1990–2023 | Volume 1, chapters 1–10

New Zealand’s Greenhouse Gas Inventory

Fulfilling reporting requirements under the United Nations Framework Convention on Climate Change and the Paris Agreement

Te Rārangi Haurehu Kati Mahana a Aotearoa

Ministry for the Environment
Manatū Mō Te Taiao

Te Kāwanatanga o Aotearoa
New Zealand Government

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Abbreviations

AAP	average animal population
AD	activity data
AGB	above-ground biomass
AG_N	above-ground nitrogen residue
AIC	Akaike information criterion
ANZSIC	Australian and New Zealand Standard Industrial Classification
APC	Agricultural Production Census
APS	Agricultural Production Survey
BGB	below-ground biomass
BG_N	below-ground nitrogen residue
BOD	biochemical oxygen demand
C	carbon
C_2F_6	perfluoroethane
C_3F_8	perfluoropropane
CaO	calcium oxide
$Ca(OH)_2$	calcium hydroxide
CCF_i	carbon content factor
CF_4	perfluoromethane
CFC	chlorofluorocarbon
CH_4	methane
CNG	compressed natural gas
CO	carbon monoxide
COD	chemical oxygen demand
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
CRA	Calculation and Reporting Application
CRF	common reporting format
CRT	common reporting table
CSC	carbon stock change
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAP	diammonium phosphate
DCD	dicyandiamide
DDOC	decomposable degradable organic carbon
DEF	diesel exhaust fluid
DM	dry matter
DMD	dry-matter digestibility
dmf	dry-matter conversion factor
DMI	dry-matter intake
DOC	degradable organic carbon
DOCf	fraction of degradable organic carbon
DPFI	Delivery of Petroleum Fuels by Industry survey
EEZ	Exclusive Economic Zone

EF	emission factor
EF_3	emission factor for N_2O emissions from urine and dung nitrogen
$EF_{3,PRP}$	emission factor for N_2O emissions from urine and dung nitrogen deposited on pasture, range and paddock by grazing animals
EPA	Environmental Protection Authority
ERT	expert review team
ETF	Enhanced Transparency Framework
ETS	Emissions Trading Scheme
FAME	fatty acid methyl ester
FAOSTAT	Database produced by the Statistics Division of the Food and Agriculture Organization of the United Nations
FDM	faecal dry matter
FENZ	Fire and Emergency New Zealand
F-gases	fluorinated gases
FOD	first order decay
FRL	forest reference level
GDP	gross domestic product
GEI	gross energy intake
Gg	gigagram(s)
GHG	greenhouse gas
GIS	geographic information system
GJ	gigajoule(s)
GPS	global positioning system
GRA	Global Research Alliance on Agricultural Greenhouse Gases
GST	goods and services tax
GWB	grassland with woody biomass
ha	hectare(s)
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HFO	hydrofluoroolefin
HI	harvest index
HWP	harvested wood products
IEA	International Energy Agency
IE	included elsewhere
IEF	implied emission factor
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
kg	kilogram(s)
kha	kilohectare(s)
kJ	kilojoule(s)
kt	kilotonne(s)
l	litre
LCDB	Land Cover Database
LCDB5	Land Cover Database version 5
LFG	landfill gas
LIC	Livestock Improvement Corporation

LiDAR	Light Detection and Ranging
LPG	liquefied petroleum gas
LTA	long-term average
LUCAS	Land Use and Carbon Analysis System
LUE	land use effect
LULUCF	Land Use, Land-Use Change and Forestry
LUM	land use map
m^3	cubic metres
MBIE	Ministry of Business, Innovation and Employment
MCF	methane conversion factor
MDI	metered dose inhaler
MDO	marine diesel oil
ME	metabolisable energy
MfE	Ministry for the Environment
MgO	magnesium oxide
MiCORE	Ministry of Climate, Oceans and Resilience (Tokelau)
MJ	megajoule(s)
MMS	manure management system
MoU	memorandum of understanding
MOS	Monthly Oil Supply survey
MPGs	modalities, procedures and guidelines
MPI	Ministry for Primary Industries
MSW	municipal waste disposal
Mt	megatonne(s) or million tonne(s)
MW	megawatt(s)
N	nitrogen
N_2O	nitrous oxide
NA	not applicable
NDC1	first Nationally Determined Contribution
NDVI	normalized difference vegetation index
NE	not estimated
NEFD	National Exotic Forest Description
N_{ex}	nitrogen excretion rates
NF_3	nitrogen trifluoride
NH_3	ammonia
NIR	national inventory report
NMVOC	non-methane volatile organic compound
NO	not occurring
NO_3	nitrate
NO_x	nitrogen oxides (other than nitrous oxide)
NZAGRC	New Zealand Agricultural Greenhouse Gas Research Centre
NZAS	New Zealand Aluminium Smelters Limited
NZD	New Zealand dollars
NZ ETS	New Zealand Emissions Trading Scheme
NZLRI	New Zealand Land Resource Inventory
NZU	New Zealand Unit

ODS	ozone depleting substances
OECD	Organisation for Economic Co-operation and Development
PFC	perfluorocarbon
PGgRc	Pastoral Greenhouse Gas Research Consortium
PJ	petajoule(s)
PSP	permanent sample plot
PV	photovoltaics
QA	quality assurance
QC	quality control
R_{BG}	ratio of below-ground residues to the harvest yield
RGG	Reporting Governance Group
SF_6	sulphur hexafluoride
SO_2	sulphur dioxide
SOC	soil organic carbon
Soil CMS	Soil Carbon Monitoring System
SO_X	sulfur oxides
SWDS	solid waste disposable sites
t	tonne(s)
t C	tonne(s) carbon
TE	total emissions
TACCC	transparency, accuracy, completeness, consistency and comparability
TJ	terajoule(s)
t/kt	tonne(s) per kilotonne
TOW	total organic product in wastewater
UEF	unique emission factor
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

The 2025 submission of *New Zealand's Greenhouse Gas Inventory* (the Inventory) contains national greenhouse gas emissions estimates for the period 1990 to 2023.

Key points

In 2023

- New Zealand's gross greenhouse gas emissions were 76,416 kilotonnes carbon dioxide equivalent (kt CO_2-e), comprising 41 per cent carbon dioxide, 48 per cent methane, 9 per cent nitrous oxide and 2 per cent fluorinated gases.
- The two largest contributors to gross emissions were the Agriculture sector, at 53 per cent, and the Energy sector, at 38 per cent.
- The Land Use, Land-Use Change and Forestry (LULUCF) sector offset 26 per cent of New Zealand's gross emissions.
- New Zealand's net emissions were 56,219 kt CO_2-e.

Between 2022 and 2023

- Gross emissions decreased by 2 per cent or 1,567 kt CO_2-e, which was largely due to a decrease in emissions from the Agriculture sector (by 2 per cent or 908 kt CO_2-e). The decrease in Agriculture sector emissions was driven mainly by reductions in *Enteric fermentation* from the *Sheep* and *Dairy cattle* categories and a reduction in *Limestone* emissions.
- Emissions from the Energy sector decreased by 1 per cent (225 kt CO_2-e), due to a combination of emissions reductions in the *Petroleum refining*, *Public electricity and heat production* and *Commercial/institutional* categories.
- Emissions from the Industrial Processes and Product Use sector decreased by 9 per cent (412 kt CO_2-e), due largely to emissions reductions in the *Refrigeration and air conditioning* category.
- Emissions from the Waste sector decreased by 1 per cent (20 kt CO_2-e), due to emissions reductions from *Solid waste disposal*, as a result of ongoing improvements in municipal landfill management.
- Net emissions decreased by 4 per cent (2,391 kt CO_2-e), due to the overall decrease in gross emissions and a decrease in net emissions of 4 per cent (824 kt CO_2-e) from the LULUCF sector. The decrease in net emissions from the LULUCF sector was largely due to emissions reductions in the *Forest land* and *Grassland* categories, as less planted forests were harvested or deforested.

Since 1990

- New Zealand's gross and net emissions peaked in 2006 at 85,740 kt CO_2-e and 63,491 kt CO_2-e, respectively.
- New Zealand's gross emissions increased by 13 per cent (8,737 kt CO_2-e). The five emission sources that contributed the most to this increase were:
  – *Enteric fermentation* from *Dairy cattle* largely due to an increase in the dairy cattle population (methane), an increase of 8,630 kt CO_2-e
  – *Road transportation* due to traffic growth (carbon dioxide), an increase of 5,851 kt CO_2-e
  – *Agricultural soils* due to increased fertiliser use (nitrous oxide), an increase of 1,717 kt CO_2-e
  – *Manufacturing industries and construction*, due to increased fuel use (carbon dioxide), an increase of 1,367 kt CO_2-e
  – *Refrigeration and air-conditioning* (hydrofluorocarbons), due to growth in refrigeration and air-conditioning use, in addition to the replacement of ozone depleting substances, an increase of 1,011 kt CO_2-e.

- Emissions from the Waste sector decreased by 11 per cent (361 kt CO_2-e) mainly from *Solid waste disposal* as a result of ongoing improvements in the management of municipal landfills, particularly in landfill gas recovery.
- New Zealand's net emissions have increased by 30 per cent (12,874 kt CO_2-e) largely due to the increase in gross emissions in addition to the increase in emissions in the *Forest land* and *Grassland* categories as a result of higher levels of planted forest harvest and deforestation.

Inventory improvements

- Improvements were introduced to the 2025 submission of the Inventory that required emissions estimates to be recalculated across the time series back to 1990.
- The overall impact of improvements on New Zealand's gross emissions estimates was a decrease of 2 per cent (1,279 kt CO_2-e) in 1990 and a decrease of 1 per cent (412 kt CO_2-e) in 2022.
- The overall impact of improvements on New Zealand's net emissions estimates, which include the LULUCF sector, was a decrease of 3 per cent (1,289 kt CO_2-e) in 1990 and a decrease of 1 per cent (546 kt CO_2-e) in 2022.

ES.1 Background information on greenhouse gas inventories and climate change

New Zealand's Greenhouse Gas Inventory (the Inventory) is the official annual estimate of all anthropogenic (human-induced) emissions and removals of greenhouse gases (GHGs) in New Zealand.

The Inventory provides the official basis for measuring New Zealand's progress under the United Nations Framework Convention on Climate Change (UNFCCC or the Convention) and the Paris Agreement, and for tracking its emissions reduction targets.

New Zealand ratified the Convention on 16 September 1993 and the Paris Agreement on 4 October 2016. This commits New Zealand to submitting the Inventory under the Convention by 15 April of each year. From the 2024 reporting year onwards, the obligations for submitting annual greenhouse gas inventories under the Convention are met by applying the reporting guidelines for greenhouse gas inventories agreed to under the Paris Agreement (decision 1/CP.24).

New Zealand's ratification of the Convention and the Paris Agreement was extended to include Tokelau on 13 November 2017. Greenhouse gas emissions and removals estimates from Tokelau have therefore been included in the Inventory since the 2019 submission.

The Inventory adheres to the modalities, procedures and guidelines (MPGs) contained in the annex to decision 18/CMA.1 (UNFCCC, 2018) and the guidance for operationalising the MPGs contained in annexes I and V to decision 5/CMA.3 (UNFCCC, 2021). These MPGs supersede the measurement, reporting and verification system established by decisions 1/CP.16 and 2/CP.17. The Inventory includes a comprehensive and detailed description of the methodologies applied for estimating national sources and sinks of anthropogenic GHGs, and a common and consistent format that enables Parties to the Convention and Paris Agreement to compare the relative contribution of different emissions sources and GHGs to climate change.

The Inventory comprises a national inventory document and a set of common reporting tables (CRTs). The national inventory document is a narrative that presents key findings, major emissions trends, and methodologies used for estimating emissions and removals.

It also includes sections on the uncertainties of the emissions estimates, recalculations and improvements. The CRTs contain inventory estimates that cover all emissions and removals from human-induced activities in New Zealand.

Inventory reporting covers seven direct GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). These are the most important GHGs directly emitted as a result of human activities. Indirect GHGs are also included in this report; however, only emissions and removals of the direct GHGs are included in estimates of total national emissions.

New Zealand's GHGs are reported under five sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); and Waste. Tokelau's emissions are also reported separately by sector as 'Other'.

ES.2 Summary of trends related to national emissions and removals

Gross emissions

Gross emissions include those from the Energy, IPPU, Agriculture and Waste sectors, and Tokelau, but do not include emissions and removals from the LULUCF sector.

2022–2023

In 2023, gross emissions were 76,416.3 kilotonnes carbon dioxide equivalent (kt CO_2-e). Between 2022 and 2023, New Zealand's gross emissions decreased by 2.0 per cent (1,566.8 kt CO_2-e). While emissions decreases were observed in all sectors, the largest reductions were in the Agriculture sector, with a decrease of 2.2 per cent (908.4 kt CO_2-e), due to the combined impact of reductions in the *Enteric fermentation* from *Sheep*, *Dairy cattle* and *Liming* categories. The largest contributors by category to the overall decrease in emissions were from:

- *Product uses as substitutes for ODS* (HFCs)
- *Enteric fermentation – Sheep* (CH_4)
- *Enteric fermentation – Dairy cattle* (CH_4)
- *Liming* (CO_2).

The reduction in emissions from the *Enteric fermentation* from *Sheep* category was due to a decrease in the sheep population. This is a continuation of the long-term trend, which reflects the declining profitability of sheep farming relative to other land uses.

The reduction in emissions from the *Enteric fermentation* from *Dairy cattle* category was due to a decrease in the dairy cattle population.

The reduction in emissions from *Liming* was due to a reduction in *Limestone* emissions, which reflects a continuation of the long-term trend of decreasing limestone application combined with historically high year-to-year variation.

Emissions from the Energy, IPPU and Waste sectors decreased by 0.8 per cent, 9.3 per cent and 0.7 per cent respectively. Emissions from Tokelau decreased by 10.4 per cent, due largely to a reduction in diesel fuel use.

While the Agriculture sector contributed the overall largest decrease in emissions between 2022 and 2023, the category with the largest decrease was in IPPU: HFCs from *Product uses as substitutes for ODS* represented the largest decrease in emissions (352.6 kt CO_2-e). The main reasons for the decrease were that, following two exceptional years impacted by an increase in heat pump sales and an associated increase in emissions from the disposal of retired equipment, heat pump sales slowed in 2023 and disposal emissions decreased.

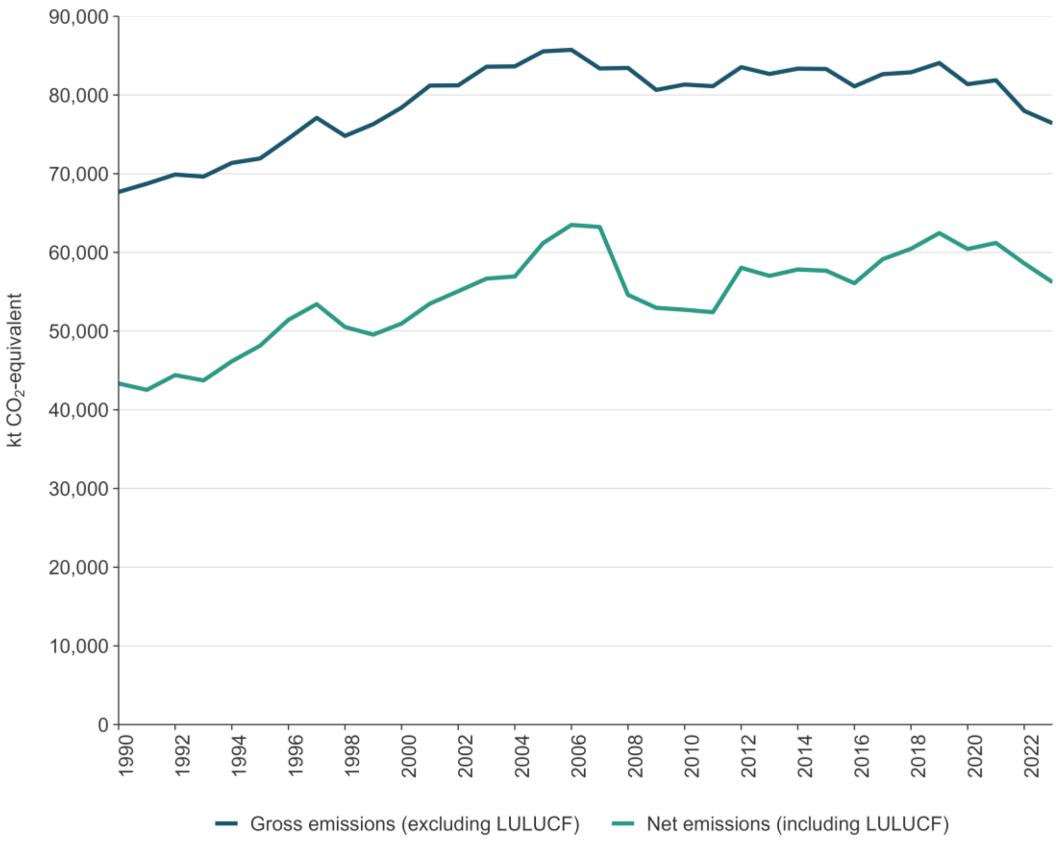
1990–2023

In 1990, New Zealand's gross GHG emissions were 67,678.9 kt CO_2-e. Between 1990 and 2023, GHG emissions increased by 12.9 per cent (8,737.4 kt CO_2-e) to 76,416.3 kt CO_2-e in 2023 (see figure ES 2.1).

From 1990 to 2023, the average annual growth in gross emissions was 0.4 per cent.

The emissions categories that contributed the most to this increase in gross emissions were: *Enteric fermentation*[1] from *Dairy cattle*, *Road transportation*, *Agricultural soils*, *Manufacturing industries and construction* (particularly from the *Food processing, beverages and tobacco* category) and *Product uses as substitutes for ozone depleting substances (ODS)*.

Figure ES 2.1 New Zealand's gross and net emissions (under the Convention), from 1990 to 2023



1 Methane emissions produced from the digestive process in ruminant livestock.

Restrictions on activity and movement as part of the response to the coronavirus (COVID-19) pandemic during the 2020 calendar year saw significant disruption to economic activity throughout New Zealand. The effects on the Energy sector were particularly notable, with national energy consumption falling 7.2 per cent compared with the 2019 level. The sector saw a slight rebound during 2021, but energy consumption has remained well below pre-2020 levels in subsequent years.

Net emissions

Net emissions include gross emissions as defined above (i.e., from the Energy, IPPU, Agriculture and Waste sectors, including Tokelau) and net emissions from the LULUCF sector.

2022–2023

In 2023, New Zealand's net emissions were 56,219.2 kt CO_2-e. Between 2022 and 2023, New Zealand's net emissions decreased by 4.1 per cent (2,391.2 kt CO_2-e). This was due to the overall decrease in gross emissions and a decrease in net emissions of 4.3 per cent (824.4 kt CO_2-e) from the LULUCF sector. The decrease in net emissions was driven by a decrease in emissions in *Forest land remaining forest land* and *Land converted to grassland* in the LULUCF sector, and the reduction in emissions from *Product uses as substitutes for ODS* in the IPPU sector.

The decrease in the LULUCF sector was largely driven by emissions reductions of 952.1 kt CO_2-e in the *Forest land* category, as harvesting rates in planted forests reduced between 2022 and 2023. However, this decrease was partially offset by a reduction in net removals from the *Harvested wood products* category of 774.0 kt CO_2-e. There was also a decrease in emissions of 684.7 kt CO_2-e from the *Grassland* category due to lower deforestation rates occurring in 2023 compared with 2022.

1990–2023

In 1990, New Zealand's net emissions were 43,344.8 kt CO_2-e. Between 1990 and 2023, net GHG emissions increased by 29.7 per cent (12,874.3 kt CO_2-e) to 56,219.2 kt CO_2-e (see figure ES 2.1).

The four categories that contributed the most to the increase in net emissions between 1990 and 2023 were: *Land converted to forest land*; *Enteric fermentation* from *Dairy cattle*; *Road transportation;* and *Agricultural soils*.

Greenhouse gas trends

Inventory reporting under the Convention covers the following direct GHGs: CO_2, CH_4, N_2O, SF_6, PFCs, HFCs and NF_3. No NF_3 data are included in this report because NF_3 emissions do not occur in New Zealand.

Table ES 2.1 provides a summary of emissions for each gas in 1990 and 2023 and the changes since 1990. This is also illustrated in figure ES 2.2.

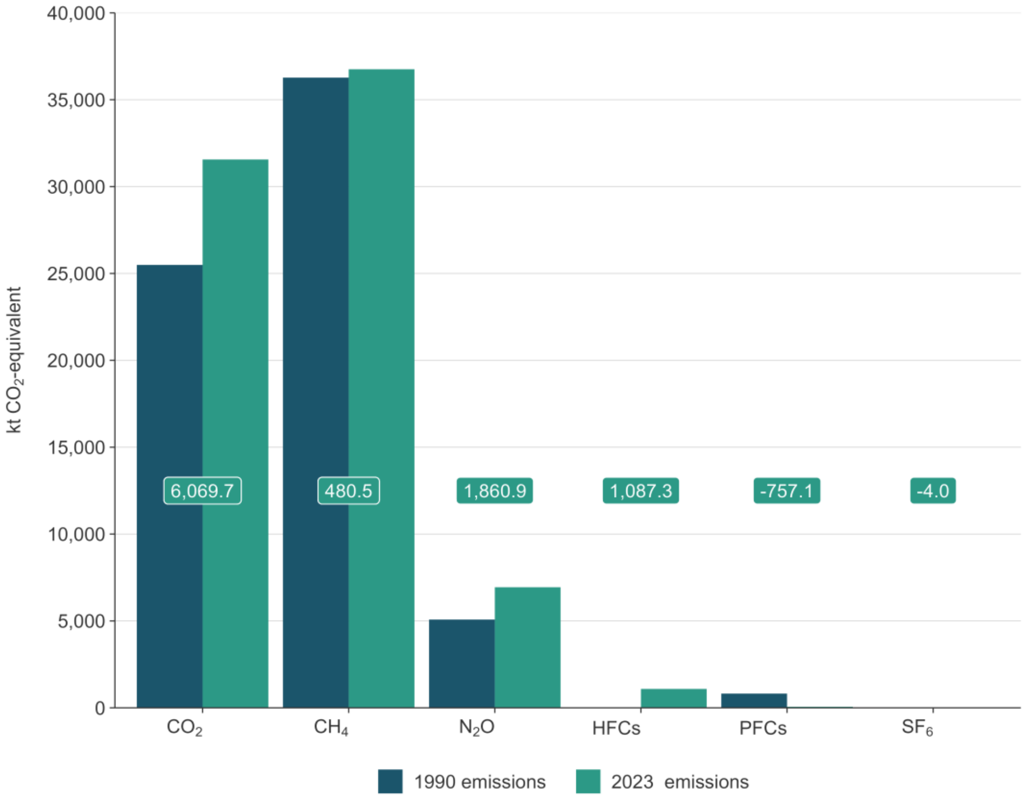
Table ES 2.1 New Zealand's gross emissions by gas in 1990 and 2023

Direct greenhouse gas emissions	1990	2023	Change from 1990 (kt CO_2-e)	Change from 1990 (%)
CO_2	25,490.1	31,559.8	6,069.7	23.8
CH_4	36,271.1	36,751.6	480.5	1.3
N_2O	5,079.1	6,940.0	1,860.9	36.6
HFCs	Not occurring	1,087.3	1,087.3	NA
PFCs	818.0	60.9	-757.1	-92.6
SF_6	20.6	16.6	-4.0	-19.2
Gross, all gases	**67,678.9**	**76,416.3**	**8,737.4**	**12.9**

Note: Gross emissions exclude net emissions from the LULUCF sector. The percentage change for HFCs is not applicable (NA) because no emissions of HFCs occurred in 1990. Columns may not total due to rounding. Percentages presented are calculated from unrounded values.

Figure ES 2.2 presents for each gas the absolute change in gross emissions (LULUCF is excluded from the estimate of gross emissions), and the change between 1990 and 2023 estimates in kt CO_2-e.

Figure ES 2.2 New Zealand's gross emissions by gas in 1990 and 2023



Note: Emissions of sulphur hexafluoride (SF_6) are not visible, due to its small emissions value, and emissions of hydrofluorocarbons (HFCs) did not occur in 1990.

In 1990 and 2023, CH_4 made the greatest contribution to gross emissions (see figure ES 2.2). While emissions of CH_4 have increased between these years, the rate of increase in CH_4 emissions relative to other gases in the Inventory has been lower over the same period. Nitrous oxide and CO_2 emissions have increased at a greater rate between these years than CH_4.

These trends reflect the changes that have occurred in the main livestock types that are farmed in New Zealand and the growth in road transport.

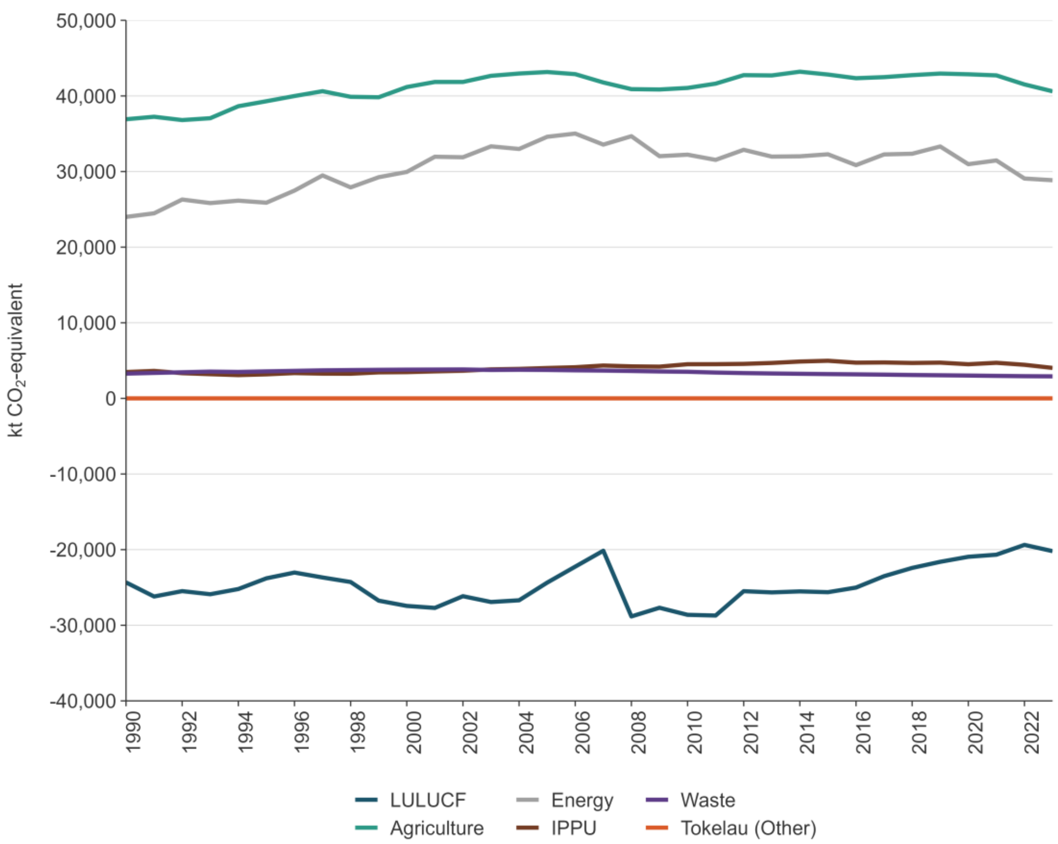
In 2023, net emissions from the LULUCF sector were -20,197.1 kt CO_2-e, or -26.4 per cent of New Zealand's gross GHG emissions. This was comprised of net emissions of -20,511.0 kt CO_2, 45.8 kt CO_2-e of CH_4 and 268.0 kt CO_2-e of N_2O.

ES.3 Overview of source and sink category emissions estimates and trends

Figure ES 3.1 shows the contribution to net emissions that each sector of *New Zealand's Greenhouse Gas Inventory* (the Inventory) has made since 1990. The Agriculture and Energy sectors have dominated New Zealand's gross emissions profile. Together, these sectors produced 90.5 per cent of New Zealand's annual gross GHG emissions from 1990 to 2023. The IPPU and Waste sectors produced relatively small amounts of GHGs, each contributing between 3.6 per cent and 6.0 per cent of annual gross emissions across the time series.

Conversely, the LULUCF sector was a net sink of GHG emissions between 1990 and 2023.

Figure ES 3.1 Trends in New Zealand's greenhouse gas emissions by sector, from 1990 to 2023



Energy (chapter 3)

2023

In 2023, emissions from the Energy sector contributed 28,851.0 kt CO_2-e, or 37.8 per cent of New Zealand's gross GHG emissions.

The largest sources of emissions in the Energy sector were the *Road transportation* category, contributing 12,599.8 kt CO_2-e (43.7 per cent), and the *Manufacturing industries and construction* category, contributing 6,126.3 kt CO_2-e (21.2 per cent) to energy emissions.

2022–2023

Between 2022 and 2023, emissions from the Energy sector decreased by 225.0 kt CO_2-e (0.8 per cent). This was primarily due to a combination of emissions decreases in *Petroleum refining* (down 166.1 kt CO_2-e or 100 per cent), *Public electricity and heat production* (down 153.5 kt CO_2-e or 5.3 per cent) and *Commercial/institutional* (down 143.1 kt CO_2-e or 10.7 per cent). This decrease was partially offset by the *Domestic aviation* category, which increased by 245.2 kt CO_2-e (24.0 per cent) and *Road transportation*, which increased by 233.7 kt CO_2-e (1.9 per cent). Further information on these changes is provided under the relevant categories of chapter 3, section 3.2.

National energy consumption in 2023 remained the same as 2022 levels, and was still 6.1 per cent below the pre-COVID level seen in 2019.

1990–2023

In 2023, emissions from the Energy sector had increased by 20.2 per cent (4,851.2 kt CO_2-e) from the 1990 level of 23,999.7 kt CO_2-e. This growth is primarily due to *Road transportation*, which increased by 5,771.3 kt CO_2-e (84.5 per cent), *Food processing, beverages and tobacco*, which increased by 1,031.4 kt CO_2-e (61.7 per cent), and *Chemicals*, which increased by 776.4 kt CO_2-e (144.8 per cent). Although the underlying drivers of these increases are often nuanced, key factors include population growth and increased economic activity.

The largest decrease since 1990 occurred in the *Manufacture of solid fuels and other energy industries* category – a historically significant contributor to New Zealand's emissions. Emissions for this category in 2023 had decreased from the 1990 level by 1,501.8 kt CO_2-e (88.1 per cent). This decrease is primarily due to the cessation of synthetic gasoline production in 1997.

Figure ES 3.1 shows the time series of Energy sector emissions from 1990 to 2023. Emissions increased from 1990 to around 2006, before decreasing slightly and then remaining steady until 2019. Since 2019, emissions have generally tracked downwards due to both the impact of the COVID-19 pandemic and the high levels of hydro power generation in 2022 and 2023.

IPPU (chapter 4)

2023

In 2023, emissions in the IPPU sector contributed 4,031.5 kt CO_2-e, or 5.3 per cent, of New Zealand's gross GHG emissions.

The *Metal industry* was the largest category of emissions, with substantial CO_2 emissions from the *Iron and steel production* and *Aluminium production* categories, as well as PFCs from the *Aluminium production* category in earlier years. The *Mineral industry* and *Chemical industry* categories also contributed significant CO_2 emissions, and most of the non-CO_2 emissions were from the *Product uses as substitutes for ODS* category.

The IPPU sector also produces smaller amounts of CH_4 from methanol production and N_2O used for medical applications in the *Other product manufacture and use* category.

Coal and natural gas were also used on a significant scale for energy in these industries, and related emissions were reported under the Energy sector in the *Manufacturing industries and construction* category.

2022–2023

Between 2022 and 2023, emissions from the IPPU sector decreased by 412.4 kt CO_2-e (9.3 per cent).

This change was mainly the result of decreased emissions from the *Refrigeration and air conditioning* category.

1990–2023

Emissions from the IPPU sector in 2023 were 548.4 kt CO_2-e (15.7 per cent) higher than emissions in 1990 (3,483.1 kt CO_2-e). This increase was mainly driven by increasing emissions from the *Product uses as substitutes for ODS* category, due to the introduction of HFCs to replace ODS in refrigeration and air conditioning, and the increased use of household and commercial air conditioning.

Carbon dioxide emissions also increased, due largely to increased production of aluminium and steel. Between 2020 and 2022, the increase was offset by reduced emissions due to COVID-19 pandemic restrictions and the progressive shutdown of the Marsden Point Oil Refinery. There was a substantial reduction in emissions of PFCs due to improved management of anode effects in the *Aluminium production* category and some reduction in emissions of N_2O used for medical applications in the *Other product manufacture and use* category.

Agriculture (chapter 5)

2023

In 2023, emissions from the Agriculture sector totalled 40,613.0 kt CO_2-e, representing 53.1 per cent of New Zealand's gross emissions in 2023.

Methane from *Enteric fermentation* was the main source of Agriculture emissions, contributing 78.0 per cent (31,661.7 kt CO_2-e) of the sector's emissions. *Agricultural soils* (15.7 per cent) were the second largest source followed by *Manure management* (4.6 per cent). *Urea application* and *Liming* contributed 1.0 per cent and 0.7 per cent respectively. *Field burning of agricultural residues* contributed less than 0.1 per cent.

Methane emissions from *Enteric fermentation* contributed 41.4 per cent of New Zealand's gross emissions, and N_2O emissions from the *Agricultural soils* category contributed 8.3 per cent of New Zealand's gross emissions.

2022–2023

Between 2022 and 2023, total Agriculture emissions decreased 2.2 per cent (908.4 kt CO_2-e), largely due to a decrease in emissions from dairy cattle, non-dairy cattle, sheep, and limestone application. Specifically:

- dairy cattle emissions decreased by 1.6 per cent (328.2 kt CO_2-e) due to a decrease in the dairy cattle population
- sheep emissions decreased by 3.1 per cent (294.6 kt CO_2-e) due to a continuing decrease in the sheep population
- emissions from limestone use decreased by 38.8 per cent (166.6 kt CO_2-e) due to a decrease in limestone use
- non-dairy cattle emissions decreased by 1.5 per cent (127.8 kt CO_2-e) due to a decrease in the beef cattle population.

Emissions from urea (CO_2 and N_2O) increased by 11.3 per cent (126.0 kt CO_2-e) due to an increase in urea use and a decrease in urease inhibitor use. This increase reflects a slight recovery in urea use following a significant decrease in 2022. The impact of increased emissions from urea from 2022 to 2023 was largely offset by a decrease in the use of other (non-urea) synthetic nitrogen fertilisers.

1990–2023

In 2023, New Zealand's Agriculture sector emissions were 10.0 per cent (3,697.9 kt CO_2-e) above the 1990 level (36,915.1 kt CO_2-e).

The greatest absolute contributions to the increase since 1990 were an increase of 1,717.3 kt CO_2-e (36.9 per cent) in emissions from *Agricultural soils*, an increase of 1,001.7 kt CO_2-e (116.5 per cent) in emissions from *Manure management* and an increase of 626.8 kt CO_2-e (2.0 per cent) in methane emissions from *Enteric fermentation*.

The increase in N_2O emissions from *Agricultural soils* was primarily a result of a 534 per cent increase in synthetic nitrogen fertiliser application since 1990. This is partly due to an increase in dairy farming, as well as increased use on other farm types. The emissions from synthetic nitrogen fertiliser use (N_2O) increased by 1,094.3 kt CO_2-e between 1990 and 2023. This is 63.7 per cent of the total increase in emissions from *Agricultural soils*.

The increase in emissions from *Manure management* and *Enteric fermentation* was driven by an increase in dairy cattle numbers. The increase in dairy *Enteric fermentation* emissions was partially offset by declining numbers of sheep and non-dairy (beef) cattle. The change in animal populations since 1990 reflects the relative financial returns in each sector. (It has become more profitable to farm dairy cattle than non-dairy cattle or sheep in New Zealand over the reporting period.)

LULUCF (chapter 6)

2023

In 2023, net emissions from the LULUCF sector were -20,197.1 kt CO_2-e. This offset 26.4 per cent of New Zealand's gross emissions.

2022–2023

Net emissions from the LULUCF sector decreased between 2022 and 2023 by 824.4 kt CO_2-e (4.3 per cent).

The largest change occurred in the *Forest land* category, with a decrease in emissions of 952.1 kt CO_2-e, driven by reduced harvesting in planted forests between 2022 and 2023. The *Harvested wood products* category had the second-largest change, with a decrease in net removals of 774.0 kt CO_2-e, which was also driven by the reduction in harvesting of planted forests, and corresponding reduction in products entering the harvested wood products pool. The *Grassland* category had the third-largest change, with a decrease in emissions of 684.7 kt CO_2-e. This was driven by lower rates of deforestation occurring in 2023 compared with 2022.

1990–2023

Net emissions in 2023 increased by 4,136.9 kt CO_2-e (17.0 per cent) from the 1990 level of -24,334.1 kt CO_2-e. This was largely due to a reduction in net removals from *Forest land* and an increase in emissions from *Grassland* (mainly due to emissions from deforestation and conversions among grassland categories) since 1990. The reduction in net removals from *Forest land* was driven by high current harvest rates, which are a result of the significant land-use changes to forest land that occurred in the 1980s and 1990s. The planted forests that were established during this period have progressively been reaching harvesting age, and will continue to do so into the mid-2020s. As the high harvesting rates continue, the average age of the planted forest estate has been reducing each year as the harvested forests are replanted. Young forest stands have lower rates of removal than older stands.

Harvesting and replanting cycles of New Zealand’s planted forests will continue to affect the trajectory of net emissions in the future due to their uneven age-class profile. The increased emissions from harvesting have been compensated for, to some extent, by increased removals in the harvested wood products pool because inputs into this pool exceed emissions from decay.

Emissions in the LULUCF sector are primarily driven by the harvest of production forests, deforestation and the decomposition of organic material following these activities. Removals are mainly from the sequestration of carbon that occurs due to plant growth and the production of harvested wood products. Nitrous oxide can be emitted from the ecosystem as a by-product of nitrification and denitrification, and the burning of organic matter. Other gases released during biomass burning include CH_4, carbon monoxide (CO), other oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOC).

The fluctuations in net emissions from the LULUCF sector since 1990 (see figure ES 3.1) were primarily influenced by afforestation, harvesting and deforestation rates. Harvesting rates are driven by several factors, particularly forest age and log prices.

Net emissions in the LULUCF sector have been generally increasing over the past decade. Current harvest rates are at near historically high levels due to the significant land-use changes to forest land that occurred from the 1980s and into the early 1990s.

Deforestation rates were driven by the profitability of forestry relative to alternative land uses.

Waste (chapter 7)*

2023

In 2023, emissions from the Waste sector contributed 2,916.6 kt CO_2-e or 3.8 per cent of New Zealand’s gross GHG emissions. The largest source of emissions is the *Solid waste disposal* category.

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* After the Inventory was finalised, a potential underestimate of emissions was identified in a Waste sector category (*Unmanaged waste disposal sites*). Preliminary analysis suggests that this may revise the decrease in Waste sector emissions from 11 per cent to 7 per cent between 1990 and 2023, and from 0.7 per cent to 0.5 per cent between 2022 and 2023. However, the impact on New Zealand's overall emissions totals is expected to be minor. Any adjustments will be made in future submissions, once a full review has been completed.

2022–2023

Between 2022 and 2023, emissions from the Waste sector decreased by 0.7 per cent (20.5 kt CO_2-e). This decrease is largely the result of decreases in CH_4 emissions in the *Managed waste disposal site* category, mainly due to increasing landfill gas (LFG) capture and changes in the composition of waste, with a reduction in the proportion of garden, food and paper waste disposed of to those sites.

1990–2023

In 2023, emissions from the Waste sector had decreased by 11.0 per cent (361.0 kt CO_2-e), from 3,277.6 kt CO_2-e in 1990.

Annual emissions peaked at 3,830.2 kt CO_2-e in 2002 and have generally been in decline since that time. Growth in both population size and economic activity since 1990 has resulted in increasing volumes of solid waste and wastewater for the whole of the time series. Ongoing improvements in the management of solid waste disposal at municipal landfills have meant total Waste sector emissions have been trending down since 2005, despite increasing volumes of solid waste and wastewater.

The reduction in emissions is primarily the result of increased CH_4 recovery through the installation of LFG capture systems, driven by National Environmental Standards for Air Quality introduced in 2004 and by the inclusion of the Waste sector in the New Zealand Emissions Trading Scheme in 2013. These legislative tools have been complemented by local government efforts to improve kerbside collections, including for organic waste, across the country, and by a central government waste work programme that includes product stewardship, plastic phase-outs and investment in resource recovery infrastructure for organic materials.

Trends in annual Waste sector emissions are shown in figure ES 3.1.

Other (Tokelau – chapter 8)

2023

In 2023, emissions from Tokelau contributed 0.006 per cent (4.20 kt CO_2-e) of New Zealand's gross GHG emissions.

The largest source category was *Domestic navigation*, which contributed 63.2 per cent (1.43 kt CO_2-e) of all energy emissions and 34.1 per cent of gross emissions from Tokelau.

Carbon dioxide dominated emissions from Tokelau, contributing 54.5 per cent (2.29 kt CO_2-e) of its total emissions in 2023. At 2.25 kt CO_2, the Energy sector contributed 98.3 per cent of total CO_2 emissions, mostly from *Domestic navigation*, with the remaining 1.7 per cent (0.04 kt) coming from *Open burning of waste* in the Waste sector.

Methane emissions contributed 39.4 per cent (1.65 kt CO_2-e) to the total emissions from Tokelau. The Agriculture sector in Tokelau contributed 55.8 per cent of CH_4 emissions (0.92 kt CO_2-e), which mostly came from *Manure management*. A significant portion of CH_4 emissions, 43.9 per cent (0.73 kt CO_2-e), came from the Waste sector, largely from *Solid waste disposal*. The Energy sector contributed the remaining 0.4 per cent of CH_4 emissions (0.01 kt CO_2-e), which mostly came from *Domestic navigation*.

Nitrous oxide emissions contributed 1.1 per cent (0.05 kt CO_2-e) to the total emissions from Tokelau. The IPPU sector (*Medical applications*) contributed the largest amount of N_2O, with 52.1 per cent (0.02 kt CO_2-e) of the total N_2O. The Energy sector contributed a further 26.0 per cent (0.01 kt CO_2-e), which comes largely from *Domestic navigation*. The Waste sector contributed the remaining 21.8 per cent of N_2O (0.01 kt CO_2-e) from *Open burning of waste*.

Emissions of fluorinated gases from Tokelau consisted of HFC emissions only, contributing 5.0 per cent (0.21 kt CO_2-e) to the total emissions from Tokelau. These emissions largely result from the use of air conditioning. Emissions of PFCs, NF_3 and SF_6 do not occur in Tokelau.

2022–2023

Total Tokelau emissions in 2023 were 0.49 kt CO_2-e (10.4 per cent) lower than emissions in 2022. The decrease in emissions is largely in the *Electricity generation* category, which is the result of reduced diesel due to fuel conservation initiatives and problems with the diesel electricity generators. The diesel generators have been in greater demand following issues with solar electricity generation since 2022. This decrease in emissions from *Electricity generation* is slightly offset by a small increase in the *Domestic navigation* category, due to an increase in shipping trips.

1990–2023

In 1990, total emissions from Tokelau were 3.37 kt CO_2-e. Between 1990 and 2023, total emissions increased by 24.7 per cent (0.83 kt CO_2-e) to 4.20 kt CO_2-e. From 1990 to 2023, the average annual increase in gross emissions was 0.89 per cent.

The emissions increase was largely due to changes in the Energy sector. The emissions categories that contributed the most to this change were *Domestic navigation* and *Electricity generation*.

The changes in *Domestic navigation* were a result of Tokelau gaining ownership and use of the ferry *Mataliki* in 2016, cargo vessel *Kalopaga* in 2018 and search and rescue vessel *Fetu o te Moana* in 2019, leading to an increasing number of sea voyages between the atolls, which increased transport emissions.

The changes in Tokelau’s Energy sector emissions from *Electricity generation* drive the overall emissions trend observed across most of the time series. Initially, up until 2003, emissions from this source were relatively stable. A significant increase in emissions (of nearly 400 per cent) was then observed due to an increase in the use of diesel generators for electricity production occurring between 2003 and 2011. This was followed by a significant drop in emissions in 2012 and 2013 (by 82.5 per cent), when solar electricity generation began. Toward the end of the time series, diesel generator use increased again as the generation from solar power decreased, with emissions increasing accordingly.

Emissions from Tokelau’s IPPU sector have also increased mainly due to the introduction of air conditioning after 2006. Emissions from Tokelau’s Agriculture sector decreased slightly as a result of a reduced population of pigs.

ES.4 Other information

Indirect gases

New Zealand reports emissions estimates of indirect gases in accordance with the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines) (Volume 1, Chapter 7) (IPCC, 2006). These indirect gases are CO, NO_X, NMVOCs and sulphur dioxide (SO_2). These gases are not greenhouse gases themselves and are not included in the national emissions totals; however, CO, NO_X and NMVOCs chemically alter the atmosphere, leading to an increase in tropospheric ozone concentrations, and SO_2 contributes to aerosol formation. Table ES 4.1 summarises New Zealand's indirect GHG emissions in 1990 and 2023 as well as the change between these years.

Table ES 4.1 New Zealand's indirect greenhouse gas emissions (excluding LULUCF) in 1990 and 2023

Indirect greenhouse gas emissions	1990	2023	Change from 1990 (kt CO_2-e)	Change from 1990 (%)
CO	622.6	662.5	39.9	6.4
NMVOCs	143.7	172.3	28.6	19.9
NO_X	102.5	150.8	48.3	47.1
SO_2	58.6	51.4	-7.2	-12.3

Note: Columns may not total due to rounding. Percentages presented are calculated from unrounded values.

ES.5 Key category analysis

The 2006 IPCC Guidelines (IPCC, 2006) identify a key category as one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct GHGs in terms of the absolute level of emissions, the trend in emissions, or both. Key categories identified within the Inventory are used to prioritise where to improve emissions estimates.

The categories that had the largest relative influence on the national trend in gross emissions were:

- CH_4 emissions from *Enteric fermentation – Sheep* (22.6 per cent as a decrease)
- CH_4 emissions from *Enteric fermentation – Dairy cattle* (18.4 per cent as an increase)
- CO_2 emissions from *Road transportation – Liquid fuels* (12.2 per cent as an increase)
- CO_2 emissions from *Energy industries – Manufacture of solid fuels and other energy industries – Gaseous fuels* (4.2 per cent as a decrease).

The categories that had the largest relative influence on the trend in net emissions were:

- CO_2 emissions from *Carbon stock change – Forest land remaining forest land* (16.2 per cent as a decrease)
- CH_4 emissions from *Enteric fermentation – Sheep* (16.2 per cent as a decrease)
- CO_2 emissions from *Carbon stock change – Land converted to forest land* (13.6 per cent as an increase)
- CH_4 emissions from *Enteric fermentation – Dairy cattle* (8.7 per cent as an increase).

Details and results of the key category assessments are presented in annex 1.

ES.6 Improvements introduced

The Inventory follows a process of continuous improvement consistent with the IPCC principles. The 2006 IPCC Guidelines (IPCC, 2006) provide guidance on building and maintaining inventories that are consistent, comparable, complete, accurate and transparent in a manner that improves the quality of the Inventory over time. Improvements are made from year to year, to follow recommendations from international expert review teams, correct errors and implement additional changes planned by the agencies involved in preparing the Inventory.

When improvements are made, it is good practice to recalculate the whole time series back to 1990 to ensure a consistent time series. This means estimates of emissions and/or removals in a given year may differ from emissions and/or removals reported in the previous submission.

A range of improvements has been made to the Inventory since the last submission. The main improvements by sector are outlined below. Chapter 10 provides further information on the recalculations made to the estimates.

The overall impact of improvements on New Zealand's gross emissions was a decrease of 1.9 per cent (1,279.3 kt CO_2-e) in 1990 and a decrease of 0.5 per cent (412.2 kt CO_2-e) in 2022.

The overall impact of improvements on New Zealand's net emissions estimates, which include the LULUCF sector, was a decrease of 2.9 per cent (1,288.7 kt CO_2-e) in 1990 and a decrease of 0.9 per cent (546.2 kt CO_2-e) in 2022.

The emissions impact of improvements introduced are provided in relation to 1990 and the previous year inventoried, as that is the last year in the time series that can be compared using previous methods.

Energy (chapter 3)

Improvements and recalculations made to the Energy sector have resulted in an increase of 0.01 per cent (1.4 kt CO_2-e) in estimated energy emissions for 1990 and an increase of 1.3 per cent (359.9 kt CO_2-e) in estimated energy emissions for 2022.

The improvements include a methodological improvement, a refinement to the implementation of software code and various changes to the underlying energy activity data. Further details on source-specific improvements are provided in their corresponding sections in chapter 3.

IPPU (chapter 4)

Improvements and recalculations made to the IPPU sector have resulted in an increase of 0.1 per cent (4.9 kt CO_2-e) in estimated IPPU emissions in 1990 and a decrease of 0.6 per cent (25.2 kt CO_2-e) in estimated IPPU emissions in 2022.

Several improvements to the *Refrigeration and air conditioning* category were undertaken, to better account for changes in stocks held by importers and users.

Further details on source-specific improvements are provided in their corresponding sections in chapter 4.

Agriculture (chapter 5)

Improvements and recalculations made to the Agriculture sector have resulted in a decrease of 0.6 per cent (206.4 kt CO_2-e) in estimated agriculture emissions in 1990 and a decrease of 0.5 per cent (191.3 kt CO_2-e) in estimated agriculture emissions in 2022.

The improvements included improved species population statistics, energy requirements, emissions factors and productivity statistics, reporting on non-manure organic amendments to soils and error corrections.

Further details are provided in the corresponding section in chapter 5.

LULUCF (chapter 6)

Improvements and recalculations made to the LULUCF sector have resulted in an increase of 0.04 per cent (9.4 kt CO_2-e) in estimated net LULUCF removals in 1990 and an increase of 0.7 per cent (133.9 kt CO_2-e) in estimated net LULUCF removals in 2022.

No methodological improvements were applied in the LULUCF sector for this submission, however, improvements were made to emissions estimates, as a result of updates to activity data arising from regular mapping improvements.

Further details on source-specific improvements are provided in their corresponding sections in chapter 6.

Waste (chapter 7)

Improvements and recalculations made to estimates in the Waste sector have resulted in a 24.8 per cent (1,079.2 kt CO_2-e) decrease in emissions in 1990 and a 15.9 per cent (555.6 kt CO_2-e) decrease in emissions in 2022.

For the 2025 submission, significant updates have been introduced to three source categories: *Managed waste disposal sites*, *Unmanaged waste disposal sites* and *Anaerobic digestion*.

Further details on source-specific improvements are provided in their corresponding sections in chapter 7.

Other (Tokelau – chapter 8)

Improvements and recalculations made to estimates in Tokelau have resulted in a decrease of 0.03 per cent (0.001 kt CO_2-e) in estimated Tokelau emissions in 1990 and an increase of 0.1 per cent (0.004 kt CO_2-e) in estimated Tokelau emissions in 2022.

One minor recalculation has been made in the Tokelau emissions estimates since the 2024 submission. This change was due to updates in New Zealand’s medical emissions data, which are assumed to be the same per capita in Tokelau.

Further details are provided in the corresponding section in chapter 8.

Improvements to national inventory system

No changes were made to the legal or institutional arrangements of the national inventory system.

Executive summary: References

IPCC. 2006. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1. General Guidance and Reporting* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

UNFCCC. 2018. FCCC/PA/CMA/2018/3/Add.2. *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on the third part of its first session, held in Katowice from 2 to 15 December 2018. Addendum 2. Part two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.*

UNFCCC. 2021. FCCC/PA/CMA/2021/10/Add.2. *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its third session, held in Glasgow from 31 October to 13 November 2021. Addendum Part two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its third session.*

Chapter 1: National circumstances, institutional arrangements and cross-cutting information

1.1 Background information on greenhouse gas inventories and climate change

Greenhouse gases (GHGs) in Earth's atmosphere trap warmth from the sun and make life as we know it possible. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC, 2021) confirms that the evidence showing humans have an influence on the climate system is unequivocal. Human-induced climate change is evident in extreme weather events all around the world. Events such as heatwaves, severe rainfall and droughts have become more frequent and extreme as a result of climate change and will continue to intensify.

Some of the changes to the climate system, including sea-level rise and loss of glaciers, are irreversible over centuries to millennia. The rate and magnitude of these committed changes, however, still depend on future GHG emissions. While the IPCC (2021) revised its estimate upwards of how much warming has occurred already, scenarios show that we can still limit warming to 1.5°C. To do that, the world must achieve net zero carbon dioxide (CO_2) emissions by around 2050 along with deep reductions in other GHGs (IPCC, 2022).

1.1.1 United Nations Framework Convention on Climate Change and the Paris Agreement

The IPCC was established by the United Nations Environment Programme and the World Meteorological Organization in 1988. Its initial task was to prepare a comprehensive review and recommendations with respect to the state of knowledge of the science of climate change; the social and economic impact of climate change; and potential response strategies and elements for inclusion in a possible future international convention on climate. In 1990, it concluded that human-induced climate change was a threat to our future.

In response, the United Nations General Assembly convened a series of meetings that culminated in the adoption of the United Nations Framework Convention on Climate Change (UNFCCC or the Convention) at the Earth Summit in Rio de Janeiro in May 1992.

The Convention has been signed and ratified by 197 nations, including New Zealand, and took effect on 21 March 1994.

The main objective of the Convention (UNFCCC, 1992, Article 2) is to achieve:

> … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

All countries that ratify the Convention (the Parties) are required to take action to address climate change, including by monitoring trends in anthropogenic GHG emissions. Producing the annual inventory of GHG emissions and removals fulfils this obligation. Parties are also obliged to protect and enhance carbon sinks and reservoirs, for example, forests, and implement measures that assist in national and/or regional climate change adaptation and mitigation. In addition, Parties listed in Annex II[2] to the Convention commit to providing technology transfer, capacity building and financial assistance to non-Annex I[3] Parties (developing country Parties).

Annex I Parties also agreed to aim to return GHG emissions to 1990 levels by the year 2000. Only a few Annex I Parties made appreciable progress towards achieving this aim. The international community recognised that the existing commitments in the Convention were not enough to ensure GHGs would be stabilised at a safe level. In response, in 1995, Parties launched a new round of talks to provide stronger and more detailed commitments for Annex I Parties. After two-and-a-half years of negotiations, the Kyoto Protocol was adopted in Kyoto, Japan on 11 December 1997 with the goal of reducing emissions to 5 per cent below 1990 levels. New Zealand ratified the Kyoto Protocol on 19 December 2002. The Protocol came into force on 16 February 2005.

The Kyoto Protocol only required Annex I Parties to reduce emissions. While research suggests that most Annex I Parties had met their emissions reduction targets, global emissions were continuing to increase.

To accelerate and intensify the actions and investments needed for a sustainable low carbon future, Parties to the Convention reached a landmark agreement in Paris, France, on 12 December 2015: the Paris Agreement. New Zealand ratified the Paris Agreement on 4 October 2016.

One result of the extension (as of 13 November 2017) of New Zealand's ratification of the Convention and the Paris Agreement is that New Zealand's national inventory now includes GHG emissions and removals estimates from Tokelau.

Although the 1997 Kyoto Protocol technically remains in force, the Paris Agreement has, in effect, superseded the Kyoto Protocol as the principal regulatory instrument governing the global response to climate change.

1.1.2 Inventory reporting

New Zealand's Greenhouse Gas Inventory (the Inventory) is the official annual report of all anthropogenic GHGs not controlled by the Montreal Protocol that occur in New Zealand and Tokelau.

A complete inventory submission contains two main components: the national inventory document and the common reporting tables (CRT). The Inventory fulfils New Zealand's national inventory reporting obligations under both the UNFCCC and the Paris Agreement, as agreed in decision 1/CP.24 of the Conference of the Parties to the UNFCCC (UNFCCC, 2018a). The Inventory has been prepared in accordance with chapter II of the Annex to the decision 18/CMA.1 Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement and decision 5/CMA.3 Guidance for operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement.

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[2] Annex II to the Convention (a subset of Annex I) lists the Organisation for Economic Co-operation and Development (OECD) member countries at the time the Convention was agreed.

[3] Annex I to the Convention lists the countries included in Annex II, as defined above, together with countries defined at the time as transitioning to a market economy, commonly known as 'economies in transition'.

Consistent with the modalities, procedures and guidelines and decision 5/CMA.3, emissions estimates provided in this Inventory have been compiled in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines) (IPCC, 2006a). New Zealand's methodologies have been improved over time and will continue to be refined as new information emerges and international practice evolves. The aim is to ensure that the estimates of emissions are accurate, transparent, complete, consistent through time and comparable with those produced in the inventories of other Parties.

Inventories are subject to a technical review process administered by the United Nations Climate Change (UN Climate Change) secretariat. The results of these reviews are available on the UN Climate Change website.[4]

The Inventory reports on emissions and removals of the gases CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).[5] The indirect GHGs,[6] carbon monoxide (CO), sulphur dioxide, oxides of nitrogen and non-methane volatile organic compounds, are also included. Only emissions and removals of the direct GHGs (CO_2, CH_4, N_2O, SF_6, PFCs, HFCs and NF_3) are reported in total gross and net emissions under the Convention.

This Inventory presents emissions for each of the non-carbon dioxide GHGs as carbon dioxide equivalents (CO_2-e) using the 100-year time horizon global warming potential values contained in the IPCC Fifth Assessment Report (IPCC, 2013). Because GHGs vary in their radiative activity, and in their atmospheric residence time, converting emissions into CO_2-e allows the integrated effect of emissions of the various gases to be compared.

The GHGs are reported under five sectors in accordance with those included in the 2006 IPCC Guidelines (IPCC, 2006b). These represent the main human activities that contribute to the release or capture of GHGs into, or from, the atmosphere:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture
- Land Use, Land-Use Change and Forestry (LULUCF)
- Waste.

Since the 2019 submission, GHG emissions from Tokelau, New Zealand's overseas dependent territory,[7] have been included in the Inventory. Because emissions from Tokelau are small, and the methodology used varies greatly between Tokelau's inventory and the inventory for New Zealand's mainland territory, emissions from Tokelau are reported separately in the Other sector.

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4 UN Climate Change. *Inventory Review Reports*. Retrieved 12 March 2025.

5 Because NF_3 emissions do not occur in New Zealand, they are not included in this report.

6 Indirect GHGs are the gases that have indirect radiative effects in the atmosphere. This may happen either through conversion of an indirect gas to a direct GHG in the atmosphere (e.g., where CO is converted to CO_2) or when chemical reactions in the atmosphere involving these gases change the concentrations of direct GHGs.

7 The United Nations Charter (United Nations, 1945) defines a non-self-governing territory as a territory "whose people have not yet attained a full measure of self-government". Tokelau has been on the United Nations list of non-self-governing territories since 1946, following New Zealand's declaration of its intention to transmit information on the Tokelau Islands under Article 73e of the United Nations Charter.

1.2 A description of national circumstances and institutional arrangements

1.2.1 National entity or national focal point

In 2002, New Zealand enacted the Climate Change Response Act 2002 (the Act).[8] This enabled New Zealand to meet its international obligations under the Convention and Kyoto Protocol. The Act has subsequently been amended to enable New Zealand to meet its obligations under the Paris Agreement. A Prime Ministerial directive for the administration of the Act named the Ministry for the Environment (MfE) as New Zealand's 'inventory agency'. Part 3, section 32, of the Act specifies the following functions and requirements.

(1) The primary functions of New Zealand's inventory agency are to:
  - (a) estimate New Zealand's human-induced emissions by sources and removals by sinks of greenhouse gases on an annual basis
  - (b) prepare the following reports for the purpose of discharging New Zealand's obligations:
    - (i) New Zealand's annual inventory report under Articles 4 and 12 of the Convention
    - (ii) report of information by New Zealand under Article 13 of the Paris Agreement[9]
    - (iii) New Zealand's national communication (or periodic report) under Article 12 of the Convention.

(2) In carrying out its functions, the inventory agency must:
  - (a) identify source categories
  - (b) collect data by means of:
    - (i) voluntary collection
    - (ii) collection from government agencies and other agencies that hold relevant information
    - (iii) collection in accordance with regulations made under this Part (if any)
  - (c) estimate the emissions and removals by sinks for each source category
  - (d) undertake assessments on uncertainties
  - (e) undertake procedures to verify the data
  - (f) retain information and documents to show how the estimates were determined.

Compliance provisions in section 36 of the Act authorise inspectors to collect information needed to estimate emissions or removals of GHGs.

1.2.2 National Inventory System

New Zealand has a national system in place for inventorying anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol.

New Zealand maintains a set of guidelines, the National Inventory System Guidelines, in which the tasks required to officially submit the national inventory are documented. These guidelines

8 The Climate Change Response Act has been amended several times since 2002. The Climate Change Response (Emissions Trading Reform) Amendment Act 2020, among other things, added reporting under the Paris Agreement to the functions of the inventory agency.

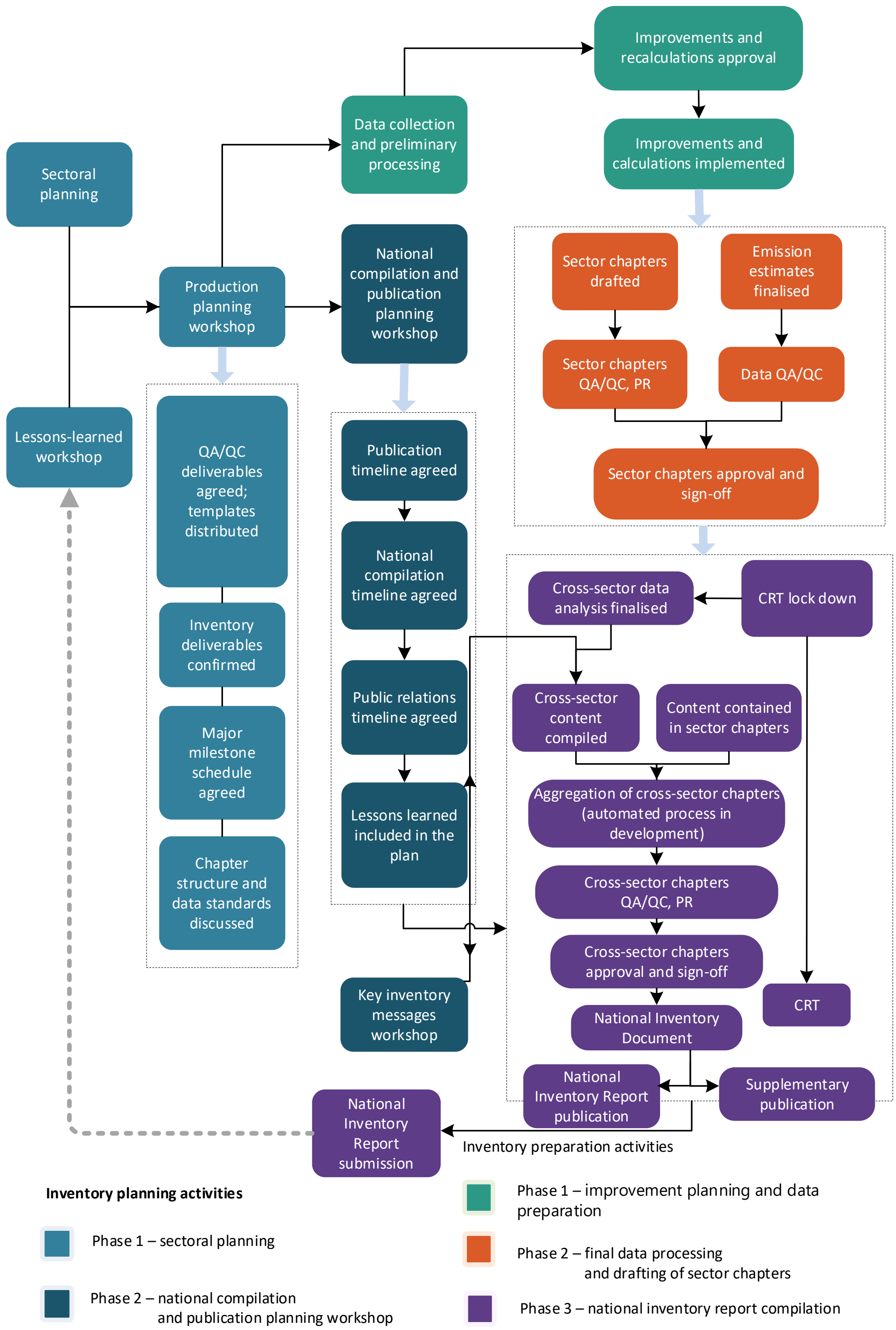
9 Inserted, on 23 June 2020, by section 56(1) of the Climate Change Response (Emissions Trading Reform) Amendment Act 2020 (2020 No 22).

cover multiple aspects of the production of the inventory: inventory management, inventory planning and preparation, quality assurance and quality control (QA/QC) processes, communication and error management.

Inventory planning and preparation

Figure 1.2.1 summarises the inventory planning and preparation process.

Figure 1.2.1 Summary of New Zealand's inventory planning and preparation



Note: CRT = common reporting tables; PR = peer review; QA/QC = quality assurance/quality control.

Inventory planning

Inventory planning is a two-phase process. The first phase, sectoral planning, involves planning for inventory compilation at the sector level. This includes planning for technical projects, actions, improvements and procedures that are specific to each sector. There are some dependencies for completing this phase, however, based on the outcomes of the lessons learned and production planning workshops, which occur during the second phase of inventory planning. Sector plans may, therefore, need to be adapted to meet the sector-specific requirements of national compilation plans.

The second phase of inventory planning, the national compilation and publication planning, involves planning for inventory compilation at the cross-sector level. It includes holding a lessons learned workshop, which is scheduled to follow each inventory submission. A second workshop, scheduled towards the end of each calendar year, is dedicated to cross-sectoral compilation and publication planning. Participants include MfE's publication and public liaison teams, sector leads and the inventory production team. Timelines discussed and agreed cover:

- national compilation
- publication
- public relations.

Lessons learned are also considered in developing the national compilation plans.

The inventory planning process for Tokelau is governed by a memorandum of understanding between New Zealand and Tokelau. For further information, see chapter 8.

Inventory preparation

The inventory preparation cycle has three phases: data collection and preliminary processing; final data processing and chapter preparation; and the national inventory compilation.

The first phase, data collection and preliminary processing (June to October), includes data cleansing, data checks and preliminary formatting of data for further use. This phase may also include analysing potential improvements and related recalculations involved in the inventory.

The second phase of the inventory preparation (October to January) includes final data processing and drafting of sector chapters. During this phase, emissions estimates are finalised, final data quality control and verification are performed, data are uploaded into the GHG Inventory Reporting Tool to populate the CRT and sector chapters are updated, reviewed and approved.

The final phase of the inventory preparation (February to April) includes cross-sector analyses, national inventory compilation and publication, and the production of supplementary material for New Zealand's Minister of Climate Change and the general public.

Tokelau follows the same inventory preparation cycle. The inventory data from Tokelau are prepared in November and undergo the same processes as the rest of the inventory.

During the inventory planning and preparation cycles, the National Inventory Compiler, technical lead, QA/QC lead and inventory project lead/s have regular meetings with sector leads and experts to ensure that requirements are delivered, risks are managed, issues are addressed and the production proceeds as planned. The inventory QA/QC lead also has regular meetings with sector leads to monitor QA/QC processes and procedures that are in place to ensure the quality of the final product meets the Paris Agreement and Convention reporting requirements and the QA/QC deliverables are produced according to the agreed plan.

Once cross-sectoral analyses have been completed, the key messages for the inventory, an integral part of the cross-sectoral compilation, are developed. The key inventory messages are agreed among the sector leads, National Inventory Compiler and primary peer reviewers. The key messages are used in both the national inventory document and supplementary inventory summary materials published on MfE's website.

The National Inventory Compiler, technical lead and the QA/QC lead provide technical support and advice to the sector leads when required.

1.2.3 Archiving of information

To provide data security and file recovery for the inventory, the information and data are held in secured locations in MfE's Microsoft 365 environment. MfE's security policies and settings, including version control and retention, protect against data breach and data loss.

New Zealand's inventory archiving system reflects the distributed system as follows.

- All files for the inventory are stored in MfE's secure file management system and backed up on several different devices held in different locations. This covers all data files and supplementary materials as part of the submission for the inventory, CRT, database back-up files from the GHG Inventory Reporting Tool, sectoral chapters, the compiled inventory, confirmations of sign-off, communication between New Zealand's inventory team and the expert review team, national inventory system documentation and other related documents for the inventory.
- Each agency involved in inventory compilation keeps its data in secure file systems, including communication with contractors, activity data, emission factors, preliminary calculations and specific software applications containing sectoral data models.
- Each agency involved in inventory compilation has security procedures in case of natural disasters, fire, flood or other accidents, which are kept at a high standard.

1.2.4 Processes for official consideration and approval of inventory

New Zealand applies a hybrid (centralised-distributed) approach to the production of the inventory. MfE, as New Zealand's inventory agency, manages and coordinates the production, compilation and publication of the inventory, and submits it to the UN Climate Change secretariat, in a centralised manner. The National Inventory Compiler is based at MfE. Designated government agencies carry out sector-specific work, which includes obtaining and processing activity data, estimating emissions, preparing sectoral CRT files and writing sectoral inventory chapters. Arrangements with these government agencies have evolved over time and continue to do so, as resources and capacity allow, in response to a growing understanding of the reporting requirements and when those requirements change.

Inventory governance within each sector, as well as sector-level quality control, is managed by the agency responsible for the sector. The Reporting Governance Group (RGG) provides cross-agency governance over New Zealand's international climate change reporting obligations, including the production of the inventory and projections of GHG emissions and removals for other international reports. The RGG is chaired by the manager of the inventory compilation project team (within MfE). Its membership includes representation from other teams within MfE, the Ministry for Primary Industries (MPI) and the Ministry of Business, Innovation and Employment (MBIE), as well as observers (Ministry of Foreign Affairs and

Trade, Ministry of Transport, the Environmental Protection Authority (EPA), Government of Tokelau and Stats NZ). The main roles and expectations of the RGG include:

- guiding, conferring and approving (on the basis of advice from technical experts) major inventory recalculations and improvements; GHG emissions projections and their assumptions; analytical systems and tools for climate change reporting; planning and priorities; key messages; and management of stakeholders and risks
- focusing on the delivery of reporting commitments to meet national and international requirements
- providing reporting leadership and guidance to analysts and technical specialists involved in this work
- sharing information, providing feedback and resolving any differences among agencies that impact on the delivery of the inventory work programme.

In addition to its overall inventory coordination role, MfE compiles estimates for the IPPU, LULUCF and Waste sectors and for Tokelau. This includes:

- compiling emissions estimates for the IPPU sector (non-CO_2 gases through industry surveys and the coordination of CO_2 emissions estimates with data provided by MBIE and the EPA)
- compiling emissions estimates for the Waste sector (sources of data include mandatory reporting under the Waste Minimisation Act 2008 and the New Zealand Emissions Trading Scheme (NZ ETS) or through targeted surveys)
- compiling emissions and removals estimates for the LULUCF sector, requiring:
  - field measurement programmes
  - land use mapping from satellite imagery
  - collation of supplementary data on forestry grant schemes, forest harvest volumes, harvested wood products production and non-CO_2 emissions that are collected through surveys
- compiling emissions estimates for Tokelau, requiring coordination of the preparation of Tokelau's inventory data and information with the Tokelau Ministry of Climate, Oceans and Resilience (MiCORE).

MBIE estimates all emissions from the Energy sector based in part on NZ ETS returns.

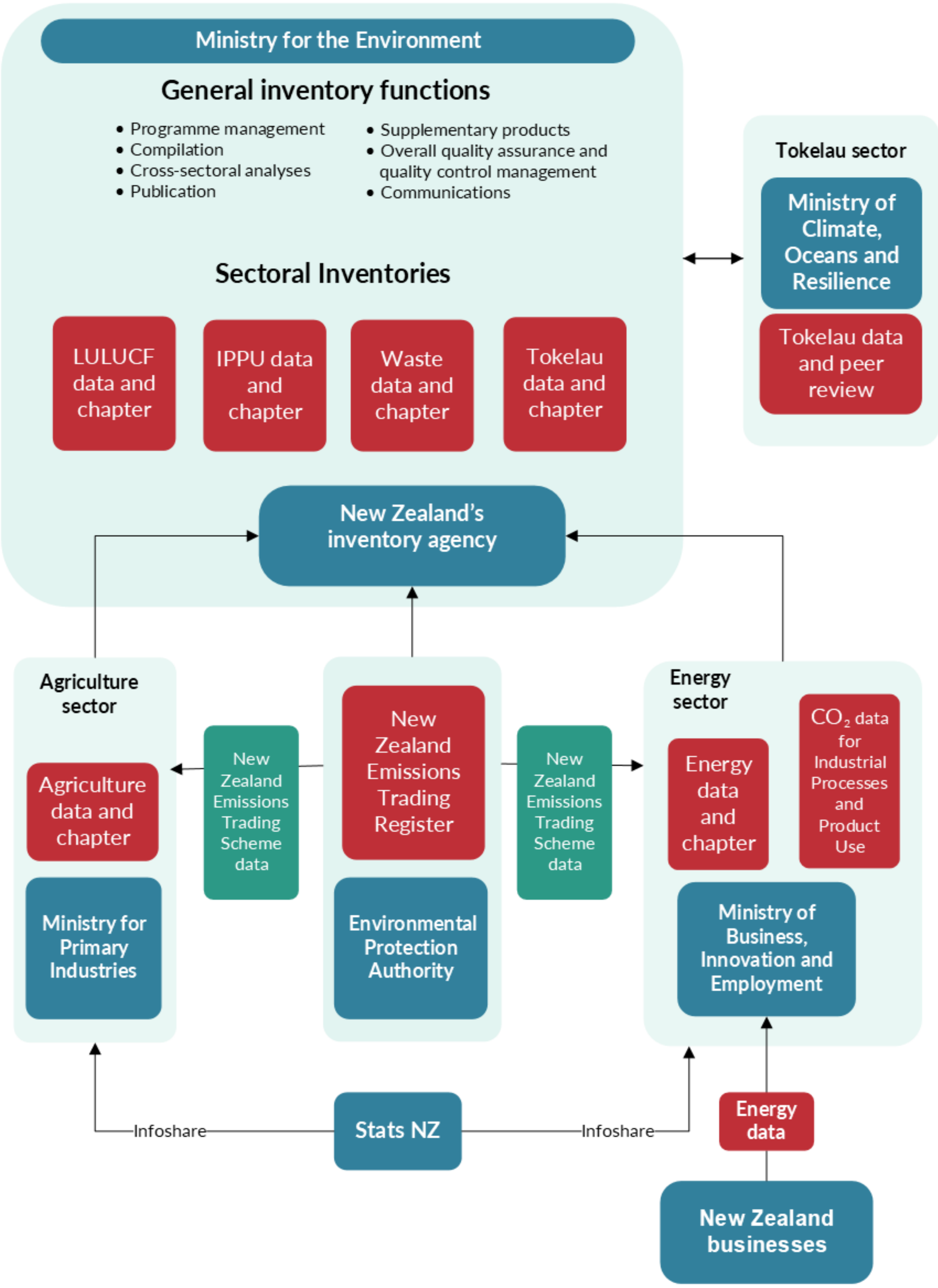
MPI estimates emissions from the Agriculture sector. The estimates are underpinned by research and modelling undertaken at New Zealand's Crown research institutes, universities and private research companies, and survey data collected by the national statistics agency Stats NZ and key sector organisations.

MiCORE and the Tokelau National Statistics Office coordinate efforts in activity data collection and data processing to estimate emissions from Tokelau for all inventory sectors.

The Climate Change Response Act 2002 establishes the requirement for an emissions trading registry and a registrar. The EPA is the designated agency responsible for managing the administration of the NZ ETS and implementing and operating New Zealand's national registry, the New Zealand Emissions Trading Register.

The EPA collects and publishes information on emissions.[10] The inventory arrangements are presented in figure 1.2.2, which shows the specific responsibilities of different agencies involved in the inventory production as well as their contribution to the submission.

Figure 1.2.2 New Zealand's inventory system at a glance: how different agencies are involved



10 EPA. *Emissions returns report*. Retrieved 12 March 2025.

The National Inventory Compiler coordinates the calculation of level and trend uncertainties, along with key category assessment, and finalises the inventory. The inventory is then approved for publication by the New Zealand Secretary for the Environment or their delegate before submission to the UN Climate Change secretariat.

The inventory is published on the MfE and UN Climate Change websites.

1.3 Brief general description of methodologies (including tiers used) and data sources used

The guiding documents underpinning the inventory's preparation are the Paris Agreement, decisions taken at the first session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (UNFCCC, 2018a), the modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement (UNFCCC, 2018b) and the guidance operationalising the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement (UNFCCC, 2021).

New Zealand applies methodologies for estimating GHG emissions and sinks that utilise a combination of country-specific and IPCC methodologies and emission factors. These methods are consistent with the 2006 IPCC Guidelines (IPCC, 2006a). The IPCC (2006a) provides a number of possible methodologies for calculating emissions or removals from a given sector and category. In most cases, these possibilities represent calculations of the same form, while differing in the level of detail at which the calculations are carried out.

The methodologies are provided in a structure of three tiers that describe and connect the various levels of detail at which estimates can be made. The choice of method depends on factors such as the importance of the inventory category and the availability of data. The tiered structure ensures that estimates calculated at a highly detailed level can be aggregated up to a common minimum level of detail for comparison with all other reporting countries. The methods for estimating emissions and/or removals are distinguished between the tiers as follows.

- Tier 1 methods apply IPCC default emission factors and use IPCC default methods.
- Tier 2 methods apply country-specific emission factors and use IPCC default methods.
- Tier 3 methods apply country-specific emission factors and use country-specific methods.

This section provides a brief description of the methodology for each sector in the inventory. Refer to each sector chapter for more details.

Energy

Greenhouse gas emissions from the Energy sector are calculated using a detailed sectoral approach that applies a mixture of Tier 1, Tier 2 and Tier 3 methods. Higher-tier methods are applied to key categories. This bottom-up approach is demand-based: it involves processing energy data collected on a regular basis through various surveys. For verification, New Zealand also applies the IPCC reference approach to estimate CO_2 emissions from fuel combustion for the time series 1990 to 2023 (see annex 3).

The activity data used for the sectoral approach are referred to as 'observed' energy-use figures. These are based on surveys and questionnaires administered by MBIE. The differences between 'calculated' and 'observed' figures are reported as statistical differences in the energy balance tables released along with *Energy in New Zealand* (MBIE, 2024a). Note that, due to the intervening time between the publication of *Energy in New Zealand* and the preparation of this submission, some data revisions may have occurred.

IPPU

New Zealand uses a combination of IPCC Tier 1 and Tier 2 methods for the IPPU sector. Tier 2 methods are used for all key categories. Country-specific emission factors are used where available, including for emissions of indirect GHGs.

For the *Product uses as substitutes for ODS* category, updated activity data are obtained through a detailed annual survey covering the electrical, refrigeration and other industry participants (Verum Group Ltd, unpublished), as well as importers of HFCs and other substances in this category.

For small amounts of indirect GHG emissions reported in the *Chemical industry* category and the *Other product manufacture and use* category, data were obtained by a detailed industry survey and analysis in 2006 (CRL Energy, unpublished). Emissions and activity data have been extrapolated for the years since that time.

Agriculture

New Zealand has developed a largely Tier 2 (with some Tier 1 aspects and other aspects reflecting Tier 3) methodology with country-specific emission factors for a range of emissions sources. This methodology uses detailed data on livestock population and production to calculate livestock energy requirements for four major livestock categories (*Dairy cattle*, *Non-dairy* (beef) *cattle*, *Sheep* and *Deer*). Other livestock are classified as 'minor' due to their small total contribution to agricultural emissions and are outlined below. Animal population data are collected by Stats NZ. Productivity data are available from the Livestock Improvement Corporation and industry organisations, such as Beef + Lamb New Zealand Ltd and Dairy NZ, which regularly collect animal sector statistics. Statistics on animal carcass weights are collected by MPI and are used to derive live weights.

Other livestock species combined (*Swine*, *Goats*, *Horses*, *Llamas and alpacas*, *Mules and asses* and *Poultry*) account for less than 0.5 per cent of New Zealand's agriculture emissions. Emissions from these minor livestock species are estimated using Tier 1 methods. Where information is available, New Zealand has used country-specific emission methodology and factors. There is no known farming of fur-bearing animals in New Zealand.

For estimating emissions from the *Agricultural soils* category, New Zealand uses methodologies based on the 2006 IPCC Guidelines (IPCC, 2006d), the outputs of the Tier 2 livestock population characterisation, modelling of the livestock nutrition and energy requirements, and data on the application of nitrogen fertilisers. New Zealand uses a combination of default and country-specific emission factors and parameters to calculate N_2O emissions from the *Agricultural soils* category.

Details on these emission factors and parameters are given in chapter 5 (tables 5.5.2, 5.5.3 and 5.5.4) and annex 5 (tables A5.1.5, A5.1.6 and A5.1.7). Chapter 5, table 5.5.5 contains the parameters used to estimate emissions where specific mitigation technologies are used. Activity data for the *Liming* category are obtained from Stats NZ, and activity data on the use of synthetic fertiliser containing nitrogen are provided by the Fertiliser Association of New Zealand. A Tier 2 (model) approach is used to calculate emissions from the *Field burning of agricultural residues* category. No rice cultivation or CO_2 emissions from other carbon-containing fertilisers occur in New Zealand.

LULUCF

New Zealand uses a combination of Tier 1, Tier 2 and Tier 3 methodologies for estimating emissions and removals for the LULUCF sector. Tier 2 or Tier 3 approaches have been applied to estimate biomass carbon in the pools with the most living biomass at maturity: *Pre-1990 natural forest, Pre-1990 planted forest, Post-1989 natural forest, Post-1989 planted forest, Perennial cropland* and *Grassland with woody biomass*. For all other land use categories, a Tier 1 approach is used for estimating biomass carbon. A Tier 2 modelling approach has also been used to estimate carbon changes in the mineral soil component of the soil organic matter pool, while Tier 1 is used for organic soils. Furthermore, a Tier 2 approach has been used to estimate carbon stock changes in the *Harvested wood products* category.

New Zealand has established a data collection and modelling program for the LULUCF sector called the Land Use and Carbon Analysis System (LUCAS). The LUCAS program includes:

- use of field plot measurements for natural and planted forests
- use of allometric models and a forest carbon modelling system to estimate carbon stock and carbon stock change in natural and planted forests respectively (Paul et al., 2020, unpublished(a), unpublished(b), unpublished(c); Paul and Wakelin, unpublished)
- wall-to-wall land use mapping for 1990, 2008, 2012, 2016 and 2020 using satellite and aircraft remotely sensed imagery, with additional information on post-1989 forest afforestation and deforestation of planted forest used for estimating the change
- development of databases and applications to store and process all data associated with LULUCF activities.

Waste

New Zealand uses Tier 2 methodologies for estimating emissions from the *Solid waste disposal source* category, which is a key category, and for some wastewater emissions. Tier 1 methodologies are used to estimate other emissions from the Waste sector.

Activity data are obtained from a variety of sources. Municipal solid waste disposal data are obtained from mandatory reporting under the Waste Minimisation Act 2008 and the NZ ETS for the years available (2010 onwards). Non-municipal waste disposal data are also derived from mandatory reporting under the Act from 2022 onwards. For all other sources, activity data are collected through targeted surveys. Interpolation based on gross domestic product (GDP) or population is used for other years.

Country-specific emission factors are used where available, including parameters for municipal waste (Eunomia, unpublished) and for treatment of some types of industrial wastewater (Cardno, unpublished).

Methodological issues are discussed under each source category in chapter 7.

Tokelau

The Tokelau National Statistics Office collects and processes activity data from Tokelau for the preparation of the inventory. Chapter 8, table 8.1.1 contains the key sources of the activity data from Tokelau used in Tokelau's GHG inventory.

Tier 1 methodological approaches with default emission factors are used for estimating emissions from all Tokelau source categories.

1.4 Brief description of key categories

The 2006 IPCC Guidelines (IPCC, 2006b) identify a key category as one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct GHGs in terms of the absolute level of emissions, the trend in emissions, or both.

Key categories identified within the inventory are used to prioritise inventory improvements.

The key categories in the inventory have been assessed using Approach 1 level (L1) and Approach 1 trend (T1) methodologies from the 2006 IPCC Guidelines (IPCC, 2006b). This is because some categories in the inventory apply default uncertainty values for emissions estimates, and developing country-specific uncertainty values is resource prohibitive.

The key category analysis identifies key categories of emissions and removals as those that sum to 95 per cent of the gross or net level of emissions and those that are within the top 95 per cent of the categories that contribute to the change between the base year (1990) and the current reporting year, or the trend of emissions. New Zealand does not currently use qualitative assessment to identify any key categories.

In accordance with the 2006 IPCC Guidelines (IPCC, 2006b), the key category analysis is performed on inventory sources excluding the LULUCF sector and then repeated for inventory sources and sinks including the LULUCF sector. Non-LULUCF categories that are identified as key in the first analysis are still included when they are not identified as a key category in the analysis that includes the LULUCF sector.

The key category analyses performed for the inventory differ from the analysis produced in the GHG Inventory Reporting Tool, because the level of aggregation of categories is adjusted to better reflect New Zealand's emissions profile. Specifically, a large proportion of emissions from the Energy and Agriculture sectors is disaggregated further than the key category analysis generated in the GHG Inventory Reporting Tool, to allow for a more evenly proportioned analysis of categories.

The major contributions to the level analysis of net emissions for 2023 were:

- CO_2 emissions from *Forest land remaining forest land* (15.3 per cent)
- CH_4 emissions from *Enteric fermentation – Dairy cattle* (14.9 per cent)
- CO_2 emissions from *Road transportation – Liquid fuels* (11.9 per cent)
- CH_4 emissions from *Enteric fermentation – Sheep* (8.1 per cent).

The key categories that were identified as having the largest relative influence on the trend, when compared with the average change in net emissions from 1990 to 2023, were:

- CO_2 emissions from *Carbon stock change – Forest land remaining forest land* (16.2 per cent as a decrease)
- CH_4 emissions from *Enteric fermentation – Sheep* (16.2 per cent as a decrease)
- CO_2 emissions from *Carbon stock change – Land converted to forest land* (13.6 per cent as an increase)
- CH_4 emissions from *Enteric fermentation – Dairy cattle* (8.7 per cent as an increase).

For gross emissions, the major contributions to the level analysis for 2023 were:

- CH_4 emissions from *Enteric fermentation – Dairy cattle* (20.4 per cent)
- CO_2 emissions from *Road transportation – Liquid fuels* (16.4 per cent)
- CH_4 emissions from *Enteric fermentation – Sheep* (11.1 per cent)
- CH_4 emissions from *Non-dairy* (beef) *cattle – Enteric fermentation* (9.3 per cent).

The key categories that were identified as having the largest relative influence on the trend, when compared with the average change in gross emissions from 1990 to 2023, were:

- CH_4 emissions from *Enteric fermentation – Sheep* (22.6 per cent as a decrease)
- CH_4 emissions from *Enteric fermentation – Dairy cattle* (18.4 per cent as an increase)
- CO_2 emissions from *Road transportation – Liquid fuels* (12.2 per cent as an increase)
- CO_2 emissions from *Energy industries – Manufacture of solid fuels and other energy industries – Gaseous fuels* (4.2 per cent as a decrease).

The full analyses and results of the key category assessments are provided in annex 1.

1.5 Brief general description of QA/QC plan and implementation

Quality assurance[11] and quality control[12] are integral parts of preparing the inventory. MfE's QA/QC plan (annex 4), required under the Paris Agreement (UNFCCC, 2018b), formalises the documentation and archiving of the QA/QC procedures. This plan has been updated over time as the QA/QC tools have been developed and, where possible, automated. Details of the QA/QC activities performed during the compilation of the 2025 submission are discussed in the relevant sections below. Examples of QA/QC checks are provided in the Excel spreadsheets accompanying this submission.

The focus of New Zealand's QA/QC plan is to meet the transparency, accuracy, completeness, consistency and comparability (TACCC) principles while ensuring efficient use of resources, and to mitigate QA/QC-related risks in the inventory planning and preparation process.

The main elements of the plan include:

- revising the QA/QC deliverables to ensure they are fit for purpose, well supported with relevant templates, and adapted to the changes in the inventory software tools
- reinforcing the error-checking process by providing dedicated personnel and support to the sector leads
- applying automated inventory tools, where available, to minimise transcription errors
- adjusting QA/QC tools to accommodate any changes in the GHG Inventory Reporting Tool software that have been introduced since the previous submission

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[11] Quality assurance (QA) is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation and development process.

[12] Quality control (QC) is a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. It is performed by personnel compiling the inventory.

- performing data integrity checks in the GHG Inventory Reporting Tool and adhering to the reporting guidelines once data compilation in each sector is complete
- ensuring the chapters in the inventory and their structure demonstrate transparency of the methods and incorporate suggestions from previous inventory reviews.

Completion of the IPCC 2006 Tier 1 QC check sheets for each sector is the responsibility of the sector leads (see table 1.5.1 for a list of the responsible agencies). The Tier 1 checks are in line with the guidance provided in the 2006 IPCC Guidelines (IPCC, 2006b). Wherever possible, manual checking is replaced by, or supplemented with, automated checks.

