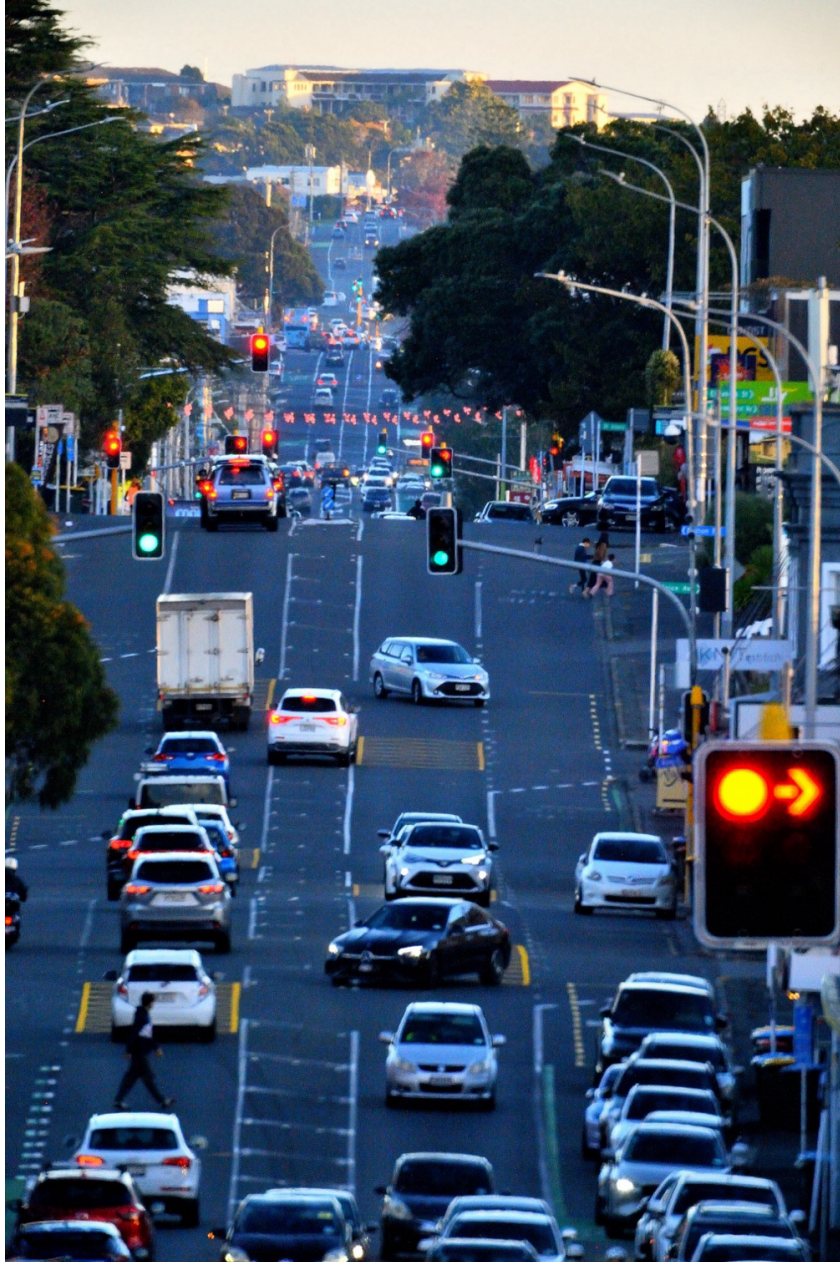


2024 Update of the New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources



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 POPs species, being much studied, with extensive information available on source discharges and environmental distribution. Estimates of releases of dioxin from 49 different source categories in New Zealand have been made for the reference year of 2024 to provide an update for New Zealand's Dioxin Inventory previously published for the reference years of 2008, 2012, 2016 and 2020. 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 2024

The total dioxin release quantity for New Zealand for 2024 has been estimated at 33.7 g TEQ¹. This can be compared with values of 36.6g for 2020, 37.1 g TEQ for 2016 and 37.0 g TEQ for 2012. Figure E-1 on the next page shows how individual sources contributed to this total and Figure E-2 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 E-1. Annual Dioxin Releases for 2024 by Source (see Appendix 2 for details)

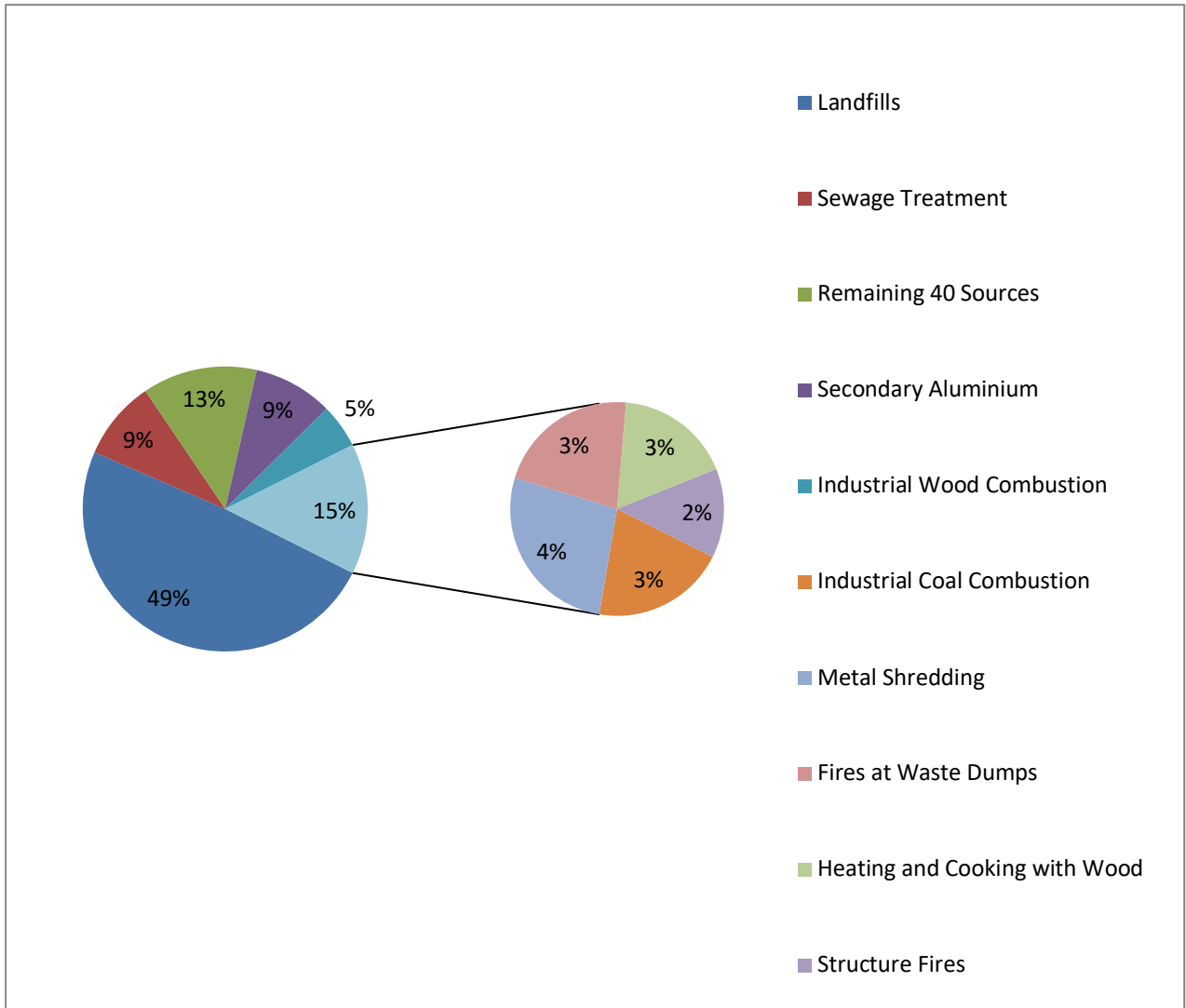


Figure E-2. Plot Showing the Contribution of Major Release Categories for Dioxin

- Figure E2 shows that about 72% of New Zealand’s estimated dioxin releases can be attributed to four categories – disposal of municipal waste in landfills, secondary aluminium production, sewage treatment and industrial wood (biomass) combustion.
- Combined with five other categories: metal shredding, industrial coal combustion, 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 5.3 million population contributed to the sewage treatment release in 2024 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 470,000 New Zealand households

Changes between 2020 and 2024

The tables E-1 and E-2 below show source categories which for 2024 had increases or decreases in their dioxin releases by more than 0.01 g TEQ compared with 2020 levels.

Table E-1. Source Categories with Increases Compared to 2020

Source Category	Change in Dioxin Release (g TEQ/annum)
Secondary aluminium production	+0.718
Medical waste incineration	+0.253
Structure fires	+0.194
Sewage/sewage treatment	+0.102
Primary steel production	+0.073
Agricultural residue burning	+0.038
Open burning of domestic wastes	+0.038
Crematoria	+0.033
Diesel engines	+0.025
2-stroke engines	+0.022
Cement production	+0.010

- Compared with 2020 levels, increases in releases from secondary aluminium production, medical waste incineration and cement production result from increased production or material through put.
- Structure fires are random unpredictable events and releases will fluctuate from year to year.
- Agricultural residue burning, although deliberate, also fluctuates randomly from year to year.
- Increases for sewage and sewage treatment and for open burning of domestic waste result from increases in population.
- Releases from crematoria reflect an increase in population but also a trend of cremation being favoured over burial.
- Diesel engine increases result from an increase in diesel fuel consumption in part related to heavy fuel oil replacement by diesel in the marine transport industry.
- Releases from primary steel production result from an increase in the estimate of waste materials produced

Table E-2. Source Categories with Decreases Compared to 2020

Source Category	Change in Dioxin Release (g TEQ/annum)
Landfills	-2.31
Metal shredding	-0.64
Industrial and commercial coal use	-0.291
Heavy oil-fired engines	-0.271
Biomass power plants	-0.235
Forest fires	-0.213
Grassland and savannah fires	-0.086
Pulp and paper production	-0.052
Fires at waste dumps	-0.042
Coal fired electricity generation	-0.025
Copper brass and bronze production	-0.017
Petroleum production	-0.016
Household heating and cooking with biomass	-0.012
Household heating and cooking with coal	-0.012

- Reductions in dioxin releases in 2024 compared to 2020 for landfills reflects a significant decrease in the amounts of waste sent to sanitary landfill.
- The reduction for metal shredding arises from a better assessment procedure for this category.
- Industrial and commercial coal use reductions have arisen from reduced coal consumption as coal-fired boilers are replaced by units fired on electricity or biomass.
- Heavy oil fired engine releases have dropped because the fuel has largely been replaced by diesel in the marine transport industry
- Forest fires, grassland and savannah fires and fires at waste dumps are random unpredictable events and releases will fluctuate from year to year.
- Drops in releases for pulp and paper, copper brass and bronze and domestic petroleum production reflect lower production volumes. Petroleum production has actually ceased with the closure of the Marsden point oil refinery.
- Reductions for household heating and cooking with biomass and coal are caused by lower fuel consumption as heat pumps replace wood and coal space heaters.

Trends in Dioxin Releases

Figures E-3 and E-4 display plots of dioxin releases versus source category for the current inventory and previous inventories. The sources have been categorised as major and minor to make the lesser sources more visible.

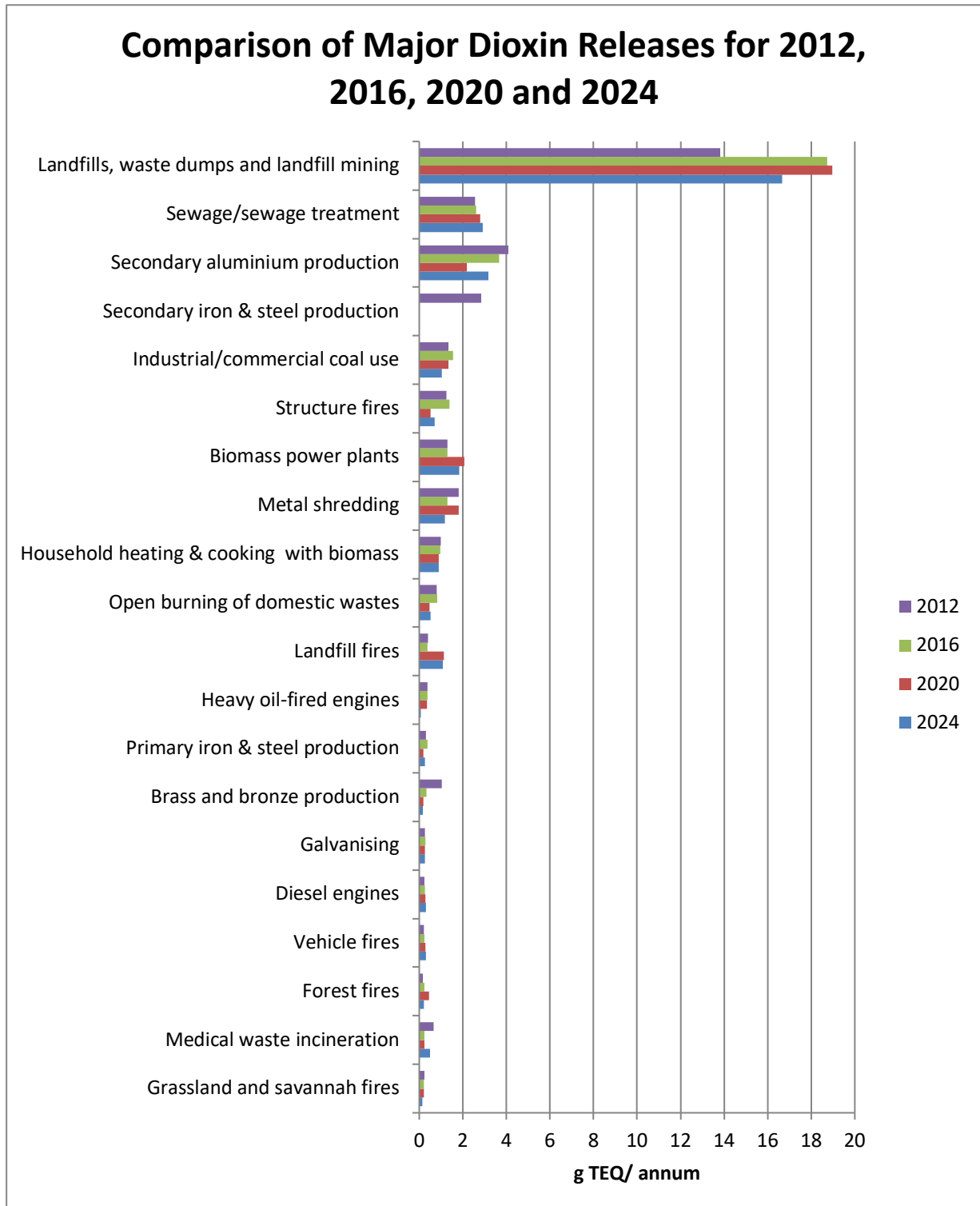


Figure E-3. Major Sources' Dioxin Releases for 2012, 2016, 2020 and 2024 (see Appendix 2 for details)

