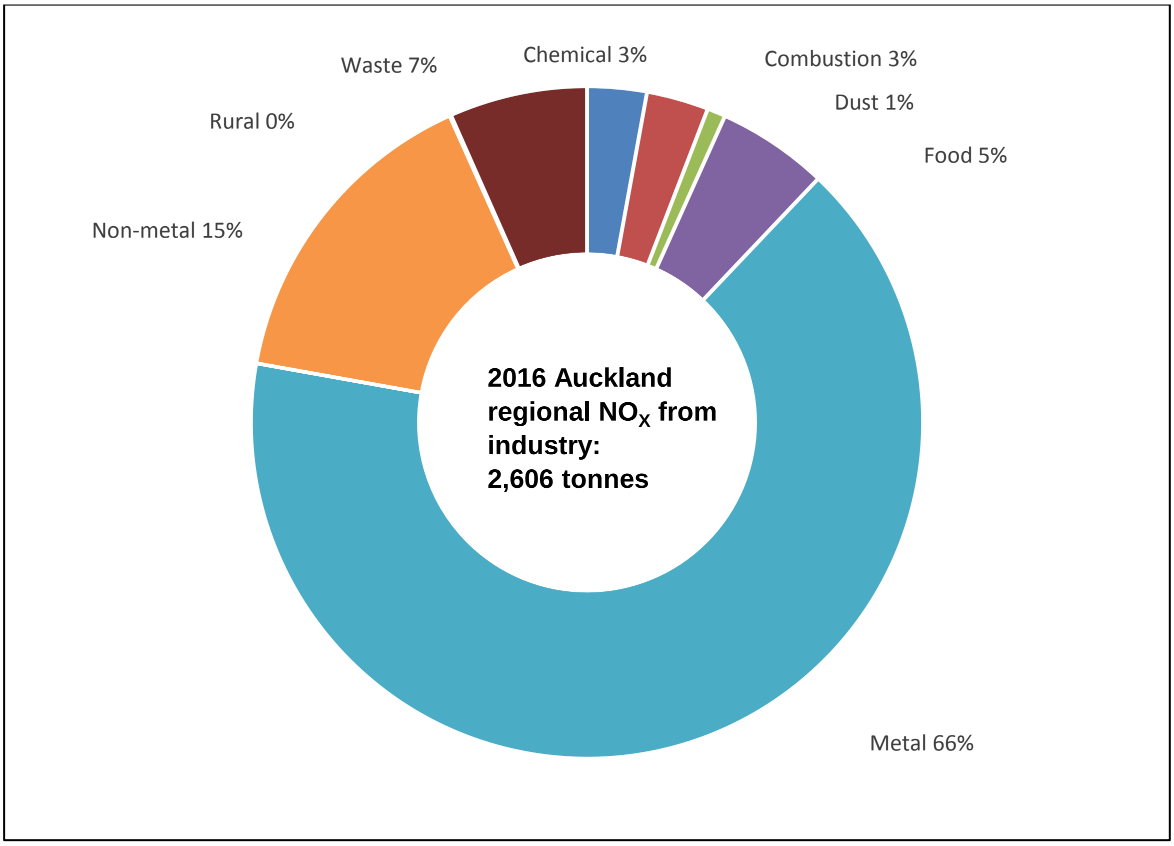

Figure 7: Proportional emissions of NO_X by primary industrial category (Auckland region)