The sectoral contributions to the inventory – that is, sector chapters and data preparation – and Tier 1 QC checks are signed off by the responsible agency before final approval of the inventory by the national inventory agency (MfE) and its submission under UNFCCC and the Paris Agreement.

MfE uses the QC-checking procedures included in the GHG Inventory Reporting Tool where available to ensure the data submitted are complete. In addition, data in the GHG Inventory Reporting Tool are checked for anomalies, errors and omissions.

After the CRT are compiled for each inventory sector, the CRT data for each sector and category are reviewed by the inventory compilation project team for data integrity and time-series consistency before sector finalisation. The purpose of this review is to ensure that the CRT do not contain blank entries in the reported categories, and that all instances of using the 'IE' (included elsewhere) and 'NE' (not estimated) notation keys for GHG emissions, as well as large variations in the implied emission factors, have been explained. The results of these checks are provided to the sector leads so they can make any corrections and include the relevant references and explanations, if required, to finalise the CRT data for each inventory sector.

Annex 4 contains details of the QA/QC plan, including the processes applied during the preparation of the inventory.

Table 1.5.1 Agency responsible for each sector

Responsibility	Responsible New Zealand agency
Energy sector	Ministry of Business, Innovation and Employment
IPPU sector	Ministry for the Environment
LULUCF sector	Ministry for the Environment
Waste sector	Ministry for the Environment
Tokelau	Ministry for the Environment, Tokelau Government
Agriculture sector	Ministry for Primary Industries
National inventory agency	Ministry for the Environment

The activity data provided by Stats NZ are official national statistics (known as 'Tier 1 statistics'). As such, they are subject to their own rigorous QA/QC procedures.

Human population and animal production statistics provided by Stats NZ are also used for estimating emissions from the Waste sector.

Tokelau's activity data undergo QC processes at the Tokelau National Statistics Office. Tokelau's emissions estimates undergo QA/QC processes that are similar to those of other inventory sectors.

Improvement planning

New Zealand's QA/QC system includes prioritisation of improvements, processes around accepting improvements into the inventory, in-depth review of sector inventories or their components every 5 to 10 years, and improving the expertise of key contributors to compiling the inventory. The government audit agency (Audit New Zealand) makes annual audits of the inventory including assuring the QA/QC procedures were followed. New Zealand also considers the international technical expert reviews of the inventory performed by qualified expert reviewers through the Enhanced Transparency Framework under the Paris Agreement as an important element of QA/QC. The main aspects of QA/QC system are explained in detail below.

All sector leads are encouraged to schedule sector-specific QA/QC audits of their systems at least every five years. Sector-specific examples are provided below.

The Energy sector lead discussed sectoral issues with the Danish inventory team during bilateral meetings in 2017 dedicated to different aspects of the Energy sectoral inventory. The specific issues covered were: data sources, data collection and verification processes; using NZ ETS data for higher-tier methods in the Energy sector; applying higher-tier methods for road transport; disaggregation of non-road liquid fuel use; and fugitive emissions from fuels. In 2019, an external consultant was contracted to review and develop a QA/QC plan for the Energy sector. Most recommendations from that review have already been implemented, and work continues on addressing the remaining issues. In 2024, as part of an audit of MBIE's annual report (MBIE, 2024b) – which features published data of GHG emissions from electricity generation as a performance indicator – Audit New Zealand carried out an independent, in-depth review of MBIE's energy and emissions data process. The auditors examined the completeness and accuracy of MBIE's emissions estimates and verified the integrity of the entire data processing chain from receipt of raw data to data entry, processing, calculation and reporting.

The Agriculture sector completed a major QA/QC review of its calculation models with an external party in 2013. Since then, other QA/QC activities for the Agriculture sector have included a bilateral review with Australia in 2014 and an external review of equations used to determine metabolisable energy requirements in 2016. From 2022 to 2023, the Agriculture calculation models were migrated from an Excel-based system combined with Visual Basic for Applications code to an R-based system. The attention to detail required to replicate the model also acted as a QA/QC review. The R model and Excel model were run in parallel over the 2023 reporting cycle and compared again in detail. The increased transparency of the R model allows for a greater level of oversight by the analysts in the inventory team, making future QA/QC of the calculations easier.

In 2024, MPI released a standard methodology and codebase for estimating on-farm emissions.[13] The work to develop a farm-level emissions calculation methodology provided additional QA/QC as this work used the inventory model and methodology as a basis. This involved experts at MPI outside of the inventory team going through the calculations in detail to adapt them for the farm-level application. For more information, see chapter 5, section 5.1.6.

[13] For more details and a link to the codebase on Github, see: MPI. *Estimating on-farm emissions.* Retrieved 12 March 2025.

Prioritisation of improvements

Priorities for the development of the inventory are guided by:

- the results of key category analyses (level and trend)
- the degree of improvement to be achieved for existing emissions and removal estimates
- the availability of resources required to implement the change
- recommendations from previous international reviews of the inventory.

Uncertainties are also considered in prioritising improvements. For example, if a change in a methodological approach may lead to a significant increase in uncertainty of the estimates, then the proposed change may be rejected based on an undesired increase in uncertainty. Otherwise, if the proposed improvement is not expected to affect the uncertainty significantly or will reduce uncertainty, then the change is likely to be prioritised. Sector leads are encouraged to develop annual inventory improvement and QA and QC plans to reflect current and future developments for their sector of the inventory.

Acceptance of improvements and recalculations

All proposed improvements in the inventory undergo peer review by an independent expert or a group of experts. The change will be included in the inventory only if the peer reviewer concludes that the change is consistent with 2006 IPCC Guidelines (IPCC, 2006a) for the preparation and continuous improvement of national GHG inventories.

Given the significance of the Agriculture sector to New Zealand's emissions, the Government established the Agriculture Inventory Advisory Panel (the Panel). The Panel is an independent group of experts who assess if proposed improvements and recalculations in the sector's emissions are scientifically robust enough to include in the inventory. Reports and/or papers on proposed changes must be peer reviewed before they are presented to the Panel. The Panel then advises MPI of its recommendations. Refer to chapter 5, section 5.1.5 for further details.

All major recalculations for and improvements to the inventory are overseen by the RGG. The recalculations need to be sufficiently explained in terms of improving one or more of the TACCC principles. If, due to the recalculations, emissions from the recalculated category are higher than 500 kilotonnes carbon dioxide equivalent (kt CO_2-e), the results of and reasons for the recalculations are documented and archived for future reference.

Verification activities

Where relevant, further verification activities carried out for a sector are discussed in the sector-specific chapters of this report.

In the Energy sector, the reference approach is used to verify the emissions estimates for CO_2 obtained from the sectoral approach. Further detail is provided in annex 3.

New Zealand Emissions Trading Scheme

The NZ ETS is one of the Government's primary tools for reducing GHG emissions. This section explains the background of the NZ ETS and how the data collected for the NZ ETS have been used to verify CO_2 emissions in the Energy and IPPU sectors.

New Zealand Units

The NZ ETS is based on trading units that each represent 1 tonne of CO_2-e, called New Zealand Units (NZUs), which are created and distributed by the New Zealand Government. The scheme was established through an amendment to the Climate Change Response Act 2002[14] and came into effect progressively from 2008, with coverage since 2010 of all substantial emissions except agricultural CH_4 and N_2O.

Sectors under the scheme are required to report on their emissions and surrender units to the Government to cover their emissions. The Government supplies units for emissions removals through forestry and exports of emitting products from New Zealand. Units are also supplied as industrial allocation to firms carrying out activities that are emissions intensive and trade exposed, to address the risk of emissions leakage, and via quarterly auctions.

More information on the NZ ETS can be found on the MfE website.[15]

Verification

Participants in the NZ ETS are required to record and report the GHG emissions for which they have obligations or if they are claiming NZUs for removing GHG emissions from the atmosphere. Participants with obligations are also required to annually surrender NZUs to cover their emissions. How participants estimate their emissions is set out in the regulations prescribed under the Climate Change Response Act 2002. The schedule for sectors entering the NZ ETS is detailed in table 1.5.2.

For this submission, data collected for the NZ ETS were used to verify the Inventory estimates for CO_2 emissions in the Energy and IPPU sectors (see chapter 3 and chapter 4 for further detail on the verification). Data from the NZ ETS were used as a primary source in the IPPU sector for the cement and lime industries, and in the Waste sector to verify activity data on municipal waste disposal. Data reported under the Waste Minimisation Act 2008 have been used as the primary data (see chapter 7 for details).

The NZ ETS data are also used for verifying activity data in the LULUCF sector. Forest age, area and deforestation as reported under the NZ ETS are used for verifying the areas of pre-1990 planted forest, post-1989 forest and deforestation.

Table 1.5.2 Dates for sector entry into the New Zealand Emissions Trading Scheme

Sector	Voluntary reporting	Mandatory reporting	Obligations
Forestry	–	–	1 January 2008
Transport fuels	–	1 January 2010	1 July 2010
Stationary energy, including electricity production	–	1 January 2010	1 July 2010
IPPU	–	1 January 2010	1 July 2010
Synthetic gases	1 January 2011	1 January 2012	1 January 2013
Waste	1 January 2011	1 January 2012	1 January 2013
Agriculture	1 January 2011	1 January 2012	–

14 Climate Change Response (Emissions Trading) Amendment Act 2008.

15 MfE. *New Zealand Emissions Trading Scheme.* Retrieved 12 March 2025.

Treatment of confidentiality issues

When specific emissions and activity data in the inventory can result in identifying individuals and/or individual businesses and, therefore, affect their wellbeing, commercial interest in trade and/or negotiations, those data are considered to be confidential.

The inventory is a Tier 1 statistic under New Zealand's Official Statistics System. The inventory compilation process adheres to the *Principles and Protocols for Producers of Tier 1 Statistics* (Stats NZ, 2007). The relevant definition of confidentiality (protocol 4) is as follows.

- Confidentiality refers to the protection of individuals' and organisations' information, and ensuring that the information is not made available or disclosed to unauthorised individuals or entities.
- The protection of respondents' information is a cornerstone of maintaining the integrity of the Official Statistics System.

Confidential data are aggregated to draw out the information that is important to the user, without disclosing confidential data (IPCC, 2006b). For New Zealand, confidentiality issues largely apply to sources of emissions in the Energy and IPPU sectors, where an entire industry or source category is often represented by just one or two companies. Therefore, a practice of presenting information as an 'industry average' is often not applicable in New Zealand because this would breach business confidentiality. Confidential information is held by the agencies preparing the inventory sector estimates (MPI, MBIE and MfE), and each agency has security procedures (e.g., password-restricted access to files on computers) to keep the data confidential.

To protect the confidentiality of businesses that contribute data to the inventory, two approaches are used.

- Where emissions cannot be reported without compromising confidentiality, the corresponding activity data are not reported and are marked as confidential in the CRT.
- Where reporting emissions data would risk breaching confidentiality, the emissions data are aggregated with other emissions from a different source category. The notation key 'IE' (included elsewhere) is used.

1.6 General uncertainty assessment, including data pertaining to the overall uncertainty of inventory totals

Uncertainty estimates are an essential element of a complete inventory. The purpose of uncertainty information is not to dispute the validity of the inventory estimates but to help prioritise efforts to improve the accuracy of inventories and guide decisions on methodological choice (IPCC, 2006b). Inventories prepared in accordance with the 2006 IPCC Guidelines (IPCC, 2006a) will typically contain a wide range of emissions estimates, varying from carefully measured and demonstrably complete data on emissions, to order-of-magnitude estimates for highly variable emissions such as N_2O fluxes from soils and waterways (IPCC, 2006b).

New Zealand includes an uncertainty analysis of the aggregated figures applying Approach 1 from the 2006 IPCC Guidelines (IPCC, 2006b).

Uncertainties in the categories are combined to provide uncertainty estimates for all emissions for the latest reporting year and the base year, and the uncertainty in the trend over time. Annex 2 sets out detailed uncertainties for net emissions, where removals under LULUCF categories are included (table A2.1.1), and gross emissions excluding LULUCF (table A2.1.2).

In most instances, the uncertainty values are determined when country-specific emission factors are developed or activity data obtained, using expert judgement from sectoral or industry experts, or by referring to uncertainty ranges provided in the 2006 IPCC Guidelines (IPCC, 2006b). Uncertainties for the source categories are originally determined at the lowest level where information and data are available.

The low-level uncertainties are then aggregated to various extents by individual sector leads as far as the second-level category for each of CO_2, CH_4, N_2O and SF_6 separately and for HFCs and PFCs as groups. These category-level aggregated data are submitted to the inventory compilation team for performing overall uncertainty calculations for level and trend uncertainties for gross and net emissions.

In most cases, to aggregate uncertainties from subcategories, sectoral compilers use Approach 1 (IPCC, 2006b, equation 3.2, page 3.28).

For more detail, refer to the sector-specific chapters.

Gross emissions

Uncertainty in 2023 – level assessment

The uncertainty in gross emissions (excluding emissions and removals from the LULUCF sector) in 2023 is ±8.6 per cent. This is a decrease of 0.2 percentage points from that reported for 2022 in the previous submission. Emissions contributing the most to the overall uncertainty of gross emissions in 2023 were CH_4 from Agriculture – *Enteric fermentation* (±16.0 per cent) at 6.6 per cent, N_2O from Agriculture – *Agricultural soils* (±55.9 per cent) at 4.7 per cent and CH_4 from Waste – *Solid waste disposal* (±89.4 per cent) at 2.6 per cent. The uncertainty in these categories reflects the inherent variability when estimating emissions from natural systems.

Uncertainty in 1990 – level assessment

In 1990, the uncertainty in gross emissions was ±9.1 per cent. This is a decrease of 0.6 percentage points from the previous submission. Emissions of CH_4 from Agriculture – *Enteric fermentation* contributed 7.3 per cent, N_2O from Agriculture – *Agricultural soils* contributed 3.8 per cent and CH_4 from Waste – *Solid waste disposal* contributed 3.5 per cent to the overall uncertainty of gross emissions in 1990.

Uncertainty in the trend

The trend uncertainty in gross emissions (excluding emissions and removals from the LULUCF sector) from 1990 to 2023 is ±5.4 per cent. This is a decrease of 0.9 percentage points from the previous submission. This decrease is primarily a result of a decrease in the Waste – *5.A Solid waste disposal* uncertainties.

Net emissions

Uncertainty in 2023 – level assessment

The uncertainty for New Zealand's Inventory, including emissions and removals from the LULUCF sector, in 2023 is ±24.7 per cent. There has been an increase of 0.4 percentage points in uncertainty from that reported for 2022 in the previous submission. Emissions contributing the most to the overall uncertainty of net emissions in 2023 were CO_2 from LULUCF – *Forest land* (±62.3 per cent) at 20.5 per cent, CH_4 from Agriculture – *Enteric fermentation* (±16.0 per cent) at 9.0 per cent and CO_2 from LULUCF – *Harvested wood products* (±68.2 per cent) at 7.1 per cent.

Uncertainty in 1990 – level assessment

In 1990, the uncertainty in net emissions was ±36.9 per cent. There has been a decrease of 1.6 percentage points from the previous submission.

Emissions of CO_2 from LULUCF – *Forest land* contributed 33.8 per cent, CH_4 from Agriculture – *Enteric fermentation* contributed 11.5 per cent and N_2O from Agriculture – *Agricultural soils* contributed 6.0 per cent to the overall uncertainty of net emissions in 1990.

Uncertainty in the trend

When emissions and removals from the LULUCF sector are included, the overall uncertainty in the trend from 1990 to 2023 is ±20.0 per cent. This is a decrease of 3.5 percentage points when compared with the previous submission. This decrease is primarily a result of a decrease in the LULUCF – *4.A Forest land* uncertainties.

1.7 General assessment of completeness

Under the Paris Agreement, the level of completeness of reported sources in national inventories must be assessed. In accordance with the 2006 IPCC Guidelines (IPCC, 2006b), New Zealand has focused its resources for inventory development on the key and non-key categories that are mandatory.

1.7.1 Information on completeness

Emissions reported as 'NE' (not estimated)

The notation key 'NE' signifies that emissions and/or removals occur but have not been estimated or reported. According to chapter II of the Annex to the decision 18/CMA.1 (UNFCCC, 2018b), 'NE' may be used when the estimates would be insignificant in terms of level according to the following considerations.

- Emissions from a category should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions, excluding LULUCF, or 500 kt CO_2-e, whichever is lower.
- The total national aggregate of estimated emissions for all gases from categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions, excluding LULUCF.

Once emissions or removals have been estimated for a category, they must continue to be reported if they continue to occur.

'NE' is also used when an activity occurs, but the 2006 IPCC Guidelines (IPCC, 2006a) do not provide methodologies to estimate emissions and removals. If this is the case, the category is considered to be non-mandatory, providing the emissions from the category have not been reported previously.

New Zealand's total (i.e., gross) emissions were 76,416.3 kt CO_2-e in 2023. The threshold of 0.1 per cent is 76.4 kt CO_2-e and the threshold of 0.05 per cent is 38.2 kt CO_2-e. Both values are below 500 kt CO_2-e.

The Inventory is largely complete. A few minor sources are not estimated due to a lack of available information, or because emissions are insignificant or methodologies to estimate emissions are not provided in the 2006 IPCC Guidelines.

Table 1.7.1 summarises New Zealand's direct GHG emissions reported as 'NE' in the 2025 submission.

Table 1.7.1 Summary of 'NE' (not estimated) entries in the 2025 submission

CRT category code	Category	Gas	Explanation
Energy			
1.B.2.a.5	Distribution of oil products	CO_2, CH_4	This category is not mandatory. The 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines) do not provide default emission factors for calculating Tier 1 estimates of methane (CH_4) emissions from the distribution of refined oil products (IPCC, 2006c). New Zealand has not reported emissions estimates from this category in previous submissions.
1.B.2.b.3	Processing	CO_2, CH_4	In accordance with chapter II of the Annex to the decision 18/CMA.1 (UNFCCC, 2018b), this category is not mandatory. Fugitive emissions of carbon dioxide (CO_2) and CH_4 have not been formally estimated, although a rough estimate of the likely level of emissions indicates that they are insignificant. While emissions from the Kapuni Gas Treatment Plant may include traces of CH_4, the level of these emissions has been determined to be insignificant in comparison with national emissions. A conservative estimate (based on default emission factors from the 2006 IPCC Guidelines) sums to 1.7 kt CO_2e emissions per year (IPCC, 2006c). CH_4: 625 Mm^3 (Kapuni field production) * 9.7e-5 * 28 = 1.7 kt CO_2-e. The conservative estimated value is below 0.05 per cent of New Zealand's total emissions. This would keep the national total aggregate of estimated emissions for all gases and categories considered insignificant below 0.1 per cent of the national total greenhouse gas emissions. Carbon dioxide from gas processing is mostly associated with direct venting through a stack and, therefore, is reported under 1.B.2.c.1, as recommended in the 2017 assessment review report (UNFCCC, 2017). However, there is a possibility of the presence of trace amounts of CO_2 from processing due to leakage, which is estimated to be no higher than 0.1 per cent of vented CO_2. A conservative estimate of 0.1 per cent of vented CO_2 from all categories is 0.26 kt, which is below 0.05 per cent of New Zealand's total emissions and thus can be considered insignificant.
1.B.2.c.ii	Venting – Gas	CH_4	In accordance with chapter II of the Annex to the decision 18/CMA.1 (UNFCCC, 2018b), this category is not mandatory. While direct venting of CH_4 does not occur, the CO_2 stream may include traces of CH_4. The level of these emissions has been determined to be insignificant in comparison with national emissions. A conservative estimate (based on default emission factors from the 2006 IPCC Guidelines) sums to 1.7 kt CO_2e per year (IPCC, 2006c). CH_4: 625 Mm^3 (Kapuni field production) * 9.7e-5 * 28 = 1.7 kt CO_2-e. The conservative estimated value is below 0.05 per cent of New Zealand's total emissions. This would keep the national total aggregate of estimated emissions for all gases and categories considered insignificant below 0.1 per cent of New Zealand's total emissions.

CRT category code	Category	Gas	Explanation
Industrial Processes and Product Use			
2.G.2.e	Medical and other product use	C_2F_6	In accordance with chapter II of the Annex to the decision 18/CMA.1 (UNFCCC, 2018b), this category is not mandatory. The level of emissions from this source has been determined to be insignificant in comparison with national emissions. No activity data are available before 2011. Based on 2011 to 2022 data, emissions of perfluoroethane (C_2F_6) from *Medical and other product use* are estimated to be approximately 2.6 t CO_2-e per annum, which is below the significance threshold.
2.G.2.e	Medical and other product use	C_3F_8	In accordance with chapter II of the Annex to the decision 18/CMA.1 (UNFCCC, 2018b), this category is not mandatory. The level of emissions from this source has been determined to be insignificant in comparison with national emissions. No activity data are available before 2011. Based on 2011 to 2022 data, emissions of perfluoropropane (C_3F_8) from *Medical and other product use* are estimated to be approximately 2.7 t CO_2-e per annum, which is below the significance threshold.
Agriculture			
3.A.4.g (for both New Zealand and Tokelau)	Poultry	CH_4	This category is not mandatory. The 2006 IPCC Guidelines state (IPCC, 2006d, page 10.27, vol 4-2) that the Tier 1 method for estimating CH_4 emissions from enteric fermentation for poultry is not developed. Also, table 10.10 (IPCC, 2006d, page 10.28, vol 42) indicates that there is insufficient research to establish a CH_4 emission factor for poultry for either developed or developing countries.
3.B.5	Indirect N_2O emissions	N_2O	This category is not mandatory. The 2006 IPCC Guidelines for determining indirect nitrous oxide (N_2O) emissions do not provide a methodology for estimating emissions from leaching and runoff (IPCC, 2006d). In addition, indirect N_2O emissions from leaching and runoff are insignificant in New Zealand, because almost all livestock are kept outdoors all year round on pasture.
3.I	Other carbon-containing fertilisers	CO_2	This category is not mandatory. The 2006 IPCC Guidelines do not provide guidance for reporting on other carbon-containing fertilisers (IPCC, 2006d). Other carbon-containing synthetic fertilisers besides limestone, dolomite and urea are not applied to agricultural land in New Zealand.
Land Use, Land-Use Change and Forestry			
4.A, 4.B,4.C,4.D	Forest land, cropland, grassland and wetlands: Drainage and rewetting and other management of organic and mineral soils	CH_4, N_2O	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for estimating emissions from this source category (IPCC, 2006d).
4.A.2	Settlements converted to other land uses	CO_2 (losses)	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for calculating Tier 1 estimates of carbon stocks in living biomass for *Settlements* (IPCC, 2006d). Therefore, with land-use change from *Settlements* to other land uses, no carbon stock loss is reported. Because New Zealand uses the stock change approach, losses are reported only in years when new land is converted to this category, or when there is harvesting of forest in the year of conversion. When neither of these activities occurs, the losses are reported with biomass gains (stock change approach) and 'IE' (included elsewhere) is reported for biomass losses.
4.A.2, 4.C.2	Other land converted to other land uses	CO_2 (losses)	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for calculating Tier 1 estimates of carbon stocks in living biomass for *Other land* (IPCC, 2006d). Therefore, with land-use change from *Other land* to other land uses, no carbon stock loss is reported. Because New Zealand uses the stock change approach, losses are reported only in years when new land is converted to this category, or when there is harvesting of forest in the year of conversion. When neither of these activities occurs, the losses are reported with

CRT category code	Category	Gas	Explanation
			biomass gains (stock change approach) and IE is reported for biomass losses.
4.A, 4.B, 4.C, 4.D, 4.F	Forest land, Cropland, Grassland, Wetlands and Other land: Rewetting and other management of organic and mineral soils	CO_2	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for estimating emissions from this source category (IPCC, 2006d).
4.B.1, 4.B.2	Land converted to cropland, Cropland remaining cropland	CO_2 (deadwood)	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for calculating Tier 1 estimates of carbon stock change in dead organic matter for land-use changes to this land use category (IPCC, 2006d). Any emissions reported are for loss of dead organic matter from the previous land use that occurs in the year of conversion.
4.B.1	Cropland remaining cropland/4(V) Biomass burning/ Wildfires/ Cropland remaining cropland	CH_4, N_2O	New Zealand does not have sufficient information on biomass burning activities occurring in this category to reliably report on it.
4.B.2	Land converted to cropland/4(V) Biomass burning/ Wildfires/ Land converted to cropland	CH_4, N_2O	New Zealand does not have sufficient information on biomass burning activities occurring in this category to reliably report on it.
4.C.1,4.C.2	Land remaining grassland, Land converted to grassland	CO_2 (deadwood)	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for calculating Tier 1 estimates of carbon stock change in dead organic matter for land-use changes to this land use category (IPCC, 2006d). Any emissions reported are for loss of dead organic matter from the previous land use that occurs in the year of conversion.
4.D.1	Wetlands remaining wetlands/4(V) Biomass burning/ Wildfires/ Wetlands remaining wetlands	CH_4, N_2O	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for calculating Tier 1 estimates of carbon stock changes in organic soils for this land use category (IPCC, 2006d). New Zealand does not have sufficient information on biomass burning activities occurring in this category to reliably report on it.
4.D.1, 4.D.2	Wetlands remaining wetlands, Land converted to wetlands (except transitions into and out of vegetated wetlands)	CO_2	This category is not mandatory. No methodology is provided in the 2006 IPCC Guidelines for calculating Tier 1 estimates of carbon stock change in this land use (IPCC, 2006d, Volume 4, chapter 7.3.1).
4.D.2	Land converted to wetlands/Land converted for peat extraction	CO_2	New Zealand does not have activity data available to report on this activity.
4.E.2	Land converted to settlements	CO_2	This category is not mandatory. Guidance is not provided for calculating Tier 1 estimates of carbon stock changes in organic soils for this land use category. Therefore, with land-use change to or from this land use on organic soils, New Zealand reports the notation key NE.
4.F	Other land/4(V) Biomass burning/Land converted to other land	CH_4, N_2O	This is a relatively minor activity in New Zealand due to the country's temperate climate and rainfall distribution, and there is currently insufficient information to reliably report on it.
4.F.2	Land converted to other land	CO_2	This category is not mandatory. Guidance is not provided for calculating Tier 1 estimates of carbon stock changes in organic soils for this land use category. Therefore, with land-use change to or from this land use on organic soils, New Zealand reports the notation key NE.
Waste			
5.B.2.a	Anaerobic digestion of municipal solid waste	Amount of CH_4 flared and for energy recovery	The amount of CH_4 flared does not contribute to New Zealand's total emissions because it produces biogenic CO_2 (as described in the 2006 IPCC Guidelines under section 4.1.1, IPCC, 2006e).

CRT category code	Category	Gas	Explanation
5.C.1.b.i	Incineration of municipal solid waste	CO_2, CH_4, N_2O	In accordance with chapter II of the Annex to the decision 18/CMA.1 (UNFCCC, 2018b), this category is not mandatory. Around 100–200 rural schools in New Zealand still incinerate their waste production. Estimates indicate this practice emits 0.06 kt CO_2-e per year. Emissions are not estimated because New Zealand does not have sufficient information regarding the practice of incinerating waste in schools, and the estimated amount is below the significance threshold.
5.D.1 and 5.D.2	Domestic wastewater and Industrial wastewater	Amount of CH_4 flared and for energy recovery	Emissions are not estimated because New Zealand does not have any information regarding the CH_4 flaring in this source category. The amount of CH_4 flared does not contribute to New Zealand's total emissions because it produces biogenic CO_2 (as described in the 2006 IPCC Guidelines under section 6.2.1; IPCC, 2006e).
Within the Tokelau sector 6, category 3.A.4.g. Poultry	Enteric fermentation from poultry in Tokelau	CH_4	This category is not mandatory. Guidance is not provided for calculating Tier 1 estimates. Any potential emissions from this activity are expected to be very small, under 0.1 kt CO_2-e, which is the quantity of emissions for *Enteric fermentation* from swine in Tokelau.

The estimate of emissions for all of New Zealand's source categories marked as 'NE' results in 3.8 kt CO_2-e, which is below the 0.1 per cent of the total emissions threshold (76.4 kt CO_2-e). This value has decreased significantly from previous submissions because the category *Other organic fertilisers applied to soils* is now estimated.

Emissions reported as 'IE' (included elsewhere)

The notation key 'IE' (included elsewhere) signifies that emissions and/or removals for this activity or category are estimated and included in the Inventory but not presented separately for this category.

Table 1.7.2 details where the notation key 'IE' has been used in this submission of the Inventory.

Table 1.7.2 Emissions reported using the 'IE' (included elsewhere) notation key in the 2025 submission

CRT category code	Category	Source category reported under	Notation key explanation
Energy			
1.A.2.a	Iron and steel – Liquid fuels	1.A.2.g.viii – Other – Liquid fuels	Disaggregated data for this category do not exist.
1.A.2.a	Iron and steel – Solid fuels	2.C.1 – Iron and steel production	All emissions from the use of coal in this category are included in the Industrial Processes and Product Use sector because the primary purpose of the coal is to produce iron.
1.A.2.f	Non-metallic minerals – Biomass	1.A.2.g.viii – Other – Biomass	Disaggregated data for this category do not exist.
1.A.3.b.ii–iv	Road transportation (other than 'cars') – All fuels (other than gasoline and diesel)	1.A.3.b.i – Cars	Disaggregated data do not exist for all years for all fuels.
1.A.4.c.ii–iii	Agriculture/forestry/fishing – Off-road vehicles and other machinery/ Gaseous fuels Liquefied petroleum gases (LPG)	1.A.4.c.i – Agriculture/ forestry/fishing – Stationary	Agriculture/forestry/fishing has not been disaggregated into stationary, mobile and fishing for some fuels because data are not available.

CRT category code	Category	Source category reported under	Notation key explanation
1.B.2.b.1	Natural gas/exploration	1.B.2.a.1 – Oil exploration	In New Zealand, oil exploration is not separated from gas exploration by planning, processes, equipment or resources. The exploratory wells are drilled without distinction of their purpose, that is, whether the expected outcome is oil, gas, both or neither, and there is no reliable way to predict which it would be to estimate proportions of mostly oil and mostly gas wells. Disaggregated data for oil and gas exploration, therefore, do not exist. Considering that available emission factors for well drilling and testing also do not distinguish between oil and gas, all emissions from oil and gas exploration are reported in the oil exploration category.
1.B.2.c.1.i	Venting/oil and Venting/gas	1.B.2.c.1.iii – Venting/ combined	The fields produce both oil and gas and, therefore, are reported as combined. Disaggregated data do not exist.
1.B.2.c.2.i–ii	Flaring/oil and Flaring/gas	1.B.2.c.1.iii – Flaring/ combined	The fields produce both oil and gas and, therefore, are reported as combined. Disaggregated data do not exist.
Industrial Processes and Product Use			
2.A.3	Glass production	2.A.4.b – Other process uses of carbonates/Other uses of soda ash	Carbon dioxide emissions are reported in 2.A.4.b because this aggregates emissions from glass production with other uses of carbonates, due to confidentiality concerns for both glass and aluminium production. A very small number of firms in New Zealand are involved in these activities and using carbonates.
Agriculture			
3.B(b)	N_2O emissions per MMS[16]	3.D – Agricultural soils	Direct nitrous oxide (N_2O) emissions from anaerobic lagoons (dairy and swine) and daily spread (swine) are reported under *Agricultural soils*. The 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines) assume negligible direct N_2O emissions occur in anaerobic lagoons and daily spread, and only occur once the stored effluent is spread onto agricultural soils (IPCC, 2006d). For more information, see chapter 5, sections 5.3.2 ('Direct nitrous oxide emissions from manure management') and 5.5.2 ('Urine and dung deposited by grazing animals').
3.E	Prescribed burning of savannas	Biomass burning (table 4(V) of LULUCF), category C Grassland	Prescribed burning of savanna is reported under the Land Use, Land-Use Change and Forestry (LULUCF) sector. See chapter 6, section 6.11.8 ('Biomass burning' (table 4(V) of LULUCF), category C Grassland).
Land Use, Land-Use Change and Forestry			
4.A.1/4(V)	Controlled burning	Forest land remaining forest land	Carbon dioxide (CO_2) emissions are captured by the general carbon stock change calculation if the fire-damaged area is harvested and replanted. If the stand is allowed to grow on but with a reduced stocking, the CO_2 emissions are reported at the eventual time of harvest.

16 MMS stands for a manure management system (see chapter 5).

CRT category code	Category	Source category reported under	Notation key explanation
4.A.1/4(II) 4.B.1/4(II)	Forest land Cropland	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	These emissions are reported under organic soils.
4.A.1	Forest land remaining forest land	Forest land remaining forest land	Because New Zealand uses the stock change approach, losses are reported only in years when new land is converted to this category, or when there is harvesting of forest in this year. When neither of these activities occurs, the losses are reported with biomass gains (stock change approach) and 'IE' is reported for biomass losses.
4.A.2	Land converted to forest land	Land converted to forest land	Because New Zealand uses the stock change approach, CO_2 emissions from biomass losses are reported only in years when new land is converted to this category, or when there is harvesting of forest in this year. When neither of these activities occurs, the losses are reported with biomass gains (stock change approach) and 'IE' is reported for biomass losses.
4.A.1/4.A.2	Forest land remaining forest land, Land converted to forest land	Included under the Agriculture sector	New Zealand does not disaggregate data on nitrogen fertiliser by land use; therefore, all N_2O emissions are reported in the Agriculture sector.
4.A.2/4(V)	Controlled burning/Land converted to forest land Wildfires/Land converted to forest land	Land converted to forest land	Carbon dioxide emissions are captured by the general carbon stock change calculation if the fire-damaged area is harvested and replanted. If the stand is allowed to grow on but with a reduced stocking, the CO_2 emissions are reported on at the eventual time of harvest.
4.B.1 4.B.2 4.C.1 4.C.2	Cropland remaining cropland Land converted to cropland Grassland remaining grassland Land converted to grassland	Cropland remaining cropland Land converted to cropland Grassland remaining grassland Land converted to grassland	New Zealand uses the stock change approach to estimate biomass emissions; therefore, biomass losses are reported with biomass gains and 'IE' is reported.
4.B.1/4(V)	Controlled burning/Cropland remaining cropland	Included under the Agriculture sector	Carbon dioxide and methane (CH_4) emissions from burning of crop stubble are reported in the Agriculture sector.
4.B.1/4(V)	Wildfires/Cropland remaining cropland	Cropland remaining cropland	Any CO_2 emissions from wildfires on non-forest land are assumed to be offset by the subsequent carbon stock gain from the regrowth of biomass, which is also not reported. Alternatively, if the wildfire resulted in land-use change, then any CO_2 emissions are captured by the general carbon stock change calculation that is performed when land is converted to a new land use.
4.B.2/4(V) 4.C.1/4(V) 4.C.2/4(V) 4.D.2/4(V)	Wildfires/Land converted to cropland Wildfires/Grassland remaining grassland Wildfires/Land converted to grassland Wildfires/Land converted to wetlands	Land converted to cropland Grassland remaining grassland Land converted to grassland Land converted to wetlands	Any CO_2 emissions from wildfires on non-forest land are assumed to be offset by the subsequent carbon stock gain from the regrowth of biomass, which is also not reported. Alternatively, if the wildfire resulted in land-use change, then any CO_2 emissions are captured by the general carbon stock change calculation that is performed when land is converted to a new land use.

CRT category code	Category	Source category reported under	Notation key explanation
4.A.1/4(I) 4.D.1/4(I) 4.D.2/4(I) 4.E.1/4(I) 4.E.2/4(I)	Direct N_2O emissions from nitrogen (N) inputs to managed soils Inorganic N fertilisers and Direct N_2O emissions from N inputs to managed soils Organic N fertilisers In the following categories: Forest land remaining forest land Wetlands remaining wetlands Land converted to wetlands Settlements remaining settlements Land converted to settlements Settlements remaining settlements Land converted to settlements	Included under the Agriculture sector	New Zealand does not hold disaggregated activity data on nitrogen fertiliser by land use; therefore, all N_2O emissions from organic and inorganic fertilisers are reported in the Agriculture sector.
4(IV)	Indirect N_2O emissions from managed soils/Atmospheric deposition	Included under the Agriculture sector	Volatilisation of nitrogen (manure, other organic and fertiliser) on pasture range and paddock is reported under Agriculture. This includes all nitrogen fertiliser used in New Zealand.
4.B.1/4(V)	Controlled burning/Cropland remaining cropland	Included under the Agriculture sector	All emissions from burning of crop stubble are reported in the Agriculture sector.
4.C.1/4(V) 4.D.1/4(V)	Controlled burning/Grassland remaining grassland Controlled burning/Wetlands remaining wetlands Wildfires/Wetlands remaining wetlands	Grassland remaining grassland Wetlands remaining wetlands Wetlands remaining wetlands	This is not a significant activity in New Zealand due to the country's temperate climate and rainfall distribution, and any CO_2 emissions from burning on non-forest land are assumed to be offset by the subsequent carbon stock gain from the regrowth of biomass, which is also not reported. Alternatively, if the fire resulted in land-use change, then any CO_2 emissions are captured by the general carbon stock change calculation that is performed when land is converted to a new land use.
4.C.2/4(V) 4.D.2/4(V) 4.E/4(V) 4.F/4(V)	Controlled burning/Land converted to grassland Controlled burning/Land converted to wetlands Biomass burning/Land converted to settlements Biomass burning/Land converted to other land	Land converted to grassland Land converted to wetlands Land converted to settlements Land converted to other land	Carbon dioxide emissions from the controlled burning of land converted to this category are captured by the general carbon stock change calculation that is performed when land is converted to a new land use.
4.D.2.2	Land converted to flooded land	Land converted to open water	New Zealand has not yet identified what area of land converted to open water meets the definition of *Land converted to flooded land*. Emissions associated with the loss of biomass with land conversion to flooded land will be captured under *Land converted to open water*.
Waste			
5.D.1	Domestic wastewater	5.A Solid waste	Activity data – sludge amounts are included under *Solid waste disposal* because sludge is disposed to landfill.

CRT category code	Category	Source category reported under	Notation key explanation
5.D.2	Industrial wastewater	5.A Solid waste	Activity data – sludge amounts are included under *Solid waste disposal* because sludge is disposed to landfill.
5.D.2	Industrial wastewater	1.A.2.e Food processing, beverages and tobacco – Biomass	Emissions of CH_4 from the combustion of biogas from the Tirau dairy processing plant are reported under 1.A.2.e *Food processing, beverages and tobacco – Biomass.*
Within the Tokelau sector 6, categories 1.A.3.b.i. and 1.A.4.c.iii. were reported elsewhere	Road transport/Gasoline and diesel oil	1.A.3.d. Domestic navigation – Gas-diesel oil (within Tokelau sector 6)	Tokelau has a small petrol car fleet. In 2018 there were about 40 cars and 30 motorbikes, with an entire road network less than 10 kilometres. Four registered cars were recorded in the 2001 Census. Aluminium boats are the main means of family transport. There were, on average, about 100 outboard motors travelling both outside and within the large lagoons. Petrol use for road transport is relatively small compared with *Domestic navigation* totals, and all emissions are included in *Domestic navigation*.
Within the Tokelau sector 6, category 1.A.4.b. Residential is reported elsewhere	1.A.4.b. Residential liquid fuels	1.A.3.d. Domestic navigation – Gas-diesel oil (within Tokelau sector 6)	Only gas used for cooking is reported here. The amount of liquid fuel use in this category is small compared with *Domestic navigation* and all emissions are included in *Domestic navigation*.

1.7.2 Description of insignificant categories

New Zealand’s omitted insignificant emissions sources are estimated using simple methods, in line with paragraph 32 of the annex to decision 18/CMA.1 (UNFCCC, 2018b).

The data and assumptions New Zealand used to derive the likely emissions levels are presented in table 1.7.1.

1.7.3 Total aggregate emissions considered insignificant, if applicable

The estimate of emissions for all of New Zealand’s source categories marked as ‘NE’ results in 3.8 kt CO_2-e, which is below the 0.1 per cent of the total emissions threshold (76.4 kt CO_2-e).

1.8 Metrics

Consistent with decisions 1/CP.24, 18/CMA.1 and 5/CMA.3, this Inventory was prepared using 100-year time horizon global warming potential values from the IPCC Fifth Assessment Report (IPCC, 2013).

Chapter 1: References

Cardno. Unpublished. Greenhouse Gas Emissions from Industrial Wastewater Treatment. Report prepared for the Ministry for the Environment in 2015.

CRL Energy Ltd. Unpublished. Hennessy W, Maxwell D. Inventory of HFC, PFC and SF_6 Emissions for New Zealand 2004–2005. Report prepared for the Ministry for the Environment by CRL Energy Ltd in 2006.

Eunomia. Unpublished. Improvements to Estimates of Greenhouse Gas Emissions from Landfills. Report prepared for the Ministry for the Environment in 2020.

IPCC. 2006a. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Prepared by the National Greenhouse Gas Inventories Programme. Japan: IGES, Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006b. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1. General Guidance and Reporting.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006c. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006d. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006e. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2013. Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

IPCC. 2021. Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger C, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBR, Maycock TK, Waterfield T, Yelekçi O, Yu R, Zhou B (eds). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

IPCC. 2022. Shukla PR, Skea J, Slade R, Al Khourdajie A, van Diemen R, McCollum D, Pathak M, Some S, Vyas P, Fradera R, Belkacemi M, Hasija A, Lisboa G, Luz S, Malley J (eds.) *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

MBIE. 2024a. *Energy in New Zealand 2024*. Wellington: Ministry of Business, Innovation and Employment.

MBIE. 2024b. *Annual Report 2023/24*. Wellington: Ministry of Business, Innovation and Employment.

Paul TSH, Andersen C, Kimberley MO, Dash J, Beets PN. Unpublished(a). Carbon Stock Changes in New Zealand’s Pre-1990 Planted Forests Based on a Periodic Ground Inventory. Report prepared for the Ministry for the Environment by the New Zealand Forest Research Institute Ltd (trading as Scion) in 2016.

Paul TSH, Beets PN, Kimberley MO. Unpublished(b). Carbon Stocks in New Zealand’s Post-1989 Natural Forest – Analysis of the 2018/2019 forest inventory data. Report prepared for the Ministry for the Environment by the New Zealand Forest Research Institute Ltd (trading as Scion) in 2020.

Paul TSH, Kimberley MO, Beets PN. 2020. Natural Forests in New Zealand – a large terrestrial carbon pool in a national state of equilibrium. Manuscript submitted for publication.

Paul TSH, Kimberley MO, Dodunski C. Unpublished(c). The 2019 NFI Plot Analysis Yield Tables and Carbon Stocks at Measurement. Report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2020.

Paul TSH, Wakelin SJ. Unpublished. Yield Tables and Approach for Estimating Historic Carbon Stocks in Pre-1990 Planted Forests for Greenhouse Gas Inventory Reporting. Report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2020.

Stats NZ. 2007. *Principles and Protocols for Producers of Tier 1 Statistics.* Wellington: Stats New Zealand. Retrieved 12 March 2025.

UNFCCC. 1992. FCCC/INFORMAL/84 *United Nations Framework Convention on Climate Change*. Retrieved 12 March 2025.

UNFCCC. 2017. FCCC/ARR/2017/NZL. *Report on the Individual Review of the Annual Submission of New Zealand Submitted in 2017.* Centralised Review.

UNFCCC. 2018a. FCCC/CP/2018/10/Add.1. *Decision 1/CP.24 Preparations for the implementation of the Paris Agreement and the first session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.*

UNFCCC. 2018b. FCCC/PA/CMA/2018/3/Add.2. *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on the third part of its first session, held in Katowice from 2 to 15 December 2018. Addendum 2. Part two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.*

UNFCCC. 2021. CCC/PA/CMA/2021/10/Add.2. *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its third session, held in Glasgow from 31 October to 13 November 2021. Addendum Part Two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its third session.*

United Nations. 1945. *Charter of the United Nations and Statute of the International Court of Justice.* Retrieved 12 March 2025.

Verum Group Ltd. Unpublished. Hennessy W. Inventory of HFC, SF_6 and Other Industrial Process Emissions for New Zealand 2021. Report prepared by Verum Group Ltd for the Ministry for the Environment in 2022.

Chapter 2: Trends in greenhouse gas emissions and removals

This chapter describes emission trends by sector and greenhouse gas (GHG). Consistent with decisions 1/CP.24, 18/CMA.1 and 5/CMA.3, emissions are presented for each of the major GHGs as carbon dioxide equivalents (CO_2-e) using the 100-year time horizon global warming potential values contained in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2013). Because GHGs vary in their radiative activity, and in their atmospheric residence time, converting emissions into CO_2-e allows the integrated effect of emissions of the various gases to be compared.

2.1 Description of emission and removal trends for aggregated GHG emissions and removals

Gross emissions

Gross emissions include those from the Energy, Industrial Processes and Product Use (IPPU), Agriculture and Waste sectors, and from Tokelau, but do not include emissions and removals from the Land Use, Land-Use Change and Forestry (LULUCF) sector.

1990–2023

In 1990, New Zealand's gross GHG emissions were 67,678.9 kilotonnes (kt) CO_2-e. Between 1990 and 2023, GHG emissions increased by 12.9 per cent (8,737.4 kt CO_2-e) to 76,416.3 kt CO_2-e in 2023 (see figure 2.1.1).

From 1990 to 2023, the average annual growth in gross emissions was 0.4 per cent.

The emissions categories that contributed the most to this increase in gross emissions were: *Enteric fermentation*[17] from *Dairy cattle*, *Road transportation*, *Agricultural soils*, *Manufacturing industries and construction* (particularly from the *Food processing, beverages and tobacco* category) and *Product uses as substitutes for ozone depleting substances (ODS)*.

2022–2023

Between 2022 and 2023, New Zealand's gross emissions decreased by 2.0 per cent (1,566.8 kt CO_2-e). The main cause was a decrease in emissions from the Agriculture sector of 2.2 per cent (908.4 kt CO_2-e) due to reduced *Enteric fermentation* from *Sheep* and *Dairy cattle*. The largest contributors to the overall decrease in emissions were from:

- *Product uses as substitutes for ODS* (hydrofluorocarbons – HFCs)
- *Enteric fermentation – Sheep* (methane – CH_4)
- *Enteric fermentation – Dairy cattle* (CH_4)
- *Liming* (CO_2).

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17 Methane emissions produced from the digestive process in ruminant livestock.

The reduction in the *Enteric fermentation* from *Sheep* category was due to a decrease in the sheep population. This is a continuation of a long-term trend that reflects the profitability of sheep farming relative to other land uses.

The reduction in *Enteric fermentation* from *Dairy cattle* emissions was due to a decrease in the size of the dairy cattle population.

The reduction in emissions from *Liming* was due to a reduction in limestone application, which reflects a continuation of the long-term trend of decreasing limestone application combined with historically high year-to-year variation.

Emissions from the Energy, IPPU and Waste sectors decreased by 0.8 per cent, 9.3 per cent and 0.7 per cent respectively. Emissions from Tokelau decreased by 10.4 per cent, due largely to a reduction in diesel fuel use.

Restrictions on activity and movement as part of the response to the coronavirus (COVID-19) pandemic during the 2020 calendar year saw significant disruption to economic activity throughout New Zealand. The effects on the Energy sector are particularly notable, with national energy consumption falling 7.2 per cent compared with the 2019 level. The sector saw a slight rebound during 2021, but energy consumption has remained well below pre-2020 levels.

While the Agriculture sector contributed the largest overall decrease in emissions between 2022 and 2023, the category with the largest decrease was in IPPU: HFCs from *Product uses as substitutes for ODS* represented the largest decrease in emissions (352.6 kt CO_2-e). The main reasons for this decrease were that, following two exceptional years impacted by an increase in heat pump sales and an associated increase in emissions from the disposal of retired equipment, heat pump sales slowed in 2023 and disposal emissions decreased.

Net emissions

Net emissions include gross emissions as defined above (i.e., from the Energy, IPPU, Agriculture and Waste sectors, and including Tokelau) and net emissions from the LULUCF sector.

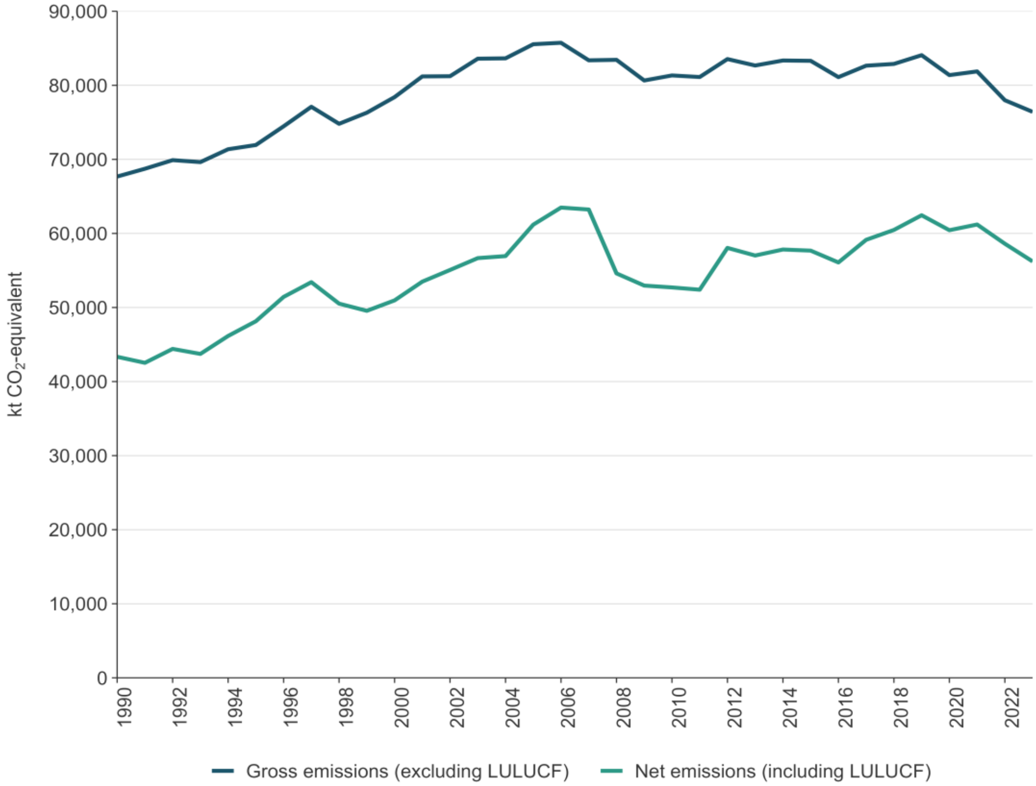
In 2023, net emissions from the LULUCF sector were -20,197.1 kt CO_2-e. This offset 26.4 per cent of New Zealand's gross emissions.

1990–2023

In 1990, New Zealand's net emissions were 43,344.8 kt CO_2-e. Between 1990 and 2023, net GHG emissions increased by 29.7 per cent (12,874.3 kt CO_2-e) to 56,219.2 kt CO_2-e (figure 2.1.1).

The four categories that contributed the most to the increase in net emissions between 1990 and 2023 were: *Land converted to forest land*; *Enteric fermentation* from *Dairy cattle*; *Road transportation*; and *Agricultural soils*.

Figure 2.1.1 New Zealand's gross and net emissions, from 1990 to 2023



2022–2023

Between 2022 and 2023, New Zealand's net emissions decreased by 4.1 per cent (2,391.2 kt CO_2-e). This was due to the overall decrease in gross emissions and a decrease in net emissions of 4.3 per cent (-824.4 kt CO_2-e) from the LULUCF sector. The decrease in net emissions was driven by an increase in removals in *Forest land remaining forest land* and *Land converted to forest land* in the LULUCF sector, and a reduction in emissions from *Product uses as substitutes for ODS* in the IPPU sector.

The decrease in the LULUCF sector was largely driven by a decrease in emissions of 952.1 kt CO_2-e in the *Forest land* category, as harvesting rates in planted forests reduced between 2022 and 2023. This led to an increase in emissions from the *Harvested wood products* category, however, offsetting the decrease by 774.0 kt CO_2-e. There was also a decrease in emissions of 684.7 kt CO_2-e from the *Grassland* category due to lower deforestation rates in 2023 compared with 2022.

Net target accounting emissions

New Zealand applies accounting rules to calculate the quantities of net emissions that contribute towards meeting emissions reduction targets. While gross emissions are fully accounted for, the contribution from the LULUCF sector is treated differently.

Information on how New Zealand accounts for the contribution from the LULUCF sector towards its first Nationally Determined Contribution under the Paris Agreement is provided in Annex 9. The LULUCF accounting quantities for the period covered by this Inventory are also reported in Annex 9.

2.2 Description of emission and removal trends by sector and by gas

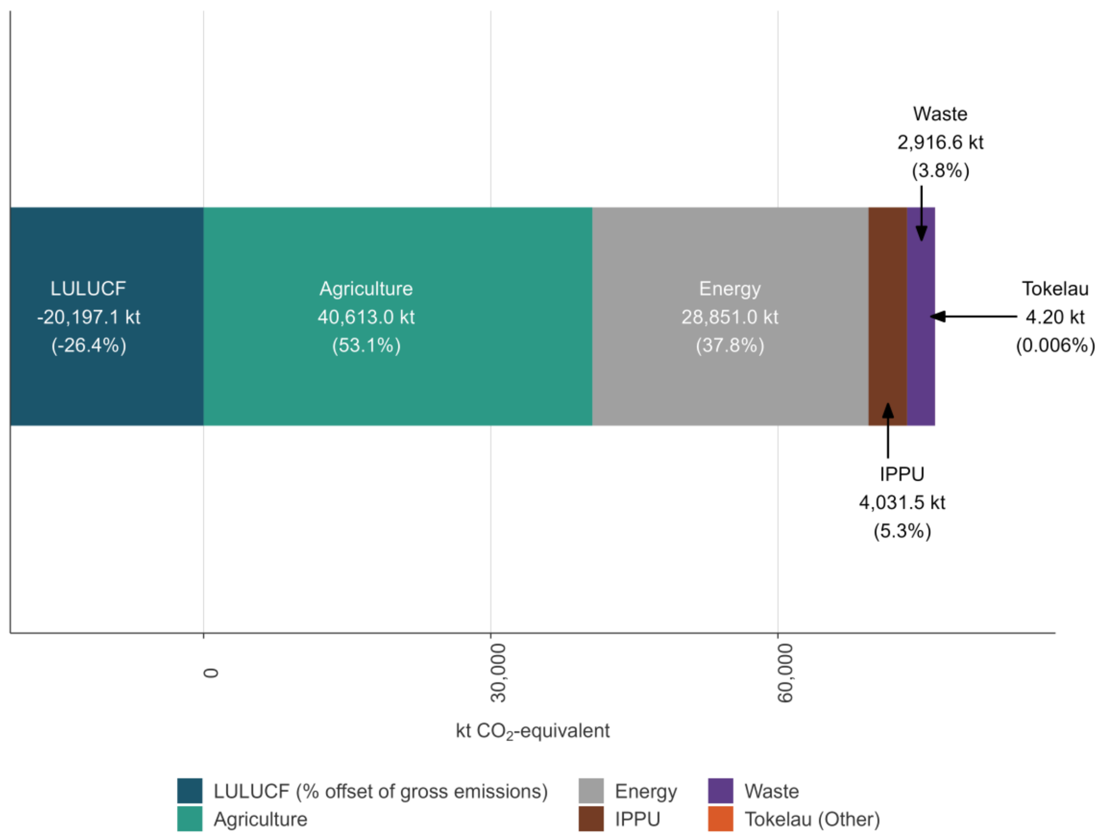
New Zealand reports emissions and removals for the Energy, IPPU, Agriculture, LULUCF and Waste sectors. Tokelau's emissions are also reported separately by sector as 'Other'. New Zealand reports emissions and removals of CO_2, and emissions from CH_4, HFCs, perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

2.2.1 New Zealand's emissions by sector and by gas in 2023

New Zealand's emissions by sector reflect the composition of the national economy. The Agriculture sector contributed 53.1 per cent of New Zealand's gross emissions in 2023. New Zealand's Energy sector contributed 37.8 per cent to the national gross emissions, while the IPPU and Waste sectors contributed 5.3 per cent and 3.8 per cent respectively (figure 2.2.1). New Zealand's 'Other' sector (Tokelau) contributed 0.006 per cent to the national gross emissions.

The LULUCF sector currently represents a sink, with net emissions of -20,197.1 kt CO_2-e. This offset 26.4 per cent of New Zealand's gross emissions in 2023.

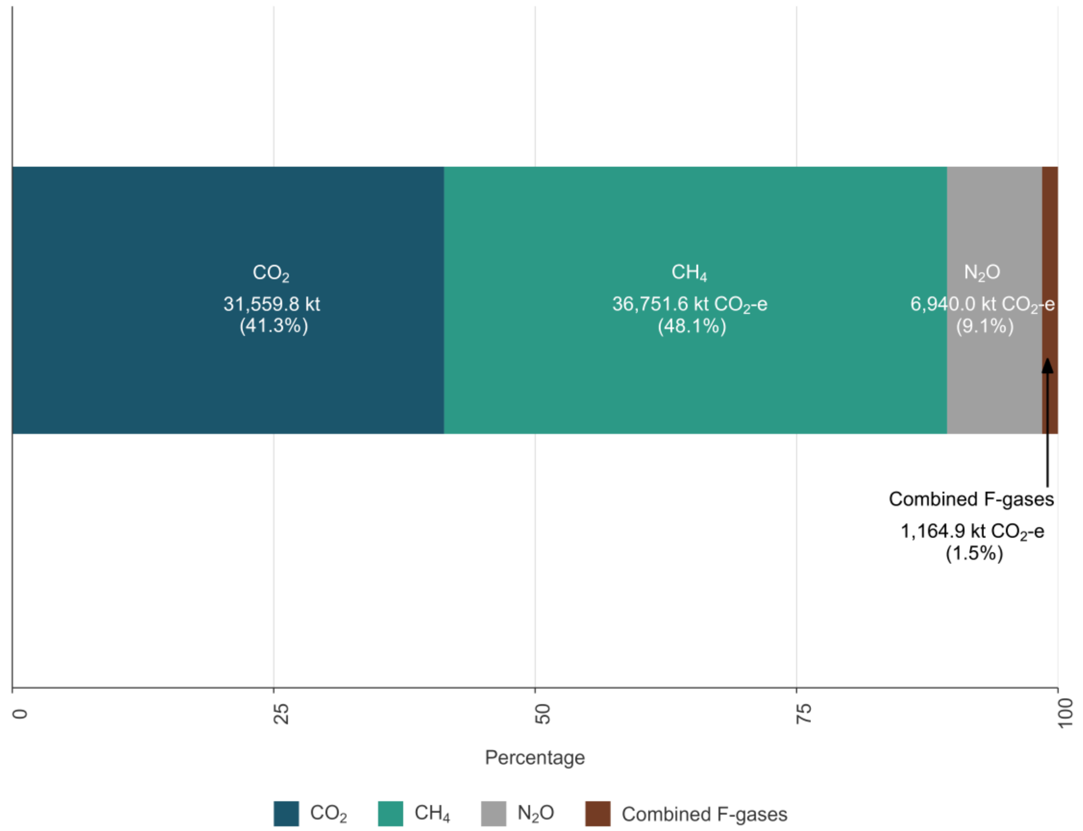
Figure 2.2.1 New Zealand's emissions by sector in 2023



Note: The percentages may not add up to 100 per cent due to rounding. The LULUCF sector, which is not a part of gross emissions, is included here as a negative value. The Tokelau sector is not visible due to its small contribution (4.2 kt CO_2-e or 0.006 per cent of New Zealand's gross GHG emissions).

Each of the sectors is dominated by one or two GHGs. Figure 2.2.2 shows New Zealand's gross emissions by gas.

Figure 2.2.2 New Zealand's gross emissions by gas in 2023



Note: The percentages may not add up to 100 per cent due to rounding. F-gases = fluorinated gases.

Methane dominated New Zealand's emissions profile in 2023, contributing 48.1 per cent (36,751.6 kt CO_2-e) of gross emissions (figure 2.2.2). The Agriculture sector contributed 91.0 per cent (33,449.8 kt CO_2-e) of New Zealand's CH_4 emissions in 2023. The largest source of CH_4 in the Agriculture sector was *Enteric fermentation*, producing 86.2 per cent (31,661.7 kt CO_2-e) of New Zealand's gross CH_4 emissions. Methane was also the largest component of New Zealand's Waste sector emissions, contributing 7.3 per cent (2,680.2 kt CO_2-e) of gross CH_4 emissions.

Carbon dioxide contributed 41.3 per cent (31,559.8 kt CO_2) towards New Zealand's gross emissions in 2023. The Energy sector contributed the largest share of CO_2, producing 89.1 per cent (28,111.6 kt) of New Zealand's gross CO_2 emissions in 2023. The categories that contributed most to CO_2 emissions in the Energy sector were *Transport* (44.5 per cent or 14,043.8 kt CO_2) and *Manufacturing industries and construction* (19.2 per cent or 6,044.4 kt CO_2). In 2023, the LULUCF sector was a CO_2 sink, sequestering 65.0 per cent (-20,511.0 kt CO_2) of New Zealand's CO_2 emissions. This resulted in net CO_2 emissions of 11,048.8 kt in 2023.

Nitrous oxide contributed 9.1 per cent (6,940.0 kt CO_2-e) of New Zealand's gross emissions. Emissions from the *Agricultural soils* category (from adding nitrogen to soil, for example, through manure or fertiliser) were the largest source of New Zealand's gross N_2O emissions (at 91.8 per cent or 6,372.4 kt CO_2-e). The Agriculture sector contributed 93.1 per cent of N_2O towards New Zealand's gross N_2O emissions totals in 2023.

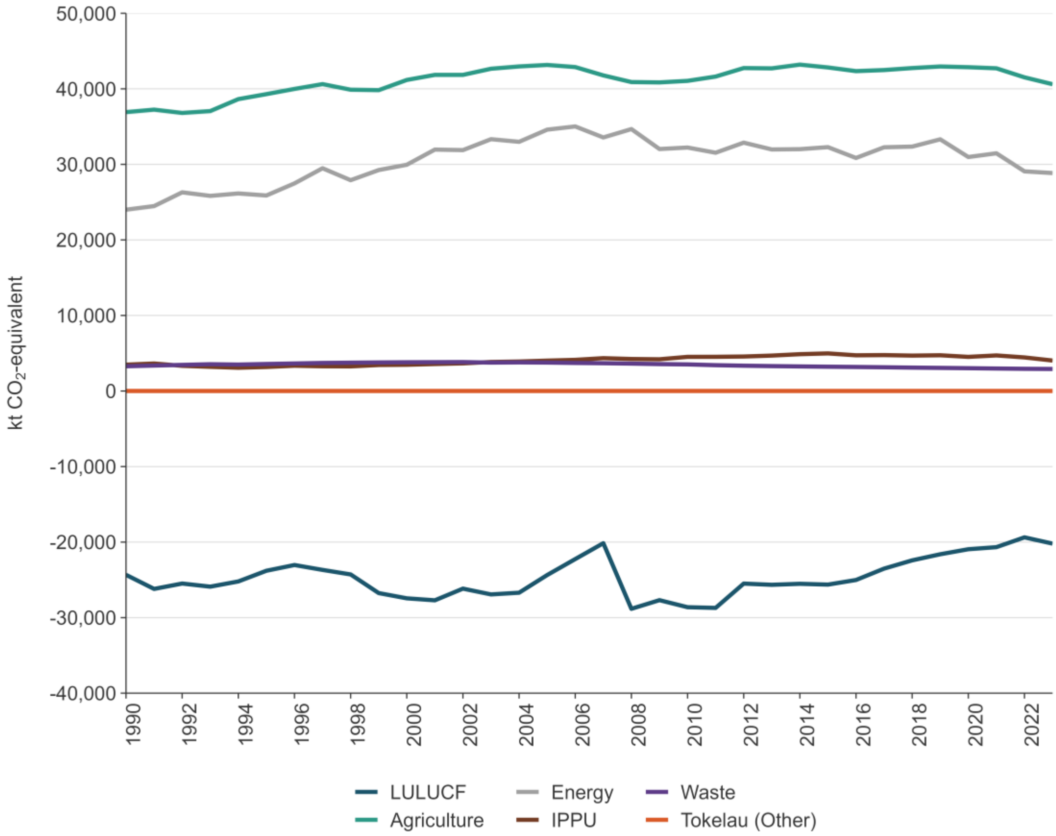
Fluorinated gases (HFCs, PFCs and SF_6) collectively contributed 1.5 per cent to New Zealand's gross emissions. The IPPU sector is the only source of fluorinated gases in New Zealand. Together, HFCs, PFCs and SF_6 emitted 1,164.9 kt CO_2-e in 2023. New Zealand does not manufacture any fluorinated gases domestically. Emissions of fluorinated gases were dominated by HFCs (93.3 per cent of all fluorinated gases). The PFCs and SF_6 contributed 5.2 per cent and 1.4 per cent to total emissions of fluorinated gases respectively. Almost all of New Zealand's PFC emissions (99.99 per cent) resulted from aluminium production.

2.2.2 Emission trends by sector from 1990 to 2023

Figure 2.2.3 shows the contribution to net emissions that each inventory sector has made since 1990. The Agriculture and Energy sectors have dominated New Zealand's gross emissions profile. Together, these sectors produced 90.5 per cent of New Zealand's annual gross GHG emissions from 1990 to 2023. The IPPU and Waste sectors produced relatively small amounts of GHGs, each contributing between 3.6 and 6.0 per cent of annual gross emissions across the time series.

Conversely, the LULUCF sector was a net sink of GHG emissions between 1990 and 2023.

Figure 2.2.3 Trends in New Zealand's greenhouse gas emissions by sector, from 1990 to 2023



Note: Net removals from the LULUCF sector are as reported under the United Nations Framework Convention on Climate Change (chapter 6).

Table 2.2.1 presents New Zealand's emissions by sector in 1990 and 2023 and the change between the years in absolute terms and by percentage. Figure 2.2.4 shows the changes in emissions by sector between 1990 and 2023.

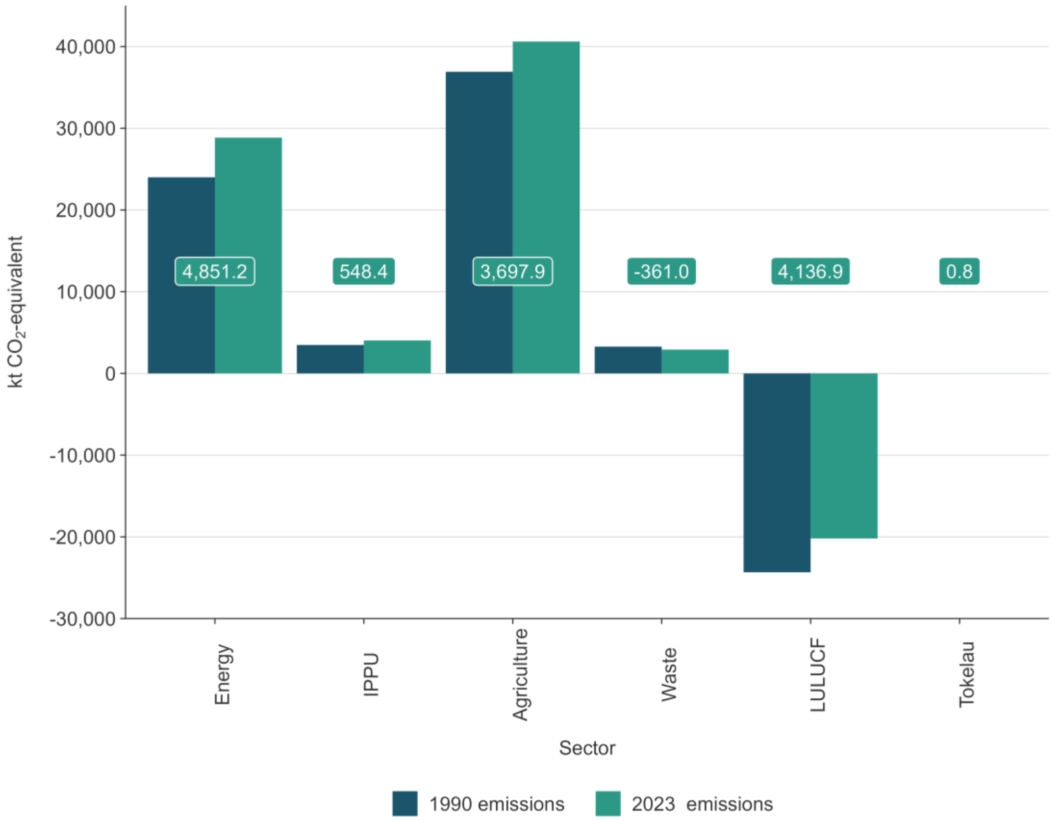
Table 2.2.1 New Zealand's emissions by sector, comparing 1990 and 2023

Sector	1990	2023	Change from 1990 (kt CO_2-e)	Change from 1990 (%)
Energy	23,999.7	28,851.0	4,851.2	20.2
IPPU	3,483.1	4,031.5	548.4	15.7
Agriculture	36,915.1	40,613.0	3,697.9	10.0
Waste	3,277.6	2,916.6	-361.0	-11.0
Tokelau	3.4	4.2	0.8	24.7
Gross	**67,678.9**	**76,416.3**	**8,737.4**	**12.9**
LULUCF	-24,334.1	-20,197.1	4,136.9	17.0
Net	**43,344.8**	**56,219.2**	**12,874.3**	**29.7**

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Figure 2.2.4 presents the emissions estimates by sector and the change between 1990 and 2023 in kt CO_2-e.

Figure 2.2.4 Change in New Zealand's emissions by sector comparing 1990 and 2023



Note: The Tokelau sector is not visible, due to its small total emissions value.

Figure 2.2.5 presents the absolute change in gross emissions for each sector (LULUCF is excluded from the estimate of gross emissions). The change between 1990 and 2023 estimates is provided for each sector in kt CO_2-e.

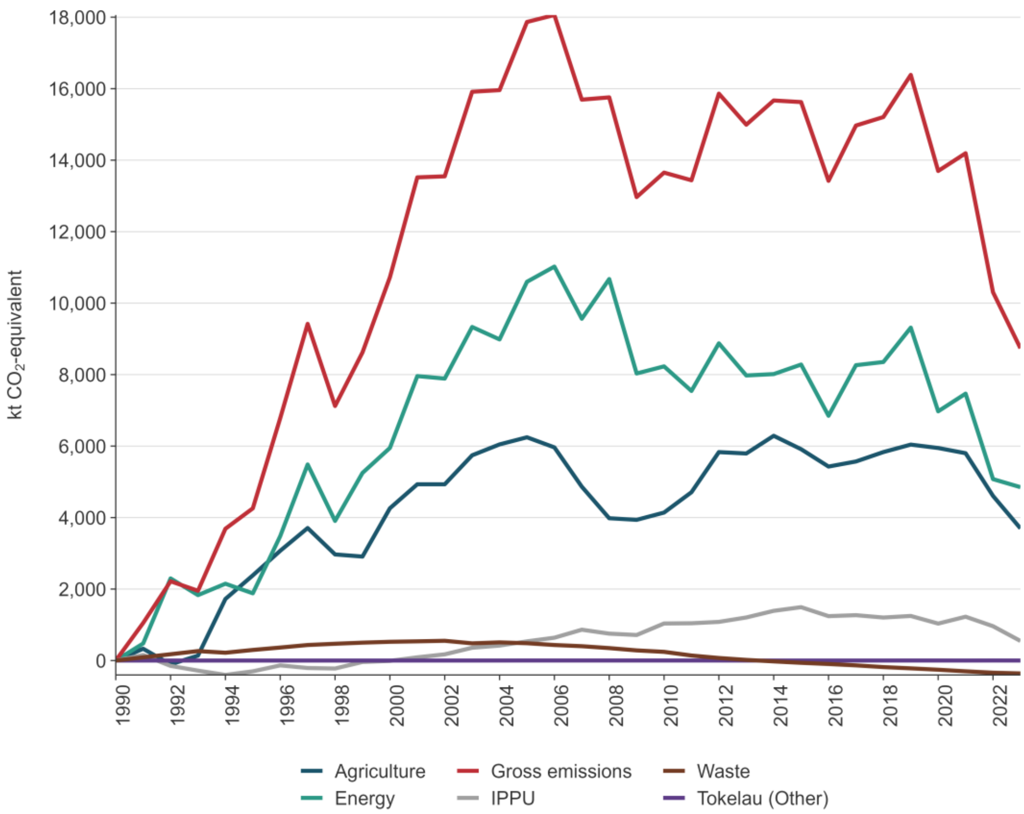
The figure shows that the main influences on the absolute changes in New Zealand's gross emissions were changes in the Energy and Agriculture sectors. This is to be expected because they are the largest sectors of the New Zealand economy and show higher sensitivity to changes in global economic conditions, extreme weather conditions and natural disasters.

For example, during droughts, the level of inflow to hydro lakes is low, resulting in lower levels of hydroelectricity production. Consequently, electricity produced from fossil fuels makes a higher contribution to the national electricity grid, resulting in increased emissions from the Energy sector.

Droughts also affect the size of the livestock population and livestock productivity, which usually results in reduced emissions from the Agriculture sector as the population and productivity decline.

Emissions from Tokelau have increased since 1990, mainly due to increases in CO_2 emissions from the *Electricity generation* category (figure 2.2.5).

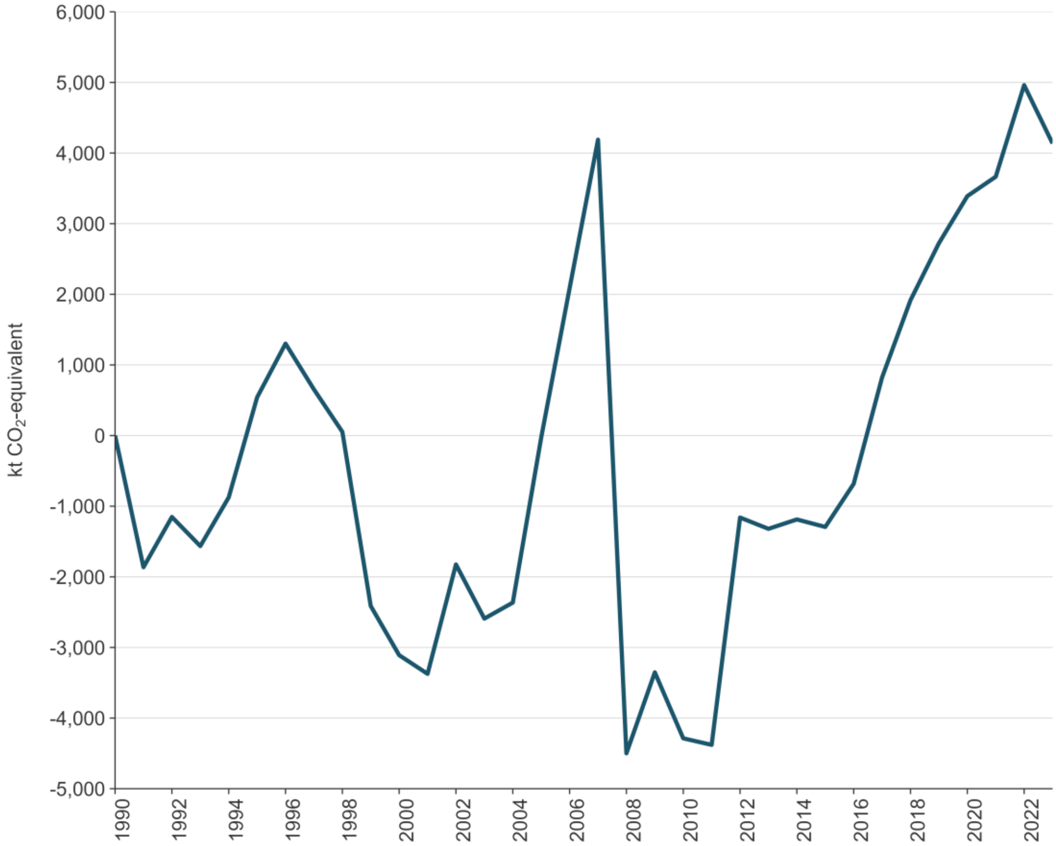
Figure 2.2.5 Absolute change in New Zealand's gross emissions by sector, from 1990 to 2023



Note: Gross emissions exclude emissions from LULUCF. Because of the small size of the Tokelau sector, the change in emissions over time is not visible in the figure.

Net emissions from the LULUCF sector fluctuated significantly over the time series. These fluctuations (figure 2.2.6) were mainly influenced by harvesting, afforestation and deforestation rates (see the section on the LULUCF sector below).

Figure 2.2.6 Absolute change in net emissions from the LULUCF sector, from 1990 to 2023



Energy sector

Emissions from the Energy sector were dominated by CO_2 (97.4 per cent of all emissions from the sector on a CO_2-e basis) and smaller amounts of CH_4 and N_2O (around 1.8 per cent and 0.7 per cent, respectively). The major source categories in the sector were *Road transportation* and *Public electricity and heat production*.

Emissions in the Energy sector were influenced by not only demand but also climatic conditions. Renewables, mainly hydro power and wind, meet a large proportion of New Zealand's stationary energy needs. Electricity generated from renewable energy sources contributed 88 per cent of total generation in 2023.

2023

In 2023, emissions from the Energy sector contributed 28,851.0 kt CO_2-e, or 37.8 per cent of New Zealand's gross GHG emissions (see figure 2.2.1).

The largest sources of emissions in the Energy sector were the *Road transportation* category, contributing 12,599.8 kt CO_2-e (43.7 per cent), and the *Manufacturing industries and construction* category, contributing 6,126.3 kt CO_2-e (21.2 per cent) to Energy sector emissions.

1990–2023

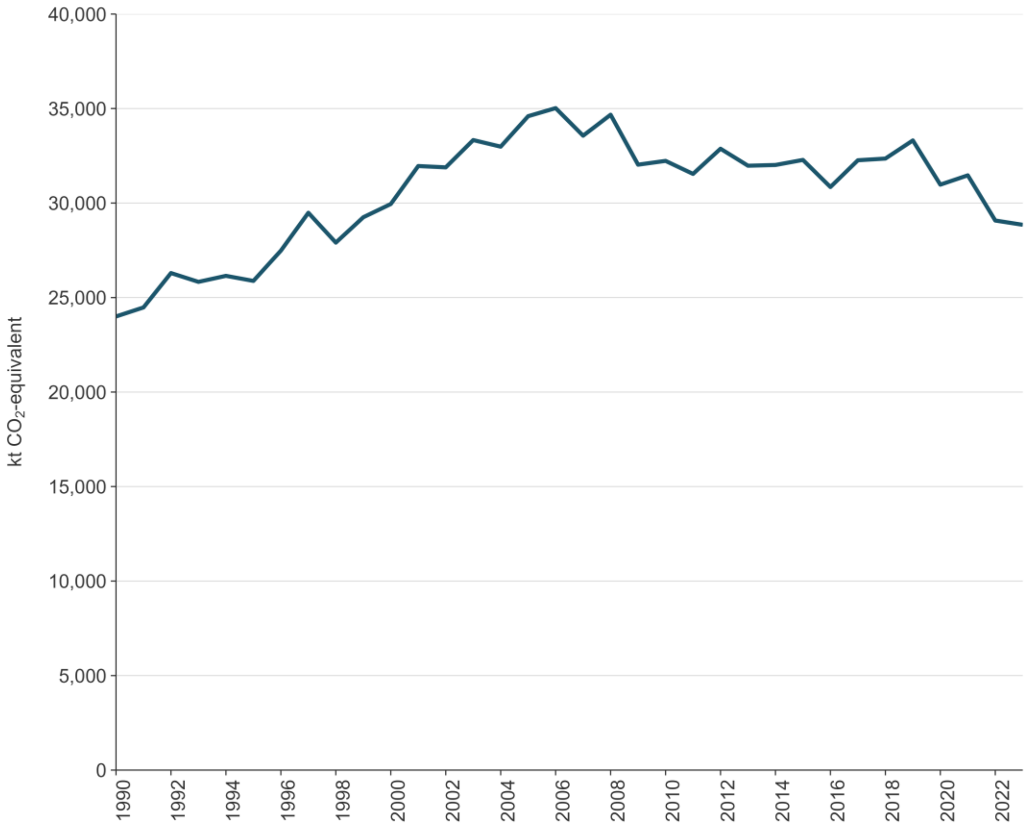
In 2023, emissions from the Energy sector increased by 20.2 per cent (4,851.2 kt CO_2-e) from the 1990 level of 23,999.7 kt CO_2-e. This growth is primarily due to *Road transportation*, which increased by 5,771.3 kt CO_2-e (84.5 per cent), *Food processing, beverages and tobacco*, which increased by 1,031.4 kt CO_2-e (61.7 per cent), and *Chemicals*, which increased by 776.4 kt CO_2-e (144.8 per cent). Although the underlying drivers of these increases are often nuanced, key factors include population growth and increased economic activity.

The category showing the largest decrease since 1990 is *Manufacture of solid fuels and other energy industries* – a historically significant contributor to New Zealand's emissions. Emissions for this category in 2023 decreased from the 1990 level by 1,501.8 kt CO_2-e (88.1 per cent). This decrease is primarily due to the cessation of synthetic gasoline production in 1997.

Figure 2.2.7 shows the time series of Energy sector emissions from 1990 to 2023. Emissions increased from 1990 through to around 2006, before decreasing slightly and then remaining steady until 2019. Since 2019, emissions have generally tracked downwards due to both the impact of the COVID-19 pandemic and the high levels of hydro power generation in 2022 and 2023.

Restrictions on activity and movement as part of the response to the COVID-19 pandemic during the 2020 calendar year saw significant disruption to economic activity throughout New Zealand. The effects on the Energy sector are particularly notable, with national energy consumption falling 7.2 per cent compared with 2019 levels. The sector saw a slight rebound during 2021, but energy consumption has remained well below pre-2020 levels in the following years.

Figure 2.2.7 New Zealand's Energy sector emissions, from 1990 to 2023



2022–2023

Between 2022 and 2023, emissions from the Energy sector decreased by 225.0 kt CO_2-e (0.8 per cent). This is primarily due to combined decreases in *Petroleum refining* (down 166.1 kt CO_2-e or 100 per cent), *Public electricity and heat production* (down 153.5 kt CO_2-e or 5.3 per cent) and *Commercial/Institutional* (down 143.1 kt CO_2-e or 10.7 per cent). This decrease was partially offset by the *Domestic aviation* category, which increased by 245.2 kt CO_2-e (24.0 per cent) and *Road transportation*, which increased by 233.7 kt CO_2-e (1.9 per cent). Further information on these changes is provided under the relevant categories of chapter 3, section 3.2.

National energy consumption in 2023 remained the same as 2022 levels, and was still 6.1 per cent below the pre-COVID level seen in 2019.

IPPU sector

The IPPU sector in New Zealand produces emissions of CO_2 (66.1 per cent of total IPPU sector emissions) and fluorinated gases (28.9 per cent), as well as smaller amounts of CH_4 and N_2O. The major categories in the IPPU sector are *Iron and steel production*, *Refrigeration and air conditioning*, *Aluminium production* and *Cement production*. Coal and natural gas are also used on a significant scale for energy in the *Mineral industry*, *Chemical industry* and *Metal industry* categories. Carbon dioxide and any other emissions from combustion of fuels in these industries are reported under the Energy sector.

2023

In 2023, emissions in the IPPU sector contributed 4,031.5 kt CO_2-e, or 5.3 per cent, of New Zealand's gross greenhouse gas emissions.

The largest category is the *Metal industry*, with substantial CO_2 emissions from the *Iron and steel production* and *Aluminium production* categories, as well as PFCs from the *Aluminium production* category in earlier years. The *Mineral industry* and *Chemical industry* categories also contribute significant CO_2 emissions, and most of the non-CO_2 emissions come from the *Product uses as substitutes for ODS* category.

The IPPU sector produces smaller amounts of CH_4 from methanol production and N_2O used for medical applications in the *Other product manufacture and use* category.

Coal and natural gas are used on a significant scale for energy in these industries, and related emissions are reported under the Energy sector in the category *Manufacturing industries and construction*.

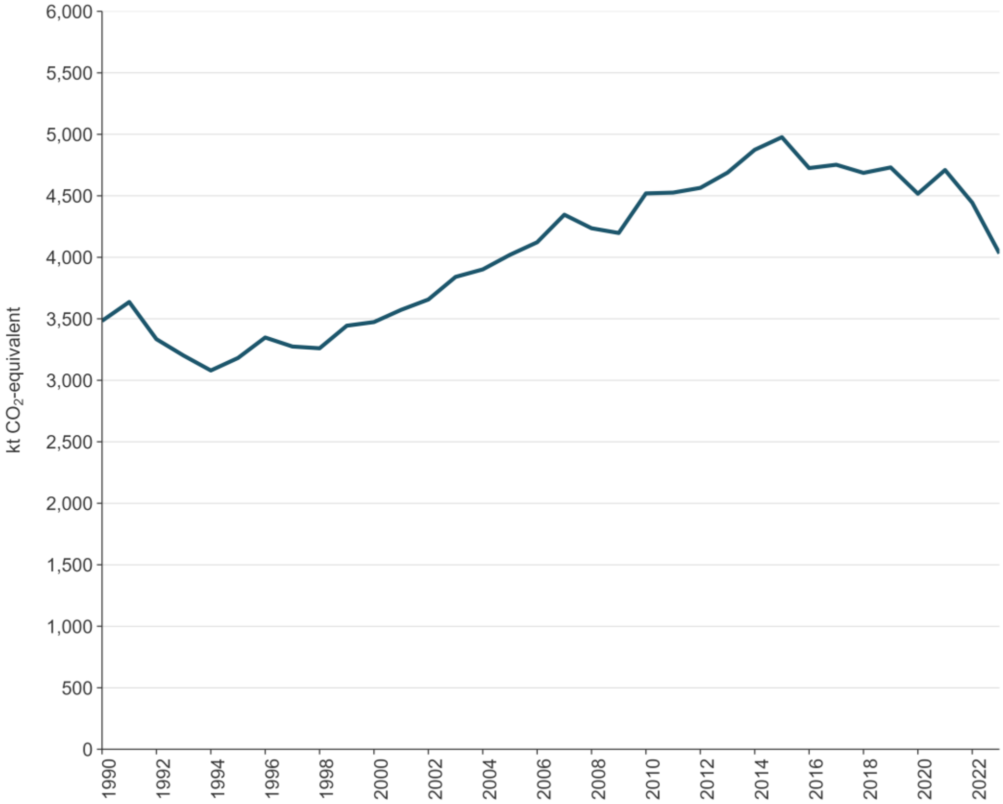
1990–2023

Emissions from the IPPU sector in 2023 were 548.4 kt CO_2-e (15.7 per cent) higher than emissions in 1990 (3,483.1 kt CO_2-e). This increase was mainly driven by increasing emissions from the *Product uses as substitutes for ODS* category, due to the introduction of HFCs to replace ODS in refrigeration and air conditioning, and the increased use of household and commercial air conditioning.

Carbon dioxide emissions also increased, due largely to increased production of aluminium and steel. Between 2020 and 2022, the increase was offset by reduced emissions due to COVID-19 pandemic restrictions and the progressive shutdown of the Marsden Point Oil Refinery. There was a substantial reduction in emissions of PFCs due to improved management of anode effects in the *Aluminium production* category and some reduction in emissions of N_2O used for medical applications in the *Other product manufacture and use* category.

The trends for the IPPU sector are shown in figure 2.2.8.

Figure 2.2.8 New Zealand's IPPU sector emissions, from 1990 to 2023



2022–2023

Between 2022 and 2023, emissions from the IPPU sector decreased by 412.4 kt CO_2-e (9.3 per cent).

This change was mainly the result of decreased emissions from the *Refrigeration and air conditioning* category.