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

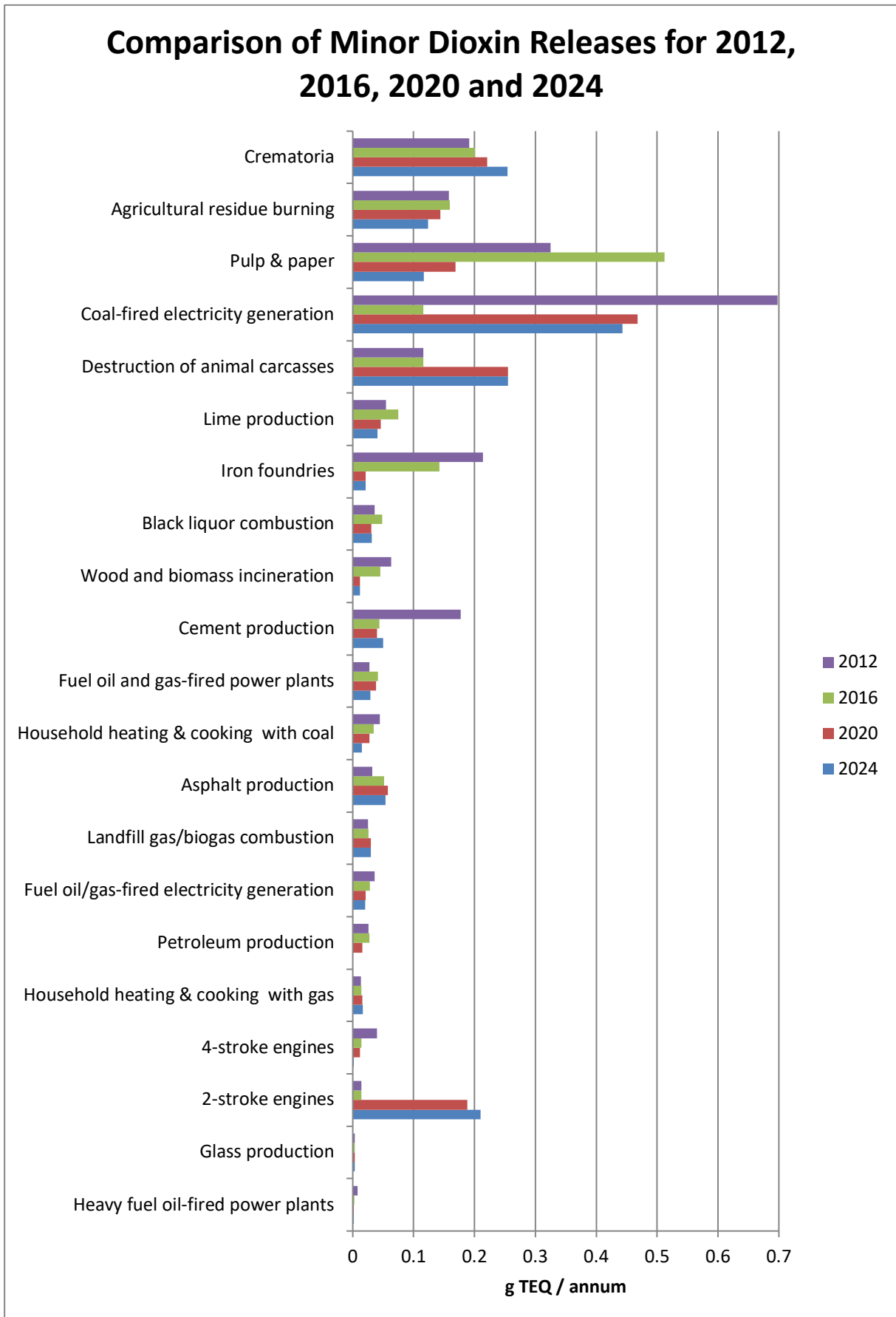


Figure E-4. Minor Sources' Dioxin Releases for 2012, 2016, 2020 and 2024 (see Appendix 2 for details)

Regarding Figures E3 and E4, in many cases there are no obvious discernible trends for each category, however sewage treatment and crematoria show a consistent trend of increasing dioxin releases as their activities are based on population numbers. Diesel engine emissions also show consistent increases.

Household heating and cooking with biomass (wood) and coal both show a decline in dioxin releases as burners are replaced by electrical heat pumps and combustion activity decreases. Heavy oil fired engines and oil and gas fired electricity generation (largely gas) also show a systematic decline. In the case of heavy oil, diesel fuel is increasingly preferred for marine vessels and the dwindling supply of natural gas from New Zealand's fields has constrained gas electricity generation.

Declines in releases from iron foundries, brass and bronze production including copper and pulp and paper production result from decreases in production, in the latter case, bleached pulp.

Dioxin Reduction Initiatives

As shown in Figures E-1 and E-2 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. The waste levy charges for municipal landfill deposition were \$60 per tonne in 2024, a significant increase from the \$20 charged in 2020. These charges will increase further to \$70 per tonne in July 2026 and \$75 per tonne in July 2027. The government continues to prioritise food and green waste in its waste and resource efficiency work programme. Separate collection and composting of food waste has diverted more than 30,000 tonnes from Auckland landfills since the programme's implementation in 2023. Other initiatives include the Tyrewise stewardship scheme designed to address the 3.9 million tyres landfilled or illegally disposed. Since 1 March 2024 a fee has been charged on newly imported tyres to assist end-of-life tyre collection and conversion into new products. Future waste reduction proposals include a refundable deposit beverage container return scheme to help deal with the 2.5 billion single use drink containers purchased annually, over half of which are sent to landfill.

Global and national perspectives

The global per capita release of dioxins is estimated to be about 15.4 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, 7.3 g TEQ per million in 2020 and 6.3 g TEQ per million in 2024.

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 2022* (Ministry for the Environment, 2022) – the 2020 Inventory. It has been prepared under contract to the New Zealand Ministry for the Environment and covers all of the 49 different source categories considered in the 2020 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. New Zealand’s updated National Implementation Plan for the Stockholm Convention requires that the dioxin inventory be reviewed and updated every four years (Ministry for the Environment, 2026).

There have been five 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. Since then emission inventory updates using the Toolkit procedure have been compiled every four years starting with the 2008 reference year. The current update is for the 2024 reference year.

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

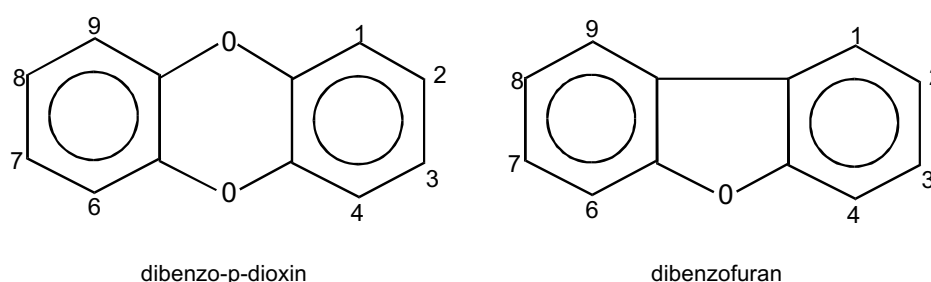
Details of the UNEP Toolkit methodology and related aspects are presented in section 2. This is followed by individual sections covering each of the 10 Toolkit source categories, and a summary and discussion section.

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 2024 Inventory 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 (e.g. 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 (e.g. the dusts collected in bag filters). These may be either processed (e.g. 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 2022 (de Vito, M et al, 2024) and this is now the internationally preferred system. Unlike the older I-TEQ system, the 2022 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 (i.e. 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 2024 calendar year, and 2024 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 (i.e. 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.

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 (e.g. presence of chlorinated materials) and condition (e.g. 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

With the closure of the Corteva Agriscience agrichemical production and packaging site at Paritutu in New Plymouth, currently there are no high-temperature hazardous waste incinerators operating in New Zealand.

Corteva had ceased manufacturing operations from May 2021 and had removed all equipment and demolished most of the buildings by the close of 2022. In February 2023 Dow Chemical (NZ) Ltd took control of the site. (Taranaki Regional Council, 2025 and Tonkin and Taylor 2024)

Consequently there will have been no discharges of dioxins from incinerator operations at the site in 2024.

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 operated by the Te Nikau Grey Hospital in Greymouth. In 2024 the total waste throughput was estimated at 162 tonnes (B Woolhouse, Grey Hospital, pers comm, 2025). 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 2024 based on these factors are shown in Table 3-1. There are no releases to water, land, or in products.

Table 3-1: 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
2024 Medical waste	162	3000		0.486	
			20		0.00324

Certainty assessment for 2024

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.

About 60% of daily sludge production at the treatment plant is incinerated. For the 2024 calendar year 5425 tonnes of solids were incinerated. This material was comprised of an average of 32.1% dry solids (A Paulino, Dunedin City Council, pers comm 2025). Consequently on a dry basis, 1,741.4 tonnes of waste water solids were incinerated.

The dioxin emissions to air are tested on an annual basis. The average dioxin result from three tests conducted in November 2024 was 58.5 ng TEQ / hr (1 ng = 1 x 10⁻⁹ g) (K2 Environmental, 2025). With the plant operating for 7866 hours in 2024, the hourly average mass emission allowed estimation of annual dioxin emissions at 460.2 µg TEQ. In turn the annual emission was used to generate a release factor of 0.264 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 2024 for the sewage sludge incinerator are shown in Table 3-2. There are no releases to water, land, or in products.

Table 3-2: 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	-	0.00023	-
		-	0.5	-	0.00071
2020	1576	0.245		0.00039	
			0.5		0.00079
2024	1741.4	0.264		0.00046	
			0.5		0.00087

Certainty assessment for 2024

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. There are no waste wood incinerators operating in New Zealand.

The National Environmental Standards for Air Quality (NZ Government, 2004) prohibit the operation of an incinerator at a school unless a resource consent has been generated for the discharge produced.

The Ministry of Education was contacted to determine the number of school incinerators currently in operation. It is estimated that there are 6 schools with existing and valid consents (S. Cruikshank, Ministry of Education, pers comm, 2026) and this number are assumed to have been operative in 2024. As with previous inventories each school is assumed to burn one tonne annually, giving an estimate of waste burnt in 2024 of 6 tonnes.

The release estimates for 2024 and the previous inventories, based on the default factors given in the UNEP Toolkit, are shown in Table 3-3. There are no releases to water, land, or in products.

Table 3-3: 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
School incinerators 2024	6	300		0.0018	
			600		0.0036

Certainty assessment for 2024

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.

The previous inventory, based on a survey of Regional Councils, revealed there were a total of 28 consented animal cremators spread throughout the country with a total estimated activity of 510 tonnes per annum.

For the current Inventory, a survey was conducted of animal cremator operators including those disposing of animal pathological waste by combustion. Information was sought about the total amount of animal material burnt in 2024. Returns from the survey were poor so the activity of 510 tonnes per annum from the previous inventory will be used for this sector.

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 from the previous inventory 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 2024 are shown in Table 3-4, along with previous inventory estimates.

Table 3-4: 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
2024	Class 1 cremators	510	500	0.255

Certainty assessment for 2024

Activity data: Low (because it is based on limited survey information)

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

3.8 Summary for this category

The 2024 release estimates for waste incineration are summarised in Table 3-5, along with the totals for 2012, 2016 and 2020.

Table 3-5: Summary of the release estimates for waste incineration

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Hazardous waste incineration	-	-	-	-	-
Medical waste incineration	0.486	-	-	-	0.0032
Sewage sludge incineration	0.00046	-	-	-	0.00087
Wood and Biomass Incineration*	0.0018	-	-	-	0.0036
Destruction of animal carcasses	0.255	-	-	-	-
2024 totals	0.743				0.0077
Totals for other inventory years					
2012 totals	0.794	-	-	-	0.047
2016 totals	0.366	-	-	-	0.032
2020 totals	0.493	-	-	-	0.010

(* 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 (e.g. 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 2024 was 571,804 tonnes (see s 4.3) which would have required 8,348 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 2024 was 571,804 tonnes and the mill also used 755,664 tonnes of coal. (C Brown, New Zealand Steel, pers comm, 2025).