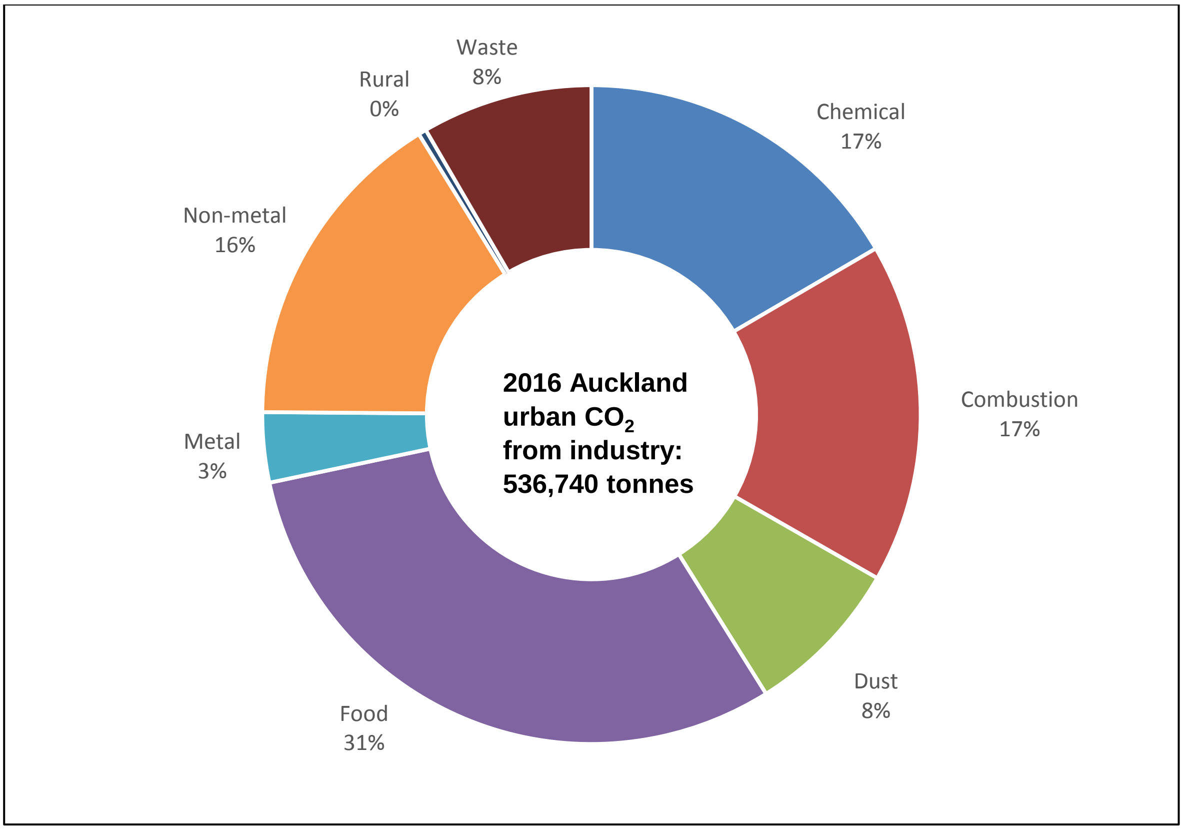

Figure 8: Proportional emissions of CO_2 by primary industrial category (Auckland urban area)

3.4 Notable industrial emission sources

The top ten TSP emitters (Table 4) account for the largest emissions of PM_{10}, $PM_{2.5}$, combustion gases and SO_2. However, some other large natural gas combustion sources, such as the hospitals, are ranked within the top ten sources of NO_x and CO_2.

The top point-source emitters of VOCs are not listed here and are dependent on which sites had VOCs testing data available for point sources. As discussed in sections 1.4 and 3.1.5, fugitive VOCs discharges from both industrial sites and fuel handling likely outweigh these few tested point-source discharges.

Table 4: Top Auckland industrial point source emitters

Site (and category)		2016 Emissions (T/yr)						
	Address	TSP	PM_{10}	$PM_{2.5}$	NO_x	SO_2	CO	CO_2
NZ Steel (Metal / Foundry)	Mission Bush Rd, Glenbrook	279.8	249.1	235.7	1,697.8	927.0	2,192.1	1,770,747
Winstone Wallboards (Non-Metal / Manufacturing)	Felix St, Te Papapa	12.6	7.0	4.6	28.0	0	23.5	33,579
O-I Glass (Non-Metal / Manufacturing)	Great South Rd, Penrose	8.1	4.1	4.1	357.4	104.6	22.0	31,374
NZ Sugar (Food / Food)	Huka Rd, Birkenhead	6.6	6.4	4.6	30.7	0.2	25.4	34,209
Visy Board (Non-Metal / Manufacturing)	Roscommon Rd, Wiri	6.3	1.1	0.3	2.9	0	2.4	3,491
Higgins (Dust / Asphalt)	Crooks Rd, East Tamaki	4.6	1.3	0.9	2.1	0.2	3.8	16,126
Tasman Insulation (Non-Metal / Manufacturing)	Holloway Pl, Penrose	4.3	4.2	3.6	0.2	0	0.2	229