Agriculture sector

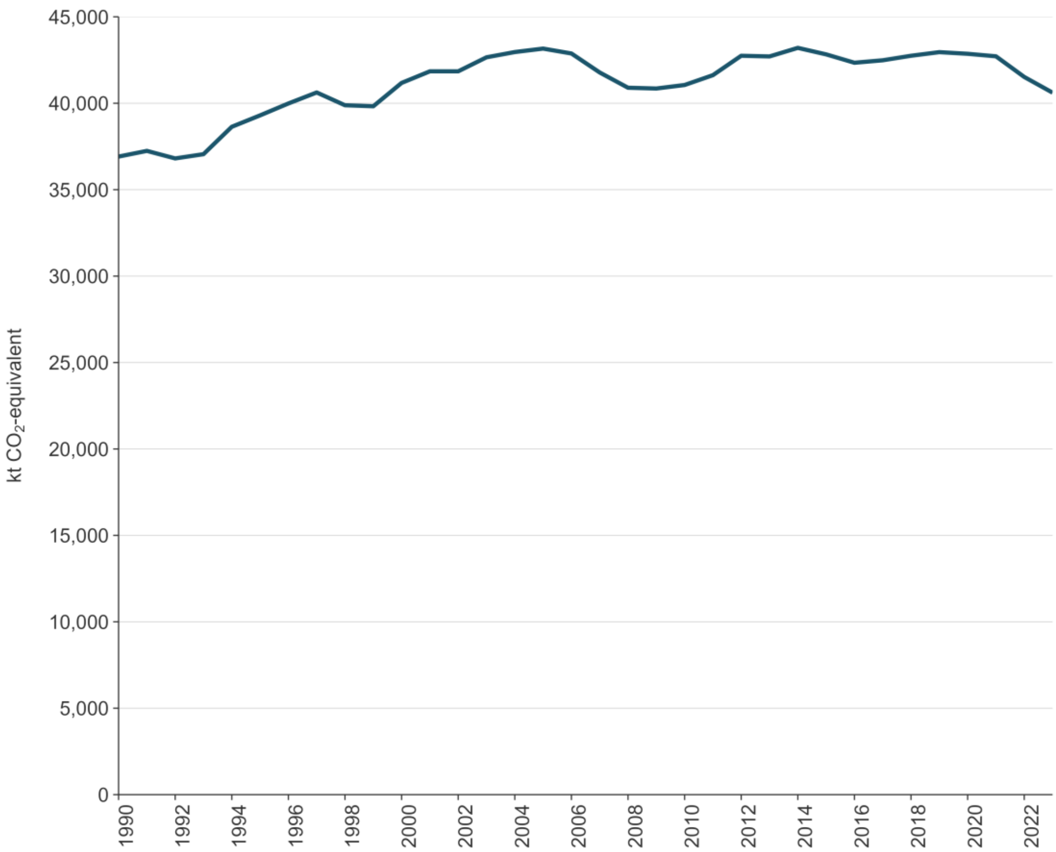
The Agriculture sector in New Zealand produced three GHGs in particular: CH_4, N_2O and CO_2, which comprised 82.4 per cent, 15.9 per cent and 1.7 per cent of all Agriculture sector emissions in 2023 respectively. Trends in Agriculture sector emissions are largely driven by the populations of ruminant livestock (dairy cattle, non-dairy (beef) cattle, sheep, and deer). The largest contributing categories in the Agriculture sector were *Enteric fermentation* and *Agricultural soils*. Emissions from the Agriculture sector reflect the total livestock population, the types of livestock and farming systems, and levels of production. Several drivers affected the emission trends for both CH_4 and N_2O in the sector. These include:

- changes over time to the population of the main livestock types farmed in New Zealand. Since 1990, the dairy cattle population has increased, while sheep and non-dairy (beef) cattle populations have decreased as the profitability of dairy products has risen relative to sheep and beef products (see chapter 5, figures 5.1.3(a) and figure 5.1.3(b))
- increases in livestock productivity (for both milk and meat yield per head of livestock), which have been achieved by New Zealand farmers since 1990. This has resulted in increased feed intake per animal to meet higher energy demands of increased production. Increased feed intake results in increased CH_4 (from increased enteric fermentation) and N_2O emissions (from increased excreta deposited on pasture) per animal

- incidents of severe drought, which have resulted in reduced livestock productivity and livestock populations, which in turn reduced livestock-related emissions. The 'Situation and Outlook for Primary Industries' reports produced by the Ministry for Primary Industries summarise the effects of these events at a sector level and provide short-term forecasts[18]
- commodity price fluctuations that drive farmer investment decisions in livestock numbers and species as well as production inputs. The 'Situation and Outlook for Primary Industries' reports also summarise these decisions at a sector level and provide short-term forecasts
- shifting land use across different types of livestock farming and other agricultural enterprises, including forestry. The Agriculture sector uses around 34 per cent of New Zealand's land area (Stats NZ, 2024), mostly for grazing of pastoral land. Between 1990 and 2023, the area used for sheep, beef and deer grazing has decreased by approximately 41.6 per cent (Beef + Lamb New Zealand Ltd, 2024), while the area used for dairy grazing has increased by 66.4 per cent (LIC and DairyNZ, 2024). The amount of synthetic nitrogen fertiliser applied to agricultural land has increased by 534 per cent since 1990.

The trends for the Agriculture sector are shown in figure 2.2.9.

Figure 2.2.9 New Zealand's Agriculture sector emissions, from 1990 to 2023



18 For more information, see Ministry for Primary Industries. *Situation and Outlook for Primary Industries*. Retrieved 20 March 2025.

2023

In 2023, emissions from the Agriculture sector totalled 40,613.0 kt CO_2-e, representing 53.1 per cent of New Zealand's gross emissions in 2023.

Methane from *Enteric fermentation* was the main source of Agriculture emissions, contributing 78.0 per cent (31,661.7 kt CO_2-e) of the sector's emissions. *Agricultural soils* (15.7 per cent) were the second-largest source followed by *Manure management* (4.6 per cent). *Urea application* and *Liming* contributed 1.0 per cent and 0.7 per cent respectively. *Field burning of agricultural residues* contributed less than 0.1 per cent.

Methane emissions from *Enteric fermentation* contributed 41.4 per cent of New Zealand's gross emissions, and N_2O emissions from the *Agricultural soils* category contributed 8.3 per cent of New Zealand's gross emissions.

1990–2023

In 2023, New Zealand's Agriculture sector emissions were 10.0 per cent (3,697.9 kt CO_2-e) above the 1990 level (36,915.1 kt CO_2-e).

The greatest absolute contributions to the change since 1990 are increases in emissions of 1,717.3 kt CO_2-e (36.9 per cent) from *Agricultural soils* and of 1,001.7 kt CO_2-e (116.5 per cent) from *Manure management*, as well as an increase in CH_4 emissions of 626.8 kt CO_2-e (2.0 per cent) from *Enteric fermentation*.

The increase in N_2O emissions from *Agricultural soils* is primarily a result of an increase of 534 per cent in the application of synthetic nitrogen fertiliser since 1990. This is partly due to an increase in dairy farming, as well as increased use of the fertiliser on other farm types. The emissions from synthetic nitrogen fertiliser use (N_2O) increased by 1,094.3 kt CO_2-e between 1990 and 2023. This is 63.7 per cent of the total increase in emissions from *Agricultural soils*.

The increase in emissions from *Manure management* and *Enteric fermentation* is driven by an increase in dairy cattle numbers. The increase in dairy *Enteric fermentation* emissions is partially offset by a decline in sheep numbers and a decrease in non-dairy (beef) cattle. The change in animal populations since 1990 reflects the relative financial returns in each sector (it has become more profitable to farm dairy cattle than non-dairy cattle or sheep in New Zealand over the reporting period).

2022–2023

Between 2022 and 2023, total Agriculture emissions decreased 2.2 per cent (908.4 kt CO_2-e), largely due to a decrease in emissions from dairy cattle, non-dairy cattle, sheep, and limestone application. Specifically:

- dairy cattle emissions decreased by 1.6 per cent (328.2 kt CO_2-e) due to a decrease in the dairy cattle population
- sheep emissions decreased by 3.1 per cent (294.6 kt CO_2-e) due to a continuing decrease in the sheep population
- emissions from limestone use decreased by 38.8 per cent (166.6 kt CO_2-e) due to a decrease in limestone use
- non-dairy cattle emissions decreased by 1.5 per cent (127.8 kt CO_2-e) due to a decrease in the beef cattle population.

Emissions from urea (CO_2 and N_2O) increased by 11.3 per cent (126.0 kt CO_2-e) due to an increase in urea use and decrease in urease inhibitor use. This increase reflects a slight recovery in urea use following a significant decrease in 2022. The impact of increased emissions from urea from 2022 to 2023 was largely offset by a decrease in the use of other (non-urea) synthetic nitrogen fertilisers.

LULUCF sector

2023

In 2023, net emissions from the LULUCF sector were -20,197.1 kt CO_2-e, or -26.4 per cent of New Zealand's gross greenhouse gas emissions. This comprises net emissions of -20,511.0 kt CO_2, emissions of 45.8 kt CO_2-e of CH_4 and 268.0 kt CO_2-e of N_2O. The category contributing the most to both removals and emissions is *Forest land remaining forest land*. This is because large removals result from the growth of all forests on this land and there are also large emissions from the sustainable harvest of New Zealand's plantation forests.

1990–2023

Net emissions in 2023 have increased by 4,136.9 kt CO_2-e (17.0 per cent) from the 1990 level of -24,334.1 kt CO_2-e (see chapter 6, table 6.1.1 and figure 6.1.1). This is largely due to a reduction in removals from *Forest land* and an increase in emissions from *Grassland* (mainly due to emissions from deforestation and conversions among grassland categories) since 1990. The reduction in removals from *Forest land* is driven by high current harvest rates (see chapter 6, figure 6.4.3), which are a result of the significant land-use changes to forest land that occurred in the 1980s and 1990s (see chapter 6, figure 6.4.1). The planted forests that were established during this period have progressively been reaching harvesting age, and that will continue into the mid-2020s. As the high harvesting rates continue, the average age of the planted forest estate is reduced each year when the harvested forests are replanted. Young forest stands have lower rates of removal than older stands.

Harvesting and replanting cycles of New Zealand's planted forests will continue to affect the trajectory of New Zealand's net emissions in the future due to their uneven age-class profile. The increased emissions from harvesting have been compensated for, to some extent, by increased removals in the harvested wood products pool due to inputs into this pool exceeding emissions from decay.

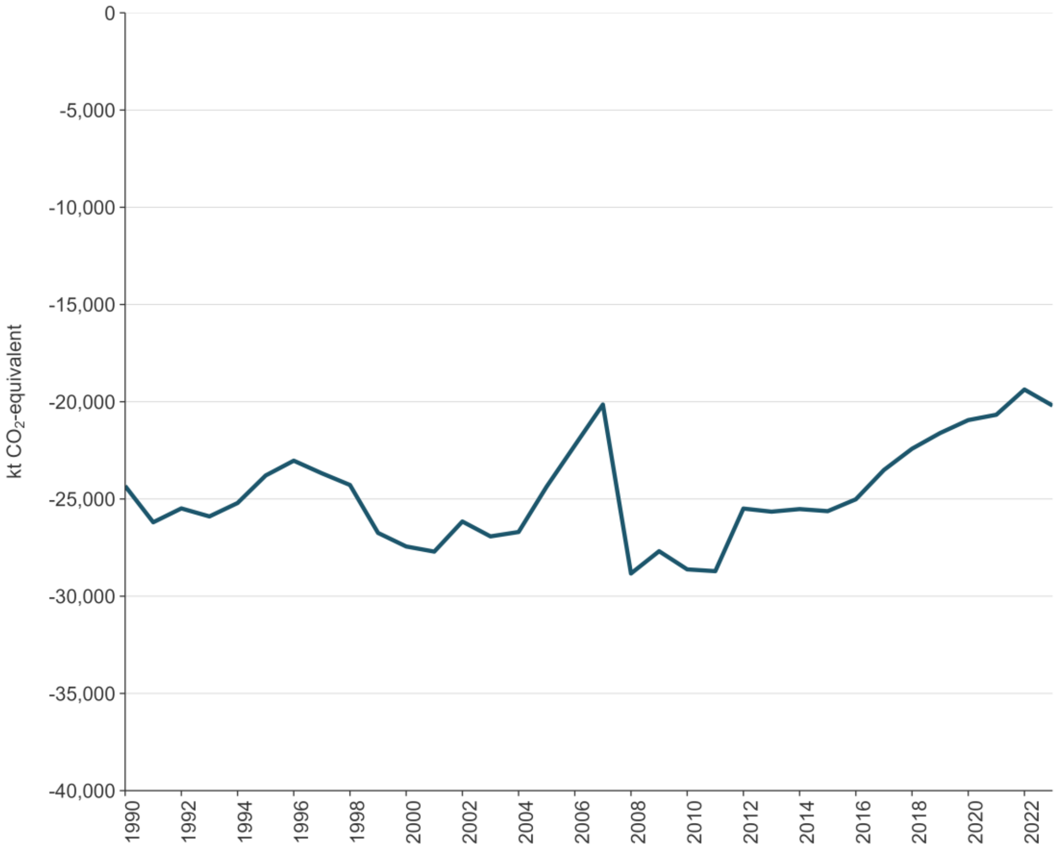
Emissions in the LULUCF sector are primarily driven by the harvest of production forests, deforestation and the decomposition of organic material following these activities. Removals are mainly from the sequestration of carbon that occurs due to plant growth and the production of *Harvested wood products*. Nitrous oxide can be emitted from the ecosystem as a by-product of nitrification and denitrification, and the burning of organic matter. Other gases released during biomass burning include CH_4, carbon monoxide (CO), other oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs).

The fluctuations in net emissions from the LULUCF sector since 1990 (see figure 2.2.10) were primarily influenced by afforestation, harvesting, and deforestation rates. Harvesting rates are driven by several factors, particularly forest age and log prices.

Net emissions in the LULUCF sector have been generally increasing over the past decade. Current harvest rates are near historically high levels due to the significant land-use changes to forest land that occurred in the 1980s and 1990s.

Deforestation rates are driven by the relative profitability of forestry compared with alternative land uses.

Figure 2.2.10 New Zealand's LULUCF sector net emissions, from 1990 to 2023



2022–2023

Net emissions from the LULUCF sector decreased between 2022 and 2023 by 824.4 kt CO_2-e (4.3 per cent) (see chapter 6, table 6.1.2).

The largest change occurred in the *Forest land* category, with a decrease in emissions of 952.1 kt CO_2-e, driven by reduced harvesting rates in planted forests between 2022 and 2023 (chapter 6, figure 6.4.3). The *Harvested wood products* category had the second-largest change, with an increase in emissions of 774.0 kt CO_2-e, which was also driven by the reduction in harvesting of planted forests, and corresponding reduction in products entering the harvested wood products pool. The *Grassland* category had the third-largest change, with a decrease in emissions of 684.7 kt CO_2-e. This was driven by lower deforestation rates in 2023 compared with 2022.

Waste sector

The Waste sector in New Zealand produces mainly CH_4 (91.9 per cent) followed by N_2O (5.3 per cent) and CO_2 (2.8 per cent) emissions. The Waste sector produces 7.3 per cent of gross CH_4 emissions in New Zealand. The disposal of solid waste also generates CO_2 emissions, however, as these are of biogenic origin, they are not reported.

2023

In 2023, emissions from the Waste sector contributed 2,916.6 kt CO_2-e or 3.8 per cent of New Zealand's gross GHG emissions. The largest source category is *Solid waste disposal*, as shown in chapter 7, table 7.1.1.

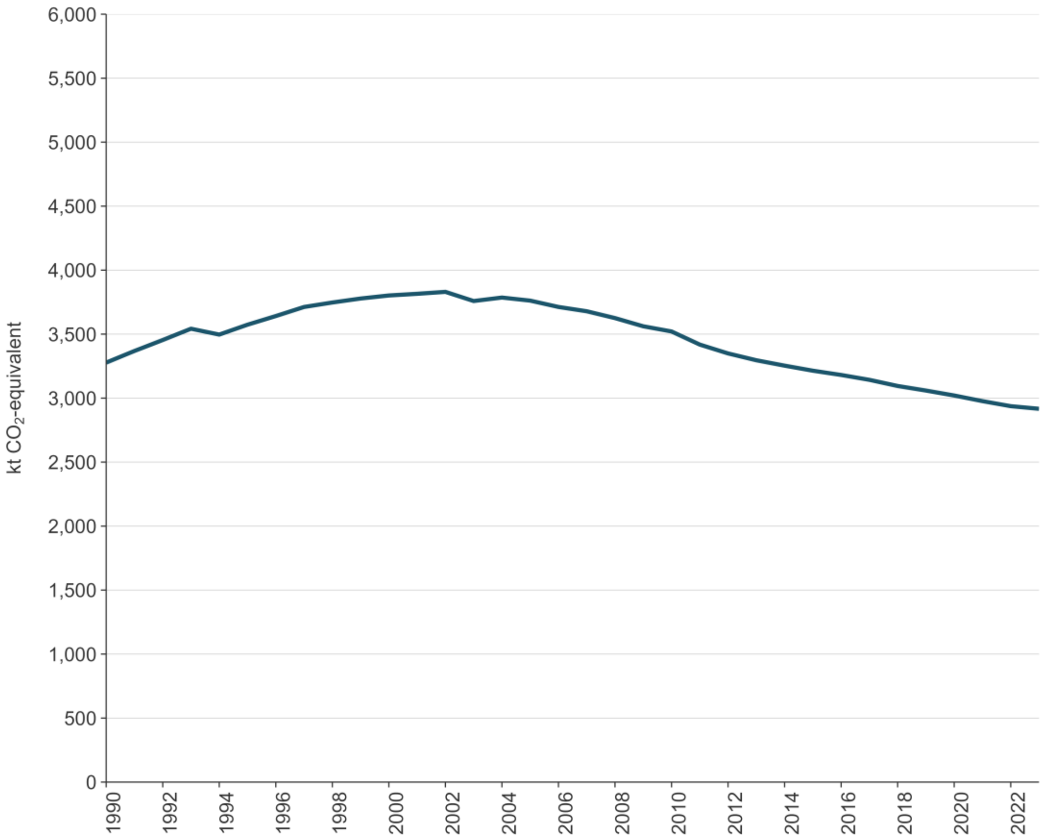
1990–2023

In 2023, emissions from the Waste sector decreased by 11.0 per cent (361.0 kt CO_2-e), from 3,277.6 kt CO_2-e in 1990.

Annual emissions peaked at 3,830.2 kt CO_2-e in 2002 and have generally been in decline since that time. Growth in population and economic activity since 1990 has resulted in increasing volumes of solid waste and wastewater for the whole of the time series. Ongoing improvements in the management of solid waste disposal at municipal landfills have meant total Waste sector emissions have been trending down since 2005, despite increasing volumes of solid waste and wastewater.

The reduction in emissions is primarily the result of increased CH_4 recovery through the installation of landfill gas (LPG) capture systems, driven by National Environmental Standards for Air Quality introduced in 2004 and by the inclusion of the Waste sector in the New Zealand Emissions Trading Scheme (NZ ETS) in 2013. These legislative tools have been complemented by local government efforts to improve kerbside collections, including for organic waste, across the country, and by a central government waste work programme that includes product stewardship, plastic phase-outs and investment in resource recovery infrastructure for organic materials. Trends in annual emissions are shown in figure 2.2.11 and in chapter 7, figure 7.1.2 and figure 7.1.3.

Figure 2.2.11 New Zealand's Waste sector emissions, from 1990 to 2023



2022–2023

Between 2022 and 2023, emissions from the Waste sector decreased by 0.7 per cent (20.5 kt CO_2-e). This decrease is largely the result of decreases in CH_4 emissions in the *Managed waste disposal site* category, mainly due to increasing landfill gas capture and changes in the composition of waste, with a reduction in the proportion of garden, food and paper waste disposed to those sites.

Other sector (Tokelau)

Beginning with the 2019 submission, New Zealand's national inventory has reported gross emissions from Tokelau, which is an overseas dependent territory of New Zealand. Table 2.2.2 shows the contribution of emissions from Tokelau. Generally, in New Zealand's inventory, net and gross emissions are reported as a total of emissions from New Zealand's mainland territory, plus gross emissions from Tokelau where applicable. Because emissions from Tokelau are small, and the methodology used varies greatly between Tokelau's inventory and the inventory for New Zealand's mainland territory, emissions from Tokelau are reported in the Other sector (CRT sector 6).

Methodological issues for Tokelau are detailed in chapter 8, separately from the sectoral chapters that focus on methods for New Zealand's mainland territory only. Annex 7 provides the common reporting tables of the time series for emissions and activity data, and information on methods and emission factors for each sector and category contributing to the gross emissions from Tokelau.

Due to its small land area, small population and absence of industry, Tokelau has a very low impact on the environment and emits very small amounts of GHGs. In relative terms, emissions have increased overall since 1990, due to increasing per capita consumption despite a decrease in population size. Tokelau produces mainly CO_2 emissions (54.5 per cent) and CH_4 emissions (39.4 per cent) followed by HFCs (5.0 per cent) and N_2O emissions (1.1 per cent). Emissions from HFCs largely come from the use of air conditioning.

Table 2.2.2 Emissions from Tokelau, 1990 and 2023

Sector	1990	2023	Change from 1990 (kt CO_2-e)	Change from 1990 (%)	Contribution to gross for Tokelau (%)	Contribution to gross NZ (incl Tokelau) (%)
Energy for Tokelau	1.26	2.27	1.01	79.75	54.04	0.003
IPPU for Tokelau	0.04	0.23	0.19	475.76	5.59	0.0003
Agriculture for Tokelau	1.29	0.92	-0.36	-28.29	21.95	0.001
Waste for Tokelau	0.78	0.77	-0.01	-0.70	18.42	0.001
Gross emissions for Tokelau	**3.37**	**4.20**	**0.83**	**24.69**	**100.00**	**0.006**

Note: The 2025 submission includes emissions from Tokelau's largest contributing sectors, which are the Energy, IPPU, Agriculture and Waste sectors. The LULUCF sector is not estimated. Tokelau has no planted or managed forests; therefore, the LULUCF sector is expected to be insignificant. The percentages may not add up to 100 per cent due to rounding.

2023

In 2023, emissions from Tokelau contributed 0.006 per cent (4.20 kt CO_2-e) of New Zealand's gross GHG emissions.

The largest source category was *Domestic navigation*, which contributed 63.2 per cent (1.43 kt CO_2-e) of all energy emissions and 34.1 per cent of gross emissions from Tokelau.

Carbon dioxide dominated emissions from Tokelau, contributing 54.5 per cent (2.29 kt CO_2-e) of its total emissions in 2023. At 2.25 kt CO_2, the Energy sector contributed 98.3 per cent of total CO_2 emissions, mostly from *Domestic navigation*; the remaining 1.7 per cent (0.04 kt) came from *Open burning of waste* in the Waste sector.

Methane emissions contributed 39.4 per cent (1.65 kt CO_2-e) to the total emissions from Tokelau. The Agriculture sector in Tokelau contributed 55.8 per cent of CH_4 emissions (0.92 kt CO_2-e), which mostly came from *Manure management*. A significant portion of CH_4 emissions, 43.9 per cent (0.73 kt CO_2-e), came from the Waste sector, largely from *Solid waste disposal*. The Energy sector contributed the remaining 0.4 per cent of CH_4 emissions (0.01 kt CO_2-e), which mostly came from *Domestic navigation*.

Nitrous oxide emissions contributed 1.1 per cent (0.05 kt CO_2-e) to the total emissions from Tokelau. The IPPU sector (*Medical applications*) contributed the largest amount of N_2O, 52.1 per cent (0.02 kt CO_2-e) of the total N_2O. The Energy sector contributed a further 26.0 per cent (0.01 kt CO_2-e), which comes largely from *Domestic navigation*. The Waste sector contributed the remaining 21.8 per cent of N_2O (0.01 kt CO_2-e) from *Open burning of waste*.

Emissions of fluorinated gases from Tokelau consisted of HFC emissions only, contributing 5.0 per cent (0.21 kt CO_2-e) to the total emissions from Tokelau. These emissions largely result from the use of *Air conditioning*. Emissions of PFCs, NF_3 and SF_6 do not occur in Tokelau.

1990–2023

In 1990, total emissions from Tokelau were 3.37 kt CO_2-e. Between 1990 and 2023, total emissions increased by 24.7 per cent (0.83 kt CO_2-e) to 4.20 kt CO_2-e (see figure 2.2.12 and chapter 8, table 8.1.2 and figure 8.1.4). From 1990 to 2023, the average annual increase in gross emissions was 0.89 per cent.

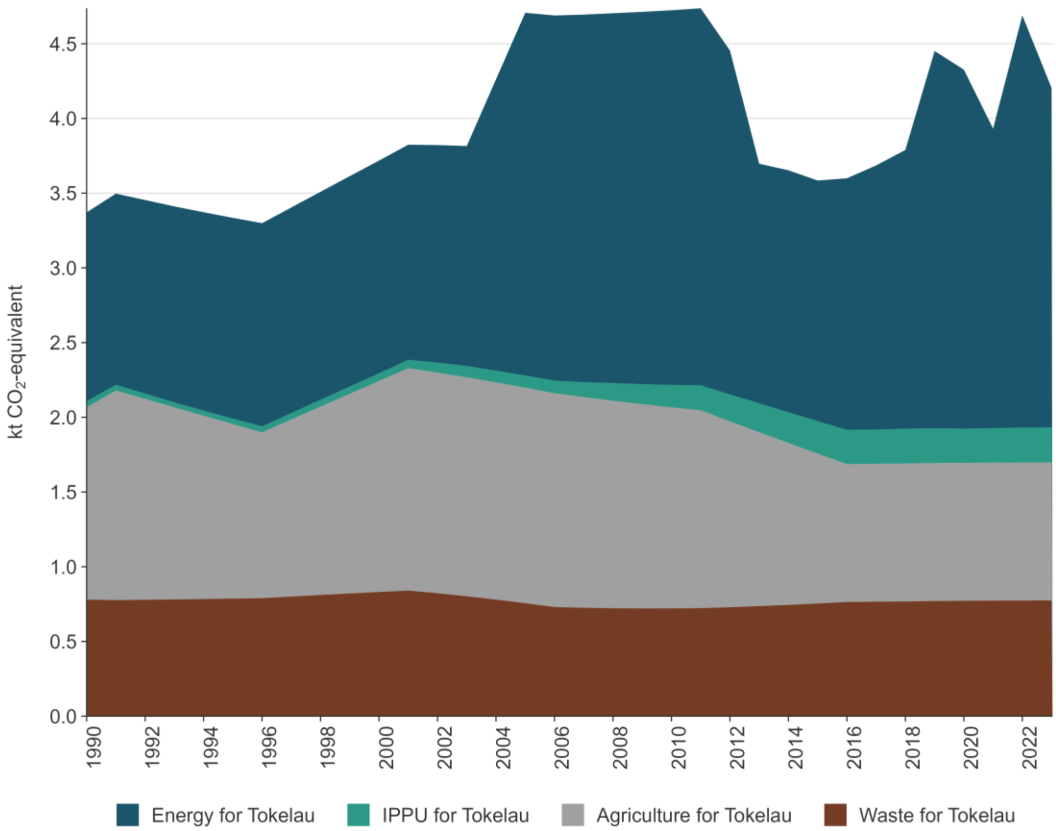
The emissions increase was largely due to changes in the Energy sector. The emission categories that contributed the most to this change were *Domestic navigation* and *Electricity generation*.

The changes in *Domestic navigation* were a result of Tokelau gaining ownership and use of the ferry *Mataliki* in 2016, cargo vessel *Kalopaga* in 2018 and search and rescue vessel *Fetu o te Moana* in 2019, leading to an increasing number of sea voyages between the atolls, which increased transport emissions.

The changes in Tokelau's Energy sector emissions from *Electricity generation* drive the overall emissions trend observed across most of the time series. Initially, up until 2003, emissions from this source were relatively stable. A significant increase in emissions was then observed (of nearly 400 per cent) due to an increase in the use of diesel generators for electricity production between 2003 and 2011. This was followed by a significant drop in emissions in 2012 and 2013 (by 82.5 per cent), when solar electricity generation began. Toward the end of the time series, diesel generator use increased again as the generation from solar power decreased, with emissions increasing accordingly.

Emissions from Tokelau's IPPU sector have also increased mainly due to the introduction of air conditioning after 2006. Emissions from Tokelau's Agriculture sector decreased slightly as a result of a reduced population of pigs.

Figure 2.2.12 Emissions by sector for Tokelau, from 1990 to 2023



2022–2023

Total Tokelau emissions in 2023 were 0.49 kt CO_2-e (10.4 per cent) lower than emissions in 2022. The decrease in emissions is largely in the *Electricity generation* category, which is the result of reduced diesel due to fuel conservation initiatives and problems with the diesel electricity generators. The diesel generators have been in greater demand following issues with solar electricity generation since 2022. This decrease in emissions from *Electricity generation* is slightly offset by a small increase in the *Domestic navigation* category, due to an increase in shipping trips.

2.2.3 Emission trends by gas from 1990 to 2023

Inventory reporting under the Paris Agreement and the United Nations Framework Convention on Climate Change covers the following direct GHGs: CO_2, CH_4, N_2O, SF_6, PFCs, HFCs and NF_3. No NF_3 data are included in this report because NF_3 emissions do not occur in New Zealand.

Table 2.2.3 provides a summary of gross emissions for each gas in 1990 and 2023 and the changes since 1990.

Table 2.2.3 **New Zealand's gross emissions by gas in 1990 and 2023**

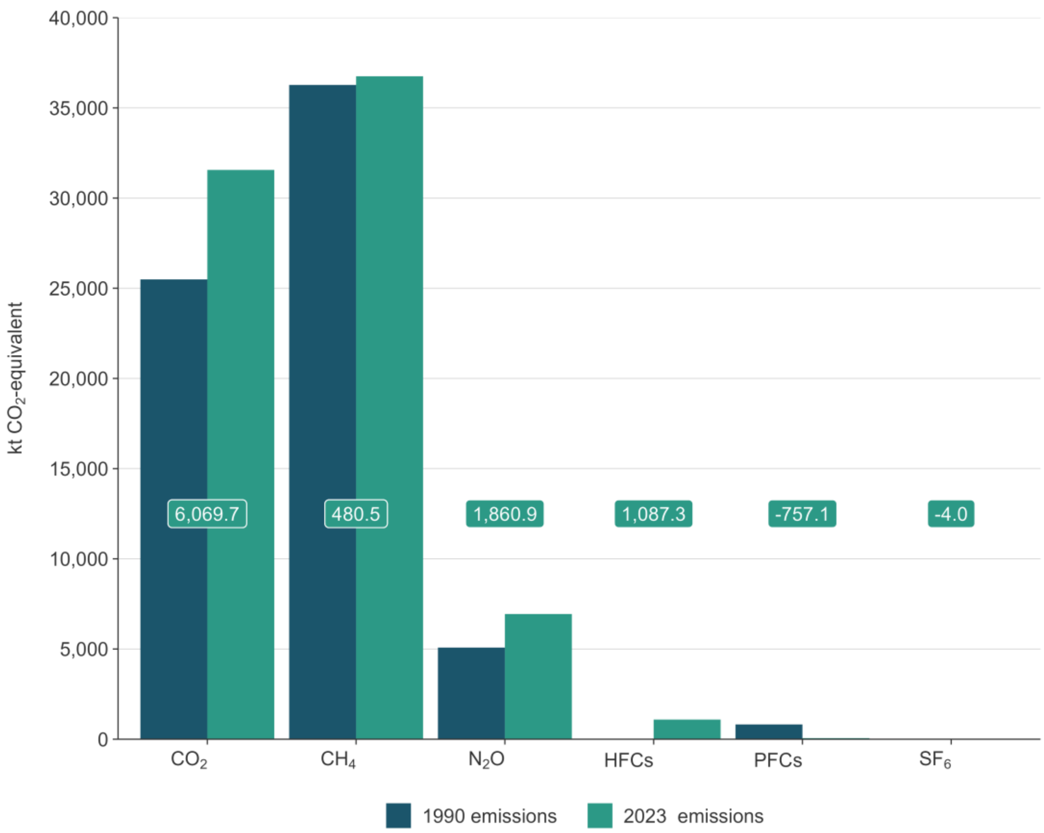
Direct greenhouse gas emissions	1990	2023	Change from 1990 (kt CO_2-e)	Change from 1990 (%)
CO_2	25,490.1	31,559.8	6,069.7	23.8
CH_4	36,271.1	36,751.6	480.5	1.3
N_2O	5,079.1	6,940.0	1,860.9	36.6
HFCs	Not occurring	1,087.3	1,087.3	NA
PFCs	818.0	60.9	-757.1	-92.6
SF_6	20.6	16.6	-4.0	-19.2
Gross, all gases	**67,678.9**	**76,416.3**	**8,737.4**	**12.9**

Note: Gross emissions exclude net emissions from the LULUCF sector. The percentage change for HFCs is not applicable (NA) because no emissions of HFCs occurred in 1990. Columns may not total due to rounding. Percentages presented are calculated from unrounded values.

In 1990 and 2023, CH_4 made the greatest contribution to gross emissions (see table 2.2.3 and figure 2.2.13). While emissions of CH_4 have increased between these years, the rate of increase in CH_4 emissions relative to other gases in the Inventory has decreased over this period. Nitrous oxide and CO_2 emissions have increased at a greater rate between these years than CH_4 emissions.

These trends reflect the changes that have occurred in the main livestock types that are farmed in New Zealand and the growth in road transport.

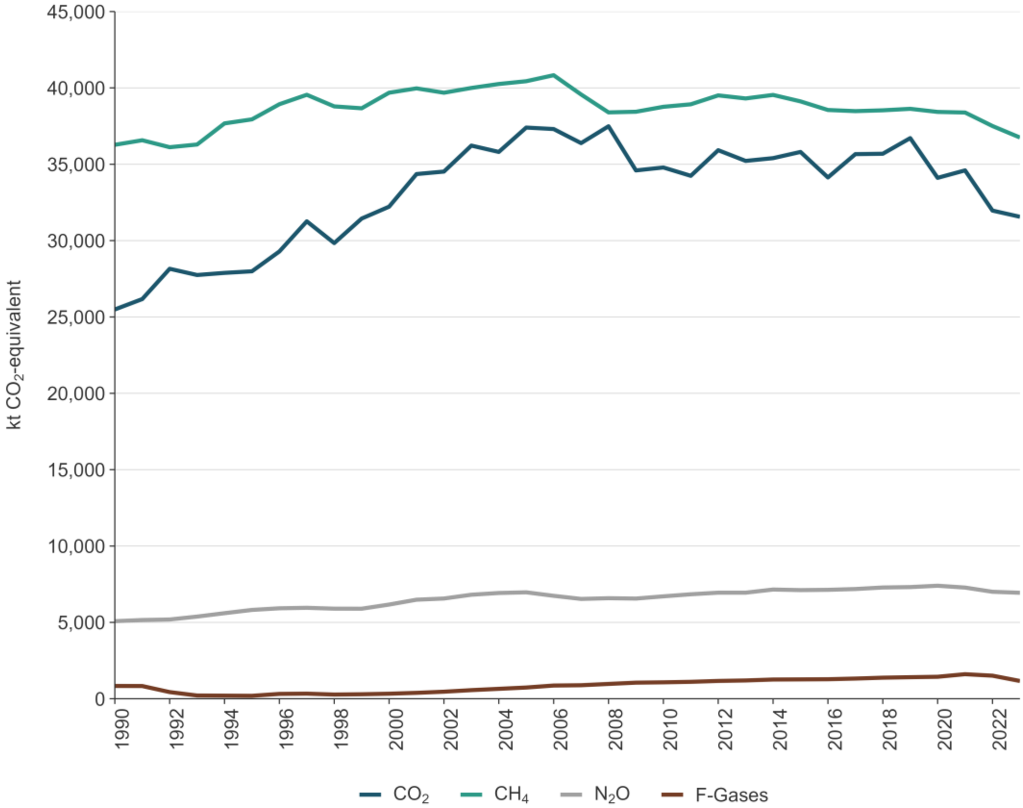
Figure 2.2.13 **New Zealand's gross emissions by gas in 1990 and 2023**



Note: Emissions of sulphur hexafluoride (SF_6) are not visible due to its small emissions value and emissions of hydrofluorocarbons (HFCs) did not occur in 1990.

New Zealand's inventory by greenhouse gas for 1990 to 2023 is presented in figure 2.2.14. The LULUCF sector is excluded from this figure because it is a net sink across the time series. The LULUCF sector and its GHG trends are explained in detail in chapter 6.

Figure 2.2.14 Trends in New Zealand's greenhouse gas emissions by gas, from 1990 to 2023



Methane emissions represent the largest source of New Zealand's gross anthropogenic GHG emissions since 1990 (figure 2.2.14). Most CH_4 emissions are produced through enteric fermentation, reported in the Agriculture sector. Carbon dioxide is the second-largest source of gross emissions for New Zealand. Most CO_2 emissions are produced through combustion of fossil fuels in the Energy sector.

Methane emissions have increased by 1.3 per cent compared with 1990 levels. Methane emissions generally tracked upwards between 1990 and 2006, when they reached their peak. Despite fluctuations, CH_4 emissions have generally been tracking downwards since 2006 and have been declining year on year since 2019. The changes observed in CH_4 emissions have largely been due to increasing dairy cattle numbers, which have been partially offset by decreasing numbers of non-dairy (beef) cattle and sheep since 1990.

Carbon dioxide emissions have increased by 23.8 per cent in 2023 compared with 1990 levels, peaking in 2008 (figure 2.2.14) and declining year on year since 2019. Since 2019, there has been a decrease in emissions due to the impact of the COVID-19 pandemic and high levels of hydro power generation in 2022 and 2023.

Nitrous oxide emissions have increased by 36.6 per cent in 2023 compared with 1990 levels, most recently peaking in 2020. Emissions from N_2O have generally been tracking upwards since 1990, although small decreases have been observed since 2020. The overall increase in N_2O emissions is primarily a result of the increased use of synthetic nitrogen fertiliser since 1990, due to an increase in dairy farming, as well as increased use on other farm types.

Combined fluorinated gas emissions have increased by 38.9 per cent in 2023 compared with 1990 levels. This increase was mainly due to the introduction of HFCs to replace ODS in refrigeration and air conditioning and the increased use of household and commercial air conditioning.

Indirect gases

New Zealand reports emissions estimates of indirect gases in accordance with the IPCC 2006 Guidelines (Volume 1, Chapter 7) (IPCC, 2006). These indirect gases are CO, NO_X, NMVOCs and sulphur dioxide (SO_2). These gases are not greenhouse gases themselves and are not included in the national emissions totals; however, CO, NO_X and NMVOCs chemically alter the atmosphere, leading to an increase in tropospheric ozone concentrations and SO_2 contributes to aerosol formation. Table 2.2.4 summarises New Zealand's indirect GHG emissions in 1990 and 2023 as well as the change between these years.

Table 2.2.4 New Zealand's indirect greenhouse gas emissions (excluding LULUCF) in 1990 and 2023

Indirect greenhouse gas emissions	1990	2023	Change from 1990 (kt CO_2-e)	Change from 1990 (%)
CO	622.6	662.5	39.9	6.4
NMVOCs	143.7	172.3	28.6	19.9
NO_X	102.5	150.8	48.3	47.1
SO_2	58.6	51.4	-7.2	-12.3

Note: Columns may not total due to rounding. Percentages presented are calculated from unrounded values.

Chapter 2: References

Beef + Lamb New Zealand Ltd. 2024. *Annual Report 2023*. Retrieved 27 November 2024.

IPCC. 2006. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1. General Guidance and Reporting.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2013. Stocker, TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

LIC (Livestock Improvement Corporation Limited) and DairyNZ. 2024. *New Zealand Dairy Statistics 2023–2024*. Hamilton: DairyNZ. Retrieved 7 January 2025.

Stats NZ. 2024. *Agricultural production statistics: Year to June 2023 (final)*. Retrieved 2 December 2024.

Chapter 3: Energy

3.1 Sector overview

3.1.1 Introduction

In New Zealand, the Energy sector covers:

- **combustion emissions**, that is, emissions resulting from fuel being burned to produce useful energy
- **fugitive emissions**, for example:
  - emissions from the production, transmission and storage of fuels
  - emissions from non-productive combustion
  - venting of carbon dioxide (CO_2) at natural gas treatment plants
  - emissions from geothermal fields.

Combustion emissions from the *Road transportation* category make up the largest share of domestic emissions from the Energy sector in New Zealand.

New Zealand has one of the highest rates of car ownership among members of the Organisation for Economic Co-operation and Development and a relatively old vehicle fleet (the average age of the light passenger fleet was around 15 years in 2023). Most freight is transported by trucks, with smaller quantities transported by rail and coastal shipping. Due to its sparse population and rural-based economy, New Zealand's domestic transport emissions per capita are high compared with many other Annex I countries.

New Zealand's electricity generation system relies heavily on renewable energy sources but is supported by the combustion of coal, oil and gas. In 2023, fossil fuel thermal plants provided 11.8 per cent of New Zealand's total electricity supply, which is very low by international standards. New Zealand's renewable electricity sources comprise mostly hydroelectric power generation (contributing 60.5 per cent of net generation), complemented by other renewable power sources such as geothermal (17.8 per cent) and wind (7.4 per cent). While this provides a strong power generation base in years with good hydro inflows, electricity emissions remain sensitive to rainfall in key catchment areas. New Zealand has low levels of hydro lake storage compared with other countries whose supply depends heavily on hydroelectric power.

Fugitive emissions make up a relatively small portion of New Zealand's energy emissions profile. The main sources of fugitive emissions in New Zealand are coal mining operations, production and processing of natural gas (largely venting and flaring), and geothermal operations (largely electricity generation).

New Zealand reports emissions from Tokelau, which is a dependent territory of New Zealand. Emissions from Tokelau are calculated using significantly different methods, and integrating these with New Zealand's emissions would be prohibitively complex. Thus, emissions from Tokelau for all activities are reported in chapter 8 and annex 7, and within the 'Other' sector in the common reporting tables (CRTs). All emissions reported under the Energy sector are from New Zealand only and exclude Tokelau. Please see chapter 8 for details of methods applied and the emissions for Tokelau.

2023

In 2023, emissions from the Energy sector contributed 28,851.0 kilotonnes of carbon dioxide equivalent (kt CO_2-e), or 37.8 per cent of New Zealand's gross greenhouse gas emissions (see chapter 2, figure 2.2.1).

The largest sources of emissions in the Energy sector were the *Road transportation* category, contributing 12,599.8 kt CO_2-e (43.7 per cent), and the *Manufacturing industries and construction* category, contributing 6,126.3 kt CO_2-e (21.2 per cent) to energy emissions.

1990–2023

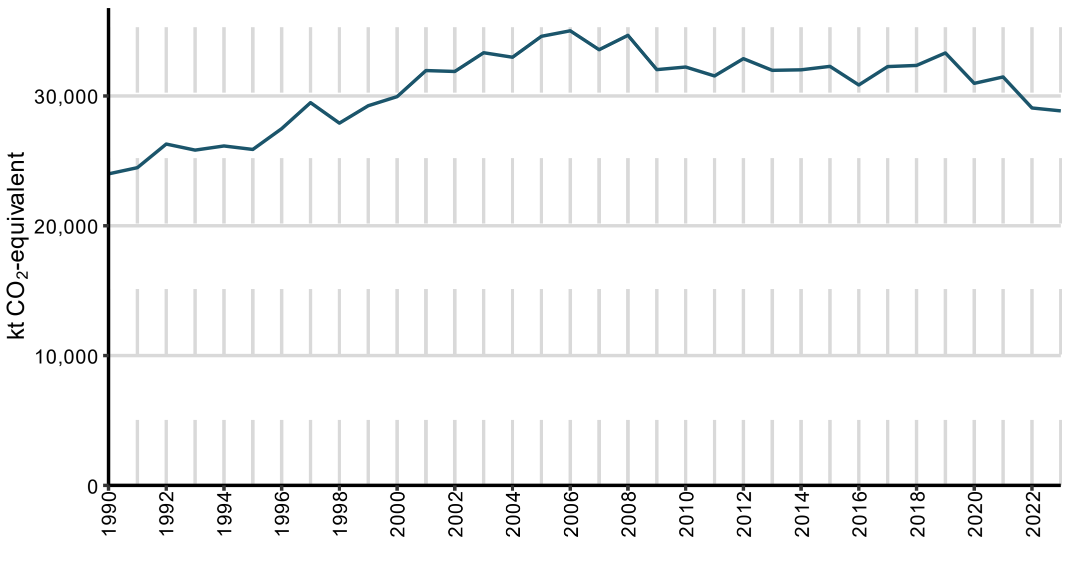
In 2023, emissions from the Energy sector increased by 20.2 per cent (4,851.2 kt CO_2-e) from the 1990 level of 23,999.7 kt CO_2-e. This growth is primarily due to *Road transportation*, which increased by 5,771.3 kt CO_2-e (84.5 per cent), *Food processing, beverages and tobacco*, which increased by 1,031.4 kt CO_2-e (61.7 per cent), and *Chemicals*, which increased by 776.4 kt CO_2-e (144.8 per cent). Although the underlying drivers of these increases are often nuanced, key factors include population growth and increased economic activity.

The category showing the largest decrease since 1990 is *Manufacture of solid fuels and other energy industries* – a historically significant contributor to New Zealand's emissions. Emissions for this category in 2023 decreased from the 1990 level by 1,501.8 kt CO_2-e (88.1 per cent). This decrease is primarily due to the cessation of synthetic gasoline production in 1997.

Figure 3.1.1 shows the time series of Energy sector emissions from 1990 to 2023. Emissions increased from 1990 to around 2006, before decreasing slightly and then remaining steady until 2019. Since 2019 emissions have decreased due to the impact of the response to the coronavirus (COVID-19) pandemic and due to high levels of hydro power generation in 2023.

Restrictions on activity and movement as part of the response to the COVID-19 pandemic during the 2020 calendar year saw significant disruption to economic activity throughout New Zealand. The effects on the Energy sector are particularly notable, with national energy consumption falling 7.2 per cent compared with 2019 levels. The sector saw a slight rebound during 2021, but energy consumption has remained well below pre-2020 levels in the following years.

Figure 3.1.1 New Zealand's Energy sector emissions, from 1990 to 2023



2022–2023

Between 2022 and 2023, emissions from the Energy sector decreased by 225.0 kt CO_2-e (0.8 per cent). This is primarily due to combined decreases in *Petroleum refining* (down 166.1 kt CO_2-e or 100 per cent), *Public electricity and heat production* (down 153.5 kt CO_2-e or 5.3 per cent) and *Commercial/Institutional* (down 143.1 kt CO_2-e or 10.7 per cent). This decrease was partially offset by the *Domestic aviation* category, which increased by 245.2 kt CO_2-e (24.0 per cent) and *Road transportation,* which increased by 233.7 kt CO_2-e (1.9 per cent). Further information on these changes is provided under the relevant categories of section 3.3.

National energy consumption in 2023 remained at the same level as 2022, and was still 6.1 per cent below the pre-COVID level seen in 2019.

3.1.2 Key categories for Energy sector emissions

Details of New Zealand's key category analysis are provided in chapter 1, section 1.4. The key categories in the Energy sector are listed in table 3.1.1.

Table 3.1.1 Key categories in the Energy sector

CRT category code	IPCC categories	Gas	Criteria for identification
1.A.1.a.	Energy industries – Public electricity and heat production Gaseous Fuels	CO_2	L1, T1
1.A.1.a.	Energy industries – Public electricity and heat production Solid Fuels	CO_2	L1
1.A.1.b.	Energy industries – Petroleum refining Liquid Fuels	CO_2	T1
1.A.1.c.	Energy industries – Manufacture of solid fuels and other energy industries Gaseous Fuels	CO_2	T1
1.A.2.c.	Manufacturing industries and construction – Chemicals Gaseous Fuels	CO_2	L1, T1
1.A.2.d.	Manufacturing industries and construction – Pulp, paper and print Gaseous Fuels	CO_2	L1, T1
1.A.2.d.	Manufacturing industries and construction – Pulp, paper and print Solid Fuels	CO_2	T1
1.A.2.e.	Manufacturing industries and construction – Food processing, beverages and tobacco Solid Fuels	CO_2	L1, T1
1.A.2.e.	Manufacturing industries and construction – Food processing, beverages and tobacco Gaseous Fuels	CO_2	L1, T1
1.A.2.e.	Manufacturing industries and construction – Food processing, beverages and tobacco Liquid Fuels	CO_2	L1
1.A.2.f.	Manufacturing industries and construction – Non-metallic minerals Solid Fuels	CO_2	T1
1.A.2.g.iii.	Other – Mining (excluding fuels) and quarrying Liquid Fuels	CO_2	L1, T1
1.A.2.g.v.	Other – Construction Liquid Fuels	CO_2	L1, T1
1.A.2.g.viii.	Other – Other (please specify) Liquid Fuels	CO_2	L1, T1
1.A.2.g.viii.	Other – Other (please specify) Solid Fuels	CO_2	T1
1.A.3.a.	Domestic aviation – Jet kerosene	CO_2	L1, T1
1.A.3.b.	Transport – Road transportation Liquid Fuels	CO_2	L1, T1
1.A.3.b.	Transport – Road transportation Gaseous Fuels	CO_2	T1
1.A.3.d.	Domestic navigation – Residual fuel oil	CO_2	T1
1.A.4.a.	Other sectors – Commercial/institutional Liquid Fuels	CO_2	L1, T1
1.A.4.a.	Other sectors – Commercial/institutional Gaseous Fuels	CO_2	L1, T1
1.A.4.a.	Other sectors – Commercial/institutional Solid Fuels	CO_2	T1
1.A.4.b.	Other sectors – Residential Liquid Fuels	CO_2	L1, T1
1.A.4.b.	Other sectors – Residential Gaseous Fuels	CO_2	L1, T1
1.A.4.b.	Other sectors – Residential Solid Fuels	CO_2	T1

CRT category code	IPCC categories	Gas	Criteria for identification
1.A.4.c.	Other sectors – Agriculture/forestry/fishing Liquid Fuels	CO_2	L1, T1
1.A.4.c.	Other sectors – Agriculture/forestry/fishing Solid Fuels	CO_2	T1
1.B.1.a.i.	Coal mining and handling – Underground mines	CH_4	T1
1.B.2.b.v.	Natural gas – Distribution	CH_4	T1
1.B.2.c.i.2.	Venting – Gas	CO_2	L1, T1
1.B.2.c.i.3.	Venting – Combined	CH_4	T1
1.B.2.c.ii.3.	Flaring – Combined	CO_2	T1
1.B.2.d.	Other (please specify) – Geothermal	CO_2	L1, T1

Note: L1 means a key category is identified under the level analysis – approach 1 and T1 is trend analysis – approach 1. See chapter 1 for more information.

3.1.3 New Zealand sectoral methodology

Greenhouse gas emissions from the Energy sector are calculated using a detailed sectoral approach. This bottom-up approach is demand-based: it involves processing energy data collected on a regular basis through various surveys. For verification, New Zealand also applies the Intergovernmental Panel on Climate Change (IPCC) reference approach to estimate CO_2 emissions from fuel combustion for the time series 1990 to 2023 (see annex 3).

The activity data used for the sectoral approach are referred to as 'observed' energy-use figures. These are based on surveys and questionnaires administered by the Ministry of Business, Innovation and Employment (MBIE). The differences between 'calculated' and 'observed' figures are reported as statistical differences in the energy balance tables released along with *Energy in New Zealand* (MBIE, 2024a). Note that, due to the intervening time between the publication of *Energy in New Zealand* and the preparation of this submission, some data revisions may have occurred.

3.1.4 International bunker fuels

The data on fuel use by international transportation are collected and published online by MBIE (2024a). This data release uses information from oil company survey returns through two surveys provided to MBIE.

- The **Delivery of Petroleum Fuels by Industry** survey (DPFI) is a quarterly survey that collects data on observed demand (i.e., actual sales figures) broken down by industrial sector.
- The **Monthly Oil Supply** survey (MOS) is a monthly survey that asks companies selling fuels to provide a liquid fuels supply balance.

Some of the international bunkers data in CRT 1.A(b) are from the MOS, whereas the international bunkers data in CRT 1.D are from the DPFI. Companies that respond to the DPFI are asked to reconcile their figures with their figures in the MOS. Discrepancies between the surveys are usually very small, and the companies attribute these differences to the difference in approach between the two surveys (the MOS follows a top-down approach, while the DPFI follows a bottom-up approach). Furthermore, the MOS and DPFI are usually completed by different sections from within the fuel companies. Also, note that the *Other fuels* category is not covered in the DPFI so data must come from the MOS.

3.1.5 Feedstock and other non-energy use of fuels

For some industrial companies, the fuels supplied are used both as fuels for combustion and as feedstocks. In these instances, process-related emissions are calculated by taking the fraction of carbon stored or sequestered in the final product (based on industry production and chemical composition of the product) and subtracting this from the total fuel supplied. This difference is assumed to be the amount of carbon emitted as CO_2 and is reported under the Industrial Processes and Product Use (IPPU) sector and in CRT 1.AD. Other fuel materials, such as bitumen, also contribute to emissions that are reported under the IPPU sector and (where appropriate) in CRT 1.AD.

In New Zealand, these non-energy fuels are as follows.

- The carbon in the natural gas used as feedstock to produce methanol is all considered to be stored in the product and therefore has no associated CO_2 emissions. The balance of the carbon is oxidised and results in CO_2. Emissions from fuel used for combustion are reported in CRT category 1.A.2.c. These figures may differ slightly from those reported online by MBIE, which are based on natural gas energy use and non-energy use as reported by the plant operator.
- All ammonia produced in New Zealand is processed into urea. Carbon dioxide emissions from the use of natural gas in ammonia production (feedstock) are reported under the IPPU sector and are included in CRT 1.AD. Emissions from fuel used for combustion are reported in CRT category 1.A.2.c.
- Bitumen produced in New Zealand is not used as a fuel but rather as a road construction material (non-energy use). Bitumen therefore has no associated direct emissions. Indirect emissions are reported under the IPPU sector.
- Coal used in steel production at New Zealand Steel Limited is used as a reductant, which is part of an industrial process. Therefore, all emissions from this coal are reported under the IPPU sector rather than the Energy sector.

For the four industries using natural gas as feedstock, the fraction of carbon stored is given in table 3.1.2. Emissions for individual products are withheld because of confidentiality concerns.

Table 3.1.2 Use of natural gas as a feedstock in New Zealand

Product	Percentage of carbon stored	Energy use reported under	Non-energy use reported under
Methanol	100	1.A.2.c	NA
Urea	80–93[19]	1.A.2.c	2.B.1
Hydrogen	0	1.A.2.c	2.B.10
Steel	0	1.A.2.a	2.C.1

Note: NA = not applicable.

All ammonia produced in New Zealand is processed into urea, and the split of feedstock gas and fuel gas used in producing urea is provided by the company. Although most of the carbon in feedstock gas used for urea production is stored in the product, this carbon is later emitted when the urea is used on farms as fertiliser. These emissions are reported under urea application in the Agriculture sector (chapter 5).

[19] For urea production, the fraction of carbon stored varies across the time series, depending on the composition of the feedstock gas.

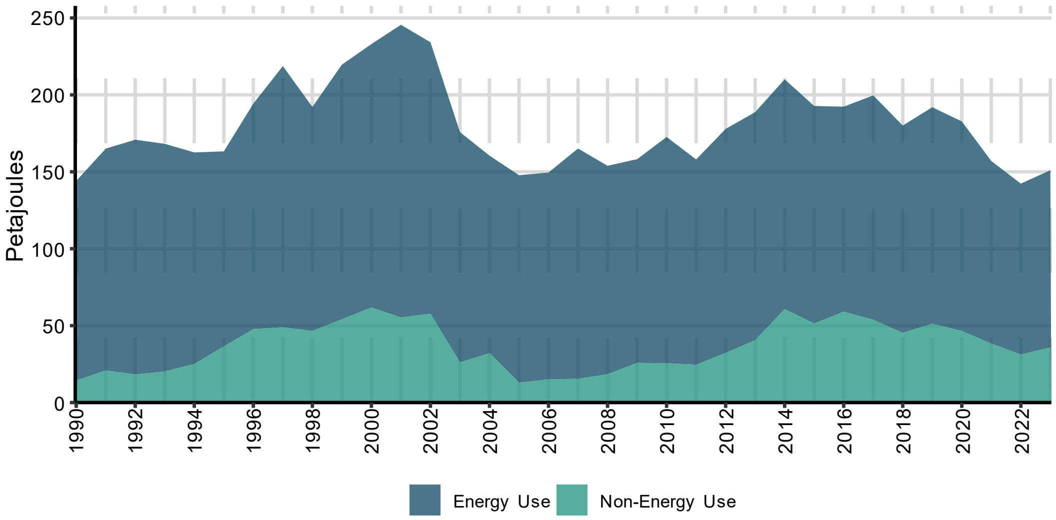
Emissions from synthetic gasoline production are reported in the *Manufacture of solid fuels and other energy industries* category. Synthetic gasoline production in New Zealand ceased in 1997.

The allocation of natural gas consumed for energy use versus non-energy use across time is shown in figure 3.1.2, and a table giving the energy versus non-energy use data for natural gas is included in annex 5. The trend in natural gas use in the *Chemicals* category can be explained partly by events in the methanol production industry in New Zealand.

Methanex New Zealand operates methanol production plants in the country and is a major gas user. Methanex significantly reduced its production in 2004 due to insufficient gas supply in 2003, but increased its capacity first in 2008 and then further in 2012. Production at full capacity resumed in December 2013. The Waitara Valley plant was mothballed in early 2021.

Details of natural gas use for the various non-energy uses are covered in chapter 4 (IPPU sector).

Figure 3.1.2 Natural gas consumption by end use type, from 1990 to 2023



3.1.6 Country-specific issues

Reporting for the Energy sector presents an issue related to the 2006 IPCC Guidelines (IPCC, 2006). The issue is described below.

Sectoral approach – methanol production

Sector activity data do not include non-energy use of fuels, and thus we do not need to modify emissions to account for the sequestration of carbon in methanol. Emissions from the natural gas used as fuel are reported in the CRT category 1.A.2.c *Chemicals* under the Energy sector, and the emissions from the natural gas used as feedstock are described in chapter 4 (IPPU sector), section 4.3.2.

3.1.7 New Zealand energy balance

New Zealand's energy balance, along with comprehensive information and analysis of energy supply and demand, is published annually in *Energy in New Zealand* (MBIE, 2024a). It covers energy statistics and includes supply and demand by fuel types, energy balance tables, pricing information and international comparisons. An electronic copy of this report is available online at: www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-publications-and-technical-papers/energy-in-new-zealand.

For the most part, categories and fuels from the energy balance correspond directly with the categories and fuels in CRT 1.A(b). A few special cases occur, as follows, where the structure of the CRT does not align with New Zealand's energy balance.

- In the New Zealand energy balance table, crude oil and refinery feedstocks are combined, whereas in CRT 1.A(b) these are separate line items.
- In New Zealand, liquefied petroleum gas (LPG) is considered a primary fuel and indigenous production is included in the national energy balance as such. The CRT does not allow entry of LPG production, so it is included in natural gas production and then allocated to LPG via stock change.
- New Zealand's energy balance includes the production of synthetic gasoline from natural gas under energy transformation. The CRT does not allow entry of synthetic gasoline transformation, so it is included in natural gas production and then allocated to gasoline via stock change.

These allocations allow a more meaningful comparison with the sectoral approach data for liquid and gaseous fuels.

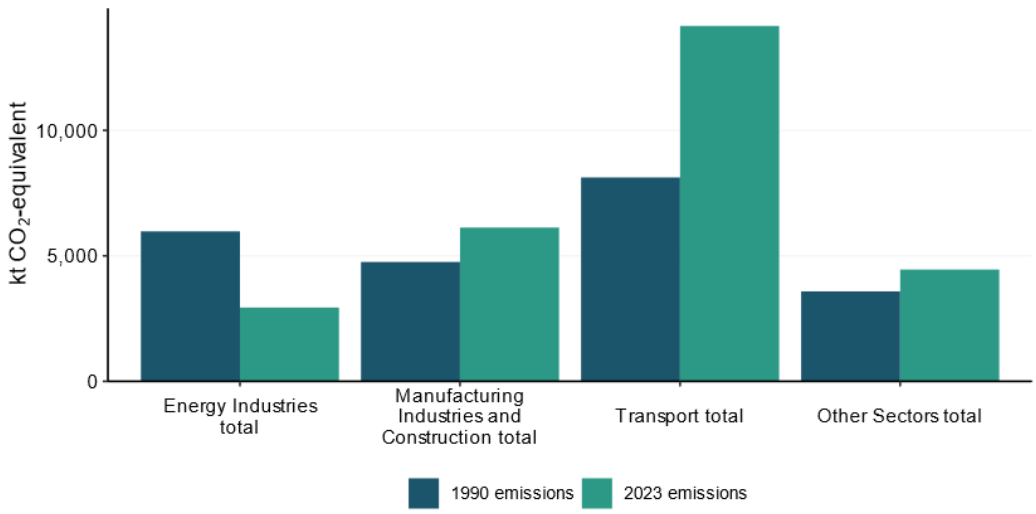
3.2 Fuel combustion (CRT 1.A)

3.2.1 Sector-wide description

The *Fuel combustion* category reports all fuel combustion activities from 1.A.1 *Energy industries*, 1.A.2 *Manufacturing industries and construction*, 1.A.3 *Transport* and 1.A.4 *Other sectors* categories (see figure 3.2.1). These categories use common activity data sources and emission factors. The CRTs require energy emissions to be reported by category. Apportioning energy activity data across categories is not as accurate as apportioning activity data by fuel type because of difficulties in allocating liquid fuel to the appropriate categories.

Information about methodologies, emission factors, uncertainty, and quality control and assurance for each of the categories is discussed below.

Figure 3.2.1 New Zealand's emissions from the *Fuel combustion* categories, 1990 versus 2023



3.2.2 Methodological issues

Energy emissions are compiled using MBIE's energy statistics, along with relevant New Zealand-specific emission factors. Unless otherwise noted in the relevant section, CO_2 emissions are calculated by multiplying a country-specific emission factor for the given fuel by the relevant activity data using an IPCC (2006) Tier 2 method. Non-CO_2 emissions are calculated using IPCC (2006) default emission factors, unless otherwise noted.

Activity data

Liquid fuels

Liquid fuel consumption data for the Energy sector are taken from MBIE's national energy balance tables. Most of those data are sourced from the DPFI. This quarterly survey includes liquid fuel sales data collected from the five oil companies importing and/or selling fuel. The purpose of the survey is to collect data on the amount of fuel delivered by all oil companies to end users and other distribution outlets. Each oil company in New Zealand supplies MBIE with the volume of petroleum fuels delivered to resellers and the industrial, commercial and residential sectors. The survey was originally conducted by Stats NZ, but MBIE took over responsibility for conducting the survey in 2009.

Petroleum fuels data are currently collected in volume units (thousand litres). Before 2009, data were collected in metric tonnes. Year-specific calorific values are used for all liquid fuels, reflecting changes in liquid fuel properties over time. Annual fuel property data were formerly provided by New Zealand's sole refinery (the Marsden Point Oil Refinery), which ceased operations in March 2022. The properties of imported fuels are now obtained from companies that import fuel.

Emissions from fuel sold for use in international transport (e.g., international bunker fuels) are reported separately as a memo item, as required (IPCC, 2006).

An MBIE-commissioned survey on liquid fuel use (MBIE, 2008) found that there were, at the time, 19 independent fuel distribution companies operating in New Zealand that bought fuel wholesale from oil companies and resold it to consumers. As a result, liquid fuel activity data were being over-allocated to the *Transport* category (where they were allocated by default). In contrast, most of the fuel purchased from these distribution companies was used by the *Agriculture/forestry/fishing* category. The study recommended starting an annual survey of deliveries of gasoline and diesel to each sector by independent distributors and using these data to correctly allocate sales of liquid fuels by small resellers to the appropriate sector.

As a result of this recommendation, the Annual Liquid Fuel Survey was started in 2009 (for the 2008 calendar year). The survey found that these independent fuel distribution companies delivered fuel equating to 18 per cent of New Zealand's total diesel consumption and 3 per cent of New Zealand's total gasoline consumption. Using these data, each company's deliveries between 1990 and 2006 were estimated, because no information was available for these years. The report *Delivering the Diesel – Liquid Fuel Deliveries in New Zealand 1990–2008* (MBIE, 2010) details the methodology employed to perform this calculation. The Annual Liquid Fuel Survey is conducted every year and the results are used to allocate resale of fuel to industry subsectors.

Solid fuels

Since 2009, MBIE has conducted the New Zealand Quarterly Statistical Return of Coal Production and Sales, previously conducted by Stats NZ. The survey covers coal mined and sold by coal producers in New Zealand. The three grades of coal surveyed are bituminous, sub-bituminous and lignite. This survey categorises coal sales by industry, recognising over 20 industries using the Australian and New Zealand Standard Industrial Classification 2006 (Australian Bureau of Statistics and Statistics New Zealand, 2006). Before 2009, when Stats NZ ran the survey, coal sales were surveyed for only seven high-level sectors.

All solid fuel used for iron and steel manufacture is reported under the IPPU sector, to avoid double counting.

Gaseous fuels

MBIE receives activity data on gaseous fuels from various sources. Individual natural gas field operators provide information on the amount of gas extracted, vented, flared and for own use at each gas field. The operator of the Kapuni Gas Treatment Plant provides information on processed gas (including at the Kapuni gas field), while gas distribution networks provide information on gas transmission and distribution throughout New Zealand.

Large users of gas, including electricity generation companies, provide their activity data directly to MBIE. Additionally, MBIE surveys retailers and wholesalers on a quarterly basis to obtain data on sales to industrial, commercial and residential natural gas users.

In response to expert review team (ERT) recommendations, all fuel combustion for electricity auto-production was disaggregated into the appropriate sector, rather than reported in category 1.A.2.g *Manufacturing industries and construction – Other*. This improvement was implemented in the 2013 submission and resulted in a reduction in unallocated industrial emissions and increases in various manufacturing and construction categories. For further information, see section 3.2.8.

Biomass

Activity data for the use of biomass come from several different sources. MBIE receives electricity and co-generation data from electricity generators.

- New Zealand reports emissions from landfill gas, sewage waste gas, sludge gas (derived from cattle effluent at the Tirau dairy processing facility) and commercial biogas use. Before 2013, New Zealand only reported emissions from landfill gas, sewage waste gas and commercial biogas use.
- New Zealand's gas biomass emissions are estimated based on electricity generation data (some of which are also estimated). No direct data are available on gas biomass emissions from landfills or sewage treatment facilities. See below for details of the estimation methodology of landfill gas and sewage waste gas.
- Gas biomass is known to be used by some local government councils, however, exploratory data collection in the past has indicated that such use occurs only in small quantities and produces insignificant emissions. Because MBIE is aware of some use, it continues to report a standard estimate introduced in 2006 to avoid any under-reporting.
- No information is collected on flared gas biomass.
- The only gas biomass direct-use data that have been collected are for the Tirau dairy processing facility (and only one data point, which has been used for all years when it is believed the plant has produced emissions).

Gas biomass emissions estimates are based on electricity generation data

Biomass electricity generation data are collected for 15 individual plants. As of 31 December 2023, New Zealand gas biomass generation was known to include the following.

- Eleven landfill facilities, totalling 33.1 megawatts (MW). These facilities are electricity only. (Some landfill gas was used to heat a swimming pool in Christchurch before the Canterbury earthquake of February 2011, but that facility suffered major earthquake damage and has been removed. A new trigeneration facility has since been built.)
- Four wastewater treatment facilities, totalling 12.9 MW. These are all cogeneration facilities that provide heat and electricity for processing sewage. No information is held on the exact type of generation plant used at these individual facilities, although they are known to be a combination of gas turbines, internal combustion engines and some steam turbine facilities.

Generation data are collected for each year ending 31 March, with generation assumed to be distributed equally across quarters to estimate December year-end generation. Generation data are usually collected from all 15 plants. However, in some years, estimates are made based on the previous year's generation.

Fuel input information from small generators (those less than 10 MW) is not currently used within the electricity generation data system. Instead, estimates of fuel input are made on the assumption of 30 per cent efficiency based on gross generation.

All generation data collected are assumed to be net generation (i.e., excluding parasitic load). These values are scaled up using default net-to-gross generation factors sourced from the International Energy Agency. For all thermal generation, the net-to-gross factor is assumed to be 1.07 (i.e., an additional 7 per cent of electricity is generated but used within the plant itself). Fuel input estimates are then calculated based on the gross generation using a default electrical efficiency factor of 30 per cent. This estimated quantity of biogas is used as total biogas for energy purposes. Biogas use estimates for landfill gas and sewage waste gas are calculated and reported in petajoules (PJ).

Energy quantities of gas biomass are then converted into greenhouse gas emissions using emission factors derived from the default IPCC (2006) emission factors (table 3.1.3).

Table 3.1.3 Emission factors for gas biomass

Gas	Tonnes per PJ
Carbon dioxide	49,170
Methane	0.9
Nitrous oxide	0.09

The CO_2 emission factor is derived from the IPCC (2006) default net emission factor – it is assumed that the net emission factor is 10 per cent lower than the gross emission factor.

Emissions from gas biomass comprise a very small part of New Zealand's emissions inventory. Given this situation, MBIE believes the current process is sufficient for estimating emissions from gas biomass and that efforts to improve the quality estimates are better focused on other areas.

Solid biomass

Residential and industrial solid biomass activity data are taken from the annual *Energy in New Zealand* publication (MBIE, 2024a).

Liquid biomass

Liquid biofuel activity data are based on information collected under the *Petroleum or Engine Fuel Monitoring Levy*, as reported in MBIE quarterly online data releases.

Electricity auto-production

All combustion activity for electricity auto-production is allocated into the appropriate manufacturing category.

Emission factors

New Zealand emission factors are based on gross calorific values. A list of emission factors for CO_2, methane (CH_4) and nitrous oxide (N_2O) for all fuel types is provided in annex 5. The characteristics of liquid, solid and gaseous fuels and biomass used in New Zealand are described under each of the fuel sections below. Where a New Zealand-specific value is not available, MBIE uses either the IPCC (2006) value that best reflects New Zealand conditions or the mid-point value from the IPCC (2006) range. All emission factors from the IPCC (2006) are converted from net calorific value basis to gross calorific value basis. New Zealand adopts the following assumptions (table 3.1.4) from the Organisation for Economic Co-operation and Development and International Energy Agency to make these conversions.

Table 3.1.4 Net-to-gross calorific value conversion factors

Fuel type	Factor
Gaseous	0.90
Liquid	0.95
Solid	0.95
Wood	0.80

Liquid fuels

Where possible, CO_2 emission factors for liquid fuels are calculated on an annual basis. Carbon dioxide emission factors for 1990 to 2021 were calculated from Refining New Zealand data on the carbon content and calorific values of the fuels that they produced. Due to the closure of the New Zealand refinery, collection of fuel property data from fuel importers started in 2022. For non-CO_2 emissions, IPCC (2006) default values are used unless otherwise specified in the relevant section. Annex 5 provides further information on liquid fuel emission factors, including a time series of gross calorific values.

Solid fuels

Emission factors for solid fuels were updated for the 2016 submission across the time series from 1990 to 2008, in response to a 2013 ERT recommendation (FCCC/ARR/2013/NZL, paragraph 32) (UNFCCC, 2014). A comprehensive list of carbon content by coal mine is not currently available. A review of New Zealand's coal emission factors in preparation for the New Zealand Emissions Trading Scheme (NZ ETS) (CRL Energy Ltd, 2009) recommended re-weighting the current default emission factors to 2007 production rather than continuing with those in the New Zealand Energy Information Handbook (Baines, 1993). However, following the recommendation of the ERT review of New Zealand's 2013 submission (FCCC/ARR/2013/NZL, paragraph 32) (UNFCCC, 2014), the emission factors between 1990 and 2008 have been interpolated.

The emission factor used to calculate emissions from coal use in the public electricity and heat production sector has been weighted to reflect the combustion of imported coal. A time series of the effect of this weighting is included in annex 5.

Gaseous fuels

New Zealand's gaseous fuel emission factors are above the IPCC (2006) default range because New Zealand natural gas fields tend to have a higher CO_2 content than most international gas fields. This is verified by regular gas composition analysis. Emission factors for 2023 from all fields, along with the production weighted average, are included in annex 5.

The annual gaseous fuel emission factor is calculated as an average of the emission factors of all natural gas fields in New Zealand, weighted by each field's relative production for the year. This method provides increased accuracy because it considers trends in gas fields' production rates over time (e.g., the decline in production from both the Māui and Kapuni gas fields). This emission factor fluctuates slightly from year to year, mainly due to the relative production volume at different gas fields.

Natural gas from the Kapuni gas field has a particularly high CO_2 content. Historically, this field has been valued by the petrochemicals industry as a feedstock. However, most of the gas from this field is now treated, and the excess CO_2 is removed at the Kapuni Gas Treatment Plant. Consequently, separate emission factors were used to calculate emissions from Kapuni treated and untreated gas, due to the difference in carbon content (see annex 5). Carbon dioxide removed from raw Kapuni gas (which is then vented) is reported in category 1.B.2.c *Venting and flaring*.

Biomass

Emission factors for wood combustion are calculated from an IPCC (2006) default emission factor and assume that the net calorific value is 20 per cent lower than the gross calorific value (IPCC, 2006). Carbon dioxide emissions from wood used for energy production are reported as a memo item and are not included in the estimate of New Zealand's total greenhouse gas emissions (IPCC, 2006). Carbon dioxide emission factors for liquid biofuels are sourced from the *New Zealand Energy Information Handbook* (Baines, 1993), while CH_4 and N_2O emission factors are IPCC (2006) default emission factors.

3.2.3 Uncertainty assessment and time-series consistency

Uncertainty in greenhouse gas emissions from fuel combustion varies depending on the type of greenhouse gas. The uncertainty in CO_2 emissions is relatively low. This is important because CO_2 emissions comprise around 96 per cent to 97 per cent of carbon dioxide equivalent (CO_2-e) emissions from fuel combustion in New Zealand. By comparison, emissions of the non-CO_2 gases are much less certain because emissions of these gases vary with combustion conditions. Uncertainties for CO_2, CH_4 and N_2O activity data and emission factors are supplied in table 3.2.1. Many of the non-CO_2 emission factors used by New Zealand are the IPCC (2006) default values. Further detailed information around uncertainties for each fuel type can be found in annex 5.

Table 3.2.1 Uncertainty for New Zealand's Energy sector emission estimates for 2023

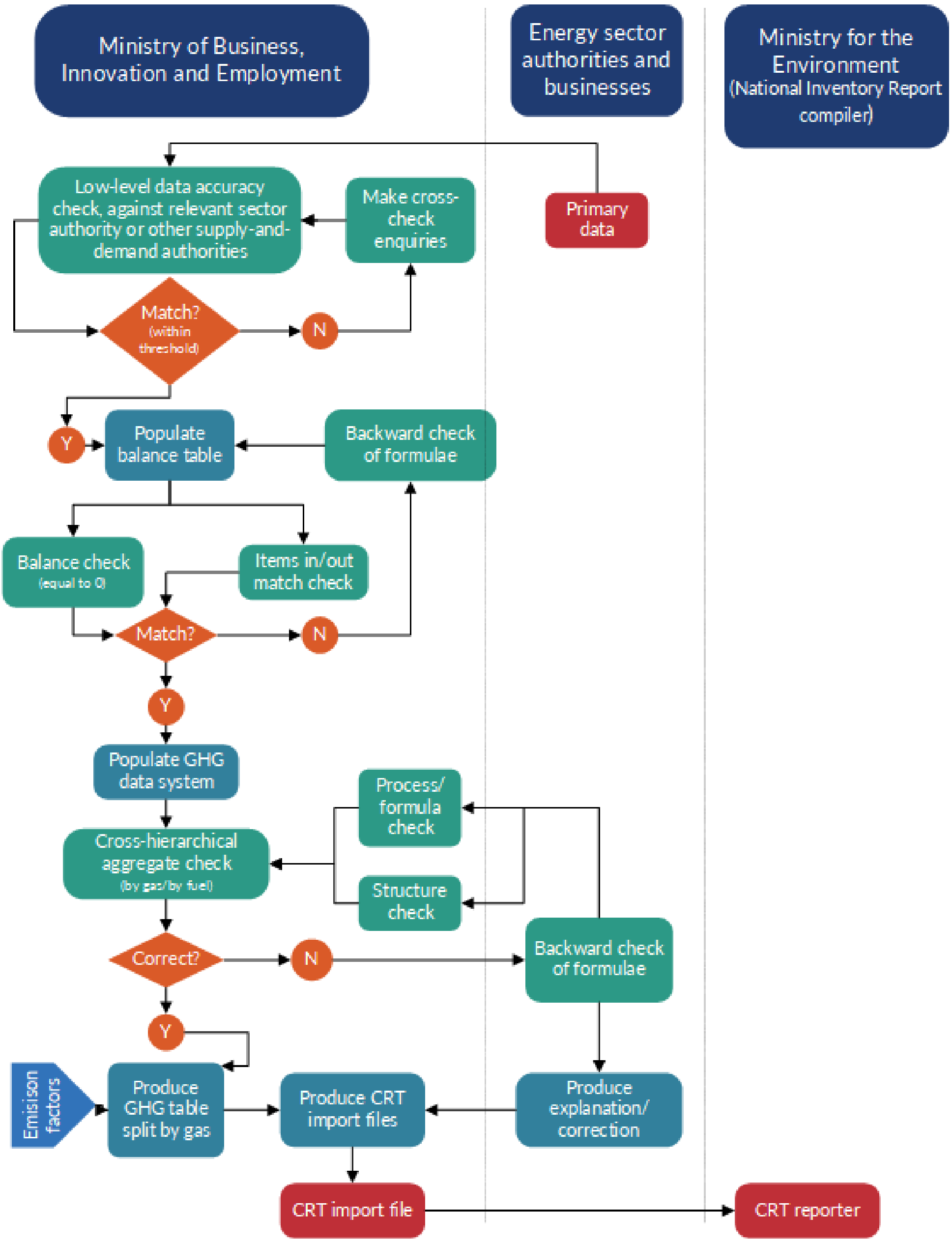
	Category	Activity data uncertainty (%)	Emission factor uncertainty (%)
CO_2	Gaseous Fuels	±7.5	±2.4
	Liquid Fuels	±2.5	±0.5
	Other Fossil Fuels	±5.0	±5.0
	Solid Fuels	±15.2	±2.2
	Fugitive – Oil Exploration	±2.5	±100.0
	Fugitive – Oil Production	±2.5	±100.0
	Fugitive – Oil Transport	±2.5	±100.0
	Fugitive – Gas Production	±7.5	±100.0
	Fugitive – Gas Transmission and Storage	±7.5	±100.0
	Fugitive – Gas Distribution	±7.5	±100.0
	Fugitive – Venting and Flaring	±7.5	±2.4
	Fugitive – Other Forms of Energy Production (Geothermal)	±5.0	±5.0
CH_4	Gaseous Fuels	±7.5	±50.0
	Liquid Fuels	±2.5	±50.0
	Other Fossil Fuels	±5.0	±50.0
	Solid Fuels	±15.2	±50.0
	Biomass	±50.0	±50.0
	Fugitive – Coal Handling	±15.2	±50.0
	Fugitive – Oil Exploration	±2.5	±50.0
	Fugitive – Oil Production	±2.5	±50.0
	Fugitive – Oil Transport	±2.5	±50.0
	Fugitive – Oil Refining	±2.5	±50.0
	Fugitive – Gas Production	±7.5	±50.0
	Fugitive – Gas Transmission and Storage	±7.5	±100.0
	Fugitive – Gas Distribution	±7.5	±100.0
	Fugitive – Venting and Flaring	±7.5	±50.0
	Fugitive – Other Forms of Energy Production (Geothermal)	±5.0	±5.0
N_2O	Gaseous Fuels	±7.5	±50.0
	Liquid Fuels	±2.5	±50.0
	Other Fossil Fuels	±5.0	±50.0
	Solid Fuels	±15.2	±50.0
	Biomass	±50.0	±50.0
	Fugitive – Venting and Flaring	±7.5	±100.0

To estimate activity data uncertainty, we use the percentage difference between annual calculated consumer energy from supply-side surveys and annual observed consumer energy from demand-side surveys. As a result, activity data uncertainty can vary significantly from year to year.

3.2.4 Sector-wide QA/QC and verification

In the preparation of this inventory, the *Fugitive emissions* category underwent Tier 1 quality-assurance (QA) and quality-control (QC) checks, as recommended in the 2006 IPCC Guidelines (IPCC, 2006). These include regular control sums throughout systems to verify system integrity, time-series consistency checks on activity data and consistency checks on implied emission factors at the industry–plant level, where possible. Figure 3.2.2 presents the quality control process map for the Energy sector.

Figure 3.2.2 Energy sector quality control process map



CRT – common reporting table
GHG – greenhouse gases

As discussed in section 3.1, the reference approach provides a good, high-level quality check for activity data. A significant deviation (greater than 5 per cent) indicates a likely issue.

Implied CO_2 emission factors for combustion of liquid, solid and gaseous fuels from this inventory were compared with those in the IPCC Emission Factor Database and converted to gross values for comparability with the New Zealand energy system.

Figures 3.2.3, 3.2.4 and 3.2.5 show the upper, lower and middle IPCC (2006) emission factor ranges for liquid, solid and gaseous fuel combustion, and compare the implied emission factors according to observed fuel consumption in New Zealand for the given year. Each fuel type falls within the IPCC (2006) default range, except for gaseous fuels. This is because, as discussed in section 3.2.2, CO_2 emission factors for New Zealand natural gas fields are established through gas composition analysis and are known to be high by international standards.

Figure 3.2.3 Carbon dioxide implied emission factor (IEF) – Liquid fuel combustion, from 1990 to 2023

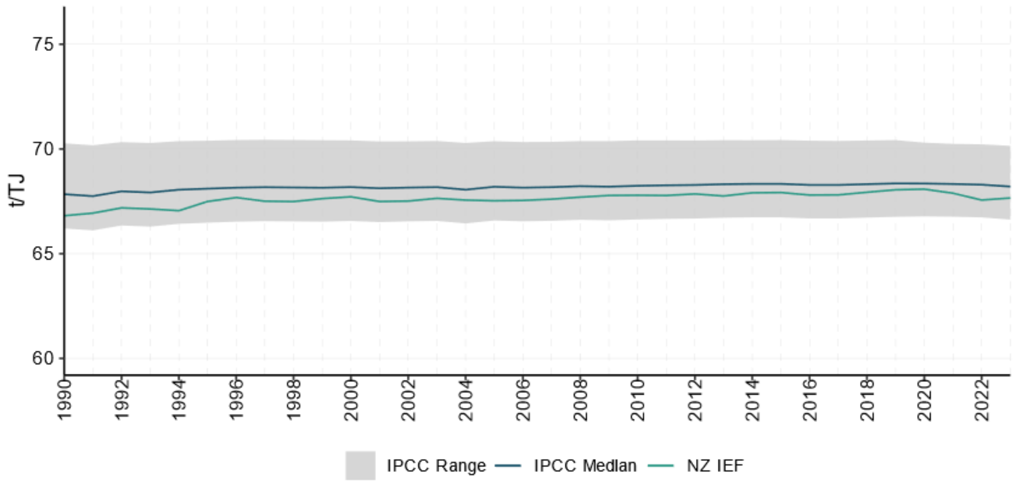


Figure 3.2.4 Carbon dioxide implied emission factor (IEF) – Solid fuel combustion, from 1990 to 2023

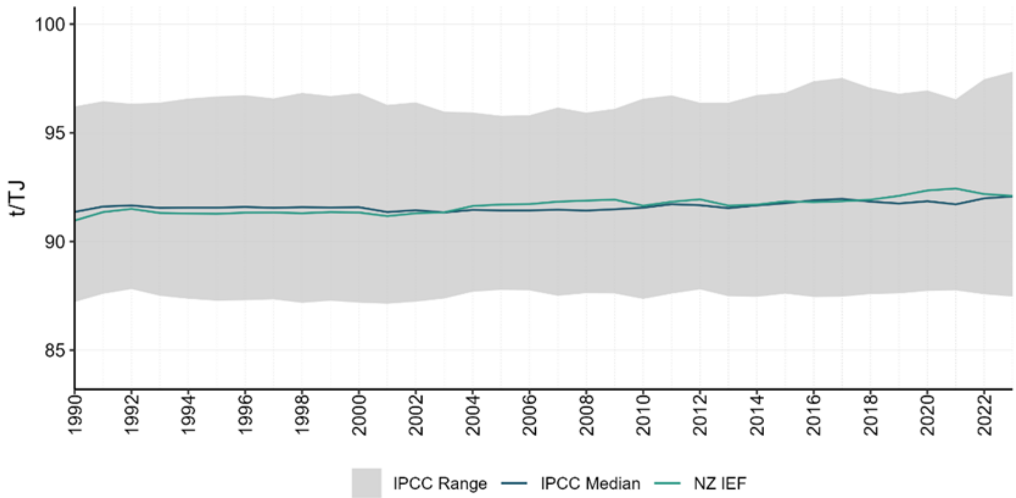
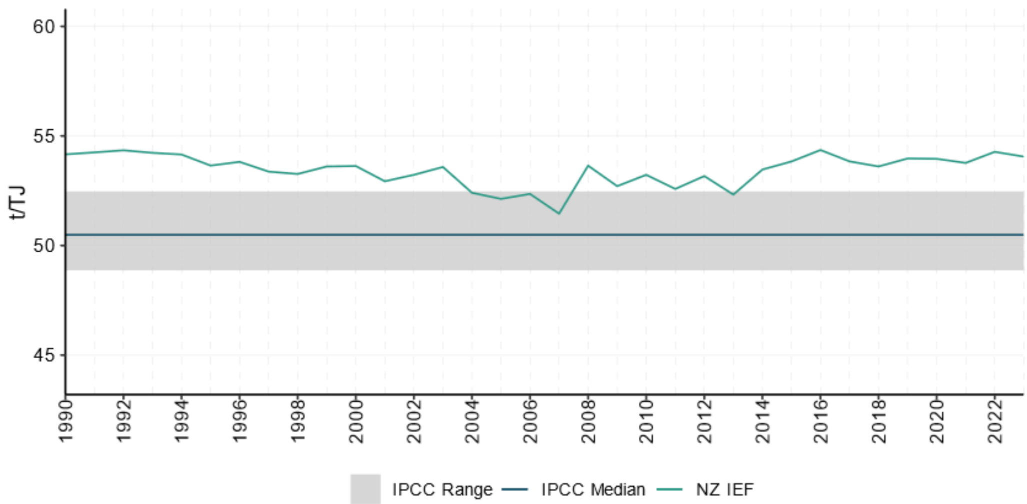


Figure 3.2.5 Carbon dioxide implied emission factor (IEF) – Gaseous fuel combustion, from 1990 to 2023



Note: As discussed in section 3.2.2 under 'Emission factors', carbon dioxide emission factors for New Zealand natural gas fields are established through gas composition analysis and are known to be high by international standards. t/TJ = tonnes per terajoule.

3.2.5 Sector-wide recalculations

There have been no sector-wide recalculations. Any category-specific recalculations are described in their relevant sections.

3.2.6 Sector-wide planned improvements

There are no sector-wide planned improvements. All category-specific planned improvements are discussed in their corresponding sections.

3.2.7 Fuel combustion: Energy industries (CRT 1.A.1)

Category description

This category includes combustion for public electricity and heat production, petroleum refining, the manufacture of solid fuels and other energy industries. The latter category includes estimates for natural gas in oil and gas extraction and from natural gas used in synthetic gasoline production.

In 2023, emissions in category 1.A.1 *Energy industries* totalled 2,939.7 kt CO_2-e (10.2 per cent of the Energy sector emissions). Emissions from energy industries in 2023 were 3,034.4 kt CO_2-e (50.8 per cent) lower than the 1990 level of 5,974.1 kt CO_2-e. Category 1.A.1.a *Public electricity and heat production* was the largest contributor to this sector, accounting for 2,737.3 kt CO_2-e of emissions from the *Energy industries* category in 2023. This is 752.6 kt CO_2-e (21.6 per cent) lower than the 1990 level of 3,489.9 kt CO_2-e.

Changes in emissions between 2022 and 2023

Between 2022 and 2023, emissions from 1.A.1.a *Public electricity and heat production* decreased by 153.5 kt CO_2-e (5.3 per cent). The share of electricity generated from renewable energy sources increased from 87 per cent to 88 per cent over this period, due mainly to higher wind and hydro generation in response to favourable weather patterns. The increased renewable generation displaced gas and coal-fired generation, which together decreased 7.8 per cent from 2022.

Between 2022 and 2023, emissions from 1.A.1.b *Petroleum refining* decreased by 166.1 kt CO_2-e (100.0 per cent). This was due to the closure of New Zealand's sole oil refinery in March 2022.

Key categories identified in the 2023 level and trend assessment for the *Energy industries* category are given in table 3.2.2.

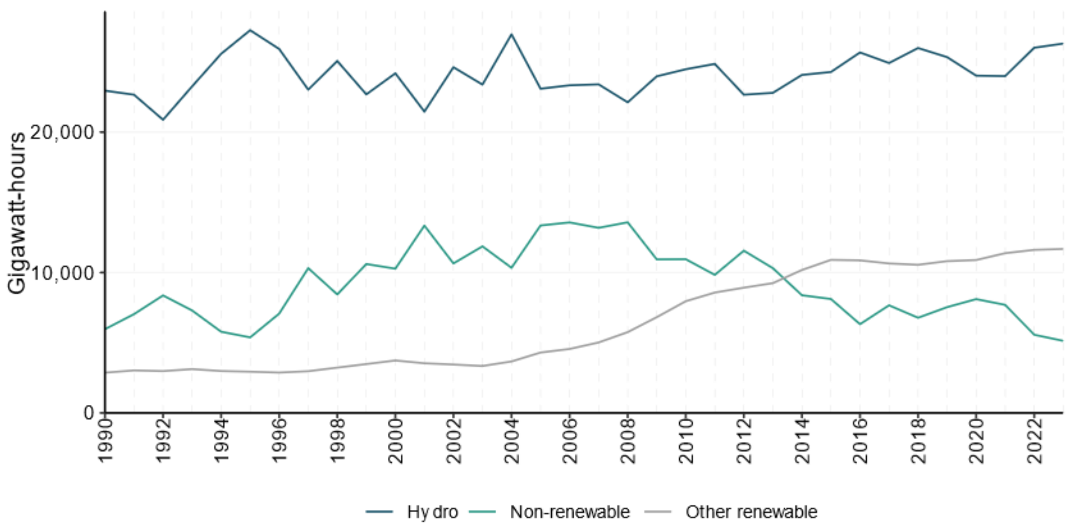
Table 3.2.2 Key categories for 1.A.1 *Energy industries*

Category	Liquid fuels	Solid fuels	Gaseous fuels
Public electricity and heat production – CO_2	–	Level	Level, trend
Petroleum refining – CO_2	Trend	–	–
Manufacture of solid fuels and other energy industries – CO_2	–	–	Trend

Electricity generation in New Zealand is dominated by hydroelectric generation. For the 2023 calendar year, hydro generation provided 60.5 per cent of New Zealand's electricity generation. A further 17.8 per cent came from geothermal, 7.4 per cent from wind, 1.6 per cent from biomass and 0.8 per cent from solar. The remaining 11.9 per cent was provided by fossil fuel thermal generation plants using natural gas, coal and oil (MBIE, 2024a).