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 2024 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 9,864 m³ per day (C Brown, New Zealand Steel, pers comm, 2025) 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 2024 estimates in the absence of any more suitable factor.

The steel mill generated 36,164 tonnes (dry weight) of solid wastes in 2024, which were disposed in a site landfill. 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 previous 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	-	-	0.014	-
	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	-	-	0.015	-
	60,300 tonnes of waste	-	-	4.55	-	-	0.274
2020	601,490 tonnes of steel	0.134			0.081		
	3.50 x 10 ⁶ m ³ water		4.7			0.017	
	19,028 tonnes of waste			4.55			0.087
2024	571,804 tonnes of steel	0.134			0.077		
	3.6 x 10 ⁶ m ³ water		4.7			0.017	
	36,164 tonnes of waste			4.55			0.165

Certainty assessment for 2024

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 and the site closed. In 2023 New Zealand Steel announced that it would construct a new arc furnace at its Glenbrook site with operation planned to commence in 2027 (New Zealand Steel, 2023). It too will process recycled scrap steel. Consequently, there was no secondary steel production in New Zealand in 2024.

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).

A 2002 secondary metal survey found that New Zealand production was dominated by a few large sites (Ministry for the Environment, 2004). Many of these in the foundry sector such as Precision Foundries (formerly Masport Foundry) in Auckland and the Hillside Foundry in Dunedin are now no longer in business or have significantly reduced production. Production is now concentrated in a few medium sized firms and many more small firms. Contact with the larger firms indicated that production in 2024 was similar to 2020 for which 1300 tonnes was estimated in the previous inventory and this value will be used here.

Release estimates for iron foundries are shown in Table 4-2. The estimates for releases to air for 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 the 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 4-2: 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		0.010
2024	1,300	8.2		0.011	
			8		0.010

Certainty assessment for 2024

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 (C Brown, pers comm, 2024). 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 are shown in the table below.

Table 4-3: Dioxin releases from hot-dip galvanising

Year	Annual releases (g TEQ/yr)	
	Air	Residue
2012	0.0056	0.245
2016	0.0073	0.268
2020	0.0058	0.261
2024	0.0057	0.253

Certainty assessment for 2024

Activity data: High (because they are based on industry data with only a small percentage of discharges from non-New Zealand Steel sources)

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 and therefore not included in the inventory (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 2024. Concerns raised by industry members over production confidentiality have meant that it is possible to publish only the estimated dioxin releases for this category without providing activity data. These are shown in Table 4-4 along with the estimates for the previous inventories.

Table 4 -4: 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
2024	0.028	2.89

Certainty assessment for 2024

Activity data: High (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.

A survey of the larger producers of copper, brass, and bronze allowed an activity estimation of 1300 tonnes per annum for 2024 which is lower than the previous inventory's estimate of 2150 tonnes per annum.

The current release estimates for this sub-category are shown in Table 4-5, along with the estimates for previous 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. All plants (rather than 66% for previous inventories) are now assumed to use bag filters, hence the increase in the residue release factor for 2024. 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 4-5: 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	
			82.8		0.993
2016	3,900	3.5		0.014	
			82.8		0.323
2020	2,150	3.5		0.008	
			82.8		0.178
2024	1300	3.5		0.0046	
			125		0.163

Certainty assessment for 2024

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

Emission factors: Low - Medium (because they are partially 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 by a number of different scrap metal companies at ten locations, the majority of which are in the North Island. 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 items mostly post-consumer in origin. These include vehicles, whiteware, end of life machinery, wire, roofing iron, manufacturing waste and many other materials (Eunomia, 2023). There are two outputs: a relatively clean ferrous metal stream, made up of small (around 50 mm) pieces of steel, and a 'fluff' or 'floc' which contains fragments of other non-ferrous metals and other waste materials in the input stream. On average shredder floc usually makes up 35-40% of shredder feed, however this proportion can vary considerably for specific items with whiteware reaching as high as 60% (Eunomia, 2023). Some of the metal stream from the shredders is processed locally with the remainder 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 recent waste recovery study estimated that the total shredder feed quantity available for New Zealand in 2019 was 261,000 tonnes per annum based on data provided by the Association of Metal Recyclers (Eunomia, 2023). Of this quantity Ministry for the Environment landfill data showed about 34,100 tonnes went straight to landfill leaving 226,900 tonnes as the best estimate for annual shredder waste throughput in New Zealand at the time. This number is still valid for the current inventory based on statistics for light commercial and light passenger vehicles exiting the New Zealand fleet (Ministry of Transport, 2026) which will comprise a significant portion of the shredder feed. For the years 2017 – 2020 these exiting vehicles averaged 196,316 while the average for 2021 – 2024 was 197,268.

The previous inventory involved a survey of metal shredding operations to estimate shredder feed quantities however 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 4-6.

Table 4-6: 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
2024	0.045	1.14

Certainty assessment for 2024

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

Release estimates for metal production are summarised in Table 4-7.

Table 4-7: Summary of the release estimates for metal production

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Primary steel production	0.077	0.017	0.165	-	-
Secondary steel production	-	-	-	-	-
Iron Foundries	0.011	-	-	-	0.010
Hot dip galvanizing plants	0.0057	-	-	-	0.253
Secondary aluminium production	0.028	-	-	-	2.89
Lead production	-	-	-	-	-
Brass and bronze production	0.005	-	-	-	0.163
Metal shredding	0.045	-	-	-	1.14
2024 totals	0.171	0.017	0.165		4.45
Totals for other inventory years					
2012 totals	0.404	0.014	0.206	-	9.71
2016 totals	0.261	0.015	0.274	-	5.54
2020 totals	0.198	0.017	0.087		4.37

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 (e.g. coal and oil versus gas). They are also highly dependent on the types and design of the fuel-burning equipment (e.g. 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 owned by Genesis Energy 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. 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 addition the amount of natural gas available to fire gas turbine electricity generation in New Zealand has declined year on year and increasingly coal fired generation at Huntly power station is seen as an important resource for maintaining the security of electricity supply at peak times, especially in dry years. However Genesis Energy is currently working on a programme to replace coal with biomass (carbonised wood pellets). The Company is targeting biomass use to exceed coal use by the 2028 financial year provided a suitable fuel supply can be arranged (Genesis Energy, 2025).

In the Winter of 2024 extremely dry conditions and constrained gas supply led to sharp price spikes in the wholesale price for electricity. This led to an agreement amongst New Zealand’s largest power companies called *the Strategic Energy Reserve Huntly Firming Option*. In return for access to the power generated by the Rankine units the other power companies will pay an annual premium and pay for running costs incurred on their behalf. This will ensure that all three Rankine units will remain in operation until 2035. (NZ Herald, 6 November 2025).

Coal consumption at Huntly in 2024 was 18,470 TJ. (Ministry of Business Innovation and Employment, 2025). This is similar to the 19,490 TJ consumed in 2020 which was also a dry year.

The coal used at Huntly Power Station is a mixture of Waikato sub-bituminous coal from the Rotowaro mine and coal imported from Indonesia. On average, Indonesian coal comprised 85% of total coal consumption (M. Hodges, Genesis Energy, pers comm, 2025).

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 2024 release estimates for coal-fired electricity generation are shown in Table 5-1, along with the estimates from the previous 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	-	0.048	-
		-	14	-	0.068
2020	19,490	10	-	0.195	-
		-	14	-	0.273
2024	18,470	10	-	0.185	-
		-	14	-	0.259

Certainty assessment for 2024

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 2024 was 17,220 TJ (1 TJ = 10¹² Joules) (Ministry of Business Innovation and Employment, 2025). 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 manufacturing and domestic heating². In 2024 they accounted for 1,667TJ. Subtracting this amount from the consumer energy total gives a total annual energy consumption associated with the remaining coal combustion sources of 15,553TJ (1 TJ = 10¹² Joules).

Coal consumption in the industrial and commercial sectors continues to decline. Fonterra has retired all its coal-fired boilers in the North Island. Electricity based electrode boilers will be installed at Fonterra's Whareroa and Edgecumbe plants and resistive element boilers at Waitoa and Waitoa UHT (Fonterra, 2025).

The estimates for the releases to air from industrial and commercial coal combustion have been based on the approach adopted for previous inventories. For plant greater than 10 MW, the UNEP Toolkit emission factor of 10 µg TEQ per TJ has been applied (10 x 10⁻⁶ g per TJ), while a factor of 100 µg TEQ per TJ has been used for plants less than 10 MW (100 x 10⁻⁶ g per TJ). The 15,553 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 comprised in the National Heat Plant Database (CRL Energy, 2011). Here the total capacity of boilers of 10 MW or greater was 662 MW (52.3% of the total), while those less than 10 MW had a total capacity of 603 MW (47.7%). This results in a coal energy distribution of 8,134 TJ for plant greater than 10 MW and 7,419 TJ for plant smaller than 10 MW.

The default release factor of 14 µg TEQ per TJ (14 x 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 2024 release estimates for industrial and commercial coal use are shown in Table 5-2, along with the estimates from the previous inventories. As shown, the releases both to air and in residues have decreased steadily as coal consumption drops. 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.

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.

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

Year	Plant size	Activity Rate (TJ of coal/year)	Release factors (µg 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	19,890			1.053	0.279	
2024	> 10 MW	8,134	10	-	0.081	
			-	14		0.114
	< 10 MW	7,419	100	-	0.742	
				14		0.104
Totals	15,553			0.823	0.218	

Certainty assessment for 2024

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 2024 the total heavy fuel oil used in New Zealand industrial applications was estimated to be 750 TJ (Ministry of Business Innovation and Employment, 2025). There was a further 760 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 2024 release estimates for heavy fuel oil-fired power plant are shown in Table 5-3.

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
2024	750	2.5	0.0019

Certainty assessment for 2024

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 2024 there were 9 power stations in New Zealand with the sole function of generating electricity using natural gas with a total capacity of 1,314 MW. (Ministry of Business Innovation and Employment, 2025). Should the three Rankine units at Huntly Power Station 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 2024 the total consumption of natural gas for electricity generation including cogeneration was 38,750 TJ (1 TJ = 10^{12} Joules), (Ministry of Business Innovation and Employment, 2025). This is considerably less than the 53,750 TJ consumed in 2020. Gas supply was the major factor which influenced this decline, dropping 20.9% on 2023 production figures. This was due to natural field decline, with net production compared to predicted production being particularly down for the Maui, Kupe and Pohokura fields. In addition there were unplanned outages at these fields (Ministry of Business Innovation and Employment, 2025).

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. The total consumption of diesel for electricity generation in 2024 was 310 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 2024 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	53,750	0.5	0.027
2024	39,060	0.5	0.020

Certainty assessment for 2024

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 51,200 TJ of energy in 2024 (Ministry of Business Innovation and Employment, 2025). In addition, the industrial and commercial uses of LPG were 5,800 TJ, half of which has been assumed to be used in heat-raising appliances (i.e. 2900 TJ).

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.

Consequently, the sum of the relevant fuel oil and gas energy consumed in this category is 58,000 TJ (51,200 TJ + 2900 TJ + 3900 TJ).

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 2024 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 previous 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	0.038
2024	58,000	0.5	0.029

Certainty assessment for 2024

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

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.

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 with domestic wood combustion comprising the remainder.

As shown in the previous sections, accurate statistical information is available for national annual consumption of coal, natural gas and petroleum products. Such statistics are not available for biomass (essentially wood waste) because the tonnages used are either not recorded or are recorded indirectly such as in the form tonnes of steam raised per hour. In addition, wood waste can vary significantly in its composition and moisture content—off cuts, shavings, saw dust, bark etc. which will affect its energy content. The 2012 and 2016 mercury inventories used the boiler rating (MW) of industrial wood burning heat plant listed in the Heat Plant Database (CRL Energy 2011) and derived the total energy consumed by assuming that plant is operated at 70% load for 320 days per year. Estimates of domestic biomass consumption from Census data were then added to obtain a total annual biomass figure.

However as with the 2020 Inventory, MBIE-derived estimates for annual industrial and domestic energy raised by biomass combustion have been used here (MBIE, 2025).

MBIE use the Scion Wood Processing Database (MBIE, 2017) developed by the Crown Research Institute Scion in 2017 to assess the wood related consumption of energy raising plants in New Zealand. The database uses two approaches to derive estimates of fuel use. In the first, the nameplate power rating (MW) of the boiler is combined with estimates of loading (percentage of time the boiler is used in a year), estimates of capacity (the ratio between typical heat demand and the boiler's nameplate capacity to supply heat) and efficiency (assumed to be 0.85 for all boilers, that is 85% of the energy in the fuel is converted to useful heat). In the second approach, annual production levels of wood products and estimates of the energy required to produce each product are used to derive a total fuel use figure.

Biomass consumption estimates are not yet available for 2024 but MBIE estimated total annual usage (including domestic consumption) of 51.98 PJ, 51.11 PJ and 44.37 PJ for 2021, 2022 and 2023 (MBIE, 2025). This allows an estimate of 49.15 PJ to be derived for 2024 based on the average of the preceding 3 years.

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 is estimated to account for 7,442 TJ in 2024. From Section 9.1, 1,240,229 tonnes of black liquor were burned in 2024. The energy content of black liquor solids is approximately 11 GJ/tonne (MBIE, 2017) so the combustion of it in 2024 released 13,643 TJ. Subtracting these quantities it is estimated that biomass fired industrial plants consumed 28,065 TJ in 2024.

Previous inventory estimates have been 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) ($1 \mu\text{g TEQ/TJ} = 1 \times 10^{-6} \text{ g TEQ/TJ}$). These factors have also been used for the current estimates.

