

**2022 Update of the New Zealand Inventory of
Dioxin Emissions to Air, Land and Water, and
Reservoir Sources**

Report to the Ministry for the Environment

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Executive Summary

As a signatory to the Stockholm Convention on Persistent Organic Pollutants (POPs), New Zealand has undertaken assessments of national releases of dioxins on a regular basis. These assessments take the form of an emission inventory. Dioxins are a useful surrogate for all POPs species, being much studied, with extensive information available on source discharges and environmental distribution. Estimates of releases of dioxin from 49 different sources in New Zealand have been made for the reference year of 2020 to provide an update for New Zealand's Dioxin Inventory previously published for the reference years of 2008, 2012 and 2016. The United Nations Environment Programme (UNEP) Dioxin Toolkit methodology was used in which the annual dioxin releases from each source are estimated by multiplying an activity statistic by an emission factor. Activity statistics are chosen from measures such as annual fuel consumption, annual production rates etc. Emission factors are based on data for the average dioxin emissions for a particular category per unit of activity. The Toolkit approach assigns releases to five environmental vectors: air, land, water, products, and residues.

Activity data was obtained through published information sources and direct contact with government agencies, and specific industries. Emission factors were based on emissions data for the specific sources, where available, or the default factors given in the UNEP Toolkit.

Although the assessment is quantitative it is important to recognise that there is uncertainty associated with each estimate and that this varies for each category. The uncertainty may be associated not only with the dioxin emission factor but also with the source activity itself. Consequently, the value of the emission inventory is not in its ability to produce absolute numbers, rather the inventory is more suited to revealing trends over time and showing which sources are more significant than others. This knowledge can assist with focussing government initiatives for dioxin release reduction.

Annual Dioxin Releases for 2020

The total dioxin release quantity for New Zealand for 2020 has been estimated at 36.6 g TEQ¹. This can be compared with values of 37.1 g TEQ for 2016 and 37.0 g TEQ for 2012. Figure E1 on the next page shows how individual sources contributed to this total and Figure E2 shows the contribution made by the major release categories. Full details of release quantities from the various sectors investigated are presented in Appendices 1 and 2.

¹ TEQ is an abbreviation for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalents. This is a means of expressing the total content of dioxin-like compounds present, in terms of the most toxic dioxin species – TCDD (see page 4).

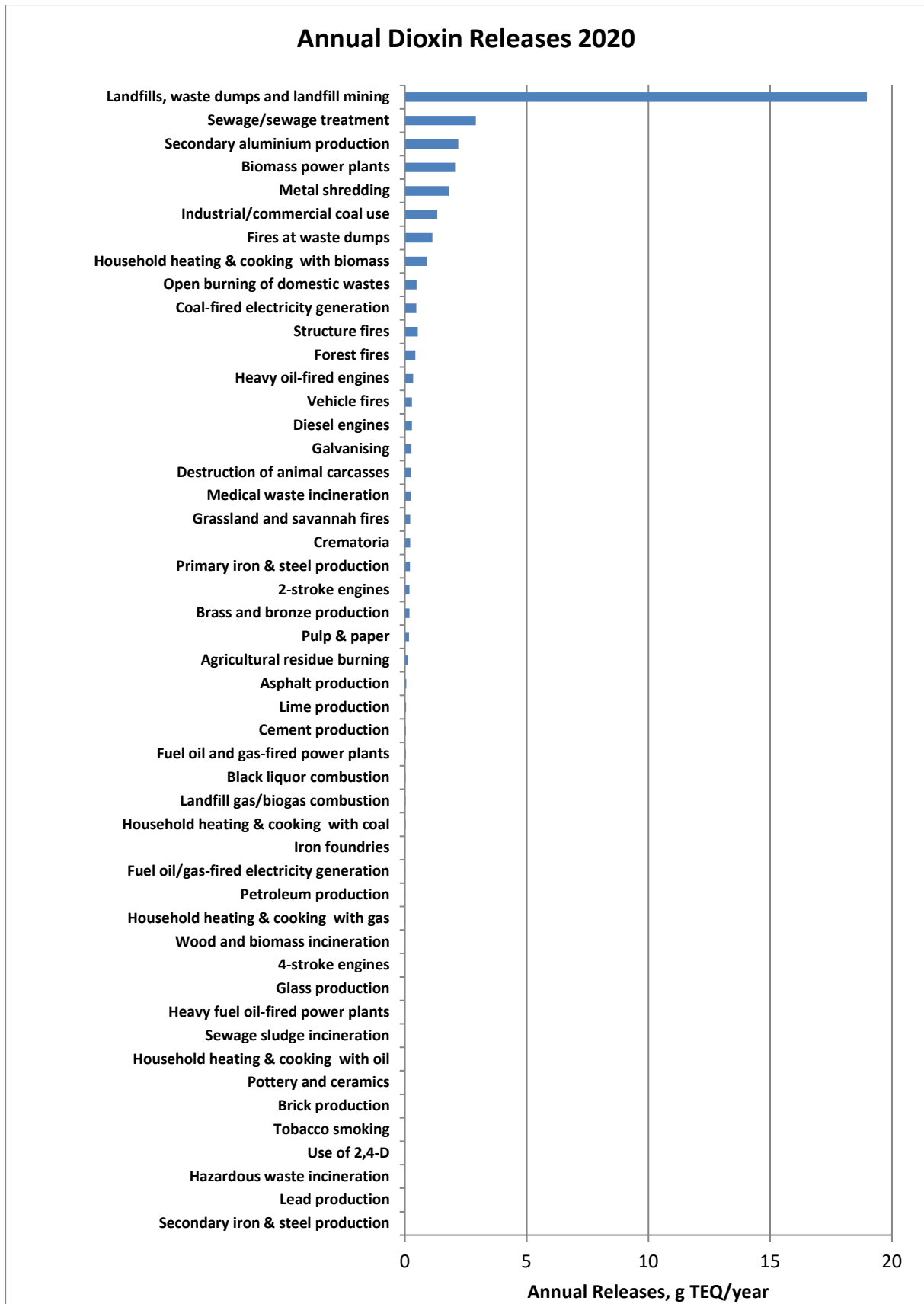


Figure E1. Annual Dioxin Releases for 2020 by Source (see Appendix 2 for details)

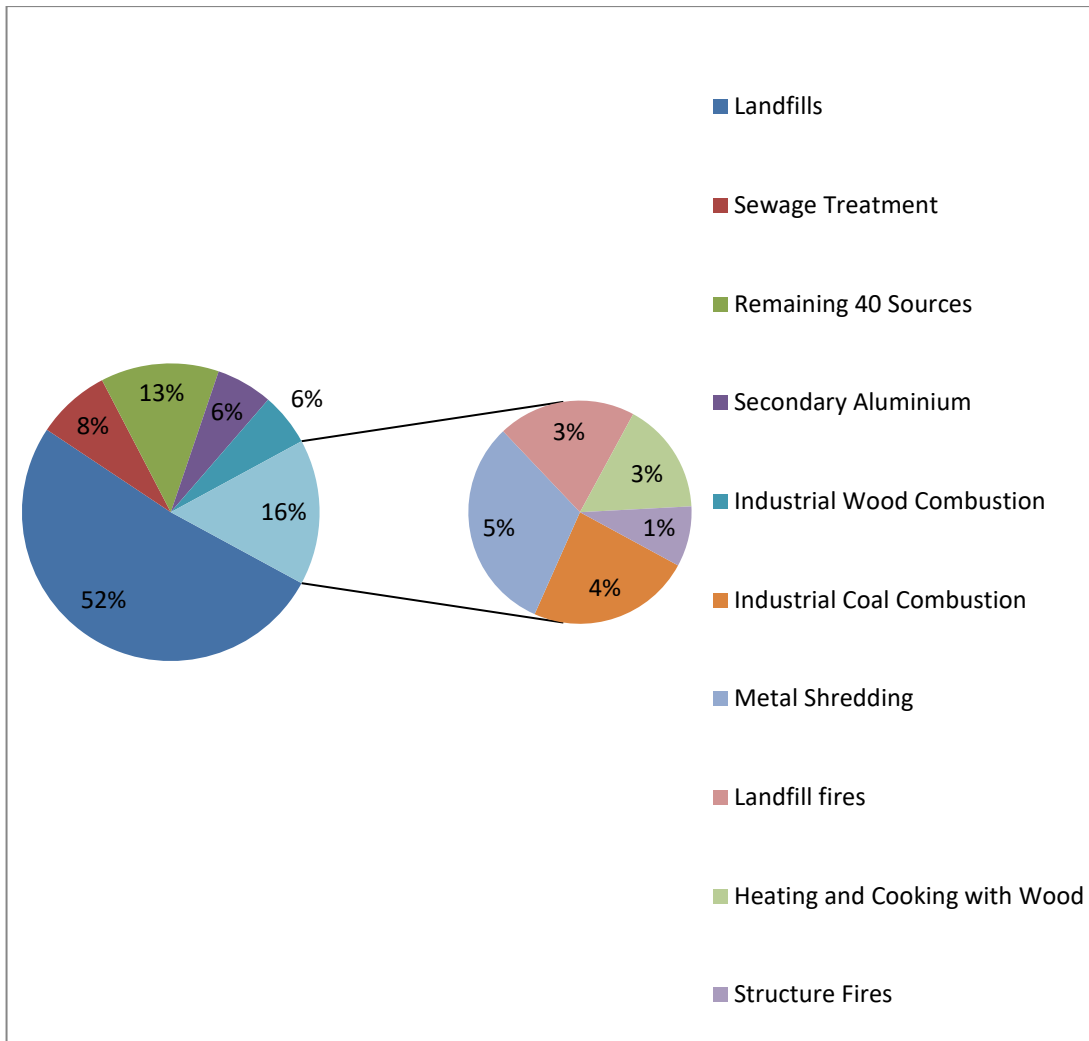


Figure E2*. Plot Showing the Contribution of Major Release Categories for Dioxin

(* The sum of all categories may not total exactly 100.0% due to rounding effects)

- Figure E2 shows that about 60% of New Zealand’s estimated dioxin releases can be attributed to two categories – disposal of municipal waste in landfills and sewage treatment.
- Combined with seven other categories: secondary aluminium processing, industrial wood combustion, industrial coal combustion, metal shredding, landfill fires, heating and cooking with wood and structure fires the nine sources comprise 87% of total dioxin releases with the remaining 13% split between 40 other categories and sub-categories.
- All members of New Zealand’s 5.025 million population contributed to the sewage treatment release in 2020 and a significant majority will have generated wastes disposed of in municipal solid waste landfills.
- Releases from industrial coal and wood-waste combustion are associated with about 500 coal-fired boilers and more than 175 wood-fired power plants.
- Structure fires and landfill fires are essentially random events.
- Heating and cooking with wood, primarily the former, occurs in about 530,000 New Zealand households

Changes between 2016 and 2020

The tables below show source categories which for 2020 had increases or decreases in their dioxin releases by more than 0.01 g TEQ compared with 2016 levels.

Table E1. Source Categories with Increases Compared to 2016

Source Category	Change in Dioxin Release (g TEQ/annum)
Industrial biomass (wood waste) combustion	+0.76
Landfill fires	+0.75
Metal shredding	+0.52
Coal-fired electricity generation	+0.35
Landfills, waste dumps and landfill mining	+0.27
Sewage/sewage treatment	+0.22
Forest fires	+0.20
2-stroke engines	+0.17
Pet cremators	+0.14
Vehicle fires	+0.046
Crematoria	+0.020
Diesel engines	+0.019

- Releases from combustion of wood waste in industrial boilers have increased because of improvements in consumption estimates.
- Landfill fires, forest fires and vehicle fires are unpredictable events which will fluctuate from year to year.
- Metal shredding releases have increased due to an increase in shredder operators and material throughput.
- Releases from coal-fired electricity generation have increased because more coal was burned to cover hydroelectricity shortages and maintenance of the Cook Strait cable in 2020.
- Increased releases from landfill deposition, sewage treatment, and crematoria can be attributed to population increase.
- Pet cremator increases can be attributed to improvements in throughput estimation following a Regional Council survey.
- Releases from 2-stroke engines are greater because of increased fuel consumption estimates for the recreational marine sector.
- Increased releases from diesel engines result from increased diesel consumption which may be related to heavy fuel oil replacement in the marine transport industry.

Table E2. Source Categories with Decreases Compared to 2016

Source Category	Change in Dioxin Release (g TEQ/annum)
Secondary aluminium production	-1.48
Structure Fires	-0.87
Open burning of domestic wastes	-0.35
Pulp & paper production	-0.34
Industrial/commercial coal use	-0.23
Primary iron & steel production	-0.18
Brass and bronze production	-0.15
Iron foundries	-0.12
Household heating & cooking with biomass (wood)	-0.069
Heavy oil-fired engines	-0.034
Wood and biomass incineration (school incinerators)	-0.033
Lime production	-0.029
Black liquor combustion	-0.018
Agricultural residue burning	-0.014
Petroleum production	-0.011

- Plant closures and / or decreases in production quantities were the cause of the release reductions for secondary aluminium, copper brass and bronze production and iron foundries.
- Structure fires are unpredictable events which will fluctuate from year to year.
- Releases from open burning of domestic wastes have reduced because of a decrease in the estimate of the amount of waste burnt by households.
- Pulp and paper releases have decreased due to a reduction in bleached kraft pulp production.
- Decreases in releases from industrial and commercial coal use are due to drops in coal consumption caused by COVID lock downs in 2020.
- Releases from primary iron and steel production have decreased because a greater proportion of waste materials are being recycled through the process rather than being sent to landfill.
- Reductions for household heating and cooking with biomass (wood) reflect a decrease in the number of wood burners.
- Heavy oil-fired engine release reductions follow a drop in fuel consumption of this type by the marine transport industry which may be related to international controls on sulphur emission levels.
- Fewer schools operating incinerators is the reason for the release drop in the wood and biomass incineration category.
- Lime production release reductions reflect a downward trend in lime production.
- The extent of agricultural residue burning fluctuates from year to year.
- Black liquor combustion release reductions are due to reduced kraft pulp production in 2020.
- Petroleum production releases have reduced due to reduced feedstock processing at the Marsden Point refinery as COVID travel restrictions impacted fuel consumption, particularly in the aviation industry, in 2020.

Trends in Dioxin Releases

Figures E3 and E4 display plots of dioxin releases versus source category for 2012, 2016 and 2020. The sources have been categorised as major and minor to make the lesser sources more visible.

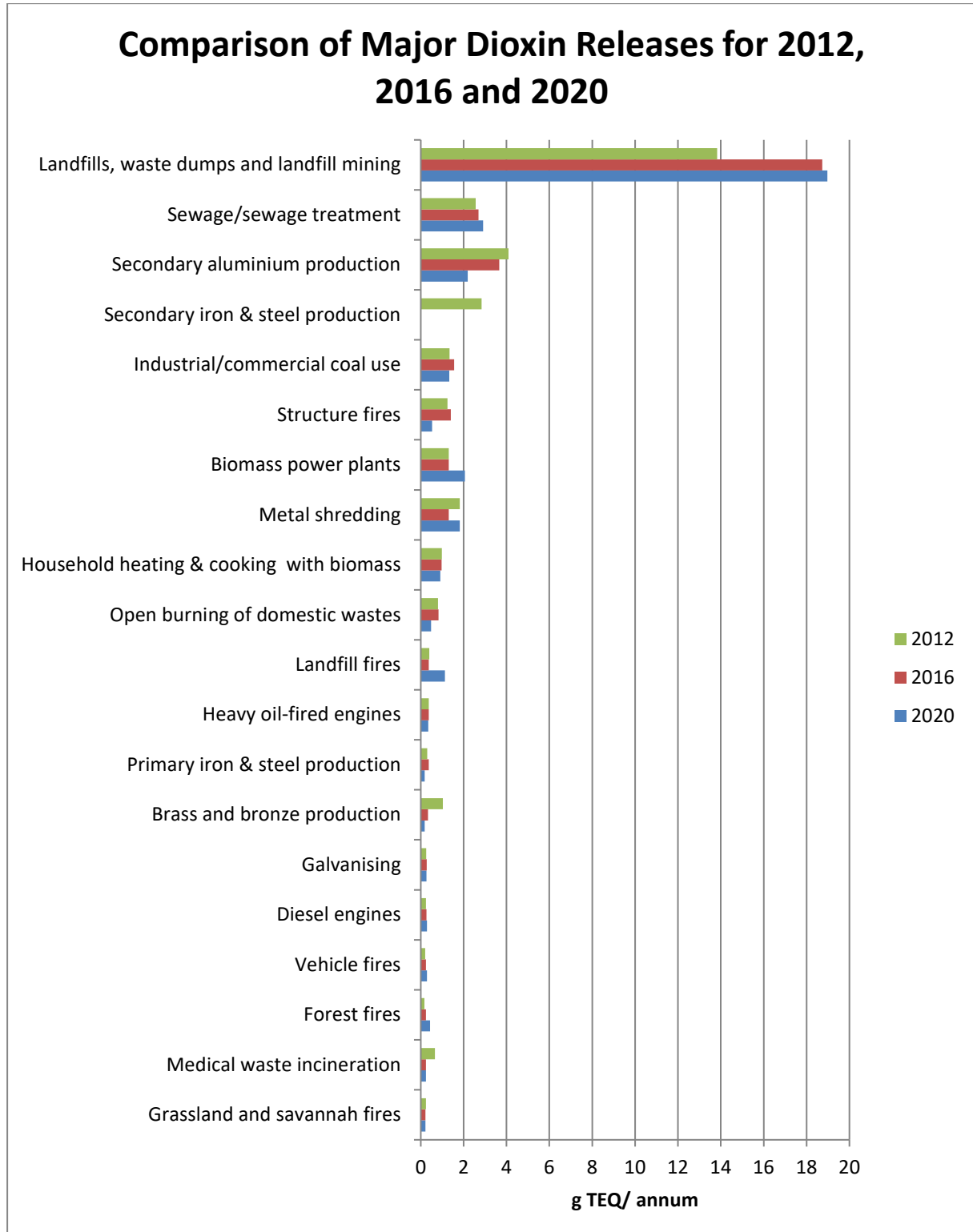


Figure E3. Major Sources' Dioxin Releases for 2012, 2016 and 2020 (see Appendix 2 for details)

(* NZ's sole secondary iron and steel plant closed in 2015 so there is no data for 2016 and 2020)

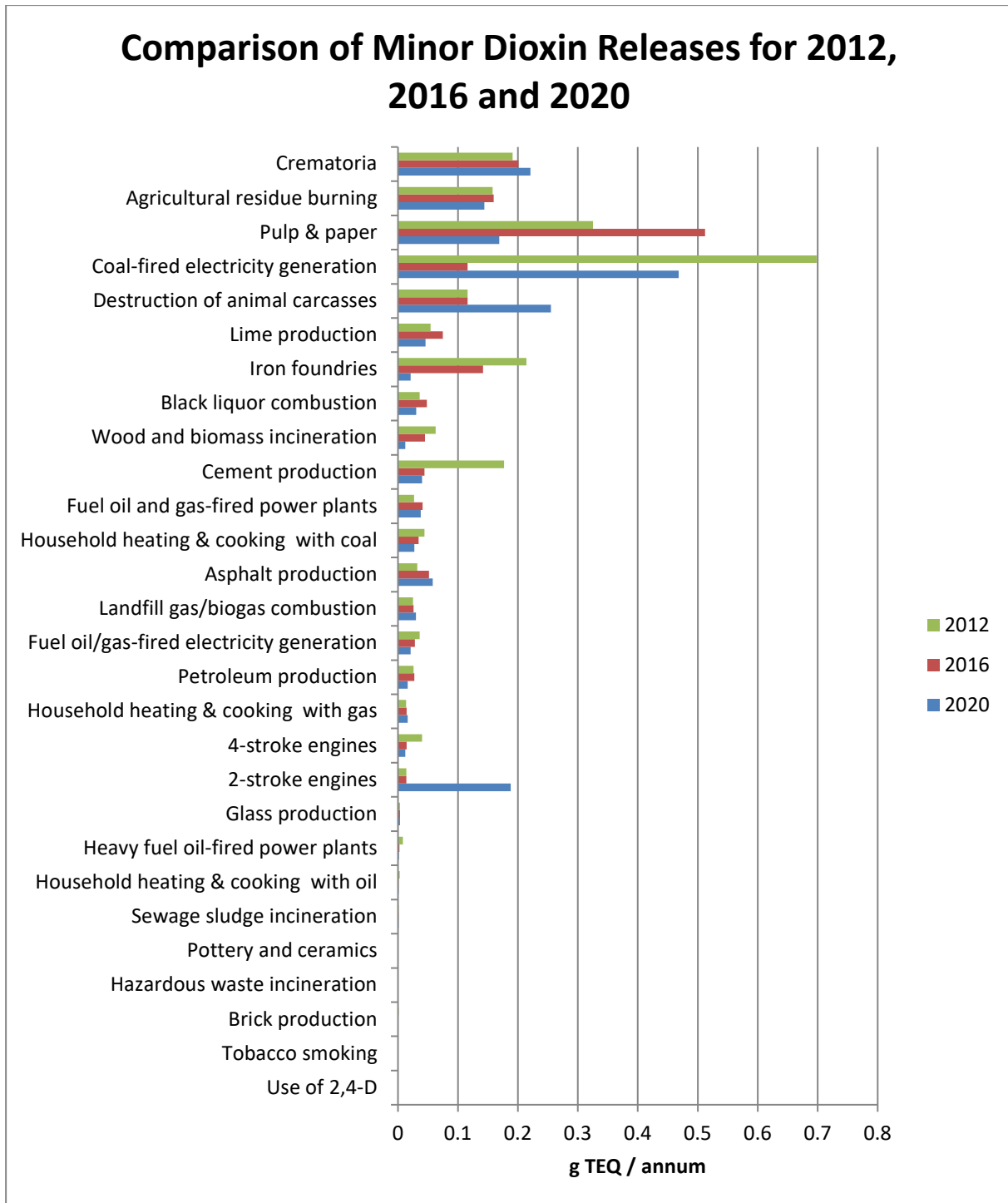


Figure E4. Minor Sources' Dioxin Releases for 2012, 2016 and 2020 (see Appendix 2 for details)

Figures E3 and E4 show an increasing trend of dioxin release for landfill deposition, although the rate of change is declining. In contrast, a decreasing trend is evident for secondary metal activities such as secondary aluminium and steel production, iron foundries and brass and bronze production largely due to plant closures.

Sewage treatment and crematoria show a trend of increasing dioxin releases as their activities are based on population numbers. Asphalt production also shows an increasing trend reflecting the fact that major new roads continue to be built while existing roads require maintenance.

Household heating and cooking with biomass (wood) and coal both show a gradual decline in dioxin releases as burners and stoves are slowly replaced with devices requiring alternative forms of energy such as electricity.

Dioxin Reduction Initiatives

As shown in Figures E1 and E2 landfills are by far the largest source of dioxins for New Zealand. Because the types of waste deposited in municipal landfills are so diverse, only a very general emission factor can be applied to estimate dioxin releases from this source. Where the waste total is comprised of significant volumes of inert materials such as food wastes, cleanfill, and garden waste it is probable that the dioxin release is being over-estimated and reducing their volume will result in a reduction in the dioxin estimation for landfills.

There are currently a number of government initiatives which are aimed at reducing waste volumes. New legislation is anticipated which will replace the current Waste Minimisation Act 2008 and Litter Act 1979, and will place greater emphasis on a circular economy where resources are kept at their highest value use for as long as possible. From 1 July 2022 the Waste Levy was significantly increased and expanded with charges for municipal landfills increasing from \$20 to \$30 per tonne. These charges will increase further to \$50 per tonne in 2023 and \$60 per tonne in 2024. Other initiatives include an investment of \$124 million in resource recovery infrastructure, continuing investment in the Waste Minimisation Fund and introducing regulated product stewardship for six waste streams including plastic packaging and tyres. In addition, the government is considering recommendations to incentivise councils to implement kerbside collection of food waste and standardise the materials collected in kerbside recycling nationally.

Global and national perspectives

Estimates of global per capita releases of dioxins are in the range 15 – 39 g TEQ per million people per year. In comparison New Zealand had releases of 8.4 g TEQ per million in 2012, 7.9 g TEQ per million in 2016 and 7.3 g TEQ per million in 2020.

There are no official recommendations for ‘acceptable’ levels of national dioxin releases, and it is also not possible to relate the release estimates directly to any potential health effects. The more relevant information is provided by national surveys of dioxin body burdens, for which there have been several New Zealand studies.

The levels of dioxins in mothers’ milk have been measured on 3 occasions in New Zealand: 1988, 1998 and 2008. These studies showed that the dioxin concentrations in New Zealand mothers are relatively low by comparison with many other countries. Also, the levels have been steadily dropping, with a reduction of 70% observed from 1988 to 1998, and a further reduction of 40% from 1998 to 2008.

The levels of dioxins in blood serum have been monitored on two occasions in New Zealand, in 1997 and 2012. Once again, these studies showed the dioxin concentrations in New Zealanders are relatively low by comparison with many other countries, and the levels have dropped over time.

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Units and abbreviations

Units

g	gram
kg	kilogram (10 ³ grams)
tonne	10 ³ kilograms or 10 ⁶ grams
ktonne	kilotonne (10 ³ tonnes or 10 ⁶ kilograms)
µg	microgram (10 ⁻⁶ grams)
ng	nanogram (10 ⁻⁹ grams)
pg	picogram (10 ⁻¹² grams)
MJ	megajoule (10 ⁶ joules)
GJ	gigajoule (10 ⁹ joules)
TJ	terajoule (10 ¹² joules)
PJ	petajoule (10 ¹⁵ joules)
L	litre
m ³	cubic metre
Nm ³	normal cubic metre of dry gas at 0°C and 101.3 kilopascals
kW	kilowatt (10 ³ watts)
kWh	kilowatt-hour
MW	megawatt (10 ⁶ watts)
GWh	gigawatt-hour

Abbreviations

BAT/BEP	best available techniques / best environmental practices
BLS	black liquor solids
CKD	cement kiln dust
dioxins	generic name for the PCDDs and PCDFs
FAO	Food and Agriculture Organization
LPG	liquefied petroleum gas
MDF	medium density fibreboard
PCDD	polychlorinated dibenzo- <i>p</i> -dioxin
PCDF	polychlorinated dibenzofuran
POPs	persistent organic pollutants
TEQ	toxic equivalents
UNEP	United Nations Environment Programme
USA	United States of America
US EPA	United States Environmental Protection Agency
WHO	World Health Organization

Update of the New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources

1 Introduction

This report provides an update of the *New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources 2018* (Ministry for the Environment, 2019) – the 2016 Inventory. It has been prepared under contract to the New Zealand Ministry for the Environment and covers all of the 49 different sources considered in the 2016 Inventory.

1.1 Background

New Zealand has an obligation under the Stockholm Convention on Persistent Organic Pollutants to periodically prepare inventories of the unintentional releases of two specific groups of persistent organic pollutants: the polychlorinated dibenzo-p-dioxins (PCDDs) and the polychlorinated dibenzofurans (PCDFs). For convenience, these are generally referred to using the collective term ‘dioxins’, or the abbreviations PCDDs and PCDFs.

There have been four previous reports on dioxin releases to air, land and water, and reservoir sources in New Zealand. The first was published in 2000, based on 1998 data (Ministry for the Environment, 2000). This study pre-dated the Toolkit and used emission factors derived from the best information available to the compilers at the time. There were also fewer source categories investigated than in the later inventories. The second was published in 2011 based on 2008 data (Ministry for the Environment, 2011a), the third published in 2014 based on 2012 data (Ministry for the Environment, 2014) and the fourth published in 2018 on 2016 data (Ministry for the Environment, 2019). This report provides an update of the 2018 inventory report (herein referred to as the 2016 Inventory) for the reference year of 2020.