Greenhouse gas emissions from the *Public electricity and heat production* category show large year-to-year fluctuations between 1990 and 2023. These fluctuations can also be seen over the time series of New Zealand's gross emissions. The fluctuations are influenced by the close inverse relationship between thermal and renewable generation (see figure 3.2.6). In a dry year, when low rainfall reduces most of New Zealand's hydro lake levels, any shortfall in hydroelectric generation is made up by increased thermal electricity generation. New Zealand's hydro resources have limited storage capacity; total reservoir storage is only around 10 per cent of New Zealand's annual demand. Hence, regular rainfall throughout the year is needed to sustain a high level of hydro generation. Electricity generation in a 'normal' hydro year does not require significant use of natural gas and coal, while a 'dry' hydro year requires greater use of natural gas and coal.

Figure 3.2.6 New Zealand's electricity generation by source, from 1990 to 2023



Methodological issues

1.A.1.c Manufacture of solid fuels and other energy industries

Methanex New Zealand produced synthetic gasoline until 1997. A Tier 2 methodology was used to estimate CO_2 emissions based on the annual weighted average gas emission factor.

Activity data

1.A.1.a Public electricity and heat production

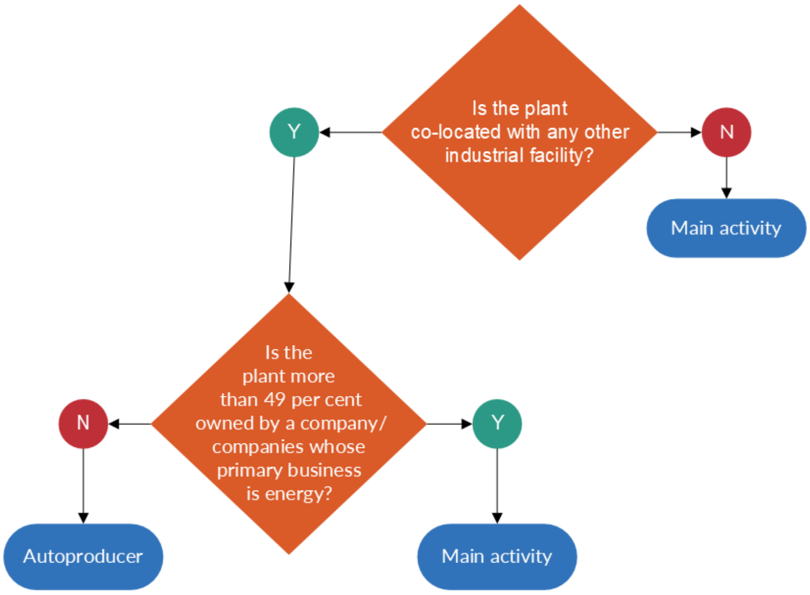
All thermal electricity generators provide figures to MBIE on coal, natural gas and oil used for electricity generation. Greenhouse gas emissions from geothermal electricity generation are reported in category 1.B.2.d *Fugitive emissions – Geothermal*.

Around 5 per cent of New Zealand's electricity is supplied by co-generation (also known as combined heat and power) (MBIE, 2024a). Most major co-generation plants are attached to large industrial facilities that consume most of the generated electricity and heat.

Six co-generation plants that fit the IPCC (2006) definition of public electricity and heat production produce electricity as their primary purpose. The emissions from these plants are included in category 1.A.1.a *Public electricity and heat production*, while emissions from other co-generation plants are included in category 1.A.2 *Manufacturing industries and construction* (section 3.2.8).

To establish a consistent approach to on-site generation, MBIE developed a decision tree to guide the allocation of associated fuel consumption and identify whether the plant is a main activity electricity generator or an autoproducer (see figure 3.2.7).

Figure 3.2.7 Decision tree to identify a main activity electricity generator or an autoproducer



1.A.1.b Petroleum refining

Petroleum refining in New Zealand occurred up until March 2022 at only one site: the Marsden Point Oil Refinery, owned by Refining New Zealand. Refining New Zealand formerly provided annual activity data and emission factors for each type of fuel consumed at the site. The fuel-type specific emission factors were adopted under the Government's Projects to Reduce Emissions in 2003 (Ministry for the Environment, 2009).

Refinery gas is obtained during the distillation of crude oil and production of oil products. As a result, emissions from its combustion are implicitly included under liquid fuels in the reference approach.

1.A.1.c.ii Manufacture of solid fuels and other energy industries – Other energy industries

Activity data for the useful combustion (own use) of natural gas during oil and gas extraction are provided to MBIE by each individual gas and/or oil field operator. Some crude oil is also combusted (own use) during oil and gas extraction, and the quantity is reported in NZ ETS returns.

Emissions from natural gas combustion (own use) for the purpose of natural gas transmission are reported directly to MBIE by the transmission network operator. Emissions from natural gas combustion (own use) for the purpose of natural gas processing are reported directly to MBIE by the plant operator.

Losses and own use of coal by coal mining entities are reported as a single item, so data on on-site coal use are not available. Historically, coal mines would use their own coal to fuel on-site water boilers. However, the last of these at the Stockton mine closed in the mid-1980s, and the expert opinion of coal industry specialists is that any water boilers on site are now fuelled by natural gas or electricity.

Emission factors

Gaseous fuels

As mentioned in section 3.2.2, New Zealand's CO_2 emission factor for natural gas fluctuates from year to year, reflecting the relative amount of gas produced from the various gas fields in a given year. New Zealand gas fields also have higher CO_2 content than most international gas fields. This is particularly evident in category 1.A.1.a *Public electricity and heat production*.

Uncertainty assessment and time-series consistency

Uncertainties in emissions and activity data estimates for this category are relevant to the entire *Fuel combustion* category (see table 3.2.1).

Category-specific QA/QC and verification

In the preparation of this inventory, the *Energy industries* category underwent Tier 1 quality-assurance and quality-control checks as recommended in the 2006 IPCC Guidelines. These include regular control sums throughout systems, to verify system integrity, and consistency checks on implied emission factors.

Category-specific recalculations

In previous submissions, the domestic production of liquid carbon dioxide was treated as an emission at the point of manufacture and reported under the Energy sector category 1.A.1 *Energy industries*. To improve consistency, transparency, and comparability with other Annex I Parties, we now report domestically produced liquid carbon dioxide as CO_2 capture under category 1.A.1, and the consumption of domestically produced liquid carbon dioxide has been reallocated to the IPPU sector to align with the consumption of imported liquid carbon dioxide. This reallocation has been applied across the entire time series.

Liquid carbon dioxide is utilised in a range of applications such as brewing and producing dry ice (which is in turn used, for example, to safely transport human organs that are destined for transplant). The domestic consumption of products derived from liquid carbon dioxide is reported as a source of CO_2 emissions in IPPU category 2.H.3 *Other (carbon dioxide consumption)*.

We have improved the method used to calculate the CO_2 emission factors of natural gas used for electricity generation, refining the implementation of the software code used in this process. This improvement has increased the accuracy of this value and has resulted in the recalculation of CO_2 emissions for 2020 to 2022.

Some historical data on fuel consumption for electricity generation have been revised in the national energy balance tables. This has resulted in minor revisions to activity data and recalculations of the corresponding emissions for some recent years.

Category-specific planned improvements

There are no planned improvements for this category.

3.2.8 Fuel combustion: Manufacturing industries and construction (CRT 1.A.2)

Category description

This category comprises emissions from fossil fuels combusted in the manufacture of iron and steel, other non-ferrous metals, chemicals, pulp, paper and print, food processing, beverages and tobacco, and in other manufacturing-related activities. Emissions from co-generation plants that do not meet the definition of co-generation as provided in the 2006 IPCC Guidelines are included in this category.

In 2023, emissions from the 1.A.2 *Manufacturing industries and construction* category accounted for 6,126.3 kt CO_2-e (21.2 per cent) of emissions from the Energy sector. The largest contributors were *Food processing* (2,703.2 kt CO_2-e) and *Chemicals* (1,312.4 kt CO_2-e).

Changes in emissions between 1990 and 2023

Emissions from this category were 1,370.3 kt CO_2-e (28.8 per cent) higher than the 1990 level of 4,756.0 kt CO_2-e. The most significant categories contributing to this increase were *Food processing* (up 1,031.4 kt CO_2-e or 61.7 per cent) and *Chemicals* (up 776.4 kt CO_2-e or 144.8 per cent).

A decline in methanol production in 2003 to 2004 caused a significant reduction in emissions from this category. Methanol production was the largest source of emissions in category 1.A.2.c *Chemicals*. Methanex New Zealand restarted previously mothballed plants in 2012/13 (the resulting increase in gas use can be seen in figure 3.1.2), but then mothballed the Waitara Valley plant in early 2021.

Changes in emissions between 2022 and 2023

Between 2022 and 2023, emissions from the *Manufacturing industries and construction* category decreased by 138.3 kt CO_2-e (2.2 per cent). This was driven chiefly by a decrease in emissions from the *Mining (excluding fuels) and quarrying* category, down 82.7 kt CO_2-e (18.8 per cent) from 2022. This drop is largely a result of a decrease in the consumption of solid fuels in this category.

Key categories identified in the 2023 level and trend assessment for the *Manufacturing industries and construction* category are given in table 3.2.3.

Table 3.2.3 Key categories for 1.A.2 *Manufacturing industries and construction*

Category	Liquid fuels	Solid fuels	Gaseous fuels
Chemicals – CO_2	–	–	Level, trend
Pulp, paper and print – CO_2	–	Trend	Level, trend
Food processing, beverages and tobacco – CO_2	Level	Level, trend	Level, trend
Non-metallic minerals – CO_2	–	Trend	–
Other – Mining and quarrying – CO_2	Level, trend	–	–
Other – Construction – CO_2*	Level, trend	–	–
Other – Other non-specified – CO_2	Level, trend	Trend	–

Note: * This key category is calculated using emissions that do not distinguish by fuel type; however, it is known to be primarily liquid fuels.

Methodological issues

Some emissions from the use of solid fuels and gaseous fuels are excluded from the *Manufacturing industries and construction* category because they are accounted for under the IPPU sector. These include the following.

- New Zealand Steel Limited uses coal as a reducing agent in the steel-making process. In accordance with the 2006 IPCC Guidelines, the emissions from this are included under the IPPU sector rather than the Energy sector.
- In several instances, natural gas is excluded from the *Manufacturing industries and construction* category because it is accounted for under the IPPU sector. Among the emissions excluded are those from urea production, hydrogen production and some of the natural gas used by New Zealand Steel (New Zealand Steel separately reports its emissions from natural gas as part of the combustion process and natural gas as part of the chemical process).

Activity data

Energy balance tables released with *Energy in New Zealand* (MBIE, 2024a) categorise industrial uses of energy using the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006. From 2009, MBIE started to collect more detailed information on the industry of fuel use in the various surveys used to compile its balance tables, and this has allowed MBIE to further disaggregate the *Manufacturing industries and construction* category. Where actual survey data are not available at the required level, estimates of the energy use across these categories have been made to ensure time-series consistency. These are described in further detail below.

Solid fuels

Prior to 2010, coal use in the *Manufacturing industries and construction* category could not be further disaggregated, because no data existed to allow for more detailed categorisation. However, in 2010, MBIE implemented disaggregation for coal use in this category based on the improved industry use data mentioned above. This disaggregation was applied from 2009 onwards, and the percentage splits (based on 2009 data) were applied to activity data for the annual inventory submission across the whole time series (back to 1990). However, during 2014, the coal data system at MBIE was revised to internally disaggregate manufacturing industries based on a 2011 survey of major coal users. Therefore, applying the disaggregation procedure previously used within the greenhouse gas data system is no longer necessary.

From 2009 onwards, the coal sales survey conducted by MBIE provides data at a more disaggregated level.

Solid biomass

The activity data for the industrial use of solid biomass are taken from the annual *Energy in New Zealand* publication (MBIE, 2024a). This dataset is estimated based on several sources. The main source used is a database of wood processors in New Zealand, which is maintained by Scion. Scion is a Crown research institute specialising in forestry, wood products and other biomaterial sectors. Scion’s Wood Processing Database covers the majority of large-scale wood processors in the country and contains a range of information, including estimates of energy demand by sites. Annual estimates of wood residual and black liquor use are sourced from the database. As these data are collected every couple of years, estimated data are carried forward using data published by the Ministry for Primary Industries on activity by wood processors for years when MBIE has not received an updated Wood Processing Database.

The Bioenergy Association of New Zealand conducted the 2006 Heat Plant Survey of New Zealand (Bioenergy Association of New Zealand, 2011) to gain information on heat plant (boiler) capacity and use in New Zealand. One area this survey examined was solid biomass use in New Zealand industrial companies (see table 3.2.4). The survey showed that most solid biomass in New Zealand is used by the wood processing industry. The industrial allocations from the survey were used to separate out solid biomass activity data for the inventory. These splits were applied across the whole time series (back to 1990) for activity data and CO_2, CH_4 and N_2O emissions.

Table 3.2.4 Solid biomass splits for 2006 that were used to disaggregate the *Manufacturing industries and construction* category between 1990 and 2023

CRT category code	Manufacturing industries and construction category	Per cent
1.A.2.a	Iron and steel	NO
1.A.2.b	Non-ferrous metals	NO
1.A.2.c	Chemicals	NO
1.A.2.d	Pulp, paper and print	99.94
1.A.2.e	Food processing, beverages and tobacco	0.05
1.A.2.g	Other – Mining and construction	NO
1.A.2.g	Other – Textiles	NO
1.A.2.f	Other – Non-metallic minerals	NO
1.A.2.f	Other – Manufacturing of machinery	NO
1.A.2.g	Other – Non-specified	0.01

Note: NO = not occurring. Survey data indicate that solid biomass combustion does not occur in the sectors.

Gas biomass

Sludge gas is produced at the Tirau dairy processing facility. Cattle effluent is used to produce sludge gas that is used to raise heat for the milk processing facility, which is open from September through to December each year. See section 3.2.2 (Biomass) for further information.

Sludge gas is not metered or analysed at the site but estimates of flow rate and CH_4 content were obtained from the facility manager for the 2011 reporting year. MBIE then used these data to calculate an estimate of the total energy content, which was then confirmed by the facility manager.

The facility has operated in the same fashion since its construction in the late 1980s. Therefore, this estimate is assumed to be valid across the time series.

Liquid fuels

As mentioned in section 3.2.2 ('Liquid fuels'), New Zealand uses the Annual Liquid Fuel Survey to capture sales by independent distributors. With this information, some liquid fuel demand that would otherwise be allocated to national transport is reallocated to the correct sector. As a result of this reallocation, emissions attributed to category 1.A.3 *Transport* decreased by around 20 per cent, and emissions attributed to other categories, such as 1.A.4.c *Agriculture/forestry/fishing*, increased significantly.

Following ERT recommendations (in the 2007 in-country review), New Zealand began to disaggregate liquid fuel combustion in the 1.A.2 *Manufacturing industries and construction* category for the 2011 inventory. Diesel and gasoline consumption were disaggregated for the 2012 submission, and the method was subsequently extended to include fuel oil.

While data are not collected at this level of detail in energy surveys for liquid fuels, New Zealand has produced estimates based on Stats NZ survey data. Stats NZ conducted an industrial and trade energy use survey (Stats NZ, 2018), which assessed energy consumption and end use across manufacturing industries for the 2016 calendar year. Proportions of liquid energy end use were then determined across the manufacturing industries. These proportions, along with category gross domestic product (GDP) data from Stats NZ for the period, were used to calculate implied energy intensities (PJ per unit of GDP) for each category for diesel, gasoline and fuel oil (see table 3.2.5). These intensities were then applied to Stats NZ GDP data across the time series and scaled to match the fuel sales reported for all manufacturing industries and construction, to estimate activity data for each category.

Table 3.2.5 Energy intensity values used to disaggregate liquid fuel use for manufacturing (gigajoules per gross domestic product index)

Category	Gasoline	Diesel	Fuel oil
Mining	2.4	1,117.9	19.6
Building and construction	30.5	334.8	2.7
Food processing	1.4	475.6	243.5
Textiles	0.9	12.8	158.6
Wood, pulp, paper and printing	1.1	199.5	43.7
Chemicals	0.2	36.3	2.0
Non-metallic minerals	0.7	587.4	263.9
Basic metals	1.2	88.1	0.4
Mechanical/electrical equipment	2.6	23.6	0.9
Industry unallocated	0.7	2.7	0.5

By disaggregating into categories, more accurate estimates of stationary versus mobile combustion for diesel were also able to be made, resulting in small changes to the emissions from manufacturing industries and construction.

Disaggregating the *Manufacturing industries and construction* category for solid fuels, solid biomass, gasoline and diesel has led to a significant decrease in the *Other – not specified* category (1.A.2.g) under *Manufacturing industries and construction*. The proportions are shown in figure 3.2.8 and figure 3.2.9.

Figure 3.2.8 Proportions used for *Manufacturing industries and construction* category – Gasoline, from 1990 to 2023

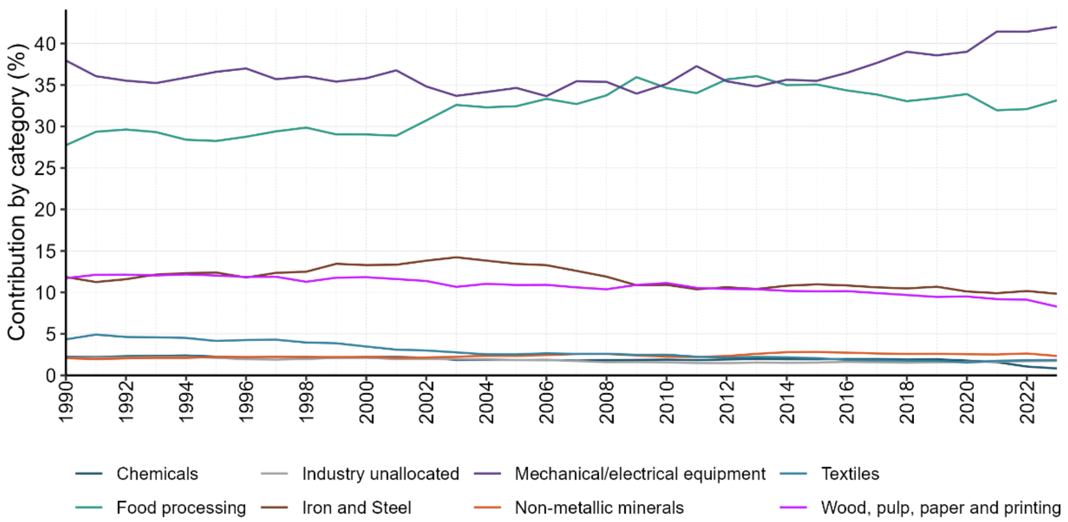
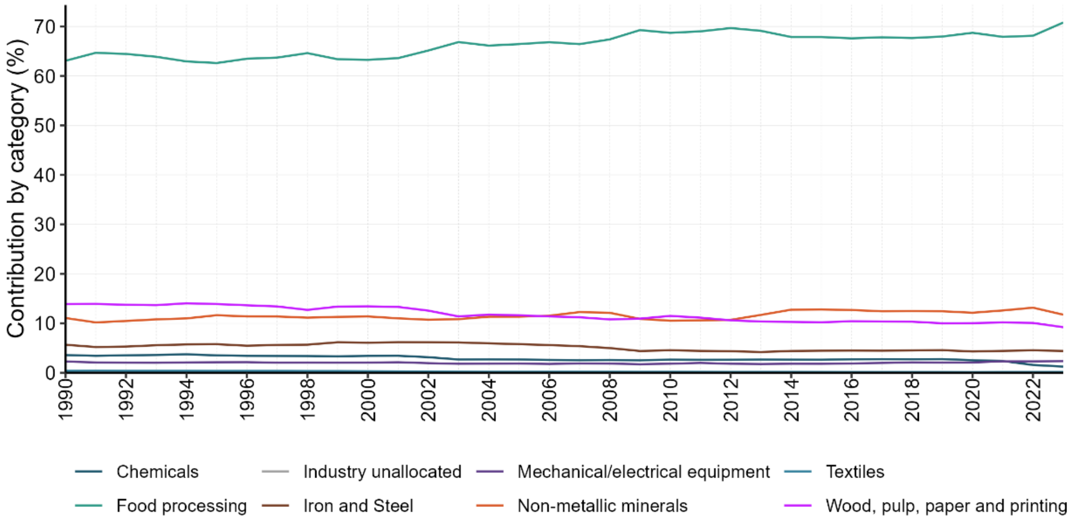


Figure 3.2.9 Proportions used for *Manufacturing industries and construction* category – Diesel, from 1990 to 2023



Gaseous fuels

Annual natural gas consumption statistics are published by MBIE (2024a). A review of the allocation of natural gas consumption data was undertaken in 2011 by MBIE. The purpose of this review was to address time-series discontinuities in the sectoral breakdown for some sectors before 2006. Several inconsistencies in sector reporting were found, along with a considerable amount of missing data for sectoral breakdowns. Inconsistencies from 2003 to 2005 were due to changes in survey design over time. Inconsistencies or missing data before 2003 were re-worked and re-estimated. These missing data comprised around 40 per cent of total natural gas use (which was not altered at a total level but only reallocated by sector).

Where necessary, new estimates of gas consumption were made, depending on data availability. The chosen data source in order of preference was as follows.

- Data from major consumers of natural gas were used if available because these data are more reliable and accurate, and more easily classified by sector.
- Where these data were not available, natural gas retailers' reported sales by sector were used.
- If these data were also not available, then estimates based on regressions using GDP data were used. GDP output and production data were used along with assumptions about energy intensity and consumption of categories (to the most detailed level possible).

Several categories are represented by only one or two major natural gas consumers: for some of these cases, data from major consumers were directly used. Where there are industries with many major natural gas consumers, gas retailers' reported sales by sector were used, though these can, at times, exhibit data quality issues.

A review was also undertaken in 2014 by MBIE covering data going back to 1999. Several sales previously identified as wholesale sales (i.e., gas bought to be on-sold) were in fact sold to consumers, but at 'wholesale' (lower) prices. Work was done to correct the classifications of these sales, based on customer name, to reflect their relevant sectors.

Other fossil fuels

This category includes waste oil and tyre-derived fuel. Activity data are sourced from the NZ ETS. A Tier 2 methodology was used to estimate CO_2 emissions based on an emission factor of 1,668 kg CO_2 per tonne (the Annex I average), while Tier 1 methodologies were used for CH_4 and N_2O based on default IPCC (2006) emission factors for industrial wastes.

1.A.2.a Iron and steel

Activity data for coal used in iron and steel production are reported to MBIE by New Zealand Steel Limited. A considerable amount of coal is used in the production of iron. Most of the coal is used in the direct reduction process to remove oxygen from iron-sand. However, all emissions from the use of coal are included in the IPPU sector because the primary purpose of the coal is to produce iron (IPCC, 2006). A small amount of natural gas is used in the production of iron and steel to provide energy for the process: this is reported under the Energy sector in category 1.A.2.a *Iron and steel*.

1.A.2.c Chemicals

The *Chemicals* category includes estimates from the following sub-industries:

- industrial gases and synthetic resin
- organic industrial chemicals
- inorganic industrial chemicals, other chemical production, rubber and plastic products.

The quantity of natural gas used for the production of methanol and ammonia (and, subsequently, urea) has been split into feedstock gas (which is included in 2.B.8.a for methanol and 2.B.1 for ammonia) and energy-use gas (which is included in category 1.A.2.c *Chemicals*). Further details are included in chapter 4 (IPPU sector).

Activity data for methanol production are supplied directly by Methanex New Zealand. Until 2004, methanol was produced at two plants by Methanex New Zealand. In November 2004, production at the Motunui plant was halted and the plant re-opened in late 2008. The Waitara Valley plant was mothballed in early 2021. Methanex New Zealand exports most of this methanol.

Methanex is the sole methanol producer in New Zealand and considers its natural gas consumption to be commercially sensitive information. New Zealand takes a Tier 2 (IPCC, 2006) approach to estimating emissions from methanol production. This approach uses natural gas consumption at the plant along with country- and field-specific emission factors to calculate potential emissions before deducting the carbon sequestered in the end product.

The major non-fuel-related emissions from the methanol process are CH_4 (reported under the IPPU sector) and non-methane volatile organic compounds.

Superphosphate fertiliser is commonly used in New Zealand to ensure that soil has a sufficiently high phosphorous content. It is manufactured from the reaction between sulphuric acid and phosphate rock.[20] During the process, the heat generated by the exothermic reaction between molten sulphur and oxygen is recovered in a waste-heat boiler to produce steam that is then used for process heating and to drive a steam turbine that produces electricity. The electricity is used on site and generally any excess is exported to the local power supplier.

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[20] Phosphate rock: rock rich in the mineral fluorapatite, $Ca_5(PO_4)_3F$.

Because the exothermic reaction is not based on the combustion of fossil fuels, there are no associated emissions to report in the Energy sector.

On-site electricity generation

As mentioned in section 3.2.2, on-site electricity generation is allocated to either the *Public electricity and heat production* category or the sector in which the associated plant operates, using the decision tree shown in figure 3.2.7.

Uncertainty assessment and time-series consistency

Uncertainties in emission and activity data estimates are those relevant to the entire Energy sector (annex 5).

Category-specific QA/QC and verification

In the preparation of this inventory, the *Manufacturing industries and construction* category underwent Tier 1 quality-assurance and quality-control checks, as recommended in the 2006 IPCC Guidelines. These include regular control sums throughout systems, to verify system integrity, and time-series consistency checks.

Category-specific recalculations

Historical energy demand data in the national energy balance tables are occasionally revised from year to year. This may result in minor revisions to activity data and recalculations to the corresponding emissions for some years in some categories.

Category-specific planned improvements

There are no planned improvements for this category.

3.2.9 Fuel combustion: Transport (CRT 1.A.3)

Category description

This category includes emissions from fuels combusted during domestic transportation, such as civil aviation, road, rail and domestic marine transport. Emissions from international marine and aviation bunkers are reported as memo items and are not included in New Zealand's total emissions.

In 2023, category 1.A.3 *Transport* was responsible for 14,155.6 kt CO_2-e (49.1 per cent of emissions from the Energy sector). The transport emissions profile in 2023 was dominated by emissions from category 1.A.3.b *Road transportation*, which accounted for 12,599.8 kt CO_2-e (89.0 per cent) of total transport emissions.

Changes in emissions between 1990 and 2023

Emissions in 2023 were 6,032.1 kt CO_2-e (74.3 per cent) higher than the 8,123.5 kt CO_2-e emitted from the transport sector in 1990. Emissions from category 1.A.3.b *Road transportation* have grown by 5,771.3 kt CO_2-e (84.5 per cent) since 1990. The underlying drivers of this increase are nuanced, but key factors include population growth and increased economic activity.

Changes in emissions between 2022 and 2023

Between 2022 and 2023, emissions from transport increased by 469.7 kt CO_2-e (3.4 per cent). This is primarily due to increases in *Domestic aviation* (up 245.2 kt CO_2-e or 24.0 per cent) and *Road transportation* (up 233.7 kt CO_2-e or 1.9 per cent). The factors behind these movements vary by mode, but a key contributor is rebounding activity following restrictions on activity and movement in response to the COVID-19 pandemic.

Key categories identified in the 2023 level and trend assessment for the *Transport* category are given in table 3.2.6.

Table 3.2.6 Key categories for 1.A.3 *Transport*

Category	Liquid fuels	Solid fuels	Gaseous fuels
Domestic aviation – CO_2	Level, trend	–	–
Road transportation – CO_2	Level, trend	–	Trend
Domestic navigation – CO_2	Trend	–	–

Methodological issues

1.A.3.a Civil aviation

A Tier 1 approach (IPCC, 2006) that does not use landing and take-off cycles has been taken to estimate emissions from the *Civil aviation* category. Given the uncertainty surrounding CH_4 and N_2O emission factors for landing and take-off cycles, a Tier 2 approach to estimating non-CO_2 emissions would not necessarily reduce uncertainty (IPCC, 2006).

Hot air ballooning is considered a form of adventure aviation rather than transport, and is included in category 1.A.4.a *Commercial/institutional*.

1.A.3.b Road transportation

The IPCC (2006) Tier 2 approach was used to calculate CO_2 emissions from *Road transportation* using New Zealand-specific emission factors. The emission factors for oil products were calculated using data provided by New Zealand’s sole oil refinery up until 2021, and by fuel importers starting in 2022. The emission factor for compressed natural gas (CNG) was calculated based on the weighted average emission factor of New Zealand natural gas fields.

Since the 2012 submission, New Zealand has used a Tier 3 (IPCC, 2006) methodology to estimate CH_4 and N_2O emissions from road transport. Annex 5 provides information on non-CO_2 emission factors.

Data collected by New Zealand’s Ministry of Transport provide comprehensive information on vehicle-kilometres-travelled by vehicle class and fuel type from 2001 to 2016. Vehicle-kilometres-travelled were sourced from national six-monthly warrant of fitness inspections. These were further split into travel type (urban, rural, highway, motorway) using New Zealand’s Road Assessment and Maintenance Management system. The New Zealand Travel Survey (Ministry of Transport, 2010) is used to further split the ‘urban’ travel type into cold and hot starts. This survey provides detailed trip-by-trip information on travel type. These data were used to establish the percentages of light-vehicle urban travel that comprise cold starts and hot starts. Before 2001, insufficient data were available, so good practice guidance was used in choosing the splicing method to ensure time-series consistency.

The current New Zealand vehicle fleet is split relatively evenly between vehicles:

- manufactured in New Zealand[21] or imported for sale as new vehicles
- produced and used in Japan and then imported into New Zealand.

This split has been relatively constant for the past nine years.

For this reason, estimates of emissions from road transport split the New Zealand vehicle fleet (and associated CH_4 and N_2O emissions) into sub-fleets: the ‘new vehicle fleet’ and the ‘used vehicle fleet’. This allocation is based on a vehicle’s year of manufacture rather than when it was first added to the New Zealand fleet.

New vehicles are allocated an appropriate vehicle class from the COPERT 4 model (European Environment Agency, 2007), and used Japanese vehicles are allocated emission factors as per categories from the Japanese Ministry of the Environment. These emission factors are broken down by:

- vehicle type
- fuel type
- vehicle weight class
- year of manufacture.

Due to the presence of expensive catalysts, many used vehicles imported into New Zealand have their catalytic converters removed before being exported from Japan. The Ministry of Transport undertook several testing studies to determine the proportion of catalytic converters that are removed in Japan before export.

MBIE and the Ministry for the Environment met with the Australian inventory reporting team in July 2011 to conduct a review of proposed methodologies for calculating emissions of CH_4 and N_2O associated with road transport. New Zealand’s Tier 3 approach for road transport was presented, resulting in a recommendation from the Australian team that the new methodology be adopted for the 2012 submission, and that New Zealand use the IPCC-recommended approach to selecting splicing techniques to choose an appropriate splicing method. New Zealand then applied splicing techniques following the 2006 IPCC Guidelines on the method selection approach.

For the 2018 submission, the Ministry of Transport implemented several improvements for its estimates of non-CO_2 emissions from road transport. First, new emission factors for Euro 5 and 6 vehicles have been used, where previously these vehicles were treated as Euro 4/IV. Second, the European Monitoring and Evaluation Programme/European Environment Agency emission inventory guidebook was updated in late 2016 (European Environment Agency, 2016). Some of the emission factors for Euro 4 and earlier vehicles were also updated in this version of the guidebook. Moreover, detailed emission factors were provided for heavy-duty trucks in different gross vehicle mass bands.

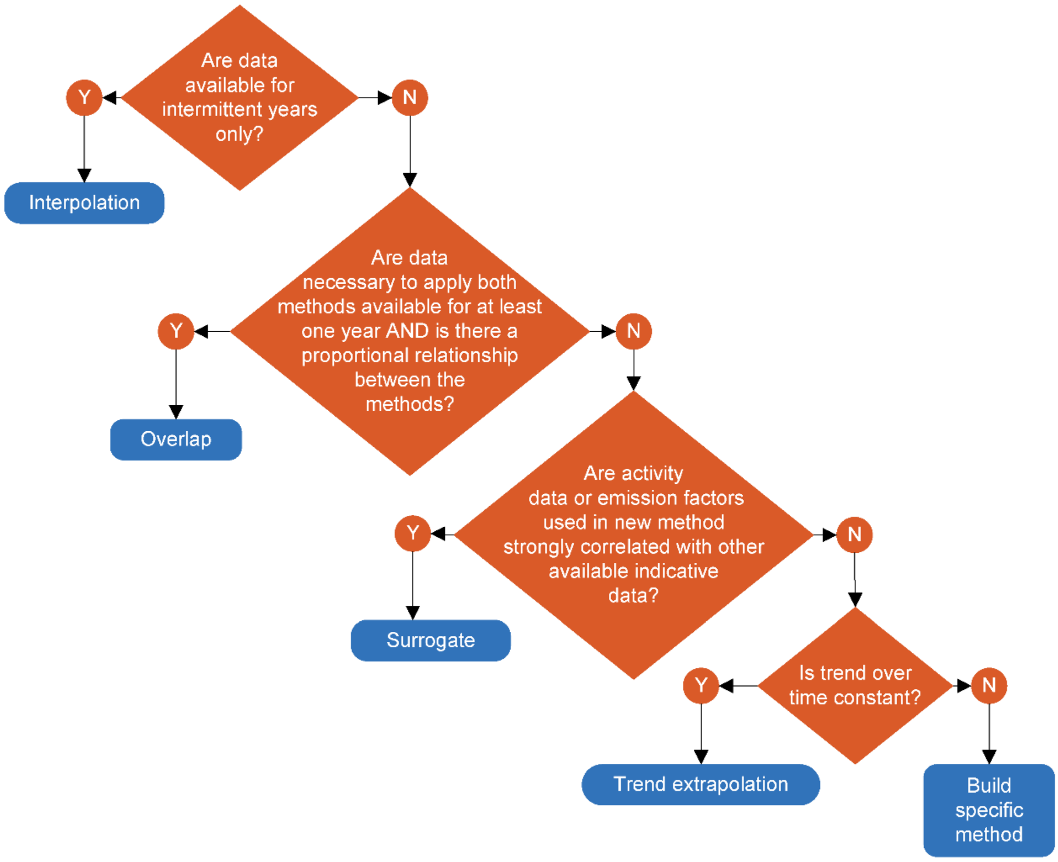
Time-series consistency

Insufficient data exist to apply the Tier 3 methodology between 1990 and 2000, so we have combined methods to form a complete time series following the IPCC (2006) guidance on data splicing (Volume 1, section 5.3.3 splicing techniques). To establish the most appropriate

[21] As of 2018, New Zealand only manufactures a small number of buses and heavy trucks.

splicing method, emissions were calculated using the Tier 1 methodology for the period 2001 to 2016. These emissions were compared against those calculated using the Tier 3 methodology, to determine the relationship between the two series (see figure 3.2.10). The guidance for the method selection process is provided in table 5.1 (volume 2) of the 2006 IPCC Guidelines.

Figure 3.2.10 Splicing method decision tree for gasoline emissions



For all fuels, interpolation was considered inappropriate due to the size of the block of unavailable data and the lack of data from before the missing block (1990–2000).

For emission estimates from LPG, the relationship between Tier 1 and Tier 3 appears nearly constant for both N_2O and CH_4 from 2001 until 2002. As a result, the overlap method was used (IPCC, 2006), with:

$$y_t = x_t \left(\sum_{i=m}^{n} y_i \bigg/ \sum_{i=m}^{n} x_i \right)$$

Where: y_t is the recalculated emission estimate computed using the overlap method

x_t is the estimate developed using the previous method

y_i and x_i are the estimates prepared using the new and previously used methods during the period of overlap, as denoted by years m through n.

However, for gasoline and diesel vehicles, the ratio Tier 3:Tier 1 appears to change approximately linearly with time. While surrogates for Ministry of Transport data were available (fuel consumption), their use resulted in a step change that is unlikely to be representative of road transport emissions for the period. While the trend in emissions was not consistent over time, the trend of the Tier 3:Tier 1 ratio emission estimates showed a strong linear relationship with time. As a result, a hybrid method of overlap and trend extrapolation was chosen with:

$$y_t = (at + b)x_t$$

Where: *t* is the year for which a new estimate is required

a is the slope of the line achieved by regressing Tier 3:Tier 1 for the overlap period

b is the intercept of the line achieved by regressing Tier 3:Tier 1 for the overlap period

x_t is the estimate for year *t* using the previous methodology.

The relationship between Tier 3 and Tier 1 emissions is linear from 2001 to 2005 (inclusive) for both CH_4 and N_2O. This relationship was extrapolated back to the beginning of the time series to derive a factor by which to multiply the Tier 1 estimate for a given year.

Dual-fuel vehicles

Historically, the New Zealand Government encouraged the production and use of dual fuels (CNG–gasoline and LPG–gasoline) in transport as a strategy to reduce New Zealand's dependence on imported oil. New Zealand saw significant use of dual fuels in vehicles until 1987, when government subsidies were removed. Since then, dual fuel use has decreased, due both to the removal of subsidies and to falling oil prices. The last recorded use of dual fuels in New Zealand was a Hamilton bus company, which continued using CNG in its bus fleet until 2017. Use of CNG or LPG for transport has not been recorded since.

The vehicle-kilometres-travelled data provided by the Ministry of Transport allocates all vehicles using dual fuels (LPG–gasoline and CNG–gasoline) to the *Gasoline* category. Historically, non-CO_2 emission factors have been lower for LPG than for gasoline, and correctly allocating dual fuel activity data between gasoline and LPG would result in a slight decrease in overall emissions. As a result, activity data for LPG–gasoline dual-fuel vehicles were not reallocated due to a desire to be conservative when applying methods that would lead to net emission reductions.

To ensure that emissions were not underestimated, an estimate of the fuel used in CNG buses was also made. The remaining natural gas was then assumed to be combusted in converted light passenger vehicles, and an IPCC default emission factor was used to estimate the associated emissions.

Blended biofuels

Since 2007, some fuel retailers have sold small volumes of biogasoline and biodiesel blended with mineral oil products (data on these exist from 2007 onwards). These fuels are categorised under 1.A.3.b *Road transportation*. To ensure that liquid biofuel combustion is considered correctly in the inventory, the energy split (i.e., gasoline as a share of combined gasoline and biogasoline or mineral diesel as a share of mineral diesel and biodiesel) was calculated first, and then the new estimate was multiplied by this factor to account for the biofuel proportion of the fuel. The emissions from the combustion of biofuels were then estimated using a Tier 1 methodology, as in previous inventories.

Biodiesel

Blended biodiesel has been disaggregated into biogenic and fossil fractions in our reporting. The biodiesel biogenic fraction continues to be classified as *Biomass*, while the biodiesel fossil fraction is classified as *Other fossil fuels*.

Biodiesel produced and consumed in New Zealand is generally fatty acid methyl ester (FAME). To produce FAME, vegetable oil or animal fat is trans-esterified with methanol, which is assumed to be of fossil origin. Consequently, every single molecule of FAME contains one fossil carbon atom. While the exact fraction of fossil carbon in FAME depends on the nature of the feedstock oil, a value of 5.4 per cent is assumed based on measurements of a range of biodiesels from Reddy et al. (2008). As a result, part of the CO_2 emissions previously reported as biomass memo items are now included in the national total emissions.

1.A.3.c Railways

Non-CO_2 emissions from the *Railways* category (including both liquid and solid fuels) were estimated using a Tier 1 approach (IPCC, 2006).

1.A.3.d Navigation (domestic marine transport)

Non-CO_2 emissions from the *Navigation* category in New Zealand were estimated using a Tier 1 approach (IPCC, 2006).

1.A.3.e Other transportation

Combustion related to pipeline transport has been recategorised from 1.A.1.c *Manufacture of solid fuels and other energy industries* to 1.A.3.e.i *Pipeline transport*, in response to feedback received from the ERT during the 2018 centralised review.

A recent development in New Zealand is the emergence of a growing aerospace industry. In New Zealand, space-related activities (launches into outer space, launch facilities, high-altitude vehicles and payloads) are overseen by the New Zealand Space Agency, based within MBIE, as regulated in legislation by the Outer Space and High-altitude Activities Act 2017. Currently, one private company is operating an ongoing programme of launching rockets from a launch complex on the Māhia Peninsula (on the east coast of New Zealand's North Island) to put small satellites in orbit around Earth. The rockets use liquid oxygen and RP-1 (a form of highly refined kerosene) as propellants. In 2022, the number of rockets New Zealand launched was the fourth highest in the world, behind the United States, China and Russia (Aerospace New Zealand, no date).

The specific categorisation of aerospace activity within energy statistics is yet to be determined, although this type of kerosene is likely classified as jet kerosene under ANZSIC code *I49 Air and Space Transport*, and so would be included in category 1.A.3.a *Civil aviation*. While the combustion characteristics of rocket engines are likely to differ somewhat from other jet-fuelled activities, no specific emission factors are provided in the 2006 IPCC Guidelines.

The 2006 IPCC Guidelines cover emissions from civil aviation but do not specifically refer to aeronautics or aerospace. Ballistic vehicles, such as rockets, are usually considered to be included under aeronautics but not aviation. While the 2006 IPCC Guidelines (volume 2, table 3.1.1) state that emissions from all remaining transport activities should be reported in category 1.A.3.e *Other transportation*, as mentioned above, the aerospace fuel activity data are currently included in category 1.A.3.a *Civil aviation*. Further justification for not disaggregating the category is that commercial data confidentiality is a concern due to the small number of companies operating in the sector.

Activity data

1.A.3.a Civil aviation

MBIE currently collects data on domestic and international aviation fuel use through the DPFI. The respondents to this survey are New Zealand's five main oil companies – namely, BP, Z Energy, ExxonMobil, Timaru Oil Services Limited and Gull. (Gull and Timaru Oil Services Limited do not supply fuel for aviation.)

Our distinction between domestic and international flights is based on refuelling at the domestic and international terminals of New Zealand airports. The allocation of aviation fuels between domestic and international segments has previously been raised by the ERT. A previous centralised review stated (UNFCCC, 2009):

> The National Inventory Report (NIR) reports that the allocation of fuel consumption between domestic and international air transport is based on refuelling at the domestic and international terminals of New Zealand's airports. Currently splitting the domestic and international components of fuels used for international flights with a domestic segment was not considered; however, the number of international flights with a domestic segment is considered to be negligible. The Expert Review Team (ERT) notes that in 2006, New Zealand began consultations with the airlines to clarify the situation and improve the relevant Activity Data (AD), and is currently working on a methodology that will allow for better international and domestic fuel use allocation. New Zealand is encouraged to adopt the new approach and report the outcome in its 2010 submissions.

In the DPFI, the oil companies report quantities of different fuels (jet A1, aviation gasoline and kerosene, among others) used for the purposes of international and domestic transport. The companies have indicated that they allocate the fuel to international or domestic transport based on whether or not they are legally required to charge goods and services tax (GST) on the activity; GST is zero rated when the destination of a flight is outside of New Zealand.

Historically, some international flights from New Zealand contained a domestic leg, for example, Christchurch–Auckland–Tokyo. Industry practice is to refuel at both points with sufficient fuel to reach the next destination so that the domestic leg will be coded appropriately. By this logic, the domestic leg will attract GST so the fuel use will therefore be coded as domestic, and the international leg, which does not attract GST, will be coded as international.

This sales-based approach is appropriate because just three companies (BP, Z Energy and ExxonMobil) supply 100 per cent of the aviation fuels market in New Zealand, and the accuracy of the international–domestic split relies solely on the reporting from these three respondents.

1.A.3.b Road transportation

Activity data for the *Road transportation* category are provided by the Ministry of Transport's six-monthly fleet data and MBIE's national energy statistics. For more information on the use of vehicle fleet data for estimating non-CO_2 emissions, see 'Methodological issues' above.

Activity data for the *Transport* category were sourced from the DPFI conducted by MBIE. LPG and CNG consumption figures are reported online by MBIE.

As mentioned in section 3.2.2, this inventory continues to use the results of the Annual Liquid Fuel Survey that began in 2009. The purpose of this survey is to capture the allocation of fuel resold by small independent resellers. In recent years, these independent resellers have accounted for around 30 per cent of national diesel sales and around 8 per cent of national gasoline sales.

As a result of resale data captured by this survey, emissions that would otherwise be reported in category 1.A.3.b *Road transportation* are allocated to their correct category. For time-series consistency, these reallocations were also made from 1990 to 2008, before the collection of data on the resale of liquid fuel by independent distributors.

The diesel activity data for the *Road transport* category are assumed to be the diesel reported for domestic transport, less that reported by KiwiRail, the operator of national rail services in New Zealand, in the categories 1.A.3.c *Railways* and 1.A.3.d *Domestic navigation*, discussed below.

The fuel sold data have been validated by estimating fuel consumption based on vehicle kilometres using a vehicle fleet model. Over the past decade, the fuel quantity from the fuel use data has been larger than that estimated using kilometres travelled. Several factors can contribute to differences between the two methods, for example, fuel sold by retailers that is then used for off-road purposes, and the real-world fuel efficiencies of vehicles differing from assumptions used in the vehicle fleet model. Across the time series (2001–15), the average difference is 1.5 per cent for gasoline and 4.8 per cent for diesel, which shows that the methods align very closely. This level of agreement compares favourably with the fuel data of other countries.

MBIE receives import–export and excise data on liquid biofuels from the New Zealand Customs Service and sales data from major fuel companies. In December 2012 the Biofuel Sales Obligation was abolished and in June 2012 the Biodiesels Grant Scheme was removed. Following the removal of these initiatives, biodiesel use fell significantly and has remained relatively stagnant since.

1.A.3.c Railways

Activity data for fuel used in this category are obtained directly from KiwiRail. This category also includes diesel sold to the metropolitan service operated in Auckland.

1.A.3.d Domestic navigation

Activity data for fuel oil use in domestic transport are sourced from the quarterly DPFI conducted by MBIE. KiwiRail (as the operator of the Interislander ferry service) provides data on diesel consumption each year. New Zealand-specific emission factors have been used to estimate CO_2 emissions and, because of insufficient data, the IPCC (2006) default emission factors have been used to estimate CH_4 and N_2O emissions.

Fuel sales to international marine bunkers are reported separately in national energy data surveys.

Historically, the Marsden Point Oil Refinery produced marine diesel oil (MDO). Production of MDO at the refinery stopped in late 2006. Data collected from the operators of the Interislander ferry service (KiwiRail) have not included MDO use since 2006. The end of the collection of these data coincided with this operator ceasing a ‘fast ferry’ service (which ran on MDO) between the North Island and South Island.

It is difficult to quantify the precise volume of diesel used for commercial domestic navigation in New Zealand. Currently, the DPFI only differentiates sales of diesel to the level of domestic transport. MBIE’s oil data system subcategorises diesel sold for domestic transport as being used for road transport.

Uncertainty assessment and time-series consistency

Uncertainties in emission estimates from the *Transport* category are relevant to the entire *Fuel combustion* sector (see table 3.2.1).

Category-specific QA/QC and verification

In the preparation of this inventory, the *Transport* category underwent Tier 1 quality-assurance and quality-control checks as recommended in the 2006 IPCC Guidelines. These include regular control sums throughout systems, to verify system integrity, and time-series consistency checks.

Comparisons of international implied emission factors across the time series (1990–2012), and those resulting from the new Tier 3 methodology for CH_4 and N_2O emissions from road transport, were made using data from the United Nations Framework Convention on Climate Change website.

Category-specific recalculations

Historical energy demand data in the national energy balance tables are occasionally revised from year to year. This may result in minor revisions to activity data and recalculations to the corresponding emissions for some years in some categories.

Category-specific planned improvements

MBIE and the Ministry of Transport are considering incorporating the results of a new aviation emissions model in the inventory estimates (for CH_4 and N_2O emissions). This will require time and resources to progress if it is deemed to be a worthwhile improvement.

3.2.10 Fuel combustion: Other sectors (CRT 1.A.4)

Category description

The category 1.A.4 *Other sectors* comprises emissions from fuels combusted in the *Commercial/institutional*, *Residential* and *Agriculture/forestry/fishing* categories.

In 2023, the *Fuel combustion – Other sectors* category accounted for 4,455.6 kt CO_2-e (15.4 per cent of the emissions from the Energy sector). This is 871.7 kt CO_2-e (24.3 per cent) higher than the 1990 value of 3,583.9 kt CO_2-e. The main contributors to this increase were *Commercial/institutional* (up 310.6 kt CO_2-e or 35.1 per cent) and *Residential* (up 383.5 kt CO_2-e or 26.3 per cent).

Changes in emissions between 2022 and 2023

Between 2022 and 2023, emissions from 1.A.4 *Other sectors* decreased by 66.9 kt CO_2-e (1.5 per cent). A decrease of 143.1 kt CO_2-e from *Commercial/institutional* was offset by a 41.4 kt CO_2-e increase from *Agriculture/forestry/fishing*.

Key categories identified in the 2023 level and trend assessment for the *Other sectors* category are given in table 3.2.7.

Table 3.2.7 Key categories for 1.A.4 *Other sectors*

Category	Liquid fuels	Solid fuels	Gaseous fuels
Commercial/institutional – CO_2	Level, trend	Trend	Level, trend
Residential – CO_2	Level, trend	Trend	Level, trend
Agriculture/forestry/fishing – CO_2	Level, trend	Trend	–

Methodological issues

Solid biomass

Outdoor combustion of biomass (e.g., bonfires, barbecues, campfires, pizza ovens, braziers, chimeneas, or in preparation for traditional methods of cooking food such as hāngī, umu and lovo) is common in New Zealand. These activities are distinct from open-burning of unwanted biomass that is not used for energy purposes, which would be reported under the Waste sector. While activity data are not available, expert opinion indicates that the likely level of activity is relatively minor compared with the indoor residential combustion of biomass; therefore, emissions associated with these outdoor activities have not been estimated.

Solid fossil fuels

Several synthetic solid fuels are used as lightweight cooking fuels by hikers and the military. Examples include hexamethylenetetramine, metaldehyde and trioxane, which are derived from chemical feedstocks such as aldehydes and ammonia, and hence contain fossil carbon. These fuels are not covered by the national energy balance, and the emissions associated with their combustion have not been estimated.

Other fossil fuels

Chafing fuel is a fuel commonly used in the commercial sector for heating food, typically placed under a chafing dish. It is usually sold in a small canister and burned directly within that canister. The fuel often contains methanol, ethanol or diethylene glycol, as these may be burned safely indoors, and produce minimal soot or odour. These fuels are also used for emergency heating, outdoor cooking, and fondue. A source of appropriate activity data is being investigated and an update will be provided in the next annual submission.

Activity data

Liquid fuels

As mentioned in section 3.2.2, this inventory uses the results of the Annual Liquid Fuel Survey that began in 2009. The purpose of the survey is to capture the allocation of fuel resold by small independent resellers. In recent years, these independent resellers accounted for around 30 per cent of national diesel deliveries and around 8 per cent of national gasoline deliveries.

As the result of resale data captured by the Annual Liquid Fuel Survey, emissions that would otherwise be reported in category 1.A.3.b *Road transportation* are allocated to their correct category. For time-series consistency, these reallocations are also made from 1990 to 2008, before the collection of data on the resale of liquid fuel by small, independent distributors began.

Historical national energy sales surveys captured fuel use by mining operations under 'other primary industry'. For consistency with the 2006 IPCC Guidelines, this inventory uses data provided by Stats NZ's Energy Use Survey (Stats NZ, 2018) to estimate the split of historical ‘other primary industry’ activity for fuel oil between forestry and logging, and mining (see table 3.2.8). The historical data are insufficient to extrapolate a historical trend for this split: instead, activity splits are interpolated between the two surveys and assumed to be constant for the period 1990 to 2008.

Table 3.2.8 Split of fuel oil activity for ‘other primary industry’

Activity	Energy Use Survey 2008 (%)	Energy Use Survey 2016 (%)
Forestry and logging	51.3	9.1
Mining	48.7	90.9

Solid fuels

In 2010, it was discovered that some coal reported as sold to the commercial sector was in fact being on-sold to resellers rather than sold directly to end users. As a result, some activity previously reported in the *Commercial* category has been reallocated to the Agriculture sector. This on-selling is assumed to continue across the time series 1990 to 2023.

Solid biomass

Residential solid biomass includes imported charcoal and domestically produced firewood. The residential combustion of firewood is estimated by MBIE using household number estimates from Stats NZ, along with five-yearly census figures estimating the percentage of households using biomass for heating. Interpolation is used to estimate shares for intermediate years. The average energy content of biomass burned in each household that uses wood for heating was estimated by the study *Energy Use in New Zealand Households* (BRANZ, 2002). The census data indicate that the popularity of woodburners is decreasing slowly over time.

Gaseous fuels

Annual natural gas consumption statistics are published by MBIE (2024a). Reviews of all natural gas consumption data were undertaken in 2011 and 2014 by MBIE. For further information, see section 3.2.8 (‘Gaseous fuels’ under ‘Activity data’).

Other fossil fuels

Mixtures of fossil fuels are combined with a wide range of metal, organic and non-organic compounds in the formulation of fireworks. In New Zealand, most towns and cities hold public fireworks displays for Guy Fawkes Night (5 November) and increasingly on other days to celebrate religious and cultural festivals, such as Diwali, Matariki and Lunar New Year, as well as at major sporting events. Fireworks are imported from overseas, generally China – there is no domestic production. Common fossil–carbon based fuels include carbon black, coal, asphaltum and gilsonite. In addition to CO_2, greenhouse gas emissions also include CH_4 and N_2O.

The annual gross weight of imported fireworks was used as activity data. Emission factors were sourced from the Danish national inventory report.

Uncertainty assessment and time-series consistency

Uncertainties in emission estimates for data from other sectors are relevant to the entire Energy sector (see table 3.2.1).

Category-specific QA/QC and verification

In the preparation of this inventory, the *Other sectors* category underwent Tier 1 quality-assurance and quality-control checks as recommended in the 2006 IPCC Guidelines. These include regular control sums throughout systems, to verify system integrity, and consistency checks of implied emission factors.

Category-specific recalculations

Historical energy demand data in the national energy balance tables is occasionally revised from year to year. This may result in minor revisions to activity data and recalculations to the corresponding emissions for some years in some categories.

Category-specific planned improvements

No improvements are planned for this category.

3.3 Fugitive emissions from solid fuels and oil and natural gas and other emissions from energy production (CRT 1.B)

Category description

Fugitive emissions arise from the production, processing, transmission, storage and use of fossil fuels, and from non-productive combustion. This category comprises two categories: *Solid fuels* and *Oil and natural gas*.

In 2023, *Fugitive emissions* from fuels accounted for 1,173.8 kt CO_2-e (4.1 per cent) of emissions from the Energy sector. This is 388.5 kt CO_2-e (24.9 per cent) lower than the 1990 level of 1,562.3 kt CO_2-e.

Changes in emissions between 2022 and 2023

Between 2022 and 2023, *Fugitive emissions* from fuels decreased by 146.7 kt CO_2-e (11.1 per cent). This was primarily the result of increased activity in category 1.B.2.c. *Venting and flaring.*

Key categories identified in the 2023 level and trend assessment for the *Fugitive emissions* category are given in table 3.3.1.

Table 3.3.1 Key categories for 1.B *Fugitive emissions*

Category	CO_2	CH_4
Coal mining and handling – Underground mines	–	Trend
Natural gas – Distribution	–	Trend
Venting – Gas	Level, trend	–
Venting – Combined	–	Trend
Flaring – Combined	Trend	–
Other – Geothermal	Level, trend	–

3.3.1 Fugitive emissions from fuels: Solid fuels (CRT 1.B.1)

Category description

In 2023, fugitive emissions from the *Solid fuels* category accounted for 63.4 kt CO_2-e (5.4 per cent) of emissions from the *Fugitive emissions* category. This is 304.0 kt CO_2-e (82.7 per cent) lower than the 367.4 kt CO_2-e reported for 1990. The factors behind this decrease include changes in the amount and type of coal produced as well as in its method of extraction (open-cast versus underground).

Between 2022 and 2023, fugitive emissions from the *Solid fuels* category decreased by 0.9 kt CO_2-e (1.4 per cent) due to decreased coal production.

New Zealand's fugitive emissions from the *Solid fuels* category are a by-product of coal mining operations. Methane is created during coal formation and released when coal is mined. The amount of CH_4 released during coal mining is dependent on the coal grade and the depth of the coal seam. Emissions also occur due to post-underground mining activities, such as coal processing, transportation and use.

In 2023, New Zealand's total coal production was 2.6 million tonnes. Fewer than 15 active coal mines are operating in New Zealand, and as of 2023 none is underground. The two largest open-cast operations, at Stockton and Rotowaro, account for most national production. For further information and data on the coal mining industry, refer to *Energy in New Zealand* (MBIE, 2024a).

At the end of 2023, no known flaring or capture of CH_4 was occurring at coal mines in New Zealand. Pilot schemes of both coal seam gas and underground coal gasification began in 2012, but these projects have not progressed.

Methodological issues

The New Zealand-specific emission factor for underground mining of sub-bituminous coal is used to calculate CH_4 emissions (Beamish and Vance, 1992). The sub-bituminous emission factor derived from Beamish and Vance is considered to be reliable because the emission factor (12.1 tonnes of CH_4 per kilotonne of coal (t/kt)) is:

- well within the IPCC (2006) default range of 6.7–16.75 t/kt
- largely based on data for the most significant sub-bituminous coal mine in New Zealand (Huntly East mine), which was in continuous operation from 1988 to 2017 and the most significant producing mine.

The emission factor for underground mining of bituminous coal is taken from the 2006 IPCC Guidelines. It is noted that any bituminous emission factor derived from Beamish and Vance (1992) would not be reliable, and should not be used, for the following reasons.

1. The derived emission factor (35.28 t CH_4/kt) is more than double the high default IPCC (2006) value. Using such an emission factor that is so far out of line with the default values would require a strong justification.
2. New Zealand already has the highest implied emission factor for underground mining among Annex I Parties. Dramatically increasing the emission factor further still would not be in the interests of comparability.
3. The bituminous data are based on production (in 1988) of only 125 kt and so represent a very small sample size (compared with the sub-bituminous mines, where the data are based on production of 655 kt). The small sample size significantly increases the uncertainty.

4. Beamish and Vance's study is based on data from 1988, for just eight bituminous coal mines. These data are out of date because all of these mines are no longer producing, and bituminous coal production comes from entirely different underground mines, to which the suggested emission factors may not be applicable.

Emission factors for the other categories, for example, surface mining, are sourced from the 2006 IPCC Guidelines.

Activity data

Activity data for this category are collected from MBIE's coal production survey. This survey gathers quarterly data on coal production by mine type (underground and/or surface) and rank (coking, bituminous, sub-bituminous, lignite).

Abandoned underground mines (1.B.1.a.1.iii)

MBIE has investigated whether there was any activity in this category. According to the 2006 IPCC Guidelines, mines of only a few acres in size should be disregarded, and, additionally, non-gassy mines and flooded mines are presumed to have negligible emissions. Most New Zealand mines are small by European standards and can be disregarded. The first stage of the project was completed in 2016 and concluded that the activity is not occurring (NO) in the North Island: details are given in table 3.3.2. The second stage of the project, focusing on collating and digitising mine data for the South Island, commenced in December 2019. A mine plans database has been made available online (WorkSafe et al., no date), although this is still a work in progress. An online exploration database is also available (New Zealand Petroleum and Minerals, no date).

During 2021, a contractor was employed to review all the coal reports within MBIE's online coal mine databases and record the following details:

- mine name
- mine number
- coalfield
- mining method
- location of the mine (grid reference or coordinates)
- mine start year
- mine closure year
- details of production
- whether the mine was gassy (mentions of problems with gas)
- whether the mine was flooded or had water problems that would indicate it is now flooded.

A long list of historical mines was collated. Only 63 mines had information on whether the mine is now flooded and only 30 mines had information on whether the mine was gassy. Further data collection and processing are required before we can make a meaningful assessment of fugitive emissions. In particular, we still need to collect:

- elevation data to determine likely flooded or unflooded status
- data on mine size to be used in applying a cut-off threshold.

Activity data in the form of CH_4 output derived from mine ventilation measurements have been obtained from mine operators for those mines where data exist. Those mines have now closed and are flooded. Category-specific details are not provided to maintain confidentiality. Recovery and/or flaring of CH_4 from abandoned mines does not occur.

Table 3.3.2 Details of abandoned underground mines in the North Island

Region/coalfield	Significant mine(s)	Status
Northland	Kamo	Only one significant mine; flooded
Waikato	Rotowaro mines	Underground mines either flooded or subsequently open-cast mined
	Huntly West	Flooded
	Taupiri/Ralphs	Mines under Huntly township; flooded
Taranaki	Tatu	Only one significant mine; flooded

Uncertainty assessment and time-series consistency

Uncertainties in fugitive emissions are relevant to the entire Energy sector (see table 3.2.1).

Category-specific QA/QC and verification

In the preparation of this inventory, the *Fugitive emissions* category underwent Tier 1 quality-assurance and quality-control checks, as recommended in the 2006 IPCC Guidelines. These include regular control sums throughout systems, to verify system integrity, and consistency checks of implied emission factors.

Category-specific recalculations

Some historical geothermal emissions data have been revised due to updated data provided by plant operators. This has resulted in minor recalculations to emissions for some years.

Category-specific planned improvements

There are no planned improvements for this category.

3.3.2 Fugitive emissions from fuels: Oil and natural gas and other emissions from energy production (CRT 1.B.2)

Category description

In 2023, fugitive emissions from the *Oil and natural gas* category contributed 1,110.4 kt CO_2-e (94.6 per cent) to emissions from the *Fugitive emissions* category. This is 84.5 kt CO_2-e (7.1 per cent) lower than the 1990 level of 1,194.9 kt CO_2-e.

A source of emissions from the production and processing of natural gas is the Kapuni Gas Treatment Plant. The plant removes CO_2 from a portion of the Kapuni gas (a natural gas high in CO_2 when untreated) before it enters the national transmission network. This activity is reported in CRT 1.B.2.c.2.

The large increase in CO_2 emissions from the Kapuni plant between 2003 and 2004 and between 2004 and 2005 is related to the drop in methanol production. Carbon dioxide previously sequestered during this separation process was instead released as fugitive emissions from venting at the plant.

While emissions from the Kapuni plant may include traces of CH_4, the level of these emissions has been determined to be insignificant in comparison with national emissions: a conservative estimate (using default emission factors from the 2006 IPCC Guidelines) gives nearly 1.5 kt CO_2-e per year.

Carbon dioxide is also produced when natural gas is flared at the wellheads of other fields. The combustion efficiency of flaring is 95 per cent to 99 per cent, leaving some fugitive CH_4 emissions due to incomplete combustion.

Fugitive emissions also occur in transmission and distribution within the natural gas transmission pipeline system. However, these emissions are relatively minor compared with those from venting and flaring.

The *Oil and natural gas and other emissions from energy production* category also includes estimates of emissions from geothermal operations. While some of the energy from geothermal fields is transformed into electricity, emissions from geothermal electricity generation are reported in the *Fugitive emissions* category because they are not the result of fuel combustion. Geothermal facilities supplying geothermal fluid for generating electricity or industrial heat are subject to the Climate Change (Stationary Energy and Industrial Processes) Regulations 2009 and are required to participate in the NZ ETS. Geothermal sites whose geothermal steam is not used for energy production have been excluded from the inventory. Operations falling outside the scope of the regulations are not included in the inventory due to a lack of data, methodology and emission factors. Besides this, such sites – rather than using high-temperature geothermal steam – use low-temperature hot water, which does not carry high levels of dissolved gases, and any emissions are considered insignificant. Naturally occurring sites do not contribute any anthropogenic emissions.

In 2023, emissions from geothermal operations were 477.0 kt CO_2-e, which is 187.1 kt CO_2-e (64.5 per cent) higher than the 1990 level of 289.9 kt CO_2-e. For reference, over the same period the total quantity of electricity generated from geothermal energy has quadrupled.

Between 2022 and 2023, emissions from geothermal sources decreased by 65.3 kt CO_2-e (12.0 per cent). A steady decline in emissions has occurred over the past eight years as the more recently developed fields have undergone degassing. Degassing is a commonly observed geothermal phenomenon just like a freshly opened bottle of carbonated water that is initially fizzy but gradually goes flat over time. Further information on the degassing of New Zealand geothermal fields is available in McLean and Richardson (2019).

Methodological issues

Unless noted otherwise, CO_2 and CH_4 emissions from sources within this category have been calculated using the IPCC Tier 2 approach, and N_2O emissions were calculated using the default Tier 1 approach (IPCC, 2006).

Ozone precursors and sulphur dioxide from oil refining

New Zealand had only one oil refinery, which closed in March 2022. This refinery used a hydro cracker rather than a catalytic cracker and thus produced no emissions from fluid catalytic cracking. However, emissions were produced from sulphur recovery plants and storage and handling.

1.B.2.c Venting and flaring

Oil and natural gas fields in New Zealand produce a mixture of natural gas, crude oil, condensate and natural gas liquids (at varying ratios). Hence, emissions for this category are reported under 'combined'. The activity data are directly reported by field operators.

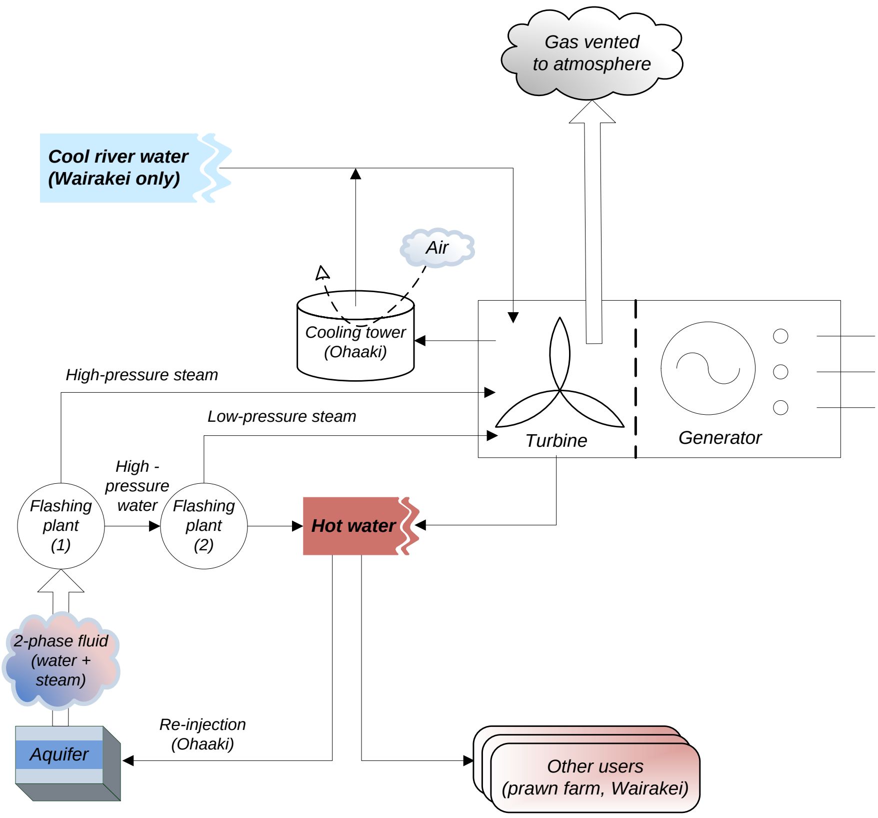
Venting of CO_2 resulting from hydrogen production at oil refineries is included under the IPPU sector to protect the confidentiality of individual companies (see chapter 4 for further information).

1.B.2.d Geothermal

When geothermal fluid is discharged, some CO_2 and small amounts of CH_4 are also released. The emissions released during electricity generation using geothermal fluid are reported in this inventory. Figure 3.3.1 shows a schematic diagram of a typical New Zealand geothermal flash power station.

Estimates of CO_2 and CH_4 emissions for the *Geothermal* category are obtained directly from geothermal power companies. New Zealand currently has around 15 geothermal power stations and most of these are owned (or partly owned) by two major power companies. Two examples of methodologies used to estimate emissions by these companies are explained below.

Figure 3.3.1 Schematic diagram of the use of geothermal fluid for electricity generation – as at Wairakei and Ohaaki geothermal stations (New Zealand Institute of Chemistry, 1998)



Emissions from geothermal activities increased up until around 2015. The increases were related to electricity generation, particularly with the additions of the 100 MW Kawerau geothermal plant since late 2008, Nga Awa Purua and Te Huka since 2010, Nga Tamariki since 2013 and Te Mihi since 2014.

The schedules to the Climate Change Response Act 2002 create obligations for people carrying out certain activities to report greenhouse gas emissions as part of the NZ ETS. The Climate Change (Stationary Energy and Industrial Processes) Regulations 2009 and Climate Change (Liquid Fossil Fuels) Amendment Regulations 2009 set out the data-collection requirements and methods for participants in those sectors to calculate their emissions, including prescribed default emission factors.

The Climate Change (Unique Emissions Factors) Regulations 2009 outline requirements for participants in certain sectors to calculate a unique emission factor (UEF) and apply for approval to use it in place of a default emission factor to calculate and report on emissions. Users of geothermal fluid are eligible to apply for a UEF.

Operators could first apply for UEFs in 2010. MBIE received five applications relating to the use of UEFs for geothermal fluid for that calendar year. These five approved UEFs were then adopted for the inventory after careful assessment of the impact on the level of emissions and the time-series consistency.

Because 2010 was the introduction year, MBIE decided that the UEF would apply only to years for which sufficient data are available, that is, from 2010 onward. This submission continues with this approach. From 1990 to 2009, emissions are calculated using field-specific default emission factors. Emissions from 2010 onwards are calculated using UEFs where available and field-specific default emission factors otherwise.

When a sufficient number of years of UEF data are available for comparison, the 1990 to 2009 emission factors for each affected field will be reviewed.

Geothermal methodology for Company A

At Company A, quarterly gas sampling analysis is conducted to measure the amount of carbon dioxide (CO_2) and methane (CH_4) in the steam. Gas samples are collected at the inlet to the electricity generation station and at the extraction process when gas is dissolved in the condensate (wastewater).

The concentration of CO_2 (e.g., 0.612 per cent) and CH_4 (e.g., 0.0029 per cent) by weight of discharged steam is then calculated by carrying out a mass balance.

'Gas discharged to atmosphere' = 'Gas to electricity generation station' – 'Gas dissolved in condensate'

Company A also collects information on the average steam flow (tonnes of steam per hour) to the electricity generation station. This average steam flow is based on an annual average (e.g., 582.3 tonnes of steam per hour).

Therefore, working out CO_2 emissions discharged to the atmosphere involves the following calculations.

Average discharge per hour is calculated as:

$$582.3\,\frac{tonnes\ of\ steam}{hour} \times \frac{0.612}{100}\,\frac{tonnes\ of\ CO_2}{tonnes\ of\ steam} = 3.565\,\frac{tonnes\ of\ CO_2}{hour}$$

And the total discharge per year is:

$$3.565\,\frac{tonnes\ of\ CO_2}{hour} \times 8{,}760\,\frac{hours}{year} = 31{,}230\ tonnes\ of\ CO_2$$

Using the same methodology above will yield 149 tonnes of CH_4. The overall emission for Company A is therefore 35,402 tonnes of CO_2-e emissions.

> **Geothermal methodology for Company B**
>
> At Company B, spot measurements of both carbon dioxide and methane concentrations are taken at the inlet steam when the power stations are operating normally. The net megawatt hours of electricity generated that day are then used to calculate the emission factor. This implied emission factor is then multiplied by the annual amount of electricity generated to work out the annual emissions for each power station.

Activity data

1.B.2.a.1 Exploration

Activity data are the number of wells drilled in each year as reported by New Zealand Petroleum and Minerals (MBIE, 2024b). Data were only available for the years from 2001 onwards, so estimates were made by extrapolation for the years preceding 2001.

1.B.2.a.3 Transport

The activity data are New Zealand's total production of crude oil (MBIE, 2024a).

1.B.2.a.4 Refining

Activity data are total intake at New Zealand's Marsden Point Oil Refinery (MBIE, 2024a).

1.B.2.a.5 Distribution of oil products

Activity data are New Zealand's total consumption of gasoline (MBIE, 2024a).

1.B.2.b.3 Processing

Venting of CO_2 is reported in CRT category 1.B.2.c.2, in accordance with a previous ERT recommendation. No activity data are available.

1.B.2.b.4 Transmission and 1.B.2.b.5 Distribution

Carbon dioxide and CH_4 emissions from gas leakage mainly occur from low-pressure distribution pipelines rather than from high-pressure transmission pipelines. Emissions from transmission and distribution are reported separately.

Data on emissions from the high-pressure transmission system were provided by the system operator. Natural gas transmission losses included both direct leakage of CH_4 and CO_2 and gas lost and/or used when starting lines compressors. Data are provided for gigajoules (GJ) of CH_4 and tonnes of CO_2. Gigajoules of CH_4 are converted to tonnes of CH_4 using the conversion factor of 55.6 GJ/t.

New Zealand has a high-pressure transmission network nearly 3,500 kilometres in length. It joins most North Island cities (reticulated natural gas is available only in New Zealand's North Island). No time series of the total length of the transmission lines is available; however, expert opinion is that it would have been nearly constant since 1990.

New Zealand bases distribution loss emissions on information about gas entering the distribution network, which is administrative data collected at the 'gas gate'. It does not follow the alternative approach of using survey information collected from gas retailers on the amount of gas sold and metered at the individual customer (household, small business) level.

For the 2023 submission, New Zealand implemented an improvement to the estimation of leakage from distribution networks, moving from a Tier 2 methodology to using more accurate industry data derived from models that represent a Tier 3 approach. The former methodology used an assumed constant leakage rate of 1.75 per cent of total reticulated natural gas. This figure was derived by the Natural Gas Corporation in the mid-1990s and a review in 2022 found it to be out of date. Engagement with industry experts revealed that the current estimate of the leakage rate from the modernised distribution pipelines in New Zealand averaged 0.35 per cent over the period 2017 to 2021.

The new estimates from industry represent a Tier 3 approach, using specific emission factors, assessed at the facility level. The industry emissions estimate model has been developed using a best-practice Marcogaz estimating template and uses internationally published emission rates (American Petroleum Institute Compendium of emissions rates) combined with company-specific asset knowledge and information to provide a bottom-up approach. Further, the industry is now completing annual asset-level leakage measurements to validate the emissions rates and estimates.

The Tier 3 methodology detailed above only applies from 2017 onwards. To preserve time-series consistency and avoid a step change between this and the previous method, data splicing was employed: for previous years where estimates from the Tier 3 models are not yet available, the leakage rate is interpolated back to the 1990 value of 1.75 per cent.

Updated data sourced from field operators have been used to improve the accuracy of emission estimates for geothermal activities.

1.B.2.b.4 Natural gas storage

Natural gas storage occurs at the Ahuroa gas storage facility. Ahuroa is a depleted gas field that can hold 5 PJ to 10 PJ of natural gas at any one point. A significant portion of this gas is used to run Contact Energy's Stratford gas peaking plant, which consists of two 100 MW open-cycle gas turbine units.

1.B.2.c Venting and flaring

Data on natural gas flaring, losses and own use are reported directly by gas field operators.

The operator of the Kapuni Gas Treatment Plant supplies estimates of CO_2 vented during the processing of natural gas.

In response to an ERT recommendation, flaring of refinery gas has been reallocated from 1.B.2.a *Oil* to 1.B.2.c *Venting and flaring*.

Emission factors

Unless noted otherwise, default IPCC (2006) emission factors have been used.

Uncertainty assessment and time-series consistency

Time-series data from various geothermal fields vary in completeness, and some historical data are not available. Individual geothermal fields each produce varying levels of output and emissions so the overall implied emission factors display a certain amount of natural variation.

Category-specific QA/QC and verification

In the preparation of this inventory, the *Fugitive emissions* category underwent Tier 1 quality-assurance and quality-control checks as recommended in the 2006 IPCC Guidelines. These include regular control sums throughout systems, to verify system integrity, and consistency checks of implied emission factors.

Category-specific recalculations

Historical energy production and processing data in MBIE's oil and gas data system are occasionally revised from year to year. This may result in minor revisions to activity data and recalculations to the corresponding emissions for some years in some categories.

Category-specific planned improvements

Updated estimates of distribution losses will be incorporated as and when Tier 3 estimates from industry models become available. This is dependent on sufficiently detailed and disaggregated information on the historical state of distribution network infrastructure and assets.

As the dataset of verified UEFs for individual geothermal fields and coal mines obtained from the NZ ETS grows, New Zealand will consider methods of incorporating these data to improve the accuracy of estimates.

3.4 Carbon dioxide transport and storage (CRT 1.C)

The bulk transport of CO_2 occurs in New Zealand by means of ship. The total quantity of international trade (reported in kilotonnes) is used as activity data. Default IPCC (2006) emission factors for fugitive emissions from CO_2 transport by ship are not available; hence, emissions have not been estimated.

No known CO_2 storage occurred in New Zealand between 1990 and 2023. During 2024, the Government proposed a regulatory regime for carbon capture, utilisation and storage (MBIE, 2024c).

Chapter 3: References

Aerospace New Zealand. No date. Aerospace New Zealand. Retrieved 20 February 2025.

Australian Bureau of Statistics and Statistics New Zealand. 2006. *Australian and New Zealand Standard Industrial Classification Revision 1.0.* Canberra: Australian Bureau of Statistics.

Baines JT. 1993. *New Zealand Energy Information Handbook*. Christchurch: Taylor Baines and Associates.

Beamish BB, Vance WE. 1992. Greenhouse gas contributions from coal mining in Australia and New Zealand. *Journal of the Royal Society of New Zealand* 22(2).

Bioenergy Association of New Zealand. 2011. *Heat Plant in New Zealand*. Retrieved 20 February 2025.

BRANZ. 2002. *Energy Use in New Zealand Households*. Porirua, Wellington: Building Research Association of New Zealand.

CRL Energy Ltd. 2009. *Review of Default Emission Factors in Draft Stationary Energy and Industrial Processes: Coal*. Contract report prepared for the Ministry for the Environment. Wellington: Ministry for the Environment. Retrieved 20 February 2025.

European Environment Agency. 2007. *EMEP/CORINAIR Emission Inventory Guidebook – 2007*. Copenhagen: European Environment Agency.

European Environment Agency. 2016. *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016: Technical guidance to prepare national emission inventories*. Copenhagen: European Environment Agency.

IPCC. 2006. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy*. IPCC National Greenhouse Gas Inventories Programme. Japan: Published for the IPCC by the Institute for Global Environmental Strategies for IPCC.

MBIE. 2008. *Liquid Fuel Use in New Zealand*. Wellington: Ministry of Business, Innovation and Employment. Retrieved 20 February 2025.

MBIE. 2010. *Delivering the Diesel – Liquid Fuel Deliveries in New Zealand 1990–2008*. Wellington: Ministry of Business, Innovation and Employment. Retrieved 20 February 2025.

MBIE. 2024a. *Energy in New Zealand*. Wellington: Ministry of Business, Innovation and Employment. Retrieved 20 February 2025.

MBIE. 2024b. *Petroleum Reserves Data*. Retrieved 20 February 2025.

MBIE. 2024c. *Proposed Regulatory Regime for Carbon Capture, Utilisation, and Storage (CCUS)*. Retrieved 20 February 2025.

McLean K, Richardson I. 2019. Greenhouse gas emissions from New Zealand geothermal power generation in context. In: *Proceedings of the 41st New Zealand Geothermal Workshop, 25–27 November 2019*. Auckland.

Ministry for the Environment. 2009. *Projects to Reduce Emissions (PRE)*. Wellington: Ministry for the Environment.

Ministry of Transport. 2010. *New Zealand Travel Survey*. Wellington: Ministry of Transport. Retrieved 20 February 2025.

New Zealand Institute of Chemistry. 1998. *Chemical Processes in New Zealand Auckland*. Christchurch: New Zealand Institute of Chemistry.

New Zealand Petroleum and Minerals. No date. *Geodata Catalogue*. Retrieved 20 February 2025.

Reddy CM, DeMello JA, Carmichael CA, Peacock EE, Xu L, Arey JS. 2008. Determination of biodiesel blending percentages using natural abundance radiocarbon analysis: Testing the accuracy of retail biodiesel blends. *Environmental Science Technology* 42(7): 2476–2482.

Stats NZ. 2018. *Energy Use Survey*. Retrieved 20 February 2025.

UNFCCC. 2009. FCCC/ARR/2008/NZL. *Report of the Individual Review of the Greenhouse Gas Inventories of New Zealand Submitted in 2007 and 2008*. Centralised Review.

UNFCCC. 2014. FCCC/ARR/2013/NZL. *Report of the individual review of the annual submission of New Zealand submitted in 2013*. Centralised Review.

WorkSafe, New Zealand Petroleum and Minerals, MBIE. No date. *NZ Mine Plans*. Retrieved 20 February 2025.

Chapter 4: Industrial Processes and Product Use (IPPU)

4.1 Sector overview

The Industrial Processes and Product Use (IPPU) sector reports greenhouse gas emissions as by-products of chemical, metal and mineral productions. The sector also covers emissions of synthetic greenhouse gases used in products such as refrigerators and air conditioners and aerosols.

4.1.1 IPPU sector in New Zealand

New Zealand has a relatively small number of industrial processing plants that emit non-energy related greenhouse gases. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from eight distinct industrial processes in New Zealand are reported under the IPPU sector. These are:

- calcination of limestone in cement production
- calcination of limestone in burnt and slaked lime production
- production of ammonia, which is further processed into urea
- production of methanol
- production of hydrogen in oil refining and for making hydrogen peroxide
- production of steel, from iron sand and scrap steel
- oxidation of anodes in aluminium smelting
- use of soda ash and limestone in glass making.

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are used in many products including refrigeration and air conditioning equipment. Some recovered HFCs are exported for destruction. Perfluorocarbons are also emitted because of anode effects in aluminium smelting. Sulphur hexafluoride (SF_6) is used in the electricity distribution sector and for small-scale medical and scientific applications. Historically, a very small amount of SF_6 has been used for magnesium casting. No fluorinated chemicals are produced in New Zealand; they are all imported.

Small amounts of CO_2 are reported from the use of lubricants and paraffin wax, imported calcium carbide, carbonates in kaolin clay used for ceramics production, and secondary lead production (recycling of lead-acid batteries). No other emission sources for direct greenhouse gases are applicable to New Zealand and no other activity data are available. Some indirect greenhouse gas emissions are reported from fertiliser, formaldehyde and other industries.

New Zealand reports emissions from Tokelau, which is a dependent territory of New Zealand. Due to the application of different methods, and the complexity of integrating emissions within the main sectors, Tokelau emissions are reported for all activities under the ‘Other’ sector of the Inventory. Therefore, all emissions reported in this sector exclude Tokelau. Please refer to chapter 8 and annex 7 for details of methods applied and the emissions for Tokelau.

4.1.2 Emissions summary

The IPPU sector in New Zealand produces CO_2 emissions (66.1 per cent of total IPPU sector emissions), fluorinated gases (28.9 per cent) and smaller amounts of CH_4 and N_2O. The major categories in the IPPU sector are *Iron and steel production*, *Refrigeration and air conditioning*, *Aluminium production* and *Cement production*. Coal and natural gas are also used on a significant scale for energy in the *Mineral industry*, *Chemical industry* and *Metal industry* categories. Carbon dioxide and any other emissions from combustion of fuels in these industries are reported under the Energy sector.

2023

In 2023, emissions in the IPPU sector contributed 4,031.5 kilotonnes carbon dioxide equivalent (kt CO_2-e), or 5.3 per cent, of New Zealand's gross greenhouse gas emissions.

The largest category is the *Metal industry*, with substantial CO_2 emissions from the *Iron and steel production* and *Aluminium production* categories, as well as PFCs from the *Aluminium production* category in earlier years. The *Mineral industry* and *Chemical industry* categories also contribute significant CO_2 emissions, and most of the non-CO_2 emissions come from the *Product uses as substitutes for ozone depleting substances (ODS)* category.

The IPPU sector also produces smaller amounts of CH_4 from methanol production and N_2O used for medical applications in the *Other product manufacture and use* category.

Coal and natural gas are also used on a significant scale for energy in these industries, and related emissions are reported under the Energy sector in the category *Manufacturing industries and construction*.

The emissions by category are shown in table 4.1.1.

1990–2023

Emissions from the IPPU sector in 2023 were 548.4 kt CO_2-e (15.7 per cent) higher than emissions in 1990 (3,483.1 kt CO_2-e). This increase was mainly driven by increasing emissions from the *Product uses as substitutes for ODS* category, due to the introduction of HFCs to replace ODS in refrigeration and air conditioning, and the increased use of household and commercial air conditioning.

Carbon dioxide emissions also increased, due largely to increased production of aluminium and steel. Between 2020 and 2022 the increase was offset by reduced emissions due to COVID-19 pandemic restrictions and the progressive shutdown of the Marsden Point Oil Refinery. There was a substantial reduction in emissions of PFCs due to improved management of anode effects in the *Aluminium production* category and some reduction in emissions of N_2O used for medical applications in the *Other product manufacture and use* category.

The trends are shown in figure 4.1.1 and figure 4.1.2.

2022–2023

Between 2022 and 2023, emissions from the IPPU sector decreased by 412.4 kt CO_2-e (9.3 per cent).

This change was mainly the result of decreased emissions from the *Refrigeration and air conditioning* category.

Table 4.1.1 New Zealand's greenhouse gas emissions for the IPPU sector by category in 1990 and 2023

Source category	Emissions (kt CO_2-e) 1990	2023	Difference (kt CO_2-e) 1990–2023	Change (%) 1990–2023	Share (%) 1990	2023
Mineral industry (2.A)	561.9	528.2	-33.7	-6.0	16.1	13.1
Chemical industry (2.B)	206.3	122.9	-83.4	-40.4	5.9	3.0
Metal industry (2.C)	2,578.3	2,100.3	-478.0	-18.5	74.0	52.1
Non-energy products from fuels and solvent use (2.D)	17.5	27.0	9.4	53.8	0.5	0.7
Product uses as substitutes for ODS (2.F)	-	1,087.1	1,087.1	-	-	27.0
Other product manufacture and use (2.G)	106.5	129.1	22.6	21.2	3.1	3.2
Other (2.H)	12.5	36.9	24.4	195.5	0.4	0.9
Total	**3,483.1**	**4,031.5**	**548.4**	**205.6**	**-**	**-**

Note: Columns may not sum to total due to rounding.