The 2024 release estimates for biomass-fired power plant are shown in Table 5-6, along with the corresponding estimates made in the previous 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	-	1.00	-
		-	15	-	0.300
2016	20,000	50	-	1.00	-
		-	15	-	0.300
2020	31,682	50	-	1.58	-
		-	15	-	0.475
2024	28,065	50	-	1.40	-
		-	15	-	0.421

Certainty assessment for 2024

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).

Data for the energy generated from combustion of sludge biogas (produced from digestion of wastewater solids), and landfill gas combustion in 2024 are not yet available. The averages for the three preceding years are 1097 TJ

for sludge biogas combustion and 2653 TJ for landfill gas combustion (Ministry of Business Innovation and Employment, 2025) which allows us to derive an estimate of 3750 TJ as a combined value for this sector.

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
2024	3,750	8	0.030

Certainty assessment for 2024

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 2024 is estimated to be 470,750 from a study conducted on the health effects of indoor combustion in New Zealand Homes by Emission Impossible (Metcalf et al, 2025) on behalf of the Energy Efficiency and Conservation Authority (EECA). The space heating function of wood burners is steadily being replaced by electrical heat pumps with over a million units installed since 2016 (Gretton, 2024).

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, 2025). Data is not yet available for 2024, so information for 2023 will be used in lieu. For household heating and cooking with biomass in 2023 the database shows a total energy consumption of 7442 TJ for wood with 5897 TJ used exclusively for space heating and 1545 TJ for a combination of space heating and water heating.

The 2024 release estimates for domestic wood combustion are shown in Table 5-8 along with the corresponding estimates made for the previous 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
2024	7,442	100		0.7442	
			20		0.149

Certainty assessment for 2024

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

Data on domestic coal consumption is available from the Ministry of Business Innovation and Employment's energy data files. (Ministry of Business Innovation and Employment, 2025). The total amount of coal burned in domestic appliances in New Zealand in 2024 was 150 TJ, (1 TJ = 10^{12} Joules).

As with the 2020 dioxin inventory the Toolkit factor of 100 µg 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 µg 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 µg 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 2024 release estimates for domestic coal combustion are shown in Table 5-9, along with the corresponding estimates made in the previous 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
2024	150		100		0.0150	
		189.8		0.41		0.000078

Certainty assessment for 2024

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

EECA no longer record a figure for diesel fueled space heating in their energy end use spreadsheet (Energy Efficiency and Conservation Authority, 2025). The value of 2600 TJ presented in MBIE's energy data files for residential diesel consumption in 2024 includes off-road vehicles and recreational marine activities which will be the dominant uses. In the absence of current reliable information the 2020 release estimates for domestic oil combustion have been used for this inventory (see Table 5-10). 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
2024	103	10	0.0010

Certainty assessment for 2024

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 available as a reticulated supply in many locations in the North Island where it is used mainly in fixed installations for heating, cooking and water heating. LPG in cylinders is used similarly in the South Island and in North Island locations where mains supply is not available. LPG also sees widespread use throughout New Zealand for portable equipment such as barbeques and patio heaters.

In the previous inventory, EECA's energy end use database was used to compile data on domestic gas consumption. (Energy Efficiency and Conservation Authority, 2025). Data is not yet available for 2024, so MBIE's energy data files have been used to compile this information (Ministry of Business Innovation and Employment, 2025). The total residential usage of natural gas in 2024 was reported to be 7280 TJ. The total for LPG use was 3900 TJ. This gives a combined total for natural gas and LPG use of 11,180 TJ.

The 2024 release estimates for domestic gas combustion are shown in Table 5-11, along with the corresponding estimates made in the previous 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 (µg TEQ/TJ of gas)	Annual releases (g TEQ/yr)
		Air	Air
2012	9020	1.5	0.014
2016	9581	1.5	0.014
2020	10,824	1.5	0.016
2024	11,180	1.5	0.017

Certainty assessment for 2024

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 2024 release estimates for heat and power generation are summarised in Table 5-12, along with the totals for previous inventories.

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

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Coal-fired power plants: electricity generation	0.185	-	0.259	-	-
Coal-fired power plants: Industrial and commercial	0.823	-	-	-	0.218
Heavy fuel oil-fired power plants	0.0019	-	-	-	-
Fuel oil and gas-fired power plants: electricity generation	0.020	-	-	-	-
Fuel oil and gas-fired power plants: industrial and commercial	0.029	-	-	-	-
Biomass power plants	1.403	-	-	-	0.421
Landfill gas/biogas combustion	0.030	-	-	-	-
Household heating & cooking with biomass	0.744	-	-	-	0.149
Household heating & cooking with coal	0.015	-	-	-	0.000078
Household heating & cooking with oil	0.0010	-	-	-	-
Household heating & cooking with gas	0.017	-	-	-	-
2024 totals	3.27		0.259		0.788
Totals for other inventory years					
2012 totals	3.33	-	0.407	-	0.745
2016 totals	3.24	-	0.068	-	0.788
2020 totals	3.72		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. Historically coal was used as the primary fuel but the supplementary use of wood waste and more recently fuel derived from waste tyres has enabled the company to reduce its coal use by 50% (Fletcher Building, 2025). The total cement production at the plant in 2024 was approximately 1 million tonnes. (Fletcher Building, 2025).

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.

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	
2024	Golden Bay	1,000,000		0.05		0.050	

Certainty assessment for 2024

Activity data: High (because it is based on 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 2023 calendar year gives a greenhouse gas emission from lime production of 96,200 tonnes CO₂. (Ministry for the Environment, 2025). This allows an estimate of actual lime production of 128,610 tonnes in 2023 which will be used in this inventory.

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 0.76 has been applied to these estimates to reflect decreased production from 170,000 to 128,610 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 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	-	0.012	-
	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					0.013	0.042
2016	Lime production	238,480	0.07	-	0.017	-
	Lime application to land	23,800	-	1.24	-	0.030
	APC equipment dust	4200	-	6.7	-	0.028
	Pulp mill lime kilns				0.0006	
Total					0.017	0.058
2020	Lime production	144,385	0.07		0.010	
	Lime application to land	14,450		1.24		0.018
	APC equipment dust	2,550		6.7		0.017
	Pulp mill lime kilns				0.0006	
Total					0.011	0.035
2024	Lime production	128,610	0.07		0.0090	
	Lime application to land	12,920		1.24		0.016
	APC equipment dust	2,280		6.7		0.015
	Pulp mill lime kilns				0.0006	
Total					0.0096	0.031

Certainty assessment for 2024

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

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 7,000 tonnes per annum in 2024 and is fired with oil (R Thomas, Canterbury Clay Bricks, pers comm, 2025). Consequently, total brick production for 2024 was 12,000 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 2024 release estimates for brick production are shown in Table 6-3, along with the corresponding estimates reported for the previous inventories.

Table 6-3: Dioxin releases from brick production

Year	Activity Rate (tonnes/year)	Release factors ($\mu\text{g TEQ/tonne}$)		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
2024	12,000	0.02		0.00024	
			0.006		0.000072

Certainty assessment for 2024

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 2024 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 previous inventories were based on the UNEP Toolkit default factor of $0.015 \mu\text{g TEQ}$ per tonne of glass ($0.015 \times 10^{-6} \text{ g TEQ/tonne}$) for releases to air, and there were no significance releases via any other media. The same approach has been adopted here. The 2024 release estimates for glass production are shown in Table 6-4, along with the corresponding estimate made in the previous 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
2024	209,077	0.015	0.0031

Certainty assessment for 2024

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). Since 2022 MBIE have discontinued their original practice of releasing annual production data to avoid identification of individual production figures (New Zealand Petroleum and Minerals, 2023). Consequently clay production for 2024 has been estimated by applying the percentage increase in production from 2016 to 2020 (6%) to the 2020 production data. This gives an estimate for 2024 clay for pottery and ceramics of 41,947 tonnes.

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 (United Nations Environment Programme, 2013). The Toolkit differentiates between small, poorly controlled kilns (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 2024 release estimates for pottery and ceramics production are shown in Table 6-5.

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
2024	41,947	0.02	0.00084

Certainty assessment for 2024

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

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 2024 in New Zealand was 1.45 million tonnes per year (A. Corrie-Johnston, pers comm 2025). This is similar to the amounts produced in 2016 and 2020.

Previous inventory estimates for this source category have been 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 2024 release estimates for asphalt production are shown in Table 6-6 along with the estimates for the previous inventories.

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		0.011	
	Plant residues (dust)	50% of the above		0.06		0.047
2024	Asphalt production	1,450,000	0.007		0.010	
	Plant residues (dust)	50% of the above		0.06		0.044

Certainty assessment for 2024

Activity data: High (because it is based on 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 2024 release estimates for mineral production are summarised in Table 6-7, along with the totals for previous inventories.

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

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Cement production	0.050	-		-	-
Lime production	0.0096	-	0.031	-	-
Brick production	0.00024	-	-	0.000072	-
Glass production	0.0031	-	-	-	-
Pottery and ceramics	0.00084	-	-	-	-
Asphalt production	0.010	-	-	-	0.044
2024 totals	0.074		0.031	0.000072	0.044
Totals for other inventory years					
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 not believed to 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 (e.g. oil versus petrol versus LPG). They are also affected by the different engine designs and the use of catalytic converters on the engine exhausts.

The vehicle fleet was comprised of the following vehicles in 2023 (Ministry of Transport, 2026):

- 3,284,941 light petrol vehicles (including hybrid and PHEVs)
- 906,754 diesel powered light vehicles (mostly vans, utes, light trucks and 4-WDs)
- 178,856 diesel heavy vehicles (trucks and buses)
- 203,183 motorcycles
- 15,558 licensed mopeds (a significant proportion of which have 2-stroke engines)
- 23 CNG powered vehicles
- 812 LPG powered vehicles.

An unusual feature of this vehicle fleet in global terms is its age. Of the light vehicle fleet 20% of vehicles are more than 20 years old and 63% 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, 2026)

Significant quantities of petrol are also combusted in engines in off-road situations. The Energy Efficiency and Conservation Authority (EECA) conducted a study in 2020 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 petrol used in recreational marine activities (383 million litres) had been mistakenly characterised as “on-road” because the fuel had been sourced from the retail network.

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.

The Massey University Environmental Health Intelligence group (EHI) compared 1990 levels of energy consumption in New Zealand with 2022 levels for different sectors including domestic transport, industrial, residential, commercial and public services and agriculture forestry and fishing. While most sectors consumed roughly the same or less energy per capita in 2022 compared to 1990, the domestic transport sector per capita

consumption increased by 12.5% (Environmental Health Intelligence, 2024). An increase in per capita usage indicates that energy is being used less efficiently, i.e. more energy is required for the same output.

EHI attributed the increase in per-capita consumption to a combination of factors, including (but not limited to):

- more frequent and longer-distance travel,
- increased reliance on private vehicles for transport
- increased air travel.
- increasing numbers of vehicles on the road relative to the number of people

Other factors include trends towards purchasing heavier vehicles, for example SUV's, which, on the whole, have lower fuel efficiencies than conventional cars (Car, 2018).

7.1 4-Stroke engines

Historically 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 2024 was 100,700 TJ, or 2,134,760 tonnes (1 TJ = 10¹² Joules) (Ministry of Business Innovation and Employment, 2025).

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 2024 was only 60 TJ (Ministry of Business Innovation and Employment, 2025) 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 New Zealand Transport Agency has required that vehicles registered after 1 May 2010 and manufactured after 1 January 1990 have a catalytic converter, if originally fitted, otherwise they will fail their inspection for a warrant of fitness or certificate of fitness (NZ Transport Agency, 2025). Consequently it is now assumed that effectively 100% of New Zealand 4-stroke vehicles are fitted with catalytic converters.

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 2024 was only 140TJ or 2,910 tonnes.

The 2024 release estimates for 4-stroke engines are shown in Table 7-1, along with the corresponding estimates from previous inventories. The activity rates were obtained by subtracting the 84,130 tonnes of petrol used in 2-stroke engines (see section 7.2 below) and adding the 2,910 tonnes for LPG consumption.

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	0.010
	catalyst	1,970,103	0.001	0.0020
	Totals			0.012
2024	no catalyst	-	0.1	-
	catalyst	2,053,540	0.001	0.0021
	Totals			0.0021

Certainty assessment for 2024

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

Neither the Ministry of Transport nor the Ministry of Business Innovation and Employment differentiate between engine types in their statistics for petrol consumption making it necessary to estimate the number of 2-stroke engines in operation and infer their fuel consumption.

Petrol engines operating on a 2-stroke cycle offer a number of advantages over their 4-stroke counterparts. The 2-stroke engine design is less complex because ports rather than valves are used for vapourised fuel introduction and exhaust gas extraction. In addition because lubricating oil is already mixed into the fuel there is no requirement for an oil sump. Consequently on a power output basis 2-stroke engines tend to be much lighter and less expensive. With no oil sump, 2-stroke engines and the devices they power are highly manoeuvrable and can operate at more extreme angles than 4-stroke engines.

The main disadvantages with 2- stroke engines are they tend to be noisier, less fuel efficient and have significantly higher exhaust emissions. Higher exhaust emissions has seen the market for jet-skis, which were originally exclusively powered by 2-stroke engines, completely replaced by 4-stroke engines following action by USEPA. Battery or mains electricity have also been used as alternative power sources for two stroke engines for lighter applications.

In 2020 Australia introduced emission standards for new spark ignition engines for smaller engines (below 19 KW) and for all spark ignition engines in marine vessels. This had a significant negative impact on sales of 2-stroke engines (Australian Government, 2024).

Despite these drawbacks there are still hundreds of thousands of small light weight 2-stroke engines used in New Zealand. Rewiring Aotearoa’s report “The Machine Count” estimated that there are the following petrol fuelled machine numbers currently in operation in New Zealand⁴ (Rewiring Aotearoa, 2025).