Watercare Mangere (Waste / WWTP)	Island Rd, Mangere	3.3	3.3	2.8	33.2	3.4	56.0	38,932
WMNZ Redvale (Waste / Landfill)	Landfill Access Rd, Dairy Flat	2.9	2.9	2.5	115.1	0.7	471.8	25,855
Downer (Dust / Asphalt)	Great South Rd, Penrose	2.0	1.9	1.4	8.2	0	6.9	9,896
Total (top ten sites)		**322.8**	**282.2**	**261.5**	**2279**	**1,036**	**2,805**	**1,954,519**
Top emitters as % of regional total		***91%***	***93%***	***95%***	***87%***	***99%***	***90%***	***83%***

3.4.1 NZ Steel

The NZ Steel site at Glenbrook is by far the largest industrial emitter of all air pollutants except VOCs in the Auckland region. Discharges of particulates and combustion gases from this site are greater than the combined total of all other industrial point sources in Auckland.

NZ Steel's current air discharge consent, granted in 2008 for a 15-year duration, requires that the mass emissions of PM_{10} from the major emission sources are quantified in a report every three years. This inventory coincided with the completion of this requirement for the 2016-2017 financial year, and this report has been relied upon as the best-available information for this important source (Van Brakel, 2017).

The main emission sources at the site are the four kilns, multi-hearth furnaces, and steel-making furnace (KOBM). Despite the presence of a range of emission control systems, the nature of the processes undertaken to manufacture steel (including the use of coal as an integral agent) results in discharges of particulate, sulphur dioxide and combustion gases (Van Brakel, 2017).

Stack testing for TSP is undertaken on these main point sources on a quarterly basis, and an average of the testing undertaken throughout the 2016 calendar year has been used to estimate average emissions. PM_{10} and $PM_{2.5}$ emissions have been pro-rated based on the TSP results for the major sources based on some previous size fraction analysis and US EPA recommendations (US EPA, 2014). Given the importance of the emissions from NZ Steel to the overall regional emissions, any alteration of assumptions or testing data for this source has the potential to significantly increase or decrease the total estimated regional emissions profile.

Emissions of other pollutants from NZ Steel relied on fewer tests (NO_x), or estimates. Annual site-wide CO_2 emissions of 1.769 million tonnes were reported for the 2014 National Greenhouse Gas Emission Inventory (MfE, 2016). Production at the site was not reported to have changed markedly since this previous inventory and it was therefore used to estimate 2016 emissions of CO_2 and CO.

Similarly, the most-recent National SO_2 Emission Inventory (Wilton, et al., 2008) estimated that NZ Steel emitted 933 tonnes of SO_2 in 2007. No testing for SO_2 emissions has been conducted at the site since this previous report. Using the US EPA (2004) emission factors for coal combustion at an estimated rating of 112MW within the iron-plant kilns (taken from the National Energy Data File (MBIE, 2012)) generated a similar figure to this previous estimate.

It was reported that 6.9% of the site's CO_2 was from natural gas combustion sources (MfE, 2016). There are numerous such sources used at NZ Steel, particularly in the finishing plants. The emissions from these processes are small when compared to the main emission sources on site (the iron and steel plants) and therefore have not been previously analysed in detail. However, it is likely that emissions from these finishing plants are comparable to other metal manufacturing operations throughout the region, and therefore, emissions of natural gas combustion pollutants and VOCs (from the coating lines) have been estimated as part of this inventory by pro-rating the quantity of reported CO_2 emissions attributed to natural gas combustion sources.

The uncertainty ratings applied to NZ Steel's discharges had a significant weighting on the total calculated level of uncertainty. For the operating hours, an uncertainty rating of 20% was assigned on account of the annual operating hours reported in the three-yearly emission quantifications being generally unchanged since 2006. The instantaneous emissions of TSP from the major on-site sources were deemed to have greater certainty as these were based on an average of quarterly emission test results. However, other pollutants and sources were assigned low confidence ratings given the lack of stack testing. The total uncertainty for NZ Steel's PM_{10} emissions was calculated as 17%.

3.4.2 O-I Glass

New Zealand's only large-scale glass smelter is located in Penrose. Between 2010 and 2013, O-I Glass undertook significant site upgrades to increase production at the site, including the addition of a third glass furnace. As part of the upgrade, O-I Glass progressively connected the furnaces to a new 50m high combined stack fitted with an electrostatic precipitator (ESP) emission control system. The upgrade works were authorised by a replacement and amendment to the site's air discharge consent, which considered the ESP as meeting the ‘best practicable option’ for reducing emissions of PM_{10}.