1.2 Methodology

The methodology used for the inventory update is summarised in Section 2 of this report. It has been based on the use of the latest version (v3) of the *Standardised Toolkit for Identification and Quantification of Dioxin and Furan Releases* (United Nations Environment Programme, 2013) (herein referred to as the UNEP Toolkit). The methodology involves an emission factor approach, in which the annual releases from each source are estimated by multiplying an activity statistic by an emission factor. Activity statistics are chosen on the basis of fuel consumption, production rates or some other similar measure, while the emission factors are based on data for the average emissions to air, land, or water, per unit of activity.

The required activity data was obtained through published information sources and direct contact with government agencies, and specific industries. The emission factors were based on emissions data for the specific sources, where available, or the default factors given in the UNEP Toolkit.

1.3 Report layout and content

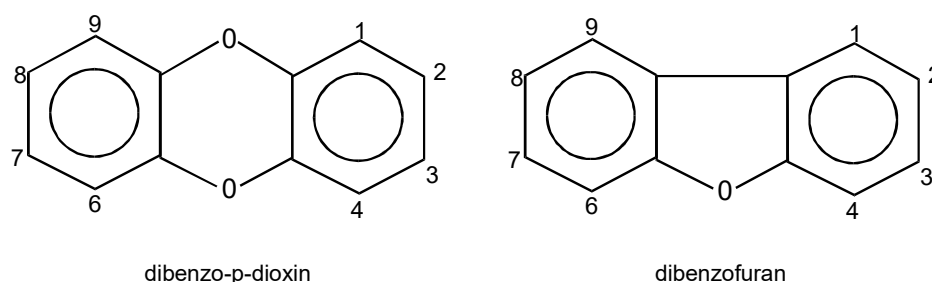
Details of the UNEP Toolkit methodology and related aspects are presented in section 2. This is followed by individual sections covering each of the 10 Toolkit source categories, and a summary and discussion section.

2 Dioxin Formation and the UNEP Toolkit

2.1 Dioxin Formation

The basic structures of the polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) are shown in Figure 2.1. Although dibenzofurans have a slightly different structure from the dibenzo-p-dioxins, their chlorinated derivatives have similar toxicities so the two groups are typically combined together under the umbrella term 'dioxins'. Both groups of chemicals can have up to eight chlorine atoms attached at positions 1 to 4 and 6 to 9 of the ring structures. Each individual compound resulting from this arrangement is referred to as a congener, and specific congeners are distinguished by the number and position of chlorine atoms around the core structure. In total there are 75 possible PCDD congeners and 135 possible PCDF congeners.

Figure 2-1: Structures of dibenzo-p-dioxin and dibenzofuran



Dioxins are not produced intentionally but are released to the environment from a variety of industrial discharges, combustion processes, and as a result of their occurrence as unwanted by-products in various chemical products (United Nations Environment Programme, 2013).

Historically, the manufacture and use of chlorinated aromatic chemicals has been a major source of dioxins. The most notable examples include the wood preservative and biocide, pentachlorophenol, the herbicide 2,4,5-T (2,4,5-trichlorophenoxy acetic acid), and the industrial chemicals known as PCBs (polychlorinated biphenyls).

Other chemical/industrial processes, such as the production of chlorine-bleached pulp, have led to environmental contamination by dioxins, as well as the trace contamination of pulp and paper products.

Combustion processes are another important source of dioxins. Dioxins have been detected in the emissions from waste incineration, particularly municipal, medical, and hazardous wastes, from the production of iron and steel and other metals, including scrap metal reclamation, from fossil fuel plants, domestic coal and wood fires, rubbish burning, and motor vehicles (especially when using leaded fuels), as well as from accidental fires.

2.2 The UNEP Toolkit

The UNEP Toolkit was developed by UNEP Chemicals with the aim of achieving an effective and standardised approach to compiling PCDD/PCDF emission inventories (United Nations Environment Programme, 2005). This was intended to ensure a reasonable degree of consistency between the inventories reported by different countries, as part of their requirements under the Stockholm Convention, and should also help in comparing inventory results between countries or changes over time.

The 2020 Inventory, like its 2016 predecessor, is based on the 3rd edition of the UNEP Toolkit (2013). The 2008 Inventory was based on the second edition of the Toolkit. Back calculations on the source categories which had changes to their release factors were performed to enable meaningful comparisons between the 2008 Inventory and later versions (see Section 2.5).

The UNEP Toolkit methodology involves estimation of the annual releases from each source by multiplying an activity statistic by an emission factor:

$$\text{annual release (g TEQ/year)} = \text{activity (tonnes/year)} \times \text{emission factor (g TEQ/tonne)}$$

Activity statistics are chosen on the basis of fuel consumption, production rates or some other similar measure, and are specific to each country. Emission factors can also be country specific if sufficient emissions data is available for individual sources. However, the UNEP Toolkit provides default factors for use when this data is not available.

The UNEP Toolkit classifies all potential dioxin sources into the following 10 categories:

1. Waste incineration
2. Ferrous and non-ferrous metal production
3. Heat and power generation
4. Production of mineral products
5. Transportation
6. Open burning processes
7. Production of chemicals and consumer goods
8. Miscellaneous sources
9. Disposal
10. Contaminated sites and hotspots.

Within the Toolkit, each of the categories is divided into sub-categories on the basis of the different types of processes (eg, incineration of hazardous wastes, municipal wastes, medical wastes, etc), and each of the sub-categories is divided into several classes, depending on the degree of process and/or emission control. Typically, class 1 processes are those with basic equipment and minimal levels of control. As the class number increases (from class 2 through classes 4 or 5), the performance of the process or activity improves, resulting in lower dioxin releases. The highest Toolkit class in each subcategory is usually representative of the emission levels that can be achieved through the application of best available techniques and best environmental practices (BAT/BEP).

The default emission factors given for each class represent the best estimate of average emission rates based on measured data at existing sources with similar technologies, process characteristics and operating practices. Most of the emission factors are based on published data found in peer-reviewed literature, or in government or institutional reports. In order to make the emission factors user-friendly, manageable, and robust, this original data has been aggregated into order-of-magnitude estimates for the majority of the source sub-categories and classes.

Emission factors have been recommended for the following release vectors: to air, water, land, or in products or residues, although not all vectors are applicable to each subcategory. The UNEP Toolkit residues vector relates mainly to sources that result in a process by-product or waste (eg, the dusts collected in bag filters). These may be either processed (eg, for materials recovery) or disposed, usually to landfill. In New Zealand, the latter option is the dominant route. However, for consistency with the UNEP Toolkit approach they have been recorded as releases via residues unless the wastes are known to be disposed at the company's own (usually on-site) landfill.

2.3 Release estimates

The choice of emission factors for each source or group of sources is discussed within each of the inventory sections. The general approach taken has been to use New Zealand data, when available. In the absence of any

local data, the factors given in the UNEP Toolkit have been used. In those cases where the amount of local data is limited, a judgement call has been made as to the most appropriate factor to use.

The estimates for the dioxin releases are expressed in terms of Toxic Equivalents. There are 210 different chlorinated dioxins, but only 17 have significant toxicity. When reporting the results of dioxin monitoring the quantities of all 210 congeners are converted to a single Toxic Equivalent (or TEQ) value, which reflects the overall toxicity of the mixture in terms of the most toxic congener; 2,3,7,8-tetrachlorodibenzo-p-dioxin (which, for simplicity is usually referred to as TCDD).

Historically, there have been several TEQ systems, but the most widely recognised are the “International” system, referred to as I-TEQs, and the World Health Organization (WHO) regime, referred to as WHO-TEQs. The most recent review of toxic equivalence was undertaken by WHO in 2005 and this is now the internationally preferred system (United Nations Environment Programme, 2013). Unlike the older I-TEQ system, the 2005 WHO TEQ system includes factors for 12 dioxin-like PCBs.

All of the dioxin release estimates presented in this inventory are reported as TEQ, with no distinction as to the TEQ system used. This is consistent with the approach taken in the UNEP Toolkit, which notes that, for the purposes of national inventories, the differences between I-TEQs and WHO-TEQs are relatively minor (United Nations Environment Programme, 2005). In addition, the primary focus of a national inventory should be on the relative (ie, order of magnitude) differences between different types of sources, and the broad-scale changes in releases over time.

The reference date for this inventory is taken as the 2020 calendar year, and 2020 activity data has been used whenever possible in deriving the estimates. The use of data from earlier years has been noted where relevant.

2.4 Certainty Estimates

No source considered in this inventory has been studied comprehensively (ie, had its emissions measured under all conditions over an extended period of time), therefore all estimates made are subject to uncertainty. This uncertainty applies to both the activity data and the emission factors used to estimate the emissions. A qualitative indication of the certainty of each estimate has been provided using three ranking levels: high, medium, and low. The certainty ranking was assigned based on the available data, including a consideration of data quality, knowledge of each source sector, and a broad knowledge of emission factors. In addition, the following general principles were adopted.

Activity statistics

- A high certainty ranking was assigned if the statistics were based on specific industry data or were derived from comprehensive survey data.
- A medium certainty ranking was applied if limited industry or survey data was available, or if the data was modified to account for confounding factors.
- A low certainty ranking was assigned if there was no data available and the level of activity was based on subjective assessment and/or modeled data.

Emission factor

- A high certainty ranking was assigned if a reasonable amount of recent emissions data was available for the specific New Zealand sources.
- A medium certainty ranking was assigned if the New Zealand emissions data was limited or dated, but the emission factors compared well with the UNEP Toolkit factors.

- A low certainty ranking was assigned if there was no New Zealand data available, and the estimate of PCDD/PCDF emissions was based solely on the UNEP Toolkit factors.

2.5 Back-calculations

The UNEP Toolkit provides emission factors for a total of about 400 different sub-categories and classes spread across the 10 source groupings. The accuracy and relevance of these factors is subject to periodic review by an Expert Group established under the Stockholm Convention. The latest version (v3) of the UNEP Toolkit was produced by the Expert Group in January 2013.

One of the key functions of an emissions inventory is to allow changes in emissions to be tracked over time. Primarily, these changes should relate to changes in the mixture of different sources in the country, and the source activity rates. However, tracking these changes becomes more complicated if the emission factors are also changed. Back calculations may also be required where errors are recognised or changes to the procedures used to estimate releases occur. For this inventory back calculations have been performed for sewage sludge generation for the 2012 and 2016 Inventories due to changes in the way activity is determined.

2.6 Units

The use of different units within this report is potentially confusing because the data cover such a wide range of values. For example, the release factors for individual sources are usually measured in nanograms per gram (10^{-9} grams/gram), or micrograms per tonne (10^{-6} grams/tonne), while the annual activity rates for different sources may be measured in kilograms, tonnes or Megatonnes (10^6 tonnes).

The complexity is further compounded by the use of different types of units. For example, most activity rates are measured in mass units (ie, tonnes/year) but those for fuels are measured in energy terms, such as Joules, and TeraJoules (10^{12} Joules). In addition, the activity rates for releases to water are measured on a volume basis (ie, litres or cubic metres (10^3 litres)).

This issue has been partially addressed by standardising the release factors given in the report to units of micrograms (μg , or 10^{-6} grams) TEQ per tonne, for releases to air or land, and in residues or products, and picograms (pg, or 10^{-12} grams) TEQ per litre, for releases to water. In addition, all of the annual releases are given in standard units of g TEQ per year. Where necessary, the numbers may also be given in alternative units, in brackets, to assist with the overall understanding.

3 Waste incineration

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 1a Municipal solid waste incineration
- 1b Hazardous waste incineration
- 1c Medical waste incineration
- 1d Light-fraction shredder waste incineration
- 1e Sewage sludge incineration
- 1f Waste wood and waste biomass incineration
- 1g Destruction of animal carcasses

Waste incineration is well-recognised as a potential source of dioxins, with the dioxins being formed mainly as a result of incomplete combustion of the waste materials. The extent of dioxin formation is strongly influenced by the waste composition (eg, presence of chlorinated materials) and condition (eg, loose or compacted, wet or dry), the combustion conditions, the temperature and composition of the discharges, and the overall design and operation of the incinerator. The presence of metals, such as copper in some of the wastes, can also have a catalytic effect on dioxin formation. In addition, the final emissions can be strongly influenced by the performance characteristics and efficiency of any pollution control equipment.

3.1 Municipal solid waste incineration

There are no large-scale facilities in New Zealand dedicated to the incineration of wastes, and most municipal solid wastes are disposed to landfill (Ministry for the Environment, 2005).

3.2 Hazardous waste incineration

There is one high-temperature hazardous waste incinerator in New Zealand, which is operated by Dow AgroSciences Ltd at their agrichemical formulation plant in New Plymouth. In 2019 Dow AgroSciences became Corteva Agriscience after the merger between Dupont and Dow Chemicals in 2017.

The incinerator is used for the treatment and disposal of some of the wastes generated on-site that are potentially contaminated with agrichemicals. In the past, air emissions from the incinerator have been tested twice a year for dioxins by an external contractor. However, since 2016 the incinerator has been largely unused and the requirement for emission testing was waived by Taranaki Regional Council for the period 2017 – 2020 (Taranaki Regional Council 2019a, Taranaki Regional Council 2019b and Taranaki Regional Council 2021).

The incinerator was out of service for most of 2020 but did operate at the end of the year for 138 hours to process liquid wastes. (T Gellen, Corteva Agriscience, pers comm, 2022). In the absence of more recent dioxin emission testing results, those for 2016 will be used. These indicated an average dioxin emission rate of 39.7 ng TEQ per hour (3.97×10^{-8} g TEQ/hr) (Ministry for the Environment, 2019). Combining the emission rate with hours of operation gives an annual dioxin emission rate of 0.00000548 grams TEQ/year.

A very small proportion of the total waste burned is left as an ash residue which is periodically removed from the unit and stored in drums prior to disposal in an approved landfill. The quantity of ash generated in 2016 was 0.696 tonnes for 8200 hours of operation. Assuming a similar rate of ash production for the 138 hours of operation in 2020 gives a total of 0.012 tonnes. Applying the previously used release estimate of 25 µg TEQ per tonne (25×10^{-6} g TEQ/tonne) gives an annual release in residues of 0.0000003 g TEQ per year.

The current release estimates for the hazardous waste incinerator are shown in Table 3-1, along with the estimates from the 2012 and 2016 Inventories. There are no direct releases to water, land, or in products.

Table 3-1: Dioxin releases from hazardous waste incineration

Year	Activity Rate	Release factors		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	8000 hrs/year operation	5.96 ng TEQ/hr	-	0.000048	-
	2. 1 tonnes ash/year	-	25 µg TEQ/t	-	0.000053
2016	8200 hrs/year operation	39.7 ng TEQ/hr	-	0.00033	-
	0.676 tonnes of ash/year	-	25 µg TEQ/t	-	0.000017
2020	138 hrs/year operation	39.7 ng TEQ/hr		0.0000055	
	0.012 tonnes of ash/year		25 µg TEQ/t		0.00000030

Certainty assessment for 2020

Activity data: Medium (because they are based on operator estimates)

Emission factors: Air- High, and residues - Low (because they are based on actual measurements, and historical analytical data, respectively)

3.3 Medical waste incineration

Quarantine waste incineration, which is not covered in the UNEP Toolkit, has been covered in this section because the incinerator design and operation are quite similar.

There is only one medical waste incinerator in New Zealand. This is a diesel-fired, dual-chamber unit, with no add-on emission controls. In 2020 the total waste throughput was 78 tonnes (B Woolhouse, Grey Hospital, pers comm, 2022) which was the same as that estimated for 2016. The emissions have not been tested for dioxins.

The only incinerator burning quarantine waste in New Zealand was closed between 2014 and 2015 so there is no longer a release from this source.

The UNEP Toolkit recommends default factors of 3000 µg TEQ/tonne for releases to air and 20 µg TEQ/tonne for residues (ash) for batch-operated medical waste incinerators with minimal or no air pollution control systems (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). This is the appropriate sub-category for the Grey Hospital incinerator and the release estimates for 2020 based on these factors are shown in Table 3-2. There are no releases to water, land, or in products.

Table 3-2: Dioxin releases from medical and quarantine waste incineration

Source	Activity Rate, tonnes of waste/year	Release factors, µg TEQ/t		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012 Medical waste and quarantine waste	219	3000	-	0.657	-
		-	20	-	0.0044
2016 Medical waste	78	3000	-	0.234	-
		-	20	-	0.00156
2020 Medical waste	78	3000		0.234	
			20		0.00156

Certainty assessment for 2020

Activity data: Medium (because they are based on operator estimates)

Emission factors: Low (because they are based on default factors given in the UNEP Toolkit)

3.4 Light-fraction shredder waste incineration

Metal shredders are used for the processing of a range of scrap metals, including car bodies, white-ware, and roofing iron. There are two outputs: a relatively clean ferrous metal stream and a ‘fluff’ or ‘flock’ stream which contains fragments of metals plus other waste materials from the input stream. This Toolkit category covers the disposal of the latter material by incineration which is a potential source of dioxins. However, in New Zealand the material is disposed to a landfill (see section 4.3.2), so need not be considered here.

3.5 Sewage sludge incineration

There is one sewage sludge incinerator in New Zealand. It is operated by the Dunedin City Council at its wastewater treatment plant in Dunedin. The incinerator is a diesel-fired, fluidised bed unit and the exhaust gases are treated in a high-efficiency venturi scrubber, followed by a packed-tower caustic scrubber. The gases are then passed through a bark biofilter which acts as a final scrubber, primarily for odour control.

The incinerator normally processes about 4,500 tonnes of wastewater solids per year. For the 2020 calendar year 4664 tonnes of solids were incinerated. This material was comprised of 33.8% dry solids (C. McGaw, Dunedin City Council, 2022). Consequently, on a dry basis, 1576.4 tonnes of wastewater solids were incinerated.

The dioxin emissions to air are tested on an annual basis. The average dioxin result from three tests conducted in November 2019 was 44.0 ng TEQ / hr (1 ng = 1 x 10⁻⁹ g) (K2 Environmental, 2020) and this was used to generate a release factor of 0.245 µg TEQ/tonne dry sludge. for releases to air. The UNEP Toolkit default factors will be used for the releases in residues.

The release estimates for 2020 for the sewage sludge incinerator are shown in Table 3-3. There are no releases to water, land, or in products.

Table 3-3: Dioxin releases from sewage sludge incineration

Year	Activity Rate, tonnes of waste/year	Release factors, µg TEQ/t		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	1700	0.057	-	0.000097	-
		-	0.5	-	0.00085
2016	1424	0.160	-	0.000228	-
		-	0.5	-	0.00071
2020	1576	0.245	-	0.000386	-
		-	0.5	-	0.000788

Certainty assessment for 2020

Activity data: High (because they are based on recorded values)

Emission factors: High for air and Low for residues (because they are based on emission test data and the Toolkit default factors, respectively)

3.6 Waste wood and waste biomass incineration

School incinerators are not specifically covered in the UNEP Toolkit, but they fit reasonably well in this sub-category because at least some of the school wastes can be considered as biomass.

For the 2008 and 2012 Inventories it was estimated that there were 70 school incinerators operating in New Zealand, mainly in small rural schools without easy access to waste collection services or a local waste transfer station. The total waste quantity burned by these incinerators was estimated to be 70 tonnes per year. The Ministry of Education was contacted to determine the number of school incinerators currently in operation. There are 13 schools with existing and valid consents (S. Cruikshank, Ministry of Education, pers comm, 2022) and this number are assumed to have been operative in 2020. The estimate of the annual waste quantity burnt has been reduced proportionally to 13 tonnes.

The release estimates for 2012, 2016 and 2020, based on the default factors given in the UNEP Toolkit, are shown in Table 3-4. There are no releases to water, land, or in products.

Table 3-4: Dioxin releases from school waste incinerators

Source	Activity Rate, tonnes/year	Release factors, µg TEQ/t		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
School incinerators 2012	70	300	-	0.021	-
		-	600	-	0.042
School incinerators 2016	50	300	-	0.015	-
		-	600	-	0.030
School incinerators 2020	13	300	-	0.0039	-
		-	600	-	0.0078

Certainty assessment for 2020

Activity data: School incinerators, High (because it is based on Ministry data)

Emission factors: Low (because they are based on default factors given in the UNEP Toolkit)

3.7 Destruction of animal carcasses

The disposal of animal carcasses in New Zealand using combustion falls into two categories depending on whether the animals are commercial livestock or domestic pets. On-farm disposal of dead livestock occurs by open burning and any releases should be captured under the general “Open Burning” sub-categories of section 8. On the other hand, domestic pets and other small animals are disposed of by controlled incineration.

For the current Inventory, a survey was conducted of regional councils and local authorities issuing consents for animal cremators and those disposing of animal pathological waste by combustion. Information was sought about the number of cremators operating in their region in 2020, the total amount of animal material burnt in the year and confirmation that cremators were batch mode with no specific air pollution equipment installed or continuous monitoring of combustion gas concentrations occurring. Responses were received from all regional councils and relevant local authorities.

The survey revealed that there was a total of 28 consented animal cremators spread throughout the country. Annual waste throughput data was available for 12 of these and the average was used to estimate the waste burnt in the remainder. Using this procedure generated a total animal cremator activity of 510 tonnes per annum was estimated for 2020.

The UNEP Toolkit classifies animal cremators into 3 classes depending on whether the process is continuous or occurs in batches, and on the performance of air pollution control equipment installed, and the extent to which combustion gas monitoring occurs during operation. Information received from the council and local authority survey confirmed that all cremators are covered by the Toolkit’s Class 1. This assigns an emission factor of 500 µg/tonne of carcasses (500×10^{-6} g TEQ/tonne) to emissions to air, with no releases to other compartments.

The release estimates for 2020 are shown in Table 3-5, along with previous estimates for 2012 and 2016

Table 3-5: Dioxin releases from animal carcass disposal

	Source	Activity Rate, tonnes/year	Release factors, µg TEQ/t	Annual releases (g TEQ/yr)
			Air	Air
2012	Class 1 cremators	231	500	0.116
2016	Class 1 cremators	231	500	0.116
2020	Class 1 cremators	510	500	0.255

Certainty assessment for 2020

Activity data: Medium – High (because it is based on survey information)

Emission factor: Low (because it is based on default factors given in the UNEP Toolkit)

3.8 Summary for this category

The 2020 release estimates for waste incineration are summarised in Table 3-6, along with the totals for 2012 and 2016.

Table 3-6: Summary of the release estimates for waste incineration

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Hazardous waste incineration	0.0000055	-	-	-	0.00000030
Medical waste incineration	0.234	-	-	-	0.00156
Sewage sludge incineration	0.000386	-	-	-	0.000788
Wood and Biomass Incineration*	0.0039	-	-	-	0.00780
Destruction of animal carcasses	0.255	-	-	-	-
2012 totals	0.794	-	-	-	0.047
2016 totals	0.366	-	-	-	0.032
2020 totals	0.493	-	-	-	0.0101

(* this category covers school incinerators)

4 Ferrous and non-ferrous metal production

This category covers the following sub-categories (United Nations Environment Programme, 2013)

- 2a Iron ore sintering
- 2b Coke production
- 2c Iron and steel production and foundries
- 2d Copper production
- 2e Aluminium production
- 2f Lead production
- 2g Zinc production
- 2h Brass and bronze production
- 2i Magnesium production
- 2j Other non-ferrous metal production
- 2k Shredders
- 2l Thermal wire reclamation

The dioxin releases from metal production processes are nearly all combustion related. They arise from the incomplete burning of small amounts of organic materials involved in production processes. For primary metal production the organic material may be present as a contaminant in the metal ore or may come from the carbon-based materials (eg, coke) used to promote ore reduction. In the case of secondary metal production, the most significant sources of organic matter are usually contaminants such as oil, grease, paint, or plastic coatings that may be present on the surfaces of the input metals. In addition, metals such as copper are known to have a catalytic effect on the rate of dioxin formation.

4.1 Iron ore sintering

Iron ore sintering is a pre-treatment step in the production of iron. The sintering process involves heating of fine iron ore particles with flux and coke or coal fines, to produce a semi-molten mass that solidifies into porous pieces of sinter with the size and strength characteristics necessary for feeding into a blast furnace. This process is not used in the New Zealand steel-making process.

4.2 Coke production (and charcoal)

Coke is produced by heating coal under vacuum in a process known as carbonisation. Along with iron ore and limestone it is an essential ingredient in the blast furnace method of steel production. Millions of tonnes of coke are produced globally for this purpose each year. However, New Zealand uses a substantially different process to reduce iron sands to raw iron which employs coal rather than coke (see s 4.3.1). Coke does find a use in the steel making plant (New Zealand Steel, 2010), but only as a relatively minor additive compared to the tonnages of steel produced – for 1 tonne of steel product only 14.6 kg of coke is used (Jaques, 2002). Total steel production at the plant in 2020 was 601,490 tonnes (see s 4.3) which would have required 8,782 tonnes of coke. This coke is not produced in New Zealand but is imported from China. New Zealand has no production of coke. (Ministry for the Environment, 2022)

Production of charcoal also involves heating under low oxygen conditions, except that wood rather than coal is used as the starting material. The 2012 inventory found that most charcoal available for sale in New Zealand was

imported product and the small amounts produced domestically were likely to have a dioxin burden significantly less than 0.001 grams TEQ per year. Consequently, release estimates were not reported, and this approach has been taken here.

4.3 Iron and steel production and foundries

This section of the UNEP Toolkit covers iron and steel plants, iron foundries, and galvanising.

4.3.1 Primary steel production

The only primary iron and steel production in New Zealand is at the Glenbrook Mill, south of Auckland, which is owned and operated by New Zealand Steel Ltd. This plant is relatively unique in that the primary source of iron is obtained from nearby reserves of iron sand, which is a mixture of magnetite and titanomagnetite (NZ Institute of Chemistry, 1998). Most conventional steel mills use an iron ore, which is usually haematite. The total steel production for 2020 was 601,490 tonnes and the mill also used 782,240 tonnes of coal. (D Bryson, New Zealand Steel, pers comm, 2022).

The dioxin release estimates for the previous Inventories were based on emission test results from the 1990s. An average air emission factor of 0.134 µg TEQ per tonne of steel produced was derived from these results. In the absence of any more recent data, this factor will also be used for the 2020 estimates. The default factors given in the UNEP Toolkit are not relevant because they relate to conventional steel mills using iron ore.

The wastewater produced by the steel mill is passed through a treatment plant and then both this and the site stormwater are discharged to a waterway. The total discharge from the site averages 9603 m³ per day (D Bryson, New Zealand Steel, pers comm, 2022) and no dioxins have ever been detected in the, now historical, tests on the discharge. The previous inventories used a water concentration factor of 4.7 pg TEQ per litre (4.7 x 10⁻¹² g TEQ/litre), based on a value of 50% of the limit of detection, and this will be used for the 2020 estimates in the absence of any more suitable factor.

The steel mill generated 19,028 tonnes (dry weight) of solid wastes in 2020, which were disposed in a site landfill. This is a significant reduction on the 60,300 tonnes reported for the 2016 Inventory and results from the new practice of recycling sand and char wastes through the kilns. There have been no recent tests for the dioxin content of these wastes, so the historical factors used in the previous Inventories will also be used here. It should be noted that for this source the waste residues are shown as a release to land, because they are disposed of on-site. When wastes are disposed off-site, they are recorded as a residue release, mainly because the actual disposal method is often not certain.

The current release estimates for primary steel production are shown in Table 4-1, along with the estimates from the 2012 and 2016 Inventories. There are no releases in residues or in products.