- 362,308 line-trimmers
- 263,605 chainsaws
- 59,778 hand held pruners (hedge cutters)
- 29,942 leaf blowers
- 1,100 post hole borers

Rewiring Aotearoa estimated that each of these small units would produce about 1 tonne CO2 equivalent over a 15-year lifetime. This equates to an individual annual petrol usage of about 45 litres per year. Consequently these small machines combined will consume an estimated 32.3 million litres of petrol per year or 24,000 tonnes.

2-stroke engines have also found use in larger powered devices particularly the outboard motors used in recreational marine activities and in 2-stroke motorcycles particularly scooters. However sales of new outboard engines are predominantly four stroke because of environmental concerns. For instance Maritime New Zealand encourages recreational boaters to switch to less harmful engine alternatives (Maritime New Zealand, 2025)

Using the 2020 EECA study results (Energy Efficiency and Conservation Authority, 2021), the previous inventory attributed 25% of the 383 million litres of petrol consumed annually by recreational marine activities to 2-stroke engines. In the absence of specific new data it has been assumed that petrol consumption remains the same for 2024 but that the share of 2-stroke engines is now 20% as older units are preferentially replaced by 4-stroke equivalents. This equates to 56,700 tonnes from this sector.

The 2020 Inventory estimated 2-stroke motorcycle fuel consumption at 3164 tonnes. Registrations of motorcycles increased 8.4% from 2020 to 2023 so this amount has been increased in proportion to 3430 tonnes.

Consequently, in total, 2-stroke engine petrol use in New Zealand is estimated to be 84,130 tonnes. This is significantly higher than the quantities used for the 2012 and 2016 Inventories and 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
2024	84,130	2.5	0.2103

Certainty assessment for 2024

Activity data: Low (because it is based on assumed annual fuel consumption)
 Emission factor: Low (because it is based on the Toolkit default factor)

⁴ Most if not all of these machines will be powered by 2-stroke engines

7.3 Diesel engines

The total consumption of diesel in transport, industrial and commercial applications, agriculture, and residential uses in 2024 was 146,290 TJ (1 TJ = 10^{12} Joules) (Ministry of Business Innovation and Employment, 2025). However, some of this usage has already been accounted for under sections 5.1.3 (industrial/commercial heat and power 4,210 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 141,977 TJ or 3,099,925 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 $\mu\text{g TEQ/tonne}$) ($1 \mu\text{g TEQ/tonne} = 1 \times 10^{-6} \text{ g TEQ/tonne}$). Specific statistics for biodiesel consumption are not available but it is expected to make a trivial contribution to dioxin emissions. For instance the 2016 Inventory estimated the 20TJ (440 tonnes) of biodiesel produced at the time changed the total release estimate by only 0.00001g TEQ. The biodiesel sector was anticipating significant stimulus in 2022 with the introduction of the Sustainable Biofuels Obligation Bill but the government announced in February 2023 that this would no longer proceed (Beehive Press Release, 2023).

The 2024 release estimates for diesel consumption in transport and stationary engines are shown in Table 7-3, along with the corresponding estimates from the earlier 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
2024	3,099,925	0.1	0.310

Certainty assessment for 2024

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 2024 was 760 TJ, or about 17,900 tonnes (Ministry of Business, Innovation and Employment, 2025). This total includes both ‘new’ fuel oil and recycled waste oil.

The 2024 release estimates are shown in Table 7-4 along with the corresponding estimates for the previous inventories. It is evident that a significant reductions in heavy fuel oil use in shipping has occurred most probably driven by new MARPOL Annex VI rules for international shipping. These rules lowered the maximum sulphur content for fuel oil in shipping from 3.5% to 0.5% resulting in the substitution of diesel for fuel oil.

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
2024	17,900	4	0.072

Certainty assessment for 2024

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 2024 release estimates for fuel use in transportation and stationary engines are summarised in Table 7-5.

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

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
4-stroke engines	0.002054	-	-	-	-
2-stroke engines	0.2103	-	-	-	-
Diesel engines	0.310	-	-	-	-
Heavy oil-fired engines	0.0716	-	-	-	-
2024 totals	0.594				
Totals for other inventory years					
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 (i.e. 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 (e.g. 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, 2025). The activity rates for biomass burning show a significant amount of variation from year to year. Consequently, the activity rates for 2024 will be based on the average data from the previous 3 years (i.e. 2021 to 2023 as 2024 data is not yet available) 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, legumes and other crop residues (Ministry for the Environment, 2025). 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 2021, 2022 and 2023 was 262,350, 221,560 and 193,340 tonnes/year, respectively, which gives an annual average rate of 225,750 tonnes/year. This average activity rate has been used for the 2024 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 New Zealand practices. The release estimates are shown in the table below, along with the corresponding estimates from the previous 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	-	0.015
2020	260,890	0.5		0.130	
			0.05		0.013
2024	225,750	0.5		0.113	
			0.05		0.011

Certainty assessment for 2024

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, 2025).

The total mass of forest biomass burned in New Zealand in 2021, 2022 and 2023 was 157,964, 162,570 and 264,691 tonnes/year, respectively, which gives an average rate of 195,075 tonnes/year. This activity rate has been used for the 2024 release estimates, coupled with the UNEP Toolkit factors. The release estimates are shown in the table below, along with the corresponding estimates from the previous 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	-	0.031
2020	380,242	1		0.380	
			0.15		0.057
2024	195,075	1		0.195	
			0.15		0.029

Certainty assessment for 2024

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, 2025).

The total mass of grassland and savannah material burned in New Zealand in 2021, 2022 and 2023 was 231,867, 234,682 and 159,135 tonnes/year, respectively, which gives an average rate of 208,561 tonnes/year. This activity rate has been used for the 2024 release estimates, coupled with the UNEP Toolkit factors. The release estimates are shown in the table below, along with the corresponding estimates from the previous inventories.

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	-	0.049
2020	341,969	0.5		0.171	
			0.15		0.051
2024	208,561	0.5		0.104	
			0.15		0.031

Certainty assessment for 2024

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)

8.2 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*.

Landfill fire incident data was obtained from Fire and Emergency New Zealand (FENZ). The number of landfill fires recorded by FENZ for 2024 was 78 (FENZ Official Information Request OIA2025 – 00020123).

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 2024 are shown in Table 8-4 along with estimates from the previous inventories.

Table 8-4: Dioxin releases from waste dump fires

Year	Activity Rate (tonnes of waste burned/year)	Release factors ($\mu\text{g TEQ/tonne}$)		Annual releases (g TEQ/yr)	
		Air	Land	Air	Land
2012	1260	300		0.378	
			10		0.013
2016	1215	300		0.365	
			10		0.012
2020	3645	300		1.094	
			10		0.036
2024	3510	300		1.053	
			10		0.035

Certainty assessment for 2024

Activity data: Low (because although based on national fire statistics it is 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 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. This approach has also been applied to the current estimates using the following parameters:

- 90% of structure fires are minor with average consumption of 0.1 tonnes of material
- 90% of the remainder are moderate consuming 0.5 tonnes of material per fire.
- 90% of the remainder are severe consuming 5 tonnes of material per fire.
- All remaining fires are very severe and consume 125 tonnes per fire.

Annual fire incident data for structure fires in 2024 has been obtained from FENZ with a total of 4900 fires recorded (FENZ Official Information Request OIA2025 – 00020123). However as with the 2020 Inventory, information on the severity of the fire has also been obtained and the 1,988 fires involving no damage has been subtracted from this total, to give 2912 fires where damage did occur.

Applying the mass calculation methodology to the 2,912 fires gives a total quantity of 898 tonnes for material consumed by fire in 2024 (262 tonnes + 131 tonnes + 130 tonnes + 375 tonnes). The UNEP Toolkit gives default factors of 400 $\mu\text{g TEQ}$ per tonne for dioxin releases to both air and land (400×10^{-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 for previous 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
2024	898.1	400		0.359	
			400		0.359

Certainty assessment for 2024

Activity data: Low (because although it is based on national fire statistics, the conversion factor for the mass of material burned has significant uncertainties)

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. The results of the survey were used to estimate that 2.5 % of New Zealand households burn 250 kg of household waste per year. This rate of domestic open burning is still considered valid for the current inventory. For the 2,012,400 households present in New Zealand in 2024 (Statistics New Zealand, 2024), this represents an activity of 12,578 tonnes.

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 previous 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	-	0.020
2020	11,660	40	-	0.466	-
		-	1	-	0.012
2024	12,578	40	-	0.503	-
		-	1	-	0.013

Certainty assessment for 2024

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 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 2,563 in 2024 (FENZ Official Information Request OIA2025 – 00020123).

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 2024 release estimates shown in Table 8-7, along with the corresponding estimates made for the previous inventories.

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	-	0.045
2024	2,563	100	-	0.256	-
		-	18	-	0.046

Certainty assessment for 2024

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

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

8.2.5 Open burning of wood (construction/demolition)

Significant quantities of construction and demolition (C&D) timber are produced annually in New Zealand but the principal form of disposal is to landfill. A recent report prepared by Beca for the Ministry for the Environment estimated about 490,000 tonnes of C&D waste timber was sent to landfill in 2023 with 78% going to a class 1 and 20% to a class 2 landfill. (Becca, 2025)

The on-site burning of waste timber produced during construction or demolition works is either prohibited or restricted (requires a resource consent) in most urban areas. While it may still occur on rural properties and in urban areas where restrictions have not been applied there is increasing public awareness fostered by regional councils that this is not good practice. Fines totalling \$50,000 were handed down to parties involved in the illegal burning of demolition waste originating from Northland's Kaikohe College (Northland Regional Council, 2019)

As with previous inventories there is no information available on the amount of C&D burnt so it is not possible to reliably estimate dioxin releases. Rough estimates used previously of 0.2g TEQ per year are probably too high but there is still a continuing need for support and enforcement of regional controls on open burning.

8.3 Summary for this category

The 2024 release estimates for accidental fires are summarised in Table 8-8, along with the totals for previous inventories.

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

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Agricultural residue burning	0.113	-	0.011	-	-
Forest fires	0.195	-	0.029	-	-
Grassland and savannah fires	0.104	-	0.031	-	-
Fires at waste dumps	1.053	-	0.035	-	-
Structure fires	0.359	-	0.359	-	-
Open burning of domestic wastes	0.503	-	0.013	-	-
Vehicle fires	0.256	-	0.046	-	-
2024 totals	2.584		0.525		
Totals for other inventory years					
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

For 2024 the total wood pulp production in New Zealand was about 1.04 million tonnes (air dry basis), of which 29% was produced by thermo-mechanical or chemi-thermo-mechanical pulping, and 71% by chemical pulping (Figure:nz, 2024).

Following the closure of the Norske Skog Kawerau Refiner Mill in 2021 and the Winstone Pulp International Karioi Refiner Mill in 2024, mechanical pulp is now solely produced at Oji Fibre Solutions' Whirinaki plant in Hawke's Bay.

Chemical (kraft) pulp is produced at two Oji Fibre Solutions pulp mills in Kawerau and Tokoroa. From January 2019 only the Tokoroa mill has produced bleached kraft pulp (Climate Leaders Coalition, 2022) which is a source of dioxin releases.

Black liquor combustion

There are two primary sources of dioxin releases to air from 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, and the total annual production of kraft pulp at the two mills in 2024 was about 689,016 tonnes on an air-dry basis (Oji Fibre Solutions, 2025). Given that the quantity of black liquor solids produced per tonne of kraft pulp production is approximately 1.8 dry tonnes of black liquor per tonne of air dry pulp (IEA Bioenergy, 2007) it is possible to estimate that a total of 1,240,229 tonnes of black liquor were combusted in 2024.

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

The 2024 estimates for releases to air from black liquor combustion are shown in Table 9-1, along with the estimates made in the previous 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		0.036	
2016	1,930,000	0.025		0.048	
2020	1,215,226	0.025		0.030	
2024	1,240,229	0.025		0.031	

Certainty assessment for 2024

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. 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. Statistics NZ’s Infoshare site shows export totals of 167, 289 tonnes for bleached kraft pulp in 2024. The 2024 estimates for releases from bleached pulp production are shown in Table 9-2.

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
2020	241,959	0.2		0.048	
			0.5		0.121
2024	167,289	0.2		0.034	
			0.5		0.084

Certainty assessment for 2024

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 2020 Inventory to be 26.19 g TEQ. This figure can now be updated for an additional 4 years' input, based on the 2024 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 0.134 g TEQ, and the total current reservoir would be 26.32 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 pentachlorophenolate

The primary use of pentachlorophenol (PCP) in New Zealand was in the timber industry, either as sodium pentachlorophenolate, for use as an antiseptic 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 2024 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 (M Matharu Nufarm, pers comm 2026). 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 2024 and previous inventories 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
2024	500	0.1	0.000050

Certainty assessment for 2024

Activity data: Medium (because it is based on a historical 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 previous 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 2024 population figures of 27.2 million and 5.34 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 only oil refinery at Marsden Point closed permanently for economic reasons on 31 March 2022. The remaining facility is an import terminal for refined fuels, mainly petrol, diesel and jet fuel (Ministry for Business Innovation and Employment, 2025). With the cessation of refinery activities there are now no related dioxin releases.

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
2024	-	-	-

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, 2016 and 2020 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 2024 release estimates for the production of chemicals and consumer goods are summarised in Table 9-5, along with the totals for previous inventories.

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

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Black liquor combustion	0.031	-	-	-	-
Pulp & paper sludge disposal	-	-	0.034	0.084	-
Use of 2,4-D	-	-	-	0.000050	-
Petroleum production	-	-	-	-	-
2024 totals	0.031		0.034	0.084	
Totals for other inventory years					
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	0.0000039

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 Burial and Cremation Act 1964 provides a framework for the management of cemeteries and the operation of crematoria. The Act is currently under review (Ministry of Health, 2019). 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, 2025) show that for 2024 there were 36,674 registered deaths with 25,429 estimated cremations or 70 % of the total⁵. Applying the UNEP Toolkit factor of 10 µg TEQ per cremation (10 x 10⁻⁶ g TEQ/cremation) gives the release estimates shown in Table 10-1, along with the corresponding estimates from the previous inventories.