Testing to quantify the emissions of TSP, PM_{10}, combustion gases and SO_2 from the combined ESP stack has been undertaken at a six-monthly frequency. The testing is typically undertaken over a period of 3-5 days to capture the variability of emissions from the furnaces as they process different grades and colours of glass.

Some products emit SO_2, which is not controlled by the ESP. As a result, O-I Glass is the second largest emitter of SO_2 in the region, although the quantification of annual emissions is highly dependent on which testing results are used.

The upgrade works undertaken at O-I Glass exemplify the trend of decreasing industrial emissions due to technological advances and the external pressures (section 3.2). The upgrade works incurred significant cost and have resulted in a large-scale reduction of particulates discharged from the site (Table 5).

Table 5: Particulate emissions from O-I Glass, Penrose – 2006 and 2016

Contaminant	2006 emissions (tonnes)	2016 emissions (tonnes)	2006 to 2016 change (% reduction)
TSP	39.6	8.1	79.5%
PM_{10}	28.0	4.1	85.4%
$PM_{2.5}$	26.8	4.1	84.7%

3.4.3 Winstone Wallboards

This site has manufactured plaster board since the 1960s and is one of the few industrial sites estimated to have increased particulate emissions between 2011 and 2016. The reason for this increase is a combination of erroneously low previous emission estimates, further information from source testing, and a process change. This inventory estimates that Winstone Wallboards is now the second largest emitter of particulates in the region at 12.6 tonnes TSP, 7.0 tonnes PM_{10} and 4.6 tonnes $PM_{2.5}$.

Size-differentiated emission testing was undertaken for a number of sources between 2012 and 2015 to support an application to amend the site’s air discharge consent in 2016. Therefore, there is a reasonable degree of confidence (±10%) in its most-recently estimated particulate discharges.

3.4.4 Fulton Hogan Reliable Way

The Reliable Way asphalt plant is the largest such facility in New Zealand. It is located within the former Mount Wellington quarry and is bordered by medium-density residential dwellings built over the past two decades. The proximity of sensitive residential receptors created additional complications for the site to obtain a replacement air discharge consent in 2013. To reduce the potential off-site effects (including odour and health effects from particulates and SO_2), the site proposed a number of upgrades, including changing the fuel for the asphalt drum from recycled waste oil to natural gas. The effect of these changes has been to greatly reduce the emissions of air pollutants: PM_{10} discharges from the asphalt plant stack are estimated to have decreased from 3.3 tonnes in 2011 to 0.3 tonnes in 2016.

4.0 Recommendations

The quantification of consented industrial point source emissions is a valuable exercise for Auckland Council to understand the relative influence of industrial emissions on regional air quality.

This inventory has simplified the previous database. However, calculating the emissions from each point source remains a cumbersome task. To expedite future inventories, the existing 2016 database could be reviewed and updated if necessary where any major differences have occurred (e.g., sites closed, operating hours changing by >50%,).

The rules of the AUP(OP) mean that more industrial combustion activities are likely to be considered as Permitted Activities for air discharges and therefore would not require resource consent. However, some of these combustion activities have relatively significant air pollutant emissions. For example, Middlemore Hospital has recently surrendered its consent as the air discharges from its 13 natural gas boilers are now deemed to be a Permitted Activity under the AUP(OP), yet it is the ninth-highest emitter of NO_x in this inventory. Where historic consenting information is available for such sites, they should remain on the database despite their now-permitted status.

As industrial point source emission controls improve, fugitive industrial sources are likely to become increasingly important, particularly for TSP and PM_{10}. Aggregate handling and vehicle movements across unsealed surfaces are likely to be the most typical industrial fugitive sources of PM_{10}. Quantifying these discharges is a difficult prospect, and therefore, the absence of fugitive sources must be highlighted whenever quoting the estimated consented industrial point source emissions. Like natural sources, source apportionment techniques are necessary to quantify the relative influence of fugitive industrial sources to regional PM_{10} concentrations.

5.0 Conclusions

Industrial operations are an important source of air pollutant emissions in the Auckland region. These emissions can impact air quality in the immediate surrounding areas with resulting effects on human health and amenity and therefore require careful management. Quantifying the scale of the emissions of hazardous air pollutants is a key management tool for understanding the spatial distribution of industrial emission sources and their relative importance to Auckland's overall air quality.