Table 4-1: Dioxin releases from primary steel production

Year	Activity Rates	Release factors (µg TEQ/tonne or pg TEQ/litre (for water))			Annual releases (g TEQ/yr)		
		Air	Water	Land	Air	Water	Land
2012	609,000 tonnes of steel	0.134	-	-	0.082	-	-
	3.05 x 10 ⁶ m ³ water	-	4.7	-	-	0.0143	-
	45,320 tonnes of waste	-	-	4.55	-	-	0.206
2016	585,770 tonnes of steel	0.134	-	-	0.078	-	-
	3.2 x 10 ⁶ m ³ water	-	4.7	-	-	0.0149	-
	60,300 tonnes of waste	-	-	4.55	-	-	0.274
2020	601,490 tonnes of steel	0.134			0.0806		
	3.50 x 10 ⁶ m ³ water		4.7			0.0165	
	19,028 tonnes of waste			4.55			0.0866

Certainty assessment for 2020

Activity data: Medium (because they are based on company estimates)

Emission factors: Medium (because they are based on historical site data)

4.3.2 Secondary steel production

Until October 2015 Pacific Steel operated an electric arc furnace at its Otahuhu site in Auckland processing recycled scrap steel. The company's production assets were then purchased by New Zealand Steel Ltd. Consequently, all steel manufactured in New Zealand is now made at New Zealand Steel's Glenbrook site from newly produced iron – that is there is no domestic steel production using recycled steel scrap (Ministry for the Environment, 2022).

The release estimates for secondary steel production are shown in Table 4-2.

Table 4-2: Dioxin releases from secondary steel production

Year	Activity Rate, tonnes/yr		Release factors (µg TEQ/tonne of steel or dust)		Annual releases (g TEQ/yr)	
	Steel	Dust	Air	Residue	Air	Residue
2012	240,000		0.15	-	0.036	
	-	4.0	-	700	-	2.8
2016	0		0.15		0.0	
		0		700		0.0
2020	0		0.15		0.0	
		0		700		0.0

Certainty assessment for 2020

Activity data: High (because there is no secondary steel production)

Emission factors: High (because they were based on annual test data)

4.3.3 Iron foundries

Iron foundries manufacture cast-iron products from scrap iron, pig iron and internal plant returns (manufacturing rejects and wastes). Alloying materials such as silicon, magnesium, copper, nickel, and carbon may also be added to the charge, along with fluxing materials which often include chlorides or fluorides. The basic foundry operations are: raw material handling and preparation, mould and core production, metal melting and alloying, casting, and mould breakout, followed by finishing processes such as trimming, cleaning, and polishing. A variety of furnaces can be used for metal melting, including electric arc and induction furnaces, cupolas, and oil- or gas-fired crucibles. The melting operations have the greatest potential for dioxin releases to air, especially when processing contaminated scrap, and there can also be releases via furnace residues, such as slag and dross (United Nations Environment Programme, 2013).

The closure of Precision Foundries (formerly Masport Foundry) in Auckland at the end of 2017 coupled with A and G Price in Thames emerging from receivership with a reduced workforce have been key influences in the reduction of foundry production since the previous inventory as these were the two largest foundries in New Zealand. Total foundry production for 2020 has been estimated at 1300 tonnes.

The current release estimates for iron foundries are shown in Table 4-3, along with the estimates from the 2012 and 2016 Inventories. The estimates for releases to air for both years are based on a factor of 8.2 µg TEQ per tonne of metal (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne), which was derived from a 2002 industry survey (Ministry for the Environment, 2004) and is marginally lower than the default factor of 10 µg TEQ per tonne given in the UNEP Toolkit. The releases in residues are based on the Toolkit factor of 8 µg TEQ per tonne of metal.

Table 4-3: Dioxin releases from iron foundries

Year	Activity Rate tonnes of iron per year	Release factors (µg TEQ/tonne of iron)		Annual releases (g TEQ/yr)	
		Air	Residue	Air	Residue
2012	16,000	8.2		0.131	
			8		0.083
2016	8,800	8.2		0.072	
			8		0.070
2020	1,300	8.2		0.011	
			8		0.0104

Certainty assessment for 2020

Activity data: Medium (because they are based on survey data)

Emission factors: Medium (because they are based on historical NZ emission data)

4.3.4 Hot-dip galvanising plants

Galvanising refers to the process of coating iron or steel with a thin layer of zinc to provide long-term protection against corrosion. The hot-dip process involves pre-cleaning of the metal by immersion in acidic and/or alkaline cleaning baths, treatment with a fluxing agent (such as zinc ammonium chloride), and then immersion in a bath of molten zinc at a temperature of around 450°C. Hot-dip galvanising has been identified as a potential source of dioxins (United Nations Environment Programme, 2013).

Information on galvanising activity at New Zealand Steel has been obtained directly from the company which performs the majority of galvanising in New Zealand (D Bryson, pers comm, 2022). For the 2012 Inventory production information for the remaining galvanising industry was obtained from the Galvanising Association of New Zealand (J Notley, pers comm, 2014) who requested that the information be kept confidential. It has not been possible to obtain similar information from the Galvanising Association of New Zealand since then, so production has been assumed to be at 2012 levels for these plants with it remaining confidential. Release estimates for 2012, 2016 and 2020 are shown in the table below.

Table 4-4: Dioxin releases from hot-dip galvanising

Year	Annual releases (g TEQ/yr)	
	Air	Residue
2012	0.00557	0.245
2016	0.00727	0.268
2020	0.00581	0.261

Certainty assessment for 2020

Activity data: High (because they are based on industry data)

Emission factors: Low (because they are based on the default factors given in the UNEP Toolkit)

4.3.5 Primary aluminium production

The only primary aluminium smelter in New Zealand is located at Tiwai Point in Southland. It produces approximately 350,000 tonnes of aluminium per year by the pre-bake Hall-Heroult process, with most production in the form of high-purity ingots.

Primary aluminium production was listed as a potential source of dioxins in the first edition of the UNEP Toolkit, although no data had been published to show that this was the case. However, more recent assessments indicate that it is no longer thought to be a significant source (United Nations Environment Programme, 2013).

4.3.6 Secondary aluminium production

The industries included in this subcategory are metal recyclers, who recover aluminium from mixed scrap, and manufacturers of cast aluminium products, such as alloy wheels and engine parts. Much of the manufacturing uses aluminium ingots and clean aluminium scrap but may also include aluminium recovery from in-house metal wastes. Scrap metal and mixed metal wastes may contain organic impurities such as plastics, paints and solvents, and their presence can result in increased formation and release of dioxins.

Secondary aluminium processors with estimated annual production over 100 tonnes were surveyed for their production in 2020. Concerns raised by industry members over production confidentiality have meant that it is

possible to publish only the estimated dioxin releases for this category. These are shown in Table 4-5 along with the estimates for the 2012 and 2016 Inventories.

Table 4 -5: Dioxin releases from secondary aluminium production

Year	Annual releases (g TEQ/yr)	
	Air	Residue
2012	0.044	4.05
2016	0.039	3.63
2020	0.023	2.17

Certainty assessment for 2020

Activity data: Medium (because they are based on survey data)

Emission factors: Medium (because they are based on historical NZ data)

4.4 Lead production

New Zealand's only secondary lead smelter was shut down in 2012 so there are no longer any releases under this sub-category.

4.5 Zinc production

This Toolkit sub-category covers the production of metallic zinc from ore and the recovery and refining of zinc from scrap metal (United Nations Environment Programme, 2013). There is no primary zinc production in New Zealand (Crown Minerals, undated). and only one firm processing 100 kg was identified in the secondary metal survey conducted for the 2012 Inventory.

4.6 Brass and bronze production

Because it is difficult to separate production of copper from brass and bronze parts, dioxin releases have been accounted for under the brass and bronze sub-category as has occurred in previous inventories. The Toolkit release factors for brass and bronze production are similar to those for secondary copper production, so the grouping has no significant effect on the overall release estimates.

The total annual secondary metal production for copper, brass, and bronze for 2020 was estimated to be 2,150 tonnes per year. Due to a number of plant closures and the effect of COVID lockdowns in 2020 this is below the production rate estimated for 2016 of 3900 tonnes per year.

The current release estimates for this sub-category are shown in Table 4-7, along with the estimates from the 2012 and 2016 Inventories. The estimates are based on the Toolkit default factors of 3.5 µg TEQ per tonne of metal for releases to air and 125 µg TEQ per tonne for releases to land, but the latter factor was adjusted to allow for only 66% of all plants using bag filters. The factor for releases to air is reasonably consistent with actual release data for New Zealand plants reported from a 2002 industry survey (Ministry for the Environment, 2004).

Table 4-6: Dioxin releases from brass, bronze, and other non-ferrous metal production

Year	Activity Rate tonnes of metal per year	Release factors (µg TEQ/tonne of metal)		Annual releases (g TEQ/yr)	
		Air	Residue	Air	Residue
2012	12,000	3.5		0.042	
			82.75		0.993
2016	3,900	3.5		0.014	
			82.75		0.323
2020	2,150	3.5		0.008	
			82.75		0.178

Certainty assessment for 2020

Activity data: Medium (because they are based on survey data)

Emission factors: Medium (because they are based on historical NZ emission data)

4.7 Magnesium production

This Toolkit sub-category covers the production of metallic magnesium, for which there is no such activity in New Zealand (Crown Minerals, undated).

4.8 Other non-ferrous metal production

This Toolkit sub-category covers the primary production of other non-ferrous metals, such as cadmium and nickel, for which there is no such activity in New Zealand (Crown Minerals, undated).

4.9 Metal shredding

Metal shredding in New Zealand is conducted at nine locations by a number of different scrap metal companies. These companies collect scrap metal from their branches throughout the country, and from numerous other scrap metal dealers.

Metal shredders are used for the processing of a range of scrap metal, including car bodies, whiteware and roofing iron. There are two outputs: a relatively clean ferrous metal stream, made up of small (around 50 mm) pieces of steel, and a 'fluff' or 'flock' which contains fragments of other non-ferrous metals and other waste materials in the input stream. With the closure of Pacific Steel most of the processed metal from the shredders is exported. Dioxins have been detected in the air discharges from shredder plants, but there is no evidence to show that these are formed as a result of the shredding process. Instead, it is believed that the emissions arise from contaminants already present in the scrap metal (United Nations Environment Programme, 2013).

A survey of metal shredding operations was conducted in order to estimate the annual throughput of steel containing material. A condition for the release of information from some firms was that the amount not be disclosed so dioxin releases only have been provided in Table 4-7. There are no releases to water, land, or in products.

Table 4-7: Dioxin releases from metal shredding

Year	Annual releases (g TEQ/yr)	
	Air	Residue
2012	0.070	1.75
2016	0.050	1.25
2020	0.070	1.75

Certainty assessment for 2020

Activity data: Medium (because they are based on a survey)

Emission factors: Low (because they are based on the default factors given in the UNEP Toolkit)

4.10 Thermal wire reclamation and e-waste recycling

This Toolkit sub-category covers the burning of electrical cables for the purposes of copper recovery, and thermal processing of other electronic wastes to recover a variety of potentially valuable metals, including copper, silver, and gold. Some secondary metal businesses process the copper in electrical cables as part of their feedstock. However, the releases from these operations have already been accounted for in section 4.8. Other than that, the open burning of plastic-coated wire is prohibited by most regional councils, so should not be occurring to any significant extent. The same restrictions would apply to the burning of other types of e-waste.

4.11 Summary for this category

The 2012, 2016 and 2020 release estimates for metal production are summarised in Table 4-8.

Table 4-8: Summary of the release estimates for metal production

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Primary steel production	0.0806	0.0165	0.0866	-	-
Secondary steel production	-	-	-	-	-
Iron Foundries	0.011	-	-	-	0.010
Hot dip galvanizing plants	0.00581	-	-	-	0.261
Secondary aluminium production	0.023	-	-	-	2.172
Lead production	-	-	-	-	-
Brass and bronze production	0.008	-	-	-	0.178
Metal shredding	0.070	-	-	-	1.75
2012 totals	0.404	0.014	0.206	-	9.71
2016 totals	0.261	0.015	0.274	-	5.54
2020 totals	0.198	0.0165	0.087		4.371

5 Heat and power generation

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 3a Fossil fuel power plants (coal, oil, gas, shale oil, and co-combustion of waste)
- 3b Biomass power plants (wood, straw, other biomass)
- 3c Landfill, biogas combustion
- 3d Household heating and cooking with biomass (wood, other biomass)
- 3e Household heating and cooking with fossil fuels (coal, oil, gas)

The dioxin releases from heat and power generation processes are all combustion-related, and they mainly arise from the incomplete combustion of the fuels being burned. For this reason, the dioxin release rates tend to be greatest for the more complex fuels (eg, coal and oil versus gas). They are also highly dependent on the types and design of the fuel-burning equipment (eg, industrial furnaces versus simple domestic ovens).

5.1 Fossil fuel power plants

It is important to note that the UNEP Toolkit uses the term “power” in its broadest technical sense, meaning energy produced by mechanical, thermal, electrical, or other means, whereas in New Zealand it is commonly used to refer specifically to electricity. The previous inventory reports avoided this potential confusion by having separate sections for electricity generation and other industrial/commercial fuel use, and this distinction will be maintained here through the use of sub-sections within each of the fuel-based sub-categories covered below.

The UNEP Toolkit lists 6 different classes within this sub-category on the basis of fuel type. These are: fossil fuel/waste mixtures, coal, peat, heavy fuel oil, shale oil and light fuel oil/natural gas. The latter group may also be taken to include LPG. There is no co-firing of wastes or usage of peat or shale oil as fuels in New Zealand, but all other fuels have been considered below.

5.1.1 Coal-fired power plants

Electricity Generation

The only coal-fired power station in New Zealand is the Huntly Power Station which, when first built, had a capacity of 1000 MW. This was based on four separate Rankine boiler/generation units of 250 MW each – known as Units 1 to 4 – which could be fired on natural gas or coal. More recently, additional generation units have been added to the power station (Units 5 and 6) giving it a nominal total capacity of 1435 MW. However, the newer units are gas-turbine systems, which use natural gas, and minor amounts of diesel.

One of the Rankine units has since been permanently decommissioned so that the total available capacity for coal burning is now only 750 MW. The amount of coal burnt in any particular year at Huntly power station is dependent on a number of factors including the amount of electricity that can be provided by hydro generation. In 2020 New Zealand had a spell of warm dry autumn weather which extended into the winter months resulting in annual hydro generation dropping by 5.2%. (Ministry of Business Innovation and Employment, 2021) In addition the HVDC Cook Strait cable underwent refurbishment in 2020 resulting in a requirement for higher thermal electricity generation in the North Island. Coal consumption at Huntly in 2020 was 19,490 TJ. This is significantly greater than the 4,820 TJ consumed in 2016 (Ministry of Business Innovation and Employment, 2021).

The coal used at Huntly Power Station is a mixture of Waikato sub-bituminous coal and coal imported from Indonesia. (E LaFace, Genesis Energy, pers comm, 2022).

The power station emissions to air have been tested for dioxins on several occasions, most recently in 2010 (Sinclair Knight Merz, 2011). However, the results from this and the other previous tests noted in the 2008 Inventory are quite comparable to the factor of 10 µg TEQ per TJ given in the UNEP Toolkit (10 x 10⁻⁶ g TEQ per TJ). Therefore, the toolkit default has been used for the current estimates.

The Huntly Power Station units are fitted with electrostatic precipitators for the control of particulate emissions to air. The fly ash collected by the precipitators is disposed to land in a specially designed ash disposal facility. No information has been obtained on the exact quantities of ash collected by the precipitators, nor the dioxin content. However, the releases to land can be calculated from the fuel consumption rate using the default factors given in the UNEP Toolkit.

The 2020 release estimates for coal-fired electricity generation are shown in Table 5-1, along with the estimates from the 2012 and 2016 Inventories. There are no direct releases to water or in products, and the residue (ash) is disposed to land.

Table 5-1: Dioxin releases from coal-fired electricity generation

Year	Activity Rate (TJ of coal/year)	Release factors (µg TEQ/TJ of coal)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	29,090	10	-	0.291	-
		-	14	-	0.407
2016	4,840	10	-	0.0484	-
		-	14	-	0.0678
2020	19,490	10	-	0.195	-
		-	14	-	0.273

Certainty assessment for 2020

Activity data: High (because it is based on actual fuel consumption data)

Emission factors: High for air and low for residues (because they are both based on the Toolkit default factors, but the factor for air has been validated by testing at the power station)

Coal-fired industrial manufacturing and commercial appliances

The total New Zealand coal consumption for consumer energy uses in 2020 was 21,930TJ (1 TJ = 10¹² Joules) (Ministry of Business Innovation and Employment, 2021). Consumer energy uses include agricultural, industrial, commercial, residential and transport with the industrial sector leading consumption. The figures for coal consumption include two sources that are covered under other sections of the inventory: cement manufacture and domestic heating². In 2020 they accounted for 2,040 TJ. Subtracting this amount from the consumer energy total gives a total annual energy consumption associated with the remaining coal combustion sources of 19,890TJ (1 TJ = 10¹² Joules).

Coal consumption in the industrial and commercial sectors was negatively impacted by the Covid pandemic in 2020. Compared to 2019 consumption levels, the industrial sector was down 11.4% and the commercial sector

² Coal use in steel production is also not included here, but this is counted in an Energy Transformation heading in the MBIE energy data summaries, rather than as Consumer Energy.

down 28% (Ministry of Business Innovation and Employment, 2021). The closure of all non-essential industries, businesses, and schools under Alert Levels 3 and 4 was a key driver for the drop. Other causes include on-going initiatives to replace coal-fired boilers with those fired by renewable fuels. For instance, in mid-2020 Fonterra replaced its coal-fired boiler with one fueled by wood pellets at its large Te Awamutu plant.

The estimates for the releases to air from industrial and commercial coal combustion have been based on the same approach as adopted for the 2012 Inventory. For plant greater than 10 MW, the UNEP Toolkit emission factor of 10 µg TEQ per TJ has been applied (10×10^{-6} g per TJ), while a factor of 100 µg TEQ per TJ has been used for plants less than 10 MW (100×10^{-6} g per TJ). The 19,890 TJ of total coal consumption in this source category has been assigned to the two size ranges in accordance with the proportion of the total boiler capacity they comprise in the National Heat Plant Database (CRL Energy, 2011). The total capacity of boilers of 10 MW or greater is 662 MW (52.3% of the total), while those less than 10 MW have a total capacity of 603 MW (47.7%). Accordingly, the energy distribution used was 10,402 TJ and 9,488 TJ, respectively.

The default release factor of 14 µg TEQ per TJ (14×10^{-6} g TEQ per TJ) given in the UNEP Toolkit has been used for estimating the annual releases in residues from these coal-fired sources.

The 2020 release estimates for industrial and commercial coal use are shown in Table 5-2, along with the estimates from the 2012 and 2016 Inventories. As shown, the releases both to air and in residues have decreased compared with 2016, due to a drop in coal consumption. There are no direct releases to water or in products. Releases from ash are assigned to the residues Toolkit compartment because the final place of disposal is not known with any certainty.

Table 5-2: Dioxin releases from industrial and commercial coal use

Year	Plant size	Activity Rate (TJ of coal/year)	Release factors ($\mu\text{g TEQ/TJ}$ of coal)		Annual releases (g TEQ/yr)	
			Air	Residue	Air	Residue
2012	> 10 MW	10,500	10	-	0.105	-
			-	14	-	0.147
	< 10 MW	9,570	100	-	0.957	-
			-	14	-	0.134
Totals	20,070			1.062	0.281	
2016	> 10 MW	12,175	10	-	0.122	-
			-	14	-	0.171
	< 10 MW	11,105	100	-	1.11	-
			-	14	-	0.156
Totals	23,280			1.232	0.327	
2020	> 10 MW	10,402	10	-	0.104	-
			-	14		0.146
	< 10 MW	9,488	100	-	0.949	
				14		0.133
Totals				1.053	0.279	

Certainty assessment for 2020

Activity data: High (because it is based on national fuel consumption data)

Emission factors: Low (because they are both based on the Toolkit default factors)

5.1.2 Heavy fuel oil-fired power plants

The survey of waste oil production shown in Appendix 3 of the 2012 Inventory estimated that about 35 million litres of waste oil were available for recycling annually in New Zealand. The use of 15.4 million litres (with an energy content of 630 TJ) was attributed to a variety of industrial process including pulp and paper, bitumen, brick and food manufacturing and various horticultural activities.

In 2020 the total heavy fuel oil used in New Zealand industrial applications was estimated to be 640 TJ (Ministry of Business Innovation and Employment, 2021). There was a further 3,720 TJ used in coastal shipping, but this should be accounted for under the Transport category. The UNEP Toolkit provides a default factor for releases to air and indicates there are no data available on the releases via other pathways, such as in residues (ash).

The 2020 release estimates for heavy fuel oil-fired power plant are shown in Table 5-3. Releases are lower than in 2012 and 2016 because of a decrease in consumption.

Table 5-3: Dioxin releases from heavy fuel oil-fired power plant

Year	Activity Rate (TJ of fuel oil/year)	Release factors ($\mu\text{g TEQ/TJ}$ of oil)	Annual releases (g TEQ/yr)
		Air	Air
2012	3,310	2.5	0.0083
2016	1,020	2.5	0.0026
2020	640	2.5	0.0016

Certainty assessment for 2020

Activity data: High (because it is based on actual fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.1.3 Fuel oil and natural gas-fired power plants**Fuel oil and natural gas-fired electricity generation**

In 2020 there were 6 power stations in New Zealand with the sole function of generating electricity using natural gas with a total capacity of 1,240 MW including the new Junction Road plant in Taranaki opened in mid-2020. Should the three Rankine units at Huntly Power be fired on natural gas they would bring an additional 750 MW of gas fired generating capacity. In addition, there are another 5 gas-fired cogeneration plants in New Zealand which produce steam energy in addition to electrical energy. Their total capacity is 156 MW. (WSP, 2020)

In 2020 the total consumption of natural gas for electricity generation was 41,190 TJ (1 TJ = 10^{12} Joules), including that used in cogeneration plants (Ministry of Business Innovation and Employment, 2021). This is considerably less than the 56,360 TJ consumed in 2016. There are a number of factors which have influenced this decline. COVID-19 and the associated national and regional lockdowns led to reduced demand for electricity. There has been some specific reduction in industrial demand with the closure of sites such as Pacific Steel, Holcim Cement, and the wind up of Norske Skog's share of the Tasman Mill. Improvements in household energy efficiency such as more efficient lighting and better insulation have led to reduced residential demand and this effect has been compounded by milder winters (Ministry of Business Innovation and Employment, 2021).

There are two diesel power stations in New Zealand - Bream Bay Peaker in Northland and Whirinaki in Hawkes Bay (WSP, 2020). Because diesel is the most expensive fuel for electricity generation it is reserved for use in periods of high electricity demand and in times of reduced power security. Whirinaki was used more in 2020 than in 2016 to cover the adverse market conditions caused by the dry year and natural gas supply shortages. The total consumption of diesel for electricity generation in 2020 was 1,430 TJ.

There are no dioxin emission data available for gas-fired electricity plants in New Zealand, so the UNEP Toolkit default factors have been used. These make no distinction between the use of gas or oil and indicate that the only relevant release route is to air.

The 2020 release estimates for fuel oil (diesel) and natural gas-fired electricity generation are shown in Table 5-4.

Table 5-4: Dioxin releases from fuel oil and natural gas-fired electricity generation

Year	Activity Rate (TJ of fuel/year)	Release factors (µg TEQ/TJ of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	72,190	0.5	0.036
2016	56,380	0.5	0.028
2020	42,620	0.5	0.021

Certainty assessment for 2020

Activity data: High (because it is based on actual fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

Industrial/commercial fuel oil and gas-fired power plants

The major industrial uses of fuel oil (diesel), LPG and natural gas are in dairy factories, meat processing plants, pulp and paper and other wood processing industries, and steel manufacture. However, there are also numerous small boilers found in industrial/commercial businesses, and institutions, such as schools and hospitals.

The industrial and commercial consumption of natural gas (excluding electricity generation) accounted for 69,970 TJ of energy in 2020 (Ministry of Business Innovation and Employment, 2021). In addition, the industrial and commercial uses of LPG were 5390 TJ, half of which has been assumed to be used in heat-raising appliances. The industrial sector has been growing rapidly since 2006, primarily being driven by growth in chemical manufacturing and food processing.

The industrial and commercial combustion of diesel in boilers is not easily distinguished from that used in stationary combustion engines³ on the basis of the available statistical information. An estimate of the heat produced by diesel-fired boilers has been made using the plant capacities recorded in the Heat Plant Database (CRL Energy, 2011). The total installed capacity is 189 MW. If it is assumed these boilers operate 24 hours a day for 320 days a year, at 75% efficiency, the total energy consumed would be about 3900 TJ per year.

The UNEP Toolkit provides an emission factor of 0.5 µg TEQ per TJ (0.5×10^{-6} g TEQ per TJ) for the discharges to air from power plants fired with natural gas and light fuel oil. There are no factors for releases to any of the other release routes. The UNEP Toolkit factor has been used in the absence of any relevant New Zealand data.

The 2020 release estimates for industrial/commercial fuel oil and gas-fired power plant are shown in Table 5-5, along with the corresponding estimates made in the 2012 and 2016 Inventories.

³ In the UNEP Toolkit, stationary combustion engines are considered under the Transport category (see section 7).

Table 5-5: Dioxin releases from fuel oil and gas-fired power plant

Year	Activity Rate (TJ of fuel/year)	Release factors (µg TEQ/TJ of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	53,530	0.5	0.027
2016	82,150	0.5	0.041
2020	76,565	0.5	0.0383

Certainty assessment for 2020

Activity data: High (because it is based on actual fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.2 Biomass power plants

There are 2 large biomass-fired cogeneration plants in New Zealand. These are the power boilers at the Kinleith pulp and paper mill and the thermo-mechanical pulp plant in Napier. Biomass is also burned in the recovery boilers at the pulp and paper mills, and in numerous other power boilers in board mills, fibreboard plants, and sawmills. The Heat Plant Database lists about 175 industrial wood-fired installations rated at greater than 1 MW capacity, with a total combined capacity of more than 1035 MW (CRL Energy, 2011). Altogether, these account for about 80% of New Zealand wood combustion.

This section addresses the industrial biomass power plants, and any incidental incineration of wood waste. Combustion processes in the pulp and paper industry are split into two with wood and biomass combustion included here and the combustion of black liquor solids covered in section 8.

For previous inventories, an estimate of the annual biomass energy burned was obtained using the gross heat energy ratings for relevant plant listed in the Heat Plant Database (CRL Energy, 2011). These ratings were summed, and an estimate of the annual energy consumption was made based on the assumption that the facilities operated 24 hours a day, at 70% capacity, for 320 days per year.

In 2017 MBIE commissioned the Crown Research Institute Scion to prepare an up-to-date database of energy raising plant in currently operating wood processing and pulp and paper operations in New Zealand (MBIE, 2017). Scion produced a database with details for 173 wood processing operations along with improved estimates of bioenergy consumption. They have continued to update this database annually and this is used by MBIE to derive annual industrial energy raised by biomass.

For 2020 a combined value of 48,660 TJ ($1 \text{ TJ} = 10^{12} \text{ Joules}$) for biomass energy consumption was reported by MBIE (Ministry of Business Innovation and Employment, 2021). To avoid double counting, the components for black liquor consumption and wood used for domestic heating must be subtracted from this total. As shown in Section 5.4, domestic wood burning accounted for 7,538 TJ in 2020. Currently data is not available for the energy value of black liquor burned in 2020 so the value of 9,440 TJ used in the 2016 Inventory will be used. On this basis it is estimated that biomass fired industrial plants consumed 31,682 TJ in 2020.

The 2012 and 2016 Inventory estimates were based on the default factors given in the UNEP Toolkit, of 50 µg TEQ per TJ for releases to air, and 15 µg TEQ per TJ for releases in residues (ash) ($1 \text{ µg TEQ/TJ} = 1 \times 10^{-6} \text{ g TEQ/TJ}$). These factors have also been used for the current estimates.