⁵ The total registered deaths included 201 repatriations and 17 used for anatomical research.

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	0.191
2016	20,129	10	0.201
2020	22,073	10	0.221
2024	25,429	10	0.254

Certainty assessment for 2024

Activity data: High (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

Following a substantial reduction in daily smoking rates from 16.4% to 6.8% between 2011 and 2023, daily smoking prevalence among adults 15 years and over in New Zealand has remained virtually unchanged since then (6.9% for 2023-2024 and 6.8% for 2024-2025) (Public Health Communication Centre Aotearoa, 2025).

Consumption of tobacco in New Zealand occurs from a combination of legal and illegally imported tobacco products. In 2024 1002 tonnes of legal tobacco products were consumed in New Zealand along with an estimated further 375 tonnes of illegal products (FTI Consulting, 2025).

Assuming 1 tonne of tobacco is the equivalent of 1 million cigarettes, New Zealand's total tobacco consumption of 1377 tonnes in 2024 equates to an annual estimated consumption of 1,377 million cigarettes. This is about 29% higher than the number derived for 2020 probably resulting from a more reliable estimate of the illegal trade.

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 estimates from the previous inventories.

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
2024	1377	0.1	0.00014

Certainty assessment for 2024

Activity data: Medium (because it is based on national statistics and an estimate for illegal imports)

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

10.6 Summary for this category

Release estimates for miscellaneous sources are summarised in Table 10-3.

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

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Crematoria	0.254	-	-	-	-
Tobacco smoking	0.00014	-	-	-	-
2024 totals	0.254				
2012 totals	0.191	-	-	-	-
2016 totals	0.202	-	-	-	-
2020 totals	0.221	-	-	-	-

11 Disposal and landfill

This category covers dioxin releases from the following sub-categories (UN 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 2023 there were 40 active Class 1 landfill facilities in New Zealand receiving municipal solid waste (Ministry for the Environment, 2025). 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 (Class 2), 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 disposed of in Class 1 landfills 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. At 1 July 2024 the levy was \$60 per tonne (Ministry for the Environment, 2025b)

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, 2025c). From July 2023 to June 2024 3,228,248 tonnes were deposited, with 2,829,929 tonnes listed for July 2024 to June 2025. Averaging these quantities gives an estimated total quantity of 3,029,089 tonnes of waste for 2024. Whereas the previous Inventory noted an increasing trend in the rate of municipal waste disposal to landfill, the current prevailing trend is one of a decreasing rate. That this is occurring while population growth steadily increases suggests that newly introduced waste minimisation and elimination policies may be having an effect, for instance the waste disposal levy described earlier. Also since Auckland Council introduced its kerbside food scraps collection service in April 2023, more than 30,000 tonnes of food waste have been diverted from landfill. (Auckland Council, 2024). Alternatively the decrease may reflect the depressed state of the building and construction sector in 2024 for which a 23% fall in waste material collected from commercial and industrial sites was reported (Scoop, 2025).

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 comments that at present New Zealand has insufficient data to determine how much of the waste disposed to municipal landfills comes from industrial sources but this should change in the near future with landfill facility owners now required to determine the exact proportion of waste disposed of at municipal landfills that originates from commercial and industrial sources. (Ministry for the Environment, 2025). Nevertheless 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 2024 are shown in Table 11-1, along with the corresponding estimates made for previous inventories.

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

Year	Activity Rate	Release factors		Annual releases (g TEQ/yr)	
		Water ($\mu\text{g TEQ}/\text{m}^3$)	Land ($\mu\text{g TEQ}/\text{tonne}$)	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
2024	3,029,089	0.5		1.515	
			5		15.15

Certainty assessment for 2024

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

Currently there are 320 active municipal wastewater treatment plants in New Zealand (Taumata Arowai, 2025). Many of these will have full secondary treatment and produce digested dewatered sludge. There are 1,510,000 residential connections to these treatment plants which service about 79% of the population (Beca, GHD and Boffa Miskell, 2020). 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.

Until 2022 Water New Zealand collated information on the volumes of liquid waste treated through New Zealand wastewater plants and this data was presented in a publicly available spreadsheet. Water NZ no longer maintains records of wastewater treatment plants. This role has fallen to the new Crown Entity, the Water Services Authority – Taumata Arowai - who took on responsibility for the environmental performance of public wastewater networks in October 2023. Taumata Arowai publish details such as the location of treatment plants, population serviced and administrative matters in its public register of wastewater networks – Hine korako – (<https://hinekorako.taumataarowai.govt.nz/publicregister/wastewater/>). However it does not yet provide details of annual wastewater treatment volumes either there or in its annual performance reports (Taumata Arowai, 2025).

In the absence of specific data on the volume of wastewater handled by New Zealand wastewater treatment plants, the 2024 volume has been estimated by applying a population growth factor of 1.07 to the volume of 497,162,000 m³/year recorded for the 2020 Inventory to give 531,963,340 m³/year.

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. At June 2024 New Zealand's estimated population was 5,338,500 (Stats NZ, 2024) so the 21% of individuals not connected to a treatment plant number 1,121,085. Consequently OWMS are estimated to have discharged 141,402,450 m³/year and therefore New Zealand's total wastewater production for 2024 was 673,365,790 m³.

There are no complete records of historical sewage sludge production in New Zealand. As with the 2020 Inventory the strategy of using a high volume well characterised treatment plant's sludge production as being representative of the country as a whole has been adopted. This allows the estimation of a per capita New Zealand sludge production value. Mangere Wastewater Treatment Plant in Auckland was chosen as the representative plant. For the treatment plant's population coverage of 1,423,900, the treatment plant produced 138,522 tonnes per annum at 20.6% wastewater solids or 37,328 dry tonnes per annum. (Y. Sun, Watercare Services Ltd, pers comm, 2025).

Applying these numbers to New Zealand's population of 5,338,500 in 2024 allows a national annual sewage sludge production of 139,951 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 previous 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 (20×10^{-6} g TEQ/tonne of sludge).

Sewage sludge makes a large contribution to New Zealand's dioxin releases with this source ranked third in significance behind landfill waste deposition and secondary aluminium processing. Consequently the relevance of the emission factor for local conditions is important to establish. A study of the dioxin levels in sewage sludges was conducted in 1998 by the New Zealand Water and Wastes Association (NZWWA, 1998). Results were presented for 6 samples conducted as part of the study with samples supplied by treatment plants in Timaru, Christchurch, Greytown, Fielding, Rotorua and Auckland (Mangere). In addition results for a separate study conducted on 3 other sites from New Plymouth, Wellington (Moa Point) and Christchurch were included. Results were presented as I-TEQ including contribution from half of the detection limit for non-detected species. The range of results was 5.64 – 108 µg TEQ/tonne dried sludge with a median of 11.5 µg TEQ/tonne dried sludge and mean of 23.9 µg TEQ/tonne dried sludge.

The mean and median result are not markedly different from the Toolkit default factor so this will continue to be used for determining output.

2024 release estimates are shown in Table 11-2, along with the corresponding estimates for previous inventories.

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						0.133
2016	Class 2	447.7		0.2		0.090	
			130,047		20		2.601
	Class 3	107.3		0.04		0.0043	
	Total releases						0.094
2020	Class 2	497.2		0.2		0.099	
			140,439		20		2.809
	Class 3	132.1		0.04		0.0053	
	Total releases						0.105
2024	Class 2	531.96		0.2		0.106	
			139,951		20		2.799
	Class 3	141.40		0.04		0.0057	
	Total releases						0.112

Certainty assessment for 2024

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

Emission factor: Medium (because they are based on Toolkit default factors validated by some historical local data).

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 (e.g. 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 2024 release estimates for the waste disposal and landfill sources are summarised in Table 11-3, along with the totals for previous inventories.

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

Category	2024 dioxin releases (g TEQ/yr)				
	Air	Water	Land	Product	Residue
Landfills, waste dumps and landfill mining	-	1.515	15.145	-	-
Sewage/sewage treatment	-	0.1120	-	-	2.799
2024 totals		1.627	15.145		2.799
Totals for other inventories					
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 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 2020: 225 to 311 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 2024 quantity of TCDD remaining in soil as a result of the past use of 2,4,5-T is estimated to be 186 - 259 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. 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 2024.

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. Consequently, the associated dioxin reservoir would be 0.66 kg TEQ (based on the Toolkit factor of 5×10^{-6} g TEQ per tonne). In the following 4 years to 2020, the quantity of waste increased by about 14 million tonnes to 146 million tonnes with the reservoir increasing to 0.73 kg TEQ. From 2020 to 2024 an additional 14 million tonnes was deposited. Thus, the existing reservoir in 2024 will be 0.80 kg TEQ.

13 Summary and discussion

The key points arising from the 2024 inventory are summarised and discussed below, along with some comparative data from the previous inventories. A table showing the complete data for all source categories and release vectors for 2016, 2020 and 2024 is given in Appendix 1 with total dioxin releases shown in Appendix 2.

13.1 Dioxin Release Estimates for 2024

The total estimated quantity of dioxin released in New Zealand for 2024 was 33.7 g TEQ. A plot of dioxin release estimates versus source category for 2024 is shown in Figure 13-1. 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. Annual Dioxin Releases for 2024 by Source (see Appendix 2 for details)

Figure 13-2 illustrates the share that these major source categories have for the total dioxin release. It shows that about 70% of New Zealand’s estimated dioxin releases can be attributed to four categories – disposal of municipal waste in landfills, secondary aluminium, sewage treatment and industrial wood (biomass) combustion. Combined with five other categories: metal shredding, industrial coal combustion, 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.

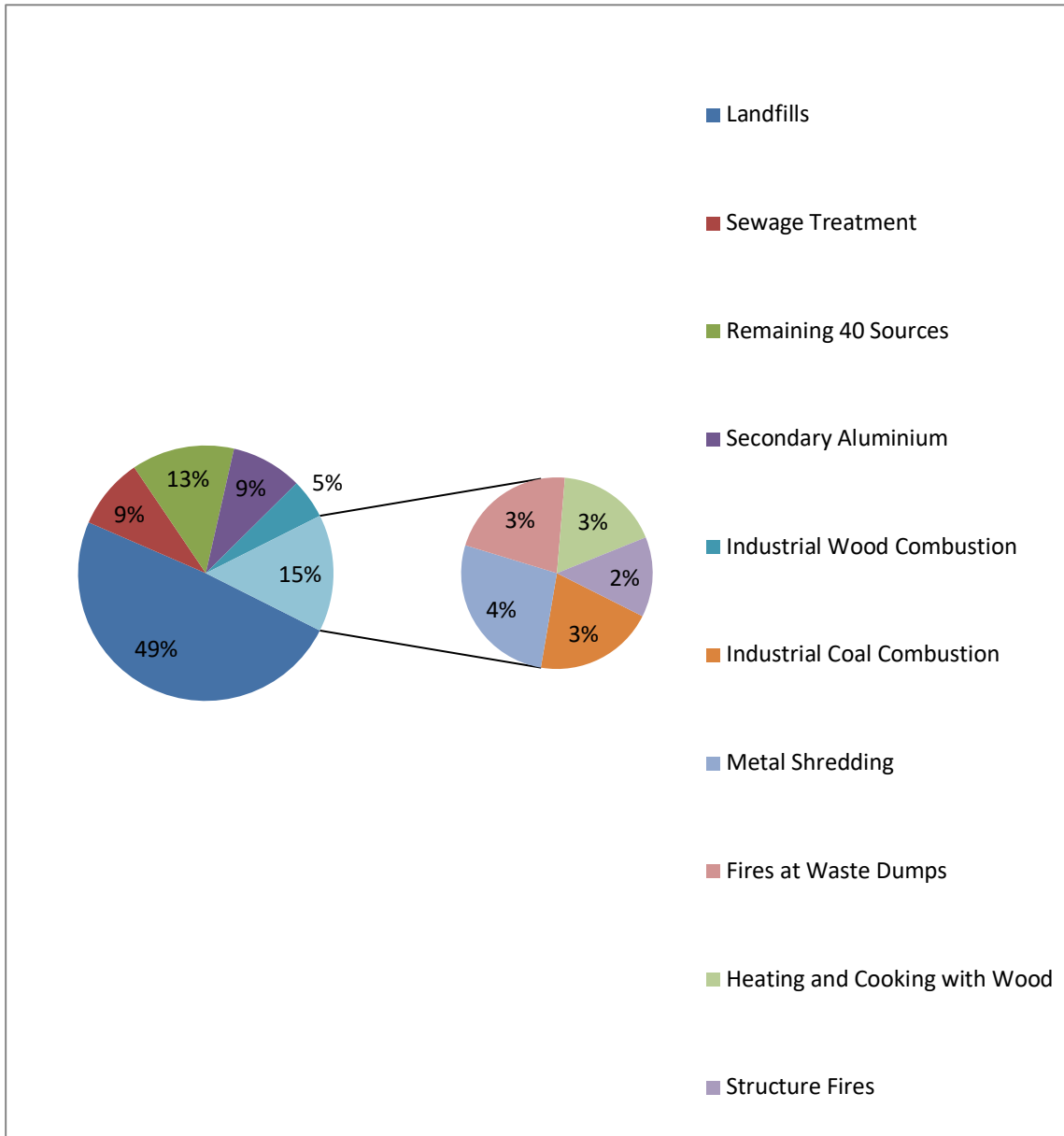


Figure 13-2 Plot Showing the Contribution of Major Release Categories for Dioxin

All members of New Zealand’s 5.3 million population contributed to the sewage treatment release in 2024 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 470,000 New Zealand households.