Combustion activities were estimated to emit the greatest quantity of hazardous air pollutants from industrial point-sources in 2016. The processing of aggregates, metals and grains were other notable industrial air discharge activities. Overall, it was estimated that 302 tonnes of PM_{10}, 275 tonnes of $PM_{2.5}$ and 2606 tonnes of NO_x were emitted from stacks and other industrial point sources in 2016.

The emissions of all considered air pollutants discharged by industrial point sources were dominated by NZ Steel, New Zealand's only steel mill, which is located outside the urban area at Glenbrook in the south of the region. Within the urban area, industrial point source emissions were largely concentrated within established industrial areas and were cumulatively of a lesser scale than NZ Steel.

Fugitive industrial air pollutant sources such as emissions of PM_{10} from aggregate handling and vehicle movements across unsealed surfaces may be a greater source of some pollutants than those consented point-source emissions captured by this inventory. Further, a large number of unconsented permitted activities such as discharges of VOCs from automotive painting and NO_x from welding and small natural gas boilers would add to overall 'industrial' air pollutant discharges within the Auckland region.

The emissions of all air pollutants from consented industrial point sources within the urban area were estimated to have declined from previous estimates. This was largely due to a combination of site closures and improved emission controls. For example, industrial NO_x emissions were estimated to have more than halved over a five-year period to 2016 in the Auckland urban area, primarily owing to the closure of the region's two natural gas fired power stations in 2015. $PM_{2.5}$ discharges from industrial point-sources in the urban area were estimated to have decreased by 86% between 2006 and 2016. However, at a regional level, industrial PM_{10} discharges were estimated to have decreased by 34% between 2006 and 2016, failing to meet the 2012 Auckland Plan target of a 50% reduction over this period.

6.0 Acknowledgements

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7.0 References

Auckland Council, 2012. *The Auckland Plan.* Available at: www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/Documents/auckland-plan-2012-full-document.pdf

Auckland Council, 2016. *Auckland Unitary Plan (Operative in Part).* Available at: www.unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx?exhibit=AucklandUnitaryPlan_Print

Bond, T. et al., 2013. Bounding the role of black carbon in the climate system: A scientific assessment. *Journal of Geophysical Research: Atmospheres,* Volume 118, p. 5380–5552.

Crimmins, P., 2017. *Quantifying Black Carbon Emissions from Residential Wood Burning by a Combination of Bottom-Up and Top-Down Approaches,* Auckland: University of Auckland (MSc Thesis).

Davy, P., Ancelet, T., Trompetter, W. and Markwitz, A., 2016. *Source apportionment and trend analysis of air particulate matter in the Auckland Region,* Wellington: GNS Science Consultancy Report 2016/194.

EEA, 2016. *Air Pollutant Emission Inventory Guidebook,* Copenhagen: European Environment Agency Report No 21/2016. Available at: www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

Grange, S. and Xie, S., 2015. *Auckland Industrial Air Emission Inventory 2011*: Auckland Council technical report, TR2015/004. Available at: www.knowledgeauckland.org.nz/assets/publications/TR2015-004-Auckland-2011-industrial-air-emission-inventory.pdf

Huntley, R., 2012. *Emissions Factors for Particulate Matter from Natural Gas, Process Gas and LPG: Not AP-42.* Available at: www.epa.gov/sites/production/files/2015-08/natgas_procgas_lpg_pm_efs_not_ap42_032012_revisions.xls

Janssen, N. et al., 2011. Black Carbon as an Additional Indicator of the Adverse Health Effects of Airborne Particles Compared with PM_{10} and $PM_{2.5}$. *Environmental Health Perspectives 119(12),* pp. 1691-1699.

Kevern, R., Travis, E. and van Kekem, D., 2009. *Background Information on the Industrial Section of the 2006 Air Emissions Inventory*. Prepared for Auckland Regional Council by URS New Zealand Ltd.