Figure 4.1.1 New Zealand's annual emissions from the IPPU sector, from 1990 to 2023

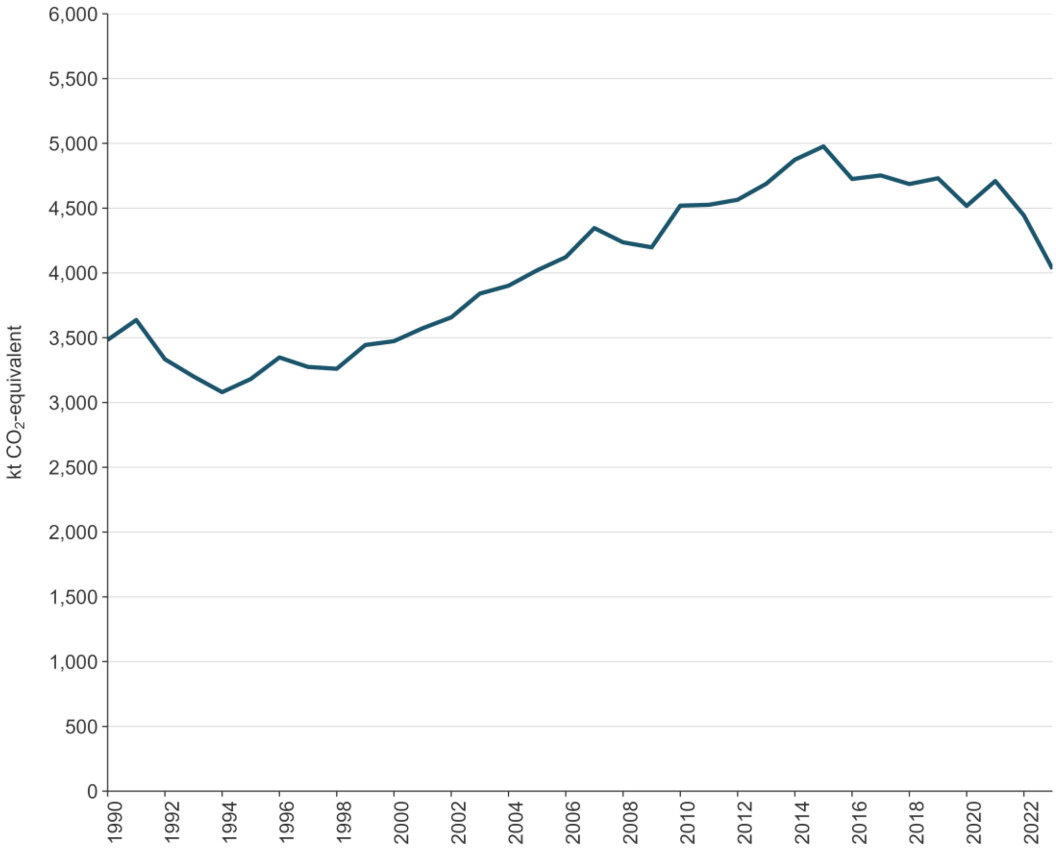
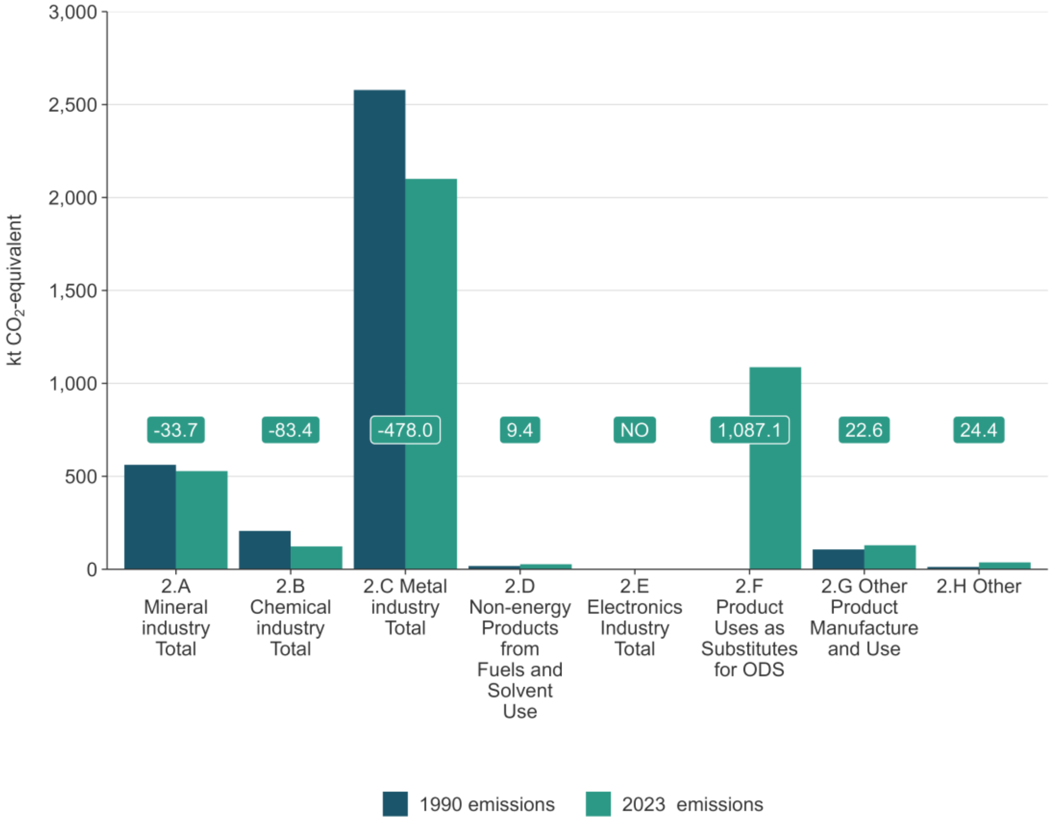


Figure 4.1.2 New Zealand's emissions from the IPPU sector in 1990 and 2023



Note: Emissions from the *Electronics industry* are not occurring (NO).

4.1.3 Key categories for IPPU sector emissions

Details of New Zealand's key category analysis are given in chapter 1, section 1.4. The key categories in the IPPU sector are listed in table 4.1.2.

Table 4.1.2 Key categories in the IPPU sector

CRT category code	IPCC categories	Gas	Criteria for identification
2.A.1.	Mineral industry – Cement production	CO_2	L1, T1
2.B.10.	Chemical industry – Other	CO_2	T1
2.C.1.	Metal industry – Iron and steel production	CO_2	L1, T1
2.C.3.	Metal industry – Aluminium production	CO_2	L1
2.C.3.	Metal industry – Aluminium production	PFCs	T1
2.F.1.	Product uses as substitutes for ODS – Refrigeration and air-conditioning	HFCs	L1, T1

Note: L1 means a key category is identified under the level analysis – approach 1 and T1 is trend analysis – approach 1. Refer to chapter 1, section 1.4, for more information.

4.1.4 Methodological issues for the IPPU sector

Activity data in the IPPU sector have been derived from a variety of sources. In the *Mineral industry* category, the primary data source is emissions data reported under the New Zealand Emissions Trading Scheme (NZ ETS). For the *Chemical industry* and *Metal industry* categories, data (including activity data) are provided to the Ministry of Business, Innovation and Employment (MBIE) in response to an annual survey.

The small scale of New Zealand's industry sector means some activities are carried out by only one or two companies. As a result, the data and emissions information supplied by these companies, in response to surveys, are frequently bound by confidentiality obligations, preventing the publication of their specific activity. The implications for reporting of activity data and emissions are as follows:

- activity data for cement, steel and glass production are reported as confidential in the common reporting tables (CRTs)
- emissions data for *Glass production* (2.A.3) are reported in *Other process uses of carbonates* category (2.A.4)
- emissions from gas used for energy purposes in ammonia production are reported in the *Manufacturing industries and construction* category in the Energy sector (1.A.2.c) where this information can be aggregated with other companies. Only chemical feedstock gas is reported in the *Chemical industry* category. Total energy use for the ammonia–urea plant is not disclosed
- fuel-related emissions from ammonia production are reported in the Energy sector.

New Zealand uses a combination of Intergovernmental Panel on Climate Change (IPCC) Tier 1 and Tier 2 methods for the IPPU sector. Tier 2 methods are used for all key categories. Country-specific emission factors have been used where available, including for emissions of indirect greenhouse gases.

For the *Product uses as substitutes for ODS* category, updated activity data were obtained through a detailed annual survey covering the electrical, refrigeration and other industry participants (Verum Group Ltd, unpublished), as well as importers of HFCs and other substances in this category.

For the small amounts of indirect greenhouse gas emissions reported in the *Chemical industry* category and *Other product manufacture and use* category, data were obtained by a detailed industry survey and analysis in 2006 (CRL Energy, unpublished(a)). Emissions and activity data have been extrapolated for the years since that time.

4.1.5 Uncertainties

Each category addresses specific uncertainties, with the default uncertainties from the IPCC being applied in almost all instances.

Country-specific estimates of uncertainty have been made in the *Product uses as substitutes for ODS* category, reflecting the quality of data provided by survey respondents, and have been updated as needed for this submission.

4.1.6 Verification

The inventory agency (the Ministry for the Environment) verified information on CO_2 emissions reported in the *Iron and steel production* category against information provided by these industries as participants in the NZ ETS.

For PFCs in the *Aluminium production* category and for CO_2 in the *Mineral industry* category, the NZ ETS is used as the primary data source. Verification is done over time as ETS returns are verified by the Environmental Protection Authority (EPA), the agency that administers the NZ ETS.

All data supplied in response to annual surveys (for the *Chemical industry*, *Metal industry* and *Product uses as substitutes for ODS* categories) were verified against national totals or other publicly available information. Where possible, anomalous data were followed up and checked.

4.1.7 Recalculations and improvements

For the IPPU sector, several improvements in the *Refrigeration and air conditioning* category were made, to better account for changes in stocks held by importers and users. These included:

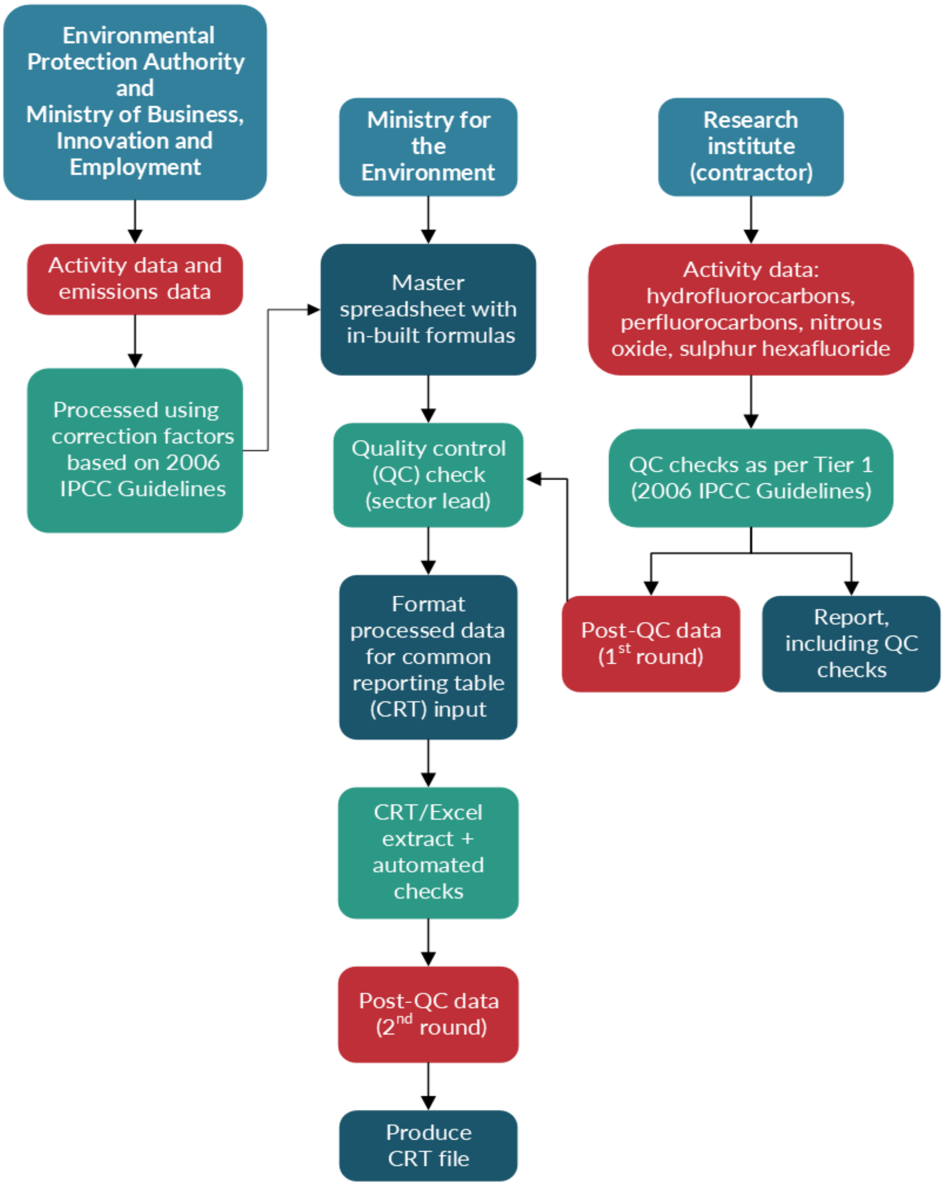
- changes to activity data for the early retirement of heat pumps (a reduction)
- changes to activity data for refrigerant recycling (a reduction)
- changes to activity data for early retirement of air conditioners (an increase) with a consequent spike in disposal trends
- reassessment of historical emissions between 2014 and 2020.

Improvements and recalculations made to the IPPU sector have resulted in an increase of 0.1 per cent (4.9 kt CO_2-e) in estimated IPPU emissions in 1990 and a decrease of 0.6 per cent (25.2 kt CO_2-e) in estimated IPPU emissions in 2022.

4.1.8 Quality-assurance/quality-control (QA/QC) processes

Tier 1 quality checks were carried out on all data collected for this sector, with minor exceptions where data did not require updating. Figure 4.1.3 describes the quality control process map for the IPPU sector. Verification against independent data sources was possible only in specific cases, such as the comparison of NZ ETS returns against data submitted in response to surveys.

Figure 4.1.3 Example: Tier 1 quality checks for the IPPU sector



Note: IPCC = Intergovernmental Panel on Climate Change.

4.2 Mineral industry (2.A)

4.2.1 Description

Emissions from the *Mineral industry* category include CO_2 from the calcination of limestone for cement and lime, and from the use of soda ash and limestone in the production of glass, aluminium, and iron and steel. Only CO_2 from calcination is reported here. Any emissions from the combustion of fuel to provide heat for these activities are reported under the Energy sector.

Only one cement production facility is now operating in New Zealand, a dry-process plant operated by Golden Bay Cement Ltd near Whangārei. Holcim New Zealand Ltd operated a wet process cement plant at Cape Foulwind, on the West Coast of the South Island, but this plant was closed at the end of June 2016 and Holcim is now marketing cement made from imported clinker. Another smaller cement company (Lee Cement Ltd) operated only from 1995 to 1998. The New Zealand cement industry produces clinker from the calcination of limestone and processes it into Portland cement or general-purpose cement.

Three companies (McDonald's Lime Ltd, Websters Hydrated Lime Company and Perry Resources Ltd) have a history of making burnt and slaked lime at five different facilities in New Zealand. The industry has been consolidated over time and two companies (Graymont New Zealand and Websters Hydrated Lime Company) now produce most of New Zealand's burnt and slaked lime. Another company (Lee Processors Limited) reported a small amount of emissions for the 2023 year.

Small amounts of indirect emissions (sulphur dioxide (SO_2) only) from the *Cement production* category are also reported. Some emissions of SO_2 from the *Lime production* category were estimated in 2006 (CRL Energy, unpublished(a)), but there is currently no provision in the CRTs to report this. Some additional SO_2 is derived from sulphur in coal or waste oil used as fuel in cement and lime kilns, and this is reported under the Energy sector.

Two companies make glass in New Zealand, with emissions from the use of soda ash and limestone generated in the process. VISY Glass (formerly O-I) New Zealand makes container glass and Tasman Insulation New Zealand Ltd makes smaller amounts of glass for building insulation products.

Limestone and soda ash are also used in the steel and aluminium industries and would normally be reported in the *Metal industry* category. Emissions from this use of mineral inputs are reported in the *Mineral industry* category (see section 4.2.2); the data are aggregated to protect the confidentiality of data provided by these two glass companies.

A very small amount of CO_2 is reported from the use of kaolin clays in ceramics production.

The only key category is CO_2 emissions from the *Cement production* category (level and trend assessment).

In 2023, the *Mineral industry* category accounted for 528.2 kt CO_2-e (13.1 per cent) of emissions from the IPPU sector. This is 33.7 kt (6.0 per cent) below the 1990 emissions. Production of cement, lime and glass containers had previously increased over time, with a peak in 2015 of 869.3 kt CO_2-e. Emissions decreased after 2015 due to the closure of the Holcim cement plant.

4.2.2 Methodological issues

Choice of activity data

Use of NZ ETS data

Firms that use limestone or soda ash in the production of clinker, cement, burnt or slaked lime, or glass have had emission reporting obligations under the NZ ETS since 2010. The emission returns submitted by participants in the NZ ETS are the primary source of data for CO_2 emissions from these categories.

The EPA administers and audits the emission returns submitted by participants. Data submitted by NZ ETS participants are protected by stringent provisions relating to commercial confidentiality. However, under section 32 and section 149 of the Climate Change Response Act 2002, the inventory agency may request information from the EPA for the purpose of compiling New Zealand's annual National Inventory Report.

All NZ ETS participants must report their emissions in the calendar year but not all receive or apply for ETS units. This encompasses production of clinker, container glass and burnt lime, including any burnt lime that is subsequently made into slaked lime (calcium hydroxide).

Cement production (2.A.1)

In 2023, the *Cement production* category accounted for 379.0 kt CO_2-e (71.8 per cent) of emissions from the *Mineral industry* category. The activity data used are the amounts of clinker produced by the cement plants. Calculation of emissions from clinker production is done on a plant-specific basis by the companies in preparing their NZ ETS returns. Because historically only two companies have been making cement in New Zealand, and now there is only one, the activity data for the *Cement production* category are not reported and have been shown as confidential in the CRTs. For the years up to 2009, activity and emissions data were supplied by the cement companies to MBIE. From 2010, the companies' NZ ETS returns have been used as the data source.

Lime production (2.A.2)

In 2023, the *Lime production* category accounted for 96.2 kt CO_2-e (18.2 per cent) of emissions from the *Mineral industry* category. The activity data used are the amounts of burnt lime produced, reported as tonnes of pure calcium oxide (CaO), as required in NZ ETS returns. This measure is used regardless of whether the lime is subsequently hydrated to make calcium hydroxide ($Ca(OH)_2$).

Activity and emissions data were supplied annually by the lime companies to MBIE until 2009. This included the amount of burnt lime produced each year. From 2010, lime companies have reported CO_2 emissions and the amounts of pure CaO in the lime that they produce in their reporting to the EPA.

Glass production (2.A.3)

Activity and emissions data for the *Glass production* category are not reported in 2.A.3. Instead, emissions from the use of soda ash and limestone in glass making are reported in the *Other process uses of carbonates* (2.A.4) category due to confidentiality concerns. These are aggregated with other relatively small amounts of CO_2 emissions that derive from the calcination of limestone and soda ash.

Other process uses of carbonates (2.A.4)

The data reported in the *Glass production* category have been aggregated as follows and reported in the *Other process uses of carbonates* category.

- Emissions from a relatively small amount of soda ash used by New Zealand Aluminium Smelters Ltd (NZAS) at the Tiwai Point smelter are reported in 2.A.4.b (*Other uses of soda ash*) and aggregated with the CO_2 emissions from soda ash used in glass making.
- Emissions from a relatively small amount of limestone used by New Zealand Steel Limited are reported in 2.A.4.d (*Other*) and aggregated with emissions from limestone used in glass making.

The amounts of soda ash and limestone used are reported as activity data in these two CRTs. Also, because the limestone emissions cannot be fully disaggregated in early data provided by New Zealand Steel Limited, an extremely small amount of CO_2 from coke and electrode use at the steel plant is also included (see section 4.4.2).

Data on glass making for the years up to 2006 were provided by the companies and updated for the years 2007 to 2009 by survey requests from MBIE. Data on limestone and soda ash use were based on the companies' records where available. In the case of one glass-making facility, some historical emissions data had to be estimated based only on glass production rates, because actual limestone and soda ash use was not recorded before 2006.

From 2010 to 2023, the glass companies' NZ ETS returns are used.

A very small amount of CO_2 is reported from the use of kaolin clays in ceramics production (2.A.4.a). The activity data used are the approximate amount of kaolin clay produced for this purpose (Christie et al., 1999). In the absence of better data, the rate of production is assumed constant for the whole time series. Emissions from ground limestone used in liming agricultural soils are reported under the Agriculture sector.

Choice of methods

For the years up to 2009, cement emissions were calculated using the methodology specified in the *Cement CO_2 Protocol* (World Business Council for Sustainable Development, 2005), which uses plant-specific emission factors based on the CaO and magnesium oxide (MgO) content of clinker produced. This also includes an adjustment for emissions due to cement kiln dust. This calculation is consistent with the IPCC Tier 2 method (IPCC, 2006a).

Emissions for lime up to 2009 were calculated using the IPCC Tier 1 method and the default emission factor of 0.75 tonnes CO_2 per tonne of burnt lime produced. For glass making, the IPCC Tier 1 method and default emission factors were also used for the years up to 2009.

For NZ ETS reporting in the *Mineral industry* category (from 2010), the methods used are specified in the Climate Change (Stationary Energy and Industrial Processes) Regulations 2009. These methods require firms making clinker or burnt lime to report CO_2 emissions calculated from the amount of pure product made from calcination. In calculating their emissions, NZ ETS participants who make clinker or lime are required to determine and report the amounts of pure CaO and MgO in the clinker or burnt lime produced, and in kiln dust if relevant. The emissions are calculated from this chemical composition. The calculation of total emissions (TE) can be summarised as:

$$\mathrm{TE} = 0.7848 \times \mathrm{A} + 1.0919 \times \mathrm{B} + 0.7848 \times \mathrm{C}$$

Where: A is the amount of CaO produced

B is the amount of MgO produced

C is the amount of kiln dust produced.

Similarly, based on the Climate Change (Stationary Energy and Industrial Processes) Regulations 2009, NZ ETS participants who make glass report the amounts of pure limestone, dolomite and soda ash that they use in the process. This is consistent with the Tier 3 methods in volume 3, *Industrial Processes and Product Use*, of the 2006 IPCC Guidelines (IPCC, 2006a) but is described as country specific in the CRT because of a minor discrepancy: NZ ETS participants are not required to report separately very small amounts of kiln dust or MgO.

NZ ETS participants in this category are not required to report annually on the specific methods that they have used to determine the amounts of pure CaO, MgO and other compounds that they report in their NZ ETS returns. They are required to keep this information available and it is verified regularly by the EPA.

All other emissions use Tier 1 methods. This includes the small amount of SO_2 emissions reported for cement production. Emissions of SO_2 from lime production were also estimated (CRL Energy, unpublished(a)). These used a country-specific emission factor of 0.5 kilograms SO_2 per tonne of burnt lime produced, derived from plant measurements carried out in earlier years. There is no provision in the CRT to report these emissions, however.

Choice of emission factors and parameters

All calculations made for NZ ETS reporting and used in the *Mineral industry* category are based on plant-specific analysis.

The small amounts of SO_2 emitted in the *Cement production* category are estimated using plant-specific emission factors taken from mass balance data derived for the two cement plants in 2002 and 2005 (CRL Energy, unpublished(a)).

For the very small emissions of CO_2 from the *Ceramics* (2.A.4.a) category, a country-specific emission factor of 0.1 per cent of carbonates (as equivalent calcium carbonate) in local kaolin clay is used.

Other emission factors used are IPCC defaults.

4.2.3 Uncertainty assessment and time-series consistency

Uncertainties

IPCC default uncertainties have been used for all CO_2 emissions from the *Mineral industry* category (see table 4.2.1), except ceramics for which there is substantial uncertainty in the activity data and in the composition of clay. Cement kiln dust is not relevant for 2017 to 2023 because the cement plant now operating reports no significant kiln dust produced. For SO_2 emissions in the *Cement production* category, an uncertainty of ±40 per cent was estimated based on the variance between surveys when these emissions were determined (CRL Energy, unpublished(a)).

Table 4.2.1 Uncertainty in emissions from mineral products

Mineral product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Cement (CO_2)	±1	±1
Cement kiln dust (CO_2)	±1	±5
Cement (SO_2)	±1	±40
Lime (CO_2)	±2	±2
Glass (SO_2)	±5	±10
Glass (NMVOC)	±5	±50
Ceramics (CO_2)	±50	±20
Other uses of soda ash (CO_2)	±3	±2
Other uses of limestone (CO_2)	±3	±2

Time-series consistency

In previous inventory submissions, the reported activity data for lime production have not been fully consistent through the time series because of the change to using NZ ETS data and the use of different calculation methods for these emissions. A consistent approach, based on the methods that companies are required to use for NZ ETS reporting, is now applied for the entire time series.

4.2.4 Category-specific QA/QC verification

For this submission, data for all CO_2 emissions in the *Mineral industry* category underwent Tier 1 quality checks in the preparation of this inventory. The only key category is CO_2 emissions from *Cement production* (level and trend assessment).

Verification of activity data from independent sources is not currently possible. The EPA carries out verification of NZ ETS participants' submitted data on a rotating basis and, as these verifications occur, the inventory agency (the Ministry for the Environment) will make use of the resulting information to verify the emissions data where possible.

4.2.5 Category-specific recalculations

There are no recalculations of direct gases for this category. There are some minor recalculations of SO_2 averaging 0.02 tonne per annum between 1990 and 2022.

4.2.6 Category-specific planned improvements

The inventory agency has worked with the companies in the *Mineral industry* category to improve transparency and robustness in the data provided. Concerns about the confidentiality of data provided by the glass industry remain a barrier to improving transparency further.

4.3 Chemical industry (2.B)

4.3.1 Description

The significant chemical processes occurring in New Zealand are the production of urea, methanol, superphosphate fertiliser, hydrogen peroxide, formaldehyde and ethanol. In addition, a substantial amount of hydrogen was made at the Marsden Point Oil Refinery until the refinery closed in March 2022. Carbon dioxide emissions from this process are reported in the *Chemical industry* category. No other relevant chemical products (such as nitric acid, adipic acid or ethylene) are produced in New Zealand.

Ammonia is made at one site in Taranaki by the catalytic steam reforming of natural gas. The ammonia produced is further processed into urea. The emissions of CO_2 reported in this category arise from the fraction of chemical feedstock CO_2 that is not recovered for urea production. Emissions from combustion at this site are reported separately under the Energy sector (1.A.2.c). Nearly all of the urea produced is used as a fertiliser in New Zealand. The emissions associated with agricultural use of urea (both manufactured in New Zealand and imported) are reported under the Agriculture sector (3.H). A small amount of urea is also used for catalytic reduction of diesel exhaust emissions. The emissions of CO_2 from this use of urea are reported in the *Non-energy products from fuels and solvent use* category (2.D.3).

Methane emissions are reported from the production of methanol, which is made from natural gas feedstock at two sites in Taranaki. From 1990 to 1997, a large proportion of the methanol made in New Zealand was processed into synthetic gasoline for transport use. All emissions associated with the production of gasoline, including the synthetic gasoline produced from 1990 to 1997, are reported under the Energy sector (1.A.1). From 1998, all methanol made in New Zealand has been chemical methanol for export and, therefore, all process emissions from the methanol plants have been reported under the IPPU sector.

A small amount of CO_2 is reported from the use of imported calcium carbide, which is used to produce acetylene for welding. No carbides are manufactured in New Zealand.

Some indirect emissions (oxides of nitrogen (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and SO_2) are reported from methanol, formaldehyde, ethanol and superphosphate fertiliser production.

Emissions from the *Chemical industry* category in 2023 were 122.9 kt CO_2-e (3.0 per cent) of emissions from the IPPU sector. This is 83.4 kt CO_2-e (40.4 per cent) below the 1990 level. The reduction occurred from 2020 and was driven by a decrease in emissions from the Marsden Point Oil Refinery. The refinery company outputs remained low as it prepared for its closure in March 2022 and due to COVID-19 pandemic restrictions.

The only key category is CO_2 emissions from the *Other* category (trend assessment).

4.3.2 Methodological issues

Choice of activity data

Ammonia and urea (2.B.1)

Data on the production of urea are supplied to MBIE by Ballance Agri-Nutrients Limited, which operates the ammonia–urea production plant. The activity data reported are the production of ammonia, which is back-estimated from the amount of urea produced on the basis of a site-specific conversion factor that reflects the actual rate of conversion of ammonia to urea achieved in this plant.

Calcium carbide (2.B.5.b)

A small amount of calcium carbide is imported to New Zealand and used to produce acetylene gas for welding. The approximate amount of calcium carbide imported is used as activity data.

Methanol (2.B.8.a)

Data on methanol production (chemical methanol produced for export) are supplied to MBIE by Methanex, which operates the two methanol plants.

Hydrogen (2.B.10)

With the closure of Refining New Zealand Ltd at the Marsden Point Oil Refinery in March 2022, Evonik Limited becomes the only company that produces a small amount of hydrogen, which is converted to hydrogen peroxide. The hydrogen is produced from CH_4 (from refinery gas and natural gas) and steam. Carbon dioxide is a by-product of the reaction and is vented to the atmosphere.

The activity data reported are the amounts of hydrogen produced, as reported to MBIE by the plant operators.

Fertiliser, formaldehyde and ethanol (2.B.10)

Some indirect emissions (SO_2 and NMVOCs) are also reported from the production of ethanol for purposes other than food and drink, superphosphate fertiliser and formaldehyde.

Choice of methods

Ammonia and urea (2.B.1)

The CO_2 emissions are estimated from a Tier 2 carbon balance, based on the feedstock gas used. The emissions are derived from all carbon in the feedstock gas used, less carbon recovered for urea production and remaining in the urea product (IPCC, 2006a). Note that only gas used as feedstock is included in this calculation. There are also significant CO_2 emissions from gas used for combustion, which are reported under the Energy sector in the *Manufacturing industries and construction* category (1.A.2.c) and aggregated with other data. This method has been used to allow data on the total gas used at the plant to remain confidential.

Calcium carbide (2.B.5.b)

The Tier 1 method was used.

Methanol (2.B.8 and 2.B.8.a)

Data on the natural gas used for methanol production are also supplied to MBIE by the plant operators. However, the available data on gas supplied to the methanol plants do not allow for any separate feedstock to be clearly distinguished from gas used for combustion. Also, close to 100 per cent of the carbon in feedstock gas is converted to methanol. Therefore, no significant CO_2 emissions can be clearly related to the process. The 2006 IPCC Guidelines do not provide a method for estimation of any CO_2 emissions from this process (IPCC, 2006a). Any small amounts of chemical process CO_2 emissions from the methanol production process are included under the Energy sector (1.A.2), along with the much larger amount of combustion-related emissions from the methanol plants.

Fugitive CH_4 from the methanol manufacturing process is estimated using the Tier 1 method. Emissions of NO_x, CO and NMVOC are also reported.

Hydrogen (2.B.10)

Emissions of CO_2 from hydrogen production are calculated using the Tier 2 methodology, based on feedstock composition (IPCC, 2006a). The required data are supplied by MBIE.

Choice of emission factors

Carbon dioxide and methane

For ammonia production, the carbon content of each type of natural gas (up to three types taken from different natural gas fields, and mixed pipeline gas) used as feedstock determines country-specific CO_2 emission factors.

In some years, these emission factors are higher than Tier 1 default emission factors, due to the use of untreated high-CO_2 gas from the Kapuni field as part of the feedstock at this plant. This gas has a carbon content factor (CCF_i) of approximately 22.5 kilograms per gigajoule in comparison with the default of 15.3 kilograms per gigajoule. Kapuni gas has not been used since 2014.

For hydrogen production, site-specific (for refinery gas) and field-specific (for natural gas) emission factors are used to determine the CO_2 emissions from the feedstock gas streams used.

IPCC default emission factors are used to estimate emissions of CH_4 from methanol manufacture and CO_2 from calcium carbide use (IPCC, 2006a). No other information on these emission sources is available.

Indirect emissions

Indirect emissions of NO_x, CO and NMVOC from methanol production are reported (2.B.8) with emission factors estimated by Methanex (CRL Energy, unpublished(a)). The emission factors for NO_x and CO were derived from site measurements, and the emission factor for NMVOC is based on American Petroleum Institute methods for estimating vapour emissions from storage tanks. Some indirect greenhouse gas emissions are also reported for superphosphate fertiliser, formaldehyde and ethanol production (2.B.10). The emission factors used are country specific (CRL Energy unpublished(a)) and are as shown in table 4.3.1.

Table 4.3.1 Country-specific emission factors for indirect emissions

Activity	Type of gas	Emission factor
Superphosphate fertiliser production	SO_2	1.5 kg per tonne of H_2SO_4
Formaldehyde production	NMVOCs	1.5 kg per tonne of formaldehyde
Ethanol production	NMVOCs	6 g NMVOC per litre of ethanol

4.3.3 Uncertainty assessment and time-series consistency

Uncertainties

The IPCC default uncertainties have been used for CO_2 and most non-CO_2 emissions from this category, as shown in table 4.3.2.

Table 4.3.2 Uncertainty in emissions from the *Chemical industry* category

Product	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Ammonia (CO_2)	±2	±6
Calcium carbide	±50	±50
Formaldehyde (NMVOCs)	±2	±50
Hydrogen	±2	±6
Methanol (NO_x and CO)	±2	±50
Methanol (NMVOCs)	±2	±30
Methanol (CH_4)	±2	±80
Superphosphate (varies by site)	±10	±25–60
Sulphuric acid	±10	±15

Time-series consistency

The implied emission factor for CO_2 in ammonia production has reduced by about 5.0 per cent through the time series, reflecting higher plant utilisation and some improvements in plant efficiency. Because ammonia is made at a single site in New Zealand, the implied emission factor may also vary from year to year as a result of maintenance shutdowns and other events that affect plant performance.

The implied emission factor for hydrogen production (2.B.10) also varies from year to year mainly due to changes in refinery gas composition. Other implied emission factors in this category only reflect the default emission factors used.

4.3.4 Category-specific QA/QC and verification

For this submission, data for all CO_2 emissions in the *Chemical industry* category underwent Tier 1 quality checks in the preparation of this inventory. The only key category is CO_2 emissions from *Other* (hydrogen production) (trend assessment).

4.3.5 Category-specific recalculations

There were no recalculations for this category.

4.3.6 Category-specific planned improvements

There were no planned improvements for this category.

4.4 Metal industry (2.C)

4.4.1 Description

The main emissions in the *Metal industry* category in New Zealand are from iron and steel production (from iron sand and historically from recycled scrap steel) and from aluminium production. New Zealand has no production of coke, sinter or ferroalloys.

New Zealand Steel Limited produces iron using an 'alternative iron-making process', from titanomagnetite iron sand (Ure, 2000). This iron-making process involves the direct reduction of iron oxide contained in the sand, with sub-bituminous coal (which forms a reactive char) as the reductant. There is no coke production and no use of blast furnaces. The iron produced is then processed into steel.

Until 2015, Pacific Steel Limited operated an electric arc furnace at a separate site to process recycled scrap steel. The owners of New Zealand Steel Limited bought the Pacific Steel Limited production assets in 2015, and all of New Zealand's steel-making capacity is now integrated at the New Zealand Steel site. Steel billet production at the Pacific Steel plant, using recycled scrap, stopped in October 2015. As a result, production in New Zealand is now focused on newly produced iron rather than recycled steel scrap.

Limestone and soda ash are also used in the steel and aluminium industries and would normally be reported in the *Metal industry* category. Emissions from this use of mineral inputs are reported in the *Mineral industry* category (see section 4.2.2); the data have been aggregated to protect the confidentiality of data provided by these two glass companies.

There is one aluminium smelter in New Zealand, operated by NZAS. The plant produces aluminium by smelting imported bauxite using centre-work prebake technology, resulting in CO_2 and PFC emissions.

Very small amounts of emissions are also reported from secondary lead production (from the recycling of lead-acid batteries) from 1990 to 2015 and from use of SF_6 in a magnesium foundry from 1990 to 1999.

Key categories in the *Metal industry* category are CO_2 emissions from *Iron and steel production* (level and trend assessment) and *Aluminium production* (level assessment), and PFCs from *Aluminium production* (trend assessment).

Emissions from the *Metal industry* category in 2023 were 2,100.3 kt CO_2-e (52.1 per cent) of emissions from the IPPU sector. This is 478.0 kt CO_2-e (18.5 per cent) below the 1990 level. The decrease was driven by a reduction in emissions of PFCs in aluminium smelting, which has been partly offset by increasing CO_2 emissions due to increasing production of steel and aluminium. A small decrease in emissions occurred in 2016 due to the closure of the Pacific Steel plant and the cessation of lead battery recycling.

The New Zealand Steel site was closed from 26 March to 27 April 2020, due to COVID-19 pandemic restrictions. Aluminium production in 2021 and 2022 was approximately 5 per cent lower than 2019.

4.4.2 Methodological issues

Choice of activity data

Iron and steel production (2.C.1 and 2.C.1.a)

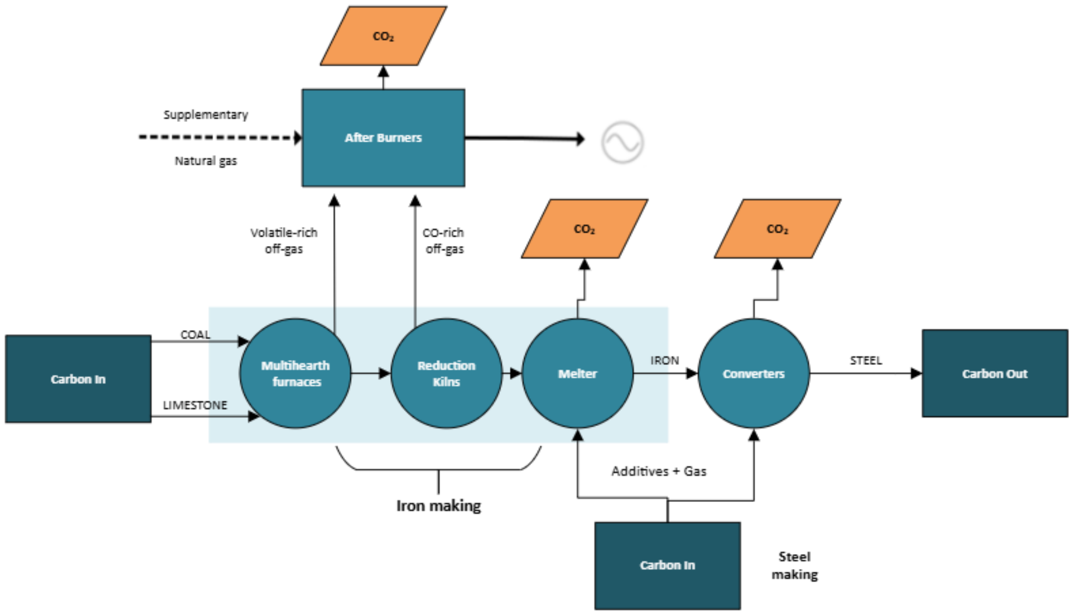
In 2023, the Iron and steel production category accounted for 1,496.4 kt CO_2-e (71.2 per cent) of emissions from the Metal industry category. The activity data (tonnes of steel produced) provided to MBIE came from two steel producers up to 2015 and now come from one; they are regarded as commercially confidential and are reported as confidential in the CRT.

Most of the CO_2 emissions from the Iron and steel production category are produced through the production of iron from titanomagnetite iron sand. Nearly all of the emissions in this process come from the use of sub-bituminous coal as a reducing agent. There is no carbon in the iron sand used by New Zealand Steel Limited (see table 4.4.1). Figure 4.4.1 shows a simplified illustration of steel production in New Zealand.

Table 4.4.1 Typical analysis from New Zealand Steel Limited of the primary concentrate (provided by New Zealand Steel Limited)

Element	Result (%)
Fe_3O_4	81.4
TiO_2	7.9
Al_2O_3	3.7
MgO	2.9
SiO_2	2.3
MnO	0.6
CaO	0.5
V_2O_3	0.5
Zn	0.1
Na_2O	0.1
Cr	0
P	0
K_2O	0
Cu	0
Total	**100**

Figure 4.4.1 Simplified schematic of steel production in New Zealand



Nearly all the carbon entering the process is from coal used as a reductant in the iron-making process, and nearly all of this is emitted as CO_2 in two waste gas streams:

- gas generated in multi-hearth furnaces used to heat and dry concentrated iron sand and coal – this gas contains excess volatiles from the coal
- gas generated in rotary reduction kilns used to convert oxide in the iron sand to iron – this gas is rich in CO.

All this waste gas is combusted in 'afterburners' and used for electricity production. It would not be acceptable for gas containing coal volatiles or CO to be emitted without this combustion stage. There is no other flaring or disposal mode for the waste gases. Emissions from supplementary natural gas used in this plant are reported under the Energy sector (1.A.2.a). New Zealand Steel reported in the past (CRL Energy Ltd unpublished(b)) that there were no detectable CH_4 emissions from this plant. No updated information is currently available.

Much smaller amounts of CO_2 are derived from limestone added to the multi-hearth furnaces, and from additives and natural gas used in melters and steel making.

New Zealand Steel's iron and steel manufacturing processes do not generate or emit CH_4.

Aluminium production (2.C.3)

Carbon dioxide is emitted during the oxidation of carbon anodes. The two PFCs perfluoromethane (CF_4) and perfluoroethane (C_2F_6) are emitted from the reduction cells used for smelting during anode effects. An anode effect occurs when the aluminium oxide concentration in the cell is low. The emissions from combustion of various fuels used in aluminium production (heavy fuel oil, liquefied petroleum gas, petrol and diesel) are reported under the Energy sector.

In 2023, the *Aluminium production* category accounted for 543.0 kt CO_2-e (25.9 per cent) of emissions from the *Metal industry* category. Activity data (production of hot metal aluminium from the smelter) and estimates of CO_2 and PFC emissions were supplied by NZAS to MBIE until 2010. From 2011 to 2023, the CO_2 and PFC emissions data and activity data were sourced from the company's NZ ETS reporting.

Magnesium and other metal production

From 1990 to 1999 a very small amount of SF_6 was used as a cover gas in a magnesium foundry. Emissions are estimated based on an approximate estimate of the amount of SF_6 that was used (2.C.4). No other activity data are available (CRL Energy, unpublished(b)).

A very small amount of CO_2 emissions was also reported from secondary lead production between 1990 and 2015, with the approximate recycled lead output as the activity data. This production has now stopped. The only other metal production that occurs in New Zealand is gold and silver mining. No emissions are reported from these activities.

Choice of methods

Iron and steel production (2.C.1 and 2.C.1.a)

The IPCC Tier 2 approach is used for calculating CO_2 emissions from the iron and steel plant operated by New Zealand Steel Limited. Emissions from pig iron and steel production are not estimated separately because all of the iron made is processed into steel. This is a mass balance approach in which all carbon in the inputs are assumed to be emitted, except the small amount sequestered in the steel produced.

Most of the input carbon comes from the coal used as a reductant. There are also some CO_2 emissions from the use of limestone in iron and steel production. These emissions are reported in the *Mineral industry* category (2.A.4.d), to preserve the confidentiality of data on limestone use supplied by companies in the *Glass production* category. A very small amount of CO_2 from other carbon-containing inputs (coke and electrodes) is also included, and the carbon in steel produced is subtracted.

Emissions from the production of steel by Pacific Steel Limited were also estimated using a Tier 2 mass balance approach. The average carbon content (0.2 per cent by mass) in the finished product is subtracted from the total carbon in the inputs to obtain the amount of carbon emitted. Due to limited process data collected and retained by Pacific Steel Limited in the past, emissions for the years 1990 to 1999 were calculated using the average of the implied emission factors for 2000 to 2008 based on production volume.

Aluminium production (2.C.3)

NZAS calculates the process CO_2 emissions using the International Aluminium Institute's Tier 3 method (International Aluminium Institute, 2006, equations 1–3), which is compliant with the IPCC Tier 2 method (IPPC, 2006a). The same method is used in NZ ETS reporting for aluminium smelting. This method breaks the prebake anode process into three stages: baked anode consumption, pitch volatiles consumption and packing coke consumption.

Also, NZAS adds soda ash to the reduction cells to maintain the electrolyte chemical composition. This results in CO_2 emissions as a by-product. These emissions are reported in the *Mineral industry* category (2.A.4.b) to preserve the confidentiality of data on soda ash use supplied by companies in the *Glass production* category.

Data on the duration of anode effects at the smelter are available for 1993 and later years. Perfluorocarbon (CF_4 and C_2F_6) emissions from aluminium production are estimated using:

- the IPCC Tier 1 method for the years 1990 and 1991. The data needed to apply a Tier 2 method are not available
- interpolation for 1992; at this time, there was still no recording of anode effect duration

- the IPCC Tier 2 method (using slope coefficients) from 1993 to 2023. This method is applied in the reporting requirements the company now uses in its NZ ETS returns.

There is no history of direct measurement of PFC emissions at the smelter, so site-specific slope coefficients (required for the use of Tier 3) are not currently available.

Magnesium production (2.C.4)

Emissions are estimated based on an approximate estimate of the amount of SF_6 that was used as cover gas and on the basis that all SF_6 used is emitted. The method is Tier 1.

Lead production (2.C.5)

The Tier 1 method was used.

Choice of emission factors

Carbon dioxide

Plant-specific emission factors are applied for the sub-bituminous coal used as a reducing agent in iron and steel production. For the early years, the coal emission factor was 0.0937 tonnes of CO_2 per gigajoule, as supplied by the steel company. Plant-specific emission factors are also used for other carbon-containing inputs in both the *Iron and steel production* and *Aluminium production* categories.

The changes of implied emission factors for steel production across the time series are mainly caused by the changes of input mixture from year to year.

For secondary lead production, the IPCC default emission factor (0.2 tonnes of CO_2 per tonne of lead recycled) is used.

Perfluorocarbons and sulphur hexafluoride

Default emission factors (slope coefficients) are used for emissions of CF_4 and C_2F_6 from aluminium production. Data on the duration of anode effects are not available for the years 1990 to 1992 and for those years a Tier 1 method is used, with the default emission factors of 0.4 kilograms CF_4 and 0.04 kilograms C_2F_6 per tonne of aluminium.

Emissions of SF_6 used in magnesium casting are immediate.

Indirect emissions

Emissions of indirect greenhouse gases (CO, SO_2 and NO_x) are reported for the *Iron and steel production* and *Aluminium production* categories. These are based on a mass balance calculation (for SO_2) and a mix of plant-specific emission factors and IPCC defaults for other gases (CRL Energy, unpublished(a)).

4.4.3 Uncertainty assessment and time-series consistency

Uncertainties

IPCC default uncertainties have been used for activity data (see table 4.4.2). For the CO_2 emission factors in the *Iron and steel production* category, an uncertainty of ±7 per cent was assessed to reflect some uncertainty in the carbon content of the product. An uncertainty of

±30 per cent was assessed for PFCs reflecting the use of Tier 1 methods for the first three years. The uncertainties for indirect gases were assessed on a site-specific basis at the time the data were collected (CRL Energy, unpublished(a)). For magnesium casting, the uncertainty of ±100 per cent represents the approximate activity data (SF_6 usage) available. This activity was already historical when the data were collected.

Table 4.4.2 Uncertainty in emissions from the metal industry

Category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Iron and steel (CO_2)	±5	±7
Iron and steel (CO)	±5	±30
Iron and steel (NO_x)	±5	±70
Aluminium (CO_2)	±5	±2
Aluminium (PFCs)	±5	±30
Aluminium (SO_2)	±5	±5
Aluminium (CO)	±5	±40
Aluminium (NO_x)	±5	±50
Magnesium (SF_6)	±100	±30
Lead (CO_2)	±50	±50

Time-series consistency

The implied emission factors for PFC emissions from aluminium production fluctuated over the time series between 1990 and 1998. The introduction of monitoring at the aluminium smelter in 1993 contributed to process and management improvements that reduced the frequency and duration of anode effects. This improvement process continued until about 1998. Since that time, emissions have been lower and relatively stable, due to the much better control of anode effects (see table 4.4.3).

Table 4.4.3 Explanation of variations in New Zealand's aluminium emissions

Variation in emissions	Reason for variation
Increase in CO_2 and PFC emissions in 1996	Commissioning of Line 4 cells
Decrease in CO_2 emissions in 1995	Good anode performance, compared with 1994 and 1996
Decrease in CO_2 emissions in 1998	Good anode performance
Decrease in CO_2 emissions in 2001, 2003 and 2006	Fewer cells operating from reduced aluminium production due to reduced electricity supply
	Good anode performance contributed in 2001
Decrease in CO_2 emissions in 1996	All cells operating, including introduction of additional cells
	Increasing aluminium production rate from the cells
Decrease in PFC emissions in 1995	Reduced anode frequencies
	The implementation of the change control strategy to all reduction cells
	Repairs made to cells exerting higher frequencies
Perfluorocarbon emissions remained high in 1997	Instability over the whole plant as the operating parameters were tuned for the material coming from the newly commissioned dry scrubbing equipment (removes the fluoride and particulate from the main stack discharge)
Decrease in PFC emissions in 1998	Cell operating parameter control from the introduction of modified software. This software has improved the detection of an anode-effect onset and will initiate actions to prevent the anode effect
Perfluorocarbons emissions remain relatively static in 2001, 2003 and 2006	Increased emissions from restarting the cells

The activities of lead-acid battery recycling and use of SF_6 in a magnesium foundry ceased during the time series resulting in zero emissions after 1999 and 2015 respectively.

4.4.4 Category-specific QA/QC and verification

The three key categories in the *Metal industry* category are CO_2 emissions from *Iron and steel production* (level and trend assessment), *Aluminium production* (level assessment) and PFCs from *Aluminium production* (trend assessment). The data for all direct emissions in this category underwent Tier 1 quality checks in the preparation of this inventory.

4.4.5 Category-specific recalculations

There were no recalculations for this category.

4.4.6 Category-specific planned improvements

There were no planned improvements for this category.

4.5 Non-energy products from fuels and solvent use (2.D)

4.5.1 Description

The emissions reported in the *Non-energy products from fuels and solvent use* category include CO_2 from the use of lubricants and a very small amount from the use of paraffin wax, some of which is likely to be used for candles.

In addition, a small amount of CO_2 is reported from the use of urea-based catalysts in diesel exhaust fluid (DEF) for control of NO_x emissions in diesel engine exhaust gas. These emissions are associated with transport, and the method used is given in volume 2, *Energy*, of the 2006 IPCC Guidelines (IPCC, 2006b); however, the CRT does not appear to allow for them to be reported under the Energy sector, so they are placed in 2.D.3.

Some emissions of indirect greenhouse gases (mainly NMVOCs) are estimated and reported from:

- the use of asphalt in road paving and roofing applications
- painting
- degreasing and dry cleaning
- use of solvents in printing
- general domestic and commercial use of solvents.

Emissions from the *Non-energy products from fuels and solvent use* category in 2023 were 27.0 kt CO_2-e (0.7 per cent) of emissions from the IPPU sector.

There were no key categories.

4.5.2 Methodological issues

Choice of activity data

Lubricant use (2.D.1)

Activity data for the years between 2018 and 2023 are provided by MBIE. However, this information is not available for the years before 2018. For earlier years, the activity data have been estimated by assuming that the amount of lubricant used was proportional to the amount of 'other petroleum products'[22] used in New Zealand in the year.

Paraffin wax use (2.D.2)

A small amount of paraffin wax is imported into New Zealand. There were no reliable data on import volumes, so the activity data have been estimated from an estimate of the value of imports. This is only available for 2005 to 2011, and the activity data for other years have been assumed to be the same.

Use of urea-based catalysts in transport (2.D.3)

The activity data (quantity of DEF used) are estimated from total sales of diesel, with the assessment that 33 per cent of fuel is used in heavy vehicles and 51 per cent of the heavy vehicle fleet currently uses DEF. The amounts for years up to 2016 are estimated by back casting the uptake of vehicles that require DEF over time. There was no use of urea catalysts before 2008.

Asphalt paving and roofing and solvent use (2.D.3)

Three main bitumen production companies that provide materials for road paving are operating in New Zealand. Data on bitumen production and emission rates were provided by these companies (CRL Energy, unpublished(a)). One company is also manufacturing asphalt roofing in New Zealand.

Solvent use was estimated in 2006 (CRL Energy, unpublished(a)) and, for all of these sources, activity data for the years up to 2005 have been extrapolated for 2006 to 2023 in the absence of any updated information.

Choice of methods

Tier 1 methods (IPCC, 2006a, 2006b) are used to estimate all emissions in this category. Only approximate activity data are available, with no country-specific information on the amounts of lubricant and paraffin wax used for specific applications.

Choice of emission factors

Lubricant use (2.D.1) and paraffin wax use (2.D.2)

Default emission factors (carbon content and 'oxidised during use' factor) are used for these categories.

Use of urea-based catalysts in transport (2.D.3)

Default emission factors are used. DEF sold in New Zealand conforms with international norms and contains 32.5 per cent urea, which is the default value.

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[22] Includes bitumen, lubricants, solvents, waxes, petroleum coke, white spirit and other liquid fuels.

Asphalt paving and roofing and solvent use (2.D.3)

The bitumen content of road paving used in New Zealand is about 6 per cent, which is lower than commonly used in most countries. The NMVOC emissions from road paving are calculated using a country-specific method based on the fraction of bitumen in asphalt used in road paving material, the fraction of solvent added to bitumen and an assessment that 75 per cent of the solvent added will be emitted (see table 4.5.1).

Table 4.5.1 Calculation of NMVOC emissions from road paving

Calculation of NMVOC emissions from road paving
NMVOC emitted = A × B × C × D
Where:
A = road paving material used (kilotonnes)
B = fraction by weight of bitumen in asphalt
C = fraction of solvent added to bitumen (0.04)
D = fraction of solvent emitted (0.75)

The fraction of bitumen in asphalt used in road paving materials was reduced over time as methods of laying roading improved (see table 4.5.2).

Table 4.5.2 Fraction of bitumen in road paving material

Reporting years	Fraction by weight of bitumen in asphalt (B above, in table 4.5.1)
1990–2001	0.8
2002–2003	0.65
2004–2018	0.6

For asphalt used as roofing material, IPCC default emission factors of 0.05 kilograms NMVOC and 0.0095 kilograms CO per tonne of product have been used.

4.5.3 Uncertainty assessment and time-series consistency

Uncertainties

IPCC default uncertainty is estimated for CO_2 from lubricant use. The uncertainties used for indirect emissions in this category are a mix of defaults and country specific. These uncertainties are shown in table 4.5.3.

Table 4.5.3 Uncertainty in emissions in non-energy products from fuels and solvent use

Category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Lubricant use	±20	±50
Paraffin wax use	±20	±100
Use of urea-based catalysts in transport	±50	±10
Asphalt road paving	±40	±40
Asphalt roofing	±50	±40
Paint application	±40	±50
Degreasing and dry cleaning	±40	±60
Printing	±50	±50
Domestic and commercial solvent use	±50	±60

Time-series consistency

For CO_2 emissions in this category, the activity data have been extrapolated and emission factors are defaults. The implied emission factors and time-series consistency reflect this.

4.5.4 Category-specific QA/QC and verification

Non-energy products from fuels and solvent use is a non-key category. Verification of the data from independent sources was not feasible.

4.5.5 Category-specific recalculations

Changes made in the lubricant activity data have led to a decrease of average annual emissions by 16.7 kt in this category between 1990 and 2022.

4.5.6 Category-specific planned improvements

This category is not a priority for improvement, due to the small scale of emissions. The inventory agency will make use of improved activity data where possible, particularly for lubricants and urea-based catalysts.

4.6 Electronics industry (2.E)

New Zealand has no significant industry engaged in the manufacture of electronic products, and no emissions are reported in this category.

4.7 Product uses as substitutes for ODS (2.F)

4.7.1 Description

Hydrofluorocarbons are used in a wide range of equipment and products, including refrigeration and air conditioning systems and aerosols. Small amounts of PFCs have also been used in these applications in some years. No HFCs or PFCs are manufactured in New Zealand. Perfluorocarbons are also emitted from the aluminium-smelting process and these emissions are reported in the *Metal industry* category (2.C.3.b).

The use of HFCs in New Zealand began in 1992 and has increased since the mid-1990s when chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) began to be phased out under the Montreal Protocol. The Ozone Layer Protection Act 1996 set out a programme for phasing out the use of ODS in New Zealand. New Zealand is a signatory to the Kigali Amendment to the Montreal Protocol and is now phasing down the consumption of HFCs. The phase-down is being implemented through a permitting system for imports, which began on 1 January 2020.

In 2023, emissions in the *Product uses as substitutes for ODS* category were 1,087.1 kt CO_2-e or 27.0 per cent of emissions from the IPPU sector. This was a decrease of 458.9 kt CO_2-e (29.7 per cent) from the 2021 level of 1,546.0 kt CO_2-e. No HFCs or PFCs were used in 1990. The first consumption of HFCs in New Zealand was reported in 1992 and the first consumption of PFCs in 1995.

Most of these emissions come from the use of HFCs in the *Refrigeration and air conditioning* category. Emissions from the use of HFCs in the *Refrigeration and air conditioning* category (level and trend assessment) were identified as a key category.

4.7.2 Methodological issues

Choice of activity data

New Zealand imports substantial amounts of new HFCs, mainly for use as refrigerants, both in bulk and in factory-charged equipment. Both bulk chemical and equipment charged in New Zealand are exported, but on a much smaller scale.

Most of the activity data for the *Product uses as substitutes for ODS* category are collected using annual surveys of companies that import, distribute and export refrigerants and other synthetic gases, manufacture or import products containing them or use them on a significant scale (Verum Group, unpublished).

Data on bulk imports and exports of refrigerant, and factory-charged imported and exported equipment, were obtained using a survey. Detailed information on the supplies and banks of chemical in each sub-application was obtained from survey questionnaires and follow-up calls to request specific data. The survey included:

- 14 companies known to be significant importers and distributors of HFCs and PFCs
- approximately 50 manufacturers, exporters, importers and significant users of air conditioning and refrigeration systems and equipment
- importers, service agents and installers of vehicle air conditioners, and their trade association
- the three companies that supply fire protection equipment
- five foam blowing companies and their suppliers
- the government pharmaceutical purchasing agency (Pharmac)
- aerosol importers
- four past importers of SF_6
- eighteen main SF_6 electrical users.

Equipment sales data are also sourced from the Energy Efficiency and Conservation Authority for equipment reported under New Zealand's mandatory energy efficiency labelling scheme. Import data are sourced from Stats NZ and the EPA for information derived from the NZ ETS and climate change levy.

Refrigeration and air conditioning (2.F.1)

Data are used to estimate the annual sales of new refrigerant and the total charge of new equipment, for input into the mass balance equation used to estimate emissions of each compound for each sub-application.

This information has been used to assess the mass balance for each sub-application. However, the attribution of bulk chemical to individual sub-applications is less accurate than the data on total amounts of each chemical imported. It is consistently challenging to attribute bulk chemical accurately to each of the six specific sub-applications.

The accurate attribution of bulk chemical to a specific year of use is also challenging, due to large year-to-year variations in the amounts imported. Imports to New Zealand are variable at any time, due to the small amounts of some refrigerants that are used. In addition, import volumes have fluctuated at various times. Significant stockpiling of refrigerant gases occurred in anticipation of NZ ETS obligations in 2013. Stockpiling also appears to have occurred in other years, in response to various price and policy changes. Stock changes are an important factor in applying the mass balance approach to calculate emissions.

Care is also needed to avoid double counting of chemical that is sold more than once by wholesalers and other owners before it is used.

Additionally, the data on the imports of refrigerant in pre-charged equipment are incomplete and inaccurate. Total reported imports do not appear to fully account for the quantities in equipment that is sold, as indicated by New Zealand's mandatory product labelling scheme. The number of vehicles imported is known accurately (*Mobile air conditioning*) but there is significant uncertainty in the quantities of refrigerant in each vehicle due to the variety of new and second-hand models imported.

As a result of these challenges, several expert judgements were made to attribute activity data for each HFC over time and across sub-applications. These are documented in the report by Verum Group (unpublished) and in the stock models used to calculate emissions.

For the *Mobile air conditioning* sub-application, only HFC-134a is used in New Zealand and has been since 1994. Data on vehicle registrations and fleet numbers are provided by the New Zealand Transport Agency. Estimates of the annual amount added to the bank, and first fill emissions, are based on information on the number of new cars, trucks and buses with air conditioning added to the fleet each year. The results of the survey of bulk importers and distributors were also used to help determine the amount of HFC-134a sold for mobile air conditioning.

In 2009, the average charge of HFC-134a in vehicle air conditioning systems added to the bank at that time was estimated to be as shown in table 4.7.1, based on IPCC defaults and information from the industry.

Table 4.7.1 Average charge (grams) of HFC-134a in mobile air conditioners, 2009

Charge for cars and vans (g)	Charge for heavy trucks (g)	Charge for buses (g)
600	800	4000

These amounts were higher in earlier years, with the charge in a car air conditioner at approximately 700 grams in 2000. New Zealand imports a wide variety of vehicles, many of them used cars, and it is not feasible to obtain accurate and up-to-date statistics on their refrigerant charge. Based on this earlier trend, the average charges in new vehicles added to the fleet were assessed to reduce by 2.0 per cent per year for 2010 to 2023. Discussion with importers in 2018 indicated that the ongoing trend to reduce these charges has continued (Verum Group, unpublished).

Foam blowing agents (2.F.2)

Only closed-cell foams are produced in New Zealand. Companies importing and using HFCs for foam blowing have provided data on the gas imported and used, in response to the annual survey. Survey data showed a growing trend in the utilisation of commercial HFC blends up until 2019. During 2021 and 2023, foam companies have moved to the increasing use of hydrofluoroolefin (HFO) blowing agents. Small quantities of HFC-245fa are estimated to be contained in insulating foam in refrigerators and freezers that are imported from Mexico and the United States of America. Imported items from other source countries are unlikely to contain HFCs.

Fire protection (2.F.3)

Three companies in New Zealand have imported and supplied fire protection equipment that contains HFC-227ea, with two other firms installing small amounts in marine fire protection systems. This gas has been used since 1994 as a substitute for ODS. No other HFCs or PFCs are used. The companies have provided data on the amount imported in equipment, in response to the annual survey. There have been no new installations in recent years. Current stocks and recovered chemical are used to replace leakage.

Aerosols (2.F.4)

Most of the HFC use and emissions in this category are for medical use in metered dose inhalers (MDIs). MDIs that use HFC-134a were introduced in 1995, and all MDIs sold in New Zealand from 2012, if they have used any propellant, have used HFCs. Most of the MDIs imported and sold in New Zealand contain either 200 or 120 doses and either 15 grams or 9.5 grams of HFC-134a propellant per inhaler. A small proportion use HFC-227ea. Also, approximately 12.0 per cent of MDIs now sold do not use a propellant at all.

All MDIs used in New Zealand are imported. Pharmac supplies annual data on the sales of MDIs, measured as millions of doses for HFC and non-propellant inhalers.

An approximate weighted average is used to estimate emissions per dose for each propellant. This average amount of propellant per dose has changed over time due to a changing mix of inhaler types (120 and 200 dose inhalers) as shown in table 4.7.2.

Table 4.7.2 Average emissions per dose in metered dose inhalers (milligrams)

Propellant	Inhalers using HFC-134a	Inhalers using HFC-227ea
1995–2015	81.4	66.9
2016	80.2	68.1
2017	79.5	68.5
2018	78.3	70.3
2019	77.9	73.5
2020	77.5	83.2
2021	76.9	87.8

HFC-134a is the predominant HFC propellant used in non-medical aerosols in New Zealand. A small amount of HFC-152a has been used from 2015. A very small amount of HFC-43-10mee was reported between 2020 and 2023, mixed with HFC-134a in a specialised aerosol product.

All non-MDI aerosols used in New Zealand now are imported, with the propellant charge already in place. Up until 2014, one company loaded specialised aerosols in New Zealand with HFC-134a as the propellant. This activity is no longer carried out.

Nearly all the aerosol cans that are imported and sold in New Zealand use hydrocarbon propellants, while only a few specialised applications use HFCs.

Information on the importation, manufacture and use of non-MDI aerosol products has been sourced from the survey data, which has been supplied by importers, from the one New Zealand aerosol manufacturer that previously used HFC-134a and from their industry association.

Import data, irrespective of the source, are not complete or reliable due to the diffuse nature of the aerosol market. The available data do not clearly differentiate aerosols containing HFCs from the significantly larger number that contain hydrocarbons.

Survey data have provided some incomplete estimates of imports containing HFCs, for example, they accounted for 6.6 tonnes of HFC-134a in 2006. By combining this information with data from the New Zealand manufacturer, an assessment has been made of the proportions of HFC-134a in aerosol products sold in New Zealand:

- zero from 1990 to 1995, when HFC propellant had not yet been introduced
- phased in from 1996 to 2000, reaching 1 per cent in 2000
- 1 per cent (approximately 17 tonnes of HFC-134a annually) from 2001 to 2016
- phasing down by 0.1 per cent each year from 2017 to 2019, driven by introduction of HFOs
- remaining at 0.7 per cent for 2020
- 0.6 per cent in 2023 due to a further increase in the use of HFOs.

For all non-MDI aerosol products using HFC-134a as the propellant, the average propellant charge is assessed to be 84 grams.

Choice of methods

Refrigeration and air conditioning (2.F.1)

The Tier 2b mass balance approach is used to estimate emissions from the *Refrigeration and air conditioning* category. This method is used because complete and accurate data are available on bulk imports of the refrigerants used for these applications. The alternative Tier 2a approach would require bottom-up data on the charges, leakage rates and population of a great variety of equipment items. This information is not available.

Annual sales and the charge in new equipment are calculated as shown in box 7.3 in the 2006 IPCC Guidelines (IPCC, 2006a) (see box 4.1). Total charge of new equipment includes equipment that is later exported.

Box 4.1

IPCC (2006a) first equation in box 7.3

Annual Sales of New Refrigerant

= Domestically Manufactured Chemical

+ Imported Bulk Chemical – Exported Bulk Chemical

+ Chemical Contained in Factory Charged Imported Equipment

– Chemical Contained in Factory Charged Exported Equipment.

Total Charge of New Equipment

= Chemical to Charge Domestically Manufactured Equipment that is not Factory Charged

+ Chemical to Charge Domestically Manufactured Equipment that is Factory Charged

+ Chemical to Charge Imported Equipment that is not Factory Charged

+ Chemical Contained in Factory Charged Imported Equipment

– Chemical Contained in Factory Charged Exported Equipment.

The mass balance approach uses equation 7.9 in the 2006 IPCC Guidelines (IPCC, 2006a) (box 4.2).

Box 4.2

IPCC (2006a) equation 7.9
***Emissions** = Annual Sales of New Refrigerant – Total Charge of New Equipment + Original Total Charge of Retiring Equipment – Amount of Intentional Destruction*

Spreadsheet models have been used to represent the refrigerant consumption and banks. Estimates have been made for the six sub-applications: *Household refrigeration*, *Commercial refrigeration*, *Industrial refrigeration*, *Transport refrigeration*, *Stationary air conditioning* and *Mobile air conditioning*. For commercial and industrial refrigeration, where the required data are available, the models distinguish and calculate separately:

- recovery for destruction
- recovery for reuse of the refrigerant.

Country-specific assessments for the lifetime of equipment have been made to calculate the 'original total charge of retiring equipment'. These assessments include progressive retirement of air conditioning equipment in years 8 to 19, and dehumidifiers in years 6 to 15. The analysis also takes into account the impact of the 2011 Canterbury earthquake, which resulted in emissions from demolition of damaged buildings in the following years.

There is currently no facility for the intentional destruction of HFCs or PFCs from this application operating in New Zealand. Some HFCs are exported for destruction in Australia, and the amounts recovered for destruction are reported.

Table 4.7.3 summarises the methodological tiers that are used for each sub-application.

Table 4.7.3 Summary of methodological tiers by sub-application

Sub-application	Chemical	Method used (Tier)
Household refrigeration	HFC-134a	2a
Commercial refrigeration	HFC-32	2a
	HFC-125	2b to 2006, 2a for 2007–2021
	HFC-134a	2a
	HFC-143a	2b
Industrial refrigeration	HFC-32	2a
	HFC-125	2a
	HFC-134a	2b
	HFC-143a	2a
Transport refrigeration	HFC-32	2a
	HFC-125	2a
	HFC-134a	2a
	HFC-143a	2a
Stationary air conditioning	HFC-32	2b
	HFC-125	2a to 2006, 2b for 2007–2021
	HFC 134a	2a
Mobile air conditioning	HFC-134a	2b

Other (2.F.2, 2.F.3 and 2.F.4)

The IPCC Tier 1a method was used for foam blowing agents and fire protection equipment.

Aerosol emissions are calculated using the IPCC Tier 1a and Tier 2a method (IPCC, 2006a, equation 7.6). Tier 2a requires subdividing these emissions by sub-application. In this submission, emissions from MDIs are reported separately as a sub-application (2.F.4.a). Insufficient data are available to further subdivide aerosol products by sub-application and all other aerosol products are reported together (2.F.4.b).

Choice of emission factors

Refrigeration and air conditioning (2.F.1)

The emission factors used in each sub-application (other than *Mobile air conditioning*) were assessed using a combination of IPCC defaults, information from the New Zealand industry and expert judgement.

In addition, the annual leakage rates were adjusted in some cases, to ensure that the total results for all sub-applications were consistent with the much more complete and accurate data available to estimate the total mass balance (for all five sub-applications) for each chemical. For each chemical, use of the Tier 2b method means that emission factors only affect the attribution of emissions among these five sub-applications, not the total emissions. Attribution to any one sub-application is subject to high uncertainties and may, consequently, be subject to significant apparent year-to-year variations.

These emission factors are detailed in the report by Verum Group (unpublished) and in the stock models used to calculate emissions.

For *Mobile air conditioning*, the model distinguishes between leakage that is replaced in regular servicing (3.0 per cent of the bank each year) and refrigerant that leaks but is not replaced because owners do not have the air conditioning units serviced. The overall average amount of loss for the fleet is assessed to be 15±10 per cent; that is, at any time a notional 'average vehicle' will have 85±10 per cent of the charge that it would have if there was no leakage. There is also some uncertainty in the proportion of bulk imports of HFC-134a used in *Mobile air conditioning* as opposed to the other sub-applications.

Foam blowing agents (2.F.2)

The IPCC default emission factors for closed-cell foam are used, that is, assuming 10.0 per cent loss in the first year of use and 4.5 per cent in each of the following 20 years.

Fire protection (2.F.3)

For fire protection equipment, a country-specific emission factor of 0.015 (1.5 per cent of the charge lost in leakage each year (Verum Group, unpublished)) is used. This estimate is based on information from one major supplier of these systems, which was able to supply records of the amount of HFC-227ea it used to replace leakage and accidental discharges. Fire protection systems have a long life and retirements are rare. Based on information from the system suppliers, it is assessed that all refrigerant present on decommissioning is recovered.

Aerosols (2.F.4)

Aerosol emissions are considered to be prompt (emitted in the first year or two after manufacture or import) and so the default emission factor of 50.0 per cent of the initial charge emitted per year is applied.

4.7.3 Uncertainty assessment and time-series consistency

Uncertainties

Data on bulk imports of refrigerant gases in the *Refrigeration and air conditioning* category are complete and accurate, with uncertainty of ±5 per cent. Data on the amount imported in factory-charged equipment, and the amount in retired equipment, are much less accurate, and uncertainties are estimated with some use of expert judgement.

Table 4.7.4 summarises the uncertainties for each category. For the *Refrigeration and air conditioning* category, uncertainty is attributed only to the activity data and is updated annually to reflect the share of different equipment types in the latest reported year. Uncertainties in this category have also been estimated for each sub-application. However, these reflect the uncertain attribution of emissions between sub-applications, which does not contribute to the overall uncertainty given for this category.

Table 4.7.4 New Zealand's uncertainties in *Product uses as substitutes for ODS*

Category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Refrigeration and air conditioning	±24	NA
Foam blowing agents	±12	±50
Aerosols	±25	±10
Fire protection	±30	±30

Note: NA = not applicable.

Time-series consistency

There is substantial variation over the time series due to the introduction and increasing use of HFCs as replacements for CFCs and HCFCs. In previous submissions, year-to-year variation in the calculated emissions from refrigeration and air conditioning has been driven by changes in stocks from year to year. Recalculations made for this submission have reduced this apparent variance.

Calculated annual HFC emissions have increased at a consistent rate from 1,010.5 kt CO_2-e in 2010 to 1,087.1 kt CO_2-e in 2023. The banks of HFCs in operating equipment are also increasing over time, particularly in air conditioners. Future emissions will depend on the maintenance and eventual retirement of this equipment.

4.7.4 Category-specific QA/QC and verification

Refrigeration and air conditioning (2.F.1)

Use of HFCs in *Refrigeration and air conditioning* was a key category (level and trend assessment). In the preparation of this inventory, the data on HFCs underwent Tier 1 quality checks. During data collection and calculation, activity data provided by industry were verified against national totals where possible, and unreturned questionnaires and anomalous data were followed up and verified to ensure a complete and accurate record of activity data.

For the years up to 2001, the survey data supplied by importers on bulk HFC imports were verified by comparison with import data supplied by Stats NZ. The former Ministry of Economic Development compiled a detailed breakdown of bulk HFCs using these data and information from import licences for a range of mixtures, such as HFCs and HCFCs. This analysis has not been carried out since 2001, due to restricted access to commercially sensitive import data.

Consequently, this independent check on the total imports reported by bulk chemical suppliers became unavailable after that year.

Survey data provided by Fisher and Paykel Limited (the largest importer and manufacturer) were used to compare with total import data, where possible. In addition, bulk importers now submit NZ ETS returns, which are used to verify survey information on import volumes, where possible.

There were no other key categories. The data underwent Tier 1 quality checks.

4.7.5 Category-specific recalculations

In this submission, the following was recalculated.

a) Correction of minor calculation errors for HFC foam blowing manufacturing chemicals re-exported. Total foam blowing emissions for each HFC were slightly affected by the accumulation of these errors: estimates of 2022 emissions increased by 0.10 kt CO_2-e, 0.03 kt CO_2-e and 0.04 kt CO_2-e for HFC-227ea, HFC-245fa and HFC-365mfc.

b) Undeclared refrigerant stock estimates were changed from 110 tonnes and 2 tonnes R134a to 140 tonnes and 77 tonnes in 2021 and 2022, respectively. New coolstores installations in 2022 reduced R134a by 10 tonnes, which affects stocks with a minor reduction of those installation emissions (0.40 kt CO_2-e). The reduced bulk supply had led to a reduction in estimates of commercial refrigeration HFC-134a operations emissions in 2021 and 2022 (totalling 38.9 kt CO_2-e and 45.1 kt CO_2-e).

c) A shortage of R32 to replace leakage from newer heat pumps suggested there may be greatly reduced leakage of HFC-32 (reduced 2022 estimate from 2.9 per cent to 2.4 per cent of stocks; -6.1 kt CO_2-e). Similarly, for the HFC-125 component of R410A in older heat pumps, somewhat reduced stocks suggested a smaller impact on 2022 leakage emissions from 2.6 per cent to 2.5 per cent (-3.5 kt CO_2-e).

d) The impact of reduced R404A supply for 2022 leakage replacement was to reduce HFC-143a emissions by -10.4 kt CO_2-e, compared with the previous estimate.

e) Several recalculation errors in the past have been discovered in historical 2000 to 2006 emissions calculations (where 'NO' emissions have been amended to small recovery and/or disposal numbers and not included in emissions calculations by mass balance). In total, this set of corrections amounted to -3.9 kt CO_2-e, -7.9 kt CO_2-e, -3.9 kt CO_2-e and -11.7 kt CO_2-e for 2000 to 2003 respectively.

f) Household refrigeration HFC-134a stock changes are: +0.08 tonnes, +0.27 tonnes, +0.23 tonnes, +0.21 tonnes, +0.34 tonnes and +0.33 tonnes, respectively, between 2017 and 2022. These would have a negligible impact (0.0002 tonnes to 0.0011 tonnes) on operations emissions. There was also a slight impact from other HFC-134a source changes on retirement share of recovery volume for 2022 leading to a 0.0025 tonnes increase in disposal emissions.

g) Commercial refrigeration net equipment stock additions for 2021 and 2022 were revised for consistency with previous years (in terms of data gap filling). The main impacts were the addition of 0.40 tonnes and 0.80 tonnes R404A to those stocks in 2021 and 2022, increasing 2022 HFC-125 and HFC-143a operations emissions by 0.17 CO_2-e and 0.30 CO_2-e respectively.

h) Transport refrigeration net equipment stock additions for 2022 were revised for consistency, with new incomplete information used to fill 2023 data gaps. The impacts on installation and operating emissions were increases of 0.01 kt CO_2-e, 0.18 kt CO_2-e and 0.02 kt CO_2-e for HFC-32, HFC-125, HFC-143a respectively, totalling 0.21 kt CO_2-e. Improved information for the disposed vehicle calculations for 2022 had the impact of increasing disposal HFC-134a emissions by 0.21 tonnes. This represented a 0.27 kt CO_2-e (0.13 per cent) increase in total MAC HFC-134a emissions, compared with the previous 2022 estimate (Verum Group, unpublished).

4.7.6 Category-specific planned improvements

No specific improvements are planned for this category. There are still some unexplained year-to-year variations in emissions from the *Refrigeration and air conditioning* category, which is an indication that further improvements can be made by better accounting for stockpiling of bulk chemical. Future submissions will continue to address this issue.

4.8 Other product manufacture and use (2.G)

4.8.1 Description

The *Other product manufacture and use* category in New Zealand comprises emissions from:

- use of SF_6 as an insulant and arc-extinguishing agent in electrical switchgear
- use of SF_6 in eye surgery
- use of PFCs (C_2F_6 and perfluoropropane (C_3F_8)) in eye surgery
- use of SF_6 as a tracer gas in scientific experiments
- possible other uses of SF_6, such as in vehicle tyres and industrial equipment
- medical uses of N_2O.

There were no emissions of nitrogen trifluoride (NF_3) in New Zealand.

There were no key categories.

In 2023, emissions from the *Other product manufacture and use* category totalled 129.1 kt CO_2-e or 3.2 per cent of emissions from the IPPU sector. This is an increase of 22.6 kt (21.2 per cent) from the emissions in 1990, driven by a slight increase in the importation and use of N_2O in 2023.

4.8.2 Methodological issues

Choice of activity data

Companies importing or using SF_6 and N_2O provided data on their imports and holdings in response to an annual survey. This included all significant electricity companies, equipment manufacturers and industrial electricity users. In addition, companies report their holdings and emissions in NZ ETS returns if they use SF_6 in electrical equipment and have more than 1 tonne of the gas in operating equipment.

Electrical equipment (2.G.1)

Data on bulk imports of SF_6 and the charge in installed equipment were supplied by New Zealand's only manufacturer of relevant electrical equipment (ABB Limited) and by the electricity transmission and generation companies. The transmission and generation companies import SF_6 for their own use.

Sulphur hexafluoride and perfluorocarbons from other product use (2.G.2)

One company (BOC Limited) imported SF_6 into New Zealand (for uses other than electrical switchgear) until 2012. There is no other known importer, and some users appear to have been using previously imported supplies since that time. The current usage rate is assessed (from earlier importation rates) to be approximately 120 kilograms per year. This is made up of 30 kilograms for medical use, 50 kilograms for scientific use and 40 kilograms for other uses.

Extremely small amounts of C_2F_6 and C_3F_8 have been imported into New Zealand from 2011, for use in a specialised type of eye surgery. The importer provided information on the amount imported: between 0.1 kilograms and 0.3 kilograms per year. Enquiries to importers and the tyre industry have indicated that there is no use of SF_6 in New Zealand for other applications such as double-glazed windows, tyres and shoes.

Nitrous oxide from product uses (2.G.3)

Data on the import quantities of N_2O were available from the New Zealand Customs Service and Stats NZ from 2005, but some of these are considered unreliable due to classification errors by importers. Survey responses from companies that sell N_2O and from import data have been assessed together to estimate the total imports, which vary between 181 tonnes and 205 tonnes per year (CRL Energy, unpublished(b)).

Choice of methods

Electrical equipment (2.G.1)

The national grid company, Transpower, and several of the larger electricity generation companies have supplied stocks and usage data that are detailed enough to allow the use of a Tier 3 approach for the years 2003 to 2019. This uses a mass balance calculation for closed pressure equipment and an emission factor calculation for sealed pressure equipment.

For all data prior to 2003, and for the other distribution companies that do not have ETS reporting obligations and have not provided detailed data, a Tier 1 approach is used.

Both approaches account for emissions from the operation and disposal of equipment.

Other

Because the quantities are small and the emissions are all considered to be prompt, Tier 1 methods are used for all other emissions in this category. All SF_6 or N_2O that is imported is assumed to be sold and emitted.

Choice of emission factors

Electrical equipment (2.G.1)

Default loss rates have been used, where required, for sealed pressure equipment and where a Tier 1 method has had to be used. Factors based on Europe have been used, because these are based on a study that distinguished between sealed and closed equipment types (IPCC, 2006a).

Improved information from surveys has allowed the use of these two different equipment types in New Zealand to be better disaggregated over time, and the choice of emission factors has become progressively more accurate (Verum Group, unpublished). However, this distinction is not always clear and remains a source of uncertainty. Units that are described as sealed can sometimes be topped up with SF_6 in service.

Losses on disposal are assessed as 95.0 per cent if a service agent is not used, and 5.0 per cent when service agents carry out the disposal and implement good recovery practices. No recovery of SF_6 was reported before the year 2000.

Other

Emissions of SF_6 and other gases for all other applications are assumed to be prompt, and an emission factor of either 50.0 per cent or 100.0 per cent is used, as appropriate.

4.8.3 Uncertainty assessment and time-series consistency

Uncertainties

A mix of expert judgement and IPCC default uncertainties has been used for emissions in this category (see table 4.8.1). The IPCC (2006a) recommends the use of expert judgement for sources such as N_2O from product uses, because the uncertainties vary from country to country. For categories other than *Electrical equipment*, there is no uncertainty in emission factors because emissions are immediate.

Table 4.8.1 Uncertainty in emissions from *Other product manufacture and use*

Category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Electrical equipment	±20	±30
Medical and other product use (SF_6)	±80	-
Medical and other product use (PFCs)	±80	-
Nitrous oxide from other product uses	±15	-

Time-series consistency

The implied emission factors for the *Electrical equipment* category have declined, due to improvements both in data quality and in the actual management of SF_6 utilisation and recovery by Transpower and other users over time. Recovery did not occur before 2000. Imports of SF_6 and N_2O for other purposes have varied over time.

4.8.4 Category-specific QA/QC and verification

Other product manufacture and use was a non-key category.

4.8.5 Category-specific recalculations

There were no recalculations for the 2025 submission.

4.8.6 Category-specific planned improvements

For the *Electrical equipment* category, it is expected that further improved activity data and more detailed reporting on stocks of SF_6 will become available over time from NZ ETS reporting and from surveys, as SF_6 handling practices in the industry improve. Better information may enable the consistent use of Tier 2 or Tier 3 methods for this category in future submissions.

4.9 Other (2.H)

4.9.1 Description

This is a new category for New Zealand.

The *Other* category in New Zealand comprises emissions from:

- pulp and paper production
- food and beverage production
- fibreboard production
- particleboard production
- liquid carbon dioxide consumption.

Pulp and paper production, food and beverage production, fibreboard production and particleboard production were reported under 2.G *Other product manufacture and use* in previous inventories and now are moved under 2.H to comply with the CRT format.

Small amounts of indirect emissions (NMVOC and SO_2) are reported from the manufacture of food and drink, pulp and paper, and board products (fibreboard and particleboard).

Imported liquid carbon dioxide has now been added in the national inventory, along with domestic production of liquid carbon dioxide that was previously included under the Energy sector category 1.A.1 *Energy industries*.

In 2023, emissions from 2.H *Other* totalled 36.9 kt CO_2-e or 0.9 per cent of emissions from the IPPU sector. This is an increase of 24.4 kt (195.5 per cent) from the emissions in 1990.

There are no key categories.

4.9.2 Methodological issues

Choice of activity data

Carbon dioxide consumption (2.H.3)

The activity data (tonnes of liquid carbon dioxide) are provided by MBIE. The data is the sum of imported liquid carbon dioxide and domestic production of liquid carbon dioxide, which was previously included as an emission at the point of manufacture and reported under the *Energy sector* category 1.A.1 *Energy industries*.

Choice of methods

Carbon dioxide consumption (2.H.3)

No set method was provided by the IPCC (2006a). In this case, no calculation was needed.

Choice of emission factors

Carbon dioxide consumption (2.H.3)

Carbon dioxide has a default of emission factor of 1.

4.9.3 Uncertainty assessment and time-series consistency

Uncertainties and Time-series consistency

No IPCC default uncertainties were given. Imports of liquid carbon dioxide for consumption have varied over time.

4.9.4 Category-specific QA/QC and verification

This category was a non-key category.

4.9.5 Category-specific recalculations

There are no recalculations for the 2025 submission.

4.9.6 Category-specific planned improvements

There were no planned improvements for this category.

Chapter 4: References

Christie T, Thompson B, Brathwaite B. 1999. *Mineral Commodity Report 20 – Clays*. Wellington: Institute of Geological and Nuclear Sciences.

CRL Energy Ltd. Unpublished(a). Hennessy W, Maxwell D. Inventory of HFC, PFC and SF_6 Emissions for New Zealand 2004–2005. A report by CRL Energy Ltd to the Ministry for the Environment in 2006.

CRL Energy Ltd. Unpublished(b). Hennessy W, Maxwell D. Inventory of Non-CO_2 Greenhouse Gas Emissions from Industrial Sources and Solvents for New Zealand 2004–2005. A report by CRL Energy Ltd to the Ministry for the Environment in 2006.

International Aluminium Institute. 2006. *The Aluminium Sector Greenhouse Gas Protocol*. London: International Aluminium Institute.

IPCC. 2006a. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3. Industrial Processes and Product Use*. IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006b. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

Ure CR. 2000. Alternative Iron-making at BHP New Zealand Steel. In: *58th Electric Furnace Conference and 17th Process Technology Conference Proceedings.* Orlando, FL: Iron and Steel Society. 12–15 November 2000. pp 535–546.

Verum Group Ltd. Unpublished. Hennessy W. Inventory of HFC, SF_6 and Other Industrial Process Emissions for New Zealand 2024. A report by Verum Group Ltd to the Ministry for the Environment in 2024.

World Business Council for Sustainable Development. 2005. *The Cement CO_2 Protocol: CO_2 Accounting and Reporting Standard for the Cement Industry.* Switzerland: World Business Council for Sustainable Development.

Chapter 5: Agriculture

5.1 Sector overview

Emissions summary

2023

In 2023, emissions from the Agriculture sector totalled 40,613.0 kilotonnes carbon dioxide equivalent (kt CO_2-e), representing 53.1 per cent of New Zealand's gross emissions in 2023.

Methane from *Enteric fermentation* was the main source of Agriculture emissions, contributing 78.0 per cent (31,661.7 kt CO_2-e) of the sector's emissions. *Agricultural soils* (15.7 per cent) were the second largest source followed by *Manure management* (4.6 per cent). *Urea application* and *Liming* contributed 1.0 per cent and 0.7 per cent respectively. *Field burning of agricultural residues* contributed less than 0.1 per cent.

Methane (CH_4) emissions from *Enteric fermentation* contributed 41.4 per cent of New Zealand's gross emissions, and nitrous oxide (N_2O) emissions from the *Agricultural soils* category contributed 8.3 per cent of New Zealand's gross emissions.

New Zealand reports emissions from Tokelau, which is a dependent territory of New Zealand. Due to the application of different methods and the complexity of integrating emissions within the main sectors, Tokelau emissions are reported for all activities under the 'Other' sector of the Inventory. Therefore, all emissions reported in this sector exclude Tokelau. Please refer to chapter 8 and annex 7 for details of methods applied and the emissions for Tokelau.

1990–2023

In 2023, New Zealand's Agriculture sector emissions were 10.0 per cent (3,697.9 kt CO_2-e) above the 1990 level (36,915.1 kt CO_2-e) (table 5.1.1).

Table 5.1.1 Trends and relative contribution of New Zealand's agricultural greenhouse gas emissions by category between 1990 and 2022

	Emissions (kt CO_2-e)		Change (%)	Difference (kt CO_2-e)	Share (%) of sector	
Category	1990	2023	1990–2023	1990–2023	1990	2023
Enteric fermentation (3.A)	31,034.9	31,661.7	2.0	626.8	84.1	78.0
Manure management (3.B)	859.8	1,861.5	116.5	1,001.7	2.3	4.6
Rice cultivation (3.C)	NO	NO	-	-	-	-
Agricultural soils (3.D)	4,655.1	6,372.4	36.9	1,717.3	12.6	15.7
Field burning of agricultural residues (3.F)	29.6	17.9	-39.3	-11.6	0.1	0.0
Liming CO_2 emissions (3.G)	296.5	273.8	-7.7	-22.7	0.8	0.7
Urea application CO_2 emissions (3.H)	39.2	425.7	986.0	386.5	0.1	1.0
Other carbon-containing fertilisers (3.I)	NE	NE	-	-	-	-
Total	**36,915.1**	**40,613.0**	**10.0**	**3,697.9**	**100.0**	**100.0**

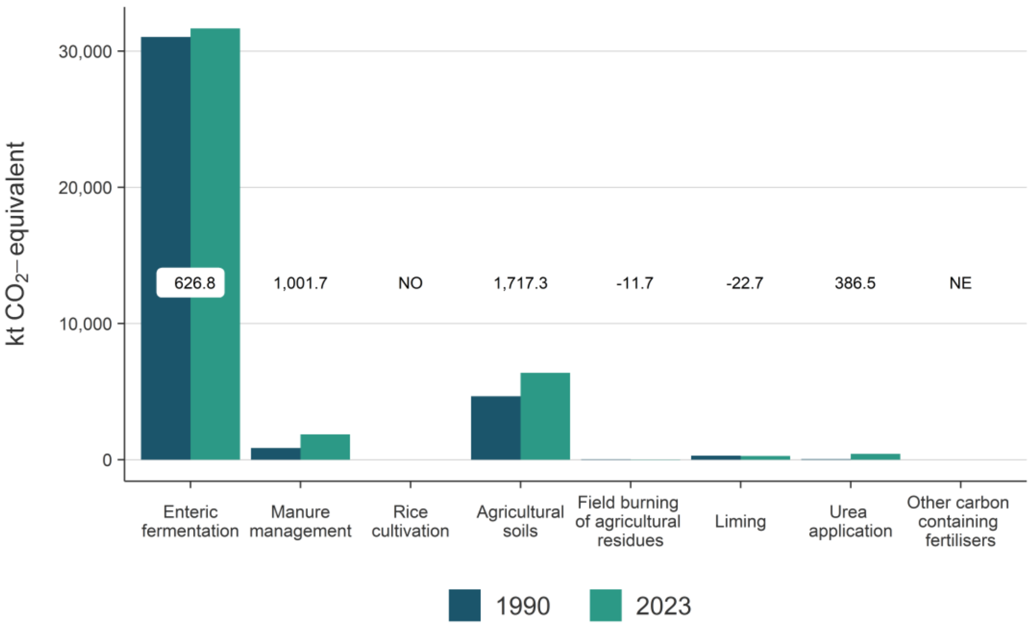
Note: NO = not occurring, NE = not estimated. Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

The greatest absolute contributions to the increase since 1990 are a 1,717.3 kt CO_2-e (36.9 per cent) increase in emissions from *Agricultural soils*, a 1,001.7 kt CO_2-e (116.5 per cent) increase in emissions from *Manure management*, and a 626.8 kt CO_2-e (2.0 per cent) increase in CH_4 emissions from *Enteric fermentation* (table 5.1.1 and figure 5.1.1).