The 2020 release estimates for biomass-fired power plant are shown in Table 5-6, along with the corresponding estimates made in the 2012 and 2016 Inventories. There are no direct releases to water or in products. The ash production is assigned to the residues Toolkit vector because the final place of disposal is not known with any certainty.

Table 5-6: Dioxin releases from biomass-fired power plant

Year	Activity Rate (TJ of biomass/year)	Release factors (µg TEQ/TJ of biomass)		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	20,000	50	-	1.000	-
		-	15	-	0.300
2016	20,000	50	-	1.000	-
		-	15	-	0.300
2020	31,682	50	-	1.584	-
		-	15	-	0.475

Certainty assessment for 2020

Activity data: Medium (because it is based on an estimate of fuel consumption)

Emission factor: Low (because it is based on the Toolkit default factors)

5.3 Landfill, biogas combustion

Landfill gas from solid waste disposal and biogas from domestic wastewater treatment are both generated from anaerobic digestion of organic matter. The resulting gas is predominantly methane but may also contain carbon monoxide, carbon dioxide, ammonia and smaller fractions of volatile organic compounds (United Nations Environment Programme, 2013). Dioxins can be produced when the gases are burned, either in a flare or a gas engine (eg, for electricity generation).

For 2020 combustion of sludge biogas, produced from digestion of wastewater solids, generated 1,090 TJ and landfill gas combustion generated 2,700 TJ (Ministry of Business Innovation and Employment, 2021) giving a combined value for this sector of 3,790 TJ.

The Toolkit emission factor for landfill and biogas utilisation is 8 µg TEQ/TJ gas burned (8×10^{-6} g TEQ/TJ), and the estimated releases to air are shown in Table 5-7 below. There are no releases to any other environmental compartments.

Table 5-7: Dioxin releases from landfill gas and biogas combustion

Year	Activity Rate (TJ of gas/year)	Release factors (µg TEQ/TJ of gas)		Annual releases (g TEQ/yr)	
		Air		Air	
2012	3,104	8		0.025	
2016	3,250	8		0.026	
2020	3,790	8		0.030	

Certainty assessment for 2020

Activity data: Medium (because it is based on a national data source)

Emission factor: Low (because it is based on the Toolkit default factor)

5.4 Household heating and cooking with biomass

The number of wood burners in operation in New Zealand in 2020 New Zealand was estimated at 532,280 by a residential energy baseline study conducted in 2021 (EnergyConsult, 2021). The study shows a steady decline has occurred in wood burner numbers in the last 10 years and this is reflected in a decline in energy consumption.

The Energy Efficiency and Conservation Authority (EECA) produces an energy end use database which provides details on energy consumption for a wide variety of end use categories including household consumption (Energy Efficiency and Conservation Authority, 2022). For household heating and cooking with biomass in 2020 the database shows a total energy consumption of 7538 TJ for wood. This total comprised 7231 TJ for wood burner space heating, 222 TJ for space heating with an open fire and 85 TJ was used for water heating.

The 2020 release estimates for domestic wood combustion are shown in Table 5-8 along with the corresponding estimates made in the 2012 and 2016 Inventories. There are no direct releases to water or in products. Releases from ash are assigned to the residues Toolkit vector because the final place of disposal is not known with any certainty.

Table 5-8: Dioxin releases from domestic wood combustion

Year	Activity Rates (TJ wood/year)	Release factors (µg TEQ/TJ wood)		Annual releases (g TEQ/yr)	
		Air	Residues	Air	Residues
2012	8,200	100		0.820	
			20		0.164
2016	8118	100	-	0.812	-
		-	20	-	0.162
2020	7,538	100	-	0.754	
		-	20		0.151

Certainty assessment for 2020

Activity data: High (because it is based on a national survey of energy use coupled with census data)

Emission factors: Low (because they are based on the Toolkit default factors)

5.5 Household heating and cooking with fossil fuels

This sub-section addresses the dioxin emissions from the domestic burning of oil, coal and gas. The oil category covers both fuel oil and diesel, while gas consumption includes both natural gas and LPG.

5.5.1 Coal

The total amount of coal burned in domestic appliances in 2020 was 267 TJ (Energy Efficiency and Conservation Authority, 2022), (1 TJ = 10^{12} Joules). All of the coal burned was for space heating, with 91 TJ used in coal burners and 176 TJ in open fires.

As with the 2016 dioxin inventory the Toolkit factor of 100 $\mu\text{g TEQ/TJ}$ of coal has been used for estimating the releases to air ($1 \mu\text{g TEQ/TJ} = 1 \times 10^{-6} \text{ g TEQ/TJ}$). Also, the releases via ash have been determined using a factor of 0.41 $\mu\text{g TEQ/tonne}$ of ash, which was originally used in the 2000 Inventory report. This was derived from a UK study, but it was considered more appropriate than the Toolkit factor of 5 $\mu\text{g TEQ/tonne}$ of ash, which relates to the dioxin concentrations in soot rather than ash. The ash quantities were calculated using a factor of 1.265 tonnes/TJ, which was derived from an assumed average ash content of 3.15% for New Zealand coal and a calorific value of 25 MJ/kg ($25 \times 10^6 \text{ J/kg}$).

The 2020 release estimates for domestic coal combustion are shown in Table 5-9, along with the corresponding estimates made in the 2012 and 2016 Inventories. There are no direct releases to water or in products. Releases from ash are assigned to the residues Toolkit vector because the final place of disposal is not known with any certainty.

Table 5-9: Dioxin releases from domestic coal combustion

Year	Activity Rates		Release factors		Annual releases (g TEQ/yr)	
	(TJ coal/year)	(tonnes ash/year)	Air ($\mu\text{g TEQ/TJ coal}$)	Residues ($\mu\text{g TEQ/tonne ash}$)	Air	Residues
2012	440		100		0.044	
		557		0.41		0.00023
2016	343	-	100	-	0.034	-
	-	434	-	0.41	-	0.00018
2020	267		100		0.027	
		338		0.41		0.00014

Certainty assessment for 2020

Activity data: High for coal, medium for ash (because the coal quantities are based on national fuel data, but the ash quantities are derived using an assumed average ash content)

Emission factors: Low (because the air release is based on the Toolkit default factor, and the ash release factor is taken from a now relatively dated UK publication)

5.5.2 Oil

A total of 103 TJ was used for diesel fueled space heating in 2020 (Energy Efficiency and Conservation Authority, 2022). The 2020 release estimates for domestic oil combustion are shown in Table 5-11, along with the

corresponding estimates made in the 2012 and 2016 Inventories. The Toolkit factor shown is the same as that used previously and there are no releases to land, water, or in products or residues.

Table 5-10: Dioxin releases from domestic oil combustion

Year	Activity Rate (TJ of oil/year)	Release factors ($\mu\text{g TEQ/TJ}$ of oil)	Annual releases (g TEQ/yr)
		Air	Air
2012	290	10	0.0029
2016	120	10	0.0012
2020	103	10	0.0010

Certainty assessment for 2020

Activity data: High (because it is based on national fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.5.3 Gas

The domestic use of gas in New Zealand includes both natural gas and LPG. Natural gas is used mainly in fixed installations for heating, cooking and water heating, while LPG is more commonly used in portable equipment such as barbeques and patio heaters.

The total residential usage of natural gas in 2020 was reported to be 7198 TJ. Gas water heating totalled 5007 TJ, space heating 2124 TJ and cooking appliances 67 TJ. The total for LPG use was 3626 TJ comprising 2313 TJ for water heating, 1263 TJ for space heating and 50 TJ for cooking appliances. (Energy Efficiency and Conservation Authority, 2022). This gives a combined total for natural gas and LPG use of 10,824 TJ.

The 2020 release estimates for domestic gas combustion are shown in Table 5-11, along with the corresponding estimates made in the 2012 and 2016 Inventories. The Toolkit factor remains and there are no releases to land, water, or in products or residues.

Table 5-11: Dioxin releases from domestic gas combustion

Year	Activity Rate (TJ of gas/year)	Release factors ($\mu\text{g TEQ/TJ}$ of gas)	Annual releases (g TEQ/yr)
		Air	Air
2012	9020	1.5	0.0135
2016	9581	1.5	0.0144
2020	10,824	1.5	0.0162

Certainty assessment for 2020

Activity data: High (because it is based on national fuel consumption data)

Emission factor: Low (because it is based on the Toolkit default factors)

5.6 Summary for this category

The 2020 release estimates for heat and power generation are summarised in Table 5-12, along with the totals for 2012 and 2016.

Table 5-12: Summary of the release estimates for heat and power generation

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Coal-fired power plants: electricity generation	0.195	-	0.273	-	-
Coal-fired power plants: Industrial and commercial	1.053	-	-	-	0.279
Heavy fuel oil-fired power plants	0.0016	-	-	-	-
Fuel oil and gas-fired power plants: electricity generation	0.021	-	-	-	-
Fuel oil and gas-fired power plants: industrial and commercial	0.038	-	-	-	-
Biomass power plants	1.584	-	-	-	0.475
Landfill gas/biogas combustion	0.030	-	-	-	-
Household heating & cooking with biomass	0.754	-	-	-	0.151
Household heating & cooking with coal	0.027	-	-	-	0.00014
Household heating & cooking with oil	0.0010	-	-	-	-
Household heating & cooking with gas	0.0162	-	-	-	-
2012 totals	3.329	-	0.407	-	0.745
2016 totals	3.241	-	0.068	-	0.788
2020 totals	3.721		0.273		0.905

6 Production of mineral products

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 4a Cement production
- 4b Lime production
- 4c Brick production
- 4d Glass production
- 4e Ceramics production
- 4f Asphalt mixing
- 4g Oil shale pyrolysis

The dioxin releases from the production of mineral products are all basically combustion related. However, the alkaline nature of many of the materials being processed may help to reduce dioxin formation, either by neutralising some of the active chlorine species or by surface absorption of the dioxins after they are formed.

6.1 Cement production

Following the closure of the Holcim cement plant at Cape Foulwind in 2016, currently New Zealand has only one cement manufacturer – Golden Bay Cement in Whangarei. The Golden Bay plant uses a ‘dry’ process in which the raw materials are fed into the system in a dry state. Coal is used as the primary fuel but is supplemented with wood waste and more recently tyre-derived fuel. The total cement production at the plant in 2020 was 802,121 tonnes (C. Ehlers, Northland Regional Council, pers comm, 2022).

The default factor given in the UNEP Toolkit for dry process kilns is 0.05 µg TEQ per tonne. There are no releases of cement kiln dust (CKD) from the Golden Bay plant, although this did occur in the now-closed Holcim plant.

The 2020 release estimates for cement production are shown in Table 6-1, along with the corresponding estimates made in the 2012 and 2016 Inventories.

Table 6-1: Dioxin releases from cement production

Year	Plant	Activity Rate (tonnes/year)		Release factors (µg TEQ/tonne of cement or CKD)		Annual releases (g TEQ/yr)	
		Cement	CKD	Air	Land	Air	Land
2012	Golden Bay	690,000	-	0.05	-	0.035	-
	Holcim	420,000	-	0.02	-	0.008	-
		-	20,000	-	6.7	-	0.134
2016	Golden Bay	887,025	-	0.05	-	0.044	-
2020	Golden Bay	802,121	-	0.05	-	0.040	-

Certainty assessment for 2020

Activity data: High (because it is based on actual cement production data)

Emission factor: Low because it is based on the Toolkit default factor

6.2 Lime production

There are 5 lime kilns in New Zealand located at Te Kuiti, Otorohanga (2) and Te Kumi, all in the Waikato region and Dunback in Otago, which produce burnt lime from limestone. Two North Island Kraft pulp and paper mills also operate lime kilns but these process the so-called “lime-mud” produced in the recovery process.

Due to economic confidentiality, data is no longer provided for the total burnt lime production in New Zealand in New Zealand’s greenhouse Gas Emission Inventory (Ministry for the Environment, 2022). However, it is possible to derive a production figure from the carbon dioxide emission figures that burnt lime manufacturers must declare annually to New Zealand’s Emission Trading Scheme. This calculation takes the form: total carbon dioxide emissions (tonnes) = 0.748 x (tonnes calcium oxide produced). Data given in the most recent New Zealand Greenhouse Gas Inventory report for the 2019 calendar year gives a greenhouse gas emission from lime production of 108,000 tonnes CO₂. (Ministry for the Environment, 2022). This allows an estimate of actual lime production of 144,385 tonnes in 2019.

The 2012 Inventory estimates for releases to air were based on the default UNEP Toolkit factor of 0.07 µg TEQ per tonne of lime (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). For releases to land it was assumed that there would be about 3000 tonnes of dust collected from the air pollution control equipment on the kilns, with a dioxin content of 6.7 µg TEQ per tonne, and 17,000 tonnes of product (lime) applied to land, with a dioxin content of 1.24 µg TEQ per tonne. The same factors and assumptions have been applied to the current estimates, but the calculations have only been applied to the annual burnt lime production at the 5 limestone kilns (ie, excluding the pulp mill kilns). An additional factor of 0.85 has been applied to these estimates to reflect decreased production from 170,000 to 144,385 tonnes.

The lime kilns used at the pulp and paper mills do produce some dioxin emissions to air. These emissions were tested on the two kilns at the Bay of Plenty mill in 2002 and showed dioxin concentrations of 23 and 14 pg TEQ/Nm³ (1 pg TEQ/Nm³ = 1 x 10⁻¹² g TEQ/Nm³) (Beca Amec, 2006). On the basis of the gas flow data provided in a more recent report (Beca Amec, 2009), and assuming the same release rate for the Waikato mill, the total annual dioxin release is estimated at 0.0006 g TEQ per year. There would be no releases to land or water from these kilns.

The release estimates for lime production for 2012, 2016 and 2020 are shown in Table 6-2.

Table 6-2: Dioxin releases from lime production

Year	Activity Rate (tonnes of lime/year)		Release factors (µg TEQ/tonne of lime)		Annual releases (g TEQ/yr)	
			Air	Land	Air	Land
2012	Lime production	170,000	0.07	-	0.0119	-
	Lime application to land	17,000	-	1.24	-	0.022
	APC equipment dust	3,000	-	6.7	-	0.020
	Pulp mill lime kilns	-	-	-	0.0006	-
Total					0.0125	0.042
2016	Lime production	238,480	0.07	-	0.0167	-
	Lime application to land	23,800	-	1.24	-	0.0295
	APC equipment dust	4200	-	6.7	-	0.0281
	Pulp mill lime kilns				0.0006	
Total					0.0173	0.0576
2020	Lime production	144,385	0.07		0.0101	
	Lime application to land	14,450		1.24		0.0179
	APC equipment dust	2,550		6.7		0.0171
	Pulp mill lime kilns				0.0006	
Total					0.0107	0.0350

Certainty assessment for 2020

Activity data: Medium (because it is based on estimated production data)

Emission factor: Low (because it is based on the Toolkit default factors and other published information)

6.3 Brick production

With the closure of New Zealand's largest brick manufacturing facility, CSR Building Products (Monier Bricks), there are now only two significant manufacturers of bricks in New Zealand located in Huntly and Christchurch. The Huntly plant is fired by gas and produces about 5,000 tonnes per annum, whereas the Christchurch plant produced 6,000 tonnes per annum in 2020 and is fired with oil (R Thomas, Canterbury Clay Bricks, pers comm, 2022). Consequently, total brick production for 2020 was 11,000 tonnes.

The UNEP Toolkit differentiates between small, poorly controlled kilns (which it assigns as Class1) and larger better-controlled kilns (Class 2). Kilns can qualify for the class 2 category if they have either emission control technology in place or state of the art process control, in which case they can burn fuels of any type including those which the Toolkit refers to as "contaminated". Alternatively larger kilns with no emission control technology, but

which use uncontaminated fuels, also qualify as class 2. On this basis the two New Zealand brick-making facilities should be assigned to Class 2.

The Toolkit provides emission factors for releases to air, in products and in residues. The residues produced in brick making are the ash products resulting from the combustion of solid fuels. Where the fuel is natural gas or a liquid fuel such as oil or diesel, virtually no ash is produced. Consequently, there are no significant releases via residues for the New Zealand plants.

The 2020 release estimates for brick production are shown in Table 6-3, along with the corresponding estimates reported for the 2012 and 2016 Inventories.

Table 6-3: Dioxin releases from brick production

Year	Activity Rate (tonnes/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Products	Air	Products
2012	44,546	0.02	-	0.00089	-
		-	0.006	-	0.00027
2016	10,000	0.02	-	0.00020	-
		-	0.006	-	0.00006
2020	11,000	0.02	-	0.00022	-
		-	0.006	-	0.000066

Certainty assessment for 2020

Activity data: High (because it is based on industry production data)
 Emission factor: Low (because it is based on the Toolkit default factors)

6.4 Glass production

There are two industrial glass manufacturers in New Zealand both based in Auckland. Visy (formerly O-I Glass Ltd) produces glass bottles and jars, while Tasman Insulation, produces fibreglass insulation. The latter process uses recycled window glass as its feedstock and an electric melter (M Burgess, Fletcher Building, pers comm, 2018) so its production does not contribute to the sector’s activity. It has not been possible to obtain 2020 production quantities from Visy, so the amount used for the 2016 Inventory (209,077 tonnes per year of glass product) has been used as an estimate.

The emission estimates for the 2012 and 2016 Inventories were based on the UNEP Toolkit default factor of 0.015 µg TEQ per tonne of glass (0.015 x 10⁻⁶ g TEQ/tonne) for releases to air, and there were no significance releases via any other media. The same approach has been adopted here. The 2020 release estimates for glass production are shown in Table 6-4, along with the corresponding estimate made in the 2012 and 2016 Inventories.

Table 6-4: Dioxin releases from glass production

Year	Activity Rate (tonnes of glass/year)	Release factors (µg TEQ/tonne of glass)	Annual releases (g TEQ/yr)
		Air	Air
2012	230,511	0.015	0.0035
2016	209,077	0.015	0.0031
2020	209,077	0.015	0.0031

Certainty assessment for 2020

Activity data: Medium (because it is based on an estimate of actual production data)

Emission factor: Low (because it is based on the Toolkit default factor)

6.5 Pottery and ceramics production

Statistics for the annual production of clay for pottery and ceramics in New Zealand are kept by the New Zealand Petroleum and Minerals group of the Ministry of Business, Innovation and Employment (MBIE). Most production comes from a single site in Northland (C. McCabe, MBIE, pers comm, 2018). The statistical records show that the amount of clay listed can vary significantly from year to year. As a consequence, the practice was adopted for the 2016 Inventory of using a four yearly average of clay production to represent the activity for the reference year and will be continued here. The average clay production for 2017 to 2020 inclusive was 39,573 tonnes. (New Zealand Petroleum and Minerals, 2022)

The UNEP Toolkit notes that dioxins will most likely be released to air during ceramics production as a result of the thermal processes involved. However, no specific emission data has been reported and it recommends using the emission factors developed for brick making to give an indication of the likely releases (United Nations Environment Programme, 2013). The Toolkit differentiates between small, poorly controlled kilns (which it assigns as Class 1) and other types of kilns (Class 2). The Class 2 category covers a variety of situations, including kilns with no emission control technology, but which use uncontaminated fuels. It has been assumed that all New Zealand kilns will comply with Class 2 conditions. The 2020 release estimates for pottery and ceramics production are shown in Table 6-5 along with the estimates for the 2012 and 2016 Inventories.

Table 6-5: Dioxin releases from pottery and ceramics production

Year	Activity Rate (tonnes/year)	Release factors (µg TEQ/tonne)	Annual releases (g TEQ/yr)
		Air	Air
2012	37,475	0.02	0.00075
2016	37,439	0.02	0.00075
2020	39,573	0.02	0.00079

Certainty assessment for 2020

Activity data: High (because it is based on national clay production data)

Emission factor: Low (because it is based on the Toolkit default factor)

6.6 Asphalt mixing

Civil Contracting New Zealand have estimated that the annual asphalt production for 2020 in New Zealand was 1.57 million tonnes per year which was higher than the 1.4 million tonnes used for the previous inventory despite April to June being a slow period due to COVID-19 lockdown (S. Goldsworthy, pers comm, 2022).

The 2012 and 2016 Inventory estimates for this source category were based on the UNEP Toolkit default factors of 0.007 µg TEQ per tonne of asphalt for emissions to air, and 0.06 µg TEQ per tonne of asphalt for releases in residues (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). However, the latter factor was only applied to 50% of the total production, because in about half of the plants the dust collected in the air pollution control equipment is recycled back to the process. The same factors have been applied to the current estimates.

The 2016 release estimates for asphalt production are shown in Table 6-6 along with the estimates for 2012 and 2016.

Table 6-6: Dioxin releases from asphalt production

Year	Activity	Activity Rate (tonnes of asphalt)	Release factors (µg TEQ/tonne of asphalt)		Annual releases (g TEQ/yr)	
			Air	Residues	Air	Residues
2012	Asphalt production	850,000	0.007	-	0.006	-
	Plant residues (dust)	50% of the above	-	0.06	-	0.026
2016	Asphalt production	1,400,000	0.007		0.0098	
	Plant residues (dust)	50% of the above		0.06		0.042
2020	Asphalt production	1,570,000	0.007		0.0110	
	Plant residues (dust)	50% of the above		0.06		0.047

Certainty assessment for 2020

Activity data: Medium (because it is based on estimated production data)

Emission factor: Low (because it is based on the Toolkit default factors and other published information)

6.7 Oil shale pyrolysis

Oil shale is a general term applied to a group of hard rocks rich enough in bituminous material to yield petroleum upon pyrolysis and distillation (Ministry of Economic Development, 2008). Some of New Zealand's oil reserves occur in soft clay-based rocks that are also described as shales. However, the oil is extracted from these *in situ* rather than by pyrolysis. Hence this is not a potential source for New Zealand.

6.8 Summary for this category

The 2020 release estimates for mineral production are summarised in Table 6-7, along with the totals for 2012 and 2016.

Table 6-7: Summary of the release estimates for mineral production

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Cement production	0.040	-		-	-
Lime production	0.0107	-	0.0350	-	-
Brick production	0.00022	-	-	0.000066	-
Glass production	0.0031	-	-	-	-
Pottery and ceramics	0.00079	-	-	-	-
Asphalt production	0.0110	-	-	-	0.047
2012 totals	0.066	-	0.176	0.00027	0.026
2016 totals	0.076	-	0.0576	0.00006	0.042
2020 totals	0.066		0.0350	0.00007	0.047

7 Transport

This source category covers emissions to air from the combustion of petroleum-based fuels in transportation. The primary focus is on fuel use in motor vehicles, but the methodology also captures fuel consumption by other forms of transport, such as trains, boats, and off-road vehicles, and also fuel use in stationary engines, such as generators (United Nations Environment Programme, 2013). Aircraft are not included because the combustion of aviation fuel is believed to not result in any significant releases of dioxins. The category is broken down into the following sub-groups:

- 5a 4-Stroke engines
- 5b 2-Stroke engines
- 5c Diesel engines
- 5d Heavy oil-fired engines

The dioxin releases from transport are all combustion-related and they mainly arise from the incomplete combustion of the fuels being burned. For this reason, the dioxin release rates tend to be greatest for the more complex fuels (eg. oil versus petrol versus LPG). They are also affected by the different engine designs and the use of catalytic converters on the engine exhausts. An additional factor specific to leaded petrol is noted below.

The vehicle fleet was comprised of the following vehicles in 2020 (Ministry of Transport, 2022):

- 3,399,000 light petrol vehicles (including hybrid and PHEVs)
- 818,300 diesel powered light vehicles (mostly vans, utes, light trucks and 4-WDs)
- 164,000 diesel heavy vehicles (trucks and buses)
- 161,000 motorcycles
- 32,000 mopeds (a significant proportion of which have 2-stroke engines)
- 25 CNG powered vehicles
- 1049 LPG powered vehicles.

An unusual feature of this vehicle fleet in global terms is its age. Of the light vehicle fleet 21% of vehicles are more than 20 years old and 65% are 10 years or older. The average light vehicle age in New Zealand is 14 years whereas in Australia it is 10 years. (Ministry of Transport, 2022)

Significant quantities of petrol are also combusted in engines in off-road situations. The Energy Efficiency and Conservation Authority (EECA) recently conducted a study aimed at improving estimates of off-road petrol and diesel use in New Zealand (Energy Efficiency and Conservation Authority, 2021). One of the findings of the study was that of the 445 million litres of petrol used for off-road activities, 383 million litres (86%) were being used for recreational marine activities. Because this fuel has been sourced from the retail network to fill boats for recreation, currently it is being captured as “on-road” use when it should be “off-road”. This may have led to previous underestimation of the quantities of petrol being used in boats. For instance, in the 2016 Inventory, the Ministry of Transport estimated that New Zealand’s boats and jet skis consumed 65.6 million litres (I McGlinchy, Ministry of Transport, pers comm, 2018).

Apart from recreational marine activities, the EECA study reported that other major off-road petrol uses occurred in agriculture (33 million litres) and commercial activities (21 million litres), although the latter encompasses a wider range than purely commercial functions. Light vehicles such as agricultural and recreational quad bikes and motor bikes, utes, and small equipment such as chainsaws, pumps and motor mowers are the principal users of petrol here.

7.1 4-Stroke engines

The use of leaded petrol was the major cause of dioxin emissions from motor vehicles, due to the presence of chemicals such as dichloroethane that were used as scavengers for the lead (United Nations Environment Programme, 2013). Dioxins have also been detected in the emissions from vehicles burning unleaded petrol and diesel, but in much lower amounts. The use of modern emission control technologies, especially catalytic converters, has been shown to reduce the emissions to almost negligible levels. The engines of most petrol-fuelled vehicles operate on a 4-stroke cycle and, in New Zealand, all petrol has been unleaded since the late 1990s. The total petrol consumption in 2020 was 100,710 TJ, or about 2,146,270 tonnes (1 TJ = 10¹² Joules) (Ministry of Business Innovation and Employment, 2021).

The UNEP Toolkit provides different emission factors for 4-stroke vehicles with or without catalysts and also for vehicles operated on petrol/ethanol blends containing 50% or more ethanol. Petrol/ethanol blends are available in New Zealand, but the proportion of ethanol is limited under the *Engine Fuel Specifications Regulations 2011* to no more than 10%. The total amount of biofuels (bioethanol and biodiesel) produced in New Zealand in 2020 was only 320 TJ (Ministry of Business Innovation and Employment, 2021) and the consumption for transport has already been included in the total petrol figure given above. For the previous Inventory it was estimated that 95% of the on-road use of petrol was in vehicles fitted with catalytic converters. The Ministry of Transport is not able to provide a current update but feels that the proportion of vehicles with a catalytic converter should be fairly high (H. Wang, Ministry of Transport, pers comm, 2022). Given New Zealand's fleet age profile it is assumed that a figure of 95% is still relevant.

The use of LPG in vehicles is also included in this category and the emissions are expected to be similar to those from 4-stroke engines fitted with exhaust catalysts. The total LPG consumption for transport in 2016 was only 130 TJ or 2,700 tonnes,

The 2020 release estimates for 4-stroke engines are shown in Table 7-1, along with the corresponding estimates for the 2012 and 2016 Inventories. The activity rates were obtained by subtracting the petrol used in 2-stroke engines (see section 7.2 below) and then distributing 5% of the remainder to non-catalyst vehicles and 95% to those fitted with catalysts. The annual LPG consumption has been added to the latter figure.