Kuschel, G. et al., 2012. *Updated health and air pollution in New Zealand study. Volume 1: Summary report,* Auckland: Emission Impossible. Available at: www.hapinz.org.nz/

MBIE, 2012. *New Zealand Energy Data File.* Available at: www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications/energy-data-file/documents-image-library/energy-data-file-2012.pdf

Metcalfe, J., Fisher, G., Sherman, M. and Kuschel, G., 2006. *Auckland Air Emissions Inventory: 2004,* Auckland: Auckland Regional Council, TP292. Available at: www.aucklandcity.govt.nz/council/documents/technicalpublications/TP292%20Auckland%20Air%20Emissions%20Inventory%202004.pdf

Metcalfe, J., Wickham, L. and Sridhar, S., 2014. *Use of Background Air Quality Data in Resource Consent Applications: Auckland Council Guideline Document 2014/01*:

Prepared by Emission Impossible Ltd for Auckland Council. Available at: www.knowledgeauckland.org.nz/assets/publications/GD2014-001-Use-of-background-air-quality-data-in-resource-consent-applications.pdf

MfE, 2016. *New Zealand's Greenhouse Gas Inventory 1990-2014,* Ministry for the Environment. Available at: www.mfe.govt.nz/sites/default/files/media/Climate%20Change/national-inventory-report-2016.pdf

Pope, C. and Dockery, D., 2006. Health effects of fine particulate air pollution: Lines that connect. *Journal of the Air & Waste Management Association 56,* pp. 709-742.

Resource Management (National Environmental Standards for Air Quality) Regulations. 2004. Statutes of New Zealand, No. 309. Available at: www.legislation.govt.nz/regulation/public/2004/0309/29.0/DLM286835.html

Tonkin+Taylor, 2010. *Assessment of Environmental Effects Discharges to Air: Redvale Landfill,* Auckland: Tonkin+Taylor report 24786.200.

US EPA, 2004. *AP-42 Compilation of Air Pollutant Emission Factors, Fifth Edition. Chapter 1.4: Natural Gas Combustion*. US EPA. Avaialble at: www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors

US EPA, 2008. *Chapter 2.4: Municipal Solid Waste Landfills (Draft).* Available at: www3.epa.gov/ttn/chief/ap42/ch02/draft/d02s04.pdf

US EPA, 2014. *SPECIATE Database Version 4.4,* Research Triangle Park, NC: United States Environmental Protection Agency. Available at: https://cfpub.epa.gov/speciate/

US EPA, 2016. *EPA Method 202 Best Practices Handbook.* Available at: www3.epa.gov/ttnemc01/methods/m202-best-practices-handbook.pdf

Van Brakel, P., 2017. *Emissions for Major PM_{10} and NOx Sources for the Glenbrook Site*, Auckland: NZ Steel.

Wilton, E., Baynes, M. and Iseli, J., 2008. *New Zealand Sulphur Dioxide Industrial Emission Inventory - 2007,* Christchurch: Environet Ltd. Available at: www.environet.co.nz/environet/documents/SO2_InventoryFinalEnvironetCover.pdf

Xie, S., Sridhar, S. and Metcalfe, J., 2014. *Auckland Air Emissions Inventory 2006,* Auckland Council technical report, TR2014/015. Available at: http://knowledgeauckland.org.nz/assets/publications/ TR2014-015-Auckland-air-emissions-inventory-2006.pdf

Appendix A Emission factors used

Table A1: Emission factors for combustion sources

Combustion type	Fuel gross specific energy	Emission factor (kg/MW)						
		TSP	PM_{10}	$PM_{2.5}$	NOx	SO_2	CO	CO_2
Natural gas	41.3 MJ/m³	0.001	0.001	0.001	0.139	0.000	0.117	167.3
Coal	20.2 MJ/kg	1.515	1.105	0.227	0.784	0.936	0.446	428.6
Diesel	36.1 MJ/L	0.024	0.023	0.018	0.240	0.002	0.060	267.1
Diesel generator	36.1 MJ/L	0.480	0.480	0.351	6.827	0.449	1.471	253.9
Waste oil	38.8 MJ/L	0.143	0.114	0.104	0.212	0.819	0.056	245.0
Wood	12.1 MJ/kg	0.464	0.418	0.248	0.759	0.039	0.929	301.9
Landfill gas boiler	37.7 MJ/m³	0.012	0.012	0.011	0.065	0.015	0.009	170.3
Landfill gas engine	37.7 MJ/m³	0.003	0.003	0.002	0.382	0.015	0.808	170.3
Landfill gas flare	37.7 MJ/m³	0.023	0.023	0.019	0.060	0.015	0.070	170.3