The increase in N_2O emissions from *Agricultural soils* is primarily a result of increased application of synthetic nitrogen fertiliser by 534 per cent since 1990. This is partly due to an increase in dairy farming, as well as increased use on other farm types. The emissions from synthetic nitrogen fertiliser use (N_2O) increased by 1,094.3 kt CO_2-e between 1990 and 2023. This is 63.7 per cent of the total increase in emissions from *Agricultural soils.*

The increase in emissions from *Manure management* and *Enteric fermentation* is driven by an increase in dairy cattle numbers. The increase in dairy *Enteric fermentation* emissions is partially offset by a decline in sheep numbers and a decrease in *Non-dairy* (beef) *cattle*. The change in animal populations since 1990 reflects the relative financial returns in each sector (it has become more profitable to farm dairy cattle than non-dairy cattle or sheep in New Zealand over the reporting period).

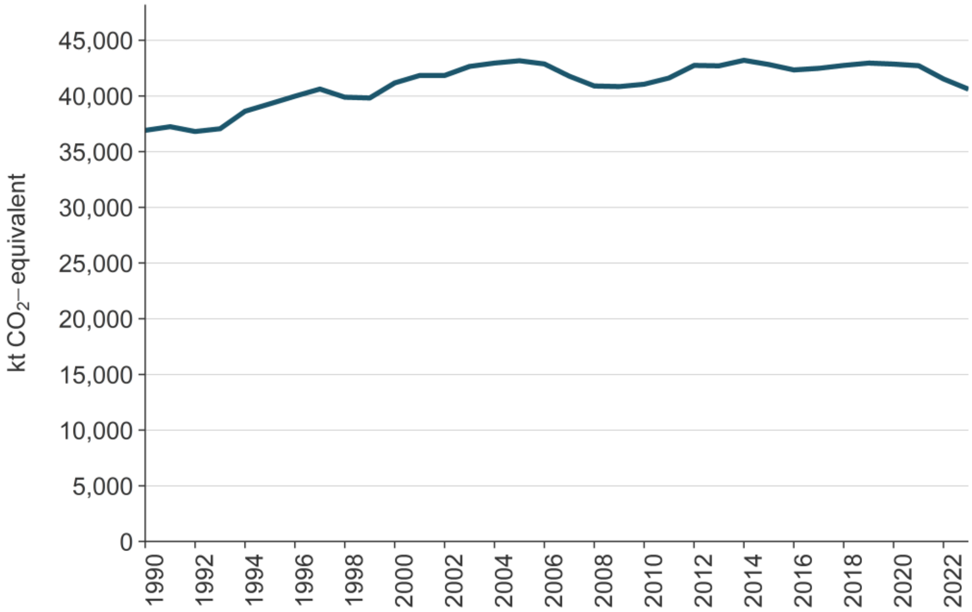
Figure 5.1.1 New Zealand's emissions from the Agriculture sector, from 1990 to 2023



Note: Rice cultivation does not occur (NO) in New Zealand. Emissions from other carbon-containing fertilisers are not estimated (NE). The change between 1990 and 2023 is presented for each category in kt CO_2-e.

Agriculture emissions most recently peaked at 43,203.4 kt CO_2-e in 2014, corresponding with a peak in overall cattle numbers. Prior to 2014, Agriculture emissions were at their highest in 2005 (43,161.7 kt CO_2-e) but dropped by around 1,400 kt CO_2-e during the Global Financial Crisis (2007–08) and another 900 kt CO_2-e during a 2008 nationwide drought. Agriculture emissions have remained slightly below the 2014 peak in the years 2015 to 2021 and have dropped significantly in 2022 and 2023 (figure 5.1.2).

Figure 5.1.2 New Zealand's Agriculture sector emissions, from 1990 to 2023



2022–2023

Between 2022 and 2023, total Agriculture emissions decreased 2.2 per cent (908.4 kt CO_2-e), largely due to a decrease in emissions from dairy cattle, non-dairy cattle, sheep, and limestone application. Specifically:

- dairy cattle emissions decreased by 1.6 per cent (328.2 kt CO_2-e) due to a decrease in the dairy cattle population
- sheep emissions decreased by 3.1 per cent (294.6 kt CO_2-e) due to a continuing decrease in the sheep population
- emissions from limestone use decreased by 38.8 per cent (166.6 kt CO_2-e) due to a decrease in limestone use
- non-dairy cattle emissions decreased by 1.5 per cent (127.8 kt CO_2-e) due to a decrease in the beef cattle population.

Emissions from urea (carbon dioxide (CO_2) and N_2O) increased by 11.3 per cent (126.0 kt CO_2-e) due to an increase in urea use and decrease in urease inhibitor use. This increase reflects a slight recovery in urea use following a significant decrease in 2022. The impact of increased emissions from urea from 2022 to 2023 was largely offset by a decrease in the use of other (non-urea) synthetic nitrogen fertilisers.

5.1.1 New Zealand farming practices and trends

Agriculture is a major component of the New Zealand economy, and exports from food and fibre products comprised around 81 per cent of New Zealand's merchandise exports and delivered $54.6 billion in export earnings in the year to 30 June 2024 (MPI, 2024). The production of agricultural products in New Zealand is helped by the favourable temperate climate and access to abundant fresh water and highly productive soils. Typical farming practices in New Zealand include the use of year-round outdoor pastoral grazing systems and nitrogen inputs through nitrogen fixation by legumes, particularly white clover (*Trifolium repens*), complemented (if required) by synthetic nitrogen fertiliser and supplementary feeds.

The widespread use of outdoor pastoral grazing systems means New Zealand's agricultural production is more sensitive to climatic variation affecting feed production than countries that use intensive grain-fed systems and/or indoor feedlots.

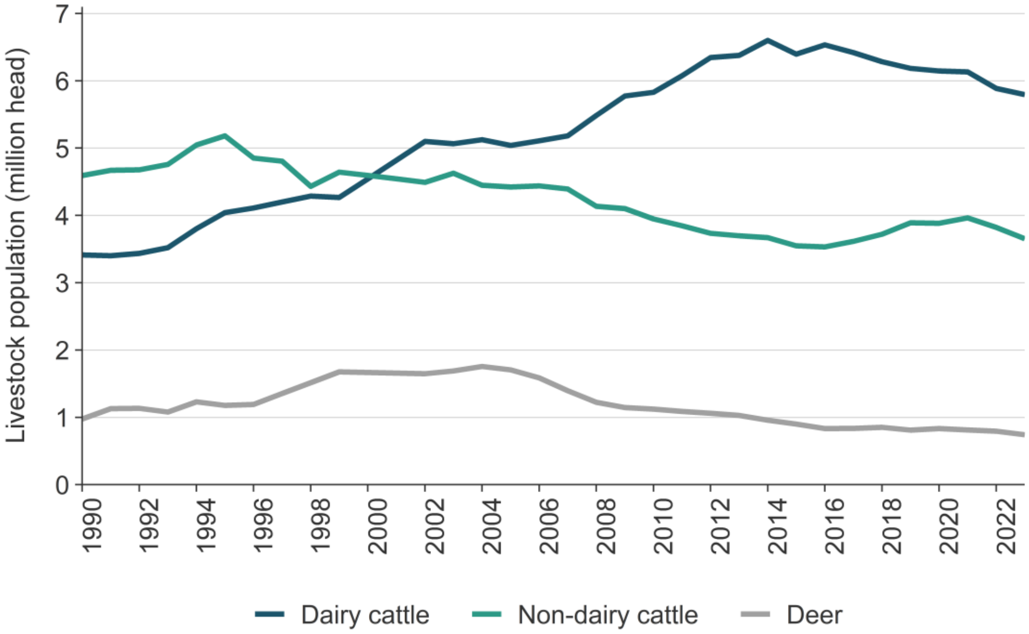
Intensive housing of major ruminant livestock species rarely occurs in New Zealand. Farmers may temporarily take animals off regular grazing areas to prevent damage to soils and limit any subsequent loss in pasture growth, although most off-paddock pads are also outdoors. This means New Zealand has a much lower proportion of agricultural emissions from *Manure management*, compared with other Annex I Parties, because most manure is deposited directly onto pastures. For further information about New Zealand's agricultural farming conditions, see section 2.1.6.4 (National circumstances, Agriculture) of New Zealand's first Biennial Transparency Report under the Paris Agreement (MfE, 2024).

Trends in emissions from the Agriculture sector are largely driven by the populations of the ruminant livestock categories (dairy cattle, non-dairy cattle, sheep and deer). In 1990 and 2023 respectively, 95.0 per cent and 92.4 per cent of agricultural emissions originated from these ruminant livestock categories.

Agricultural livestock activities use around 34 per cent of New Zealand's total land area (Stats NZ, 2024). Since 1990, the proportions of the main livestock categories farmed in New Zealand have changed (see figure 5.1.3a and figure 5.1.3b). The population of dairy cattle has increased while the populations of sheep, non-dairy cattle, and deer have decreased. Between 1990 and 2023, the land area used for sheep and non-dairy cattle grazing has decreased by 41.6 per cent (5.2 million hectares) from 12.5 million hectares to 7.3 million hectares (Beef + Lamb New Zealand Ltd, 2024a), while the area used for dairy farming has increased by 66.4 per cent (679,859 hectares) (LIC and DairyNZ, 2024). Dairy farming has also intensified over this period, with the average number of cows per hectare increasing by 17.4 per cent. However, since 2015, both the total land under dairy production and the national herd size have decreased 2.8 per cent and 5.9 per cent respectively since 2015 (LIC and DairyNZ, 2024).

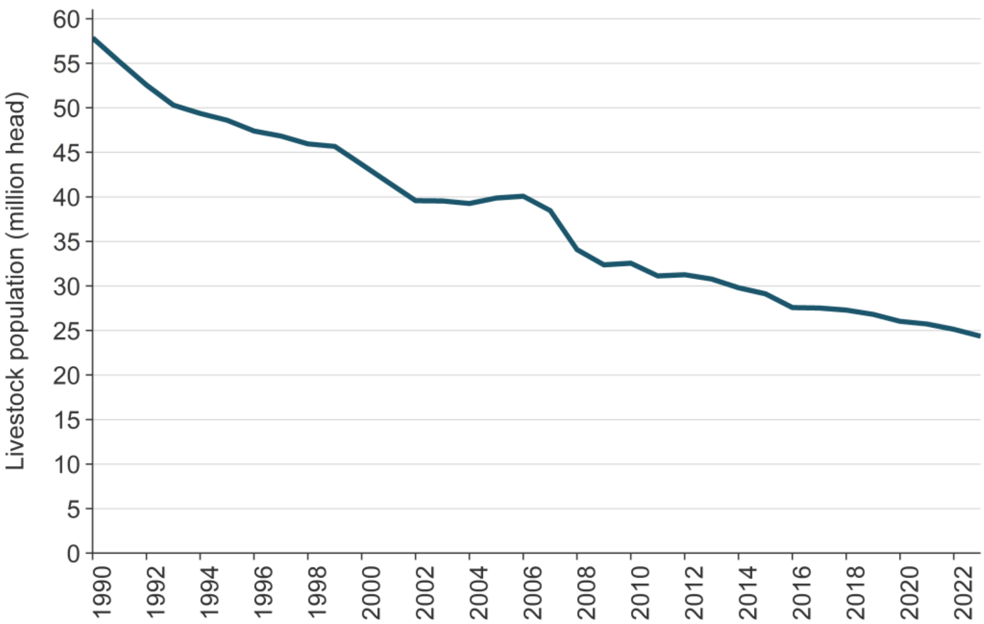
The use of synthetic nitrogen fertiliser in the Agriculture sector has increased by 534 per cent since 1990, although total use has decreased in recent years. Total emissions from synthetic nitrogen fertiliser (including CO_2 from urea) have increased from 0.8 per cent of agricultural emissions in 1990 to a peak of 5.2 per cent in 2020. Since 2020, synthetic nitrogen fertiliser use has decreased. Total emissions from synthetic nitrogen fertiliser (including CO_2 from urea) contributed 4.3 per cent of agricultural emissions in 2023.

Figure 5.1.3(a) Populations of New Zealand's dairy cattle, non-dairy cattle and deer, from 1990 to 2023 (June year ending)



Source: Stats NZ

Figure 5.1.3(b) Population of New Zealand's sheep, from 1990 to 2023 (June year ending)



Source: Stats NZ

Effect of productivity improvements and climatic events on implied emission factors

From 1990 to 2023, a gradual increase has occurred in the implied CH_4 and N_2O emission factors[23] per head of the major livestock species and types farmed in New Zealand. This trend reflects the increased levels of productivity (milk and meat yield per head) achieved by New Zealand farmers between 1990 and 2023. Increases in animal liveweight and milk yield

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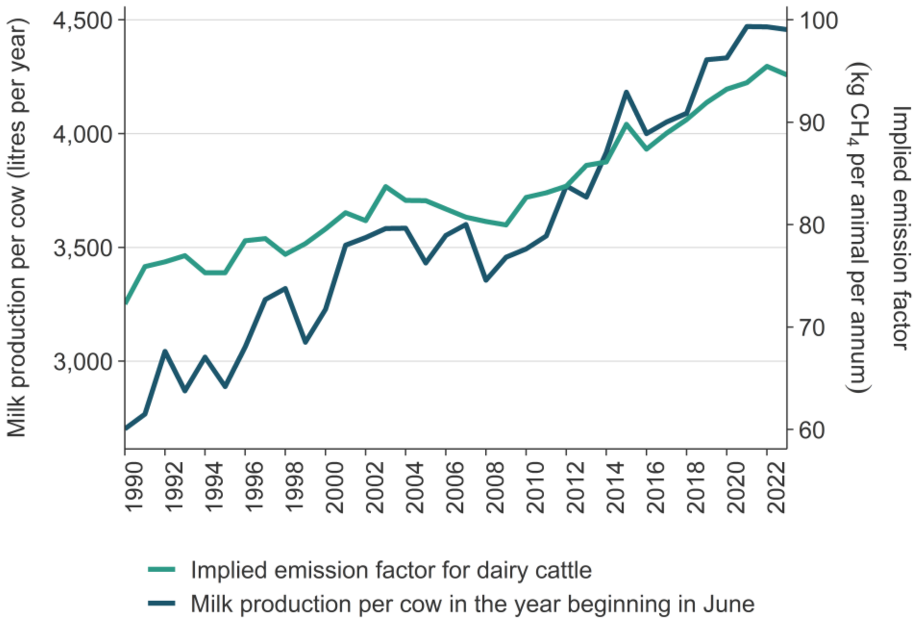
23 Implied emission factors (IEFs) are calculated by dividing the total emissions of a particular animal species and sector (e.g., enteric fermentation from sheep) by the number of animals in that species and sector.

per animal require increased feed intake to meet higher energy demands, which results in higher CH_4 and N_2O emissions per animal (i.e., higher implied emission factors (IEFs)). The increased levels of productivity have also caused emissions per unit of product (i.e., milk and meat emissions intensity) to steadily decrease overall since 1990.

The use of year-round outdoor pastoral grazing systems means New Zealand production is dependent on the quantity and quality of pasture grown on land managed by farmers, as well as the use and/or availability of any supplementary feeds and fertiliser inputs. Pasture growth is strongly influenced by weather and climatic events, such as droughts and floods, however, the temperate maritime climate is generally favourable for pastoral agriculture. These factors can cause changes in per-animal productivity and mean that IEFs can be noticeably different in adjacent years. For example, in 2008, a major nationwide drought affected both livestock numbers and animal performance, resulting in lower livestock emissions and overall agricultural emissions (see figure 5.1.2). The livestock population and IEFs started to increase after the drought, once seasonal growing conditions improved, and farmers restored herd and flock numbers.

An example of this is included in figure 5.1.4, which overlays milk production per milking dairy cow with the IEFs (enteric fermentation) for all dairy cattle from 1990 to 2023. The figure shows that, while per cow productivity has trended upward, there is a large amount of inter-annual variability (mainly influenced by climatic conditions and international product prices). It also shows that the IEFs are affected by these changes in productivity.

Figure 5.1.4 Dairy milk productivity and implied enteric fermentation methane emission factors for dairy cows, from 1990 to 2023



Note: Milk production per cow is calculated by dividing total milk production by the milking dairy cattle population (i.e., excluding replacements and breeding bull numbers).

5.1.2 Key categories for Agriculture sector emissions

Details of New Zealand's analysis of key categories are in chapter 1, section 1.4. The key categories in the Agriculture sector are listed in table 5.1.2.

Table 5.1.2 Key categories in the Agriculture sector

CRT category code	IPCC categories	Gas	Criteria for identification
3.A.1.a.	Option A – Dairy cattle	CH_4	L1, T1
3.A.1.b.	Option A – Non-dairy cattle	CH_4	L1, T1
3.A.2.	Enteric fermentation – Sheep	CH_4	L1, T1
3.A.4.c.	Other livestock – Deer	CH_4	L1, T1
3.A.4.d.	Other livestock – Goats	CH_4	T1
3.B(a).	CH_4 emissions – 3.B.2. Sheep	CH_4	T1
3.B.1.a.	Option A – Dairy cattle	CH_4	L1, T1
3.D.1.a.	Direct N_2O emissions from managed soils – Inorganic N fertilizers	N_2O	L1, T1
3.D.1.c.	Direct N_2O emissions from managed soils – Urine and dung deposited by grazing animals	N_2O	L1, T1
3.D.1.d.	Direct N_2O emissions from managed soils – Crop residues	N_2O	L1
3.D.1.f.	Direct N_2O emissions from managed soils – Cultivation of organic soils	N_2O	L1, T1
3.D.2.a.	Indirect N_2O emissions from managed soils – Atmospheric deposition	N_2O	L1
3.D.2.b.	Indirect N_2O emissions from managed soils – Nitrogen leaching and run-off	N_2O	L1
3.G.	Agriculture – Liming	CO_2	L1
3.H.	Agriculture – Urea application	CO_2	L1, T1

Note: L1 means a key category is identified under the level analysis – approach 1 and T1 is trend analysis – approach 1. See chapter 1, for more information.

5.1.3 Methodological issues for the Agriculture sector

The Agriculture sector includes emissions of CH_4 and N_2O from livestock industries (estimated in *Enteric fermentation* (CH_4) and *Manure management* (CH_4 and N_2O)). In New Zealand, the predominant species (in terms of population) are sheep, followed by dairy cattle, non-dairy cattle and deer. The majority of New Zealand animals are selected to perform under outdoor pastoral farming systems.

Other agricultural emission sources include N_2O from *Agricultural soils*, CH_4 and N_2O from *Field burning of agricultural residues* and CO_2 from *Liming* and *Urea application*.

New Zealand uses a range of models and tiers appropriate to the size of the different emission categories for calculating emissions. For example, in 2023, 92.4 per cent of emissions from the Agriculture sector come from *Dairy cattle*, *Non-dairy cattle*, *Sheep* and *Deer* ('major' livestock categories). Emissions from major livestock categories are estimated using Intergovernmental Panel on Climate Change (IPCC) Tier 2 methodologies. Other livestock species, including *Swine*, *Goats*, *Horses*, *Llamas and alpacas*, *Mules and asses* and *Poultry* ('minor' livestock categories) account for only 0.4 per cent of Agriculture emissions, and are estimated using Tier 1 methodologies with some Tier 2 components. As such, most of New Zealand's reported agricultural emissions are calculated using a Tier 2 methodology. A partial Tier 3 methodology is used for calculating emissions from *Agricultural soils* for *Urine and dung deposited by grazing animals*. Table 5.1.3 summarises methods and emission factors for Agriculture categories.

Table 5.1.3 Methods and emission factors in the Agriculture sector

	Source category	CH_4 Method applied	CH_4 Emission factor	N_2O Method applied	N_2O Emission factor	CO_2 Method applied	CO_2 Emission factor
A	**Enteric Fermentation**						
	Cattle						
1	Dairy Cattle	T2	CS	-	-	-	-
	Non-Dairy Cattle	T2	CS	-	-	-	-
2	Sheep	T2	CS	-	-	-	-
3	Swine	T1	CS	-	-	-	-
4	Other Livestock (Camels, Deer, Goats, Horses, Mules and Asses, Poultry)	T1, T2	CS, D	-	-	-	-
B	**Manure Management**						
	Cattle						
1	Dairy Cattle	T2	CS	T2	CS	-	-
	Non-Dairy Cattle	T2	CS	NA	NA	-	-
2	Sheep	T2	CS	NA	NA	-	-
3	Swine	T1	CS	T1	CS	-	-
	Poultry	T1	D	T1	CS	-	-
4	Other Livestock (Camels, Deer, Goats, Horses, Mules and Asses)	T1, T2	CS, D	NA	NA	-	-
C	**Rice Cultivation**	NA	NA	-	-	-	-
D	**Agricultural Soils**						
	Direct Emissions						
	Synthetic Fertilisers			T2	CS	-	-
	Animal Manure Applied to Soils			T1, T2	CS	-	-
	Sewage Sludge Applied to Soils			NA	NA	-	-
1	Other Organic Fertilisers Applied to Soils			T1	D	-	-
	Urine and Dung Deposited by Grazing Animals			T1, T2, T3	CS	-	-
	Crop Residues			T2	CS	-	-
	Mineralisation associated with Loss of Soil Organic Matter			T1	D	-	-
	Cultivation of Organic Soils			T1	D	-	-
	Indirect Emissions						
2	Atmospheric Deposition			T1, T2	D	-	-
	Nitrogen Leaching and Run-off			T1, T2	CS	-	-
E	**Prescribed Burning of Savannas**	NA	NA	NA	NA	-	-
F	**Field Burning of Agricultural Residues**	T2	CS	T2	CS	-	-
G	**Liming**	-	-	-	-	T1	D
H	**Urea Application**	-	-	-	-	T1	D
I	**Other Carbon-containing Fertilisers**	-	-	-	-	NA	NA

Note: CS = country specific; D = IPCC (2006) default; NA = not applicable; T1 = Tier 1; T2 = Tier 2.

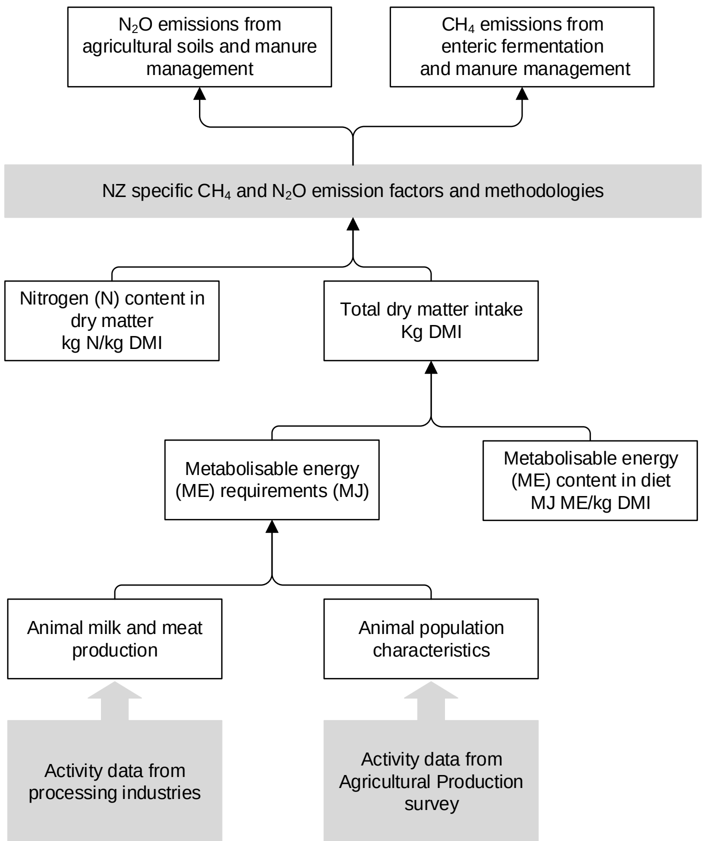
Further technical details on emissions calculations are provided in the Agriculture inventory methodology document on the Ministry for Primary Industries (MPI) website (www.mpi.govt.nz/dmsdocument/13906-Detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation) and in the methodological issues section for each category in this document. The approach for determining livestock nutritional and energy requirements, which is required to calculate *Enteric fermentation* emissions and nitrogen excreted by livestock as the precursor for calculating *Manure management* (and some *Agricultural soils* emissions), is described in the following paragraphs.

Description of the Tier 2 model for determining emissions from energy requirements for major ruminant livestock categories

New Zealand uses a Tier 2, process-based model to calculate emissions from the major livestock categories (Clark et al., 2003). Components of the national Agriculture inventory model are constantly being improved through findings from new international and commissioned domestic research. The thoroughly researched country-specific emission factors and monthly data for livestock populations, animal productivity and feed quality mean New Zealand's model is close to a Tier 3 inventory. However, data that informs pasture and non-pasture feed quality are not as comprehensive as would be required to report at a Tier 3 level. Figure 5.1.5 outlines the current Tier 2 methodology used to estimate emissions for the four major livestock categories.

Agricultural production (meat, milk and wool) and livestock population data are combined in the model with data on the total metabolisable energy (ME) content of the animal's diet. To calculate CH_4 emissions from enteric fermentation, the production data are used to determine the dry-matter intake (DMI) required to meet total annual productivity levels for each of the livestock categories and are then multiplied by a country-specific CH_4 emission factor per unit of DMI. *Manure management* emissions are primarily CH_4 from manure dung and urine deposited directly onto pasture, but also N_2O from manure breaking down due to the processes of nitrification, denitrification, volatilisation and leaching. Information on the nitrogen content of feed is multiplied with the DMI previously calculated to determine quantity of animal nitrogen intake and subsequent nitrogen excretion after allowing for nitrogen in growth and milk production.

Figure 5.1.5 Simplified methodology for calculating emissions for major ruminant livestock categories



Note: CH_4 = methane; DMI = dry-matter intake; kg = kilogram; MJ = megajoule; N_2O = nitrous oxide; NZ = New Zealand.

The main emissions from ruminant livestock are CH_4 from enteric fermentation and N_2O from manure (urine and dung). The quantity of livestock emissions has a linear relationship with DMI, which is a function of livestock energy requirements and the energy concentration of the feed:

$$DMI = \frac{ME_{TOTAL}}{E}$$

Where: DMI is the dry-matter intake (kg year^{-1})

ME_{TOTAL} is the total metabolisable energy requirement of the animal (kJ), and

E is the energy concentration in the feed (kJ/kg DMI).

Calculating metabolisable energy requirements (ME_{TOTAL})

For dairy cattle, non-dairy cattle and sheep, the approach for calculating total ME requirements was developed in Australia by the Commonwealth Scientific and Industrial Research Organisation (CSIRO, 1990). The CSIRO algorithms have been chosen because they specifically include methods to estimate the energy requirements of grazing ruminants outdoors, which is the predominant feeding method used in New Zealand. Further, the CSIRO algorithms consider animal liveweight and production requirements based on the rate of liveweight gain, gender, milk yield and physiological state. All calculations are performed monthly. The equation below is derived from the general equation used in the Australian feeding standards and adjusted to suit New Zealand conditions.

The total energy required (ME_{TOTAL}) is made up of:

- energy required to maintain animal weight, which is a function of the animal's liveweight, gender, breed, stage of maturity and physiological state (e.g., growing or lactating) (ME_m)
- energy required for the production of milk, wool, velvet, and live weight gain (ME_p)
- energy required for gestation or growth of the conceptus at any given time during pregnancy (ME_c)
- the additional amount of energy expended during grazing, compared with similar housed animals (ME_{GRAZE}).

$$ME_{TOTAL} = ME_m + ME_P + ME_{GRAZE} + ME_c$$

Where: ME_m is the energy requirement for maintenance

ME_P is the energy used directly for production (meat, milk, wool and so on)

ME_{GRAZE} is the additional energy required by grazing livestock, and

ME_c is the energy used for gestation or growth of the conceptus (MJ day^{-1}).

The ME_m requirement for an animal of a defined weight is not constant and will vary with energy costs of production. Increased productivity requires higher feed intakes and this affects the proportion of viscera and costs associated with respiration, cardiac output and so on. The Agriculture inventory model accounts for this by adding 10 per cent of the dietary ME allocated to production (ME_p) to ME_m (CSIRO, 1990). The addition of the term $0.1 \times ME_p$ is used to account for this.

The Agriculture inventory model uses a generic equation to calculate ME_m for dairy and beef cattle, sheep and deer, but equations used to calculate ME_p and ME_{GRAZE} differ for each animal category:

$$ME_m = K \times S \times \frac{0.28LW^{0.75} \times e^{-0.03A}}{k_m} + 0.1 \times ME_p$$

Where: ME_m = metabolisable energy required to maintain animal weight (MJ/d)

K = coefficient that accounts for differences in fasting heat production across species (CSIRO, 1990, p 22). This value is 1.0 for sheep and 1.4 for cattle and deer (CSIRO, 2007)

S = coefficient that accounts for differences in basal metabolic rate between males and females. This value is 1.0 for mature females and castrates or 1.15 for entire mature males (CSIRO, 2007)

LW = live weight of animal (kg)

A = age in years

k_m = efficiency of utilisation of ME for maintenance, or the factor used to convert ME to NE for maintenance

ME_p = ME required for production (MJ/d).

For further details, see the Agriculture inventory methodology document on the MPI website (www.mpi.govt.nz/dmsdocument/13906-detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation).

Monthly diet energy (E) concentration

In New Zealand, dairy cattle, beef cattle, sheep and deer are predominantly fed on pasture all year round. Data sets of estimated monthly energy concentrations of pasture consumed by different livestock species are used in the Agriculture inventory model. This diet is typically supplemented with feeds of various types, such as hay and silage, and a range of different crops and crop wastes. Data on the concentration of pasture are reported in the Agriculture inventory methodology document (Pickering et al., 2024, appendices 3, 9 and 19) and are derived from published and unpublished research trial data and supplemented with additional data from farm surveys on commercial cattle and sheep farms.

To ensure consistency across the livestock emission source categories, a single enhanced livestock population characterisation and DMI estimate is produced by the Tier 2 model for each livestock class. The enhanced livestock characterisation and DMI are used to estimate CH_4 emissions for the *Enteric fermentation* category, CH_4 and N_2O emissions, derived from nitrogen concentration of the feed DMI, for the *Manure management* category and N_2O emissions for urine and dung deposited by grazing animals onto pasture in the *Agricultural soils* category.

5.1.4 Activity data

Major livestock categories

The Tier 2 methodology developed by New Zealand uses data on livestock population and productivity to calculate livestock energy requirements and DMI. Animal population data are collected by Stats NZ, New Zealand's official data agency. Productivity data for dairy are provided jointly by the Livestock Improvement Corporation (LIC, a farmer-owned cooperative genetics improvement organisation) and DairyNZ (an industry good dairy research, statistics and advisory body), with other data provided by industry organisations such Beef + Lamb New Zealand Ltd (an industry good non-dairy cattle and sheep research, survey and advisory body) and Deer Industry New Zealand (an industry good deer research and advisory body), which regularly collect animal sector statistics. Statistics on animal carcass weights are collected by MPI from all major meat processors and are used to derive inventory animal liveweights.

A challenge for New Zealand activity data is that the inventory is calculated on a calendar year basis for international comparability purposes, while the New Zealand agricultural sector uses a June year-end basis for animal statistics because this reflects the natural biological cycle for animals in the southern hemisphere. New Zealand developed a Tier 2 model that estimates livestock emissions on a monthly time step, beginning on 1 July of one calendar year and ending on 30 June of the next year. To calculate emissions for a single calendar year (1 January – 31 December), the calculated emissions data from the last six months of a July–June year are combined with the first six months' emissions of the next July–June year. This approach enables comparisons with the agricultural inventories of other countries.

Dairy cattle are the only livestock type where emissions are currently calculated on a sub-national regional area basis represented by regional council areas. This allows the Agriculture inventory model to take into account regional differences in productivity for dairy livestock as a result of New Zealand's different climatic conditions and management systems (Clark, 2008a). A regional emissions assessment is not carried out for other livestock types because regional productivity data are currently unable to be accurately collected at the sub-national level and integrated into the national population data.

Animal population data

Stats NZ collects animal population data on a sub-national territorial authority basis. Animal population data are collected on an annual basis through the Agricultural Production Census and Agricultural Production Survey. The census occurs every five years (the most recent occurred in 2022) and the survey is conducted in the interim years. The only difference between these two processes is the sample size. The Census attempts to gather information from the entire target population, and the Survey attempts to gather information from a representative random sample of that population. Further details about the scope and accuracy of the Stats NZ Agricultural Production data collection are provided in annex 5, section A5.1.

Livestock population data for 2024 are needed to estimate emissions for the 2023 year. The timing of Stats NZ final data releases (June the year after the survey) and the inventory submission deadlines mean that actual 2024 population data are not available for this inventory submission. Projections based on figures published in New Zealand's first Biennial Transparency Report under the Paris Agreement (MfE, 2024) have been used as a replacement for 2024 data.

The New Zealand Agriculture inventory model uses a country-specific population characterisation for pasture-based livestock, compared with the default recommended by the IPCC for Tier 2 inventories (IPCC, 2000, 2006, 2019). The full list of categories for the major livestock populations can be found in annex 5, table A5.1.2, and in the Agriculture inventory methodology document on the MPI website (www.mpi.govt.nz/dmsdocument/13906-detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation).

For the purposes of emissions data reporting, dairy cattle encompasses all cattle that support the milking dairy herd. In addition to dairy heifers, this includes calves, young growing non-lactating heifers, dry cows and dairy bulls. All other cattle in New Zealand are characterised as non-dairy cattle. These include non-dairy breeding lactating cows used for producing slaughter animals, such as calves, dry cows, bulls and all slaughter classes. A proportion of male and female dairy calves not required for dairy replacements are transferred into the non-dairy herd and are slaughtered for meat consumption, generally at 24 to 36 months of age.

A detailed livestock population model is used to calculate monthly populations for dairy cattle, non-dairy cattle, sheep and deer (see annex 5, table A5.1.2, for the full list of categories).

This monthly population delineation has been developed by using industry knowledge and assumptions as detailed in Burggraaf et al. (2022), Clark (2008b), Stevens and Ward (2023), Stevens et al. (2022), Suttie (2012) and Thomson et al. (2010). Populations within a given year are adjusted on a monthly basis to account for births, deaths and transfers between age groups. For example, because most lambs are born and slaughtered between August and May, their numbers do not appear in the June census or survey data. Additionally, male and female dairy calves not necessary for replacements are usually slaughtered at four days of age or transferred to the non-dairy herd. The monthly population model ensures that the calculated feed demand more accurately reflects the status of each livestock category at a particular time of the year. Average national estimates of monthly birth and death dates and rates are used, which are based on expert opinion and limited published data. In reality, these vary across the country, due to differences in climate and farming systems in different parts of New Zealand.

Animal productivity data

Animal productivity data are obtained from LIC and DairyNZ, Beef + Lamb New Zealand Ltd and Deer Industry New Zealand. Slaughter statistics are collected by MPI and used as a proxy to establish changes in animal liveweight over time (www.mpi.govt.nz/resources-and-forms/economic-intelligence/data). Animal liveweight is derived from published slaughter-weight statistics and general nationally derived killing-out percentages (Clark et al., 2003; Muir et al., 2008; Muir and Thomson, 2010).

The same data sources are used each year to ensure consistency. Other information, such as the liveweight of non-dairy cattle and breeding bulls, is collected at irregular intervals from small survey populations. For years when data are not available, expert opinion and extrapolation from existing data are used.

Dairy cattle – milk production: Regional data on milk production, proportions of dairy cattle breeds and animal liveweights are provided in the New Zealand dairy statistics reports. These data are collectively compiled by LIC and DairyNZ.

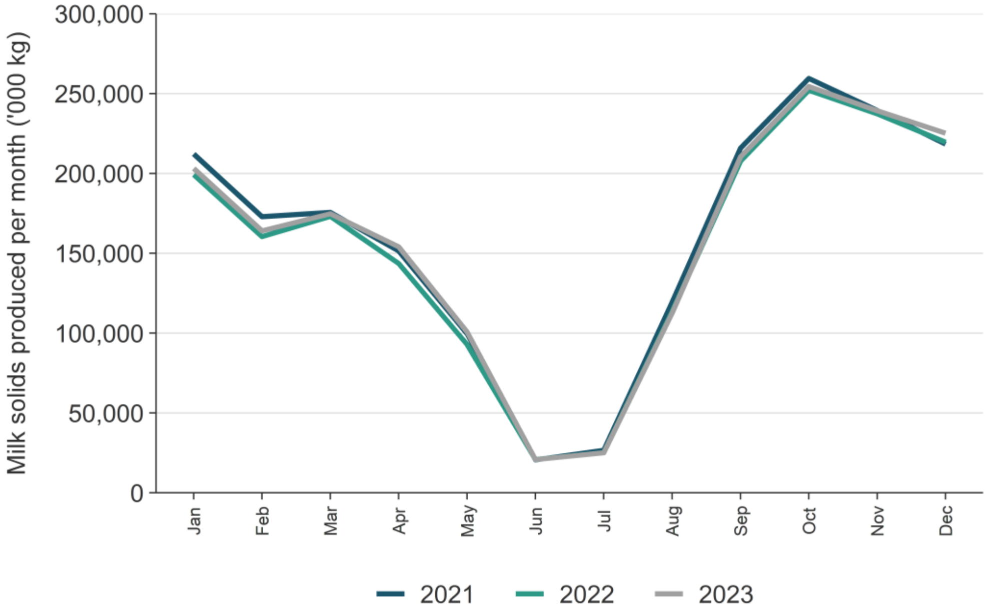
Data on New Zealand's total milk production are taken from the amount of milk processed through New Zealand dairy factories for both the export and domestic markets. Data on individual animal production are sourced from the Dairy Industry Good Animal Database, maintained by DairyNZ. Dairy farmers are paid on total kilograms of milk solids (fat and protein) collected. Tankers that collect the milk also meter the milk collected from individual farms. These meters are regularly calibrated and audited. Each time a tanker picks up milk (daily or every other day depending on the season; B Bills, pers. comm., 2024), samples from individual farms are independently tested for milk solids, milk fat percentage and protein content.

LIC and DairyNZ provide annual milk production data (milk yield and composition), but the Tier 2 livestock model operates on a monthly time step. Monthly milk production is determined by multiplying the assessed proportion of annual milk production for each month by the total annual milk production (see annex 5, table A5.1.4). Milk production commences from mid-July to early August every year, peaking around October–November and declines during autumn (April–May in the southern hemisphere). Milk production is low to non-existent in June and July in most herds (see figure 5.1.6). Some farms may milk during June–July to provide fresh milk for domestic consumers in winter.

New Zealand's dairy production per animal is lower than in other developed countries. This is because New Zealand has predominantly pasture-based dairy systems rather than the housed grain-fed systems used in Europe and North America.

Annual milk yields per animal have been obtained and reported as additional data in the common reporting table (CRT) for Annex I country inventories by dividing the total milk produced by the total number of milking dairy cows and heifers.

Figure 5.1.6 National monthly milk production in New Zealand, from 2021 to 2023



Source: Dairy Companies Association of New Zealand (2024)

Before 1993, no productivity data were collected at a territorial authority level, so pre-1993 data have been estimated by extrapolating from the trends observed in existing data from 1994 to 2008.

Before 2004, not all productivity data required could be collected from LIC at a territorial authority level. From 1993 to 2003, annual milk yield per cow was determined by the following equation:

$$Litres\ per\ cow = \frac{mean\ milk\ fat\ \left(\frac{kg}{cow}\right) \times 100}{\%milk\ fat}$$

From 2004 onwards, productivity data have been collected by LIC and DairyNZ at a similar regional level as the livestock population data collected by Stats NZ. In some instances, the regional level data provided by LIC and DairyNZ are disaggregated more than required. MPI officials allocate this to other regions so that it lines up with the population data, for example, districts identified under the region ‘Central Plateau’ are allocated to the ‘Bay of Plenty’. This is a straightforward process because the districts provided by LIC and DairyNZ clearly fall within the specified regional boundaries that the Stats NZ data are based upon.

In the 2023/24 season, 77 per cent of all dairy cattle in milk were tested by LIC for milk production, along with milk fat and protein levels (LIC and DairyNZ, 2024). LIC also does genetic testing to identify superior breeding stock and their genetic background. Genetic improvement has contributed to the productivity improvements in the New Zealand dairy cattle herd (LIC, 2009).

Dairy cattle – liveweight: Average liveweight data for dairy cows are obtained by considering the proportion of each breed in the national herd and its age structure based on LIC, Dairy Industry Good Animal Database and DairyNZ data. Dairy cow liveweight data are only available from LIC and DairyNZ from 1996 onwards and have been disaggregated into eight regions, some of which comprise several regional council regions. Data from the livestock improvement regions were appropriately apportioned to regional council areas. Liveweights before 1996 were estimated using the trend in liveweights from 1996 to 2008, together with data on the breed composition of the national herd (LIC, 2009).

In the Agriculture inventory model, replacement dairy animals (calves) are assumed to be about 9 per cent of the weight of the average cow at birth and to reach the weight of the average adult cow at calving (at two years of age) (Clark et al., 2003). Growth between birth and calving is divided into two periods: birth to weaning (two months of age) and weaning to calving. Higher growth rates are applied in the model between birth and weaning when animals receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire length of the period and applied nationally.

No data are available on the liveweights and performance of most breeding dairy bulls, which can range from the small Jersey breeds through to larger European non-dairy breeds. It is assumed, based on expert opinion and industry data (Clark et al., 2003), that the average mature weight of a breeding dairy bull is 500 kilograms as of 1 January and that they grow at 0.5 kilograms per day. This gives an average liveweight (at the mid-point of the year) of 592 kilograms. This is almost 25 per cent higher than the average weight of a New Zealand breeding dairy cow but is supported by expert opinion, given that some of the bulls will be of a heavier breed (e.g., Friesian and some non-dairy breeds). Total emissions are not sensitive to these assumed liveweight values because breeding bulls in the dairy herd are low in number and contribute less than 0.1 per cent of emissions to the dairy sector.

LIC and DairyNZ (2024) reported the proportions of different breeds in the New Zealand dairy herd in 2023 as:

- Holstein–Friesian/Jersey crossbreed (60.4 per cent)
- Holstein–Friesian (23.9 per cent)
- Jersey (7.5 per cent)
- Ayrshire (0.4 per cent)
- other breeds (7.8 per cent).

The Holstein–Friesian/Jersey crossbreed has been developed specifically for New Zealand's pasture-based systems. This breed is 8.4 per cent lighter on average than a Holstein–Friesian cow (LIC and DairyNZ, 2024) and has lower maintenance feed requirements. It does less damage to pasture during wet periods due to its lower liveweight. It also has higher milk volumes than the Jersey breed while maintaining a high percentage of milk solids.

Non-dairy cattle: The principal source of information for estimating productivity for non-dairy cattle is livestock slaughter statistics provided to MPI by meat processors, which are also used to estimate the liveweight of non-dairy cattle at slaughter, assuming killing-out percentages[24] of 55 per cent. Non-dairy cattle are assumed to be slaughtered at various ages depending on the sex and reproductive status of the animal (Stevens et al., 2022). Liveweights at birth are assumed to be around 7 per cent of an adult cow liveweight for heifers and 7 per cent of bull live weight for steers and bulls. As with dairy cattle, growth rates of all growing animals are divided into two periods in the model: birth to weaning and weaning to slaughter. Higher

[24] Percentage of carcass weight in relation to liveweight.

growth rates are applied before weaning as animals also receive milk as part of their diet. Within each period, the same daily growth rate is applied for the entire period.

MPI slaughter statistics only began to separate carcass weights of adult dairy cows and adult non-dairy cows in 2016. Therefore, several assumptions[25] are made to estimate the liveweights of breeding non-dairy cows. A total milk yield of 800 litres is assumed to be produced per breeding non-dairy cow, which is then consumed by non-dairy calves (Clark et al., 2003).

Sheep: Livestock slaughter statistics provided to MPI by meat processors are used to estimate the liveweights of adult sheep and lambs at slaughter, assuming killing-out percentages of around 40 per cent for ewes and 45 per cent for lambs (Thomson et al., 2010). Lamb liveweights at birth are assumed to be 9 per cent of the adult ewe weight, with all lambs assumed to be born on 11 September (Thomson et al., 2010). Growing breeding and non-breeding ewe hoggets are assumed to reach full adult size when subsequently mated at an age of 20 months. Adult wethers (castrated male sheep) are assumed to be the same weight as adult breeding females. No within-year pattern of liveweight change is assumed for either adult wethers or adult ewes. All ewes rearing a lamb are assumed to have a total milk yield of 100 litres. Breeding rams are assumed to weigh 40 per cent more than adult ewes (Clark et al., 2003). Wool growth (greasy fleece) is assumed to grow at a rate twice as fast as mature sheep (ewes, rams and wethers) than in growing sheep and lambs. Beef + Lamb New Zealand Ltd provides estimates of the total wool production from 1990 to 2024 from which the individual fleece weight is estimated (Beef + Lamb New Zealand Ltd, 2024b).

***Deer*:** Liveweights of growing hinds and stags are estimated from Deer Industry New Zealand statistics, assuming a killing-out percentage of 55 per cent. A fawn birth weight of 9 per cent of the adult female weight and a common birth date of mid-November are assumed. Liveweights of breeding stags and hinds are based on a report by Suttie (2012). Research by Stevens and Ward (2023) has shown that hind liveweights have not risen above 110 kilograms, so a cap to liveweight is applied. It is assumed there is no pattern of liveweight change within any given year for mature deer. The lactation assumptions are 204 litres of milk over 120 days, an average daily lactation yield of 1.7 litres of milk per day (Suttie, 2012).

Minor livestock categories

Tier 1 methodology is used for goats, horses, mules and asses, swine, poultry, and alpacas (IPCC, 2006), using a combination of country-specific and IPCC default emission factors (annex 5, section A5.1.2, table A5.1.5).

The populations of goats, horses and swine are reported using data from the Stats NZ Agricultural Production Census and the inter-census Agricultural Production Survey. Data on the population of alpacas before 2009 are provided by Henderson and Cameron (2010) based on data from the Alpaca Association of New Zealand. Alpaca populations for 2009 to 2022 are based on modelling by Sise (2023). From 2023 onwards, registration numbers from the Alpaca Association of New Zealand and the New Zealand Llama Association are used assuming a 51 per cent registration rate (Sise, 2023).

[25] The number of beef cows slaughtered is assumed to be 17 per cent of the total beef cow herd, with other adult cows slaughtered assumed to be dairy cows. The carcass weight of dairy cattle slaughtered was estimated using the adult dairy cow liveweights and a killing-out percentage of 42 per cent (Thomson et al., 2010). The total weight of dairy cattle slaughtered was calculated (carcass weight × number slaughtered) and then deducted from the national total carcass weight of slaughtered adult cows. This figure was then divided by the number of beef cows slaughtered, to obtain an estimate of the carcass weight of adult beef cows. Liveweights were calculated assuming a killing-out percentage of 42.6 per cent (Thomson et al., 2010).

A small number of buffalo are farmed in New Zealand, with 699 animals being reported (Stats NZ, 2024). Because the buffalo livestock are used for producing milk, they are reported within the dairy herd.

Mules and asses are not farmed commercially or used as working animals in New Zealand. A constant population of 1,500 donkeys has been included in the Agriculture inventory model under mules and asses (Sise, 2023). The emissions from these populations of animals are extremely small relative to the major livestock categories.

Poultry is further classified into three categories: broiler chicken,[26] layer hens and other poultry. Stats NZ provides estimates of average annual broiler chicken flock sizes using industry data on the numbers of broilers processed every year since 1990. Mortality rates and days alive are used as suggested by Fick (2010). Stats NZ also obtains estimates of the number of layer hens and other poultry (e.g., ducks, turkeys, emus and ostriches) from the Agricultural Production Census and Agricultural Production Survey. Ostrich and emu farming in New Zealand is extremely rare. In 2015, it was estimated only 739 ostriches were in the country. Other poultry manure management emissions are included and calculated. Enteric fermentation is negligible and therefore not estimated.

The average annual flock size of chickens is determined by the following equation:

$$Average\ annual\ flock\ size = \frac{days\ alive}{365} \times annual\ number\ of\ birds\ processed\ \times (1 - mortality\ rate)$$

Rabbits are considered an agricultural pest, and only a very small number are farmed in the country (R Sanson, pers. comm., 2019). Because of this, emissions from farmed rabbits are reported as ‘not estimated’ (NE) because their emissions are insignificant. There is no known farming of platypus or other fur-bearing animals.

5.1.5 Recalculations

Agricultural emissions research

New Zealand invests in a comprehensive research programme to develop technologies and practices to reduce biological greenhouse gas emissions from agriculture. This is facilitated through the following.

- The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), which was established in 2009. It aims to contribute to agricultural greenhouse gas understanding and mitigation through research programmes and international collaboration, and to enhance New Zealand’s research capability and infrastructure in this area.
- The Pastoral Greenhouse Gas Research Consortium (PGgRc), which was established in 2003 by New Zealand agricultural sector organisations and private companies in partnership with the Government. It funds research, primarily into mitigation technologies and management practices for ruminants but also to provide information to improve on-farm greenhouse gas inventories. The PGgRc was funded in partnership between the Government, through the Ministry of Business, Innovation and Employment and Agriculture sector parties. Funding from the Ministry of Business, Innovation and Employment has since ceased and the PGgRc now largely operates on funding from industry.
- New Zealand is one of the founding members of the Global Research Alliance on Agricultural Greenhouse Gases (GRA), which facilitates international research

[26] Also known as ‘meat chickens’, which tend to be larger breeds with higher muscle content.

collaboration to study means of increasing global food production while reducing agricultural greenhouse gas emissions. This includes building capability, improving greenhouse gas inventories in developing countries, and facilitating the transfer of technologies and knowledge between members. New Zealand has hosted the GRA Secretariat since its establishment in 2009 and coordinates New Zealand's contribution of research, knowledge transfer and capability building largely through the NZAGRC.

- New Zealand's Greenhouse Gas Inventory Research Fund aims to support continuous improvement of the Agricultural Greenhouse Gas Inventory to improve the accuracy and reduce uncertainty of emissions reporting and forecasting. This follows the IPCC's guidelines for the preparation and continuous improvement of national greenhouse gas inventories (IPCC, 2000, 2006). It has supported greenhouse gas agricultural inventory research since 2004.
- The Centre for Climate Action on Agricultural Emissions was established in 2022 to accelerate the research, development and commercialisation of tools and technology to reduce emissions. It aims to achieve this via two main components:
  - AgriZeroNZ: a joint venture partnership between the Government and industry to drive a targeted research programme and support the pathway and uptake of new mitigation tools and technologies
  - enhancing the NZAGRC via additional investment

Research and data from these sources feed into New Zealand's improvement of the Agriculture inventory, and these research activities allow New Zealand to share technical skills and expertise internationally.

Recalculation and improvement approval process in the Agriculture inventory

The process for developing improvements and agreeing methodological changes to the Agriculture inventory is shown in figure 5.1.7.

Domestically, New Zealand has a network of scientific experts in the fields of CO_2, CH_4 and N_2O emissions. Research findings are presented annually at the Greenhouse Gas Inventory Research Workshop. New inventory research ideas raised by the research community inform decisions for future inventory research. Final decisions on research priorities are made by MPI, following discussions between the network leaders and Ministry for the Environment (MfE) staff. Research is contracted to address specific questions relating to gaps in New Zealand's knowledge base and to review, test and improve current model parameters used. Draft research reports are peer reviewed by at least one external independent expert with knowledge in the field and are assessed for their scientific robustness and suitability to be included in the Agriculture inventory model. A standard peer review report template is used.

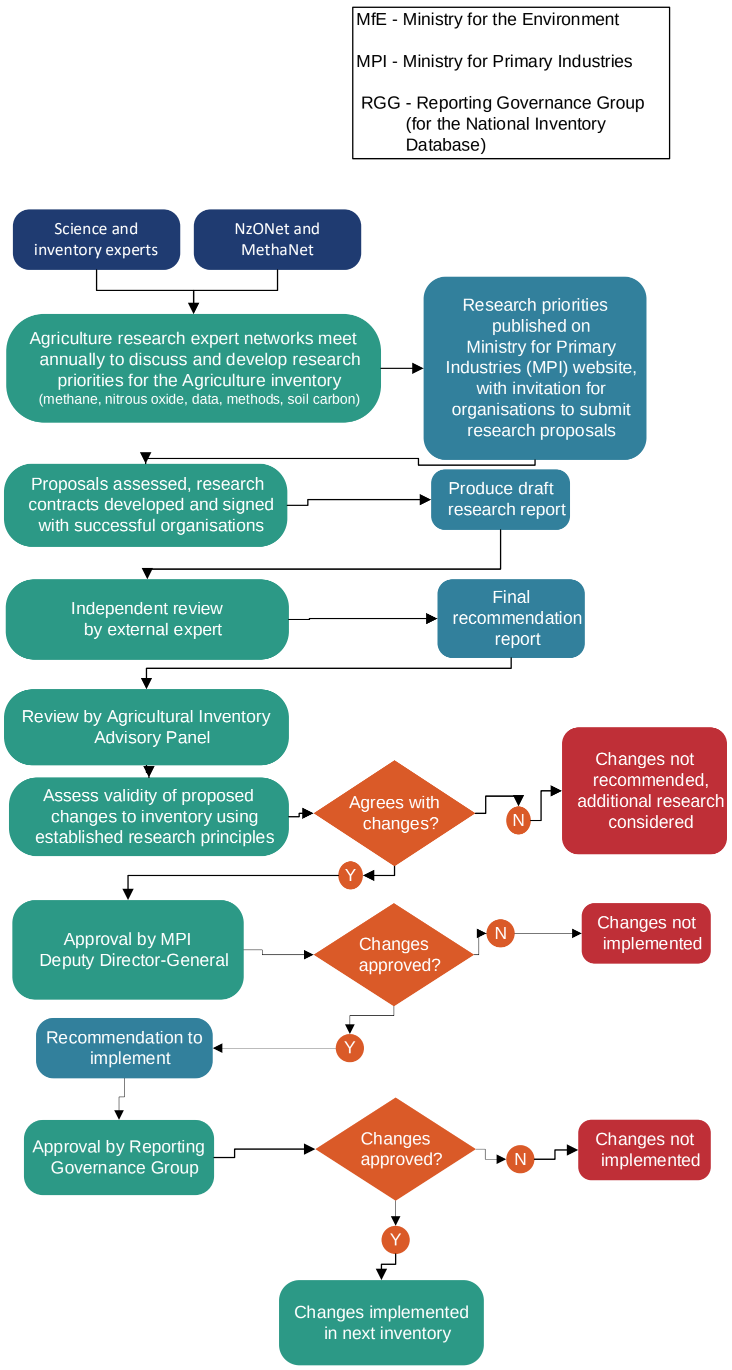
If the report recommends changes, a briefing and the final report, including the draft results of changes, are provided to the Agriculture Inventory Advisory Panel, which currently meets annually to review proposed changes to the Agriculture inventory model. The Panel comprises expert representatives from MPI and MfE and nominated science representatives from the Methanet and NzOnet expert advisory groups.[27] The Panel is independent of policy and

[27] Methanet and NzOnet contain experts on methane (CH_4) and nitrous oxide (N_2O) respectively. These advisory groups have been running since the early 2000s. The groups were formed to identify the main direction of research needed to improve the CH_4 and N_2O inventory accounts and mitigation, develop a collaborative approach to improve the quality of CH_4 and N_2O emissions data, and build and maintain inventory research capability.

industry influences and has been formed to give independent advice on whether changes to the Agriculture section of the National Inventory Report are scientifically robust, justifiable and internationally defensible. The Panel assesses if the proposed changes have been appropriately researched, using recognised scientific methods, principles and practices, and if there is sufficient scientific evidence to support any recommended changes.

Changes recommended by the Panel must be approved by the Deputy Director-General (Policy and Trade) at MPI, as well as the Reporting Governance Group, which is chaired by MfE and leads the reporting, modelling and projections of emissions and removals across government and all sectors. Further details of the Reporting Governance Group are provided in chapter 1, section 1.2.4.

Figure 5.1.7 Agriculture sectoral approval process for inventory recalculations and improvements



Agriculture Inventory Advisory Panel meeting – October 2024

The Panel meeting was held on 2 October 2024 and considered the following potential inventory changes:

1. inclusion of non-manure organic fertilisers
2. improvements to the deer population model and activity data
3. introducing seasonality into the wool growth calculations
4. updating donkey, poultry, alpaca and llama populations
5. corrections to the Agriculture inventory model code and incorporation of new activity data
6. inclusion of the EcoPond generation 2 mitigation technology for dairy cattle
7. updating emission calculations for swine.

The Panel recommended that all of the proposed changes should be incorporated into the 2025 submission, with the exception of EcoPond.

EcoPond is an effluent treatment system intended to reduce CH_4 emissions from dairy effluent ponds. The Panel also considered the inclusion of EcoPond in 2023. The Panel concluded that the research and trial results demonstrate clearly that the EcoPond technology significantly reduces CH_4 from effluent ponds by more than 90 per cent. However, the Panel recommended that EcoPond should only be included in the inventory after further research is carried out using a standard operating procedure for the technology to reflect how it would be used commercially.

All of the changes made have been backdated to the 1990 baseline. Further details on these changes are outlined in sections 5.2.5, 5.3.5 and 5.5.5 (category-specific recalculations), as well as chapter 10 (all recalculations).

The Panel also discussed progress towards including low-methane sheep in the inventory. The discussion focused on progress on developing a gene-flow model to track the impact of genetic improvement in the flock and activity data collection (which is still being investigated). This item did not result in recommended changes that affect emissions estimates.

The briefings, reports, supporting documentation and minutes of the 2024 Panel meeting (as well as Panel meetings for previous years) are available on the MPI website (www.mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/agricultural-inventory-advisory-panel).

Recalculations approved for the 2025 National Inventory Report submission in the Agriculture sector

Following the recommendations from the Agriculture Inventory Advisory Panel and approval from the Deputy Director-General (Policy and Trade) at MPI and the Reporting Governance Group, New Zealand has implemented all of the recommendations in its 2025 annual inventory submission.

The implementation of these improvements results in an approximate 0.3 per cent *increase* in the estimate of Agriculture sector emissions in 2022. However, the 2022 estimate of Agriculture sector emissions in the 2025 submission is 0.5 per cent *lower* than the 2022 estimate in the 2024 submission due to revisions to key activity data for 2022 (that were published after the compilation of the 2024 submission). See chapter 10, section 10.2.5 for more detail on the implemented improvements for the Agriculture sector.

5.1.6 Quality assurance and quality control (QA/QC)

The MPI Inventory team maintains close contact with the teams responsible for the collation of primary industries (agriculture, horticulture, forestry and fishing) data. These teams liaise with Stats NZ and provide analysis and forecasts of primary industries' activity and performance. This arrangement ensures that the MPI Inventory team has a good understanding of activity data and agricultural performance.

The connection with Stats NZ ensures that statistical data are aligned with changes in agricultural management practices in the primary industries sector. Capturing this data is required to be able to track changes in emissions as a result of mitigation and shifts in farm management in the Agriculture inventory model.

The MPI Inventory team also maintains relationships with industry bodies that provide additional data, such as Beef + Lamb New Zealand Ltd, DairyNZ, LIC, Deer Industry New Zealand, the Poultry Industry Association New Zealand and the Fertiliser Association of New Zealand.

As part of the quality-control procedures, the Agriculture inventory sector is reviewed by MPI personnel with expertise in climate change policy, international policy, climate change science and livestock farming policy. The review ensures that the Agriculture inventory sector clearly explains the sources of agricultural emissions in New Zealand as well as the trends in emissions from year to year. The results from the Agriculture inventory sector also inform domestic and international climate change policy.

MPI's Agriculture inventory sector experts meet regularly with the team at MfE that is responsible for coordinating the annual national inventory submission. MfE monitors MPI progress in implementing recommendations from previous expert review reports and on meeting timelines during the year.

MPI participates in the annual inventory debrief coordinated by MfE, to ensure the National Inventory Compiler and each sector lead understand what is working well and where improvements could be made.

In 2016, an external audit firm (Deloitte), with specialist skills in quality-assurance and quality-control (QA/QC) management, was engaged to evaluate and improve QA/QC processes for the Agriculture inventory sector. New Zealand has used this feedback to update and improve the QA/QC methodology.

A process of quality-control checks is mandated in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006) and the internal compilation process is provided in table 5.1.4.

Table 5.1.4 Agriculture sectoral approval process for inventory recalculations and improvements

QA/QC area	Details of QA/QC procedure
Activity data	• Data collection, requests, inputs and checks are recorded in a data check table, which is signed by the individual staff members performing the data input and checks. • A comprehensive list of all external data to be collected annually from internal and external sources is included as a part of the data check sheet. • New activity data and a sample of historical data are cross checked for accuracy and completeness by someone who did not input that data. • The data check table is included with the managerial sign-off materials before delivery to the Ministry for the Environment.
Emissions	• Implied emission factors are checked over time (1990 to most recent year) and against previous submissions. Any anomalies are investigated.

QA/QC area	Details of QA/QC procedure
	• Some key category emissions are compared against Tier 1 default methodologies and against similar parties, particularly Australia. A challenge for New Zealand is the lack of countries with similar agricultural circumstances and management practices. For example, New Zealand's major livestock types are almost all kept outdoors on pasture in all seasons. • Total emissions and each row of activity data from the common reporting tables are checked for accuracy against total emissions and activity outputs from the model. Category totals are also checked. Latest data points (2022) as well as 1990 and a random sample of years are checked. • An automated tool is run on the common reporting tables that identifies blank inputs, duplicates, changes in data type, implied emission factor time-series consistency, included elsewhere (IE) and not estimated (NE) inputs and instances where a country-specific emission factor is used with a Tier 1 methodology. Each resulting occurrence is investigated to determine if there is an issue or error, and a justification is provided if the result is expected.
Recalculations	• Recalculations are agreed with the Ministry for the Environment and the Reporting Governance Group every year before the Agriculture inventory sectoral compilation commences. • Recalculations are compared with previous submissions and, as far as possible, explained and confirmed by the changes in method or activity data. • The cumulative effect of any recalculations is investigated (the impact will not always be the sum of the impact of the changes, due to interactions between changes) and the level of interaction between changes is assessed. • Anomalous results from recalculations are checked and corrected, if necessary. • The Agriculture inventory sector compiler completes recalculation forms, signs the forms and forwards them to the Ministry for the Environment.
Periodic reviews	• Periodic reviews are completed on different aspects of the Agriculture inventory sector. Examples of these reviews are below. • The livestock population models and productivity parameters have been reviewed (e.g., Thomson et al., 2010). These reviews have also been used to update and improve the Tier 2 model. • During the 2012 submission, new crops were included in the National Inventory Report and a new complex methodology was implemented. For the 2013 submission, Plant and Food Research, a Crown research institute that has expertise in this area, was hired to review the workbooks, check the formulae, and model parameters. • During the 2015 submission, a mutual bilateral greenhouse gas inventory review was held between Australia and New Zealand, which included the Agriculture sector (Australian Government, unpublished). • In 2018, the population models in the Agriculture inventory model were reviewed. Small errors in the implementation of the population equations in the inventory model were found and corrected for in the 2019 (1990–2017) submission. • From 2022 to 2023, the Agriculture inventory model was migrated from Excel to R. For the 2023 (1990–2021) submission, the R model was run in parallel with the Excel model. During this process, the results between the two models were reviewed in detail. Some differences were identified and resulted in corrections of errors in the workings of the original model. The R model is now the active working model and was used for the 2024 (1990–2022) submission. • From 2023 onwards, in parallel to the inventory model, MPI has been developing an on-farm emissions calculation methodology and model. As part of this process, many of the calculations in the inventory model have been replicated in a way that could be implemented (and suitable) at the farm level. As errors are identified and corrections are made in the inventory model for the 2025 submission, they have been reviewed and verified internally by the team developing the on-farm emissions calculator.
Error checking and reporting	• Errors confirmed during the year are recorded, and the National Inventory Compiler is notified. The factors contributing to the error are assessed. • A checklist of quality-control activities is followed during data collection and entry into the model, data upload to the Greenhouse Gas Inventory Reporting Tool and National Inventory Report chapter preparation. • The Agriculture chapter of the National Inventory Report and the data exported to the Greenhouse Gas Inventory Reporting Tool are signed off by the chapter compiler, people involved in data checking and the responsible manager.

QA/QC area	Details of QA/QC procedure
Documentation	• Internal working instructions are maintained, to allow for staff movements. • Workbooks and calculations are kept on a MPI electronic archiving and management system, enabling wider team access to all workbooks. • The R model is stored in a git repository, code commits (updates) are accompanied by descriptions of changes, and good comment etiquette is followed, which allows for effective version management, change control and diagnostic testing. • Hyperlinks between check sheets, sign-off documents and workbooks are used to link relevant files on the document management system.

5.1.7 Planned improvements and research

MPI has planned and commissioned several projects aimed at further improving New Zealand's Agriculture inventory.

Short-term studies (around one year) currently under way or recently completed include:

- development of a method for inclusion of biochar amendments to soil in New Zealand's Greenhouse Gas Inventory and design of a comprehensive biochar database to inform this methodology (below)
- collecting additional field trial measurements of N_2O emissions from the application of synthetic nitrogen fertilisers in autumn 2024 (see section 5.5.6).

Longer-term studies (more than one year) include:

- measuring the CH_4 emissions from feed supplemented dairy cows (see section 5.2.6)
- undertaking integrative greenhouse gas evaluation of forages (see section 5.2.6)
- updating data on the use of different manure and effluent management systems in New Zealand dairy farms (see section 5.3.6)
- improving organic soils activity data and providing for the implementation of the IPCC 2013 Wetland Supplement (IPCC, 2014) (see section 5.5.6)
- increasing measurements of N_2O emissions in spring and summer to develop N_2O emission factors for dung and urine (EF_3), which vary by season (see section 5.5.6)
- developing a database of greenhouse gas activity data for whenua Māori (Māori land) (below)
- top-down measuring and modelling of CH_4 emissions as a verification tool (below)
- modelling liveweight change in growing heifers and dairy cows due to seasonality or disease (below)
- improving liveweight estimates for dairy cattle across their lifespans, from birth to first calving, within lactation, and across lactations (below)
- developing a process-based N_2O emissions model (see section 5.5.6)
- quantifying greenhouse gas emissions in cropland, and grassland biomass carbon stock dynamics (below)
- continuing work to improve activity data, including through the annual collection of agricultural data by Stats NZ.

New Zealand also intends to review the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2019) and investigate changes to methodology and emission factors for Agriculture, where appropriate. Meanwhile, any recalculations considered for implementation have included the relevant changes detailed in IPCC, 2019. Ongoing research into organic soils is being conducted, with the aim of enabling the implementation of the IPCC 2013 Wetland Supplement (IPCC, 2014).

Some of this research and potential improvements cover multiple categories of the Agriculture inventory sector and are described below. The remaining improvements relate only to a single Agriculture inventory sector category and are discussed in further detail in the relevant planned improvement sections 5.2.6 (*Enteric fermentation* (3.A)), 5.3.6 (*Manure management* (3.B)) and 5.5.6 (*Agricultural soils* (3.D)).

Method for inclusion of biochar

Biochar is a carbon-rich material produced from biomass through pyrolysis, with the potential to be a long-lasting carbon sink when applied to soils alongside generating possible production benefits. This project aims to develop a methodology to estimate greenhouse gas emissions or sinks from biochar amendments to soil for New Zealand's greenhouse gas inventory, enhancing the country's ability to report its emissions and removals effectively and potentially stimulating biochar-related activities. An investigation of the current state of biochar technology and use in New Zealand will inform the design of a database holding the required information to inform the methodology developed and support future reporting.

Greenhouse gas activity data for whenua Māori

This project will work to develop a database of activity and emission data for whenua Māori (Māori land). Māori have significant agricultural interests across New Zealand and current calculations of emissions are applied across the country, irrespective of land ownership and management differences. This will allow New Zealand to account for agricultural greenhouse gas emissions more accurately at a national level, while also helping to understand the implications of domestic policies on Māori land owners.

Top-down measuring and modelling of methane emissions as a verification tool

Accurate and regular reporting of CH_4 is vital to New Zealand's efforts to monitor and reduce anthropogenic greenhouse gas emissions. This research aims to investigate the feasibility of regular reporting of regional CH_4 emissions using both ground-based observations and observations from satellites. This could be valuable as a verification tool for the current bottom-up methodology, while also providing a more up-to-date reporting mechanism that could be provided to other stakeholders across New Zealand.

Modelling liveweight change in growing heifers and dairy cows

Currently, the Greenhouse Gas Inventory has relatively simple assumptions about dairy cattle liveweight and liveweight change. With additional data and modelling, these estimates can be made more accurate, accounting for key genetic and environmental factors, and time of year. The primary objective of this project is to improve liveweight estimates for dairy cattle, from birth to first calving, within lactation and across lactations. This work will allow for regional and genetic (breed, genetic potential) differences and will consider differences in environment and management, such as feeding level, which correlate with different farm systems. The long history of data in the Dairy Industry Good Animal Database should allow robust estimates from 1990 to the present with appropriate documentation to allow for transparency and consistency for updating future inventory years.

Improving liveweight estimates for dairy cattle across their lifespans

The current New Zealand inventory model assumes that dairy heifers grow linearly and mature dairy cows have a constant weight throughout the year. However, growing and lactating cattle have a non-linear growth curve affected by physiology and life stage, season and health of animals. This project aims to determine typical body weight change patterns for growing heifers and dairy cows. The project will also investigate liveweight change for dairy cattle during a disease event and determine their impact on predicted greenhouse gas emissions.

Quantifying greenhouse gas emissions in cropland, and grassland biomass carbon stock dynamics

This work has two contributing projects. The first project will provide a meta-analysis of estimates of the vegetation biomass carbon stocks for grassland types and the impacts of environment and management. This project will use a combination of literature, databases and modelling to better represent the way in which grassland biomass carbon stocks vary in space and time, and respond to management manipulations (e.g., grazing intensity, irrigation and fertiliser). This will allow a more accurate assessment of the impact of land use change within the grassland biome on carbon stocks for the purpose of inventory monitoring.

The second project aims to review estimates of biomass carbon stocks for croplands. Outcomes will include updated methods, revised parameters, and improved data sources and emission factors tailored to estimate emissions from cropland burning and vegetable and arable systems.

Completed research and research priorities

Refer to MPI's website for published reports on completed Agricultural Greenhouse Gas Inventory-related research projects (www.mpi.govt.nz/science/open-data-and-forecasting/greenhouse-gas-reporting/agricultural-greenhouse-gas-inventory-reports).

On the page for the Greenhouse Gas Inventory Research Fund (www.mpi.govt.nz/funding-rural-support/environment-and-natural-resources/greenhouse-gas-inventory-research-fund) there is a list of projects approved from the most recent funding round.

Future proposed research

MPI has proposed research on new topics that would begin in 2025. Refer to MPI published Greenhouse Gas Inventory Research Fund 2024 priorities, for more information on these topics (www.mpi.govt.nz/dmsdocument/57106-Greenhouse-Gas-Inventory-Research-Fund-2024-25-Priorities).

5.2 Enteric fermentation (3.A)

5.2.1 Category description

Methane is produced predominantly by ruminants as a by-product of enteric fermentation, which is the digestive process that breaks down consumed plant material in the rumen under anaerobic conditions. A portion of the plant material is fermented in the rumen to simple fatty acids, hydrogen, CO_2 and CH_4. The gases from this process are released by eructation (burping) and exhalation by the animal. The amount of CH_4 released is dependent on the type, quality and quantity of feed consumed, and energy expenditure of the animal. Energy expenditure depends on the type, age, weight, health and production of the animal, as well as whether the animal is pregnant (and the stage of pregnancy) or lactating.

Methane emissions from the *Enteric fermentation* category from *Dairy cattle*, *Non-dairy* (beef) *cattle*, *Sheep* and *Deer* were identified as among the largest key categories for New Zealand in the 2025 level assessment, and were also assessed as key categories in the trend assessment. The methodology used by New Zealand for calculating CH_4 emissions from enteric fermentation in domestic livestock is a Tier 2 modelling approach.

Enteric fermentation contributed an estimated 31,661.7 kt CO_2-e, representing 41.6 per cent of New Zealand's gross emissions and 78.0 per cent of Agriculture emissions in 2023. The major livestock categories contributing to *Enteric fermentation* are:

- *Dairy cattle* (49.2 per cent of *Enteric fermentation*)
- *Sheep* (26.8 per cent of *Enteric fermentation*)
- *Non-dairy cattle* (22.5 per cent of *Enteric fermentation*)
- *Deer* (1.3 per cent of *Enteric fermentation*).

Trends

Emissions from *Enteric fermentation* increased 2.0 per cent (626.8 kt CO_2-e) between 1990 and 2023. Since 1990, there have been changes in the relative sources of emissions within the *Enteric fermentation* category (see table 5.2.1). A large increase in CH_4 emissions from *Dairy cattle* (124.0 per cent increase in *Enteric fermentation* emissions between 1990 and 2023) has been partially offset by decreases in *Enteric fermentation* emissions from *Sheep* (46.7 per cent decrease) as well as *Non-dairy cattle* (3.7 per cent decrease) and minor livestock species, such as *Goats*, *Horses* and *Swine* (83.7 per cent decrease).

Table 5.2.1 Trends and relative contribution of enteric fermentation (methane expressed in kt CO_2-e) from livestock categories between 1990 and 2022

Livestock category	Emissions (kt CO_2-e) 1990	Emissions (kt CO_2-e) 2023	Change from 1990 %	Change from 1990 kt CO_2-e	Share of *Enteric fermentation* category (%) 1990	Share of *Enteric fermentation* category (%) 2023	Share of total Agriculture sector (%) 1990	Share of total Agriculture sector (%) 2023
Dairy cattle	6,960.4	15,590.4	124.0	8,630.0	22.4	49.2	18.9	38.4
Non-dairy cattle	7,400.7	7,125.9	-3.7	-274.8	23.8	22.5	20.0	17.5
Sheep	15,949.8	8,493.7	-46.7	-7,456.1	51.4	26.8	43.2	20.9
Deer	444.4	406.2	-8.6	-38.3	1.4	1.3	1.2	1.0
Minor livestock	279.5	45.6	-83.7	-234.0	0.9	0.1	0.8	0.1
Total	**31,034.9**	**31,661.7**	**2.0**	**626.8**	**100.0**	**100.0**	**84.1**	**78.0**

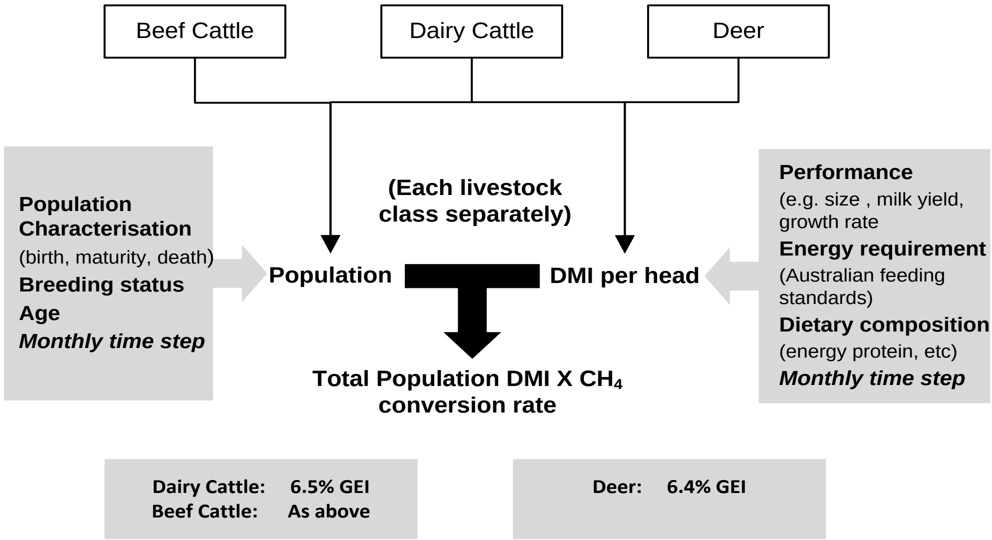
Note: Percentages presented are calculated from unrounded values.

5.2.2 Methodological issues

Emissions from *Non-dairy cattle*, *Dairy cattle* and *Deer*

The total amount of enteric CH_4 emitted by *Non-dairy cattle, Dairy cattle* and *Deer* is calculated using a CH_4 conversion factor for emissions per unit of dry matter feed intake in kilograms of DMI per livestock category (see figure 5.2.1). The enhanced livestock population characterisation and DMI per head is calculated by New Zealand's Tier 2 inventory model (see section 5.1.3). A more complex algorithm has been used to calculate enteric CH_4 emissions for *Sheep* and is discussed in the next section.

Figure 5.2.1 **Schematic diagram showing how New Zealand's methane emissions from enteric fermentation for dairy and beef cattle and deer are calculated**



Note: CH_4 = methane; DMI = dry-matter intake; GEI = gross energy intake.

The equation for the production of enteric CH_4 for cattle and deer is:

$$CH_{4-enteric} = \sum_{livestock\ type} Pop_{livestock\ type} \times DMI \times \frac{MCR}{1000}$$

Where: $CH_{4\text{-enteric}}$ = enteric CH_4 emissions per day (kg)

$Pop_{\text{livestock type}}$ = population of each livestock category (head)

DMI = dry-matter intake (kg per animal per day)

MCR = methane conversion rate (21.6 grams of CH_4 per kg of DMI for dairy cattle and non-dairy cattle and 21.25 grams of CH_4 per kg of DMI for deer).

Emissions from *Sheep*

Enteric CH_4 emissions from *Sheep* are calculated using the methodology outlined in a peer reviewed paper published by Swainson et al. (2016). The study confirmed that DMI alone has the largest influence on CH_4 emissions and that pasture quality (as measured by the ME content) has a small but statistically significant effect on emissions from sheep less than one year of age.

Swainson et al. (2016) concluded that two log-transformed linear regressions (one for sheep less than one year of age and one for sheep greater than one year of age) provided the best fit for the data and recommended that these equations be used in the National Inventory Report.

The equation[28] for the total production of enteric CH_4 for sheep less than one year of age is:

$$CH_{4-enteric} = \sum_{class} \sum_{month} d_m\, Lamb_{cm} \frac{11.705}{1000} e^{0.05 \times ME} DMI^{0.734}$$

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[28] The equation displayed here is a rearranged form of the equation displayed in Swainson et al. (2016): $\ln(CH_4) = 0.734 \times \ln(DMI) + 0.05 \times ME + 2.46$.

The equation[29] for the total production of enteric CH_4 for sheep greater than one year of age is:

$$CH_{4-enteric} = \sum_{class} \sum_{month} d_m \, Sheep_{cm} \frac{21.977}{1000} DMI^{0.765}$$

Where: $CH_{4\text{-enteric}}$ = total CH_4 from enteric fermentation (kg CH_4/year)

d_m = number of days in month m

$Lamb_{cm}$ = population of sheep in class c during month m (head), less than one year of age (i.e., lambs)

$Sheep_{cm}$ = population of sheep in class c during month m (head), greater than one year of age

ME = metabolisable energy concentration of diet during month m (megajoules of metabolisable energy per kg of dry matter)

DMI = daily dry-matter intake of an individual sheep of class c in month m (kg dry matter/head/day)

class refers to the different categories of sheep greater than one year of age (e.g., dry ewes, wethers, rams) used in the Agriculture inventory model, and

month refers to the 12 months of the calendar year.

Dry-matter intake per sheep per day is calculated by New Zealand's Tier 2 inventory model (see section 5.1.3). Monthly values of ME concentration for total diet (pasture and non-pasture feed) are calculated using New Zealand's Tier 2 inventory model (see section 5.1.3).

Methane measurement and modelling

New Zealand uses country-specific methodology and emission factors for estimating enteric fermentation CH_4 emissions per kilogram of dry matter feed intake (i.e., DMI) for several reasons. First, the data requirements for existing digestion models[30] are less relevant to New Zealand's predominantly outdoor pasture-based systems. Existing digestion models have been largely derived from animals fed indoors on diets unlike the grass-based diets fed to New Zealand livestock. Further, these existing models have a lower predictive power when compared with empirical experimental data derived from New Zealand research (Clark et al., 2003).

Since 1996, New Zealand scientists have been measuring CH_4 emissions from grazing (non-housed) cattle and sheep initially using the sulphur hexafluoride (SF_6) tracer technique (Lassey et al., 1997; Ulyatt et al., 1999). In recent years, New Zealand-based research has used closed-circuit respiration chambers, which are considered the benchmark for assessing CH_4 emissions from livestock. These have been used to derive respiration-chamber-based measurements of CH_4 emissions for sheep and, more recently, an expanded programme for dairy and non-dairy cattle.

To obtain New Zealand-specific values (or algorithms for sheep emissions), all relevant published and unpublished New Zealand-specific data were collated and used to derive

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29 The equation displayed here is a rearranged form of the equation displayed in Swainson et al. (2016): $\ln(CH_4) = 0.765 \times \ln(DMI) + 3.09$.

30 For example, Blaxter and Clapperton (1965); Moe and Tyrrel (1975); Baldwin et al. (1988); Djikstra et al. (1992) and Benchaar et al. (2001), all cited in Clark et al. (2003).

average values for CH_4 emissions from different categories of livestock (Clark et al., 2003; Swainson et al., 2016). The associated data are presented in table 5.2.2 together with the IPCC (2006, tables 10.12 and 10.13) default values for per cent gross energy intake (GEI) used to calculate CH_4. The New Zealand values for cattle fall within the IPCC range and are applied in this submission.

Table 5.2.2 Methane (CH_4) emissions and gross energy intake (GEI) from New Zealand measurements and IPCC (2006) default values

	Adult cattle	Adult sheep (> 1 year)	Young sheep (< 1 year)
New Zealand CH_4 emission rates from Clark et al. (2003) and Swainson et al. (2016) (g CH_4/kg DMI)	21.6 × DMI	$21.977 \times DMI^{0.765}$	$11.705 \times e^{0.5ME} \times DMI^{0.734}$
New Zealand data (GEI, %)	6.5	-	-
IPCC (2006) default Y_m values (GEI, %)	6.5 ± 1.0	6.5 ± 1.0	4.5 ± 1.0

Note: DMI = dry-matter intake; Y_m = methane yield, ME = metabolisable energy.

The adult cattle value is applied to all dairy and non-dairy cattle, irrespective of age. The value for deer is calculated based on the average value for adult cows and the (now defunct) CH_4 emission rate for adult ewes[31] (Clark et al., 2003). This is due to: (i) a lack of country-specific data for deer and (ii) that their liveweights are around halfway between cattle and sheep, both of which have emission factors based on robust, country-specific research. No CH_4 emissions are assumed to arise from very young animals during the time that their diet only consists of milk (first two months of age for dairy calves, non-dairy calves and lambs, first four months of age for fawns).

Table 5.2.3 shows a time series of CH_4 IEFs (total emissions produced per animal type divided by the population of animals for each category) for dairy cattle, non-dairy cattle, sheep and deer. New Zealand experiences large inter-annual variability in these IEFs, which is explained further in section 5.1.1. In table 5.2.3, *Milking dairy cattle* is a subset of *All dairy cattle* and only includes mature dairy cows that are being milked. *All dairy cattle* includes milking cows as well as calves, dairy bulls and other dairy cattle not being milked.

Table 5.2.3 New Zealand's implied emission factors for enteric fermentation, from 1990 to 2023

Year	All dairy cattle (kg CH_4 per animal per annum)	Milking dairy cattle (kg CH_4 per animal per annum)	Non-dairy cattle (kg CH_4 per animal per annum)	Sheep, all (kg CH_4 per animal per annum)	Deer (kg CH_4 per animal per annum)
1990	72.2	76.6	57.5	9.8	16.3
1995	75.3	83.0	60.4	10.5	18.0
2000	79.6	89.3	64.0	11.6	17.9
2005	82.3	86.6	67.8	11.9	17.8
2010	82.7	90.5	66.4	11.7	18.2
2015	89.8	95.9	64.9	12.2	18.7
2020	93.2	101.1	66.1	12.6	19.0
2023	94.6	103.0	69.6	12.5	19.6

Emissions from minor livestock categories

A Tier 1 approach is adopted for the minor livestock categories of *Goats*, *Horses*, *Swine*, *Llamas and alpacas*, and *Mules and asses*, using either IPCC (2006) default emission factors (horses, llamas and alpacas, and mules and asses) or New Zealand country-specific emission

[31] Value used in earlier versions of the National Inventory Report (21.25 grams CH_4 per kilogram dry-matter intake).

factors (goats and swine). These minor livestock species comprised 0.1 per cent of the total *Enteric fermentation* emissions in 2023. The populations of goats, horses, swine, llamas and alpacas, and mules and asses are reported using the statistics and assumptions described in section 5.1.4.

Goats: New Zealand uses a Tier 1 approach with country-specific emission factors to determine enteric fermentation emissions from goats. From 1990 to 2023, the domesticated goat population declined from 1,062,900 to 78,055. This was largely driven by a decrease in demand for goat fibre and meat. New Zealand uses a country-specific emission factor for goats for enteric fermentation of 7.4 kg CH_4 head^{-1} year^{-1} for 1990 and 8.5 kg CH_4 head^{-1} year^{-1} for 2009 based on the differing population characteristics for those two years (Lassey, 2011). For the intermediate years between 1990 and 2009 and for 2010 to 2018, the emission factor is calculated based on the goat population, with the assumption that the dairy goat population has remained relatively consistent over time while the rest of the goat population has declined (Burggraaf et al., 2019). From 2019 onward, a constant value of 9.0 kg CH_4 head^{-1} year^{-1} is used. This will be updated when the research is reviewed. This is higher than the IPCC (2006) default value for goats for developed countries, which is 5.0 kg CH_4 head^{-1} year^{-1}.

Swine: New Zealand uses a Tier 1 approach with country-specific emission factors to determine enteric fermentation emissions from swine. Gross energy data from swine diets were used in the Tier 2 IPCC equation (equation 10.21, IPCC, 2006) to determine the country-specific enteric fermentation emission factors for breeding pigs and growing pigs (see table 5.2.4). Surveys of commercial pig diet were conducted in 2009 (Hill, 2012) and 2022 (Ritchie, 2024). For years between the surveys the emission factors are interpolated. These factors are then multiplied by population data to obtain the total CH_4 emissions produced by swine from enteric fermentation for a given inventory year.

Table 5.2.4 Enteric fermentation emissions factors (kg CH_4 head^{-1} year^{-1}) for pig classes

Year	Breeding pigs (kg CH_4 per animal per annum)	Growing pigs (kg CH_4 per animal per annum)
1990	2.21	0.89
1995	2.21	0.89
2000	2.21	0.89
2005	2.21	0.89
2010	2.19	0.89
2015	2.10	0.85
2020	2.01	0.82
2022	1.97	0.81
2023	1.97	0.81

The country-specific emission factors were developed from industry data on GEI (Hill, 2012; Ritchie, 2024) in which data on the composition of swine diets and industry practices in place to manage waste from production systems were obtained from representative surveys of swine farms in 2009 and 2022. Nutritional information was available for different swine age classes and categories. Additionally, the average value of GEI was adjusted for population and further verified against national animal welfare standards.

The New Zealand emission factors for swine are lower than the IPCC (2006) default for developed countries.[32] The IPCC (2006) default value for swine is based on average values derived from 1980s Western German swine production and population statistics, and is not representative of New Zealand swine systems. In particular, the default value does not

[32] The IPCC (2006) default emission factor for swine is identical to the IPCC (1996) emission factor.

reflect changes in production due to improvements in genetic selection, reproductive cycle performance, housing and feed, animal husbandry and herd management. Further information on these factors is provided in the report by Hill (2012) and Ritchie (2024).

Horses: The IPCC (2006) default value (18 kg CH_4 head^{-1} year^{-1}) is used to estimate CH_4 emissions from this livestock category.

Llamas and alpacas: The IPCC (2006) default value (8 kg CH_4 head^{-1} year^{-1}) is used to estimate CH_4 emissions from this livestock category.

Mules and asses: The IPCC (2006) default value is used (10 kg CH_4 head^{-1} year^{-1}) to estimate CH_4 emissions from this livestock category.

5.2.3 Uncertainty assessment and time-series consistency

To ensure consistency across emission categories, a single enhanced livestock population characterisation and feed-intake estimate is produced by the Tier 2 model (see annex 5, table A5.1.2 for the full list of livestock categories). It is used in different parts of the calculations for the National Inventory Report to estimate: CH_4 emissions for the *Enteric fermentation* category, CH_4 and N_2O emissions for the *Manure management* category and N_2O emissions for the *Pasture, range and paddock manure* category.

Livestock numbers

The calculations for total enteric fermentation require livestock population data. Information on the uncertainties and time-series consistency for the livestock population data is included in section 5.1.4 and annex 5, section 5.1.

Uncertainty of methane emissions from enteric fermentation in sheep and cattle

Kelliher et al. (2009) calculated the uncertainty of enteric fermentation CH_4 emissions for sheep and cattle using a Monte Carlo approach. This superseded a previous analysis undertaken by Clark et al. (2003). Kelliher et al. (2009) calculated the uncertainty by expressing the coefficient of variation according to the standard deviation of the CH_4 yield using a larger sample of measurements (relative to the previous analysis). The analysis was restricted to grass–legume pasture, the predominant diet of sheep and cattle in New Zealand. The resulting overall uncertainty of the enteric CH_4 emissions inventory, expressed as a 95 per cent confidence interval, was ±16 per cent (see table 5.2.5).