Table 7-1: Dioxin releases from 4-stroke petrol engines

Year	Type of 4-stroke engine	Activity Rate (tonnes of fuel/year)	Release factors (µg TEQ/tonne of fuel)	Annual releases (g TEQ/yr)
			Air	Air
2012	no catalyst	383,758	0.1	0.0038
	catalyst	1,881,442	0.001	0.002
	Totals			0.040
2016	no catalyst	119,411	0.1	0.012
	catalyst	2,268,809	0.001	0.0023
	Totals			0.014
2020	no catalyst	103,548	0.1	0.0104
	catalyst	1,970,103	0.001	0.00197
	Totals			0.0124

Certainty assessment for 2020

Activity data: High (because it is based on national fuel data)

Emission factor: Low (because it is based on the Toolkit default factor)

7.2 2-Stroke engines

Petrol engines operating on a 2-stroke cycle were commonly used in the past in applications that required relatively small light-weight power units, such as chain saws, lawn mowers, outboard motors, motor bikes and jet-skis. However, the 2-stroke engines were generally less fuel-efficient than 4-stroke engines and also produced proportionately higher quantities of exhaust pollutants, including dioxins (eg, see Maritime New Zealand, undated-2). As a result, the engines used in many of these applications are now 4-stroke.

Much of the fuel used in 2-stroke engines will be in off-road or non-road applications. As discussed in the introduction to this section, the Energy Efficiency and Conservation Authority estimate off-road petrol use to total about 445 million litres or 333,750 tonnes which equates to 15.6% of total petrol consumption in 2020. This is higher than the estimate of 4 to 5% assumed for off-road use in the 2016 Inventory Report. The proportion of 2-stroke engines involved is difficult to establish because neither the Ministry of Transport nor the Ministry of Business Innovation and Employment differentiate between engine types in their statistics.

As previously, noted the majority of off-road petrol consumption in 2020, 383 million litres or 287,000 tonnes, is now attributed to recreational marine activities (Ministry of Business Innovation and Employment, 2021). In 2019 the Auckland Harbourmaster's office estimated that about 10–20% of new vessels and 50% of older vessels in the Auckland region were powered by 2-stroke engines. Of the 3717 active jet-skis in the Auckland, Northland and Bay of Plenty regions registered with the Auckland Harbourmaster, it was estimated that about 10% have 2-stroke engines in 2019. (M. Madsen, Auckland Harbourmasters Office, pers. comm., 2019).

Using these figures, the share of 2-stroke motors in the recreational marine sector is likely to be about 25% with corresponding petrol consumption in 2020 of about 71,750 tonnes. With regard to other sectors which involve 2-stroke engine use, the 2016 Inventory report used a figure of 2800 tonnes for 2-stroke motorcycles. Registrations of motorcycles increased 13% from 2016 to 2020 so this amount has been increased in proportion to 3164 tonnes. The amount of petrol consumed by small motors such as chainsaws may not be large. For instance, forestry operations are estimated to consume only 75 tonnes (100,000 litres) of off-road petrol annually for uses which include not only 2-stroke chainsaws but also 4-stroke applications such as generators, pumps, and quad bikes (Energy Efficiency and Conservation Authority, 2021). Other small 2-stroke engine petrol consumption has been estimated to be 10% of that of 2-stroke motorcycles, that is 316 tonnes.

Consequently, in total, 2-stroke engine petrol use in New Zealand is estimated to be 75,230 tonnes. This is significantly higher than the 5,600 tonnes used for the 2012 and 2016 Inventory Reports but as discussed, this increase results from improved fuel consumption estimates.

Table 7-2: Dioxin releases from 2-stroke petrol engines

Year	Activity Rate (tonnes of fuel/year)	Release factors (µg TEQ/tonne of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	5,600	2.5	0.014
2016	5,600	2.5	0.014
2020	75,230	2.5	0.188

Certainty assessment for 2020

Activity data: Low (because it is based on assumed annual fuel consumption)

Emission factor: Low (because it is based on the Toolkit default factor)

7.3 Diesel engines

The total consumption of diesel in transport, industrial and commercial applications, agriculture, and residential uses in 2016 was 135,870 TJ (1 TJ = 10^{12} Joules) (Ministry of Business Innovation and Employment, 2021). However, some of this usage has already been accounted for under sections 5.1.3 (industrial/commercial heat and power, 5,330 TJ) and 5.5.2 (domestic heating and cooking, 103 TJ). Subtracting these figures from the total gives an annual diesel usage in transportation and stationary engines of 130,437 TJ or 2,847,961 tonnes.

The UNEP Toolkit includes a separate release factor for biodiesel, although it is only marginally lower than that for normal diesel (0.07 vs 0.1 $\mu\text{g TEQ/tonne}$) ($1 \mu\text{g TEQ/tonne} = 1 \times 10^{-6} \text{ g TEQ/tonne}$). For the 2016 Inventory Report, the 20TJ (440 tonnes) of biodiesel produced at the time was regarded as trivial as it changed the total release estimate by only 0.00001g TEQ. The quantity of biodiesel produced in 2020 is not available but will be significantly less than the 2016 figure following the closure of Z-Energy's Te Kora Hou biofuel plant in Wiri in early 2020. This was caused primarily by high international prices for tallow, an important feedstock for biodiesel (Ministry of Business Innovation and Employment, 2021).

The 2020 release estimates for diesel consumption in transport and stationary engines are shown in Table 7-3, along with the corresponding estimates from the 2012 and 2016 Inventories.

Table 7-3: Dioxin releases from diesel engines

Year	Activity Rate (tonnes of fuel/year)	Release factors ($\mu\text{g TEQ/tonne of fuel}$)	Annual releases (g TEQ/yr)
		Air	Air
2012	2,380,000	0.1	0.238
2016	2,660,722	0.1	0.266
2020	2,847,961	0.1	0.285

Certainty assessment for 2020

Activity data: High (because it is based on national fuel data)

Emission factor: Low (because it is based on the Toolkit default factor)

7.4 Heavy oil-fired engines

The consumption of heavy fuel oil for transportation is primarily confined to its use in coastal shipping, for which the total fuel consumption in 2020 was 3720 TJ, or about 85,630 tonnes (Ministry of Business, Innovation and Employment, 2021). This total includes both ‘new’ fuel oil and recycled waste oil.

The 2021 release estimates are shown in Table 7-4 along with the corresponding estimates made in the 2012 and 2016 Inventories. The reduction in consumption compared to 2016 levels may be partially related to COVID-19 restrictions on activity occurring in 2020 but it is also thought that there may have been some substitution of diesel for fuel oil caused by new MARPOL Annex VI rules for international shipping. These rules lower the maximum sulphur content for fuel oil in shipping from 3.5% to 0.5%.

Table 7-4: Dioxin releases from heavy fuel oil-fired engines

Year	Activity Rate (tonnes of fuel/year)	Release factors (µg TEQ/tonne of fuel)	Annual releases (g TEQ/yr)
		Air	Air
2012	92,000	4	0.368
2016	94,340	4	0.377
2020	85,630	4	0.343

Certainty assessment for 2020

Activity data: High (because it is based on national fuel data)

Emission factor: Low (because it is based on the Toolkit default factor)

7.5 Summary for this category

The 2016 release estimates for fuel use in transportation and stationary engines are summarised in Table 7-5, along with the revised comparative totals for 2012 and 2016.

Table 7-5: Summary of the release estimates for transport

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
4-stroke engines	0.0124	-	-	-	-
2-stroke engines	0.188	-	-	-	-
Diesel engines	0.285	-	-	-	-
Heavy oil-fired engines	0.343	-	-	-	-
2012 totals	0.660				
2016 totals	0.672	-	-	-	-
2020 totals	0.828	-	-	-	-

8 Open burning processes

This category covers the following dioxin sources (United Nations Environment Programme, 2013):

- 6a Biomass burning
- 6b Waste burning and accidental fires

Open burning processes are usually characterised by the presence of mixtures of waste materials, with little or no control over their condition (ie, wet or dry) and little or no control over the burning processes. As a result, there is often a high potential for dioxins to be formed as a result of incomplete combustion processes. Despite this, the potential for dioxin formation from the burning of clean biomass is relatively low, unless the material is contaminated with specific dioxin precursors, such as chlorinated phenoxy herbicides (see section 9). Also, it is much higher for waste burning and accidental fires because of the potential presence of chlorinated materials (eg some plastics, such as PVC) and catalytic metals, such as copper.

8.1 Biomass burning

. The category is divided into the following sub-categories:

- i. Agricultural residue burning
- ii. Sugarcane burning
- iii. Forest fires
- iv. Grassland and savannah fires

The activity data for all of these sources is taken from the annual greenhouse gas inventory reports produced by the Ministry for the Environment. (Ministry for the Environment, 2022) The activity rates for biomass burning show a significant amount of variation from year to year. Consequently, the activity rates for 2020 will be based on the average data from the previous 3 years ie, 2018 to 2020, as was done for the previous dioxin inventories.

8.1.1 Agricultural residue burning

This source category covers the burning of crop residues in the fields where the crops were originally grown, usually as a land clearance activity prior to the planting of the next crop. This practice is used in New Zealand for barley, wheat, and oats, but not for maize (Ministry for the Environment, 2022). The total area of crop land burned is obtained through annual surveys carried out by Statistics New Zealand, and then converted to a mass basis using biomass density factors.

The total mass of crop residues burned in New Zealand in 2018, 2019 and 2020 was 221,250, 281,580 and 279,840 tonnes/year, respectively, which gives an annual average rate of 260,890 tonnes/year. This average activity rate has been used for the 2020 release estimates, coupled with the UNEP Toolkit factors for burning under relatively favourable combustion conditions. The alternative Toolkit factors for burning under poor combustion conditions and in the presence of dioxin precursors, such as chlorinated pesticides, are not relevant to the New Zealand practices. The release estimates are shown in the table below, along with the corresponding estimates from the 2012 and 2016 inventories.

Table 8-1: Dioxin releases from agricultural residue burning

Year	Activity Rate (tonnes biomass burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	288,274	0.5		0.144	
			0.05		0.0014
2016	290,417	0.5	-	0.145	-
		-	0.05	-	0.0145
2020	260,890	0.5		0.130	
			0.05		0.0130

Certainty assessment for 2020

Activity data: High (because they are based on the national greenhouse gas inventory data)

Emission factor: Low (because they based on the Toolkit default factors)

8.1.2 Sugarcane burning

This source has not been assessed because there are no sugarcane plantations in New Zealand.

8.1.3 Forest fires

This source category covers wildfires and controlled burn-offs in forests. Both of these activities are addressed in the greenhouse gas inventory reports and estimates for the total area of forest land burned are obtained through surveys of forestry owners and data available from the National Rural Fire Authority. These are converted to a mass basis using a single biomass density factor for all forest types (Ministry for the Environment, 2022).

The total mass of forest biomass burned in New Zealand in 2018, 2019 and 2020 was 149,212, 473,983 and 517,529 tonnes/year, respectively, which gives an average rate of 380,242 tonnes/year. This activity rate has been used for the 2020 release estimates, coupled with the UNEP Toolkit factors. The release estimates are shown in the table below, along with the corresponding estimates from the 2012 and 2016 inventories.

Table 8-2: Dioxin releases from forest fires

Year	Activity Rate (tonnes biomass burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	151,129	1	-	0.151	-
		-	0.15	-	0.023
2016	204,953	1	-	0.205	-
		-	0.15	-	0.0307
2020	380,242	1		0.380	
			0.15		0.057

Certainty assessment for 2020

Activity data: Medium (because they are based on the national greenhouse gas inventory data)

Emission factor: Low (because they based on the Toolkit default factors)

8.1.4 Grassland and savannah fires

This source category covers both controlled and accidental burning of grassland and savannah. In New Zealand, the savannah category is used for land covered in tussock. The total area of grassland and savannah burned is obtained through national information on changes in land-use and data from the National Rural Fire Authority. These are converted to a mass basis using biomass density factors (Ministry for the Environment, 2022).

The total mass of grassland and savannah material burned in New Zealand in 2018, 2019 and 2020 was 417,288, 326,730 and 281,888 tonnes/year, respectively, which gives an average rate of 341,969 tonnes/year. This activity rate has been used for the 2020 release estimates, coupled with the UNEP Toolkit factors. The release estimates are shown in the table below, along with the corresponding estimates from the 2012 and 2016 inventories.

Certainty assessment for 2020

Activity data: Medium (because they are based on the national greenhouse gas inventory data)

Emission factor: Low (because they based on the Toolkit default factors)

Table 8-3: Dioxin releases from grassland and savannah fires

Year	Activity Rate (tonnes biomass burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	378,763	0.5	-	0.189	-
		-	0.15	-	0.057
2016	328,541	0.5	-	0.164	-
		-	0.15	-	0.0493
2020	341,969	0.5		0.171	
			0.15		0.0513

8.2 Waste burning and accidental fires

The category is divided into the following sub-categories:

- v. Fires at waste dumps
- vi. Accidental fires in houses, factories
- vii. Open burning of domestic waste
- viii. Accidental fires in vehicles
- ix. Open burning of wood (construction/ demolition)

8.2.1 Fires at waste dumps

Landfill fires were identified in the first dioxin inventory as New Zealand's most significant source of dioxin releases to air (Ministry for the Environment, 2000). In response to this, the deliberate lighting of fires and burning of wastes at landfills was banned under the *Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004*.

Previous inventories have shown a general decline in the number of landfill fires from 274 fires in 1998, 50 fires in 2008, 28 fires in 2012 and 27 fires in 2016. These estimates were based on fire incident data published by the NZ Fire Services, now known as Fire and Emergency New Zealand (FENZ). The landfill fire estimate for 2020 based on FENZ data supplied is 81 (Official Information Request OIA2022 – 00008550).

The previous inventories assumed an average waste quantity of 45 tonnes of waste per fire which has been retained. The Toolkit recommends a factor of 300 µg TEQ per tonne for releases to air, and 10 µg TEQ per tonne for releases to land (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne) (United Nations Environment Programme, 2013). Release estimates for 2020 are shown in Table 8-4 along with 2012 and 2016 estimates from the previous inventories.

Table 8-4: Dioxin releases from waste dump fires

Year	Activity Rate (tonnes of waste burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	1260	300		0.378	
			10		0.0126
2016	1215	300		0.365	
			10		0.0122
2020	3645	300		1.094	
			10		0.0364

Certainty assessment for 2020

Activity data: Low (because it based on national fire statistics but coupled with a highly uncertain conversion factor for the mass of material burned)

Emission factors: Low (because they are based on the Toolkit default factors)

8.2.2 Accidental fires in houses, factories

The release estimates for the previous dioxin inventories were based on New Zealand Fire Service (now Fire and Emergency New Zealand, FENZ) statistics for the numbers of structure fires attended each year. The quantities of materials involved in the fires were estimated using an approximate size distribution, which was first presented in the 2000 Inventory Report, and subsequently modified for the 2008, 2012 and 2016 Inventories. This approach has also been applied to the current estimates.

Annual fire incident data for structure fires in 2020 has been obtained from FENZ with a total of 5418 fires recorded (Official Information Request OIA2022 – 00008550). However, for this inventory information on the severity of the fire has also been obtained and the 2,422 fires involving no damage has been subtracted from this total, to give 1996 fires where damage did occur.

Applying the mass calculation methodology gives a total quantity of 655.8 tonnes for material consumed by fire in 2020. The UNEP Toolkit gives default factors of 400 µg TEQ per tonne for dioxin releases to both air and land (400 x 10⁻⁶ g TEQ/tonne). These factors have been used for the current release estimates, which are shown in Table 8-5, along with the corresponding estimates made in the 2012 and 2016 Inventories.

Table 8-5: Dioxin releases from structure fires

Year	Activity Rate (tonnes burned/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	1562	400		0.625	
			400		0.625
2016	1744	400		0.698	
			400		0.698
2020	655.8	400		0.262	
			400		0.262

Certainty assessment for 2020

Activity data: Medium (because it is based on national fire statistics coupled with an approximate conversion factor for the mass of material burned)

Emission factor: Low (because it is based on the Toolkit default factors)

8.2.3 Open burning of domestic waste

This section covers the emissions from the burning of domestic wastes in open fires or crude incinerators, where combustion conditions are poor and no controls are applied. Most of the waste disposed of in this way comprises wood, paper, leaves, and vegetation, together with a range of other possible materials, including kitchen wastes and plastics.

A review was conducted in 2015 of the current state and main sources of dioxin around the world. One of its conclusions was that domestic waste was probably the most important non-industrial source and one of the most difficult to determine precisely given the variability in composition of waste and mostly uncontrolled combustion techniques (Dopico & Gomez, 2015)

For the 2020 Inventory, a survey of regional councils and relevant territorial local authorities was conducted to help estimate the mass of material burnt in open fires and crude home incinerators. Participants were asked for details of any surveys or emission inventories covering this type of waste burning. They were also asked for any information they had regarding the percentage of active households in their areas, frequency of burning and the amount of waste burnt on each occasion. Participants were also asked if they considered the parameters used in the 2016 Inventory as still valid, that is 5% of all households burn domestic waste on 5- 10 occasions per year with a total of 250 kg domestic waste burnt per active household per year which gave a national activity of 20,170 tonnes per year for 2016.

Many councils felt not able to comment. Of those who did respond opinion was equally divided on the validity of the 2016 Inventory parameters with about half saying the parameters were about right, with the remainder saying

the parameters were too high. On a population basis the country is approximately evenly divided between households which live in an area where open burning is permitted and those which live in an area where the activity is banned. Generally, open burning of rubbish is permitted in rural areas in New Zealand, but this may be banned in cases if rural properties are served by municipal waste collection.

Some councils were able to provide results of air emission inventories for outdoor burning in towns or cities in their region. For instance for Hamilton, it was estimated that outdoor burning involved an average of 2.6 tonnes material per day or 961 tonnes per year (Jonathan Caldwell, Waikato Regional Council, pers comm, 2022). At 54,939 households, the city comprises about 3% of New Zealand’s estimated 1,865,300 households in March 2021 (Statistics New Zealand, 2022) which on a pro rata basis would result in a national total of 32,630 tonnes.

The respondent for Auckland Regional Council, which represents about 500,000 households, made the point that most outdoor burning in the region, in rural areas where it can legally occur, is of green waste and that only negligible quantities of municipal waste are burnt (Paul Crimmins, Auckland Regional Council, pers comm, 2022). The emission factors for green waste combustion should be similar to forest fires and grassland fires as shown in Sections 8.1.3 and 8.1.4 (0.5 µg TEQ/tonne for releases to air and 0.15 µg TEQ/tonne for releases to land) rather than those for outdoor burning (40 µg TEQ/tonne for releases to air and 1 µg TEQ/tonne for releases to land) which are higher because of the presence of municipal waste components.

Even in areas where open burning is permitted there are other factors which are increasingly acting to reduce this form of waste disposal such as a greater public consciousness of the role of particulate matter in air pollution and the risk that outdoor fires may get out of control.

On the basis of the survey findings, it has been decided that the number of households participating in outdoor burning should be reduced from 5% to 2.5 % but that the quantity burnt per household should remain at 250 kg/year. For 1,865,300 households nationally this represents an activity of 11,660 tonnes.

As discussed, the UNEP Toolkit gives default factors of 40 µg TEQ per tonne of waste, for dioxin releases to air, and 1 µg TEQ per tonne of waste, for releases to land (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). These factors have been used for the current release estimates, which are shown in Table 8-6, along with the corresponding estimates made in the 2012 and 2016 Inventories.

Table 8-6: Dioxin releases from open domestic waste burning

Year	Activity Rate (tonnes/year)	Release factors (µg TEQ/tonne)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	19,500	40	-	0.780	-
		-	1	-	0.020
2016	20,170	40	-	0.807	-
		-	1	-	0.0202
2020	11,660	40	-	0.466	-
		-	1	-	0.0117

Certainty assessment for 2020

Activity data: Low (because it is based on limited survey data)
 Emission factor: Low (because it is based on the Toolkit default factors)

8.2.4 Accidental fires in vehicles

The release estimates for the previous dioxin inventories were based on New Zealand Fire Service (now FENZ) statistics for the numbers of mobile property fires attended each year, and the same approach has been taken here. FENZ data for fires involving vehicles totalled 2,475 in 2020. (Official Information Request OIA2022 – 00008550)

The UNEP Toolkit gives default factors of 100 µg TEQ per fire, for dioxin releases to air, and 18 µg TEQ per fire, for releases to land (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). These factors have been used for the 2020 release estimates shown in Table 8-7, along with the corresponding estimates made for the 2012 and 2016 Inventories.

Certainty assessment for 2020

Activity data: High (because it is based on national fire statistics)

Emission factor: Low (because it is based on the Toolkit default factors)

Table 8-7: Dioxin releases from vehicle fires

Year	Activity Rate (vehicle fires/year)	Release factors (µg TEQ/fire)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	1712	100	-	0.171	-
		-	18	-	0.031
2016	2094	100		0.209	
			18		0.038
2022	2,475	100		0.248	
			18		0.0446

8.2.5 Open burning of wood (construction/demolition)

The on-site burning of waste timber produced during construction or demolition works is either prohibited or restricted in most urban areas but is still likely to occur on rural properties and in urban areas where restrictions have not been applied. There may also be some illegal burning in the controlled areas.

In 2006 it was estimated that construction and demolition (C&D) wastes made up about 14% of the total wastes disposed in landfills ie, about 440,000 tonnes per year (Ministry for the Environment, 2007). An additional 300,000 tonnes per year was disposed at cleanfill sites. There is no more recent data available on C&D waste quantities, and nor is there any information on the quantities of C&D wastes disposed by burning. As a result, it is not possible to provide any reliable estimates of the dioxin releases associated with this activity.

Some indication of the potential releases can be obtained by assuming that the quantities of C&D wastes disposed by burning are equivalent to no more than 1 % of the total disposed of at landfills and cleanfill sites; ie, 7,400 tonnes per year. If the amount of material burned in each fire was 1 tonne (ie, a small rubbish skip full), the total annual quantity would equate to 7,400 fires per year⁴, or just over 20 fires per day. The UNEP Toolkit recommends an emission factor of 60 µg TEQ per tonne (60 x 10⁻⁶ g TEQ/tonne), for dioxin releases to air. Applying this factor

⁴ FENZ attends about 4000 to 5000 fires per year that are specifically identified as involving some form of 'rubbish'.

to 1% of the total C&D waste quantities indicates possible annual releases to air of 0.2 g TEQ per year. If correct, this would make C&D waste burning a small, but not insignificant, contributor to the total dioxin releases to air. It therefore suggests the need for continuing support for, and enforcement of, the regional controls on open burning.

8.3 Summary for this category

The 2020 release estimates for accidental fires are summarised in Table 8-8, along with the totals for 2012 and 2016.

Table 8-8: Summary of the release estimates for open burning processes

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Agricultural residue burning	0.130	-	0.013	-	-
Forest fires	0.380	-	0.057	-	-
Grassland and savannah fires	0.171	-	0.0513	-	-
Fires at waste dumps	1.094	-	0.0364	-	-
Structure fires	0.262	-	0.262	-	-
Open burning of domestic wastes	0.466	-	0.0117	-	-
Vehicle fires	0.248	-	0.0446	-	-
2012 totals	2.439	-	0.782	-	-
2016 totals	2.593		0.863	-	-
2020 totals	2.751		0.476	-	-

9 Production of chemicals and consumer goods

This category covers dioxin releases from the following sub-categories (United Nations Environment Programme, 2013):

- 7a Pulp and Paper Production
- 7b Chlorinated Inorganic Chemicals
- 7c Chlorinated Aliphatic Chemicals
- 7d Chlorinated Aromatic Chemicals
- 7e Other Chlorinated and Non-Chlorinated Chemicals
- 7f Petroleum Production
- 7g Textile Production
- 7h Leather Refining

The dioxin releases from these sources are not combustion-related, apart from black-liquor combustion in the pulp and paper mills, and the various releases from petroleum production. Historically, pulp and paper mills were a significant source of dioxin releases due to the use of elemental chlorine as a bleaching agent, which reacted with phenolic species in the pulp to form dioxins. The dioxins associated with most of the other chemical products are also similar, in that they are formed as reaction by-products of the chemical processes used in manufacturing. Generally, the dioxins are accounted for as releases into products, and these then lead on to the last two sub-categories in this group, where the dioxins are transferred to textile and leather products through the use of treatment chemicals contaminated with dioxins.

9.1 Pulp and paper production

At the time of writing Ministry of Primary Industries data on wood pulp production in New Zealand is available only until the end of 2018. For 2018 the total wood pulp production in New Zealand was about 1.44 million tonnes (air dry basis), of which 47% was produced by thermo-mechanical or chemi-thermo-mechanical pulping, and 53% by chemical pulping (Ministry for Primary Industries, 2022). Mechanical pulp is produced at three plants in the Bay of Plenty, Hawke's Bay, and Manawatu–Wanganui regions. There are also two other mills in Auckland and the Bay of Plenty that produce paper and paperboard products from mixtures of wood pulp and waste paper. Chemical (kraft) pulp is produced at two pulp and paper mills in Kawerau and Tokoroa. From January 2019, only the Tokoroa mill produced bleached kraft pulp (Climate Leaders Coalition, 2022) which is the source of primary interest for dioxin releases.

Black liquor combustion

There are two primary sources of dioxin releases to air from bleached kraft mills: the combustion of wood and other biomass in the power boilers, and the combustion of black liquor in the chemical recovery boilers. The contributions from the power boilers have already been addressed under section 5.2, so only the recovery boilers are covered here.

Black liquor is the liquid residue that is left after the cellulose fibre has been extracted from wood chips with pulping liquor in the kraft process. Releases from black liquor combustion are directly related to pulp production figures, and the total annual production of kraft pulp at the two mills in 2020 was about 498,338 tonnes on an air-dry basis. A total of 1,215,226 tonnes of black liquor were combusted (E Mercer, Oji Fibre Solutions, pers comm, 2022).

The release estimates for the previous inventories were based on the results of emission testing on the two recovery boilers at the Waikato mill with a resulting release factor of 0.025 µg TEQ per tonne of black liquor solids. This factor has been used for the current estimates (0.025×10^{-6} g TEQ/tonne).

The 2020 estimates for releases to air from black liquor combustion are shown in Table 9-1, along with the estimates made in the 2012 and 2016 Inventories. There are no releases to water, land, or in products or residues.

Table 9-1: Dioxin releases from black liquor combustion

Year	Activity Rate (tonnes of black liquor solids/year)	Release factors (µg TEQ/tonne of BLS)		Annual releases (g TEQ/yr)	
		Air		Air	
2012	1,440,000	0.025		0.0360	
2016	1,930,000	0.025		0.0483	
2020	1,215,226	0.025		0.0304	

Certainty assessment for 2020

Activity data: High (because it is based on actual production data)

Emission factor: Medium (because it is based on historical emission data)

Releases to land and products

The wastewater treatment systems used at both mills result in the production of both primary and secondary sludge, and these are the only solid waste streams expected to contain dioxin residues. As with previous inventories the release calculations have been based on an annual production rate for bleached kraft pulp only. The UNEP Toolkit default emission factors of 0.2 µg and 0.5 µg TEQ per tonne of air-dry pulp have been used for releases to land and products respectively. Total bleached kraft pulp production in 2020 was 241,959 tonnes (E. Mercer, Oji Fibre Solutions, pers comm, 2022).

The 2020 estimates for releases from bleached pulp production are shown in Table 9-2, including 2012 and 2016 Inventory estimates. Releases have decreased because bleach pulp production has decreased, with the Bay of Plenty mill now focussing on unbleached pulp products (Climate Leaders Coalition, 2022).

Table 9-2: Dioxin releases to land and product from bleached pulp production

Year	Activity Rate (tonnes of air-dried bleach pulp/year)	Release factors (µg TEQ/tonne of bleached pulp)		Annual releases (g TEQ/yr)	
		Land	Product	Land	Product
2012	464,000	0.2	-	0.093	-
		-	0.5	-	0.232
2016	732,000	0.2		0.146	
			0.5		0.366
2022	241,959	0.2		0.0484	
			0.5		0.121

Certainty assessment for 2020

Activity data: High (because it is based on actual production data)
 Emission factor: Low (because it is based on the Toolkit default factors)

Releases to water

The dioxins in the pulp mill wastewater are absorbed onto suspended solids and are therefore removed with the sludge. As such, they have already been accounted for in the estimates given above for releases to land, and the releases to water should be taken as zero.