Table A2: Source documents for emission factors

Combustion type	Source of emission factors detailed in Table A1
Natural gas	AP-42 c01s04: Small uncontrolled boilers (US EPA, 2004), except PM (Huntley, 2012)
Coal	AP-42 c01s01: Sub-bituminous spreader stoker with multiple cyclones (US EPA, 2004)
Diesel	AP-42 c01s03: Distillate oil fired <100 M Btu/hr (US EPA, 2004)
Diesel generator	AP-42 c03s03: Uncontrolled stationary diesel fuel engine (US EPA, 2004)
Waste oil	AP-42 c01s11: Small boilers (US EPA, 2004)
Wood	AP-42 c01s06: Dry wood, mechanical collector (cyclone) (US EPA, 2004)
Landfill gas boiler	Updated draft AP-42 s2.4: Landfill gas boiler (US EPA, 2008)
Landfill gas engine	Updated draft AP-42 s2.4: Landfill gas boiler (US EPA, 2008), Redvale Landfill AEE for PM (Tonkin & Taylor, 2010)
Landfill gas flare	Updated 2008 draft AP-42 s2.4: Landfill gas flare (US EPA, 2008)

Table A3: Particulate size fraction speciation values (US EPA, 2014)

Source type	PM_{10} (% of TSP)	$PM_{2.5}$ (% of TSP)
Default (source type not listed)	97.6	68.8
Gaseous fuel combustion	100	100
Liquid fuel combustion	97.0	73.2
Solid material combustion	99.7	65.6
Incineration (gaseous fuel)	100	85.0
Aggregate screening and handling	50.0	14.6
Steel abrasive blasting	85.9	43.0

Appendix B Estimated 2016 Auckland regional industrial point source emissions by category

Primary category	Secondary category	2016 Emissions (T/yr)							
		TSP	PM_{10}	$PM_{2.5}$	NOx	SO_2	CO	CO_2	VOCs
Chemical	Manufacturing	2.8	1.7	1.1	33.2	0.0	27.9	39,826.5	29.3
	Printing	0.1	0.1	0.1	13.7	0.0	11.5	16,410.0	239.6
	VOCs	1.9	1.9	1.4	27.8	0.0	21.1	32,798.7	104.7
Combustion	Crematoria	2.0	2.0	1.7	3.8	0.0	3.2	4,549.4	0.0
	Minor	2.3	1.6	0.9	74.1	0.2	63.5	86,236.8	0.0
Dust	Abrasive Blasting	0.5	0.4	0.2	0.0	0.0	0.0	0.0	0.0
	Aggregate	1.1	0.7	0.3	0.4	0.0	0.4	520.1	0.0
	Asphalt	7.0	3.7	2.6	20.4	1.7	19.9	39,497.0	0.0
	Concrete	0.0	0.0	0.0	2.1	0.0	1.8	2,548.2	0.0
	Earthwork	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Quarry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Food	Abattoir	0.1	0.1	0.0	9.8	0.0	8.2	11,771.0	0.0
	Combustion	0.2	0.2	0.1	30.2	0.0	25.4	36,234.7	0.0
	Food	11.8	9.5	6.5	99.4	3.9	83.1	116,580.1	0.0
Metal	Foundry	282.2	251.2	237.2	1,699.4	927.0	2,193.4	1,772,639	0.8
	Galvanising	2.7	2.6	1.9	4.4	0.0	3.7	5,288.0	0.0
	Manufacturing	0.8	0.6	0.4	9.2	0.0	7.8	11,078.0	70.4
	Scrap	0.2	0.2	0.2	0.2	0.0	0.2	191.2	4.7
Non-metal	Manufacturing	32.2	17.2	13.1	399.4	104.6	57.2	81,705.5	13.3
	VOCs	0.0	0.0	0.0	3.9	0.0	3.3	4,688.8	0.0

Primary category	Secondary category	2016 Emissions (T/yr)							
		TSP	PM_{10}	$PM_{2.5}$	NOx	SO_2	CO	CO_2	VOCs
Rural	Food	1.5	1.5	1.0	1.7	0.0	1.5	2,094.4	0.0
	Intensive Livestock Farm	0.0	0.0	0.0	0.1	0.0	0.1	242.4	0.0
Waste	Compost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Haz-Mat	0.1	0.1	0.1	1.1	0.1	0.7	1,909.6	17.5
	Landfill	3.4	3.4	2.9	134.6	1.6	512.4	36,391.6	0.0
	Pumping Station	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Transfer Station	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WWTP	3.4	3.4	2.9	37.2	3.5	64.5	40,722.1	0.0
Total		**356.2**	**301.9**	**274.7**	**2,606**	**1,043**	**3,110**	**2,343,923**	**480.5**

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