13.2 Changes in the dioxin release estimates over time

The dioxin release estimates for 2016, 2020 and 2024 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 2024 was 33.70 g TEQ. This can be compared with releases of 36.99 g TEQ in 2012, 37.10 g TEQ in 2016, and 36.60 g TEQ in 2020.

Table 13-1: Summary of the release estimates for 2016, 2020 and 2024

Major Source Categories		Annual Releases (g TEQ/a)											
		Air			Water			Land			Residue		
		2016	2020	2024	2016	2020	2024	2016	2020	2024	2016	2020	2024
1	Waste Incineration	0.37	0.49	0.743	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.010	0.011
2	Ferrous and Non-Ferrous Metal Production	0.26	0.20	0.171	0.02	0.02	0.017	0.27	0.09	0.165	5.54	4.37	4.45
3	Heat and Power Generation	3.24	3.72	3.27	0.00	0.00	0.00	0.07	0.27	0.259	0.79	0.91	0.788
4	Production of Mineral Products	0.08	0.07	0.074	0.00	0.00	0.00	0.06	0.04	0.031	0.04	0.05	0.044
5	Transportation	0.67	0.83	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Uncontrolled Combustion	2.60	2.75	2.58	0.00	0.00	0.00	0.86	0.48	0.525	0.00	0.00	0.00
7	Production of Chemicals and Consumer Goods	0.07	0.044	0.031	0.01	0.00	0.00	0.15	0.048	0.034	0.00	0.00	0.00
8	Miscellaneous	0.20	0.22	0.25	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	1.80	1.83	1.63	17.03	17.25	15.15	2.60	2.81	2.80
Totals		7.47	8.32	7.72	1.82	1.85	1.64	18.44	18.17	16.16	9.00	8.14	8.09
Totals* for all release vectors		2016			2020			2024					
		37.10			36.60			33.70					

(* 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 0.084 g TEQ for 2024.

Tables 13-2 and 13-3 show source categories which for 2024 had increases or decreases in their dioxin releases greater than 0.01 g compared with 2020 levels.

Table 13-2: Categories which had increases in release estimates for 2024 compared with 2020

Source Category	Change in Dioxin Release (g TEQ/annum)
Secondary aluminium production	+0.718
Medical waste incineration	+0.253
Structure fires	+0.194
Sewage/sewage treatment	+0.102
Primary steel production	+0.073
Agricultural residue burning	+0.038
Open burning of domestic wastes	+0.038
Crematoria	+0.033
Diesel engines	+0.025
2-stroke engines	+0.022
Cement production	+0.010

Compared with 2020 levels, increases in releases from secondary aluminium production, medical waste incineration and cement production result from increased production or material through put.

Structure fires are random unpredictable events and releases will fluctuate from year to year.

Agricultural residue burning, although deliberate, also fluctuates randomly from year to year.

Increases for sewage and sewage treatment and increases for open burning of domestic waste result from increases in population.

Releases from crematoria reflect an increase in population but also a trend of cremation being favoured over burial.

Diesel engine increases result from an increase in diesel fuel consumption.

Releases from primary steel production result from an increase in the estimate of waste materials produced.

Table 13-3: Categories which had decreases in release estimates for 2024 compared to 2020

Source Category	Change in Dioxin Release (g TEQ/annum)
Landfills	-2.31
Metal shredding	-0.64
Industrial and commercial coal use	-0.291
Heavy oil-fired engines	-0.271
Biomass power plants	-0.235
Forest fires	-0.213
Grassland and savannah fires	-0.086
Pulp and paper production	-0.052
Fires at waste dumps	-0.042
Coal fired electricity generation	-0.025
Copper brass and bronze production	-0.017
Petroleum production	-0.016
Household heating and cooking with biomass	-0.012
Household heating and cooking with coal	-0.012

Reductions in dioxin releases in 2024 compared to 2020 for landfills reflects a significant decrease in the amounts of waste sent to sanitary landfill.,

The reduction for metal shredding arises from a better assessment procedure for this category.

Industrial and commercial coal use reductions have arisen from reduced coal consumption as coal-fired boilers are replaced by units fired on electricity, biomass or natural gas.

Heavy oil fired engine releases have dropped because heavy fuel oil has largely been replaced by diesel in the marine transport industry

Forest fires, grassland and savannah fires and fires at waste dumps are random unpredictable events and releases will fluctuate from year to year.

Drops in releases for pulp and paper, copper brass and bronze and domestic petroleum production reflect lower production volumes. Petroleum production has actually ceased with the closure of the Marsden point oil refinery.

Reductions for household heating and cooking with biomass and coal are caused by lower fuel consumption as heat pumps replace wood and coal space heaters.

Trends in Dioxin Releases

Figures 13-3 and 13-4 display plots of dioxin releases versus source category for the current inventory and previous inventories. The sources have been categorised as major and minor to make the lesser sources more visible.

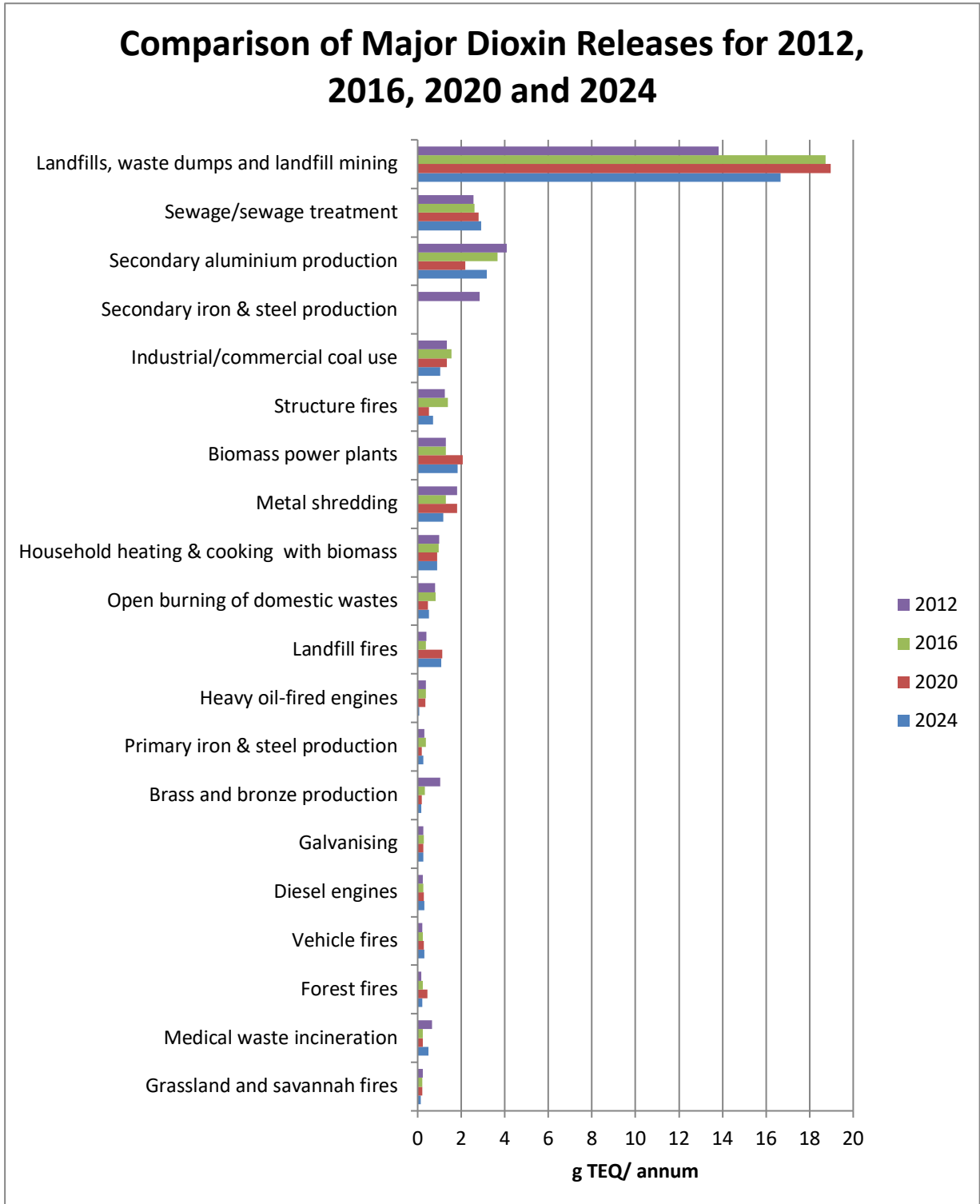


Figure 13-3. Major Sources' Dioxin Releases for 2012, 2016, 2020 and 2024 (see Appendix 2 for details)

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

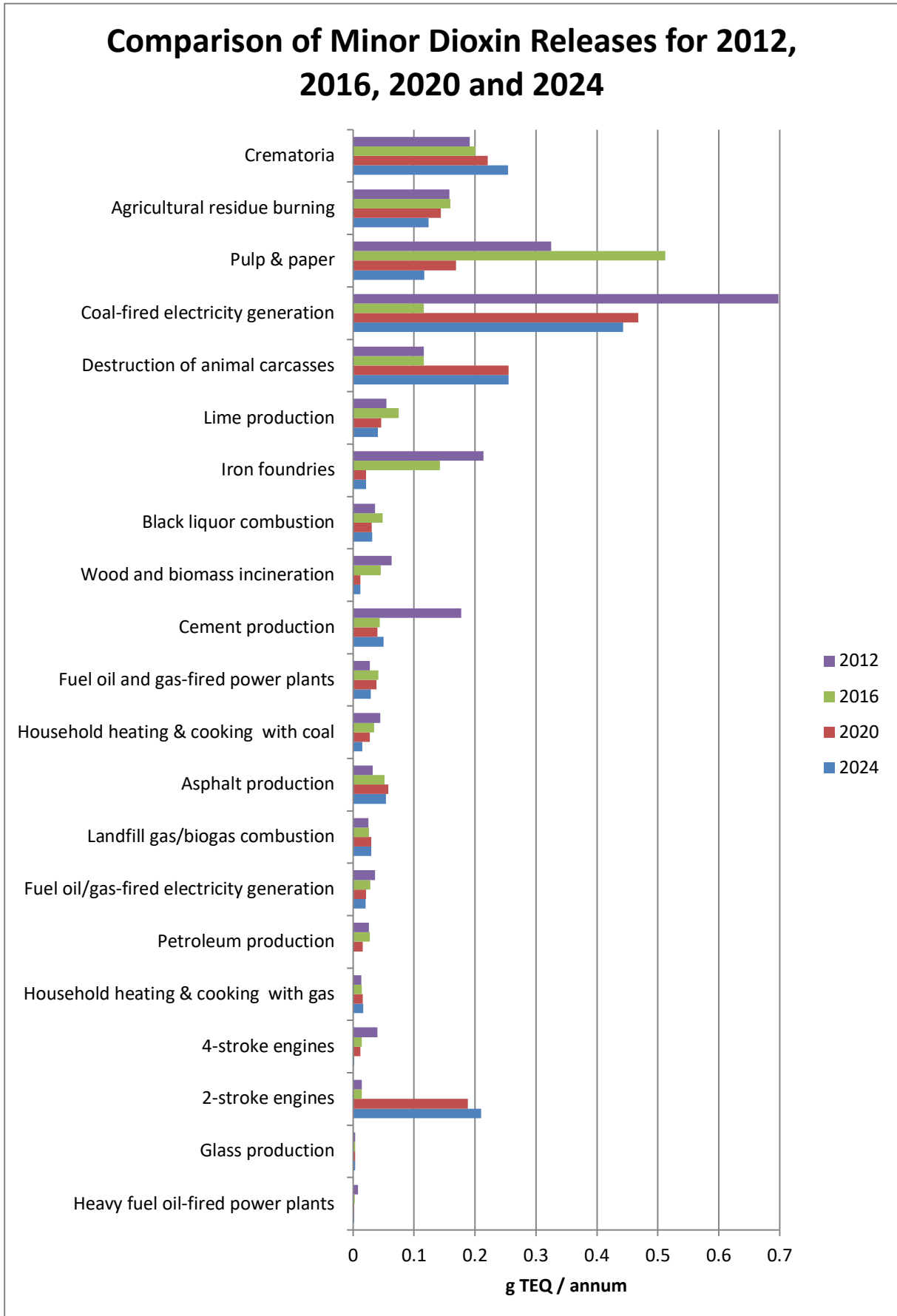


Figure 13-4. Minor Sources' Dioxin Releases for 2012, 2016, 2020 and 2024 (see Appendix 2 for details)

Regarding Figures E3 and E4, in many cases there are no obvious discernible trends for each category, however sewage treatment and crematoria show a consistent trend of increasing dioxin releases as their activities are based on population numbers. Emissions from diesel engine fuel combustion also show a consistent increase.

Household heating and cooking with biomass (wood) and coal both show a decline in dioxin releases as burners are replaced by electrical heat pumps and combustion activity decreases. Heavy oil fired engines and oil and gas fired electricity generation (largely gas) also show a systematic decline. In the case of heavy oil, diesel fuel is increasingly preferred for marine vessels and the dwindling supply of natural gas from New Zealand's fields has constrained gas electricity generation.

Declines in releases from iron foundries, brass and bronze production including copper and pulp and paper production result from decreases in production, in the latter case, bleached pulp.