Additions to existing land reservoir

The disposal of primary and secondary sludge produced in the pulp mills contributes to existing reservoirs of dioxins which have been created at the company's various waste disposal sites (landfills). The overall size of the reservoir was estimated in the 2016 Inventory at 26.0 g TEQ on the basis of historical sludge production. This figure can now be updated for an additional 4 years' input, based on the 2020 release rate shown in Table 9-2. If this rate is assumed to apply for all of the last 4 years, the additional inputs to the reservoir would be 0.194 g TEQ, and the total current reservoir would be 26.19 g TEQ.

9.2 Chlorinated inorganic chemicals

This sub-category covers dioxin releases from the manufacture of chlorine gas by electrolysis of solutions of sodium chloride. Prior to the 1980s most chlorine plants used either mercury cells or a diaphragm system, and both of these processes were shown to be significant sources of dioxins (United Nations Environment Programme, 2013). Nowadays, most plants use an alternative membrane cell process which, until recently, had not been shown to produce any dioxins. However, the latest version of the Toolkit indicates that dioxins have also been detected in the releases from these plants, albeit at very low levels.

There is one chlorine plant in New Zealand which uses the modern membrane cell process, and has a total capacity of about 20,000 tonnes per year of chlorine. However, it is associated with the pulp and paper mill discussed in section 9.1 and its dioxin releases have already been accounted for under the mill-wide release estimates given in that section. However, for the sake of completeness, it can be noted that the releases from the chlorine plant would be in the order of about 0.00004 g TEQ to water, and 0.006 g TEQ to land, if considered separately from the rest of the mill.

9.3 Chlorinated aliphatic chemicals

This sub-section covers dioxin releases from the manufacture of polyvinyl chloride (PVC) resin, which usually starts with the manufacture of ethylene dichloride (EDC), followed by conversion to vinyl chloride monomer (VCM), and then a final polymerisation process to form PVC. Almost without exception, the first two of these steps are carried out in petrochemical manufacturing complexes, while the third may be done in a separate manufacturing plant, using imported VCM. However, there are no such facilities in New Zealand and the manufacture of PVC products is carried out using imported resin (Plastics New Zealand, 2011). Hence this source category is not relevant to New Zealand.

9.4 Chlorinated aromatic chemicals

This sub-section covers a range of different chemicals, only some of which are relevant to New Zealand. Each of the chemicals is discussed under separate sub-headings below.

9.4.1 1,4-dichlorobenzene

Dichlorobenzene may be contaminated with dioxins during manufacturing and can therefore represent a potential source of releases via products, in subsequent uses. The chemical is not manufactured in New Zealand, but it is listed in the New Zealand Inventory of Chemicals maintained by the Environmental Protection Authority (see www.epa.govt.nz). The UNEP Toolkit indicates that 1,4-dichlorobenzene has been used as an insecticide and fungicide, but the chemical is not registered for any such uses under the *Agricultural Compounds and Veterinary Medicines Act (ACVM) 1997* (see www.foodsafety.govt.nz/industry/acvm/registers-lists.htm). Other possible uses are as a disinfectant and odour control agent in waste containers and restrooms, but products such as these are not subject to any specific controls in New Zealand that would allow these uses to be readily identified. Hence it is not possible to provide a quantitative assessment for this chemical.

9.4.2 Polychlorinated biphenyls (PCBs)

PCBs were used in the past as transformer oils and in other related applications (United Nations Environment Programme, 2013). In New Zealand the import, manufacture, and use of PCBs is prohibited under the *Hazardous Substances and New Organisms Act (HSNO) 1996* without an exemption, and any stocks of old PCBs must be safely stored, managed, and disposed in accordance with the *Hazardous Substances (Storage and Disposal of Polychlorinated Biphenyls) Notice 2007*. There are no facilities in New Zealand for the destruction of PCB-containing wastes, so disposal is by export to a suitable facility overseas (Ministry of Health, 2008).

The UNEP Toolkit provides no specific factors for estimating the possible dioxin releases from the storage of PCBs. However, if the storage is being carried out properly in accordance with the HSNO requirements, the releases due to leakages should be minimal.

9.4.3 Pentachlorophenol and sodium pentachlorophenate

The primary use of pentachlorophenol (PCP) in New Zealand was in the timber industry, either as sodium pentachlorophenate, for use as an antispain treatment, or as a preservative in diesel oil (Ministry for the Environment, 2011a). PCP was also used to a relatively minor extent as a slimicide in the pulp and paper industry, as a soil and timber steriliser in mushroom production, and in a variety of other applications for the control of moss and algae. The use of PCP in the timber industry voluntarily ceased in 1988, and PCP was deregistered for all uses by the Pesticides Board in 1991.

Past releases of dioxins from the use of PCP have resulted in a number of contaminated sites throughout New Zealand, and these are discussed further in Section 12 of this report.

9.4.4 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) and 2,4,6-trichlorophenol

The herbicide 2,4,5-T was manufactured in New Zealand from 1948 to 1987 and was widely used for the control of gorse, blackberry, and other woody weeds (Ministry for the Environment, 2011a). The manufacturing process involved the initial formation of 2,4,5-trichlorophenol from 1,2,4,5-tetrachlorobenzene, and PCDDs and PCDFs (primarily 2,3,7,8-TCDD) were formed as a by-product of this reaction.

The residual soil contamination resulting from the past uses of 2,4,5-T is discussed in section 12 of this report.

9.4.5 Chloronitrofen, chlornitrofen, or 2,4,6 trichlorophenyl-4-nitrophenylether (CNP)

This chemical is not listed in the New Zealand Inventory of Chemicals or in any of the other registers of approved substances maintained by the Environmental Protection Authority (see www.epa.govt.nz). Hence it should not be found in New Zealand.

9.4.6 Pentachloronitrobenzene (PCNB - Quintozene)

Quintozene is a broad-spectrum, contact fungicide which was approved in New Zealand for the control of soil fungi in vegetable and ornamental seedlings, and non-grazed turf. However, this approval was revoked in January 2011 because of concerns about the presence of dioxin impurities (ERMA New Zealand, 2011). The presence of these impurities had only come to the attention of regulatory agencies, both here and overseas, in the preceding 2 years.

It is not known what quantities of Quintozene were previously used in New Zealand, but the Environmental Risk Management Authority (now EPA (Environmental Protection Authority)) determined that the uses were mainly limited to bowling greens and golf courses, and the quantities were “not large”. For the purposes of this inventory, it can be assumed that the usage in 2020 was nil, and hence there were no associated dioxin releases.

9.4.7 2,4-Dichlorophenoxyacetic acid (2,4-D) and derivatives

The phenoxy herbicide 2,4-D is used in New Zealand, mainly on hill country farms, to control thistles and other broadleaf weeds. This agrichemical has been shown in the past to contain dioxin residues as production by-products, although with current manufacturing technologies the contamination levels are very low (United Nations Environment Programme, 2013). For the 2016 Inventory the annual usage in New Zealand was estimated at about 500 tonnes per year and current usage is thought to be at similar rates (A Cliffe, Nufarm NZ, Auckland, pers comm, 2022).

The Toolkit puts the dioxin contamination level at 0.1 µg TEQ/tonne of product (1 µg TEQ/tonne = 1 x 10⁻⁶ g TEQ/tonne). Release estimates for 2012, 2016 and 2020 are shown in Table 9-3.

Table 9-3: Dioxin releases to land (via product) from the use of 2,4-D

Year	Activity Rate (tonnes of 2,4-D used/year)	Release factors (µg TEQ/tonne of product)	Annual releases (g TEQ/yr)
		Land/Product	Land
2012	335	0.1	0.000034
2016	500	0.1	0.000050
2020	500	0.1	0.000050

Certainty assessment for 2020

Activity data: High (because it is based on an industry estimate of national production)

Emission factor: Medium (because it is based on the Toolkit default factor supported by analytical data obtained previously from one of the manufacturers)

9.4.8 Chlorinated Paraffins

Chlorinated paraffins (CPs) are produced by chlorination of straight-chain hydrocarbons, with chain lengths generally ranging from C₁₀ to C₃₀. The largest use of CPs is in industrial cutting fluids, but they may also be present in paints, adhesives, sealants, and caulks, as well as plasticizers for PVC and flame retardants in other plastics and rubber.

Given the nature of their uses, most chlorinated paraffins are likely to be imported as minor constituents of a wide range of manufactured products. As such, it would be virtually impossible to determine the total quantities of CPs entering the country, or the dioxin contamination levels.

9.4.9 p-Chloranil

Chloranil (2,3,5,6-tetrachloro-2,5-cyclohexadiene-1,4-dione) was used in the past as a fungicide and seed dressing, although these uses were discontinued in most countries by the early 1980s. It is still used in the manufacture of dioxazine dyes and as a laboratory reagent (eg, for the detection of primary and secondary amines). Chloranil has been shown to be contaminated with dioxins, but the level of contamination is highly dependent on the method of manufacture (United Nations Environment Programme, 2013).

Chloranil is listed in the New Zealand Inventory of Chemicals maintained by the Environmental Protection Authority (see www.epa.govt.nz). The HSNO approval for chloranil lists it as a pesticide, veterinary medicine, or pharmaceutical active ingredient. However, the substance is not currently registered under the Agricultural Chemicals and Veterinary Medicines Act 1997 (see www.foodsafety.govt.nz/-industry/acvm/registers-lists.htm), and therefore, cannot be used in New Zealand for any of these applications.

No current uses of chloranil have been specifically identified for New Zealand, although there may be some minor uses as a laboratory reagent.

9.4.10 Phthalocyanine dyes and pigments

Phthalocyanine dyes are artificial organic pigments which can be used in a wide range of dye applications. However, the UNEP Toolkit is primarily concerned with two specific substances; phthalocyanine copper (blue) and phthalocyanine green. The first of these can have minor levels of dioxin contamination (70 µg TEQ/tonne, ie, 70×10^{-6} g TEQ/tonne) while the contamination levels in the latter can be 200 times greater. Phthalocyanine green is not listed in the New Zealand Inventory of Chemicals. These substances are mainly used on textiles.

There is no specific import data available for phthalocyanine copper. For the 2012 and 2016 Inventories it was assumed that the quantity annually in New Zealand would be no more than 10 tonnes per year and the same assumption will be made for this Inventory. For this activity, the associated dioxin release would be 0.0007 g TEQ per year. This would make only a very minor contribution to the New Zealand dioxin burden so, given the lack of any specific import data, no releases will be reported for this Toolkit sub-category.

9.4.11 Tetrachlorophthalic acid (TCPA) and related pigments

TCPA is listed in the Toolkit as a potential source of dioxins but there are no data available on the possible contamination levels. There is no readily available information on the quantities of TCPA-based pigments imported into New Zealand.

9.4.12 Dioxazine dyes and pigments

The dioxazine pigments with the potential for dioxin contamination are CI Pigment Violet 23, and CI Direct Blue 106 and 108. However, the contamination has only been reported for dyes made by a specific chemical process, which was replaced by a 'cleaner' method in the 1990s (United Nations Environment Programme, 2013).

These pigments can be used in a wide range of materials, including plastics, paints, and printing inks, and they are also used in the production of dyes for use on textiles and leather. Only the first of these pigments is listed in the New Zealand Inventory of Chemicals. It is also listed in Schedule 7 to the ACVM Act as being acceptable for use as a seed treatment, provided the total levels of dioxins are no more than 20 µg/kg (note: this refers to total dioxins rather than TEQ). This indicates that the pigment should be essentially dioxin-free and is therefore not one of the highly contaminated forms of the product that are considered in the Toolkit.

9.4.13 Triclosan

Triclosan (5-chloro-2-(2,4-dichlorophenoxy)phenol) is used throughout the world as an antibacterial and antifungal agent in consumer products, including soaps, deodorants, toothpastes, shaving creams, mouth wash, and cleaning supplies. In New Zealand, its use in cosmetics is limited to a concentration of no more than 0.3%, under the *Cosmetics Products Group Standard*, issued under the HSNO Act.

There is no readily available information on the extent of triclosan usage in New Zealand. However, a recent assessment for Australia indicated total annual imports there of between 21 and 31 tonnes per year (NICNAS, 2009). On a simple pro rata basis this would suggest annual imports for New Zealand of between 4 and 6 tonnes per year (based on 2020 population figures of 25.7 million and 5.03 million, respectively).

The UNEP Toolkit indicates that triclosan can have dioxin contamination levels of 3 to 60 µg TEQ/tonne (i.e. 3 to 60 x 10⁻⁶ g TEQ/tonne) when made using current manufacturing technologies. This suggests that the overall contribution to New Zealand releases would be in the range of 0.000011 and 0.000342 g TEQ/year. This would make only a very minor contribution to the total dioxin releases in New Zealand so, given the lack of any specific import data, no releases will be reported for this Toolkit sub-category.

9.5 Other chlorinated and non-chlorinated chemicals

This section of the Toolkit covers dioxin releases from the manufacturing of titanium dioxide (via titanium tetrachloride) and caprolactam, which is a starting material for the manufacture of nylon (United Nations Environment Programme, 2013). Neither of these substances is produced in New Zealand.

9.6 Petroleum production

New Zealand's petroleum refining needs are served by a single refining plant at Marsden Point in Northland. The refining process involves a catalytic reforming unit where naphtha is turned into high octane petrol products, but there is no coking unit at the plant. In 2020 throughput at the refinery was about 30% lower than for 2019 – a direct consequence of the COVID-19 pandemic. Land fuel volumes recovered to near normal levels by the end of the year, but jet fuel volumes remained weak. (Refining NZ, 2022). It should be noted that on 1 April 2022 Refining New Zealand relaunched its business as Channel Infrastructure New Zealand following a decision to cease refining operations at Marsden Point, mothball the plant and become an import only terminal for refined fuels.

Dioxin production during petroleum refining results from the combustion of volatile process gases in flares and complex reactions of hydrocarbons at elevated temperatures on catalytically active surfaces (United Nations Environment Programme, 2013). There can also be releases via wastewater and solid wastes.

For the emissions to air, the UNEP Toolkit assigns an emission factor for flares of 0.25 µg TEQ per TJ of fuel burnt and for the catalytic refining unit an air emission factor of 0.017 µg TEQ per tonne of fuel processed is applicable (1 µg = 10⁻⁶ g, and 1 TJ = 10¹² Joules). In 2020 311 TJ of gas were combusted in the flares (L Gillingham, Channel Infrastructure NZ, pers comm, 2022). This amount was significantly higher than the 259 TJ used in the 2016 Inventory and is the result of plant operation interruptions as a result of COVID lockdowns. The flared gas corresponds to a release to air of 0.000078 g TEQ per annum. Also 787,863 tonnes of oil were passed through the catalytic converter unit (L Gillingham, Channel Infrastructure NZ, pers comm, 2022), resulting in a release to air of 0.0134 g TEQ/annum.

Refinery wastewater treatment is assigned an emission factor of 5 pg TEQ per litre by the Toolkit (1 pg = 10⁻¹² grams). In 2020 a total of 628,800 million cubic metres of wastewater was processed through the plant's wastewater treatment system (L Gillingham, Channel Infrastructure NZ, pers comm, 2022). This gives a release of 0.0031 g TEQ/annum.

For releases in residues, the Toolkit assigns a factor of 14 µg TEQ per tonne of waste generated from the catalytic refining unit. A total of 0.426 tonnes of waste was produced by this unit in 2020 (L Gillingham, Channel Infrastructure NZ, pers comm, 2022), giving a release to residues of 0.0000059 g TEQ/annum.

2012, 2016 and 2020 estimates for releases from petroleum production are shown in Table 9-4. For clarity, the entries in the table have been limited to only the release estimates, rather than showing all of the different types of activity data and related releases factors noted above.

Table 9-4: Dioxin releases from petroleum production

Year	Annual releases (g TEQ/yr)		
	Air	Water	Residues
2012	0.018	0.0078	0.00007
2016	0.019	0.0084	0.000017
2020	0.0135	0.0031	0.0000039

Certainty assessment for 2020

Activity data: High (because they are based on actual production data)

Emission factor: Low (because they are based on the Toolkit default factors)

9.7 Textile (and leather) production

The UNEP Toolkit indicates that dioxins may be found in textile and leather products and production wastes as a result of a number of factors, including:

- the treatment of raw materials with agrichemicals, especially pentachlorophenol,
- the use of dioxin-contaminated dyestuffs (eg, dioxazine dyes)
- the formation of dioxins as unintentional by-products in the production processes.

Pentachlorophenol and the sodium salt of pentachlorophenol were mainly used in New Zealand for timber treatment (see section 9.4.3), but they may have also been used in the textiles and leather industries, mainly as a fungicide or preservative. All uses of pentachlorophenol were deregistered by the Pesticides Board in 1989 and the substance approval under the HSNO Act was formally withdrawn in 2008 (Environmental Risk Management Authority, 2008). In the 2008 Inventory it was noted that the testing of New Zealand pelts and hides intended for export had not shown any detectable levels of pentachlorophenol.

The uses of pentachlorophenol have been either banned or severely restricted in many other countries. For example, the register maintained by the Secretariat of the Rotterdam Convention indicates that the substance has been banned or is no longer approved for use in at least 45 countries and is prohibited from import in a further 42 (Secretariat of the Rotterdam Convention, 2013). Imports and/or uses may still be permitted in other countries, including Australia, and Canada, but with conditions, for example, a residue limit in finished products.

The potential for dioxin contamination from dioxazine dyes was discussed in section 9.4.12. In the previous inventory report it was noted that some of these dyes have been used in the past in the New Zealand leather and textiles industries, but there were no current known uses.

Dioxins are expected to occur in the wastes from textile and leather-processing plants, especially wastewater discharges, but mainly as a result of contaminated inputs from the chemicals noted above (United Nations

Environment Programme, 2013). There is also the potential for dioxin production as unintentional by-products when incineration processes are used for waste disposal. However, incineration is not used in New Zealand.

On the basis of the above information, there is no reason to expect any significant dioxin releases from the processing and manufacture of textiles and leather products within New Zealand. However, there is some potential for them to be present in imported products, especially those sourced from countries where pentachlorophenol or dioxazine dyes are still in use.

In the 2012 inventory report it was estimated that the total annual releases from dioxins present in imported textiles and leather goods would be no more than about 0.036 g TEQ. There is no new information available to suggest that this estimate will have changed significantly since 2012. The practice for the 2012 and 2016 Inventories was not to include this estimate in the inventory results because of the associated very high uncertainties, and the same approach will be adopted here.

9.8 Leather refining

See section 9.7.

9.9 Summary for this category

The 2020 release estimates for the production of chemicals and consumer goods are summarised in Table 9-5, along with the totals for 2012 and 2016.

Table 9-5: Summary of the release estimates for the production of chemicals and consumer goods

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Black liquor combustion	0.0304	-	-	-	-
Pulp & paper sludge disposal	-	-	0.0484	0.121	-
Use of 2,4-D	-	-	-	0.000050	-
Petroleum production	0.0135	0.0031	-	-	0.000039
2012 totals	0.054	0.0078	0.093	0.232	0.00007
2016 totals	0.067	0.0084	0.146	0.366	0.000017
2020 totals	0.0439	0.0031	0.0484	0.121	0.000039

10 Miscellaneous sources

This category covers dioxin releases from the following sub-categories (United Nations Environment Programme, 2013):

- 8a Drying of Biomass
- 8b Crematoria
- 8c Smoke houses
- 8d Dry cleaning
- 8e Tobacco smoking

The dioxin releases from most of these sources are combustion-related, and they mainly arise from the incomplete combustion of the fuels and/or materials being burned. The only exception is dry cleaning where the dioxins arise as a result of incoming contamination on the materials being cleaned.

10.1 Drying of Biomass

This Toolkit category refers to the drying of biomass such as wood chips or animal fodder using direct heating methods, in which the material to be dried is exposed directly to combustion off-gases. The biomass can become contaminated with dioxins if the fuel being used is contaminated with dioxin precursor materials, such as pentachlorophenol. Thus, the category mainly applies to biomass drying using other biomass as the fuel.

The most significant biomass drying operations in New Zealand, by size, take place in the board and fibreboard mills already considered in section 5.2, and the potential releases have already been accounted for under the heat and power generation source category. Other biomass drying in New Zealand (eg, grain drying) is carried out using dryers fired by fossil fuels, especially natural gas, LPG, or diesel. The dioxin releases from these activities have already been accounted for under section 5.

10.2 Crematoria

The Law Commission reported that in 2013 there were 52 crematoria in New Zealand, 15 of which are operated by local authorities with the remainder being run by private providers. (New Zealand Law Commission, 2013)

Annual dioxin release estimates from crematoria are based on the annual numbers of cremations multiplied by the default factor given in the UNEP Toolkit for releases to air. There are no significant releases to land, water, or in products or residues. Annual data obtained from the Department of Internal Affairs (V Millar, pers comm, 2022) show that for 2020 there were 32,712 registered deaths with 22,073 estimated cremations⁵ or 68 % of the total. Applying the UNEP Toolkit factor of 10 µg TEQ per cremation (10×10^{-6} g TEQ/cremation) gives the release estimates shown in Table 10-1, along with the corresponding estimates from the 2012 and 2016 Inventories.

⁵ The cremation/burial split is a little uncertain because the records note the place of disposal rather than the method of disposal.

Table 10-1: Dioxin releases from crematoria

Year	Activity Rate (no of cremations/year)	Release factors (µg TEQ/cremation)	Annual releases (g TEQ/yr)
		Air	Air
2012	19,053	10	0.1905
2016	20,129	10	0.201
2020	22,073	10	0.221

Certainty assessment for 2020

Activity data: Medium (because it is based on national death registration data)

Emission factor: Low (because it is based on the default factor given in the UNEP Toolkit)

10.3 Smokehouses

Smoking is used to add flavour, colour, and aroma to various meats, including pork, beef, poultry, and fish. Several methods are used to produce the smoke, but the most common approach is based on the pyrolysis of wood chips or sawdust. In a typical smoke generator, the wood is placed on a heated metal surface at 350° to 400°C. Another method involves use of the heat generated by constantly rubbing blocks of wood against a blunt metal blade, or vice versa. Liquid smoke, which is a washed and concentrated natural smoke, is also used.

The release factors given in the UNEP Toolkit relate to smoking processes based on wood pyrolysis. No data is available on the amount of fuel used in New Zealand for this purpose and there is also no information on the proportion of smoked meats that are produced in this way. Hence, there is insufficient information to allow any reliable estimates of the releases for this source. However, it can be noted that the 2008 Inventory produced a worst-case estimate, based on total smoked food production, of no more than 0.15 g TEQ per year (Ministry for the Environment, 2011a). This estimate has not been included in any of the subsequent inventory totals because of the associated very high uncertainties.

10.4 Dry cleaning

Dioxins have been detected in the distillation residues from dry cleaning, but this is believed to originate from contaminants already present on the textiles from the use of chemicals such as pentachlorophenol and dioxazine dyes (United Nations Environment Programme, 2013). The dry-cleaning process itself does not generate any dioxins. The UNEP Toolkit recommends release factors of 3000 µg TEQ per tonne of residue for cleaning of textiles with high levels of PCDD/PCDF contamination, and 50 µg TEQ per tonne of residue for 'normal' textiles (1 µg = 10⁻⁶ g). These factors are based on European work published in 1992 and 1993, and it is likely that the current contamination levels in New Zealand will be much lower than those reported, simply because there is now little or no use of the contaminated chemicals.

There is no accurate data available on the quantities of dry-cleaning distillation residues produced in New Zealand. In the 2008 Inventory report it was estimated that the potential releases could be in the order of only 0.007 grams TEQ per year, but this figure was not included in the inventory totals because it was highly uncertain (Ministry for the Environment, 2011a). There is no reason to believe that the current releases would be substantially different from the 2008 estimate.

10.5 Tobacco smoking

National statistics on tobacco consumption are only available up to the end of 2009⁶. Consequently, it is difficult to obtain an accurate estimate of current tobacco consumption. The trendline for the 4-weekly equivalent cigarette sales volume (based on sales data) stands at 61.18 million cigarettes for 16 June 2019, the latest statistical data available (Health Promotion Agency, 2022). Multiplying by 13 this volume of sales equates to an annual consumption of 795.3 million cigarettes.

However, this data applies to legal purchases of tobacco products. It is thought that annual consumption of illicit looseleaf tobacco in 2021 totalled 185.8 tonnes (Scoop, 2021). Assuming that 1 tonne of tobacco is the equivalent of 1 million cigarettes, an extra 185.8 million cigarettes must be added, giving a total annual estimated consumption of 981.1 million cigarettes in 2020.

The UNEP Toolkit default factor of 0.1 pg TEQ per cigarette for releases to air (0.1×10^{-12} g TEQ/cigarette), has been applied to this total as shown in Table 10-2, along with the corresponding estimates from 2012 and 2016.

Table 10-2: Dioxin releases from tobacco smoking

Year	Activity Rate (million cigarettes/year)	Release factors (pg TEQ/cigarette)	Annual releases (g TEQ/yr)
		Air	Air
2012	2769	0.1	0.00028
2016	2132	0.1	0.00021
2020	981.1	0.1	0.000098

Certainty assessment for 2020

Activity data: Medium (because it is based on national statistics)

Emission factor: Low (because it is based on the default factor given in the UNEP Toolkit)

10.6 Summary for this category

The 2012, 2016 and 2020 release estimates for miscellaneous sources are summarised in Table 10-3.

Table 10-3: Summary of the release estimates for miscellaneous sources

Category	2016 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Crematoria	0.221	-	-	-	-
Tobacco smoking	0.000098	-	-	-	-
2012 totals	0.191	-	-	-	-
2016 totals	0.202	-	-	-	-
2020 totals	0.221	-	-	-	-

⁶ Statistics New Zealand stopped publishing these on the basis that the data was commercially sensitive.

11 Disposal and landfill

This category covers dioxin releases from the following sub-categories (United Nations Environment Programme, 2013):

- 9a Landfills, waste dumps and landfill mining
- 9b Sewage/sewage treatment
- 9c Open water dumping
- 9d Composting
- 9e Waste oil disposal

All of the sources in this category should be considered as secondary dioxin sources, in that there are no new dioxins being produced. The dioxins are simply associated with the incoming and outgoing wastes.

11.1 Landfills, waste dumps and landfill mining

According to the UNEP Toolkit this category covers wastes generated at a national level which are landfilled. In 2020 there were 39 significant landfill facilities in New Zealand receiving municipal solid waste (Ministry for the Environment, 2022). These receive treated hazardous waste, industrial waste, commercial waste, household waste, municipal solid waste, construction and demolition waste, managed fill material and clean-fill material. In addition to these there were a number of cleanfills or construction and demolition fills, and farm fills which are used for disposal of household waste and other on-farm waste to land. The latter are not adjudged to be significant sources of dioxins and their activity has not been included in this dioxin release assessment. There is one example of a dedicated hazardous waste landfill in New Zealand which no longer receives wastes (Bell & Wilson, 1988). There are also a small number of private industrial landfills. Industrial wastes containing dioxins have already been accounted for in the other sections of this report dealing with individual processes, and there is no landfill mining done in New Zealand. Consequently, municipal solid waste is the sole focus for this waste category.

New Zealand's waste disposal levy scheme is currently the best means of estimating domestic waste activity. The Waste Minimisation Act was introduced in 2008 with the purpose of encouraging waste minimisation and a decrease in waste disposal. To achieve this aim a levy of \$10 for every tonne of waste arriving at domestic waste landfills was introduced in 2009. Imposition of the levy has resulted in more accurate monitoring of waste quantities disposed.