Table 5.2.5 New Zealand's uncertainty in the annual estimate of enteric fermentation emissions for 1990 and 2023, estimated using the 95 per cent confidence interval (±16 per cent)

Year	Enteric CH_4 emissions (kt CH_4/annum)	95% confidence interval minimum (kt CH_4/annum)	95% confidence interval maximum (kt CH_4/annum)	Range of uncertainty (kt CH_4/annum)
1990	1,108.4	931.0	1,285.7	354.7
2023	1,130.8	949.9	1,311.7	361.8

Note: The methane (CH_4) emissions used in the Monte Carlo analysis exclude those from swine, horses, goats, mules and asses, and llamas and alpacas, which represent a very small proportion of total CH_4 emissions.

Uncertainty in the annual CH_4 estimate is dominated by variance in the measurements of the 'CH_4 per unit of intake' factor. This uncertainty is predominantly due to natural variation from one animal to the next due to genetic, management and environmental factors. Uncertainties in the estimates of livestock energy requirements, forage quality and animal population data are much smaller (Clark et al., 2003).

5.2.4 Category-specific QA/QC and verification

Methane from *Enteric fermentation* from *Dairy cattle*, *Non-dairy cattle*, *Sheep* and *Deer* was identified as a key category (level and trend assessment). In the preparation for this inventory, the data for this category underwent Tier 1 and Tier 2 quality checks.

Enteric CH_4 emission rates per animal have been verified using micrometeorological techniques. Laubach and Kelliher (2004) used the integrated horizontal flux technique and the flux gradient technique to measure CH_4 emission flux above a dairy herd. Both techniques are comparable, within estimated errors, to scaled-up dairy animal emissions. The emissions from the cows measured by integrated horizontal flux (averaged over three trials) were 329 (±153) g CH_4/day/cow, compared with 365 (±61) g CH_4/day/cow for the scaled-up measurements reported by Waghorn et al. (unpublished(a), unpublished(b)) using the SF_6 technique for CH_4 measurement.

Enteric CH_4 emissions from lactating dairy cows have also been measured using the New Zealand SF_6 tracer method compared with the respiration chamber techniques (Grainger et al., 2007). Total CH_4 emissions were similar when measured using respiration chambers (322 g CH_4/day/cow) or the SF_6 tracer technique (331 g CH_4/day/cow) but the uncertainty of the SF_6 technique measurements was greater.

The calculations in New Zealand's model for all cattle, sheep and deer are Tier 2 and are based on the 2006 IPCC Guidelines (IPCC, 2006). Table 5.2.6 shows a comparison of the New Zealand-specific 2023 IEFs for enteric fermentation with the IPCC Tier 1 Oceania default value, the IPCC Tier 2 net energy-based value and the Australian-specific 2022 IEF for dairy cattle, non-dairy cattle and sheep.

The IPCC Tier 2 net energy-based values are determined from the net energy algorithms in the 2006 IPCC Guidelines (equation 10.16) for dairy cattle, non-dairy cattle and sheep (IPCC, 2006). New Zealand's inventory model calculates emissions for sheep (one year of age and older) and lambs (less than one year old) separately. Therefore, to provide an appropriate comparison between the New Zealand-specific IEF and the IPCC Tier 2 net energy-based values for sheep, the gross energy values determined using the IPCC Tier 2 energy equations were obtained for both sheep and lambs.

Table 5.2.6 Comparison of the IPCC (2006) default emission factor and country-specific implied emission factors (IEFs) for methane (CH_4) from *Enteric fermentation* for *Dairy cattle*, *Non-dairy cattle* and *Sheep*

	Dairy cattle (kg CH_4/head/year)	Non-dairy cattle (kg CH_4/head/year)	Sheep (kg CH_4/head/year)
IPCC (2006) Tier 1 Oceania default value	90.0	60.0	8.0
IPCC (2006) Tier 2 net energy-based value	72.5	51.6	8.9
Australian-specific IEF 2022 value[33]	95.1	51.3 (pasture) 68.8 (feedlot)	6.7
New Zealand-specific IEF 2023 value	94.6 (all dairy cattle, including calves) 103.0 (mature milking cattle only)	69.7	12.5

Note: The IPCC (2006) value for sheep is for developed countries.

[33] As reported in Australia's *2024 Common Reporting Table*. Retrieved 20 November 2024. Note that the Australian-specific beef cattle IEF value is calculated from a population-based weighted average of pasture and feedlot IEF values from beef cattle.

Dairy cattle: New Zealand's 2023 IEF for all dairy cattle, including calves, is higher than the IPCC Tier 1 Oceania default value and similar to the Australian-specific IEF. New Zealand's 2023 IEF for mature milking cattle is higher than the IPCC Tier 1 Oceania default value and the 2022 Australian-specific IEF.

Although New Zealand's predominantly outdoor pasture-based system is similar to Australian dairy cattle management, differences in IEF values could be explained by differences in proportions of different cattle breeds (with different liveweights). The 2022 Australian dairy herd comprised 73 per cent Holstein; other breeds include Jersey, Brown Swiss, Ayrshire, the Australian Red and the Illawarra (DataGene Limited, 2023). In 2023, 60.4 per cent of New Zealand's cow population comprised a Holstein–Friesian/Jersey crossbreed, 23.9 per cent are Holstein–Friesian and 7.5 per cent are Jersey (LIC and DairyNZ, 2024).

In New Zealand's Tier 2 inventory model, dairy cattle encompass all cattle that are required to support the milking dairy herd. This includes calves, young growing non-lactating heifers, dry cows and bulls. Because the emissions from these animals are included in the IEF calculations, the IEF will be lower than if only mature milking cows had been considered.

New Zealand's dairy 2023 IEF is higher than the IPCC Tier 2 net energy-based value. This could be because of the different energy intakes and requirements of housed animals compared with animals grazing on pasture, or differences in per-animal productivity in New Zealand compared with other countries. The feeding algorithms within New Zealand's national inventory use New Zealand-specific activity data and methodology that better reflect the outdoor pastoral-based farming systems in New Zealand.

Non-dairy cattle: The New Zealand-specific 2023 IEF for *Non-dairy cattle* is greater than the IPCC Tier 1 Oceania default value, the IPCC Tier 2 net energy-based value and Australian-specific IEFs. Differences such as feed type and quality, breed and which animals are characterised as non-dairy will influence the IEFs. As explained for dairy cattle above, the main difference between the IPCC Tier 2 value and the New Zealand-specific value (apart from the different energy equations determining them) is that the feeding algorithms within New Zealand's national inventory use New Zealand-specific activity data and methodology that better reflect New Zealand's outdoor pastoral-based farming systems.

Sheep: New Zealand's 2023 IEF for sheep is greater than the IPCC Tier 1 default value, the Tier 2 net energy-based value and the 2022 Australian-specific IEF. This is in part because the annual sheep population figure used to calculate the IEF is based on the June population, in mid-winter. This count excludes most lambs, born in spring (August–September) and raised and slaughtered during summer and early autumn (February, March and April). New Zealand does take lambs into account when determining total annual enteric CH_4 emissions because emissions are calculated monthly, but it does not include the lamb population slaughtered during summer and early autumn when estimating the IEF. The same rationale around the impact of feed type and quality, breed, and New Zealand's outdoor pastoral-based farming systems as put forward for cattle is also a contributing factor to the difference between the New Zealand IEF and IPCC values.

Verifying regional methane emissions using inverse modelling techniques

New Zealand has invested in developing country-specific methods and emission factors to estimate CH_4 emissions from ruminant animals, given their contribution to gross greenhouse gas emissions in the New Zealand inventory. Methane emissions can be robustly calculated from estimates of animal populations, DMI and emission factors, but it is challenging to verify the efficacy of mitigation technologies in the field. A possible solution is inverse modelling of emissions, based on atmospheric greenhouse gas measurements from a network of observing stations, combined with models that describe the pathway the air took before arriving at the station, to infer regional to national greenhouse gas emissions or uptake. The inversion is conducted by taking all existing data, the initial estimates of regional CH_4, observations and back trajectory modelling, to infer what the regional emissions of CH_4 were.

In Geddes et al. (2021), atmospheric inverse modelling was tested on regional and national emission estimates for 2011 to 2013 and 2018 using data collected from the National Institute of Water and Atmospheric Research observing stations at Lauder, Central Otago, and Baring Head, Wellington region. The emission estimates from this research are underpinned by several key resources: (i) an initial estimate of monthly CH_4 emissions and distributions; (ii) atmospheric CH_4 measurements at an inland and a background (baseline CH_4 levels) site; (iii) an atmospheric transport model that describes the pathway air took before arriving at the observing sites; and (iv) an inverse method that estimates the best combination of emissions to match the available data.

Due to the atmospheric observing network's insensitivity to North Island CH_4 emissions (partly due to the lack of stations north of Wellington), calculated emissions for the South Island using the inverse model were more robust than North Island estimates. For the South Island, estimated emissions using this technique were found to be comparable with those reported using inventory bottom-up methods and data. The analysis showed that the atmospheric observations are providing new information that can be used to validate and enhance the Agriculture inventory estimates. The inverse modelling approach has the potential to shed light on seasonal and inter-annual variability and detect emission changes.

The accuracy of these estimates will be improved by the addition of more observations, the installation of additional sites, ground calibration, and further quality control. An expansion of New Zealand's national CH_4 observing network from two to eight sites is under way through the CarbonWatch NZ research programme (more information available at: niwa.co.nz/atmosphere/carbonwatch-nz).

Satellites could also be a useful addition to allow further analysis of historical emissions and to assess emissions where ground-based measurements are challenging (Geddes et al., 2021). In 2019, New Zealand's Ministry of Business, Innovation and Employment signed on to collaborate on MethaneSAT, a state-of-the-art satellite designed to detect global CH_4 emissions. MethaneSAT launched in March 2024 and is currently collecting data. MethaneSAT has the potential to provide a valuable tool alongside the atmospheric observing network.

A project is under way to investigate the feasibility of regular reporting of regional CH_4 emissions using top-down approaches (see section 5.1.7, for more details) from both ground-based observations and satellites enabling quarterly estimates of regional CH_4 emissions across New Zealand. Any relevant data can be incorporated into the reports, with the ground-based inversion adapted to provide relevant intercomparison.

5.2.5 Category-specific recalculations

Emissions estimates in the *Enteric fermentation* category reported in the 2025 submission have been affected by methodological improvements pertaining to: (i) minor species population changes; (ii) updating deer population and productivity statistics; (iii) updating emissions calculations for pigs; (iv) seasonality of wool growth; and (v) small error corrections to model code.

Minor species population value changes

Emissions estimates in all categories relating to donkeys, poultry, llamas and alpacas have been improved by an update to the estimated populations.

The New Zealand inventory calculates emissions from these minor species using country-specific methods and emission factors where possible. IPCC Tier 1 emission factors and methodology are also used.

Recent research carried out by AbacusBio (Sise, 2023) has used industry data, data from Stats NZ, other agricultural databases and additional information provided from industry stakeholders to improve the population assumptions for donkeys, poultry, llamas and alpacas.

The following recommendations from Sise (2023) were implemented in the 2025 inventory submission.

- Update the donkey population to 1,500 (previously 141).
- Use disaggregated Stats NZ data to calculate the poultry population.
- Use the modelled alpaca population levels and the modelled llama population levels for 2009 to 2022, with information from both the alpaca and llama registries used to provide population estimates from 2023 onwards.

Implementing these changes caused emissions from the *Enteric fermentation* category to increase by 0.4 kt CO_2-e in 1990 and 2.1 kt CO_2-e in 2022 (see table 5.2.7).

Table 5.2.7 Comparison of the previous minor species populations and the updated minor species populations for emissions from *Enteric fermentation*

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Enteric fermentation*	2024 (1990–2022) emissions estimate	31,212.5	32,617.2	1,404.7	4.5
	2024 (1990–2022) emissions estimate *with improvement*	31,212.9	32,619.3	1,406.4	4.5
	Difference in emissions estimates	0.4	2.1		
	Percentage difference in emissions estimates (%)	0.00	0.01		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Updating deer population and productivity statistics

Emissions estimates in all categories relating to deer have been improved by an update to the estimated populations, mature hind liveweight, and velvet antler production.

Recent research carried out by Crown research institute AgResearch, by Stevens and Ward (2023), has developed a method to assign deer reported in the Stats NZ Agriculture Production Survey data to venison or velvet production as well as to age and sex. The research also used industry data to improve estimates of the mature weight of hinds and stags, stag slaughter date, and suggest a more accurate source of velvet antler production.

The following recommendations from Stevens and Ward (2023) were implemented in the 2025 inventory submission.

- Update the methodology to assign deer animals reported in the Stats NZ Agriculture Production Survey data to class, including the adoption of separate classes for the venison and velvet value streams.
- Update the values used for hind liveweight to a maximum of 110 kilograms.
- Use the Deer Industry New Zealand record of velvet antler production.
- Add an additional slaughter for stag populations at 25 months.

Implementing these changes caused emissions from the *Enteric fermentation* category to decrease by 15.0 kt CO_2-e in 1990 and 66.6 kt CO_2-e in 2022 (see table 5.2.8).

Table 5.2.8 Comparison emissions from *Enteric fermentation* using the updated deer population and productivity statistics

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Enteric fermentation*	2024 (1990–2022) emissions estimate	31,212.5	32,617.2	1,404.7	4.5
	2024 (1990–2022) emissions estimate *with improvement*	31,197.5	32,550.6	1,353.1	4.3
	Difference in emissions estimates	-15.0	-66.6		
	Percentage difference in emissions estimates (%)	-0.05	-0.20		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Updating emissions calculations for pigs

Emissions estimates in all categories relating to pigs have been improved by updates to the emissions calculations.

The 2024 inventory submission used New Zealand-specific emission factors for pigs developed by Hill (2012), in conjunction with default data provided by the IPCC. The methodology was based on a 2009 survey of New Zealand pig farmers. Changes to the commercial New Zealand pork industry have occurred since then, such as improvements in genetic selection, animal housing, feed, husbandry and herd management.

Recent research carried out by NZ Pork (Ritchie, 2024) resurveyed commercial pig farmers in New Zealand to gather current data on relevant industry characteristics and practices. The survey was conducted in 2022. This has led to several recommendations for updates to emissions factors and other relevant data.

The following recommendations from Ritchie (2024) were implemented in the 2025 inventory submission.

- Enhanced Tier 1 methodology for pigs that differentiates between breeding and growing pigs in the calculation of CH_4 emissions and nitrogen excretion.
- Updated enteric fermentation emission factors for pigs.
- Updated emission factors and proportions of animal waste sent to different management systems for calculating CH_4 emissions from manure management.
- Updated emission factors and proportions of nitrogen sent to different management systems used in the calculation of N_2O emissions.

The report used a two-part process to update the enteric CH_4 emission factor used in the Tier 1 inventory calculations. First, calculating GEI from pig diets, and secondly using the Tier 2 IPCC equation (equation 10.21, IPCC, 2006) and the GEI value to recalculate the emissions factor for breeding pigs and growing pigs. The resulting emission factors are in table 5.2.4. The previous country-specific emission factor for enteric fermentation was developed using a similar approach. Hill (2012) also reported separate emission factors for breeding and growing pigs, but the weighted average for the whole population was used (1.06 kg CH_4 head^{-1} year^{-1}).

For years 2010 to 2021, the enteric fermentation emission factor values are linearly interpolated between those reported in Hill (2012) and Ritchie (2024), to reflect changing GEI (Ritchie, 2024).

Implementing these changes caused emissions from the *Enteric fermentation* category to decrease by 0.3 kt CO_2-e in 1990 and 0.1 kt CO_2-e in 2022 (see table 5.2.9).

Table 5.2.9 Comparison emissions from *Enteric fermentation* using the updated pig calculations

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Enteric fermentation*	2024 (1990–2022) emissions estimate	31,212.5	32,617.2	1,404.7	4.5
	2024 (1990–2022) emissions estimate *with improvement*	31,212.2	32,617.1	1,404.8	4.5
	Difference in emissions estimates	-0.3	-0.1		
	Percentage difference in emissions estimates (%)	0.00	0.00		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Seasonality of wool growth

Emissions estimates in all categories relating to sheep have been improved by an update to monthly wool growth.

In the 2024 inventory submission, wool growth was assumed to be constant through the year, and in the case of the calculation of the energy required for wool growth, constant for the entire time series.

Recent research carried out internally by MPI analysed data available in several published papers, to determine an appropriate seasonal adjustment to wool growth. The research fit a sinusoidal curve to published monthly wool growth data (Woods and Orwin, 1988) to develop a seasonal adjustment.

Annual wool yield is now apportioned to class and month using a calculated seasonal adjustment and accounts for the slower wool growth in lambs. The same wool growth distribution is used for both the energy for wool growth and nitrogen retention calculations.

Implementing these changes caused emissions from the *Enteric fermentation* category to decrease by 124.4 kt CO_2-e in 1990 and 115.7 kt CO_2-e in 2022 (see table 5.2.10).

Table 5.2.10 Comparison emissions from *Enteric fermentation* using the updated monthly wool calculations

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Enteric fermentation*	2024 (1990–2022) emissions estimate	31,212.5	32,617.2	1,404.7	4.5
	2024 (1990–2022) emissions estimate *with* improvement	31,088.1	32,501.5	1,413.4	4.5
	Difference in emissions estimates	-124.4	-115.7		
	Percentage difference in emissions estimates (%)	-0.4	-0.4		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Corrections to inventory model

Each year, the MPI Inventory team identifies changes to improve alignment between the model code and the written methodology (Pickering et al., 2024). Improvements to the input data and methodology have also been implemented, in response to comments from international reviewers.

Many of the issues corrected for the 2025 submission were discovered as a part of the development of an on-farm emissions calculation methodology by MPI. This process went through both the published methodology document and inventory model code to replicate many of the calculations in a way that would work for the requirements at a farm level.

The main changes are related to milk consumed by young animals, energy requirements for gestation, sheep, beef and mature dairy cow liveweight estimates, and dairy cattle monthly milk production estimates.

Implementing these changes caused emissions from the *Enteric fermentation* category to decrease by 34.3 kt CO_2-e in 1990 and increase by 335.9 kt CO_2-e in 2022 (see table 5.2.11).

Table 5.2.11 Comparison of model results with and without corrections for emissions from *Enteric fermentation*

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Enteric fermentation*	2024 (1990–2022) emissions estimate	31,212.5	32,617.2	1,404.7	4.5
	2024 (1990–2022) emissions estimate *with corrections applied*	31,178.2	32,953.1	1,774.9	5.7
	Difference in emissions estimates	-34.3	335.9		
	Percentage difference in emissions estimates (%)	-0.1	1.0		

5.2.6 Category-specific planned improvements

New Zealand is carrying out ongoing research to improve estimates of CH_4 emissions from *Enteric fermentation*. The projects described below outline research focused specifically on the *Enteric fermentation* reporting category of the Agriculture inventory sector, although several cross-cutting, broader projects that will improve the accuracy of emissions estimates in multiple categories (including *Enteric fermentation*, *Manure management* and *Agricultural soils*) are described in section 5.1.7.

Development of a gene flow sub-model for sheep to account for increasing use of low-methane rams across the sheep sector

Research in New Zealand during the past two decades has proven that breeding sheep with lower CH_4 emissions per unit of DMI is feasible. A deterministic gene flow model has been developed to account for the emissions reduction due to the use of this mitigation in the New Zealand sheep industry. The core functionality of the model is to track the impact of the use of low-methane rams in the national sheep flock. This involves tracking the number of 'expressions' of genetic merit observed in both the rams, and descendants of each of the ram teams used, and then calculating the impact on emissions according to changes in ram merit over time and the introduction of their genes into the general sheep population.

Development of a national repository of relative genetic merit of New Zealand sheep

The successful implementation of a gene flow model requires genetic activity data. This research described a value that could be ascribed to an individual animal that defined the amount of CH_4 emissions expected for a given amount of feed for the animal and its future offspring. The final breeding value defined has been adopted by Beef + Lamb New Zealand for a national breeding scheme and will be implemented over the next one-to-two years.

Methane emissions from supplemented dairy cows

This project will determine CH_4 emissions, using several measurement techniques, from early to mid-lactation dairy cows grazing ryegrass-based pasture and feed graded levels of concentrates (two contrasting types, for example, starch-rich and fibre-rich). These new data will be combined with relevant existing data from New Zealand and international databases on CH_4 emissions from dairy cattle fed pasture plus supplements. This will be used to determine if CH_4 emissions differ between dairy cattle fed (i) pasture alone or (ii) pasture with concentrate supplementation, including if there are any differences in CH_4 emissions per unit of DMI.

Integrative greenhouse gas evaluation of forages

Forage rape (*Brassica napus*) and plantain (*Plantago lanceolata*) have been identified as forages with the potential to reduce CH_4 emissions per unit of dry matter eaten, as well as reducing the direct and indirect N_2O emissions from urine patches. The effect of growing and grazing these forages on soil carbon stocks is largely unknown. While previous studies have identified some emissions reduction potential from their use, these findings need to be integrated across all greenhouse gases and whole-year operations, to quantify their overall emissions reduction potential, including implications for soil carbon. These forages are used differently in farming practice: forage rape is a crop grown in cultivated ground and used over short periods as supplementary feed. In contrast, plantain is commonly used in pasture mixes with grasses and legumes throughout the year.

5.3 Manure management (3.B)

5.3.1 Category description

Most emissions from the *Manure management* category are from CH_4 produced during the storage and treatment of manure, and from manure deposited on pasture. The category also includes N_2O emissions produced during the storage and treatment of manure. It does not include N_2O emissions from the spreading of animal manure and from manure deposited directly onto pasture by grazing livestock. Instead, emissions from these sources are included in the *Agricultural soils* category (under *Organic nitrogen fertilisers* and *Urine and dung deposited by grazing animals* respectively).

Methane is produced when manure decomposes in the absence of oxygen (anaerobic conditions). When manure is stored or treated as a liquid (e.g., in lagoons or ponds), it decomposes anaerobically and can produce CH_4. The temperature and the length of time spent in storage also affect the cumulative amount of CH_4 produced over the inventory year. When manure is handled as a solid or deposited directly on pastures, it tends to decompose under aerobic conditions (in the presence of oxygen) and less CH_4 is produced overall.

The main factors affecting total reported CH_4 emissions from *Manure management* are the amount of manure produced and the proportion of the manure that decomposes anaerobically. If more manure is produced, more manure decomposes and produces a greater quantity of CH_4. If a larger proportion of manure decomposes anaerobically, more CH_4 will be produced.

Nitrous oxide emissions from managed manure occur directly through the processes of nitrification and denitrification of the nitrogen contained in the manure. Nitrous oxide is also emitted indirectly through diffusion of oxides of nitrogen (NO_x) into the surrounding air (volatilisation) or via leaching and runoff. As with CH_4, the amount of manure N_2O emissions produced depends on the system of waste management and the duration of storage. In New Zealand, most manure is deposited directly on pasture by grazing animals, with only a small proportion going into manure management systems.

Methane from *Manure management* from *Dairy cattle* (level and trend assessment) and *Sheep* (trend assessment) were identified as key categories for New Zealand in 2023.

Manure management contributed an estimated 1,861.5 kt CO_2-e, representing 4.6 per cent of Agriculture emissions in 2023. Estimated emissions from this category consist of:

- CH_4 emissions (95.2 per cent of *Manure management* emissions)
- N_2O emissions (4.8 per cent of *Manure management* emissions).

In 2023, N_2O emissions from *Manure management* totalled 88.8 kt CO_2-e (0.2 per cent of gross emissions from the Agriculture sector) (see table 5.3.1). In comparison, the combined direct and indirect N_2O emissions from spreading animal manure as fertiliser and manure deposited directly by grazing livestock reported in the *Agricultural soils* category totalled 4,186.0 kt CO_2-e in 2023 (10.3 per cent of emissions from the Agriculture sector).

Table 5.3.1 Trends and relative contribution of methane and nitrous oxide emissions in the *Manure management* category between 1990 and 2023

	Emissions (kt CO_2-e)		Change from 1990		Share of *Manure management* category (%)		Share of total Agriculture sector (%)	
Manure management category	1990	2023	%	Difference (kt CO_2-e)	1990	2023	1990	2023
Methane (3.B.(a))	824.8	1,772.6	114.9	947.8	95.9	95.2	2.2	4.4
Nitrous oxide (3.B.(b))	35.0	88.8	153.8	53.8	4.1	4.8	0.1	0.2

Table 5.3.2 shows the distribution of livestock waste across animal waste management systems in New Zealand. The New Zealand inventory assumes all non-dairy cattle, sheep and deer manure is deposited directly onto pasture (there are minor instances where this does not occur).

A small amount of excreta from dairy cattle (7.2 per cent) is stored in anaerobic lagoon waste systems (Rollo et al., 2017). This is based on the proportion of time dairy cattle spend on pasture compared with the time they spend in the milking shed, surrounding yards and off-paddock structures that transfer animal excreta to anaerobic lagoons.

The minor livestock categories of *Goats*, *Horses*, *Mules and asses*, and *Llamas and alpacas* are assumed to graze outdoors all year and deposit all their manure directly onto pastures. Estimates of the proportions of different waste management systems for swine and poultry in the manure management systems in New Zealand have been provided by Hill (2012) (swine), Ritchie (2024) (swine) and Fick et al. (2011) (poultry).

Table 5.3.2 Distribution of livestock waste across animal waste management systems in New Zealand in 2023

Livestock category	Anaerobic lagoon (%)	Daily spread[34] (%)	Pit storage (%)	Deep bedding (%)	Pasture, range and paddock[35] (%)	Composting (%)	Digesters (%)	Other (%)
Dairy cattle[36]	7.2	0	0	0	92.8	0	0	0
Non-dairy cattle	0	0	0	0	100	0	0	0
Sheep	0	0	0	0	100	0	0	0
Deer	0	0	0	0	100	0	0	0
Goats	0	0	0	0	100	0	0	0
Horses	0	0	0	0	100	0	0	0
Swine[37]	16.0	7.6	18.0	32.7	14.5	1.9	9.4	0
Poultry – broilers[38]	0	0	0	0	4.9	0	0	95.1
Poultry – layers[39]	0	0	0	0	5.8	0	0	94.2
Poultry – other[40]	0	0	0	0	3.0	0	0	97.0
Llamas and alpacas	0	0	0	0	100	0	0	0
Mules and asses	0	0	0	0	100	0	0	0

5.3.2 Methodological issues

Methane from manure management systems (3.B.(a))

New Zealand uses a Tier 2 approach to calculate CH_4 emissions from ruminant animal wastes from the major livestock categories in New Zealand (*Dairy cattle*, *Non-dairy cattle*, *Sheep* and *Deer*). This approach is based on the methods recommended by Saggar et al. (unpublished) and is consistent with the 2006 IPCC Guidelines (IPCC, 2006).

Because New Zealand has detailed information on the dairy cattle population and its characteristics (such as feed intake), the IPCC (2006) Tier 2 methodology for dairy anaerobic lagoons is used. New Zealand uses a Tier 1 methodology with country-specific and IPCC (2006) default emission factors for estimating emissions from the various manure management systems for minor livestock categories.

34 Reported under *Agricultural soils*, under *Organic nitrogen fertilisers* (3.D.1.2).

35 Reported under *Agricultural soils*, under *Urine and dung deposited by grazing animals* (3.D.1.3).

36 Rollo et al. (2017).

37 Hill (2012), Ritchie (2024).

38 Fick et al. (2011) and pers. comm. (2010).

39 Fick et al. (2011) and pers. comm. (2010).

40 IPCC (1996) default waste management proportions for Oceania.

Manure methane from the major livestock categories

The approach for calculating manure CH_4 emissions from the major livestock categories relies on:

(1) an estimation of the total quantity of faecal material produced, split into dung and urine

(2) allocating the faecal material to the appropriate manure management system, either onto pastures or anaerobic lagoons (based on the distributions in table 5.3.2)

(3) New Zealand-specific emission factors for the quantity of CH_4 produced per unit of faecal dry-matter (FDM) output.

The following equation is used to determine the monthly FDM output for each livestock category (*Dairy cattle*, *Non-dairy cattle*, *Sheep* and *Deer*):

$$FDM = DMI \times (1 - DMD)$$

Where: FDM is faecal dry matter (kg head^{-1} month^{-1})

DMI is dry-matter intake (kg head^{-1} month^{-1}), and

DMD is dry-matter digestibility (decimal proportion).

The DMI and dry-matter digestibility estimates in this calculation are the same as those used to calculate CH_4 from *Enteric fermentation* and nitrogen in excreta. These Tier 2 model calculations are based on livestock performance statistics (see section 5.1.4).

Methane from dairy effluent anaerobic lagoons

Each year, a proportion of manure from dairy cows is stored in anaerobic lagoons (Rollo et al., 2017). A Tier 2 methodology derived from the 2006 IPCC Guidelines (equations 10.23 and 10.24, IPCC, 2006) linking volatile solids to FDM is used for calculating CH_4 emissions from this activity.

The following equation is used to determine CH_4 emissions ($CH_{4\text{-}MM}$) from dairy cattle manure in anaerobic lagoons:

$$CH_{4AL-dairy} = FDM \times (1 - ASH) \times B_0 \times 0.67 \times MCF \times MS$$

Where: FDM is the faecal dry matter excreted by dairy cows (on pasture and stored in anaerobic lagoons) (kg head^{-1} month^{-1})

ASH is the ash content of manure, 0.08 (IPCC, 2006, default value)

B_0 is the maximum CH_4-producing capacity of manure variable by species and diet, 0.24 (IPCC, 2006; Oceania default value, verified by Pratt et al., 2012)

0.67 is the conversion factor for converting CH_4 from cubic metres to kilograms (IPCC, 2006)

MCF is the CH_4 conversion factor, 0.74 (IPCC, 2006, table 10.17, default for uncovered anaerobic lagoons, average annual temperature 15 degrees Celsius, verified by Pratt et al., 2012)

MS is the fraction of total dairy manure excreted that ends up in anaerobic lagoons.

Methane emissions from the major livestock categories

The following equation is used to determine CH_4 emissions ($CH_{4\text{-}PRP}$) from non-dairy cattle, sheep and deer manure deposited onto pasture:

$$CH_{4PRP-dairy} = FDM \times MS_{PRP} \times Y_m$$

Where: FDM is the faecal dry matter (kg/head/month)

MS_{PRP} is the proportion of manure excreted on pasture

Y_m is the CH_4 yield value (kg CH_4/kg FDM).

Country-specific CH_4 yield values have been developed from New Zealand studies. Details on the values used for each of the major livestock categories are provided below.

Dairy cattle: The quantity of CH_4 produced per kilogram of FDM is 0.98 g CH_4/kg for manure deposited on pasture. This value is obtained from New Zealand studies on dairy cows and varies from around 0.92 g CH_4/kg to 1.04 g CH_4/kg (Saggar et al., unpublished; Sherlock et al., unpublished).

Non-dairy cattle: The value of 0.98 g CH_4/kg per unit of FDM is based on New Zealand studies on dairy cattle manure (Saggar et al., unpublished; Sherlock et al., unpublished). No specific studies have been conducted in New Zealand on CH_4 emissions from non-dairy cattle manure.

Sheep: The quantity of CH_4 produced per unit of sheep FDM is 0.69 g CH_4/kg. This value was obtained from a New Zealand study on sheep in which values ranged from 0.340 g CH_4/kg to 1.288 g CH_4/kg over six sampling periods (Carran et al., 2003).

Deer: The quantity of CH_4 produced per unit of FDM is assumed to be 0.91 g CH_4/kg. Deer are not housed in New Zealand, and all faecal material is deposited directly onto pasture. This value is derived from New Zealand studies on sheep (Carran et al., 2003) and dairy cattle (Saggar et al., unpublished; Sherlock et al., unpublished). No New Zealand studies have been completed on CH_4 emissions from deer manure. Further information on the calculation of the manure CH_4 emission factor for deer is contained in section 7.1.4 of the Agriculture inventory methodology (Pickering et al., 2024).

Methane emissions from minor livestock categories

Manure CH_4 emissions from the minor livestock categories are calculated per head^{-1}, using a combination of country-specific and IPCC default emission factors.

Swine: New Zealand uses country-specific emission factors (Ritchie, 2024) for estimating CH_4 emissions from swine manure management. Industry data on swine diets (to determine digestible energy of the swine feed and volatile solid excretion levels) and the use of waste management systems used by New Zealand swine producers were used to determine a country-specific manure management emission factor for growing pigs and breeding pigs. The manure management CH_4 emission factors were calculated using the CH_4 conversion factors for each manure management system provided by the 2019 IPCC Refinement (IPCC, 2019). Further information on this is provided by Ritchie (2024). For consistency, CH_4 emission factors from manure management systems prior to 2010 are calculated using data from Hill (2012) using the CH_4 conversion factors recommended in the 2019 Refinement (IPCC, 2019). For the years 2010 to 2021 the values are linearly interpolated (see table 5.3.3).

Table 5.3.3 Average annual methane emissions factors from manure management systems ($kg\ CH_4\ head^{-1}\ yr^{-1}$) for pigs

Year	Breeding pigs	Growing pigs
1990	11.3	5.4
1995	11.3	5.4
2000	11.3	5.4
2005	11.3	5.4
2010	11.2	5.4
2015	10.9	5.4
2020	10.6	5.4
2022	10.6	5.4
2023	10.6	5.4

Poultry: Methane emissions from poultry manure management use New Zealand-specific emission factor values derived from Fick et al. (2011). These are based on New Zealand-specific volatile solids and proportions of poultry faeces in each manure management system for each production category. The poultry population has been disaggregated into three different categories, and the manure management emission factor values for each category are: *Broiler birds* 0.022 kg CH_4 head^{-1} year^{-1}; *Layer hens* 0.016 kg CH_4 head^{-1} year^{-1}; and *Other*[41] 0.117 kg CH_4 head^{-1} year^{-1}. The overall IEF for poultry is affected by the change over time in the population proportions of these different poultry categories.

Goats*, *Horses*, and *Mules and asses: New Zealand uses IPCC (2006) default emission factors for CH_4 emissions from manure management for *Goats*, *Horses*, *Mules and asses* (table 10.15 of the 2006 IPCC Guidelines (IPCC, 2006)). The emission factors are 0.20 kg CH_4 head^{-1} year^{-1} for *Goats*, 2.34 kg CH_4 head^{-1} year^{-1} for *Horses* and 1.10 kg CH_4 head^{-1} year^{-1} for *Mules and asses*. These are the IPCC values for temperate developed countries.

Llamas and alpacas: No IPCC default value is available for CH_4 emissions from manure management for *Llamas and alpacas*. The emissions are calculated by assuming that the CH_4 emission factor from manure management for *Llamas and alpacas* for all years is equal to the CH_4 manure management IEF for *Sheep* in 1990. The *Llamas and alpacas* emission factor (0.10 kg CH_4 head^{-1} year^{-1}) is not indexed to sheep over time because there are no data indicating that alpacas or llamas have had the productivity increases over time seen in sheep.

Nitrous oxide from manure management systems (3.B.(b))

Nitrous oxide emissions from manure management can be classified as either direct or indirect. Direct N_2O emissions occur from nitrification and denitrification of nitrogen contained in the manure. Indirect N_2O emissions result from volatile nitrogen losses in the forms of ammonia (NH_3) and NO_x that are emitted via diffusion into the surrounding air (volatilisation) or via leaching and runoff.

Nitrous oxide emissions from manure are calculated for each livestock category based on:

(1) livestock population characterisation data (consistent with section 5.1.3)

(2) the average nitrogen excretion rate (kg) per head^{-1} year^{-1}

[41] *Other* poultry generally consists of ostrich and emus, hence the higher emissions per head.

(3) an estimation of the total quantity of faecal material produced (consistent with the calculations in the previous section for CH_4 from manure management) split into dung and urine

(4) the partitioning of this faecal material between manure management systems (based on the manure distributions in table 5.3.2)

(5) the total amount of nitrogen managed in each system multiplied by an emission factor (IPCC, 2006).

Nitrogen excretion rates for the major livestock categories

The nitrogen excretion (N_{ex}) rates for the main livestock categories in New Zealand are calculated from the nitrogen intake less the nitrogen retained through digestion and contained within animal products, such as liveweight gain, milk, wool and velvet. Nitrogen intake is determined from the dry-matter feed intake and the nitrogen content of the feed eaten. Feed intake and animal productivity values are the same as those used in the Tier 2 model for determining DMI (Clark et al., 2003; and see section 5.1.3). Monthly values for the nitrogen content of feed are provided by Giltrap and McNeill (2020) for dairy cattle and sheep and beef cattle separately.

The nitrogen content of animal products is derived from industry data. For lactating dairy cows, the nitrogen content of milk is derived from the protein content of milk, which is published annually by LIC. The nitrogen content of sheep meat, milk and wool, as well as non-dairy (*beef*) meat, and the nitrogen retained in deer velvet, is taken from New Zealand research (Bown et al., 2013).

Table 5.3.4 shows the N_{ex} rates for the major livestock categories. These rates have increased over time, reflecting the increases in animal productivity and animal DMI in New Zealand since 1990. Nitrogen excretion rates are also affected by adverse weather events, which affect the amount of DMI and can cause changes in productivity and N_{ex} rates in subsequent years (see section 5.1.1).[42]

Table 5.3.4 Nitrogen excretion rates (N_{ex}) for New Zealand's major livestock categories, from 1990 to 2023

Year	Dairy cattle N_{ex} (kg/head/year)	Non-dairy cattle N_{ex} (kg/head/year)	Sheep N_{ex} (kg/head/year)	Deer N_{ex} (kg/head/year)
1990	100.1	76.0	12.7	24.5
1995	103.6	79.9	13.6	26.7
2000	107.3	84.6	15.6	26.6
2005	108.8	89.3	16.2	26.2
2010	106.8	87.3	15.9	25.9
2015	112.6	85.1	16.6	26.6
2020	116.8	86.5	17.4	27.0
2022	119.6	88.5	17.2	27.5
2023	118.3	91.1	17.2	27.8

42 For full details of how nitrogen excretion rates are derived for each livestock category, see the technical detail provided in the Agriculture inventory model methodology document on the MPI website (www.mpi.govt.nz/dmsdocument/13906-Detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation).

Nitrogen excretion rates for the minor livestock categories

Swine: A New Zealand-specific N_{ex} rate for breeding pigs and growing pigs is calculated for each year (see table 5.3.5) based on the 2022 value of 24.25 kg nitrogen (N) head^{-1} year^{-1} for breeding pigs and 5.89 kg N head^{-1} year^{-1} for growing pigs (Ritchie, 2024). The 2022 values are based on the weighted average of the distribution of animal liveweights by swine category. Estimates of N_{ex} rates for all other years are indexed relative to 2022 for the average pig carcass weights for each year.

Average pig weights have increased since 1990 due to improvements in productivity. Data on pig carcass weights are collected by MPI from meat processors.

Goats: New Zealand uses country-specific N_{ex} rates for goats of 10.6 kg N head^{-1} year^{-1} for 1990 and 12.1 kg N head^{-1} year^{-1} for 2009 based on the differing population characteristics for those two years (Lassey, 2011). As explained in section 5.2.2 for *Enteric fermentation*, for the intermediate years between 1990 and 2009 and for later years, the excretion rate was interpolated based on assumptions that the dairy goat population has remained in a near constant state over time while the rest of the goat population has declined (see table 5.3.5).

Poultry: New Zealand-specific and IPCC default N_{ex} rates are used for poultry (Fick et al., 2011). These are the country-specific values of 0.39 kg N head^{-1} year^{-1} for broiler birds and 0.42 kg N head^{-1} year^{-1} for layer hens. Ducks, turkeys and other poultry types, such as ostriches, make up around 1 per cent of New Zealand's poultry population, and flock sizes are uncertain because they are reported by Stats NZ under 'other poultry'. Therefore, the value of 0.60 kg N head^{-1} year^{-1} for ducks and turkeys recommended by Fick et al. (2011) is retained. These values are used for all years from 1990. The overall N_{ex} rate for poultry is affected by the change over time in the population proportions of these different poultry categories.

Horses*, and *Mules and asses: New Zealand-specific N_{ex} rates are not available for horses or mules and asses, and the default N_{ex} rate for Oceania of 0.3 kg N per 1,000 kg of animal mass per day is used (IPCC, 2006, table 10.19).

Llamas and alpacas: Because there is no IPCC default N_{ex} rate for *Llamas and alpacas*, this was calculated by assuming a default N_{ex} rate for llamas and alpacas for all years that is equal to the per-head value of the average sheep in 1990 (i.e., 12.7 kg head^{-1} year^{-1}). The llama and alpaca emission factor is not indexed to sheep over time because there are no data indicating that alpacas or llamas have had the productivity increases over time seen in sheep. Sheep were used, rather than the IPCC default value for 'other animals', because the literature indicates that alpacas have a nitrogen intake close to that of sheep and no significant difference in the partitioning of nitrogen (Pinares-Patino et al., 2003).

Table 5.3.5 Nitrogen excretion (N_{ex}) rates for New Zealand's swine and goats, from 1990 to 2023

Year	Goat N_{ex} (kg/head/year)	Growing pigs N_{ex} (kg/head/year)	Breeding pigs N_{ex} (kg/head/year)
1990	10.6	4.6	23.9
1995	11.0	5.0	22.8
2000	11.4	5.3	23.5
2005	11.8	5.5	25.5
2010	12.2	5.6	28.4
2015	12.6	5.9	28.5
2020	12.7	5.9	26.2
2022	12.7	5.9	24.3
2023	12.7	5.9	26.1

Direct nitrous oxide emissions from manure management

Major livestock categories: For the major livestock categories (*Dairy cattle*, *Non-dairy cattle*, *Sheep* and *Deer*), most manure is deposited directly onto pasture by grazing animals (see table 5.3.2). Direct and indirect N_2O emissions from the manure deposited by grazing animals are reported in the *Agricultural soils* category (*Urine and dung deposited by grazing animals* (3.D.1.3)).

The remainder of dairy manure is managed in anaerobic lagoons. The 2006 IPCC Guidelines note that the production of emissions of direct N_2O from managed manure requires aerobic conditions for the formation of oxidised forms of nitrogen but assumes that negligible direct N_2O emissions occur during storage in anaerobic lagoons (IPCC, 2006, table 10.21). Direct N_2O emissions from dairy effluent anaerobic lagoons are reported in the *Agricultural soils* category (*Organic nitrogen fertilisers* (3.D.1.2)) when the stored effluent is spread onto agricultural land.

A report by Rollo et al. (2017) found that only 8 per cent of dairy farms use land application of manure. Manure is applied by direct pumping from a sump. In all cases, manure that was collected was stored for at least one or two days before spreading to pasture via irrigation. Therefore, it does not meet the IPCC definition of daily spread and the notation key 'NO' (not occurring) is reported in 3.B(b) of the CRT.

Swine: Swine manure is managed under various types of waste management systems (see table 5.3.2). The 2006 IPCC Guidelines (table 10.21, IPCC, 2006) assume that negligible direct N_2O emissions occur in anaerobic lagoons and daily spread. Nitrous oxide emissions from manure from these systems occur once the stored effluent is spread onto agricultural land and are reported in the *Agricultural soils* category (*Organic nitrogen fertilisers* (3.D.1.2)). Nitrous oxide emissions from the manure management of swine are estimated using the IPCC (2019) default emission factors for direct N_2O emissions from manure management (EF_3) for each manure management system.

Poultry*:* Direct N_2O emissions from poultry manure deposited directly on pasture are reported in the *Agricultural soils* category (*Urine and dung deposited by grazing animals* (3.D.1.3)). For other manure management systems, the IPCC (2006, table 10.21) default emission factor for EF_3 of 0.001 kg N_2O-N/kg N for poultry manure with and without litter is assumed.

***Goats*, *Horses*, *Llamas and alpacas*, and *Mules and asses*:** All faecal material from these livestock is deposited directly onto pasture, and direct N_2O emissions from grazing animals are reported in the *Agricultural soils* category (*Urine and dung deposited by grazing animals* (3.D.1.3)).

Indirect nitrous oxide emissions from manure management

Indirect N_2O emissions from manure management result from diffusion into the surrounding air (volatilisation) and from leaching and runoff. All indirect N_2O emissions for the pasture, range and paddock manure management systems (MMS) are reported in the *Agricultural soils* category.

The IPCC (2006) Tier 1 methodology is used for calculating N_2O emissions resulting from volatilisation:

$$N_2O_{MM-volatilisation} = \frac{44}{28}(N_{volatilisation-MMS} \cdot EF_4)$$

And:

$$N_{vol-MMS} = \sum_S \left[\sum_T \left[\left(N_T \cdot Nex_T \cdot MS_{T,S} \right) \cdot \left(\frac{Frac_{GasMS}}{100} \right)_{T,S} \right] \right]$$

Where: $N_{vol-MMS}$ is the amount of manure nitrogen that is lost due to volatilisation (kg/year)

EF_4 is the emission factor for N_2O emissions from volatilisation; the IPCC (2006) default value of 0.01 kg N_2O-N/(kg NH_3-N + NO_x-N volatilised) is used

N_T is the number of livestock per category (head), detailed in section 5.1.4

Nex_T is the average nitrogen excretion for each livestock category, T, detailed above

$MS_{T,S}$ is the fraction of total nitrogen excretion per livestock category, T, per manure management system, S, derived from table 5.3.2, and

$Frac_{GasMS}$ is the per cent of managed manure nitrogen for each livestock category, T, which volatilises as NH_3 and NO_x per manure management system, S. New Zealand uses default values for $Frac_{GasMS}$ detailed in table 5.3.6.

The IPCC (2006) Tier 1 guidelines do not provide a methodology for determining indirect N_2O emissions from leaching and runoff. There have been no country-specific emission factors derived for leaching and runoff from manure management systems in New Zealand (e.g., Hill, 2012), and available data are extremely limited (IPCC, 2006). Leaching and runoff from dairy anaerobic lagoons is likely to be an insignificant activity in New Zealand (T Wilson, pers. comm., 2014). All indirect N_2O emissions from leaching and runoff are reported in the *Agricultural soils* category.

Table 5.3.6 IPCC default values for the fraction of managed manure nitrogen that volatilises as ammonia and oxides of nitrogen ($Frac_{GasMS}$/100) for livestock categories per manure management system in New Zealand

Manure management system	Livestock category	Value (fraction)
Anaerobic lagoons	Dairy	0.35
	Swine	0.40
Daily spread	Swine	0.07
Anaerobic digester	Swine	0.25[43]
Deep bedding	Swine	0.4
Composting passive windrow	Swine	0.6
Pit storage	Swine	0.25
Other	Swine	0.25
	Poultry – broilers	0.25
	Poultry – layers	0.25
	Poultry – other	0.25

Source: IPCC (2019) table 10.22

5.3.3 Uncertainty assessment and time-series consistency

To ensure consistency, a single enhanced livestock population characterisation and feed-intake estimate is produced by the Tier 2 model for the major livestock categories. It is used in different parts of the calculations to estimate CH_4 emissions for the *Enteric fermentation* category, CH_4 and N_2O emissions for the *Manure management* category and N_2O emissions for the *Agricultural soils* category.

43 Mid-point in IPCC 2019 range (IPCC, 2019).

Methane emissions

The major sources of uncertainty in CH_4 emissions from *Manure management* are the accuracy of emission factors for manure management system distribution, livestock population numbers, and the classification and use of the various manure management systems (IPCC, 2006). The ranges for measured emissions for the major livestock categories have been stated, where available.

The IPCC (2006) states that emission factor estimates are likely to have uncertainties of ±30 per cent for Tier 1 methodologies and ±20 per cent for Tier 2 methodologies. New Zealand does not currently have country-specific uncertainty values for CH_4 from *Manure management*. Because around 95 per cent of CH_4 from *Manure management* is calculated using Tier 2 methodologies, an uncertainty value of ±20 per cent has been used instead for the Tier 1 *Manure management* CH_4 emissions uncertainty value.

Uncertainties for the livestock characterisation are also discussed in section 5.1.4 and annex 5, section A5.1.1.

Nitrous oxide emissions

The main factors causing uncertainty in direct and indirect N_2O emissions from manure management are the N_{ex} rates, the emission factors for manure and manure management systems, activity data on the livestock population, and the classification and use of the various manure management systems (IPCC, 2006).

Uncertainty ranges for the default N_{ex} values are estimated at about ±50 per cent (IPCC, 2006), and may be substantially smaller for the values for the livestock whose N_{ex} rates were derived from in-country statistics on productivity. New Zealand uses the default values for EF_3 for direct N_2O emissions from the manure management of swine and poultry, which have uncertainties ranging from -50 per cent to +100 per cent (IPCC, 2006, table 10.21). An uncertainty value range of ±100 per cent has been used for the *Manure management* N_2O emissions uncertainty (Giltrap et al., 2016).

As above, uncertainties for the livestock characterisation are discussed in section 5.1.4 and annex 5, section A5.1.1.

5.3.4 Category-specific QA/QC and verification

Methane from *Manure management* from *Dairy cattle* was identified as a key category for New Zealand in the 2023 level and trend assessment. Methane from *Manure management* from *Sheep* was identified as a key category for New Zealand in the 2022 trend assessment.

In the preparation for this inventory submission, the data for this category underwent Tier 1 and Tier 2 quality checks.

Table 5.3.7 shows a comparison of the New Zealand-specific 2023 IEF for CH_4 from *Manure management* with the IPCC (2006) Tier 1 Oceania default, the IPCC Tier 2 net energy-based value and the 2022 Australian-specific IEF for *Dairy cattle*, *Non-dairy cattle* and *Sheep* (Australian Government, 2024). The IPCC Tier 2 value was determined from net energy equations to determine gross energy for each of New Zealand's major livestock categories. This information is then used to determine volatile solid excretion and the annual CH_4 emission factors for each livestock category as per the equations described in the 2006 IPCC Guidelines (i.e., equations 10.16, 10.23 and 10.24, IPCC, 2006).

New Zealand has lower IEFs for CH_4 from *Manure management* for dairy cattle, non-dairy cattle and sheep than the IPCC Tier 1 Oceania default emission factors. New Zealand has higher IEFs for dairy and non-dairy cattle and a lower IEF for sheep than the IPCC Tier 2 net energy-based emission factors. Additionally, New Zealand has lower dairy and non-dairy IEFs for CH_4 from *Manure management* than the Australian-specific 2022 IEFs. Differences between New Zealand's IEFs, the IPCC Tier 1 and Tier 2 and the Australian-specific IEFs are due to the reasons outlined under *Enteric fermentation* (see section 5.2.4): that is, size and productivity of the animals, the age classes of livestock included in New Zealand's modelling and the use of different algorithms to determine energy intake. The New Zealand-specific IEF from *Manure management* for dairy cattle also reflects the activity data on the use of dairy effluent management systems in New Zealand (see section 5.3.2).

The IEF for dairy cattle is much higher than the IEFs for non-dairy cattle and sheep. All manure for non-dairy cattle and sheep is deposited onto pasture. In contrast, 7.2 per cent of dairy cattle manure is captured by anaerobic lagoons (see table 5.3.2). When manure is stored in anaerobic lagoons, it decomposes anaerobically and can produce CH_4. When manure is deposited directly on pastures it tends to decompose under aerobic conditions and less CH_4 is produced overall. Therefore, because some dairy cattle manure is captured by anaerobic lagoons, more CH_4 is produced by dairy cattle manure management than non-dairy cattle or sheep manure management. Hence, the IEF is higher.

Table 5.3.7 Comparison of IPCC (2006) table 10A-4 default emission factors and country-specific implied emission factors (IEFs) for methane from manure management

	kg CH_4/head/year		
	Dairy cattle	Non-dairy cattle	Sheep
IPCC Tier 1 Oceania default value (average temperature 15°C (cattle)/developed temperate default value (sheep))	27.00	2.00	0.28
IPCC Tier 2 net energy-based value	5.97	0.82	0.18
Australian-specific IEF 2022 value[44]	13.98	4.71 (pasture) 3.64 (feedlot)	0.34
New Zealand-specific IEF 2023 value	9.22 (all dairy cattle, including calves) 11.54 (mature milking cows only)	0.96	0.13

5.3.5 Category-specific recalculations

Emissions estimates in the *Manure management* category reported in the 2025 submission have been affected by methodological improvements to: (i) minor species population value changes; (ii) updating deer population and productivity statistics; (iii) updating emissions calculations for pigs; (iv) seasonality of wool growth; and (v) small error corrections to model code.

Minor species population value changes

For more detail on these changes, see section 5.2.5.

[44] As reported in Australia's *Common Reporting Format 2024*, table3.B(a). Retrieved 4 November 2024. Note that the Australian-specific beef cattle IEF value is calculated from a population-based weighted average of pasture and feedlot IEF values from beef cattle.

Table 5.3.8 Comparison of the previous minor species populations and the updated minor species populations for emissions from *Manure management*

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Manure management*	2024 (1990–2022) emissions estimate	874.8	1,901.6	1,026.8	117.4
	2024 (1990–2022) emissions estimate *with improvement*	874.8	1,900.3	1,025.5	117.2
	Difference in emissions estimates	0.04	-1.28		
	Percentage difference in emissions estimates (%)	0.00	-0.07		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Updating deer population and productivity statistics

For more detail on these changes, see section 5.2.5.

Table 5.3.9 Comparison of emissions from *Manure management* using the updated deer population and productivity statistics

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Manure management*	2024 (1990–2022) emissions estimate	874.8	1,901.6	1,026.8	117.4
	2024 (1990–2022) emissions estimate *with improvement*	874.6	1,900.8	1,026.2	117.3
	Difference in emissions estimates	-0.18	-0.80		
	Percentage difference in emissions estimates (%)	-0.02	-0.04		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Updating emissions calculations for pigs

The 2024 inventory submission used New Zealand-specific emission factors for pigs developed by Hill (2012), in conjunction with default data provided by the IPCC. The methodology was based on a 2009 survey of New Zealand pig farmers. Changes to the commercial New Zealand pork industry have occurred since then, such as improvements in genetic selection, animal housing, feed, husbandry and herd management.

Recent research carried out by NZ Pork (Ritchie, 2024) resurveyed commercial pig farmers in New Zealand to gather current data on relevant industry characteristics and practices. The survey was conducted in 2022. This has led to several recommendations for updates to emissions factors and other relevant data.

Ritchie (2024) used a three-step process to update the emission factor for CH_4 from manure for pigs. The first step was to calculate the average volatile solids excretion rates based on farmer survey data. The second step was to calculate the proportion of manure entering each manure management system based on farm survey data. The manure management CH_4 emission factor was then calculated using the CH_4 conversion factors for each manure management system provided by the 2019 IPCC Refinement (IPCC, 2019).

For consistency, CH_4 emission factors from manure management systems prior to 2010 are calculated using data from Hill (2012) using the CH_4 conversion factors recommended in the 2019 Refinement (IPCC, 2019). For the years 2010 to 2021 the values are linearly interpolated and the 2023 values are kept the same as the 2022 values.

The nitrogen excretion value was also updated. Updating the N_{ex} value used a two-part process, first calculating the typical animal mass for pigs based on farmer survey data, then calculating the N_{ex} value based on typical animal mass data. For values, refer to table 5.3.5.

Several changes have been made to the calculation of N_2O emissions from manure management. This includes updates to the percentage of manure treated in each manure management system and moving to using the EF_3 values specified in the IPCC 2019 Refinement (IPCC, 2019).

The IPCC 2006 Guidelines note that the fraction of manure handled in each manure management system should be the same for calculations of both CH_4 and N_2O emissions (IPCC, 2006). However, the inclusion of solid separation techniques means the management system values need to be recalculated specifically for nitrogen because solid separation affects the loading rate of volatile solids and nitrogen differently.

The data show some changes have occurred to the apportionment of manure to manure management systems since the report prepared by Hill (2012). Most notably, changes have included a higher use of pasture, range and paddock and anaerobic digesters and less use of daily spread and uncovered anaerobic lagoons (see table 5.3.10). For the years 2010 to 2021 the values are linearly interpolated.

Parameters for calculating indirect N_2O emissions now use values from the 2019 Refinement (IPCC, 2019). These parameters were the proportion of managed manure that volatilises as NH_3 and NO_x ($Frac_{GasMS}$), fraction of leaching and runoff from nitrogen in managed manure ($Frac_{LeachMS}$) and fraction of leaching and runoff from organic nitrogen applied to soil ($Frac_{leach(ON)}$).

Implementing these changes caused emissions from the *Manure management* category to decrease by 9.3 kt CO_2-e in 1990 and 1.6 kt CO_2-e in 2022 (see table 5.3.11).

Table 5.3.10 Proportion of pig manure treated in each manure management system in 2022

Animal waste management system	Percentage of manure treated (%)	Percentage of manure N treated (%)
Pasture/range/paddock*	14.5	14.5
Daily spread	7.6	7.6
Uncovered anaerobic lagoon	14.7	16.0
Pit storage below animal confinement < 30 days	12.6	13.3
Pit storage below animal confinement > 30 days	3.9	4.8
Anaerobic digester	8.4	9.4
Cattle and pigs deep bedding < 60 days	22.0	22.0
Cattle and pigs deep bedding > 60 days	11.1	10.8
Composting passive windrow	5.3	1.9

Note: *N_2O emissions reported under Agricultural soils, under Urine and dung deposited by grazing animals (3.D.1.3).

Table 5.3.11 Comparison for emissions from *Manure management* using the updated pig calculations

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Manure management*	2024 (1990–2022) emissions estimate	874.8	1,901.6	1,026.8	117.4
	2024 (1990–2022) emissions estimate *with improvement*	865.5	1,900.0	1,034.5	119.5
	Difference in emissions estimates	-9.3	-1.6		
	Percentage difference in emissions estimates (%)	-1.1	-0.1		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Seasonality of wool growth

For more detail on these changes, see section 5.2.5.

Table 5.3.12 Comparison of emissions from *Manure management* using the updated monthly wool calculations

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Manure management*	2024 (1990–2022) emissions estimate	874.8	1,901.6	1,026.8	117.4
	2024 (1990–2022) emissions estimate *with improvement*	873.4	1,900.1	1,026.7	117.6
	Difference in emissions estimates	-1.4	-1.5		
	Percentage difference in emissions estimates (%)	-0.2	-0.1		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Corrections to inventory model

For more detail on these changes, see section 5.2.5.

Table 5.3.13 Comparison of model results with and without corrections for emissions from *Manure management*

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Manure management*	2024 (1990–2022) emissions estimate	874.8	1,901.6	1,026.8	117.4
	2024 (1990–2022) emissions estimate *with corrections applied*	870.6	1,901.8	1,031.2	118.4
	Difference in emissions estimates	-4.1	0.2		
	Percentage difference in emissions estimates (%)	-0.5	0.0		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

5.3.6 Category-specific planned improvements

The following section covers the planned improvements being undertaken for *Manure management*. These findings may be incorporated in future annual inventory submissions.

Updating data on the use of different manure and effluent management systems in New Zealand dairy farms

A nationwide farm survey of dairy manure and effluent management practices will be carried out to collect information on effluent storage duration, farm off-paddock structure and loafing pad use, effluent to soils separation and frequency of emptying effluent storage ponds. Earlier research to determine whether the methane conversion factor for *Dairy cattle* needed to be updated highlighted the importance of effluent storage and management in resulting emissions. This new information will be important in determining whether New Zealand can reliably update the methane conversion factor for dairy cattle.

This change will be supported by previous research to determine a New Zealand-specific emission factor for anaerobic lagoons on dairy farms. The report *Refining New Zealand's GHG Inventory Methodology: Manure Management* (Luo et al., 2019b) develops a revised model framework that allows the management conditions of anaerobic lagoons to be accounted for when calculating emissions.

5.4 Rice cultivation (3.C)

5.4.1 Category description

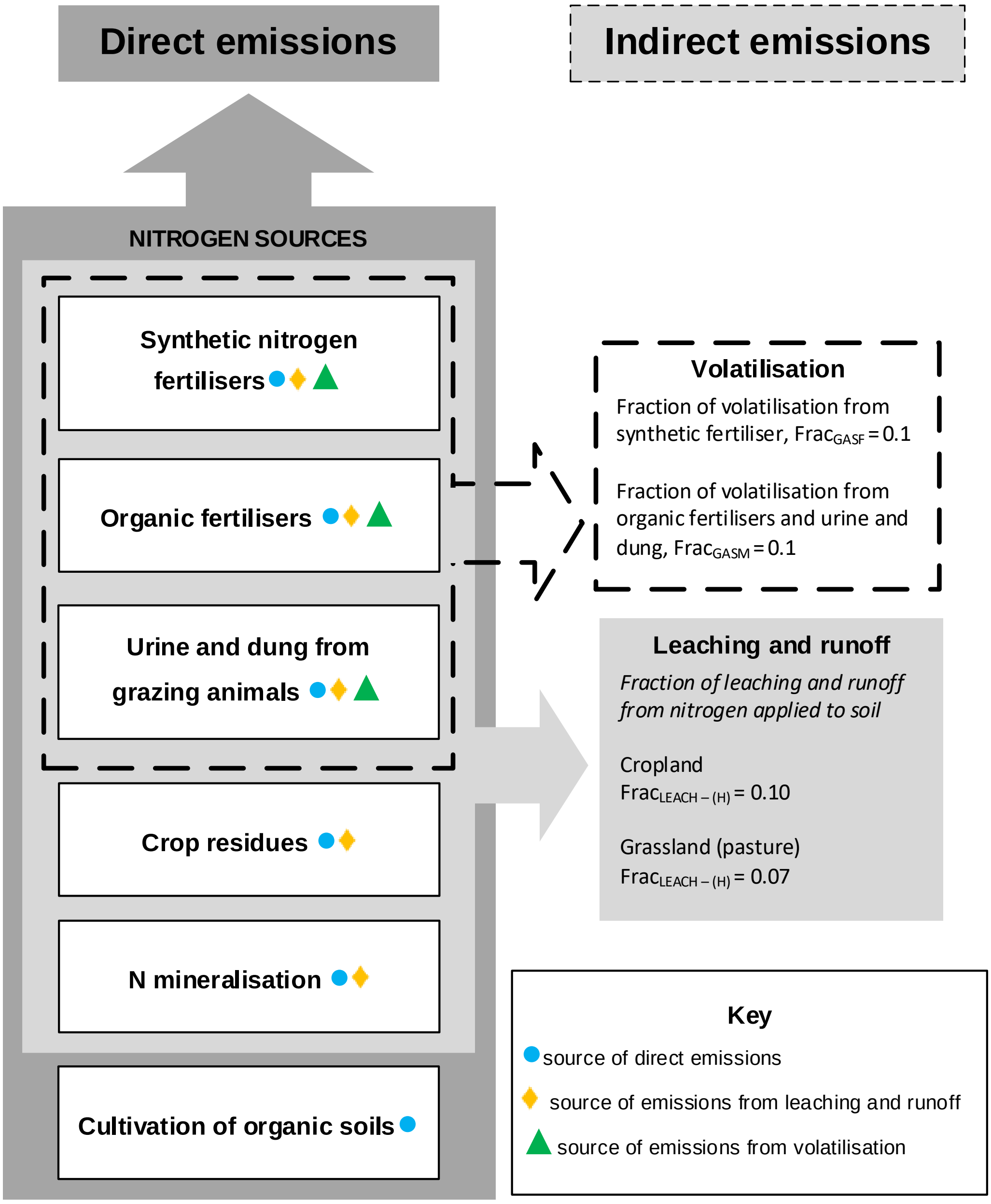
At present, there is no commercial rice cultivation in New Zealand. This has been confirmed with experts from Plant and Food Research, a New Zealand Crown research institute. The 'NO' (not occurring) notation is reported in the CRT.

5.5 Agricultural soils (3.D)

5.5.1 Category description

Several categories contribute to N_2O emissions from *Agricultural soils* through both direct and indirect pathways; these are summarised in figure 5.5.1.

Figure 5.5.1 **Sources of nitrous oxide emissions from *Agricultural soils*, showing the contribution of each source to emissions through both direct and indirect pathways**



Direct N_2O emissions come directly from soils that have had nitrogen applied in either organic (animal excreta and organic fertilisers) or inorganic (synthetic nitrogen fertiliser) form. Indirect emissions come from the volatilisation (evaporation or sublimation) of nitrogen from the land and water. A fraction of this volatilised nitrogen returns to the ground during rainfall and is then re-emitted as N_2O. Indirect emissions also arise from nitrogen lost through leaching and runoff. This nitrogen enters the groundwater, riparian areas and wetlands, rivers, and eventually the ocean, where it enhances biogenic production of N_2O (IPCC, 2006).

Indirect emissions from livestock waste management systems are reported in section 5.3 (*Manure management*). Carbon dioxide emissions from lime and dolomite fertilisers are reported in section 5.8 (*Liming*), and CO_2 emissions from urea fertiliser are reported in section 5.9 (*Urea application*).

Agricultural soils contributed an estimated 6,372.4 kt CO_2-e, representing 8.3 per cent of New Zealand's gross emissions and 15.7 per cent of Agriculture emissions in 2023. The *Agricultural soils* category was the source of 91.8 per cent of New Zealand's total 2023 N_2O emissions.

The categories that contribute the most to emissions from *Agricultural soils* and that are identified as key categories are outlined below in order of significance:

- urine and dung deposited by grazing animals (pasture, range and paddock manure) (level and trend assessment): 49.5 per cent of emissions from *Agricultural soils*
- inorganic nitrogen fertiliser (level and trend assessment): 17.4 per cent of emissions from *Agricultural soils*
- cultivation of organic soils (level and trend assessment): 11.6 per cent of emissions from *Agricultural soils*
- atmospheric deposition (level assessment): 9.3 per cent of emissions from *Agricultural soils*
- nitrogen leaching and run-off (level assessment): 7.5 per cent of emissions from *Agricultural soils*
- crop residues (level assessment): 3.6 per cent of emissions from *Agricultural soils.*

Trends

Emissions from *Agricultural soils* increased 36.9 per cent (1,717.3 kt CO_2-e) between 1990 and 2023. Increases in the use of synthetic nitrogen fertiliser and in the dairy cattle population are the predominant drivers of increasing emissions from *Agricultural soils*, which have been partially offset by decreases in the sheep and non-dairy cattle populations.

Trends from 1990 and 2023 across the key categories in *Agricultural soils* are detailed below:

- urine and dung deposited by grazing animals (pasture, range and paddock manure) (level and trend assessment): 18.9 per cent (501.5 kt CO_2-e) increase
- direct emissions from synthetic nitrogen fertiliser (level and trend assessment): 441.9 per cent (905.1 kt CO_2-e) increase
- volatilisation (level assessment): 16.4 per cent (104.3 kt CO_2-e) increase
- management of organic soils (level and trend assessment): 1.2 per cent (6.9 kt CO_2-e) increase
- leaching and runoff (level assessment): 21.3 per cent (83.5 kt CO_2-e) increase
- crop residues (level assessment): 47.4 per cent (74.0 kt CO_2-e) increase.

Table 5.5.1 shows the trends and relative contribution of N_2O emissions from these categories between 1990 and 2023.

Table 5.5.1 Trends and relative contribution of nitrous oxide emissions from *Agricultural soils* categories between 1990 and 2023

Agricultural soils category		Emissions (kt CO_2-e) 1990	Emissions (kt CO_2-e) 2023	Change from 1990–2023 kt CO_2-e	Change from 1990–2023 %	Share of Agricultural soils category 2023(%)	Share of total Agriculture sector 2023 (%)
Direct	Synthetic nitrogen fertilisers	204.8	1,109.9	905.1	441.9	17.4	2.7
	Organic fertilisers	31.4	73.3	41.9	133.4	1.1	0.2
	Pasture, range and paddock manure	2,650.3	3,151.8	501.5	18.9	49.5	7.8
	Crop residue	156.0	230.0	74.0	47.4	3.6	0.6
	Cropland nitrogen mineralisation from soil organic matter loss	0.0	0.2	0.1	528.5	0.0	0.0
	Management of organic soils	583.1	590.0	6.9	1.2	9.3	1.5
Indirect	Volatilisation	636.8	741.1	104.3	16.4	11.6	1.8
	Leaching and runoff	392.6	476.1	83.5	21.3	7.5	1.2
Total Agricultural soils		4,655.1	6,372.4	1,717.3	36.9	100.0	15.7

Note: Columns may not add due to rounding. Percentages presented are calculated from unrounded values.

5.5.2 Methodological issues

New Zealand uses methodologies based on the 2006 IPCC Guidelines (IPCC, 2006), outputs of the Tier 2 livestock population characterisation, modelling of the livestock nutrition and energy requirements, and some country-specific equations to calculate N_2O emissions from *Agricultural soils*. A combination of default and country-specific emission factors and parameters is also used to calculate emissions from this category. Details on these emission factors and parameters are listed in tables 5.5.2 and 5.5.3; annex 5, tables A5.1.6, A5.1.7, A5.1.8 and A5.1.9; and in table 5.5.5 for mitigation technologies.

The largest inputs of nitrogen to agricultural soils are manure (urine and dung) from grazing livestock and synthetic nitrogen fertilisers, which together contribute just over two thirds of emissions from the *Agricultural soils* category. The following paragraphs provide an overview of the ongoing country-specific improvements made to the *Agricultural soils* category.

Overview of research and improvements in the Agricultural soils category

Considerable research effort has gone into establishing New Zealand-specific emission factors for emissions from synthetic fertiliser application (EF_1) and emissions from manure deposition onto pasture by grazing livestock ($EF_{3,PRP}$). In New Zealand, most livestock waste is excreted directly onto pasture during grazing (see table 5.3.2).

Direct N_2O emission factors for dung and urine are separated based on livestock type (for *Dairy cattle*, *Non-dairy* (beef) *cattle*, *Sheep* and *Deer*) and hill slope category based on research by Saggar et al. (2015) and van der Weerden et al. (2019, 2020) (see table 5.5.3). A 'nutrient transfer model' developed by Saggar et al. (2015) is used to calculate the amount of dung and urine deposited on different hill slope categories. Around 79 per cent of sloped land on sheep, non-dairy and deer farms is classed as medium (12–24 degrees) or steep (greater than 24 degrees) sloped land (see annex 5, figure A5.1.3).

For minor livestock categories, such as *Horses*, *Llamas and alpacas*, *Poultry*, *Swine*, *Goats*, and *Mules and asses*, New Zealand uses IPCC default emission factors and methodology. Research conducted in New Zealand confirmed that the IPCC default emission factors and methodology for direct N_2O emissions from manure deposited on soil ($EF_{3,PRP\text{-}MINOR}$) are appropriate for New Zealand conditions (Carran et al., 1995; de Klein et al., 2003; Muller et al., 1995).

New Zealand uses country-specific emission factors for urea fertiliser (0.0059) and dairy cattle effluent manure (0.0025) applied to soils (van der Weerden et al., 2016a and 2016b). The IPCC default value of 0.01 is used for other nitrogen inputs including synthetic nitrogen fertiliser (excluding urea), animal manure from minor livestock species applied to soils, and crop residues. This emission factor of 0.01 has been verified as suitable for New Zealand conditions by Kelliher and de Klein (2006).

The emission factor for indirect N_2O emissions from leaching and runoff (EF_5) for rivers, lakes and estuaries has also been reviewed (Clough and Kelliher, 2014). The review concluded that further research is required to develop a country-specific value, and that the IPCC (2006) default emission factor (0.0075) is appropriate for New Zealand in the meantime.

In addition to these country-specific emission factors, New Zealand has developed country-specific parameters for volatilisation, leaching and nitrogen input from crop residue burning and pasture renewal (see table 5.5.4). New Zealand has also incorporated country-specific emission factors and country-specific parameters for calculating emissions from the use of the following mitigation technologies (see table 5.5.5):

- urease inhibitors such as N-butyl thiophosphoric triamide
- dicyandiamide (DCD), a nitrification inhibitor.

Table 5.5.2 Nitrous oxide (N_2O) emission factors for *Agricultural soils* in New Zealand, excluding $EF_{3,PRP\text{-}URINE}$ for cattle, sheep and deer

Category	Emission factor			Source
3.D.1 Direct N_2O emissions				
Synthetic nitrogen fertiliser (urea)	$EF_{1\text{-}UREA}$	0.0059	kg N_2O-N/kg N	van der Weerden et al. (2016a, 2016b)
Organic fertiliser (dairy cattle manure)	$EF_{1\text{-}DAIRY}$	0.0025	kg N_2O-N/kg N	van der Weerden et al. (2016a, 2016b)
Organic fertiliser (non-manure)	$EF_{1\text{-}ORGANIC}$	0.006	kg N_2O-N/kg N	IPCC (2019, table 11.1)
Synthetic nitrogen fertiliser (other), organic fertiliser (swine and poultry manure) crop residue, nitrogen loss due to soil organic matter mineralisation, organic soil mineralisation due to cultivation	EF_1	0.01	kg N_2O-N/kg N	IPCC (2006, table 11.1); Kelliher and de Klein (2006)
Cultivation of organic soils	EF_2	8.0	kg N_2O-N/ha/kg N	IPCC (2006, table 11.1)
Manure (dung and urine) from minor grazing animals (i.e., *excluding* cattle, sheep and deer) in pasture, range and paddock systems	$EF_{3,PRP\text{-}MINOR}$	0.01	kg N_2O-N/kg N	Carran et al. (1995); de Klein et al. (2003); IPCC (2006, table 11.1); Muller et al. (1995)
Dung from grazing cattle, sheep and deer in pasture, range and paddock systems	$EF_{3,PRP\text{-}DUNG}$	0.0012	kg N_2O-N/kg N	van der Weerden et al. (2019, 2020)
3.D.2 Indirect N_2O emissions				
Volatilisation	EF_4	0.010	kg N_2O-N/kg N	IPCC (2006, table 11.3)
Leaching and runoff	EF_5	0.0075	kg N_2O-N/kg N	IPCC (2006, table 11.3), confirmed by Clough and Kelliher (2014)

Table 5.5.3 Direct nitrous oxide emission factors for urine deposited by cattle, sheep and deer, by livestock type and slope, using values calculated by van der Weerden et al. (2019, 2020)

Livestock type	Emission factors by slope Flat and low sloped land (less than 12° gradient) $EF_{3,PRP\text{-}FLAT}$	Medium and steep sloped land (greater than 12° gradient) $EF_{3,PRP\text{-}STEEP}$
All cattle (includes dairy and non-dairy)	0.0098	0.0033
Deer	0.0074	0.0020
Sheep	0.0050	0.0008

Table 5.5.4 Parameters for indirect nitrous oxide (N_2O) emissions from *Agricultural soils* in New Zealand

Category	Parameter			Source
3.D.2 Indirect N_2O emissions				
Fraction of volatilisation from synthetic fertiliser	$Frac_{GASF}$	0.1	kg NH_3-N + NO_x-N/kg N	IPCC (2006), verified by Sherlock et al. (2008)
Fraction of volatilisation from organic nitrogen additions including pasture manure	$Frac_{GASM}$	0.1	kg NH_3-N + NO_x-N/kg N	Sherlock et al. (2008)
Fraction of leaching and runoff from all nitrogen applied to soil	Cropland $Frac_{LEACH-(H)}$	0.1	kg N/kg N	Welten et al. (2021)
	Grassland $Frac_{LEACH-(H)}$	0.08	kg N/kg N	Welten et al. (2021)
	Synthetic N fertiliser $Frac_{LEACH\text{-}(H)}$	0.082	kg N/kg N	Calculated based off of Welten et al. (2021)
Fraction of crop residue burned in the field	$Frac_{BURN}$	Crop-specific	kg N/kg crop-N	Thomas et al. (2008, table 14)
Fraction of legume crop residue burning in the field	$Frac_{BURNL}$	0 (not burned in NZ)	kg N/kg crop-N	Thomas et al. (2008)
Fraction of land undergoing pasture renewal	$Frac_{RENEW}$	Year-specific		Beare et al. (2012); Thomas et al. (2014)
Fraction of nitrogen in above-ground residues removed for bedding, feed or construction	$Frac_{REMOVE}$	0	kg N/kg crop-N	Thomas et al. (2014)

Table 5.5.5 Emission factors and parameter values for use of mitigation technologies

Category	Parameter and value (%)		Source
Urine from grazing dairy cattle in pasture, range and paddock systems with application of dicyandiamide (DCD)	$EF_{3(PRP\text{-}DCD)}$	0.67	Clough et al. (2008)
Fraction of nitrogen from leaching and runoff with application of DCD	$Frac_{LEACH-(H)\text{-}DCD}$	0.53	Clough et al. (2008)
Volatilisation from synthetic nitrogen fertiliser (urea only) coated with urease inhibitor (nBTPT)	$Frac_{GASF\text{-}UI}$	0.055	Saggar et al. (2013)

Direct nitrous oxide emissions from managed soils (3.D.1)

Emissions from the *Direct N_2O emissions from managed soils* category arise from:

- synthetic nitrogen fertiliser use (F_{SN})
- organic fertilisers (which in New Zealand are solely the spreading of animal manure, F_{AM})
- manure deposited by grazing livestock in pasture, range and paddock (F_{PRP})
- decomposition of crop residues left on fields (F_{CR})
- nitrogen mineralisation associated with loss of soil organic matter (F_{SOM})
- management of organic soils.

Many of these sources of emissions have N_2O emissions from indirect pathways as well, and these calculations are described in detail in the section on indirect N_2O emissions from managed soils.

New Zealand's methodology for determining the values for nitrogen inputs to soils for F_{AM} and F_{PRP} is consistent with other parts of the Agriculture inventory sector. The underlying values for N_{ex} and for the allocation of excreta to animal waste management systems are the same as in the *Manure management* category. These N_{ex} values have been calculated based on the same animal intake and animal productivity values used for calculating CH_4 emissions for the different animal categories and species in the Tier 2 model (see section 5.1.3). This ensures the same base DMI values are used for both the CH_4 and N_2O emission calculations. Further details can be found in the Agriculture inventory model methodology document on the MPI website (www.mpi.govt.nz/dmsdocument/13906-detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation).

Synthetic nitrogen fertiliser (3.D.1.1)

Anthropogenic N_2O emissions from synthetic nitrogen fertiliser are a relatively small proportion of total N_2O emissions, but have grown since 1990. Most synthetic nitrogen fertiliser used in New Zealand is urea fertiliser applied to dairy pastures to increase pasture growth during spring (September to November) and autumn (March to May).

In accordance with IPCC Guidelines (IPCC, 2006), the following equation is used to determine direct N_2O emissions from the application of nitrogen-based fertiliser:

$$N_2Odirect = \frac{44}{28} \times \left((F_{SN(UREA)} \times EF_{1(UREA)}) + (F_{SN(OTHER)} \times EF_1) \right)$$

Where: 44/28 is the molecular conversion factor used to convert nitrogen to N_2O

F_{SN} is the total annual amount of synthetic nitrogen fertiliser applied to soils (urea-based and other fertilisers)

$EF_{1(UREA)}$ is the proportion of direct N_2O emissions from nitrogen input to the soil for urea fertilisers (0.0059; table 5.5.2), and

EF_1 is the proportion of direct N_2O emissions from nitrogen input to the soil (0.01; table 5.5.2).

Data on synthetic fertiliser use are provided by the Fertiliser Association of New Zealand. Sales records from the two major fertiliser companies for 1990 to 2023 comprise approximately 98 per cent of the total tonnage used, with fertiliser use estimates from smaller companies added.

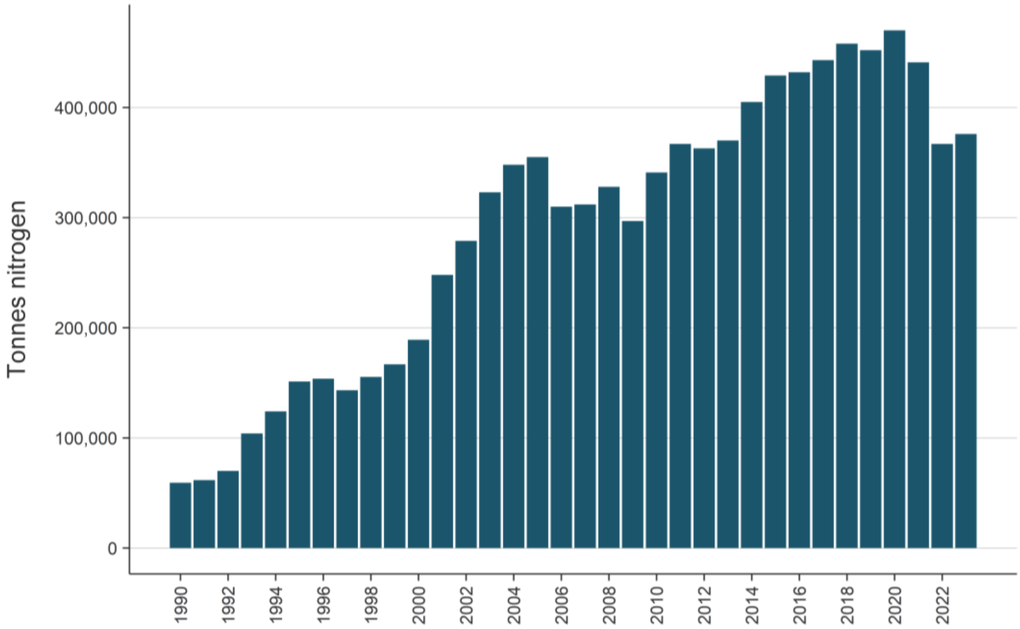
The $EF_{1(UREA)}$ value was changed to 0.0059 in 2017, following a recommendation from the Agriculture Inventory Advisory Panel in 2016. The Panel agreed that the value of 0.0059, based on research by van der Weerden et al. (2016a), was more representative of New Zealand farming practices and conditions, where only small (30–50 kg N/ha/application) urea dressings are applied but on several occasions during a year. The lower value of $EF_{1(UREA)}$, compared with the IPCC default of 1 per cent, is comparable with studies conducted in Australia (Chen et al., 2010; Galbally et al., 2005) and The Netherlands (Kuikman et al., 2006), which have found EF_1 urea fertiliser values of around 0.5 per cent.

Since 1990, a large increase in nitrogen applied through synthetic fertiliser has occurred, from 59,265 tonnes in 1990, increasing to 376,000 tonnes in 2023 (see figure 5.5.2). The proportion of urea fertiliser applied increased from just over 41.5 per cent in 1990 to 91.7 per cent in 2007.

In 2023, the applied tonnage of urea was 71.0 per cent of all synthetic nitrogen fertiliser applied (see figure 5.5.3).

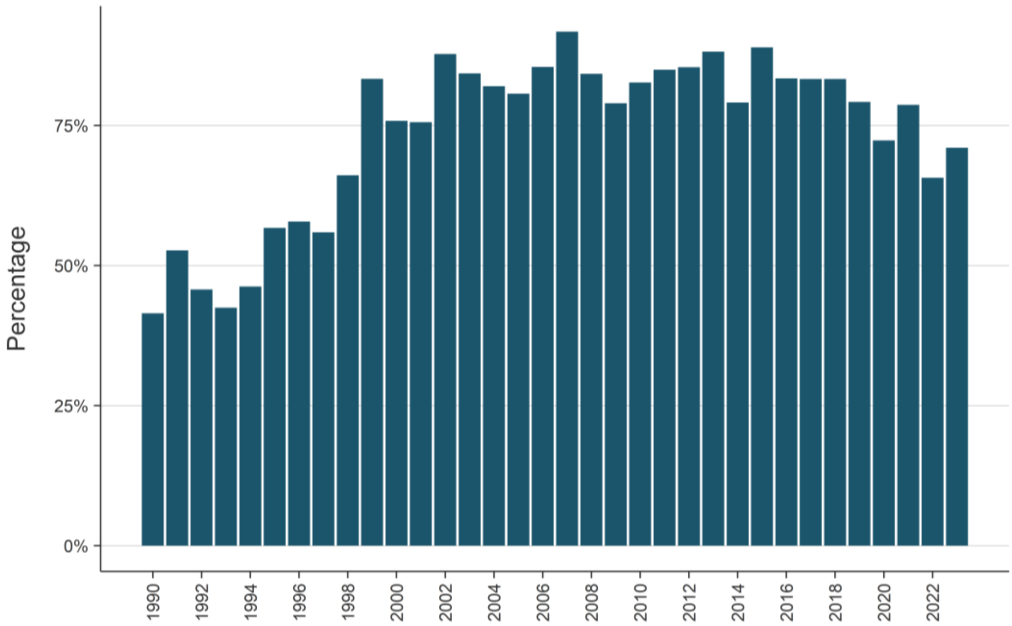
The nitrogen fertiliser applied has decreased significantly (14.7 per cent) in the past two years in part due to higher fertiliser prices.

Figure 5.5.2 Synthetic nitrogen fertiliser use in New Zealand, from 1990 to 2023



Source: Fertiliser Association of New Zealand

Figure 5.5.3 Percentage of total synthetic nitrogen fertiliser derived from urea, from 1990 to 2023



Source: Fertiliser Association of New Zealand

The increase in synthetic nitrogen fertiliser use since 1990 has resulted in an increase in emissions from this category, from 204.8 kt CO_2-e in 1990 (0.6 per cent of total Agriculture emissions) to 1,109.9 kt CO_2-e in 2023 (2.7 per cent of Agriculture emissions).

Organic nitrogen fertilisers (3.D.1.2)

In New Zealand, emissions from organic nitrogen fertilisers are mainly from animal manure that is spread onto pasture after collection in manure management systems. While most animal manure in New Zealand is excreted directly onto pasture, some manure from dairy farms is collected in manure management systems and applied to soils as an organic fertiliser (see table 5.3.2). A report by Rollo et al. (2017) found that only 8 per cent of dairy farms use land application of manure, through the use of direct pumping from a sump. In all cases, manure that was collected was stored for at least one or two days before spreading to pasture largely via irrigation. Therefore, it does not meet the definition of *daily spread* and the notation key 'NO' is reported in 3.B(b) of the CRT. The emissions calculation in this category (*Organic nitrogen fertilisers*) excludes manure deposited directly on pasture by grazing livestock, which is covered in the next section (*Urine and dung deposited by grazing animals* (3.D.1.3)). Animal manure is not used for fuel or construction in New Zealand.

New Zealand has developed a country-specific emission factor for N_2O from dairy cattle manure applied to soils of 0.0025 (van der Weerden et al., 2016a, 2016b). This value was based on a meta-analysis of field trials carried out in New Zealand that measured emissions from dairy cattle manure on soil. This emission factor was changed to 0.0025 in 2017, following a recommendation from the Agriculture Inventory Advisory Panel in 2016. The Panel agreed that the new value was more representative of New Zealand farming practices and conditions. Given that dairy cattle manure is a mixture of urine and dung (combined with water), the value of 0.0025 is consistent with the EF_3 emission factor values for N_2O used in New Zealand for dairy cattle urine (0.0098 and 0.0033 for flat and medium to steep sloped land respectively) and dung (0.0012) (van der Weerden et al., 2016a). Direct N_2O emissions from dairy cattle manure applied as organic fertiliser in 2023 (using the emission factor of 0.0025) were 0.128 kt N_2O.

Manure from poultry and swine spread onto soil has an emission factor of 0.01, which is consistent with the IPCC default.

The following equation is used to determine direct N_2O emissions from the application of animal manure to soil:

$$N_2O\ emissions = \frac{44}{28} \times \left((F_{AM} \times EF_1) + (F_{AM(Dairy)} \times EF_{1(Dairy)}\right)$$

Where: F_{AM} is the total amount of animal manure nitrogen (swine and poultry) applied to soils from manure management systems (other than pasture, range and paddock), which is derived as a fraction of the nitrogen excretion rates, N_{ex}, described in section 5.3.2

44/28 is the molecular conversion factor used to convert nitrogen to N_2O

EF_1 is the proportion of direct N_2O emissions from animal manure (swine and poultry) applied to soils (0.01; table 5.5.2)

$F_{AM(DAIRY)}$ is the total amount of animal manure nitrogen (dairy) applied to soils from manure management systems (other than pasture, range and paddock), which is derived as a fraction of the nitrogen excretion rates, N_{ex}, described in section 5.3.2, and

$EF_{1(DAIRY)}$ is the proportion of direct N_2O emissions from animal manure (dairy cattle) applied to soils (0.0025; table 5.5.2).

New Zealand also accounts for emissions from non-manure organic fertilisers. Sources include dairy processing wastewater, compost sold to the rural sector, meat processing wastewater, grape marc, vegetable processing wastewater and sewage sludge applied to land. The amount of nitrogen from these sources between 1990 and 2022 has been estimated (van der Weerden and Rutherford, 2024). For years after 2022 the latest available value is used, with a review intended in 2027.

The 2019 refinement of the 2006 IPCC guidelines (IPCC, 2019) retained the default value of 1 per cent for nitrogen additions to agricultural soils. However, the refinement also provides additional emission factor values disaggregated by nitrogen type and climate, where climate is disaggregated into wet and dry. New Zealand falls into this ‘wet climate’ category according to the IPCC definition. Therefore, New Zealand uses the 2019 IPCC disaggregated EF_1 of 0.6 per cent, to ensure calculations are employing the latest scientific knowledge. This provides a more appropriate value for organic nitrogen amendments to soils in wet climates rather than remaining with the aggregated value of 1 per cent that is applied to all nitrogen inputs, across all climatic zones.

Urine and dung deposited by grazing animals (3.D.1.3)

Most livestock in New Zealand are grazed outdoors on pasture, with around 92.8 per cent of dairy cattle excreta and 100 per cent of non-dairy cattle, sheep, deer and other livestock excreta deposited on pasture (see table 5.3.2). In New Zealand, dairy cattle are kept close to the milking shed and dairy farming tends to be on flatland. Sheep, non-dairy and deer farming predominantly occur on hill country and less frequently on flatland.

The following equations are used to determine direct N_2O emissions from grazing livestock manure.