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. The waste levy charges for municipal landfill deposition were \$60 per tonne in 2024, a significant increase from the \$20 charged in 2020. These charges will increase further to \$70 per tonne in July 2026 and \$75 per tonne in July 2027 (Parliamentary Counsel Office, 2024). The government continues to prioritise food and green waste in its waste and resource efficiency work programme (Ministry for the Environment, 2025d). Separate collection and composting of food waste has diverted more than 30,000 tonnes from Auckland landfills since the programme's implementation in 2023 (Auckland Council, 2024). Other initiatives include the Tyrewise stewardship scheme designed to address the 3.9 million tyres landfilled or illegally disposed (Parliamentary Counsel Office, 2025). Since 1 March 2024 a fee has been charged on newly imported tyres to assist end-of-life tyre collection and their conversion into new products. Future waste reduction proposals include a refundable deposit beverage container return scheme to help deal with the 2.5 billion single use drink containers purchased annually, over half of which are sent to landfill. The refundable deposit would be added to the price of a purchase (Ministry for the Environment, 2025d).

Changes in Production Focus

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 has removed sources of dioxin release such as the combustion of volatile process gases in flares, wastewater, and solid wastes.

As noted in Section 4.3.2, New Zealand's only secondary steel manufacturing plant, Pacific Steel, ceased operations in 2015. However New Zealand Steel plans to open a new electric arc furnace in 2027 at its Glenbrook plant to process scrap steel. Fast track consent has also just been issued for a structural steel manufacturing plant at Hampton Downs near Auckland which will include a scrap-steel shredding plant and electric arc furnaces to produce structural steel (New Zealand Herald, 2026). At present the feedstock for these plants is being exported so future processing in New Zealand will lead to new dioxin releases.

As discussed in Section 4.1.1 Fonterra completed retirement of its North Island coal fired plant in 2024 and is currently installing electrical powered boilers at three North Island processing locations.

13.4 Global Perspective

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 2024 release of 33.7 g TEQ combined with a population of 5.34 million gives a per capita value of 6.3 g TEQ per million people. The per capita values for 2012, 2016 and 2020 were 8.4, 7.9 and 7.3 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)

Another measure of dioxin release is emission density. A recent review of the global impact of dioxin emissions gave the following dioxin emission densities for each of the six continents (Mathew, Somanathan, Tirpude, Pilai, Mondal and Arfin, 2025):

- 1.64 mg TEQ per km² in Asia
- 1.40 TEQ per km² in Africa
- 0.33 mg TEQ per km² in South America
- 0.32 mg TEQ per km² in Europe
- 0.23 mg TEQ per km² in Oceania
- 0.22 mg TEQ per km² in North America

The review commented that open-pit burning techniques were traditionally regarded as the leading cause of dioxins world-wide and that unintentional fires also significantly influence dioxin emissions. Other significant global sources are metal production, heat and power generation and landfilling.

A review of the current state and main sources of dioxins around the world was conducted in 2015 (Dopico & Gomez, 2015). 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.

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.

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).

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

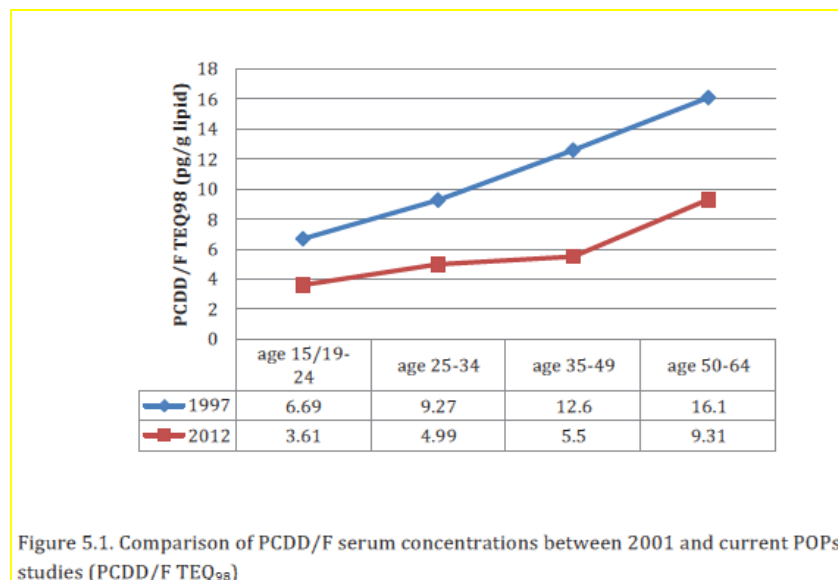


Figure 5.1. Comparison of PCDD/F serum concentrations between 2001 and current POPs studies (PCDD/F TEQ₉₈)

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

Historically there have been concerns about the transfer of a dioxin body burden from mother to child, both *in-utero* and during breast feeding because earlier it was accepted that dioxin had a relatively long half-life in the body of 7- 11 years. Recent research has shown that dioxin half lives in children and adolescents are much shorter. For instance the half life in infants (0 - 12 months) has been estimated to be 0.4 years and for children aged between one and six years the half life is in the range 0.5 – 1 year. Similarly adolescents have a range of 1.8 – 2.4 years and at age 40 it is expected to be about 5.1 years. Coupled with the fact that dietary exposure to dioxin, the main route of entry to the body, has reduced dramatically over the last 40 years, researchers are having to re-visit risk assessment implications with respect to evaluating accumulated body burdens and dose-response trends in humans.(Kreger and Loccisano, 2025).

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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)		
	2016	2020	2024	2016	2020	2024	2016	2020	2024	2016	2020	2024
Hazardous waste incineration	0.00033	-	-	-	-	-	-	-	-	0.000017	0.0000003	
Medical waste incineration	0.234	0.234	0.486	-	-	-	-	-	-	0.0016	0.0016	0.0032
Sewage sludge incineration	0.00023	0.00039	0.00046	-	-	-	-	-	-	0.00071	0.00079	0.00087
Wood and biomass incineration ²	0.015	0.0039	0.0018	-	-	-	-	-	-	0.03	0.0078	0.0036
Destruction of animal carcasses	0.116	0.255	0.255	-	-	-	-	-	-	-	-	-
Primary iron & steel production	0.078	0.081	0.077	0.0149	0.0165	0.0169	0.274	0.0866	0.165	-		-
Secondary iron & steel production	-	-	-	-	-		-	-	-	-	-	-
Iron foundries	0.072	0.011	0.011	-	-		-	-	-	0.07	0.0104	0.010
Galvanising	0.0073	0.00581	0.0057	-	-	-	-	-	-	0.268	0.261	0.253
Secondary aluminium production	0.039	0.023	0.028	-	-	-	-	-	-	3.63	2.17	2.885
Lead production	0			-	-	-	-	-	-	-	-	-
Brass and bronze production	0.014	0.008	0.005	-	-		-	-	-	0.323	0.178	0.163
Metal shredding	0.05	0.07	0.045	-	-	-	-	-	-	1.25	1.75	1.135

Dioxin Inventory Update

Category	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2016	2020	2024	2016	2020	2024	2016	2020	2024	2016	2020	2024
Coal-fired electricity generation	0.0484	0.195	0.185	-	-	-	0.0678	0.273	0.259	-		
Industrial/commercial coal use	1.232	1.053	0.8232	-	-	--	-	-	-	0.327	0.279	0.218
Heavy fuel oil-fired power plants	0.0026	0.0016	0.0019	-	-	-	-	-	-	-		
Fuel oil/gas-fired electricity generation	0.028	0.0021	0.0195	-	-	-	-	-	-	-		
Fuel oil and gas-fired power plants	0.041	0.038	0.029	-	-	-	-	-	-	-		
Biomass power plants	1.000	1.584	1.403	-	-	-	-	-	-	0.300	0.475	0.421
Landfill gas/biogas combustion	0.028	0.030	0.030	-	-	-	-	-	-	-		
Household heating & cooking with biomass	0.812	0.754	0.7442	-	-	-	-	-	-	0.162	0.151	0.149
Household heating & cooking with coal	0.034	0.027	0.0150	-	-	-	-	-	-	0.00018	0.00014	0.000078
Household heating & cooking with oil	0.0012	0.0010	0.0010	-	-	-	-	-	-	-		
Household heating & cooking with gas	0.0144	0.0162	0.0168	-	-	-	-	-	-	-		
Cement production	0.044	0.040	0.050	-	-	-	-	-	-	-	-	
Lime production	0.0173	0.0107	0.0096	-	-	-	0.0576	0.035	0.031	-	-	
Brick production	0.0002	0.00022	0.00024	-	-	-	-	-	-	-	-	

Dioxin Inventory Update

Category	Air (g TEQ / annum)			Water (g TEQ / annum)			Land (g TEQ / annum)			Residue (g TEQ / annum)		
	2016	2020	2024	2016	2020	2024	2016	2020	2024	2016	2020	2024
Glass production	0.0031	0.0031	0.0031	-	-	-	-			-	-	-
Pottery and ceramics	0.00075	0.00079	0.00084	-	-	-	-			-	-	-
Asphalt production	0.0098	0.011	0.0102	-	-	-	-			0.042	0.047	0.044
4-stroke engines	0.0142	0.0124	0.0021	-	-	-	-			-	-	-
2-stroke engines	0.014	0.188	0.210	-	-	-	-			-	-	-
Diesel engines	0.266	0.285	0.310	-	-	-	-			-	-	-
Heavy oil-fired engines	0.377	0.343	0.0716	-	-	-	-			-	-	-
Agricultural residue burning	0.145	0.130	0.113	-	-	-	0.0145	0.0130	0.0113	-	-	-
Forest fires	0.205	0.380	0.195	-	-	-	0.0307	0.057	0.0293	-	-	-
Grassland and savannah fires	0.164	0.171	0.104	-	-	-	0.0493	0.0513	0.0313	-	-	-
Fires at waste dumps	0.365	1.094	1.053	-	-	-	0.0122	0.0364	0.0351	-	-	-
Structure fires	0.698	0.262	0.359	-	-	-	0.698	0.262	0.359	-	-	-
Open burning of domestic wastes	0.807	0.466	0.503	-	-	-	0.0202	0.0117	0.0126	-	-	-
Vehicle fires	0.209	0.248	0.256	-	-	-	0.038	0.0446	0.0461	-	-	-
Black liquor combustion	0.0483	0.0304	0.0310	-	-	-				-	-	-
Pulp & paper sludge disposal	-			-	-	-	0.146	0.048	0.0335	-	-	-
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)		
	2016	2020	2024	2016	2020	2024	2016	2020	2024	2016	2020	2024
Petroleum production	0.019	0.0135	-	0.0084	0.0031	-	-	-	-	0.000017	0.0000039	-
Crematoria	0.201	0.221	0.254							-		
Tobacco smoking	0.00021	0.000098	0.000138							-		
Landfills, waste dumps and landfill mining	-			1.703	1.725	1.515	17.03	17.25	15.145	-		
Sewage/sewage treatment	-			0.0938	0.105	0.1120				2.601	2.809	2.799
Totals³	7.94	8.32	7.72	1.82	1.85	1.64	18.44	18.17	16.16	9.00	8.14	8.09

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 0.0837g TEQ for 2024
- 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 2016 (g TEQ / annum)	Total Dioxin for 2020 (g TEQ / annum)	Total Dioxin for 2024 (g TEQ / annum)
Hazardous waste incineration	0.00035	0.000006	0
Medical waste incineration	0.236	0.236	0.489
Sewage sludge incineration	0.00095	0.0012	0.00133
Wood and biomass incineration	0.045	0.012	0.0054
Destruction of animal carcasses	0.116	0.255	0.255
Primary iron & steel production	0.367	0.185	0.258
Secondary iron & steel production	0	0	0
Iron foundries	0.142	0.021	0.021
Galvanising	0.275	0.267	0.259
Secondary aluminium production	3.669	2.195	3.165
Lead production	0	0	0
Brass and bronze production	0.337	0.185	0.168
Metal shredding	1.30	1.82	1.18
Coal-fired electricity generation	0.116	0.468	0.443
Industrial/commercial coal use	1.559	1.332	1.041
Heavy fuel oil-fired power plants	0.0026	0.0016	0.0019
Fuel oil/gas-fired electricity generation	0.028	0.021	0.020
Fuel oil and gas-fired power plants	0.041	0.038	0.029
Biomass power plants	1.300	2.059	1.824
Landfill gas/biogas combustion	0.026	0.030	0.030
Household heating & cooking with biomass	0.974	0.905	0.893
Household heating & cooking with coal	0.034	0.027	0.015
Household heating & cooking with oil	0.0012	0.0010	0.0010
Household heating & cooking with gas	0.014	0.016	0.017
Cement production	0.044	0.040	0.050
Lime production	0.075	0.046	0.041
Brick production	0.00026	0.00029	0.00031
Glass production	0.0031	0.0031	0.0031
Pottery and ceramics	0.00075	0.00079	0.00084
Asphalt production	0.052	0.058	0.054

4-stroke engines	0.014	0.012	0.0021
2-stroke engines	0.014	0.188	0.210
Diesel engines	0.266	0.285	0.310
Heavy oil-fired engines	0.377	0.343	0.072
Agricultural residue burning	0.160	0.144	0.124
Forest fires	0.236	0.437	0.224
Grassland and savannah fires	0.213	0.222	0.136
Fires at waste dumps	0.377	1.130	1.088
Structure fires	1.396	0.524	0.718
Open burning of domestic wastes	0.827	0.478	0.516
Vehicle fires	0.247	0.292	0.302
Black liquor combustion	0.048	0.030	0.031
Pulp & paper	0.512	0.169	0.117
Use of 2,4-D	0.00005	0.00005	0.00005
Petroleum production	0.027	0.016	0
Crematoria	0.201	0.221	0.254
Tobacco smoking	0.00021	0.000098	0.00014
Landfills, waste dumps and landfill mining	18.733	18.970	16.660
Sewage/sewage treatment	2.601	2.809	2.911