Waste deposition data is available on the "Waste" site of the Ministry for the Environment's "Facts and Science" web pages (Ministry for the Environment, 2021). This shows that from July 2019 to June 2020 3,352,322 tonnes were recorded, with 3,547,485 tonnes listed for July 2020 to June. Averaging these quantities gives an estimated total quantity of 3,449,904 tonnes of waste for 2020. The Ministry for the Environment comment that there was a slight decrease of waste to class 1 landfills in 2019 and 2020 with the decrease in 2020 likely due to COVID-19. However longer-term trends suggest that the rate of disposal is increasing for many sites around the country. Over time there has been a change in waste composition with inert waste (such as plastics) increasing, food waste decreasing, and wood waste increasing.

The UNEP Toolkit gives three classifications for landfills:

Class 1 applies to landfills where wastes from (Toolkit) source groups 1 to 8 are deposited.

Class 2 applies to landfilling of waste which may contain some hazardous components. A typical situation is where a country has no organised waste management systems.

Class 3 applies to landfilling of non-hazardous wastes.

The greenhouse gas inventory report commented that New Zealand has insufficient data to determine how much of the waste disposed to municipal landfills comes from industrial sources (Ministry for the Environment, 2022). However current New Zealand landfill practice does involve waste assessment and would reject for disposal any industrial wastes which were known to contain significant quantities of dioxins. Landfills in New Zealand are engineered facilities where the wastes deposited are contained by impermeable liners and water ingress prevented by capping materials. Consequently, the Toolkit class 3 category is considered appropriate for all waste currently being deposited in landfills.

With regard to releases to water, the situation is more complicated. The leachate produced by a landfill is not solely associated with the waste currently being deposited. It may originate, or come in contact with waste from earlier periods, which may have had higher concentrations of dioxins. Class 2 emission factors are seen as more appropriate for New Zealand landfill leachate.

The estimates for dioxin releases from landfilling for 2020 are shown in Table 11-1, along with the corresponding estimates made in the 2012 and 2016 Inventories.

Table 11-1: Dioxin releases from landfills, waste dumps and landfill mining

Year	Activity Rate	Release factors		Annual releases (g TEQ/yr)	
		Water (µg TEQ/m ³)	Land (µg TEQ/tonne)	Water	Land
2012	2,514,182	0.5	-	1.257	-
		-	5	-	12.57
2016	3,406,031	0.5	-	1.703	-
		-	5	-	17.03
2020	3,449,904	0.5	-	1.725	-
		-	5	-	17.25

Certainty assessment for 2020

Activity data: High (because it is based on the national waste levy data)

Emission factors: Low (because they are based on the Toolkit default factors)

11.2 Sewage/sewage treatment

The Ministry for the Environment commissioned a major review of the wastewater sector in New Zealand in 2020 (Beca, GHD and Boffa Miskell, 2020). The report indicated that there were 318 active municipal wastewater treatment plants in New Zealand servicing 79% of the population. Many of these will have full secondary treatment and produce digested dewatered sludge. The remaining 21%, who live largely in rural areas, must treat their own household wastewater flows using an on-site wastewater management system (OWMS) such as a septic tank. An OWMS typically discharges treated wastewater effluent to land on the property via a drainage field. In addition, septic tanks are recommended to have accumulated sludge removed at least every three years (Auckland Council, 2022).

The total volume of wastewater produced annually in New Zealand will be the sum of wastewater treated in wastewater treatment plants per annum and the volume of water discharged from OWMS annually.

Water New Zealand collate information on the volumes of liquid waste treated through New Zealand wastewater plants and this data is presented in a publicly available spreadsheet: “2020-2021 Combined WWTP Data.xlsx” (Water New Zealand, 2022). Averaging data for 2019-2020 and 2020-2021 from the spreadsheet gives a total estimated volume of 497,162,000 m³/year handled by New Zealand wastewater treatment plants in 2020.

Similar records are not kept for OWMS. For the purposes of this inventory people using OWMS are assumed to discharge wastewater at the same rate as individuals who are connected to a wastewater treatment plant. In June 2020 New Zealand’s estimated population was 5,025,000 (Stats NZ, 2020) so the 21% of individuals not connected to a treatment plant number 1,055,250. Consequently, OWMS are estimated to have discharged 132,117,300 m³/year and therefore New Zealand’s total wastewater production for 2020 was 629,279,000 m³.

Total dewatered sludge production for all WWTPs (wastewater treatment plants) in the 2012 and 2016 Inventories was estimated at 320,000 and 343,120 tonnes per annum, respectively. These figures were derived from the assumption of a per capita biological oxygen demand (BOD) of between 70 and 90 g per person per day (Walmsley, 2012) and were therefore not quantitative measurements of sludge produced.

Water New Zealand now record details of wastewater treatment plants’ annual sludge production in their database, where plants submit this data (Water New Zealand, 2022). The percentage of wastewater solids present in the sludge is a parameter which is also recorded. This allows amounts of sludge generated to be calculated on a dry basis to allow compatibility with emission factors.

Because sludge quantities in the Water New Zealand database are incomplete, for the 2020 Inventory an alternative strategy of using a high volume well characterised treatment plant as being representative of the country as a whole was adopted. In this case Mangere Wastewater Treatment Plant was chosen. For 2019-2020 the Water NZ database lists Mangere’s sludge production as 118,000 tonnes per annum at a wastewater solids content 19% and with the treatment plant’s population coverage as 997,242. However, it was possible to obtain sludge data for the 2020 calendar year directly from the treatment plant which was 135,295 tonnes per annum at 20.6% wastewater solids (Y. Sun, Watercare Services Ltd, pers comm, 2022).

Applying these numbers to New Zealand’s population of 5,025,000 in 2020 allows a national annual sewage sludge production of 140,439 tonnes to be estimated.

With regard to the Toolkit emission factors, Class 2 – “urban and industrial inputs” and class 3 – “domestic inputs” are appropriate for New Zealand. For the 2012 and 2016 Inventories it was decided that the distinction between the two classes should be on the basis of whether or not the wastewater is reticulated, and that Class 2 should be used for all WWTP releases and Class 3 for septic tank releases. It was also decided that all WWTP releases to water be classified as “sludge removed”. This approach has been continued here. For Class 2 discharges of treated wastewater from a WWTP to water involving sludge removal, the emission factor is 0.2 pg TEQ/litre (0.2 x 10⁻¹² g TEQ/litre). For Class 3 discharges of wastewater, the emission factor is 0.04 pg TEQ/litre (0.04 x 10⁻¹² g TEQ/litre). For Class 2 releases of sludge, the emission factor is 20µg TEQ/tonne dried sludge (20 x 10⁻⁶ g TEQ/tonne of sludge).

2020 release estimates are shown in Table 11-2, along with the corresponding estimates made in the 2012 and 2016 Inventories. It should be noted that the 2012 and 2016 values have undergone a back calculation which is explained more fully below.

Table 11-2: Dioxin releases from sewage/sewage treatment

Year	Class	Activity Rates		Release factors		Annual releases	
		Water (10 ⁹ litres/yr)	Residue (tonnes/yr)	Water (pg TEQ/litre)	Residue (µg TEQ/tonne)	Water (g TEQ/yr)	Residue (g TEQ/yr)
2012	Class 2	657		0.2		0.131	
			121,620		20		2.432
	Class 3	54.6		0.04		0.0022	
	Total releases						0.1332
2016	Class 2	447.7		0.2		0.090	
			130,047		20		2.601
	Class 3	107.3		0.04		0.0043	
	Total releases						0.0943
2020	Class 2	497.2		0.2		0.0994	
			140,439		20		2.809
	Class 3	132.1		0.04		0.00528	
	Total releases						0.105

Back calculation for 2012 and 2016 Residues

The residue (sewage sludge) activities for 2012 and 2016 have undergone a back calculation to correct anomalies associated with the previous method of estimating sludge production. It is now realised that dewatered sludge can contain significant amounts of moisture and is therefore different from dry sludge. This will have led to an over estimation of dioxin releases for residues for 2012 and 2016. In addition, previous estimates were based on theoretical sludge production rather than actual quantities. Although the current estimate is based on sludge output from a single wastewater treatment plant, the sludge is well characterised and is representative of 20% of the population.

The procedure adopted for back calculation is to use 2020 sludge values and apply a correction factor which is the ratio of national population at the time divided by national population in 2020.

Certainty assessment for 2020

Activity data: Medium (because they are based on national estimates, rather than complete data)

Emission factor: Low (because they are based on the Toolkit default factors).

11.3 Open water dumping

This Toolkit source category refers to the practice of discharging untreated wastewater or other liquid wastes directly into surface waters, such as streams, rivers, lakes, or the sea. It was not considered for inclusion in the report on the 2008 Inventory, mainly because of the unavailability of any relevant data.

New Zealand has 425,000 kilometres of rivers and streams, almost 4,000 lakes that are larger than 1 hectare, and about 200 aquifers (Ministry for the Environment, 2008a). Water quality is generally poorest in rivers and streams in urban and farmed catchments and in coastal areas adjacent to urban centres. This reflects the impact of non-point-sources of pollution, such as urban stormwater, animal effluent, or fertiliser run-off. Urban stormwater is the most likely of these to be contaminated with dioxins. However, it would be almost impossible to determine stormwater volumes on a national basis, or their likely contamination levels, with any reasonable degree of accuracy. In addition, the most significant dioxin contributions should have already been accounted for under other environmental compartments, especially air and land. Similarly, the most significant point source discharges should have already been accounted for under other source sub-categories (eg, WWTP effluents).

Waste discharges within New Zealand's exclusive economic zone are controlled by Maritime New Zealand, in accordance with standards derived from the 1996 Protocol to the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (Maritime New Zealand, 2001). Permits may be issued for the disposal at sea of a variety of solid and liquid wastes, provided it can be shown that any adverse effects will be avoided, remedied, or mitigated. There is some national data available on the quantities of these wastes, but the dioxin contamination levels are unknown. This therefore precludes any estimates of the likely dioxin discharges.

11.4 Composting

The Toolkit category mainly relates to compost made from the organic fraction of municipal solid wastes, whereas most New Zealand compost is made from green waste which should have little or no dioxin contamination.

11.5 Waste oil disposal

The UNEP Toolkit refers to this source sub-category as Waste Oil Treatment (non-thermal) but provides no release factors because of the highly variable nature of the possible treatment processes and the lack of any reliable release data. It also notes that no new dioxins are created in the treatment processes. The dioxins are simply present as contaminants introduced via previous uses of the oil (United Nations Environment Programme, 2013). There are several waste oil processors in New Zealand, and any potential discharges from their operations are subject to controls in resource consents issued under the *Resource Management Act 1991*. The consents are mainly targeted at minimising oil releases, rather than dioxins. However, it would be reasonable to assume that any dioxin releases will also be minimised if the oil discharges are properly controlled. No data has been found that would allow for any specific estimates of the releases from this source.

11.6 Summary for this category

The 2020 release estimates for the waste disposal and landfill sources are summarised in Table 11-3, along with the totals for 2012 and 2016.

Table 11-3: Summary of the release estimates for the disposal and landfill category

Category	2020 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Landfills, waste dumps and landfill mining	-	1.7250	17.250	-	-
Sewage/sewage treatment	-	0.105	-	-	2.809
2012 totals	-	1.391	12.57	-	2.432
2016 totals	-	1.797	17.03	-	2.601
2020 totals		1.83	17.250		2.809

12 Contaminated sites and hotspots

This section of the UNEP Toolkit does not generate any data for inclusion in the national inventory. Rather, it is simply intended to provide ‘an indicative list of activities that might have resulted in the contamination of soils and sediments with PCDD/PCDF and other unintentional POPs, including related deposits’ (United Nations Environment Programme, 2013). No significant new work has been undertaken in the preparation of this section, which simply provides an update of the information given in section 28 of the previous inventory report for the following sources:

- the manufacture of phenoxy herbicides
- the use of the herbicide 2,4,5-T
- timber treatment using pentachlorophenol
- gasworks
- landfills.

12.1 Pesticide manufacture

This sub-section is concerned with the dioxins present in a reservoir associated with the historical manufacture of phenoxy herbicides. The Waireka Secure Containment Facility, in the Taranaki region, was constructed in 1985 and contains waste from earlier manufacturing of phenoxy herbicides, including 2,4-D and 2,4,5-T. The accumulated wastes were deposited in 1985 and the landfill was closed. The facility is a secure landfill, fully lined and capped, with leak detection wells that are routinely monitored. Any leachate collected from within the landfill is disposed of in the incinerator described in section 3.2 of this report.

Although dioxins are known to be present in the Waireka facility, insufficient data is available to enable an accurate estimate of the quantity present.

12.2 Historical use of 2,4,5-T

The herbicide 2,4,5-T was manufactured in New Zealand from 1948 to 1987 and was widely used for the control of gorse, blackberry, and other woody weeds. The manufacturing process involved the initial formation of 2,4,5-trichlorophenol from 1,2,4,5-tetrachlorobenzene, and dioxins, primarily 2,3,7,8-TCDD, were formed as a by-product of this reaction.

The total quantity of 2,4,5-T manufactured was estimated in the 2000 Inventory at 11,640 tonnes, with about 15% of this being exported (Ministry for the Environment, 2000). The levels of TCDD in the final product varied greatly, depending on the manufacturing conditions and purification efficiency. From 1973 the level of TCDD was restricted by requirements imposed by the Agricultural Chemicals Board. On the basis of the total production figures and the known residue concentrations, it was estimated that the total quantity of TCDD distributed over the land surface of New Zealand, throughout the entire period of manufacture and use, was between 2.71 and 3.38 kg TEQ.

The size of the reservoir from 2,4,5-T usage was estimated in the previous inventory reports by making an allowance for TCDD degradation over time, using a half-life of 15 years. Thus, for 1998 the residual amount of TCDD was estimated to have dropped to a level of 620 to 860 g TEQ, by 2008: 390 to 540 g TEQ by 2012: 324 to 437 g TEQ and by 2016: 270-374 g TEQ (calculated using a factor of $A = A_0 \cdot 1/2^{t/h}$, where A = amount remaining, A_0 = original amount, t = time elapsed(years) and h = half-life (years)). Using the same methodology, the 2020 quantity of TCDD remaining in soil as a result of the past use of 2,4,5-T is estimated to be 225 - 311 g TEQ.

12.3 Historical use of pentachlorophenol for timber treatment

The primary use of pentachlorophenol (PCP) in New Zealand was in the timber industry, either as the sodium salt (NaPCP), for use as an antisapstain treatment, or as a preservative mixed with diesel oil. The use of PCP in the timber industry commenced in the mid- to late-1950s and voluntarily ceased in 1988, and the chemical was deregistered for all uses by the Pesticides Board in 1991. The total amount of PCP imported into New Zealand for use in the timber industry is believed to be about 6000 tonnes (Ministry for the Environment, 2011a), and the total input of dioxins into the New Zealand environment was estimated to be 9.9 kg TEQ.

The concentrations of dioxins in the antisapstain formulations marketed in NZ were believed to be in the range 0.2 –1.85 g TEQ per tonne, with a mean of 0.9 g TEQ per tonne. Investigations at some of the timber treatment sites have been used to produce an estimate of the total dioxin contamination resulting from antisapstain use (Ministry for the Environment, 2011a), and in 2008 the residual amount remaining was estimated to be 0.81 kg TEQ. This estimate was based on site assessments completed in 2002, and some of the sites have since been remediated. However, there have been no specific treatments aimed at removing the dioxin contaminants. In addition, much of the remediation work is based simply on soil removal and replacement. Hence, the quantities of dioxins in the reservoirs are unlikely to have changed, but they may have been moved to other locations.

The use of PCP as a preservative in diesel oil was only undertaken at four sites in New Zealand, although only two of these are believed to be of any significance: the Waipa Mill near Rotorua and a plant at Hanmer Springs in Canterbury. The total usage of PCP was estimated to be approximately 2700 tonnes and the average contamination level of the PCP was believed to be 1.65 g TEQ per tonne, which gives a total dioxin input of 4.5 kg TEQ. As reported in the previous inventory, it was estimated that 0.23 kg TEQ of this total would have contributed to soil contamination at the sawmill sites, and the remaining 4.27 kg TEQ was absorbed in the treated products and distributed more widely. It is not expected that these reservoirs will substantially change over time, unless specific action is taken to destroy the dioxin contamination prior to the disposal of waste materials.

12.4 Gasworks sites

Prior to the introduction of natural gas in New Zealand, ‘town gas’ was produced by coal gasification plants at gasworks sites throughout the country. There were approximately 54 gasworks sites, which operated for varying periods from the mid-1800s through to 1988. Internationally, dioxins have not been recognised as a priority contaminant of gasworks waste. However, New Zealand studies have found that some dioxins may be present in the wastes produced from coal gasification and can be found at some of the sites where gasworks were previously located (Ministry for the Environment, 2011a).

In the first dioxin inventory report it was noted that at least five of the 54 gasworks sites had been remediated, and the reservoir estimates for the remaining 49 sites were reported to be between 0.028 and 6.4 g TEQ (Ministry for the Environment, 2000). The second inventory reported that a further 10 sites had been remediated and the 2008 dioxin reservoir was estimated at 0.022 to 5.2 g TEQ. No reports have been found of any more recent remediation work, so the 2008 estimate should still apply for 2020.

12.5 Landfills

Solid waste landfills also represent a reservoir of dioxins. In the 2016 Inventory it was estimated that the total mass of waste stored in landfills in 2016 was 132 million tonnes, and the associated dioxin reservoir would be 0.79 kg TEQ (based on a Toolkit factor of 6×10^{-6} g TEQ per tonne). In the following 4 years, the quantity of waste will have increased by about 14 million tonnes to 146 million tonnes (see section 11.1). Thus, the existing reservoir in 2020 will be 0.88 kg TEQ.

13 Summary and discussion

The key points arising from the 2020 inventory are summarised and discussed below, along with some comparative data from the previous inventories for 2012 and 2016. A table showing the complete data for all source categories and release vectors for 2012, 2016 and 2020 is given in Appendix 1.

13.1 Dioxin Release Estimates for 2020

The total estimated quantity of dioxin released in New Zealand for 2020 was 36.6 g TEQ. A plot of dioxin release estimates versus source category for 2020 is shown in Figure 13-2. Viewing the plot, it is apparent that most dioxin emissions can be attributed to a relatively small number of categories and that many categories make only a very minor contribution to the total. Figure 13-1 illustrates the share that major source categories have for the total dioxin release. It shows that about 60% of New Zealand's estimated dioxin releases can be attributed to two categories – disposal of municipal waste in landfills and sewage treatment. Combined with seven other categories: secondary aluminium processing, industrial wood combustion, industrial coal combustion, structure fires, metal shredding, landfill fires, heating and cooking with wood and structure fires, the nine sources comprise 87 % of total dioxin releases with the remaining 13% split between about 40 other categories and sub-categories.

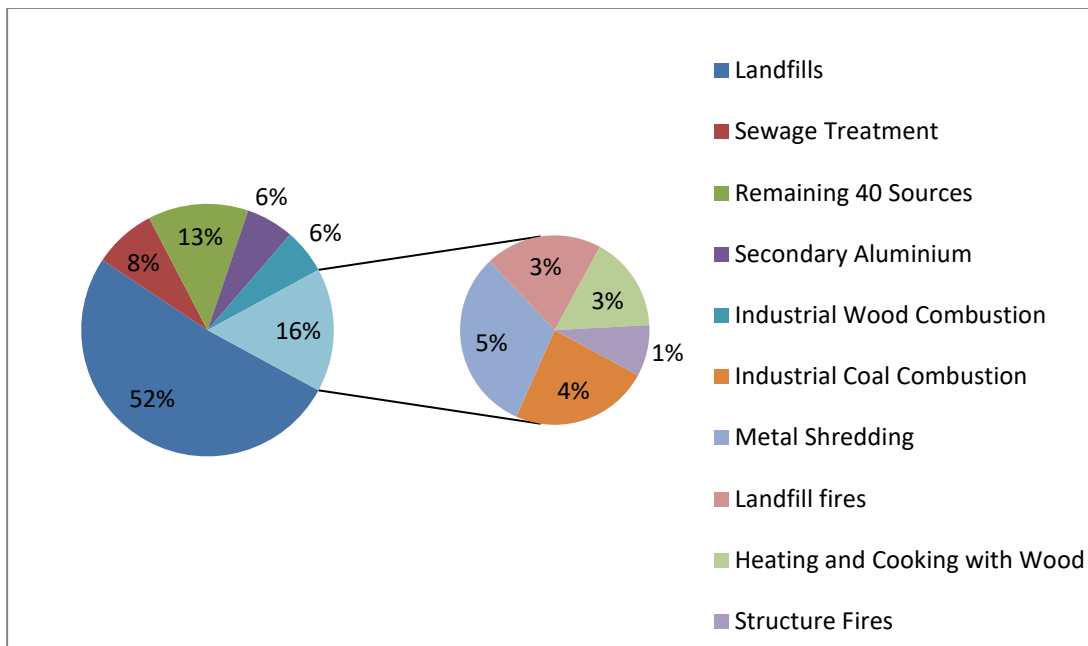


Figure 13.1. Plot Showing the Contribution of Major Release Categories for Dioxin

(* The sum of all categories may not total exactly 100.0% due to rounding effects)

All members of New Zealand's 5.025 million population contributed to the sewage treatment release in 2020 and a significant majority will have generated wastes disposed of in municipal solid waste landfills. Releases from industrial coal and biomass combustion (the latter largely wood-waste) are associated with about 500 coal-fired boilers and more than 175 biomass-fired power plants. Structure fires are essentially random events. Heating and cooking with wood, primarily the former, occurs in about 530,000 New Zealand households.

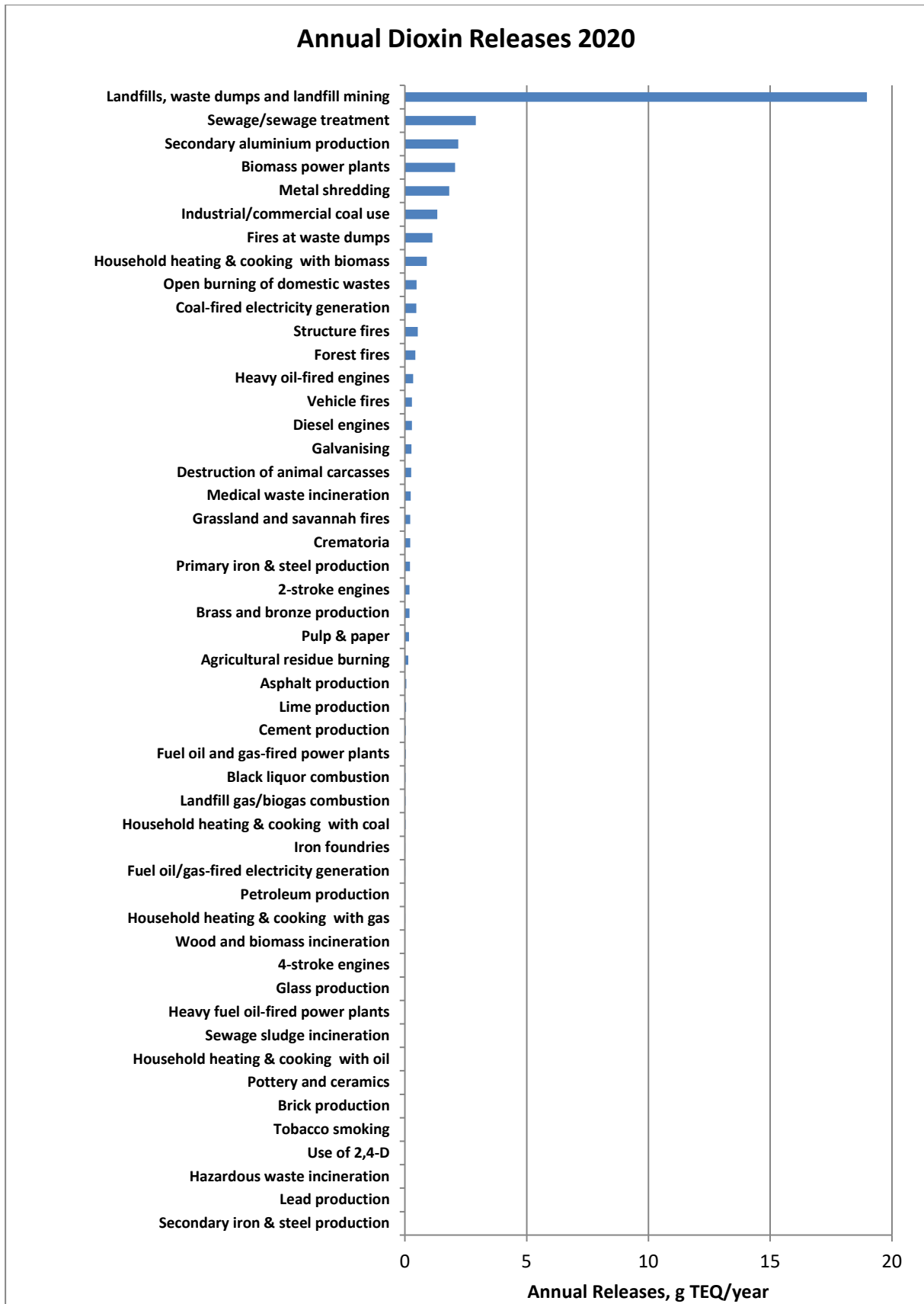


Figure 13.2. Annual Dioxin Releases for 2020 by Source (see Appendix 2 for details)

13.2 Changes in the dioxin release estimates over time

The dioxin release estimates for 2012 and 2016 and 2020 are summarised in Table 13-1 below. This summary is based on nine of the Toolkit major source categories, which is the summary level used for country reports under the Stockholm Convention. As shown in the Table the total release of dioxin in New Zealand for 2020 was 36.60 g TEQ. This can be compared with releases of 36.99 g TEQ in 2012 and 37.10 g TEQ in 2016.

Table 13-1: Summary of the release estimates for 2012, 2016 and 2020

Major Source Categories		Annual Releases (g TEQ/a)											
		Air			Water			Land			Residue		
		2012	2016	2020	2012	2016	2020	2012	2016	2020	2012	2016	2020
1	Waste Incineration	0.79	0.37	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.010
2	Ferrous and Non-Ferrous Metal Production	0.40	0.26	0.20	0.01	0.02	0.02	0.21	0.27	0.09	9.71	5.54	4.37
3	Heat and Power Generation	3.33	3.24	3.72	0.00	0.00	0.00	0.41	0.07	0.27	0.75	0.79	0.91
4	Production of Mineral Products	0.07	0.08	0.07	0.00	0.00	0.00	0.18	0.06	0.04	0.03	0.04	0.05
5	Transportation	0.66	0.67	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Uncontrolled Combustion	2.44	2.60	2.75	0.00	0.00	0.00	0.78	0.86	0.48	0.00	0.00	0.00
7	Production of Chemicals and Consumer Goods	0.05	0.07	0.044	0.01	0.01	0.00	0.09	0.15	0.048	0.00	0.00	0.00
8	Miscellaneous	0.19	0.20	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Waste Treatment	0.00	0.00	0.00	1.39	1.80	1.83	12.57	17.03	17.25	2.43	2.60	2.81
Totals		7.94	7.47	8.32	1.41	1.82	1.85	14.24	18.44	18.17	12.97	9.00	8.14
Totals* for all release vectors		2012			2016			2020					
		36.99			37.10			36.60					

(* The sums of the figures in some columns may not agree exactly with the totals shown, due to rounding effects)

The estimates for releases in products have not been shown in the table because the only significant release is in the Production of Chemicals and Consumer Goods category with a total annual release of 0.121 g TEQ for 2020.

Tables 13-2 and 13-3 show source categories which for 2020 had increases or decreases in their dioxin releases greater than 0.01 g compared with 2016 levels.

Table 13-2: Categories which had increases in release estimates for 2020 compared with 2016

Source Category	Change in Dioxin Release (g TEQ/annum)
Industrial biomass (wood waste) combustion	+0.76
Landfill fires	+0.75
Metal shredding	+0.52
Coal-fired electricity generation	+0.35
Landfills, waste dumps and landfill mining	+0.27
Sewage/sewage treatment	+0.22
Forest fires	+0.20
2-stroke engines	+0.17
Pet cremators	+0.14
Vehicle fires	+0.046
Crematoria	+0.020

Compared with 2016 levels, releases from combustion of wood waste in industrial boilers have increased due to improvements in consumption estimates.

Landfill fires, forest fires and vehicle fires are unpredictable events which will fluctuate from year to year.

Metal shredding releases have increased due to an increase in shredder operators and material throughput.

Releases from coal-fired electricity generation have increased because more coal was burned to cover hydro electricity shortages and maintenance of the Cook Strait cable in 2020.

Increased releases from landfill deposition, sewage treatment and crematoria can be attributed to population increase.

Pet cremator increases can be attributed to improvements in throughput estimation following a regional council survey.

Releases from 2-stroke engines are greater following increased fuel consumption estimates in the recreational marine sector.

Increased releases from diesel engines result from increased diesel consumption which may be related to heavy fuel oil replacement by diesel in the marine transport industry.

Table 13-3: Categories which had decreases in release estimates for 2020 compared to 2016

Source Category	Change in Dioxin Release (g TEQ/annum)
Secondary aluminium production	-1.48
Structure Fires	-0.87
Open burning of domestic wastes	-0.35
Pulp & paper production	-0.34
Industrial/commercial coal use	-0.23
Primary iron & steel production	-0.18
Brass and bronze production	-0.15
Iron foundries	-0.12
Household heating & cooking with biomass (wood)	-0.069
Heavy oil-fired engines	-0.034
Wood and biomass incineration (school incinerators)	-0.033
Lime production	-0.029
Black liquor combustion	-0.018
Agricultural residue burning	-0.014
Petroleum production	-0.011

Plant closures and / or decreases in production quantities were the cause of the release reductions for secondary aluminium, copper brass and bronze production and iron foundries.

Structure fires are unpredictable events which will fluctuate from year to year.

Releases from open burning of domestic wastes have reduced due to a decrease in the estimate of the amount of waste burnt following a regional council survey.

Pulp and paper sludge disposal releases have decreased due to a reduction in bleached pulp production.

Decreases in releases from industrial and commercial coal use are due to drops in coal consumption caused by COVID lock downs in 2020.

Releases from primary iron and steel production have decreased because a greater proportion of waste materials are being recycled through the process.

Reductions for household heating and cooking with biomass (wood) reflect a decrease in the number of wood burners.

Heavy oil-fired engine release reductions follow a drop in fuel consumption of this type by the marine transport industry which may be related to international controls on sulphur emission levels.

Fewer schools operating incinerators is the reason for the release drop in the wood and biomass incineration category.

Lime production release reductions reflect a downward trend in lime production.

The extent of agricultural residue burning fluctuates from year to year.

Black liquor combustion release reductions are due to reduced kraft pulp production in 2020.

Petroleum production releases have reduced because throughput of crude oil at the Marsden Point refinery reduced as COVID travel restrictions impacted fuel consumption, particularly in the aviation industry, in 2020.

Trends in Dioxin Releases

Figures 13.3 and 13.4 display plots of dioxin releases versus source category for 2012, 2016 and 2020. The sources have been categorised as major and minor to make the lesser sources more visible.

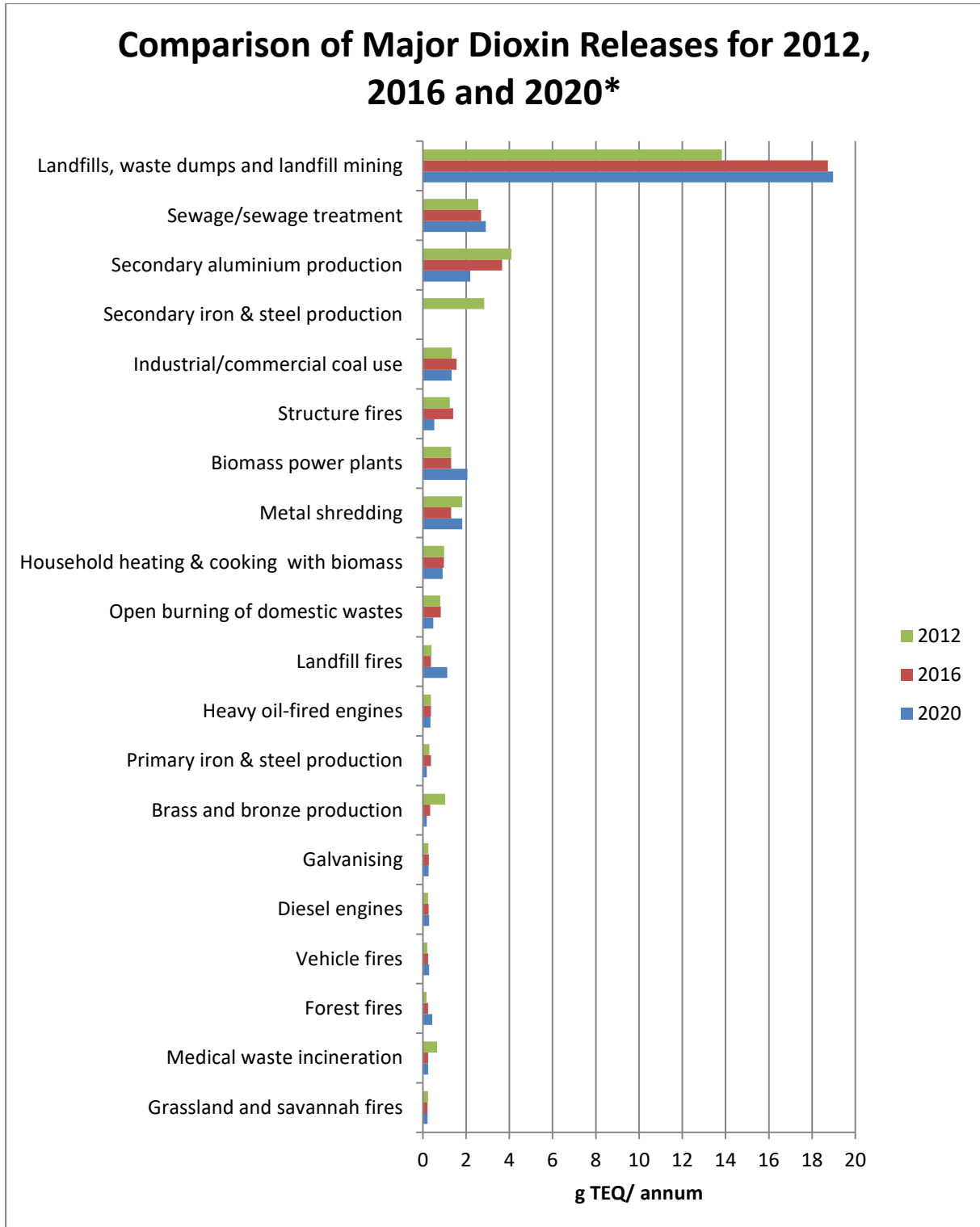


Figure 13.3 Major Sources’ Dioxin Releases for 2012, 2016 and 2020 (see Appendix 2 for details)

(* NZ’s sole secondary iron and steel plant closed in 2015 so there is no data for 2016 and 2020)

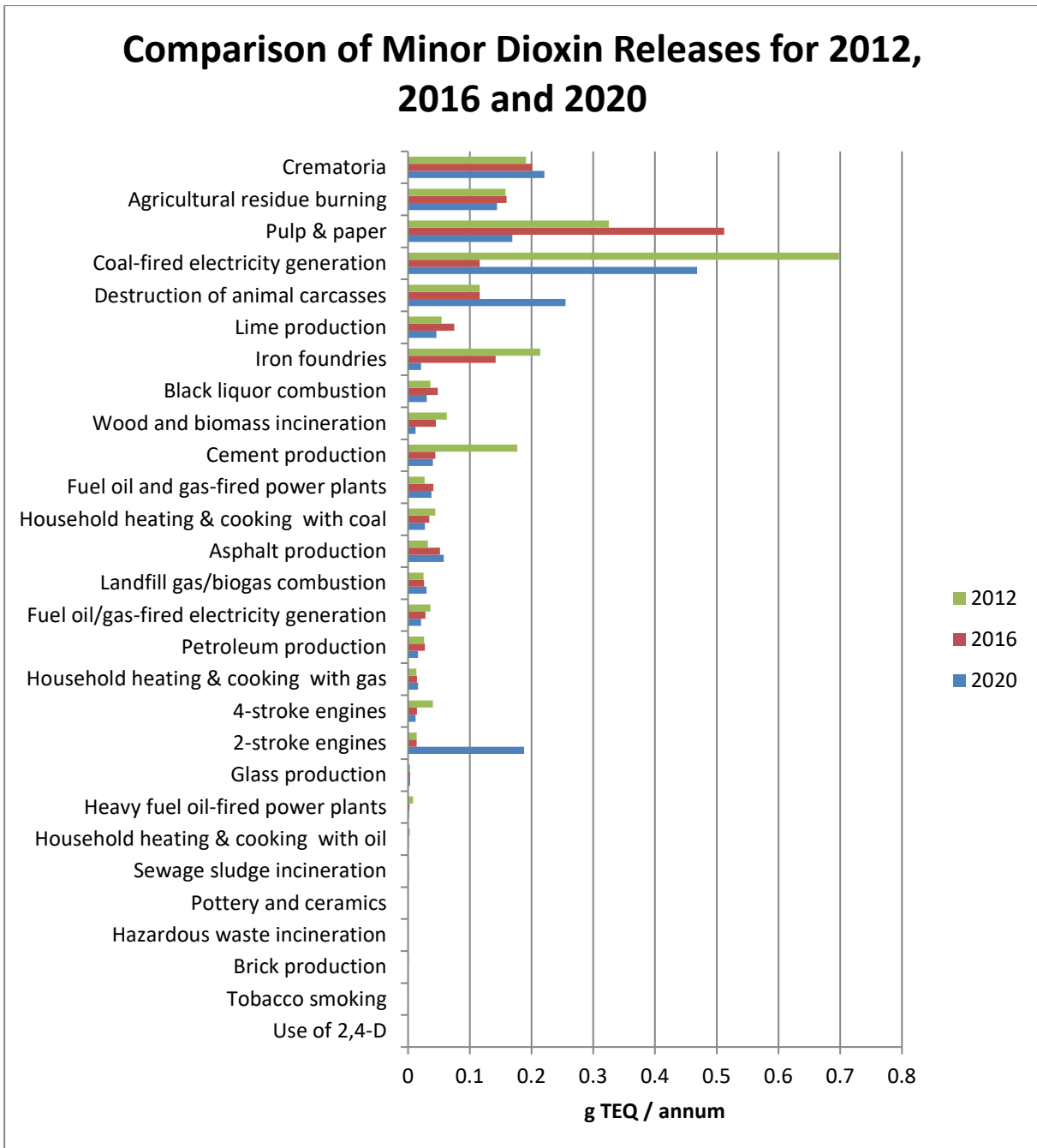


Figure 13.4 Minor Sources' Dioxin Releases for 2012, 2016 and 2020 (see Appendix 2 for details).

Figures E3 and E4 show an increasing trend of dioxin release for landfill deposition, although the rate of change is declining. In contrast a decreasing trend is evident for secondary metal activities such as secondary aluminium and steel production, iron foundries and brass and bronze production largely due to plant closures.

Sewage treatment and crematoria show a trend of increasing dioxin releases as their activities are based on population numbers. Asphalt production also shows an increasing trend reflecting the fact that major new roads continue to be built while existing roads require maintenance.

Household heating and cooking with biomass (wood) and coal both show a gradual decline in dioxin releases as burners and stoves are slowly replaced with devices requiring alternative forms of energy such as electricity.

13.3 New Zealand Initiatives Leading to Reductions in Dioxin Releases

Waste Reduction Strategies

As shown in Figures 13.1 and 13.2 landfills are by far the greatest source of dioxins for New Zealand. Because the types of waste deposited in municipal landfills are so diverse only a very general emission factor can be applied to estimate dioxin releases from this source. Where the waste total is comprised of significant volumes of inert materials such as food wastes, clean fill, and garden waste it is probable that the dioxin release is being over-estimated and reducing their volume will result in a reduction in the dioxin estimation for landfills.

There are currently a number of government initiatives which are aimed at reducing waste volumes (Ministry for the Environment, 2021b). New legislation is in train which will replace the current Waste Minimisation Act and Litter Act and will place greater emphasis on a circular economy where resources are kept at their highest value use for as long as possible. From 1 July 2022 the Waste Levy was significantly increased and expanded with charges for municipal landfills increasing from \$20 to \$30 per tonne. These charges will increase further to \$50 per tonne in 2023 and \$60 per tonne in 2024. Other initiatives include an investment of \$124 million in resource recovery infrastructure, continuing investment in the Waste Minimisation Fund and introducing regulated product stewardship for six waste streams including plastic packaging and tyres. In addition, the government is considering recommendations to incentivise councils to implement kerbside collection of food waste and standardise the materials collected in kerbside recycling nationally (Ministry for the Environment, 2021b).

Changes in Production Focus

Oji Fibre Solutions closed its bleaching operations at its Tasman Mill in March 2019 to allow the company to produce more fibre cement pulp and other unbleached kraft pulp products (Climate Leaders Coalition, 2022). As discussed in Section 9.1, pulp bleaching is a source of dioxins, and this contribution is now be removed from the plant's output.

On 1 April 2022 Refining New Zealand ceased refining operations at the country's only oil refinery and became an import only terminal for refined fuels. This move will remove sources of dioxin release such as the combustion of volatile process gases in flares, wastewater, and solid wastes.

13.4 Global Perspective

A review of the current state and main sources of dioxins around the world was conducted in 2015 (Dopico & Gomez, 2015). The annual global dioxin production for 2015 was estimated at approximately 287 kg TEQ. About 57% of this quantity was deposited in land areas of the globe and 40% in the oceans with the remaining 3% in the air. Industrialised countries in North America, Europe and South and East Asia were considered the biggest producers of dioxins. The authors commented that for many industrialised countries, following peak dioxin emissions in the 1970s and 80s, emissions decreased after the implementation of policies of flue gas treatment, social awareness campaigns and application of strict legislative emission controls. On the other hand, in countries where non-industrial sources have been traditionally high contributors, emissions have remained more or less constant because it is more difficult to control this type of process.

It is possible to estimate a global per capita release of 38.7 g TEQ per million people per year based on the world's dioxin release of 287 kg TEQ and its 2016 population of 7.42 billion (Population Reference Bureau, 2016).

A predictive global dioxin release model was developed by Wang and co-authors (Wang et al, 2016). This used markers of human social economic activities including gross national income and per capita national income, carbon dioxide emissions per unit GDP combined with land area to estimate releases for individual nations. The total dioxin release for 189 countries was estimated to be 100.4 kg TEQ per year with the authors giving a global per capita average release of 15.4 g TEQ per million people per year.

In comparison New Zealand’s 2020 release of 36.6 g TEQ combined with a population of 5.025 million gives a per capita value of 7.3 g TEQ per million people. The values for 2012 and 2016 were 8.4 and 7.9 g TEQ per million people, respectively.

Other countries of similar population size and economic status had the following per capita values (g TEQ per million people): Cyprus 7.6, Hungary 11.8, and Portugal 6.7 (Saral, Gunes and Demir, 2014)

13.5 Other New Zealand Studies

There are no official recommendations for ‘acceptable’ levels of national dioxin releases, and it is also not possible to relate the release estimates to any potential health effects. The more relevant information is provided by national surveys of dioxin body burdens, for which there have been several New Zealand studies.

The levels of dioxins in mothers’ milk have been measured on 3 occasions in New Zealand, 1988, 1998 and 2008 (Mannetje, Douwes, & Duckett, Concentrations of Persistent Organic Pollutants in the Milk of New Zealand Women, 2010). These studies showed that the dioxin concentrations in New Zealand mothers are relatively low by comparison with many other countries. Also, the levels have been steadily dropping, with a reduction of 70% observed from 1988 to 1998, and a further reduction of 40% from 1998 to 2008.

Figure 13-5: Serum dioxin concentrations in New Zealanders, 1997 and 2012

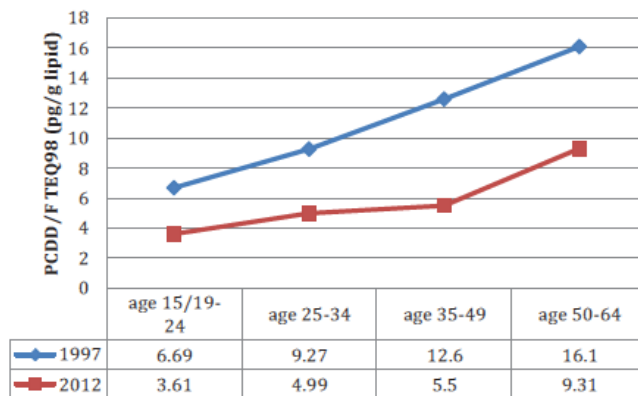


Figure 5.1. Comparison of PCDD/F serum concentrations between 2001 and current POPs studies (PCDD/F TEQ₉₈)

(Reproduced from (Mannetje, Coakley, Bates, Borman, & Douwes, 2013))

The levels of dioxins in blood serum have been monitored on two occasions in New Zealand, in 1997 and 2012 (Mannetje, Coakley, Bates, Borman, & Douwes, 2013). Once again, these studies showed the dioxin concentrations in New Zealanders are relatively low by comparison with many other countries, and the levels have dropped over time. This reduction is illustrated in Figure 13-5 and shows both a reduction from one ‘generation’ to the next (eg, 25–34-year-olds had lower dioxin levels in 2012 compared to 1997) but also a reduction as people get older (eg, 50–64-year-olds have lower dioxin levels in 2012 than in 1997, when they were 35-49 years old).

A recent Japanese study confirms these trends (Muzembo et al, 2019). Here the median blood dioxin level was found to have decreased by 41% when comparing levels from a survey conducted between 2002- 2010 with one conducted between 2011-2016. For the latter survey, the median dioxin blood level was 5.7 pg TEQ/g lipid with 25th and 75th percentile levels of 3.8 and 8.3 pg TEQ/g lipid, respectively. A similar correlation of age and increasing dioxin serum concentrations was observed.

It should be noted the Japanese study used WHO 2005 toxic equivalence factors. To make a direct comparison with the Mannetje study results for 2012 shown above, it is necessary to express them in terms of the same toxic equivalence scheme as they have been calculated with earlier WHO 1998 factors. Using WHO 2005 factors the weighted mean serum concentration for New Zealand in 2012 was 5.81 with the following age distributions: age 19-24: 3.27 pg TEQ/g lipid; age 25-34: 4.47 pg TEQ/g lipid; age 35-49: 4.97 pg TEQ/g lipid and age 50-64: 8.51 pg TEQ/g lipid

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Appendix 1: Summary of release estimates¹

Category	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2012	2016	2020	2012	2016	2020	2012	2016	2020	2012	2016	2020
Hazardous waste incineration	0.000048	0.00033		0.0000055	-	-	-	-	-	0.000053	0.000017	0.0000003
Medical waste incineration	0.657	0.234	0.234	-	-	-	-	-	-	0.0044	0.0016	0.0016
Sewage sludge incineration	0.000097	0.00023	0.00039	-	-	-	-	-	-	0.00085	0.00071	0.00079
Wood and biomass incineration ²	0.021	0.015	0.0039	-	-	-	-	-	-	0.042	0.03	0.0078
Destruction of animal carcasses	0.116	0.116	0.255	-	-	-	-	-	-	-	-	
Primary iron & steel production	0.082	0.078	0.081	0.0143	0.0149	0.0165	0.206	0.274	0.0866	-	-	
Secondary iron & steel production	0.036	0	0	-	-		-	-	-	2.80	0	0
Iron foundries	0.131	0.072	0.011	-	-		-	-	-	0.083	0.07	0.0104
Galvanising	0.0056	0.0073	0.00581	-	-	-	-	-	-	0.245	0.268	0.261
Secondary aluminium production	0.044	0.039	0.023	-	-	-	-	-	-	4.05	3.63	2.17
Lead production	-	0		-	-	-	-	-	-	-	-	
Brass and bronze production	0.042	0.014	0.008	-	-		-	-	-	0.993	0.323	0.178
Metal shredding	0.070	0.05	0.07	-	-	-	-	-	-	1.75	1.25	1.75

Dioxin Inventory Update

Category	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2012	2016	2020	2012	2016	2020	2012	2016	2020	2012	2016	2020
Coal-fired electricity generation	0.291	0.0484	0.195	-	-	-	0.407	0.0678	0.273	-	-	
Industrial/commercial coal use	1.062	1.232	1.053	-	-	--	-	-	-	0.281	0.327	0.279
Heavy fuel oil-fired power plants	0.0083	0.0026	0.0016	-	-	-	-	-	-	-	-	
Fuel oil/gas-fired electricity generation	0.036	0.028	0.0021	-	-	-	-	-	-	-	-	
Fuel oil and gas-fired power plants	0.027	0.041	0.038	-	-	-	-	-	-	-	-	
Biomass power plants	1.000	1.000	1.584	-	-	-	-	-	-	0.300	0.300	0.475
Landfill gas/biogas combustion	0.025	0.028	0.030	-	-	-	-	-	-	-	-	
Household heating & cooking with biomass	0.82	0.812	0.754	-	-	-	-	-	-	0.164	0.162	0.151
Household heating & cooking with coal	0.044	0.034	0.027	-	-	-	-	-	-	0.00023	0.00018	0.00014
Household heating & cooking with oil	0.0029	0.0012	0.0010	-	-	-	-	-	-	-	-	
Household heating & cooking with gas	0.0135	0.0144	0.0162	-	-	-	-	-	-	-	-	
Cement production	0.043	0.044	0.040	-	-	-	0.134	-		-	-	-
Lime production	0.0125	0.0173	0.0107	-	-	-	0.042	0.0576	0.035	-	-	-
Brick production	0.00089	0.0002	0.00022	-	-	-	-	-		-	-	-

Dioxin Inventory Update

Category	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2012	2016	2020	2012	2016	2020	2012	2016	2020	2012	2016	2020
Glass production	0.0035	0.0031	0.0031	-	-	-	-	-		-	-	-
Pottery and ceramics	0.00032	0.00075	0.00079	-	-	-	-	-		-	-	-
Asphalt production	0.006	0.0098	0.011	-	-	-	-	-		0.026	0.042	0.047
4-stroke engines	0.040	0.0142	0.0124	-	-	-	-	-		-	-	-
2-stroke engines	0.014	0.014	0.188	-	-	-	-	-		-	-	-
Diesel engines	0.238	0.266	0.285	-	-	-	-	-		-	-	-
Heavy oil-fired engines	0.368	0.377	0.343	-	-	-	-	-		-	-	-
Agricultural residue burning	0.144	0.145	0.130	-	-	-	0.014	0.0145	0.0130	-	-	-
Forest fires	0.151	0.205	0.380	-	-	-	0.023	0.0307	0.057	-	-	-
Grassland and savannah fires	0.189	0.164	0.171	-	-	-	0.057	0.0493	0.0513	-	-	-
Fires at waste dumps	0.378	0.365	1.094	-	-	-	0.0126	0.0122	0.0364	-	-	-
Structure fires	0.625	0.698	0.262	-	-	-	0.625	0.698	0.262	-	-	-
Open burning of domestic wastes	0.780	0.807	0.466	-	-	-	0.020	0.0202	0.0117	-	-	-
Vehicle fires	0.171	0.209	0.248	-	-	-	0.031	0.038	0.0446	-	-	-
Black liquor combustion	0.036	0.0483	0.0304	-	-	-	-	-	-	-	-	-
Pulp & paper sludge disposal	-	-	-	-	-	-	0.093	0.146	0.048	-	-	-
Use of 2,4-D	-	-	-	-	-	-	-	-	-	-	-	-

Dioxin Inventory Update

Category	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2012	2016	2020	2012	2016	2020	2012	2016	2020	2012	2016	2020
Petroleum production	0.018	0.019	0.0135	0.00775	0.0084	0.0031	-			0.00007	0.000017	0.0000039
Crematoria	0.1905	0.201	0.221	-			-			-	-	
Tobacco smoking	0.00028	0.00021	0.000098	-			-			-	-	
Landfills, waste dumps and landfill mining	-	-		1.257	1.703	1.725	12.57	17.03	17.25	-	-	
Sewage/sewage treatment	-	-		0.134	0.0938	0.105	-			2.432	2.601	2.809
Totals³	7.94	7.47	8.32	1.41	1.82	1.85	14.24	18.44	18.17	12.97	9.00	8.14

Footnotes

- 1 The estimates for releases in products have not been shown in the table because there are only three sources: brick production, bleached kraft pulp production and the use of the herbicide 2,4-D, with a total annual release of 0.121g TEQ for 2020
- 2 This category covers school incinerators.
- 3 The sums of the figures in some columns may not agree exactly with the totals shown due to rounding effects.

Appendix 2: Total dioxin releases

Category	Total Dioxin for 2012 (g TEQ / annum)	Total Dioxin for 2016 (g TEQ / annum)	Total Dioxin for 2020 (g TEQ / annum)
Hazardous waste incineration	0.000101	0.000347	0.000006
Medical waste incineration	0.661	0.236	0.236
Sewage sludge incineration	0.000947	0.000947	0.00117
Wood and biomass incineration	0.063	0.045	0.012
Destruction of animal carcasses	0.116	0.116	0.255
Primary iron & steel production	0.302	0.367	0.185
Secondary iron & steel production	2.836	0	
Iron foundries	0.214	0.142	0.0214
Galvanising	0.2506	0.2753	0.267
Secondary aluminium production	4.094	3.669	2.195
Lead production	0	0	
Brass and bronze production	1.035	0.337	0.185
Metal shredding	1.82	1.30	1.82
Coal-fired electricity generation	0.698	0.116	0.468
Industrial/commercial coal use	1.343	1.559	1.332
Heavy fuel oil-fired power plants	0.0083	0.0026	0.0016
Fuel oil/gas-fired electricity generation	0.036	0.028	0.021
Fuel oil and gas-fired power plants	0.027	0.041	0.038
Biomass power plants	1.300	1.300	2.059
Landfill gas/biogas combustion	0.025	0.026	0.030
Household heating & cooking with biomass	0.984	0.974	0.905
Household heating & cooking with coal	0.0442	0.0342	0.0271
Household heating & cooking with oil	0.0029	0.0012	0.0010
Household heating & cooking with gas	0.0135	0.0144	0.0160
Cement production	0.177	0.044	0.040
Lime production	0.0545	0.0749	0.0460
Brick production	0.0012	0.00026	0.00029
Glass production	0.0035	0.0031	0.0031
Pottery and ceramics	0.00075	0.00075	0.00079
Asphalt production	0.032	0.0518	0.058

4-stroke engines	0.04	0.0142	0.012
2-stroke engines	0.014	0.014	0.188
Diesel engines	0.238	0.266	0.285
Heavy oil-fired engines	0.368	0.377	0.343
Agricultural residue burning	0.158	0.160	0.144
Forest fires	0.174	0.2357	0.437
Grassland and savannah fires	0.246	0.2133	0.222
Fires at waste dumps	0.391	0.377	1.130
Structure fires	1.250	1.396	0.524
Open burning of domestic wastes	0.800	0.8272	0.478
Vehicle fires	0.202	0.247	0.292
Black liquor combustion	0.036	0.048	0.030
Pulp & paper	0.325	0.512	0.169
Use of 2,4-D	0.000034	0.00005	0.00005
Petroleum production	0.0258	0.0274	0.0160
Crematoria	0.1905	0.201	0.221
Tobacco smoking	0.00028	0.00021	0.000098
Landfills, waste dumps and landfill mining	13.827	18.733	18.970
Sewage/sewage treatment	2.432	2.601	2.809