For urine deposited on flatland and low slopes by sheep, cattle and deer only:

$$\begin{aligned} N_2O\ emissions &= \frac{44}{28}(N_2O-N) \\ &= \frac{44}{28}\left(\sum_T N_T \cdot \left(Nex_{URINE,FLAT} + Nex_{URINE,LOW}\right) \cdot MS_T\right) \\ &\cdot EF_{3(PRP-FLAT)} \end{aligned}$$

For urine deposited on medium and steep slopes by sheep, cattle and deer only:

$$\begin{aligned} N_2O\ emissions &= \frac{44}{28}(N_2O-N) \\ &= \frac{44}{28}\left(\sum_T N_T \cdot \left(Nex_{URINE,MED} + Nex_{URINE,STEEP}\right) \cdot MS_T\right) \\ &\cdot EF_{3(PRP-STEEP)} \end{aligned}$$

For all dung from sheep, cattle and deer:

$$N_2O\ emissions = \frac{44}{28}(N_2O-N) = \frac{44}{28}\left(\sum_T N_T \cdot Nex_{DUNG,T} \cdot MS_T\right) \cdot EF_{3(PRP-DUNG)}$$

For urine and dung from other livestock categories (swine, goats, horses, llamas and alpacas, mules, asses and poultry):

$$N_2O\ emissions = \frac{44}{28}(N_2O - N) = \frac{44}{28}\left(\sum_T N_T \cdot Nex_T \cdot MS_T\right) \cdot EF_{3(PRP-MINOR)}$$

Where: N_T is the population of the livestock category (sheep, cattle, deer or other)

T is the population as calculated in section 5.1.3

$Nex_{URINE,FLAT}$ is the annual urinary nitrogen excretion per head deposited on flatland[45] (kg N/head/year)

$Nex_{URINE,LOW}$ is the annual urinary nitrogen excretion per head deposited on low slopes[46] (kg N/head/year)

$Nex_{URINE,MED}$ is the annual urinary nitrogen excretion per head deposited on medium slopes[47] (kg N/head/year)

$Nex_{URINE,STEEP}$ is the annual urinary nitrogen excretion per head deposited on steep slopes[48] (kg N/head/year)

$Nex_{DUNG,T}$ is the annual average excretion per head (kg N/head/year)

Nex_T is the annual average nitrogen excretion per head (kg N/head/year) (see section 5.3)

MS_T is the proportion of manure excreted directly onto pasture, range and paddock (see table 5.3.2)

$EF_{3(PRP-FLAT)}$ is the emission factor for urinary nitrogen deposited on flatland and low slopes by sheep, deer and cattle (note that emission factors vary by animal category, see table 5.5.2)

$EF_{3(PRP-STEEP)}$ is the emission factor for urinary nitrogen deposited on medium and steep slopes, for sheep, deer and cattle (note emission factors vary by animal category, see table 5.5.2)

$EF_{3(PRP-DUNG)}$ is the emission factor for dung nitrogen excreta deposited by sheep, deer and cattle on pasture, range and paddock (0.0012, see table 5.5.2)

$EF_{3(PRP-MINOR)}$ is the emission factor for dung from minor animal categories deposited on pasture, range and paddock (see table 5.5.2).

For cattle, sheep and deer, the estimated N_{ex} values are separated into urine and dung components using the methodology outlined by Pacheco et al. (2018).

The Agriculture inventory model assumes that all dairy cattle graze on flatland, due to New Zealand farming practices, therefore, all dairy urinary nitrogen is allocated to $Nex_{URINE,FLAT}$.

Urinary nitrogen from non-dairy cattle, sheep and deer is allocated to the different slope types; $Nex_{URINE,LOW}$, $Nex_{URINE,MED}$ and $Nex_{URINE,STEEP}$. However, there is zero land allocated to flatland ($Nex_{URINE,FLAT}$), which is generally used for grazing dairy cattle.

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45 Flatland is classified as flat pastoral land or plains with a gradient lower than 12 degrees (i.e., equivalent to low slopes).

46 Low slopes are classified as hill country pastoral land with a gradient on average lower than 12 degrees.

47 Medium slopes are classified as hill country pastoral land with a gradient on average between 12 degrees and 24 degrees.

48 Steep slopes are classified as hill country pastoral land with a gradient on average greater than 24 degrees.

EF_3 emission factors for excreta deposited by cattle, sheep and deer on sloped land

New EF_3 emission factors were incorporated in the 2020 inventory and are detailed in table 5.5.2 ($EF_{3(PRP\text{-}DUNG)}$) and table 5.5.3. These EF_3 emission factors used to calculate N_2O emissions from cattle (dairy and non-dairy cattle), sheep and deer are based on a meta-analysis undertaken by van der Weerden et al. (2019, 2020) based on field studies carried out in the past decade (de Klein et al., 2014; Hoogendoorn et al., 2013; Luo et al., 2013, 2016, 2019a; Saggar et al., 2015). The research collectively shows (see table 5.5.6):

- a statistically significant difference in urine emission factors between cattle and sheep
- that emissions from sheep, non-dairy cattle and dairy cattle excreta deposited on medium (between 12 degrees and 24 degrees) and steep (greater than 24 degrees) sloped land are significantly lower than corresponding emissions on land that is flat or of a low gradient (between 0 degrees and 12 degrees).

Evidence and meta-analysis for EF_3 emission factors for excreta deposited on sloped land

The meta-analysis (van der Weerden et al., 2020), built on a previous study by Kelliher et al. (2014), calculated new emission factors based on animal type, season and slope. This was based on an expanded data set of 1,217 replicate-level emission factors from 236 field experiments conducted over the past decade, largely measured using the same standardised experimental methods for N_2O (see table 5.5.7).

The meta-analysis included results of studies from dung and urine deposited onto flatland and steep sloped land both published in scientific journals (Hoogendoorn et al., 2008; Ledgard et al., 2014; Luo et al., 2013; van der Weerden et al., 2011) and reported to MPI's inventory reporting team (Hoogendoorn et al., 2013; Luo et al., 2016, 2019a). These data were compiled to contribute to existing data on emissions from dung and urine deposited on low and medium sloped land from the Kelliher et al. (2014) study.

Additional evidence conducted overseas supporting the use of emission factors that vary by land slope has been provided in a study in the United Kingdom by Marsden et al. (2018), who found that sheep EF_3 values are lower on upland and hill areas compared with intensively managed lowlands.

Table 5.5.6 Number of replicate-level EF_3 values collated by the van der Weerden et al. (2019, 2020) analysis, for each nitrogen source and topography (number of individual trials shown in brackets)

Nitrogen source	Flatland (0–12°)	Low sloped land (0–12°)	Medium sloped land (12–24°)	Steep sloped land (>24°)	Total
Dairy cattle urine	341 (57)	108 (22)	20 (4)		469 (83)
Dairy cattle dung	84 (19)	46 (9)	20 (4)		150 (32)
Non-dairy cattle urine	8 (1)	40 (8)	60 (12)	20 (4)	128 (25)
Non-dairy cattle dung		76 (16)	60 (12)	20 (4)	156 (32)
Sheep urine	40 (7)	64 (12)	60 (12)	20 (4)	184 (35)
Sheep dung	54 (13)	36 (8)	20 (4)	20 (4)	130 (29)
Total urine	**389 (65)**	**212 (42)**	**140 (28)**	**40 (8)**	**781 (143)**
Total dung	**138 (32)**	**158 (33)**	**100 (20)**	**40 (8)**	**436 (93)**
Total excreta	**527 (97)**	**370 (75)**	**240 (48)**	**80 (16)**	**1,217 (236)**

Table 5.5.7 **Number of replicate-level EF_3 values collated by the van der Weerden et al. (2019, 2020) analysis, for each nitrogen source, season that trial was undertaken and topography**

Nitrogen source	Topography class	Autumn	Winter	Spring	Summer	Total
Dairy cattle urine	Flatland (0°)	128	105	88	12	333
	Low slope (0–12°)	34	34	28	20	116
	Medium slope (12–24°)		20			20
	Steep slope (>24°)					
Dairy cattle dung	Flatland (0°)	14	34	36		84
	Low slope (0–12°)		26		20	46
	Medium slope (12–24°)		20			20
	Steep slope (>24°)					
Non-dairy cattle urine	Flatland (0°)		8			8
	Low slope (0–12°)		20		20	40
	Medium slope (12–24°)	10	30		20	60
	Steep slope (>24°)	10	10			20
Non-dairy cattle dung	Flatland (0°)					
	Low slope (0–12°)	20	28	8	20	76
	Medium slope (12–24°)	10	30		20	60
	Steep slope (>24°)	10	10			20
Sheep urine	Flatland (0°)	8	8	20		36
	Low slope (0–12°)	24		44		68
	Medium slope (12–24°)	30	10	20		60
	Steep slope (>24°)	10	10			20
Sheep dung	Flatland (0°)	10	16	28		54
	Low slope (0–12°)	20	8	8		36
	Medium slope (12–24°)	10	10			20
	Steep slope (>24°)	10	10			20
Total urine		**254**	**255**	**200**	**72**	**781**
Total dung		**104**	**192**	**80**	**60**	**436**
Total excreta		**358**	**447**	**280**	**132**	**1,217**

The meta-analysis used arithmetic means to calculate new average EF_3 values (categorised by animal, slope and excreta type). Because the differences between some of these values were not statistically significant, some of the arithmetic means were pooled. This resulted in the dung EF_3 averages being combined into a single value (0.0012). The urine EF_3 values were pooled into four categories:

- cattle urine on flatland/low slopes (0.0098)
- cattle urine on medium/steep slopes (0.0033)
- sheep urine on flatland/low slopes (0.005)
- sheep urine on medium/steep slopes (0.0008).

The lower emission factors observed for urine on steeper slopes are thought to be due to these soils having lower soil fertility, nitrogen status and moisture content compared with less steep slopes (Luo et al., 2013).

The new urine emission factor values for each livestock type by slope are lower than the current IPCC default EF_3 value. The default value is based on common international farming systems where, on average, livestock farmed land is on less sloped terrain than much of the farmland in New Zealand. In addition to the large proportion of farmed hill country, New Zealand's climate and soil characteristics contribute to differences between international default emission factors and New Zealand's country-specific emission factors. When using these emission factors, the IEF for direct N_2O from dung and urine was 0.0054 in 2020. This value is comparable with that calculated for the United Kingdom (0.0037) and Australia (0.0040) in their respective inventory submissions for 2021.

Nitrous oxide emissions have not been measured for deer excreta, therefore, deer EF_3 values were calculated using average EF_3 values from cattle and sheep. Based on animal liveweight, deer excreta characteristics (in terms of total deposition volume and weight) are assumed to be between the excreta characteristics of cattle and sheep (van der Weerden et al., 2019, 2020).

To apply these emission factors, estimates of the amount of urine and dung deposited onto different slope categories are needed. A nutrient transfer model developed by Saggar et al. (2015) is used to allocate total excreta (N_{ex}, calculated using the methods described in section 5.3) by livestock type to the different slope categories. The nutrient transfer model uses data on the national area of farmland for each slope category, and accounts for animal behaviour where livestock spend relatively more time on lower slopes, and so deposit more excreta on these lower slopes and flatland. For more information on this model, see annex 5, section 5.1.3.

The use of these revised EF_3 emission factors and the nutrient transfer model was recommended by the Agriculture Inventory Advisory Panel in 2019.

Direct nitrous oxide emission factors for minor livestock types

Minor livestock types, including *Swine, Goats, Horses, Llamas and alpacas, Mules and asses,* and *Poultry*, make up a small proportion of total agricultural emissions. New Zealand will therefore continue to use the previous emission factor for minor livestock types ($EF_{3(PRP\text{-}MINOR)}$) of 0.01, which is the IPCC default. Research conducted in New Zealand has confirmed this value is appropriate for New Zealand's conditions (Carran et al., 1995; de Klein et al., 2003; Muller et al., 1995).

In 2023, direct N_2O emissions from *Urine and dung deposited by grazing animals* (pasture, range and paddock manure from all livestock categories) contributed 49.5 per cent (3,151.8 kt CO_2-e) of emissions from *Agricultural soils*, or 7.8 per cent of total agricultural emissions. Emissions from this category have increased by 18.9 per cent since 1990. Emissions for each livestock category are given in table 5.5.8. Emissions from *Urine and dung deposited by grazing animals* were identified as a key category (level and trend assessment).

Table 5.5.8 Trends and relative contribution of direct nitrous oxide emissions from urine and dung deposited by grazing animals per livestock category between 1990 and 2022

	Emissions (kt CO_2-e)		Change from 1990–2021		Share of Agricultural soils category (%)		Share of total Agriculture sector (%)	
Livestock category	1990	2023	kt CO_2-e	%	1990	2023	1990	2023
Dairy cattle	1,020.0	1,945.5	925.5	90.7	21.9	30.5	2.8	4.8
Non-dairy cattle	753.2	730.0	-23.3	-3.1	16.2	11.5	2.0	1.8
Sheep	765.7	427.5	-338.3	-44.2	16.5	6.7	2.1	1.1
Deer	39.6	33.3	-6.4	-16.0	0.9	0.5	0.1	0.1
Minor livestock	71.7	15.6	-56.1	-78.2	1.5	0.3	0.2	0.0

Note: Percentages presented are calculated from unrounded values.

Nitrous oxide from crop residue returned to soil (3.D.1.4)

This emissions category includes emissions from nitrogen added to soils by above-ground and below-ground crop residue (including residue left behind by crop burning), and the nitrogen added as a result of mineralisation of forages during pasture renewal. It includes both nitrogen-fixing and non-nitrogen-fixing crop species. Crop residues are materials left in an agricultural field after the crop has been harvested. Pasture renewal is the destruction of low-quality pasture followed by the sowing of improved pasture species and varieties to increase farm productivity. The direct emissions from agricultural residue burning are reported in section 5.7.

New Zealand does not include an adjustment for crop residue removed for feed and bedding, which is estimated to be minor by Thomas et al. (2008).

Nitrogen from crop residue: The major non-nitrogen-fixing crops grown in New Zealand are barley, wheat, oats, potatoes, maize for seed, and other seed crops. From the 2012 submission onwards, New Zealand has reported emissions from additional cropping activity not previously estimated, such as onions, squash and sweetcorn (Thomas et al., 2011). The nitrogen-fixing crops grown in New Zealand include peas grown for both processing and seed markets as well as lentil production, and forage legume seeds (*Trifolium repens*) grown for pasture production.

A country-specific methodology is used to calculate emissions from crop residue (Thomas et al., 2008):

$$N_2O_{FCR}\ emissions = \frac{44}{28}(N_2O - N)_{FCR} = \frac{44}{28}(AG_N + BG_N) \cdot EF_1$$

Where: AG_N and BG_N are the annual nitrogen residue returned to soils from above- and below-ground crop residue, and crop-specific values are given in annex 5, table A5.1.9, and the country-specific value of EF_1 of 0.01 is used (see table 5.5.2).

$$AG_N = AG_{DM} \cdot N_{AG}\ BG_N = (AG_{DM} + Crop_T) \cdot R_{BG} \cdot N_{BG}$$

Where: AG_{DM} is the mass of the above-ground residue dry matter (explained in the equation below)

$Crop_T$ is the crop yield, or mass, removed during harvest

N_{AG} and N_{BG} are the above- and below-ground crop-specific nitrogen concentration factors, and

R_{BG} is the crop-specific root:shoot ratio of below-ground dry matter against the total above-ground crop biomass (crop gathered, $Crop_T$, plus above-ground residue dry matter, AG_{DM}), 0.1 (see annex 5, table A5.1.9).

$$AG_{DM} = \left(\frac{Crop_T}{HI}\right) - Crop_T \cdot Frac_{BURN} \cdot C_f$$

Where: HI is the crop-specific harvest index or fraction of the crop that is harvested (see annex 5, table A5.1.9)

$Frac_{BURN}$ is the fraction of residue burned in the field (see table 5.5.4), and

C_f is the combustion factor; a value of 0.7 is recommended (Thomas et al., 2008).

The country-specific value for $Frac_{BURN}$, the fraction of residue burned in the field, was derived from Stats NZ data and farmer surveys (Thomas et al., 2011). The parameters used to estimate the nitrogen added by above-ground and below-ground crop residues were compiled from published and unpublished reports for New Zealand-grown crops (Cichota et al., 2010) and 'typical' values derived for use in the OverseerFM nutrient budget model for New Zealand. The OverseerFM model provides average estimates of the fate of nitrogen for a range of pastoral, arable and horticultural systems (www.overseer.org.nz).

The per-year harvested tonnage of most non-nitrogen-fixing crops in New Zealand is supplied by Stats NZ from its Agricultural Production Census and Agricultural Production Survey. Additional information on potatoes is provided by Potatoes New Zealand, and updated information on seed crops is provided by AsureQuality, which provides verification and certification services for the seed industry (Thomas, unpublished; S Thomas, pers. comm., 2014). The tonnage of nitrogen-fixing crops is supplied by Stats NZ from its Agricultural Production Census and Agricultural Production Survey (lentils and legumes) and Horticulture New Zealand (peas) (S Thomas, pers. comm., 2014).

Nitrogen from pasture renewal: Of the four categories of perennial forage that the IPCC (2006) lists for pasture renewal, only two categories are appropriate for New Zealand (Thomas et al., 2014): these are grass–clover pastures and lucerne, a nitrogen-fixing perennial forage. New Zealand has calculated emissions from pasture renewal per plant species type, T, separately:

$$F_{CR-RENEW} = \sum_{T} \Big[Crop_T \times Area_T \times Frac_{RENEW(T)} \times \big[R_{AG(T)} \times N_{AG(T)} \times \left(1 - Frac_{REMOVE(T)}\right) + R_{BG(T)} \times N_{BG(T)}\big]\Big]$$

Where: $Area_T$ is the total annual area harvested (hectares per year). No burning is used for pasture renewal in New Zealand

$Frac_{RENEW(T)}$ is the fraction of the area under each crop that is renewed

$R_{AG(T)}$ is the ratio of above-ground residue dry matter (DM) to harvested yield (kg N/kg DM)

$N_{AG(T)}$ is the nitrogen content of above-ground residue (kg N/kg DM)

$Frac_{REMOVE\ (T)}$ is the fraction of above-ground residue removed annually for feed, assumed zero for New Zealand

$R_{BG(T)}$ is the ratio of below-ground residue DM to harvest yield (kg N/kg DM), and

$N_{BG(T)}$ is the nitrogen content of below-ground residue (kg N/kg DM).

The areas for each perennial forage crop were obtained from the Stats NZ Agricultural Production Census and Agricultural Production Survey, which include the area of grassland and annual crops from 1990 to 2023. The disaggregation of grass–clover systems has been considered, but there is insufficient activity data for pastures of different compositions in New Zealand because the proportion of clover varies widely due to the variability of nitrogen inputs to various farming systems, climate soil, fertility and management variables. This means that disaggregated data on the nitrogen content are not currently available.

The contribution of crop residues and pasture renewal to overall agricultural emissions is small, with 156.0 kt CO_2-e (0.4 per cent of total agricultural emissions) in 1990 and 230 kt CO_2-e (0.6 per cent of total agricultural emissions) in 2023.

Nitrogen mineralisation from loss of soil organic matter in mineral soils (3.D.1.5)

Nitrogen mineralisation is the process by which organic nitrogen is converted to plant-available inorganic forms. Nitrogen mineralisation occurs when soil carbon is lost due to land-use or management change. Most of New Zealand's emissions from nitrogen mineralised during the loss of soil organic matter are covered under the Land Use, Land-Use Change and Forestry

(LULUCF) sector. The exception is for activities in the *Cropland remaining cropland* land use category, which are reported under the Agriculture sector (IPCC, 2006).

The following equations are used to determine emissions from this activity:

$$N_2O_{FSOM} = \frac{44}{28}(F_{SOM} \cdot EF_1) \cdot 10^{-6}$$

Where: N_2O_{FSOM} is the N_2O emitted as a result of nitrogen mineralisation from loss of soil organic matter in mineral soils (kt), and

F_{SOM} is the nitrogen mineralisation from loss of soil organic matter in mineral soils through land management for *Cropland remaining cropland* (kg)

The emission factor EF_1 is 0.01 (Kelliher and de Klein, 2006).

And:

$$F_{SOM} = \frac{\Delta C_{Mineral,CrC}}{R} \cdot 10^3$$

Where: $\Delta C_{Mineral,CrC}$ is the loss of soil carbon (C) in mineral soil during management of cropland (kt), and

R is the C:N ratio. The IPCC (2006) default value of 10 is used.

Activity data on the soil carbon loss that is associated with cropland since 1990 were provided using calculations under the LULUCF sector (see chapter 6, section 6.5).

The contribution of nitrogen mineralisation from loss of soil organic matter to overall agricultural emissions is small, with 0.03 kt CO_2-e in 1990 and 0.16 kt CO_2-e in 2023.

Cultivation (management) of organic soils (3.D.1.6)

The management of organic soils is a source of N_2O emissions. The area of managed organic soils (histosols) in New Zealand includes both the area of managed organic soils (as reported under the LULUCF sector) and the area of mineral agricultural soils with a peaty layer that is cultivated (Dresser et al., 2011). Mineral soils with a peaty layer are included in the definition of organic soils because these soils have similar emissions behaviour to that of organic soils (Dresser et al., 2011). The full definition used in the Agriculture sector for organic soils (plus mineral soils with a peaty layer) is:

- at least 17 per cent organic matter content (includes slightly peaty, peaty and peat soils)
- 0.1 metres of this depth occurring within 0.3 metres of the surface.

The total area of managed organic soils in New Zealand in 2023 was 177,098 hectares, with about 95 per cent of this area on grassland and 5 per cent on cropland (Pronger et al., 2022). It is assumed that all of this area meets the definition of 'managed' for the purpose of estimating emissions. The estimate of managed organic soils on cropland and grassland is consistent with data and methodology used for the LULUCF sector. The total area of managed organic soils has increased slightly by 1.2 per cent (2,058 hectares) since 1990.

Emissions from organic soils are calculated using the Tier 1 methodology for all years of the time series by multiplying the area of managed organic soils by the default value of emission factor EF_2 of 8 kg N_2O-N/ha (IPCC, 2006).

In 2023, direct N_2O emissions from the management of organic soils contributed 9.3 per cent (590.0 kt CO_2-e) of emissions from *Agricultural soils*, or 1.5 per cent of total agricultural emissions). This is an increase of 1.2 per cent since 1990. Emissions from *Cultivation of organic soils* were identified as a key category (level and trend assessment).

Indirect nitrous oxide emissions from managed soils (3.D.2)

In addition to direct N_2O emissions from managed soils, emissions of N_2O also occur through two indirect pathways: volatilisation, and leaching and runoff.

Volatilisation (3.D.2.1)

Some of the nitrogen deposited or spread on agricultural land is emitted into the atmosphere through volatilisation in the form of NH_3 and NO_x. A fraction of this volatilised nitrogen returns to the ground during rainfall and is then re-emitted as N_2O. The fraction of nitrogen that becomes N_2O during this process is calculated using the parameters $Frac_{GASF}$ for synthetic nitrogen fertiliser and $Frac_{GASM}$ for organic inputs from animal excreta. New Zealand uses country-specific values for both of these parameters.

In New Zealand, nitrogen added to agricultural soils from synthetic nitrogen fertiliser (F_{SN}), organic nitrogen fertiliser from the spreading of managed manure (F_{ON}), and excreta from grazing livestock on pasture (F_{PRP}) all contribute to N_2O emissions from volatilisation. The collection of activity data for F_{SN}, F_{ON} and F_{PRP} is described above (see *Direct N_2O emissions from managed soils* (3.D.1)). Volatilisation from manure stored in manure management systems (before application to land) is reported in the *Manure management* category (see section 5.3.2).

New Zealand uses a Tier 1 methodology with country-specific emission factors for $Frac_{GASF}$ and $Frac_{GASM}$ and a default value for the EF_4 emission factor to calculate emissions from volatilisation:

$$\begin{aligned} N_2O_{ATD}\ emissions &= \frac{44}{28}(N_2O_{ATD} - N) \\ &= \frac{44}{28}\left[(F_{SN} \cdot Frac_{GASF}) + \left((F_{ON} + F_{PRP}) \cdot Frac_{GASM}\right)\right] \cdot EF_4 \end{aligned}$$

Where: N_2O_{ATD}–N is the annual amount of N_2O-N produced by atmospheric deposition of volatilised nitrogen from agricultural soils (kg N_2O-N/year)

F_{SN}, F_{ON} and F_{PRP} are defined above (kg N/year)

$Frac_{GASF}$ is the fraction of nitrogen from synthetic fertiliser that volatilises as NH_3 and NO_x (see table 5.5.4)

$Frac_{GASM}$ is the fraction of nitrogen from manure spreading and pasture, range and paddock manure that volatilises as NH_3 and NO_x (see table 5.5.4), and

EF_4 is the emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water (kg N_2O-N/kg N).

New Zealand has a country-specific value of 0.1 for $Frac_{GASF}$, the fraction of volatilised nitrogen from synthetic nitrogen fertiliser. This value is based on a review by Sherlock et al. (2008) of relevant New Zealand and international research. The review determined that a value of 0.096 for $Frac_{GASF}$ was suitable for New Zealand conditions. Because this value of 0.096 is almost identical to the IPCC default value of 0.1, the value of 0.1 was adopted by New Zealand as a country-specific value for $Frac_{GASF}$.

The review by Sherlock et al. (2008) also recommended that New Zealand adopt a country-specific value of 0.1 for $Frac_{GASM}$, the fraction of volatilised nitrogen from manure spreading and pasture, range and paddock manure. The review showed that the default value of 0.2 for $Frac_{GASM}$ (IPCC, 2006) was too high for New Zealand circumstances and that 0.1 was more appropriate. This value was also confirmed by subsequent field experiments (Laubach et al., 2012).

In 2023, N_2O emissions from volatilisation contributed 1.8 per cent (741.1 kt CO_2-e) to total Agriculture emissions, an increase of 16.4 per cent from the 1990 value of 636.8 kt CO_2-e.

Leaching and runoff (3.D.2.2)

Nitrous oxide emissions from leaching and runoff originate from the following sources:

- synthetic nitrogen fertiliser (F_{SN})
- organic nitrogen additions from the spreading of animal manure (F_{ON}), above- and below-ground crop residues (F_{CR})
- nitrogen mineralisation associated with loss of soil organic matter from cropland land management (F_{SOM})
- excreta from grazing livestock on pasture, range and paddock (F_{PRP}) (IPCC, 2006).

The collection of activity data for F_{SN}, F_{ON}, F_{CR}, F_{PRP} and F_{SOM} is described above (see *Direct N_2O emissions from managed soils* (3.D.1)).

New Zealand reports all emissions from leaching in the *Agricultural soils* category. As discussed under *Manure management* (see section 5.3.1), New Zealand livestock are predominantly grazed outdoors (see table 5.3.2). New Zealand uses a Tier 1 methodology with country-specific default parameters to calculate indirect N_2O emissions from nitrogen leaching. The general equation is:

$$N_2O_L\ emissions = \frac{44}{28}(N_2O_L - N)$$

The following are specific equations used to calculate indirect N_2O emissions from nitrogen leaching for cropping systems, grassland and synthetic nitrogen fertilisers:

$$N_2O_L\ emissions\ (cropping\ systems) = \frac{44}{28} \cdot (F_{CR} + F_{SOM}) \cdot Frac_{LEACH-H(CROPPING)} \cdot EF_5$$

$$N_2O_L\ emissions\ (grassland) = \frac{44}{28} \cdot (F_{CR} + F_{ON} + F_{PRP}) \cdot Frac_{LEACH-H(GRASSLAND)} \cdot EF_5$$

$$N_2O_L\ emissions\ (synthetic\ N\ fertiliser) = \frac{44}{28} \cdot (F_{SN}) \cdot Frac_{LEACH-H(FERTILISER)} \cdot EF_5$$

Where: N_2O_L–N is the annual amount of N_2O-N from runoff and leaching from agricultural soils (kg N_2O-N/year)

F_{SN}, F_{ON}, F_{PRP}, F_{CR} and F_{SOM} are defined above (kg N/year)

$Frac_{LEACH-H(CROPPING)}$ is the fraction of nitrogen added to, or mineralised from, cropping systems that is lost from soil through leaching and runoff (see table 5.5.4)

$Frac_{LEACH-H(GRASSLAND)}$ is the fraction of nitrogen added to, or mineralised from, grassland that is lost from soil through leaching and runoff (see table 5.5.4)

$Frac_{LEACH-H(FERTILISER)}$ is the fraction of nitrogen added to, or mineralised from, synthetic nitrogen fertiliser that is lost from soil through leaching and runoff, and

EF_5 is the IPCC (2006) default factor for N_2O emissions from leaching and runoff.

New Zealand uses differing $Frac_{LEACH}$ parameters that are dependent on the type of agricultural system the nitrogen has been applied to. These values were derived using measured values, as well as modelled values from OverseerFM, a New Zealand-specific nutrient budgeting model. The $Frac_{LEACH}$ value is 0.10 for nitrogen applied to cropland and 0.08 for grassland (Welten et al., 2021). The $Frac_{LEACH}$ value for synthetic nitrogen fertiliser applied to grassland and cropland is 0.082. This is a weighted average of nitrogen applied to cropland and grassland based on data from Stats NZ (2021) indicating that this is applied at a 90:10 ratio to grassland and cropland. Data back to 1990 show minimal fluctuations in this ratio, so it has been assumed that this nitrogen application remains static for the current inventory submission. Future inventory submissions may modify this $Frac_{LEACH}$ value if there is evidence the 90:10 ratio has changed.

The OverseerFM model provides average estimates of the leaching and runoff of nitrogen for a range of pastoral, arable and horticultural systems. In pastoral systems, OverseerFM derived nitrate (NO_3–) leaching is determined by rainfall, soil type and the amount of nitrogen entering the farm system (from nitrogen-based fertilisers, dung and urine applied as farm dairy effluent or directly excreted by grazing animals). Dung and urine output from animals is calculated from the difference between nitrogen intake by grazing animals and nitrogen retained in animal products, such as milk, meat, wool and velvet. This is based on user inputs of stocking rates and production using an internal database with information on the nitrogen content of pasture and animal products. Resulting values are calibrated against empirical field measurements. In cropping systems, two years (previous and reporting) of monthly crop and management data are required for modelling NO_3 leaching in OverseerFM. This data includes nitrogen applied as fertiliser and effluent, as well as factors influencing or indicating the water content of soil, such as temperature, irrigation, rainfall, drainage and field capacity.

In 2023, N_2O emissions from leaching and runoff made up 1.2 per cent (476.1 kt CO_2-e) of total agricultural emissions, an increase of 21.3 per cent from the 1990 value of 392.6 kt CO_2-e.

Incorporation of nitrous oxide mitigation technologies into the Agriculture inventory model

Urease inhibitors

The N_2O emissions reported in the *Agricultural soils* category take into account the use of urease inhibitors, a greenhouse gas mitigation technology. Urea is the main type of synthetic nitrogen fertiliser applied to pastures. Urease inhibitors restrict the action of the urease enzyme. Urease is a catalyst for the volatilisation of the nitrogen contained in urea fertiliser and urine into NH_3 gas.

Urease inhibitor mitigation is included in New Zealand's Agriculture inventory model by adjusting the value of the existing country-specific N_2O parameter: $Frac_{GASF}$. Saggar et al. (2013) assessed the mitigating effect of the urease inhibitor nBTPT (sold as 'Agrotain'), the most widely used urease inhibitor. Saggar et al. (2013) showed that the presently recommended country-specific value of $Frac_{GASF}$ of 0.1 should be reduced to 0.055 for urease-treated urea fertiliser. This finding was based on field and laboratory studies conducted both in New Zealand and worldwide.

Indirect N_2O emissions from volatilisation from all synthetic nitrogen fertilisers (including urea and other nitrogen fertilisers, with and without urease inhibitors applied to the urea component) are calculated as shown below:

$$N_2O_{ATD-FSN}\ emissions = \frac{44}{28}(N_2O_{ATD-FSN} - N) = \frac{44}{28}\sum_{S}[F_{SN} \cdot Frac_{GASF}] \cdot EF_4$$

Where: $N_2O_{ATD\text{-}FSN}$ is the annual amount of N_2O-N produced by atmospheric deposition of volatilised nitrogen from all synthetic nitrogen fertiliser applied to agricultural soils (kg N_2O-N/year)

S is urea fertiliser (untreated), urea fertiliser (treated) or non-urea nitrogen fertiliser

F_{SN} is the total annual amount of synthetic nitrogen fertiliser applied (kg N/year) per fertiliser type, S

$Frac_{GASF}$ is the fraction of nitrogen from synthetic nitrogen fertiliser that volatilises as NH_3 and NO_x; 0.055 for treated urea fertiliser and 0.1 for untreated urea and other nitrogen fertiliser, and

EF_4 is the emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water; 0.01 (kg N–N_2O (kg NH_3–N + NO_x–N volatilised)$^{-1}$).

All other emission factors and parameters relating to animal excreta and synthetic nitrogen fertiliser use ($Frac_{GASM}$, $Frac_{LEACH}$ and EF_1) do not change as a result of including urease inhibitors in the calculations. An adjustment for $Frac_{GASM}$ was not recommended because the effect of urease inhibitors on reducing NH_3 volatilisation from animal excreta could not be accurately assessed (Saggar et al., 2013).

Urea fertiliser coated with urease inhibitors was first used commercially in New Zealand in 2001. Activity data on urease inhibitor usage are provided by the Fertiliser Association of New Zealand from sales records.[49] These activity data record the total amount of nitrogen in urea fertiliser that has been treated with a urease inhibitor. Some urea fertiliser coated with urease inhibitors is also blended into other non-nitrogen fertiliser products. We do not have data on the amount used in this manner.

Estimates of the mitigation impact of urease inhibitors on N_2O emissions from volatilisation for the calendar years 2001 to 2023 are shown in table 5.5.9. In 2014, 2016 and 2019, large increases occurred in the use of urease inhibitors. The percentage of urea fertiliser applied with urease inhibitor passed 50 per cent in 2021 and was 47.6 per cent in 2023.

Table 5.5.9 Mitigation impact of urease inhibitors on nitrous oxide emissions from volatilisation, from 2001 to 2023

Year	Percentage of urea fertiliser applied that included urease inhibitor (urea treated/total urea)	Estimated greenhouse gas mitigation from using urease inhibitor (kt CO_2-e)
2001	5.6	2.0
2002	3.8	1.7
2003	4.6	2.3
2004	8.1	4.3
2005	1.6	0.9
2006	8.4	4.2
2007	5.0	2.7
2008	5.2	2.7
2009	9.4	4.2
2010	6.9	3.6
2011	5.3	3.1

49 Activity data on urease inhibitor usage before 2016 was provided by Ballance Agri-Nutrients Limited.

Year	Percentage of urea fertiliser applied that included urease inhibitor (urea treated/total urea)	Estimated greenhouse gas mitigation from using urease inhibitor (kt CO_2-e)
2012	7.0	4.0
2013	8.6	5.3
2014	20.2	12.1
2015	16.2	11.6
2016	26.5	17.9
2017	27.8	19.2
2018	29.9	21.3
2019	35.5	23.8
2020	41.8	26.6
2021	50.1	32.6
2022	59.8	27.0
2023	47.6	23.8

Source: Fertiliser Association of New Zealand and Ballance Agri-Nutrients Limited

Nitrification inhibitor dicyandiamide

The N_2O emissions reported in the *Agricultural soils* category take into account the use of nitrification inhibitors on dairy farms using the methodology described in Clough et al. (2008). Greenhouse gas mitigation estimates from DCD are reported in the Agriculture inventory sector only up until 2012, because sales were suspended that year due to the detection of low levels of DCD residues in milk.

Research has shown that DCD reduces N_2O emissions and nitrate (NO_3–) leaching in pastoral grassland systems grazed by ruminant animals. The Agriculture inventory model methodology incorporates DCD use by modifying the emission factors $EF_{3(PRP)}$ and the parameter $Frac_{LEACH}$ (see table 5.5.5). These were modified based on comprehensive field-based research that showed significant reductions in direct and indirect N_2O emissions and NO_3– leaching where the DCD was applied. It was determined that, on a national basis, reductions in $EF_{3(PRP)}$ and $Frac_{LEACH}$ of 67 per cent and 53 per cent respectively could be made (Clough et al., 2008).

Limited research has been conducted concerning the effect of DCD on dung ($EF_{3(PRP\text{-}DUNG)}$); however, this research was inconclusive and further work needs to be carried out before incorporating the impact of dung emissions into the Agriculture inventory model. Application of this inhibitor was found to have no effect on NH_3 volatilisation, which is supported by the results of field studies (Clough et al., 2008; Sherlock et al., 2008). Therefore, the parameter for volatilisation remains unchanged.

The DCD weighting factors are calculated based on reductions in emission factors and parameters, and the fraction of dairy land treated with the inhibitor, as follows:

$$DCD\ weighting\ factor = \left(1 - \frac{\%\ reduction\ in\ EF_x}{100} \cdot \frac{DCD\ area\ treated}{Total\ area\ of\ dairy\ land}\right)$$

The appropriate weighting factor is then used as an additional multiplier in the current methodology for calculating indirect and direct emissions of N_2O from grazed pastures, in effect creating a modified $EF_{3(PRP)}$ and $Frac_{LEACH}$ for the dairy grazing area in the months that the inhibitor is applied and is effective (May to September). The modified emission factors (see table 5.5.10) are based on information from the Stats NZ Agricultural Production Survey that 2.9 per cent of the effective dairy land area in New Zealand received DCD in 2012. The inhibitor was applied to pastures as either a slurry or DCD-coated granule to maximise N_2O emission reductions. Mitigation estimates for the calendar years 2007 to 2012 are shown in table 5.5.10.

Table 5.5.10 Emission factors, parameters and mitigation for New Zealand's dicyandiamide inhibitor calculations, from 2007 to 2012

	2007	2008	2009	2010	2011	2012
Percentage of dairy area applied with inhibitor	3.5	4.5	3.1	2.2	3.0	2.9
Final modified emission factor or parameter for dairy cattle, $EF_{3(PRP)}$ (kg N_2O-N/kg N)	0.00970	0.00968	0.00972	0.00974	0.00972	0.00972
Final modified emission factor or parameter for dairy cattle, $Frac_{LEACH}$ (kg N_2O-N/kg N)	0.0794	0.0792	0.0795	0.0796	0.0795	0.0795
Mitigation (kt CO_2-e)	15.8	21.4	15.3	11.6	16.3	16.4

Note: $EF_{3(PRP)}$ = 0.0098 and $Frac_{LEACH}$ = 0.10 for cropland and 0.08 for grassland when inhibitor is not applied. All other emission factors and parameters relating to animal excreta and fertiliser use ($Frac_{GASM}$, $Frac_{GASF}$, EF_4 and EF_5) remain unchanged when the inhibitor is used as a nitrous oxide mitigation technology.

5.5.3 Uncertainty assessment and time-series consistency

To ensure consistency in the calculations involving animal manure, a single enhanced livestock population characterisation and feed-intake estimate is produced by the Tier 2 model for each of the major livestock categories. This is used in different parts of the calculations to estimate: CH_4 emissions for the *Enteric fermentation* category, CH_4 and N_2O emissions for the *Manure management* category and N_2O emissions for the *Urine and dung deposited by grazing animals (pasture, range and paddock manure)* category.

Uncertainties in N_2O emissions from *Agricultural soils* are calculated using an analytical method developed by Kelliher et al. (2017). This method estimated the uncertainty of the *Agricultural soils* category to be ±55.9 per cent for 2023.

The benefit of using the analytical method is that it can be updated annually by the MPI inventory team. Kelliher et al. (2017) also compared the analytical method with the Monte Carlo method used for previous years and found that both produced similar results.

Uncertainties were assessed for the 1990, 2002 and 2012 inventories using the Monte Carlo method. For the 1990 and 2002 inventories, the uncertainties were assessed using a Monte Carlo simulation of 5,000 scenarios with the @RISK software (Kelliher et al., 2017).

The overall inventory uncertainty analysis shown in annex 2 demonstrates that the uncertainty in annual emissions from *Agricultural soils* is a major contributor to uncertainty in New Zealand's total greenhouse gas emissions. The uncertainty between years is assumed to be correlated, and therefore the uncertainty is mostly associated with the emission factors. The uncertainty associated with the trend in emissions from *Agricultural soils* is much lower than the uncertainty for an annual estimate.

The uncertainty in emissions from *Agricultural soils* is largely due to the parameter $EF_{3(PRP)}$ and emissions from urine and dung deposited by grazing animals. This uncertainty reflects natural variance in EF_3 due to weather, climate and soil type (Kelliher et al., 2017).

5.5.4 Category-specific QA/QC and verification

In preparation for this inventory submission, the data underwent Tier 1 and Tier 2 quality checks.

Verification of activity data

Research has been carried out to verify the activity data for crops. In 2008 and 2011, MPI commissioned reports investigating N_2O emission factors and activity data for crops (Thomas et al., 2008, 2011). The reports compared activity data from the Stats NZ Agricultural Production Survey with the Foundation for Arable Research production database. Data for wheat and maize between the two data sources were very similar, although differences were evident for some of the other crops.

The accuracy of synthetic nitrogen fertiliser data has also been assessed by comparing fertiliser sales data received from the Fertiliser Association of New Zealand with data collected from the Agricultural Production Survey.

The Fertiliser Association sales data are used rather than the Stats NZ Agricultural Production Survey data because the sales data are considered to be more comprehensive and accurate. Nearly 98 per cent of New Zealand synthetic nitrogen fertiliser is sold by two large companies that provide sales data to the Fertiliser Association (Fertiliser Association of New Zealand, 2024). The Fertiliser Association provides an estimate of the additional synthetic nitrogen fertiliser sold by other companies (around 2 per cent). In contrast, the Agricultural Production Survey data are collected from a sampling frame of around 49,300 individual farms. Some farmers use contract fertiliser spreading companies (including aerial spreading) and may not have an accurate estimate of the tonnes of fertiliser applied or are unsure on how to fill in the questionnaire accurately, given the number of different fertilisers used and their varying names. The Agricultural Production Census and Agricultural Production Survey data verified the long-term trend of the increasing use of synthetic nitrogen fertiliser.

Comparison of New Zealand emission factors and parameters with IPCC default values

Table 5.5.11 compares New Zealand's IEFs for EF_1 (synthetic nitrogen fertiliser) and $EF_{3(PRP)}$ (urine and dung deposited by grazing animals) with the 2006 IPCC default values and emission factors used by Australia. The New Zealand EF_1 value is lower than the IPCC default due to the use of a country-specific emission factor for urea fertiliser and incorporation of the effect of urease inhibitors. For EF_3, the New Zealand value is also lower than the IPCC default. This reflects research that has allowed for the development of country-specific emission factors for dung and urine from trials summarised by van der Weerden et al. (2019) (see section 5.5.2).

Table 5.5.11 Comparison of New Zealand's implied emission factors (IEFs) for EF_1 (synthetic nitrogen fertiliser) and $EF_{3(PRP)}$ (pasture, range and paddock manure) with the IPCC default and the Australian-specific value

	EF_1 (kg N_2O-N/kg N)	EF_3 (kg N_2O-N/kg N excreted)
IPCC (2006) developed temperate climate/Oceania default value	0.01	0.02 (cattle, poultry and pigs) 0.01 (sheep and other animals)
Australian-specific IEF 2022 value	0.0059/0.0018[1]	0.0040
New Zealand-specific IEF 2023 value	0.0071	0.0053

Source: UNFCCC (https://unfccc.int/documents/637882)

Note: [1] Irrigated and non-irrigated pasture respectively.

Table 5.5.12 compares the New Zealand-specific values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH-H}$ with the 2006 IPCC default and fractions used by Australia. New Zealand has taken a country-specific value for $Frac_{GASF}$ of 0.1, and it is the same as the 2006 IPCC default and almost identical to that of Australia (0.11). Research showed that the 0.1 value was appropriate for New Zealand conditions (Sherlock et al., 2008).

This research also showed that the previously used 2006 IPCC default value of 0.2 for $Frac_{GASM}$ was too high and a lower value of 0.1 was adopted after an extensive review of scientific literature (Sherlock et al., 2008), which was also confirmed by subsequent field experiments (Laubach et al., 2012). The reduction in $Frac_{GASM}$ is due to the proportion of the different sources that make up this value. In New Zealand, over 95 per cent of animal excreta is deposited onto pasture and only a small proportion is managed in waste management systems. In contrast, the 2006 IPCC default value was calculated based on systems where a much higher percentage of manure management and storage is normal. Manure management and storage results in a much higher proportion of nitrogen being volatilised and, hence, the higher $Frac_{GASM}$ for the default value compared with the country-specific New Zealand value.

New Zealand also has much lower values of $Frac_{LEACH-H}$. Research suggests that New Zealand applies a much lower rate of nitrogen fertiliser at each application than was assumed when the IPCC default value was developed (Thomas et al., 2005). When the OverseerFM nutrient budget model (Wheeler et al., 2003) took this lower rate into account, the extent of leaching was much lower than when compared with farms with greater nitrogen fertiliser rates, which can be typical in other developed countries.

Table 5.5.12 Comparison of New Zealand's country-specific factors for volatilisation ($Frac_{GASF}$, $Frac_{GASM}$) and leaching and runoff ($Frac_{LEACH-(H)}$) with the IPCC default value and the Australian implied emission factor (IEF)

	$Frac_{GASF}$ (kg NH_3-N and NO_x-N/kg of N input)	$Frac_{GASM}$ (kg NH_3-N and NO_x-N/kg of N excreted)	$Frac_{LEACH-(H)}$ (kg N/kg fertiliser or manure N)
IPCC (2006) default value	0.1	0.2	0.3
Australian-specific 2022 value	0.11	0.21	0.24
New Zealand-specific IEF 2023 value	0.1	0.1	0.10 (Cropland) 0.08 (Grassland) 0.082 (N Fert)

Source: UNFCCC (https://unfccc.int/documents/637882)

5.5.5 Category-specific recalculations

Emissions estimates in the *Agricultural soils* category reported in the 2025 submission have been affected by methodological improvements to: (i) inclusion of emissions from non-manure organic soil amendments; (ii) minor species population value changes; (iii) updating deer population and productivity statistics; (iv) updating emissions calculations for pigs; (v) seasonality of wool growth; and (vi) small error corrections to model code. The effects of these changes on emission estimates in the Agricultural soils category are set out below.

Emissions from non-manure organic amendments to soils

Emissions estimates in Agricultural soils have been improved by the inclusion of emissions from non-manure organic amendments to soil.

In 2014, research into non-manure organic fertiliser inputs estimated emissions from this source for 2013 were 0.07 kt N_2O, or 20.0 kt CO_2-e. This represented 0.052 per cent of New Zealand's total agricultural greenhouse gas emissions, or 0.024 per cent of national total greenhouse gas emissions in 2012 (van der Weerden et al., 2014). This is lower than the threshold of 0.05 per cent of national total greenhouse gas emissions (excluding LULUCF) and, as such, is considered an 'insignificant source' by the United Nations Framework Convention on Climate Change for reporting greenhouse gas emissions. New Zealand did not previously include activity data for these non-manure organic sources in national inventory reporting and reported these as 'NE' or 'not estimated'.

Recent research carried out by AgResearch (van der Weerden & Rutherford, 2024) has used industry data to estimate the quantities of organic nitrogen amendments applied to agricultural land. Industry data was sourced from sheep, cattle meat and dairy processing companies, commercial compost producers and retailers, commercial blood and bone producers and retailers, vegetable processing companies, wine producers and brewery companies.

The 2019 refinement of the 2006 IPCC guidelines (IPCC, 2019) retained the default value of 1 per cent for nitrogen additions to agricultural soils. However, the refinement also provides additional emission factor values disaggregated by nitrogen type and climate, where climate is disaggregated into wet and dry. New Zealand falls into this 'wet climate' category, according to the IPCC definition (IPCC, 2019, table 11.1 and figure 3A.5.1).

The emissions from non-manure organic amendments to soil are calculated using the 2019 IPCC disaggregated EF_1 of 0.006, to ensure calculations are employing the latest scientific knowledge. This provides a more appropriate value for organic nitrogen amendments to soils in wet climates rather than remaining with the aggregated value of 1 per cent that is applied to all nitrogen inputs, from synthetic fertiliser to compost, across all climatic zones.

Implementing these changes caused emissions from the Agricultural soils category to increase by 2.1 kt CO_2-e in 1990 and 12.4 kt CO_2-e in 2022 (see table 5.5.13).

Table 5.5.13 Comparison of emissions from *Agricultural soils* before and after the inclusion of emissions from non-manure organic amendments to soil

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agricultural soils*	2024 (1990–2022) emissions estimate	4,669.0	6,322.5	1,653.5	35.4
	2024 (1990–2022) emissions estimate *with improvement*	4,671.1	6,334.9	1,663.8	35.6
	Difference in emissions estimates	2.1	12.4		
	Percentage difference in emissions estimates (%)	0.0	0.2		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Minor species population value changes

The changes to minor species values caused emissions from the Agricultural soils category to increase by 0.2 kt CO_2-e in 1990 and 0.1 kt CO_2-e in 2022 (see table 5.5.14). For more detail on these changes, see section 5.2.5.

Table 5.5.14 Comparison of the previous minor species populations and the updated minor species populations for emissions from *Agricultural soils*

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agricultural soils*	2024 (1990–2022) emissions estimate	4,669.0	6,322.5	1,653.5	35.4
	2024 (1990–2022) emissions estimate *with improvement*	4,669.2	6,322.6	1,653.4	35.4
	Difference in emissions estimates	0.2	0.1		
	Percentage difference in emissions estimates (%)	0.0	0.0		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Updating deer population and productivity statistics

The updates to deer population and productivity statistics caused emissions from the Agricultural soils category to decrease by 1.2 kt CO_2-e in 1990 and 5.2 kt CO_2-e in 2022 (see table 5.5.15). For more detail on these changes, see section 5.2.5.

Table 5.5.15 Comparison of emissions from *Agricultural soils* using the updated deer population and productivity statistics

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agricultural soils*	2024 (1990–2022) emissions estimate	4,669.0	6,322.5	1,653.5	35.4
	2024 (1990–2022) emissions estimate *with improvement*	4,667.8	6,317.3	1,649.5	35.3
	Difference in emissions estimates	-1.2	-5.2		
	Percentage difference in emissions estimates (%)	-0.0	-0.1		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Updating emissions calculations for pigs

The updates to emissions calculations for pigs caused emissions from the Agricultural soils category to decrease by 3.6 kt CO_2-e in 1990 and 3.0 kt CO_2-e in 2022 (see table 5.5.16). For more detail on these changes, see section 5.2.5 and section 5.3.5.

Table 5.5.16 Comparison of emissions from *Agricultural soils* using the updated pig calculations

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agricultural soils*	2024 (1990–2022) emissions estimate	4,669.0	6,322.5	1,653.5	35.4
	2024 (1990–2022) emissions estimate *with improvement*	4,665.4	6,319.5	1,654.2	35.5
	Difference in emissions estimates	-3.6	-3.0		
	Percentage difference in emissions estimates (%)	-0.1	-0.1		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Seasonality of wool growth

The updates to monthly wool calculations caused emissions from the Agricultural soils category to decrease by 17.8 kt CO_2-e in 1990 and 15.5 kt CO_2-e in 2022 (see table 5.5.17). For more detail on these changes, see section 5.2.5.

Table 5.5.17 Comparison of emissions from *Agricultural soils* using the updated monthly wool calculations

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agricultural soils*	2024 (1990–2022) emissions estimate	4,669.0	6,322.5	1,653.5	35.4
	2024 (1990–2022) emissions estimate *with improvement*	4,651.2	6,307.0	1,655.8	35.6
	Difference in emissions estimates	-17.8	-15.5		
	Percentage difference in emissions estimates (%)	-0.4	-0.3		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

Corrections to inventory model

The corrections to the inventory model caused emissions from the Agricultural soils category to increase by 6.6 kt CO_2-e in 1990 and 32.1 kt CO_2-e in 2022 (see table 5.5.18). For more detail on these changes, see section 5.2.5.

Table 5.5.18 Comparison of model results with and without corrections for emissions from *Agricultural soils*

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agricultural soils*	2024 (1990–2022) emissions estimate	4,669.0	6,322.5	1,653.5	35.4
	2024 (1990–2022) emissions estimate *with improvement*	4,675.6	6,354.6	1,679.0	35.9
	Difference in emissions estimates	6.6	32.1		
	Percentage difference in emissions estimates (%)	0.1	0.5		

Note: Columns may not sum due to rounding. Percentages presented are calculated from unrounded values.

5.5.6 Category-specific planned improvements

New Zealand is carrying out ongoing research to improve estimates of N_2O emissions from the *Agricultural soils* category. The projects described below outline research focused specifically on the *Agricultural soils* component of the Agriculture inventory sector. Several cross-cutting, broader projects that will improve the accuracy of emissions in multiple categories (including *Enteric fermentation*, *Manure management* and *Agricultural soils*) are described in section 5.1.7.

Nitrous oxide emissions from nitrogen fertilisers

This research project will investigate whether more disaggregated emission factors for different types of nitrogen fertilisers are needed. The Agriculture inventory model estimates direct N_2O emissions from the application of synthetic nitrogen fertiliser, and currently has separate emission factor (EF_1) values for urea and non-urea fertiliser. The field trials were completed in 2024, with the results to be added to a wider meta-analysis (including Irish research partners) before any recommendations are made.

Measurements of nitrous oxide emissions in spring and summer to develop EF_3 values that vary by season

The database used to produce country-specific N_2O EF_3 values is currently unbalanced by season, with summer data representing only 11 per cent of the dataset and spring data also being partially under-represented. A series of summer and spring-based N_2O EF_3 field studies across New Zealand will be conducted, with key soil and climate data also being reported on. This research will expand on the collection of the existing set of soil and climate data, to provide for future development of Tier 3 emission factors via process-based modelling of the dataset.

Improving organic soil activity data

This project will build on recently completed work assessing what is required for New Zealand to implement the 2013 IPCC Wetland Supplement into the inventory (IPCC, 2014). The 2006 IPCC Guidelines (IPCC, 2006) are still used to estimate greenhouse gas emissions from managed organic soils, however, improved activity data and national emission factors are required to improve the accuracy of emissions accounting and reduce associated uncertainties.

Developing a process-based nitrous oxide emissions model

This research will investigate the potential of a process-based N_2O emissions model suitable for inventory compilation. Process-based models require more inputs (e.g., weather, soil) than the existing Tier 2 methods. Such models are also likely to have a differing sensitivity to activity data than Tier 2 methods. This project will undertake a systematic and comprehensive analysis of the needs for any process-based model, and the implications (benefits and challenges, quantitatively where possible) for implementing a process-based model.

5.6 Prescribed burning of savanna (3.E)

5.6.1 Category description

Prescribed burning of savanna is reported under the LULUCF sector from the 2016 submission onwards.

5.7 Field burning of agricultural residues (3.F)

5.7.1 Category description

Field burning of agricultural residues contributed an estimated 17.9 kt CO_2-e in 2023, which accounted for 0.04 per cent of Agriculture sector emissions. Emissions from *Field burning of agricultural residues* decreased 39.3 per cent (11.6 kt CO_2-e) between 1990 and 2023.

New Zealand reports emissions from burning barley, wheat and oats residue in this category. Maize, legume and other crop residues are not routinely burned in New Zealand.

The area of burning of residues varies between years due to climatic conditions, fire risk restrictions and the amount of residue removed before burning straw (Thomas et al., 2011). Burning of crop residues is not considered to be a net source of CO_2, because the CO_2 released into the atmosphere was absorbed by those crops earlier in the year. However, burning is a source of emissions of CH_4, carbon monoxide (CO), N_2O and NO_x (IPCC, 2006).

Field burning of agricultural residues was not identified as a key category in 2023.

5.7.2 Methodological issues

The emissions from burning agricultural residues are estimated using country-specific methodology and parameters (Thomas et al., 2008, 2011). A modification of the IPCC (1996) methodology considers differences in the available crop activity data from 1990 to 2004 compared with 2005 to 2023.

The parameters used in both estimates of emissions from crop residues and crop burning take the same country-specific values in both parts of the model. This provides consistency between the two emissions estimates for crop residue and crop burning.

Following the IPCC (1996) methodology, CH_4, CO, N_2O and NO_x emissions are calculated from the carbon and nitrogen released from the burned live and dead biomass residue using the ratios in table 5.7.1. The nitrogen released is derived from the carbon released using a carbon to-nitrogen ratio. The Agriculture inventory model also assumes that farmers generally aim to have as close to complete combustion as possible.

Table 5.7.1 Emission ratios for agricultural residue burning

Gas	Emission ratio (Revised IPCC 1996 Guidelines)	Conversion ratio from carbon or nitrogen to specified greenhouse gas (Revised IPCC 1996 Guidelines)
CH_4	0.005	16/12
CO	0.06	28/12
N_2O	0.007	44/28
NO_x	0.121	46/14

The total emissions (CH_4, CO, N_2O and NO_x) are calculated as shown below:

$$Emissions_{BURN} = AG_{BURN} \cdot Frac_{OX} \cdot ER \cdot GCR$$

Where: AG_{BURN} is the above-ground biomass burned (kt)

$Frac_{OX}$ is the fraction oxidised (see table 5.7.2)

ER is the gas-specific emission ratio, and

GCR is the gas-conversion ratio (see table 5.7.1).

The calculation for AG_{BURN} is different for 1990 to 2004 and 2005 to 2023, to account for changes in the availability of activity data over these periods. Stats NZ did not collect data on crop residue burning before 2005. Therefore, from 1990 to 2004, calculation of the amount of biomass residue burned (AG_{BURN}) was based on the total mass of crop production (from the Stats NZ Agricultural Production Census and Agricultural Production Survey) and assumed fractions burned for each crop, where:

$$AG_{BURN} = AG_{DM} \cdot Frac_{AREA-BURN} \cdot Frac_{RESIDUE} \cdot Frac_{BURN} \cdot 10^{-3}$$

Where: AG_{DM} is the above-ground residue (defined below)

$Frac_{AREA-BURN}$ is the proportion of crop area burned of the total production area (discussed further below)

$Frac_{RESIDUE}$ is the proportion of residue remaining after harvest (see table 5.7.2), and

$Frac_{BURN}$ is the proportion of remaining residue burned (see table 5.7.2).

The above-ground residue, AG_{DM} (tonnes), is:

$$AG_{DM} = \frac{Prod_{DM}}{HI} - Prod_{DM}$$

Where: HI is the harvest index (crop-specific, table 5.7.2), that is, the mass harvested over the total mass of above-ground biomass.

The dry matter, $Prod_{DM}$ (tonnes), available to be burned is:

$$Prod_{DM} = Crop_{PROD} \cdot Frac_{DM}$$

Where: $Crop_{PROD}$ is the annual crop production (tonnes) (Stats NZ Agricultural Production Census and Agricultural Production Survey), and

$Frac_{DM}$ is the fraction of crop that is dry matter (crop specific, table 5.7.2).

Table 5.7.2 Values used to calculate New Zealand emissions from burning of agricultural residues

	Barley	Wheat	Oats
Fraction oxidised	0.9	0.9	0.9
Residue remaining in field	1	1	1
Fraction of residue actually burned	0.7	0.7	0.7
Harvest index	0.46	0.41	0.30
Dry-matter fraction	0.86	0.86	0.86
Fraction of nitrogen in biomass	0.005	0.005	0.005
Fraction of carbon in biomass	0.4567	0.4853	0.4567

Source: Thomas et al. (2011)

From 2005 to 2023, calculation of the amount of biomass residue burned was based on information about the area of crop residue burning from the Stats NZ Agricultural Production Census and Agricultural Production Surveys.

Biomass burned from 2005, AG_{BURN} (as previously defined), is:

$$AG_{BURN} = AG_{DM} \cdot Frac_{RESIDUE} \cdot Frac_{BURN} \cdot 10^{-3}$$

Where: AG_{DM} is the amount of above-ground residue (tonnes)

$Frac_{RESIDUE}$ is the proportion of residue remaining after harvest (see table 5.7.2), and

$Frac_{BURN}$ is the proportion of remaining residue burned.

The above-ground residue, AG_{DM} (tonnes), is:

$$AG_{DM} = \frac{Prod_{DM}}{HI} - Prod_{DM}$$

Where: HI is the harvest index (crop specific, table 5.7.2); that is, the mass harvested over the total mass of above-ground biomass, and

$Prod_{DM}$ (measured in tonnes) is the dry matter production of the area burned and is determined as follows:

$$Prod_{DM} = Area_{BURN} \cdot Y \cdot Frac_{DM}$$

Where: $Area_{BURN}$ is the annual area burned (hectare)

Y is the average crop yield (tonnes per hectare), and

$Frac_{DM}$ is the fraction of crop that is dry matter (crop specific, table 5.7.2).

The country-specific parameters for the proportion of residue burned, harvest indices, dry-matter fractions, the fraction oxidised and the carbon and nitrogen fractions of the residue (see table 5.7.2) are derived from the OverseerFM nutrient budget model for New Zealand (Wheeler et al., 2003). These parameters are the same as those used for estimates of emissions from crop residues (see section 5.5.2). Further detail is provided in Thomas et al. (2011).

The recommended proportion of crop area burned for 1990 to 2004 was determined by a farmer survey and assumed to be 70 per cent of wheat, 50 per cent of barley and 50 per cent of oat crops (Thomas et al., 2011). These values are in alignment with Stats NZ data for 2005 to 2007 (2005 being the first year Stats NZ gathered these data) and are, therefore, applied to the years 1990 to 2004. From 2005, data on the total area of crop residues burned in New Zealand were collected but, while the data show total residue burned at a regional and national level, they do not differentiate between cereal crop types.

For 2005 onwards, the same proportions of crop area burned for wheat (70 per cent), barley (50 per cent) and oats (50 per cent) were used. However, these areas were then multiplied by a constant factor *K* such that the total area burned is consistent with the Stats NZ Agricultural Production Survey. This captures year-to-year variability, such as reduced burning during very dry and very wet years.

$$K = \frac{Total\ Area\ Burnt}{0.7 \times Area\ Burnt_{Wheat} + 0.5 \times Area\ Burnt_{Barley} + 0.5 \times Area\ Burnt_{Oats}}$$

Thomas et al. (2011) sought expert opinion that suggested if crop residue is to be burned, there is generally no prior removal for feed and bedding. Therefore, 100 per cent of residue is left for burning after the harvested proportion has been removed (i.e., $Frac_{REMOVE}$ is assumed to be zero; Thomas et al., 2011). This is consistent with section 5.5.2.

5.7.3 Uncertainty assessment and time-series consistency

The largest contributor to uncertainty in the estimated emissions is the fraction of agricultural residue burned in the field. Expert opinion for the fraction of crops burned in fields between 1990 and 2004 was taken from farmer surveys in the Canterbury area, where 80 per cent of cereal production occurs. Between 2005 and 2009, an average of 86 per cent of total residue burning occurred in Canterbury. Estimates of crop burning for 2020 were 40.6 per cent (calculated as a percentage of total crop area) and have ranged from a high in 2006 of 61.5 per cent to a low in 2015 of 29.3 per cent, reflecting variations in annual weather patterns.

Although country-specific parameters have been developed, a conservative approach to uncertainty is taken, using the IPCC (2000) value of ±20 per cent for the emission factor uncertainty. Given that emissions from field burning are low, compared with emissions from the rest of Agriculture inventory sector, the uncertainties from field burning have little impact on total emission uncertainties.

5.7.4 Category-specific QA/QC and verification

Plant and Food Research reviewed the implementation of the methodology to estimate emissions of N_2O from crop residues, nitrogen-fixing crops and *Field burning of agricultural residues* (Thomas et al., 2008, 2011).

5.7.5 Category-specific recalculations

All activity data were updated with the latest available Stats NZ data.

5.7.6 Category-specific planned improvements

No improvements are currently planned.

5.8 Liming (3.G)

5.8.1 Category description

Emissions from *Liming* (the application of limestone and dolomite) contributed an estimated 273.8 kt CO_2, representing 0.4 per cent of New Zealand's gross emissions and 0.7 per cent of Agriculture emissions in 2023.

In New Zealand, lime and dolomite fertilisers are mainly applied to acidic grassland and cropland soils, to reduce soil acidity and maintain or increase production of pasture and crops. Before the 2015 submission, emissions from lime and dolomite fertilisers were reported under chapter 6, LULUCF.

Liming was identified as a key category for the Agriculture sector in 2023 (level assessment).

Emissions from *Liming* decreased 7.7 per cent (22.7 kt CO_2) between 1990 and 2023.

5.8.2 Methodological issues

Data on the tonnage of agricultural lime (limestone and dolomite) application are collected by Stats NZ, as a part of its five-yearly Agricultural Production Census and annual Agricultural Production Survey in the intervening years. Analysis of the data indicates that, each year, around 90 per cent of agricultural lime used in New Zealand is applied to grassland, with the remaining 10 per cent applied to cropland.

New Zealand has not yet developed a country-specific methodology for calculating CO_2 emissions from the application of limestone and dolomite. Emissions from *Liming* are currently estimated by following the Tier 1 methodology (equation 11.12; IPCC, 2006), using default emission factors for carbon conversion of 0.12 and 0.13 for limestone and dolomite respectively.

5.8.3 Activity data

Limestone is more commonly applied than dolomite in New Zealand. Limestone is extracted widely in New Zealand whereas dolomite is only available from a small, localised source. Activity data sourced from the Stats NZ Agricultural Production Census show that limestone application has declined since 2002, while dolomite use peaked in 2010 and has since fallen. The quantity of lime applied as limestone and dolomite varies each year and is influenced by several factors, including farm profitability (see figure 5.8.1 and figure 5.8.2). A correction factor of 0.82 is applied to the gross weight (tonnes) of lime use reported by Stats NZ. This correction factor is specified using research from Thomson et al. (2021) and accounts for impurities in the agricultural lime applied, as well the moisture content, so that emissions are based on the dry weight of calcium carbonate applied.

Figure 5.8.1 Limestone usage on agricultural land in New Zealand, from 1990 to 2023

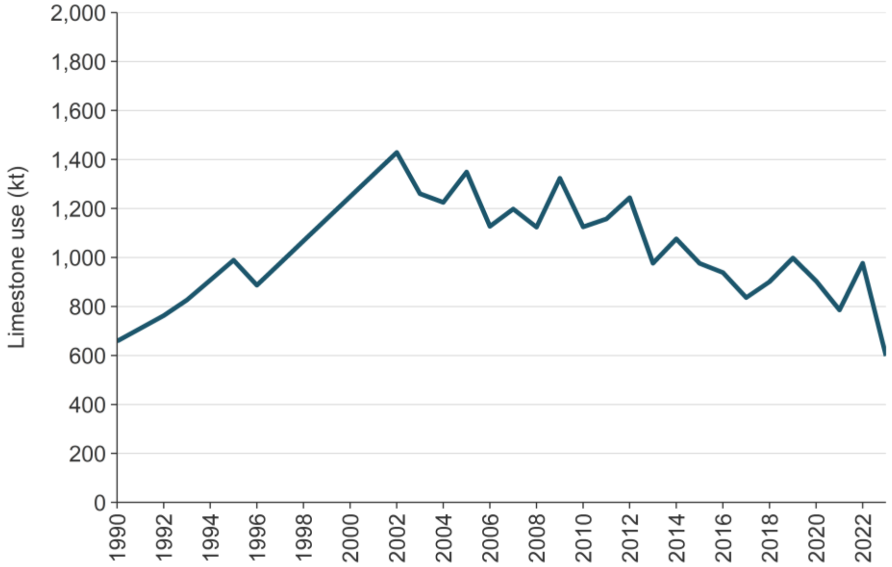
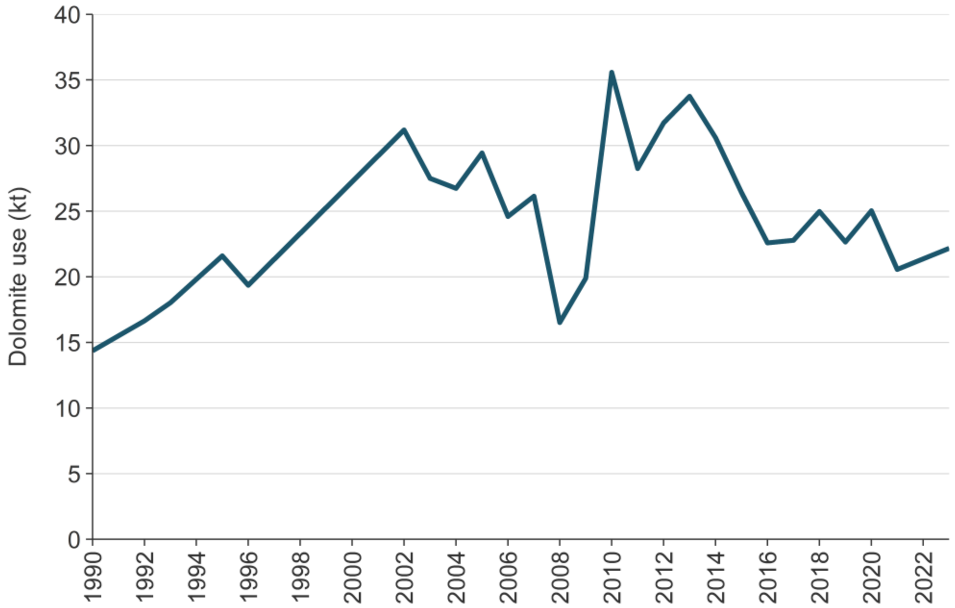


Figure 5.8.2 Dolomite usage on agricultural land in New Zealand, from 1990 to 2023



5.8.4 Uncertainty assessment and time-series consistency

Using the IPCC (2006) Tier 1 methodology, default emission factors are used, which are based on the chemical formula of lime and assume all carbon in lime is emitted as CO_2 into the atmosphere. However, the 2006 IPCC Guidelines state that the maximum available carbon is not necessarily lost and that the emissions could be up to 50 per cent lower than estimated (IPCC, 2006). The uncertainty applied is the IPCC default -50 per cent (IPCC, 2006). The uncertainty cannot exceed the emission factors because these value represent the absolute maximum emissions associated with liming.

The Agricultural Production Census and Agricultural Production Survey data used in the Agriculture inventory model have gaps in the time series: no data are available for 1991 or between 1997 and 2001. In the absence of other supporting data, linear interpolation has been used to estimate the data for these years.

5.8.5 Category-specific QA/QC and verification

In the preparation of this inventory, the data for *Liming* underwent Tier 1 quality checks. Stats NZ, the agency that collects the activity data for *Liming*, also carries out a series of quality-assurance and quality-control procedures as part of the data collection carried out each year.

5.8.6 Category-specific recalculations

No recalculations have been performed for CO_2 emissions from *Liming* in the 2025 (1990 to 2023) submission.

5.8.7 Category-specific planned improvements

In the 2024 round of the Greenhouse Gas Inventory Research Fund research into developing a New Zealand specific Tier 2 emission factor for emissions arising from liming was set as a new research priority (see the Greenhouse Gas Inventory Research Fund 2024 /25 Priorities).

5.9 Urea application (3.H)

5.9.1 Category description

Urea fertiliser accounts for the majority of synthetic nitrogen fertiliser used in New Zealand. It is mainly applied to dairy pastureland to boost pasture growth during the autumn and spring months (see figure 5.5.3).

Urea application was identified as a key category for the Agriculture sector in 2023 (level and trend assessment).

Urea application contributed an estimated 425.7 kt CO_2, representing 0.6 per cent of New Zealand's gross emissions and 1.0 per cent of Agriculture emissions in 2023. Compared with the average emissions for 2017 to 2021, this is a decrease of nearly 25.6 per cent in 2023, due to lower urea application because of higher nitrogen fertiliser prices and lower farming profitability.

Emissions from *Urea application* increased 986.0 per cent between 1990 and 2023. Since 1990, the proportion of urea fertiliser applied (relative to total synthetic nitrogen fertiliser use) increased from around 41.5 per cent in 1990 to a high of 91.7 per cent in 2007. In 2023 urea was 71.0 per cent of all synthetic nitrogen fertiliser applied (see figure 5.5.3).

5.9.2 Methodological issues

There is no country-specific methodology on CO_2 emissions from *Urea application* for New Zealand. Emissions associated with the application of urea are estimated using a Tier 1 methodology (equation 11.13; IPCC, 2006), using the default emission factor for carbon conversion of 0.20.

Research into urease inhibitors (see section 5.5.2) has demonstrated they are effective in slowing down the activity of the urease enzyme that hydrolyses urea to ammonium (as reported in section 5.5.2), but urease inhibitors do not reduce the release of CO_2 (S Saggar, pers. comm., 2014).

5.9.3 Activity data

Data on the volume of synthetic nitrogen fertiliser used are provided by the Fertiliser Association of New Zealand from fertiliser company sales records from 1990 to 2023. From 1990 to 2013, data on the percentage of synthetic nitrogen fertiliser derived from urea were sourced from the International Fertilizer Industry Association online database and were used to calculate the amount of applied urea fertiliser. Since 2014, data for total nitrogen from synthetic nitrogen fertiliser derived from urea have been provided by the Fertiliser Association of New Zealand.

A large increase has occurred in nitrogen applied to agricultural land as urea fertiliser, from 24,586 tonnes nitrogen in 1990 to 267,000 tonnes in 2023. This is a larger increase than the increase in the total amount of synthetic nitrogen fertiliser applied, which is 6.3 times the amount used in 1990. In more recent years, urea fertiliser use has generally trended downwards, having peaked at 381,527 tonnes of nitrogen in 2015 (see reporting on the *Agricultural soils* category, and figure 5.5.2 and figure 5.5.3).

5.9.4 Uncertainty assessment and time-series consistency

Under the IPCC (2006) Tier 1 methodology, default emission factors are used, which are based on the chemical formula of urea and assume all carbon in urea is emitted as CO_2 into the atmosphere. However, the 2006 IPCC Guidelines state that the maximum available carbon is not necessarily lost and that the emissions could be up to 50 per cent lower (IPCC, 2006). This gives a lower uncertainty estimate of -50 per cent and an upper uncertainty estimate of 0 per cent.

Sales data for synthetic nitrogen fertiliser have been supplied for all years by the Fertiliser Association of New Zealand, but the uncertainties in this data are not known.

5.9.5 Category-specific QA/QC and verification

In the preparation of this inventory, the data for urea fertiliser underwent Tier 1 quality checks. The Fertiliser Association of New Zealand, the organisation that collects the sales activity information for synthetic nitrogen fertiliser, also carries out a series of quality-assurance and quality-control procedures as a part of the data collection carried out each year and provides this data to the International Fertilizer Industry Association.

5.9.6 Category-specific recalculations

No recalculations have been performed for CO_2 emissions from urea in the 2025 (1990 to 2023) submission.

5.9.7 Category-specific planned improvements

New Zealand will continue to update activity data on urea as the data become available from the Fertiliser Association of New Zealand and that are able to be cross referenced with data collected in the annual Stats NZ Agricultural Production Survey.

5.10 Other carbon-containing fertilisers (3.I)

5.10.1 Category description

Other carbon-containing synthetic fertilisers besides limestone, dolomite and urea (see sections 5.8 and 5.9) are not applied to agricultural land in New Zealand (T van der Weerden and C de Klein, pers. comm., 2015).

Chapter 5: References

Some references may be downloaded directly from: mpi.govt.nz/news-and-resources/statistics-and-forecasting/greenhouse-gas-reporting/agriculture-greenhouse-gas-inventory-reports.

MPI is progressively making reports used for compiling the Agriculture inventory sector available on this page, where copyright permits.

Australian Government. Unpublished. Mutual Review of Components of National Inventory Systems: A Review between Australia and New Zealand. Provided by the Australian Government in 2014.

Australian Government. 2024. *2024 Common Reporting Table (CRT)*. Retrieved 4 November 2024.

Beare M, Thomas S, Clemens G, Hernandez-Ramirez G. 2012. *Contributions of Pasture Renewal and N Mineralisation to N_2O Emissions from Pastoral Farming Systems*. Report prepared for the Ministry for Primary Industries by Plant and Food Research. Wellington: Ministry for Primary Industries.

Beef + Lamb New Zealand Ltd. 2024a. *Annual Report 2023*. Wellington: Beef + Lamb New Zealand Ltd.

Beef + Lamb New Zealand Ltd. 2024b. *New Season Outlook 2024–25*. Wellington: Beef + Lamb New Zealand Ltd.

Bown MD, Thomson BC, Muir PD. 2013. *Evaluation of the Values for Pasture ME and N Content used in the National Greenhouse Gas Inventory*. Report prepared for the Ministry for Primary Industries by On-Farm Research. Wellington: Ministry for Primary Industries.

Burggraaf V, Benson C, Rollo M. 2022. *Dairy cattle population model: Improving estimates of within-year population changes used in the inventory.* Report prepared for the Ministry for Primary Industries. Wellington: Ministry for Primary Industries.

Burggraaf V, Rollo M, de Klein CAM, Lio, J. 2019. *A review of greenhouse gas emissions inventory methodology for farmed goats in New Zealand.* Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

Carran RA, Dewar D, Theobald PW. 2003. *Methane and nitrous oxide emissions from sheep dung*. Report prepared for the Ministry of Agriculture and Forestry by the New Zealand Pastoral Agricultural Research Institute. Wellington: Ministry for Primary Industries.

Carran RA, Theobald PW, Evans JP. 1995. Emissions of nitrous oxide from some grazed pasture soils in New Zealand. *Australian Journal of Soil Research* 33: 341–352.

Chen D, Li Y, Kelly K, Eckard R. 2010. *Simulation of N_2O emissions from an irrigated dairy pasture treated with urea and urine in Southeastern Australia*. Agriculture, Ecosystems & Environment 136(3–4): 333–342.

Cichota R, Brown H, Snow VO, Wheeler DM, Hedderley D, Zyskowski R, Thomas S. 2010. A nitrogen balance model for environmental accountability in cropping systems. *New Zealand Journal of Crop and Horticultural Science* 38: 189–207.

Clark H, Brookes I, Walcroft A. 2003. *Enteric Methane Emissions from New Zealand Ruminants 1990–2001 Calculated Using an IPCC Tier 2 Approach*. Report prepared for the Ministry of Agriculture and Forestry by AgResearch and Massey University. Wellington: Ministry of Agriculture and Forestry.

Clark H. 2008a. *A Comparison of Greenhouse Gas Emissions from the New Zealand Dairy Sector Calculated Using either a National or a Regional Approach*. Report prepared for the Ministry of Agriculture and Forestry by AgResearch. Wellington: Ministry of Agriculture and Forestry.

Clark H. 2008b. *Guidelines to Accompany Computerised Inventory*. Report prepared for the Ministry of Agriculture and Forestry by AgResearch. Wellington: Ministry of Agriculture and Forestry.

Clough TJ, Kelliher FM, Clark H, van der Weerden TJ. 2008. *Incorporation of the Nitrification Inhibitor DCD into New Zealand's 2009 National Inventory*. Report prepared for the Ministry of Agriculture and Forestry by Lincoln University and AgResearch. Wellington: Ministry of Agriculture and Forestry.

Clough TJ, Kelliher FM. 2014. *Literature Review of EF5.* Report prepared for the Ministry for Primary Industries by Lincoln University. Wellington: Ministry for Primary Industries.

Clough T, Cameron K, Hong D. Unpublished. The Case for Including EcoPond Generation#2 in the New Zealand Greenhouse Gas Inventory as a Methane Mitigation Tool for Dairy Cattle Manure Management. Report prepared for the Ministry for Primary Industries by Lincoln University in 2024.

CSIRO. 1990. *Ruminants: Feeding Standards for Australian Livestock*. Victoria, Australia: Commonwealth Scientific and Industrial Research Organisation.

CSIRO. 2007. *Nutrient Requirements of Domesticated Ruminants*. Victoria, Australia: Australian Agricultural Council, Ruminants Sub Committee

Dairy Companies Association of New Zealand. 2024. *Latest New Zealand Milk Production Data Report*. Retrieved from dcanz.com (13 December 2024).

DataGene Limited. 2023. *Australian Dairy Herd Improvement Report 2023*. Melbourne: DataGene Limited.

de Klein CAM, Barton L, Sherlock RR, Li Z, Littlejohn RP. 2003. Estimating a nitrous oxide emission factor for animal urine from some New Zealand pastoral soils. *Australian Journal of Soil Research* 41: 381–399.

de Klein CAM, Luo J, Woodward KB, Styles T, Wise B, Lindsey S, Cox N. 2014. The effect of nitrogen concentration in synthetic cattle urine on nitrous oxide emissions*. Agriculture Ecosystems & Environment* 188: 8–92.

Dresser M, Hewitt A, Willoughby J, Bellis S. 2011. *Area of Organic Soils*. Report prepared for the Ministry of Agriculture and Forestry by Landcare Research. Wellington: Ministry of Agriculture and Forestry.

Fertiliser Association of New Zealand. 2024. *About*. Retrieved 1 February 2024.

Fick J. 2010. *Emission Estimations for the Commercial Chicken, Non-chicken and Layer Industries within New Zealand*. Report prepared for the Ministry of Agriculture and Forestry by the Poultry Industry Association and Egg Producers Federation of New Zealand. Wellington: Ministry of Agriculture and Forestry.

Fick J, Saggar S, Hill J, Giltrap D. 2011. *Poultry Management in New Zealand: Production, Manure Management and Emissions Estimations for the Commercial Chicken, Turkey, Duck and Layer Industries within New Zealand*. Report prepared for the Ministry of Agriculture and Forestry by Poultry Industry Association, Egg Producers Association, Landcare Research and Massey University. Wellington: Ministry of Agriculture and Forestry.

Galbally I, Meyer C, Bentley S, Weeks I, Leuning R, Kelly K, Phillips F, Barker-Reid F, Gates W, Baigent R, Eckard R, Grace P. 2005. A study of environmental and management drivers of non-CO_2 greenhouse gas emissions in Australian agroecosystems. *Environmental Sciences* 2(2-3): 133–142.

Geddes A, Mikaloff-Fletcher S, Schaefer H, Smale D, Brailsford G, Law R, Ausseil A. 2021. *Atmospheric Methane Modelling: Evaluating Regional Methane Emission Using Inverse Modelling*. MPI Technical Paper No: 2021/02. Report prepared for the Ministry for Primary Industries by NIWA and Landcare Research. Wellington: Ministry for Primary Industries.

Giltrap D, McNeill S, Vickers S. 2016. *Development of Infrastructure to Calculate Agricultural Greenhouse Gas Inventory Emissions Uncertainty In-house*. Report prepared for the Ministry for Primary Industries by Landcare Research and RSV Consulting Ltd. Wellington: Ministry for Primary Industries.

Giltrap D, McNeill S. 2020. *Revised Pasture Quality Analysis in the Agricultural Greenhouse Gas Inventory*. Report prepared for the Ministry for Primary Industries by Manaaki Whenua – Landcare Research. Wellington: Ministry for Primary Industries.

Grainger C, Clarke T, McGinn SM, Auldist MJ, Beauchemin KA, Hannah MC, Waghorn GC, Clark H, Eckard RJ. 2007. Methane emissions from dairy cows measured with sulphur hexafluoride (SF_6) tracer and chamber techniques. *Journal of Dairy Science* 90(6): 2755–2766.

Henderson H, Cameron C. 2010*. Review of the Methodology for Alpaca Population Estimations Used in the National Greenhouse Gas Inventory*. Report prepared for the Ministry for Primary Industries. Wellington: Ministry for Primary Industries.

Hill J. 2012. *Recalculate Pork Industry Emissions Inventory*. Report prepared for the Ministry of Agriculture and Forestry by Massey University and the New Zealand Pork Industry Board. Wellington: Ministry of Agriculture and Forestry.

Hoogendoorn CJ, de Klein CAM, Rutherford AJ, Letica S, Devantier BP. 2008. The effect of increasing rates of nitrogen fertiliser and a nitrification inhibitor on the nitrous oxide emissions from urine patches on sheep grazed hill country pasture. *Australian Journal of Experimental Agriculture* 48(2): 147–151.

Hoogendoorn CJ, Luo J, van der Weerden T, Saggar S, Wise B, Lloyd-West C, Judge A. 2013. *Evaluation of beef cattle excreta nitrous oxide emission factors*. Report prepared for the Ministry for Primary Industries by AgResearch in 2013. Wellington: Ministry for Primary Industries.

IPCC. 1996. Houghton JT, Meira Filho LG, Lim B, Treanton K, Mamaty I, Bonduki Y, Griggs DJ, Callender BA (eds). *IPCC/OECD/IEA. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*. Bracknell: United Kingdom Meteorological Office.

IPCC. 2000. Penman J, Kruger D, Galbally I, Hiraishi T, Nyenzi B, Emmanuel S, Buendia L, Hoppaus R, Martinsen T, Meijer J, Miwa K, Tanabe K (eds). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2006. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use*. IPCC National Greenhouse Gas Inventories Programme. Published for the IPCC by the Institute for Global Environmental Strategies: Japan.

IPCC. 2013. Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

IPCC. 2014. Hiraishi T, Krug T, Tanabe K, Srivastava N, Baasansuren J, Fukuda M, Troxler TG (eds). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. Switzerland: IPCC.

IPCC. 2019. Calvo Buendia E, Tanabe K, Kranjc A, Baasansuren J, Fukuda M, Ngarize S, Osako A, Pyrozhenko Y, Shermanau P, Federici S (eds). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Switzerland: IPCC.

Kelliher FM, Clark H, Smith MH, Lassey KR, Sedcole R. 2009. *Reducing Uncertainty of the Enteric Methane Emissions Inventory*. Report prepared for the Ministry of Agriculture and Forestry by Lincoln University, National Institute of Water and Atmospheric Research and AgResearch. Wellington: Ministry of Agriculture and Forestry.

Kelliher FM, Cox N, van der Weerden TJ, de Klein CAM, Luo J, Cameron KC, Di HJ, Giltrap D, Rys G. 2014. Statistical analysis of nitrous oxide emission factors from pastoral agriculture field trials conducted in New Zealand. *Environmental Pollution* 186: 63–66.

Kelliher FM, de Klein CAM. 2006. *Review of New Zealand's Fertiliser Nitrous Oxide Emission Factor (EF1) Data*. Report prepared for the Ministry for the Environment by Landcare Research and AgResearch. Wellington: Ministry for Primary Industries.

Kelliher FM, Henderson H and Cox N. 2017. The uncertainty of nitrous oxide emissions from grazed grasslands: A New Zealand case study. *Atmospheric Environment* 148: 329–336.

Kuikman PJ, van der Hoek KW, Smit A, Zwart K. 2006. Update of emission factors for nitrous oxide from agricultural soils on the basis of measurements in the Netherlands. *Alterra Report 1217*. Wageningen, The Netherlands: Alterra.

Lassey K. 2011. *Methane Emissions and Nitrogen Excretion Rates for New Zealand Goats*. Report for the Ministry of Agriculture and Forestry, National Institute of Water and Atmospheric Research. Wellington: National Institute of Water and Atmospheric Research.

Lassey KR, Ulyatt MJ, Martin RJ, Walker CF, Shelton ID. 1997. Methane emissions measured directly from grazing livestock in New Zealand. *Atmospheric Environment* 31: 2905–2914.

Laubach J, Grover SPP, Taghizadeh-Toosi A, Sherlock RR, Gibbs J, Kelliher FM. 2012. *Ammonia from Animal Excreta*. Report prepared for the Ministry for Primary Industries by Landcare Research. Wellington: Ministry for Primary Industries.

Laubach J, Kelliher FM. 2004. Measuring methane emission rates of a dairy cow herd by two micrometeorological techniques. *Agricultural and Forest Meteorology* 125: 279–303.

Ledgard SF, Luo J, Sprosen MS, Wyatt J, Balvert S, Lindsey S. 2014. Effects of the nitrification inhibitor dicyandiamide (DCD) on pasture production, nitrous oxide emissions and nitrate leaching in Waikato, New Zealand. *New Zealand Journal of Agricultural Research* 57(4): 294–315.

LIC (Livestock Improvement Corporation Limited) and DairyNZ. 2024. *New Zealand Dairy Statistics 2023–2024*. Hamilton: DairyNZ.

LIC. 2009. *100 Years of Herd Testing*. Hamilton: Livestock Improvement Corporation Limited.

Luo J, Hoogendoorn C, van der Weerden T, Saggar S, de Klein C, Giltrap D. 2016. *Nitrous oxide emission factors for animal excreta deposited on hill country steep slopes*. Report prepared for the Ministry for Primary Industries by AgResearch Ltd. Wellington: Ministry for Primary Industries.

Luo J, Hoogendoorn C, van der Weerden TJ, Saggar S, de Klein CAM, Giltrap D, Rollo M, Rys G. 2013. Nitrous oxide emissions from grazed hill land in New Zealand. *Agriculture Ecosystems & Environment* 181: 58–68.

Luo J, Saggar S, van der Weerden T, de Klein C. 2019a. Quantification of nitrous oxide emissions and emission factors from beef and dairy cattle excreta deposited on grazed pastoral hill lands. *Agriculture, Ecosystems & Environment* 270–271: 103–113.

Luo J, van der Weerden T, Saggar S, de Klein C, Rollo M, Longhurst B. 2019b. *Refining New Zealand's GHG Inventory Methodology: Manure Management*. Prepared for the Ministry for Primary Industries by AgResearch Ltd. Wellington: Ministry for Primary Industries.

Marsden KA, Holmberg JA, Jones DL, Chadwick DR. 2018. Sheep urine patch N_2O emissions are lower from extensively-managed than intensively-managed grasslands. *Agriculture Ecosystems & Environment* 265: 264–274.

MfE (Ministry for the Environment). 2024. *New Zealand's first Biennial Transparency Report under the Paris Agreement*. Wellington: Ministry for the Environment.

MPI (Ministry for Primary Industries). 2024. *Situation and Outlook for Primary Industries June 2024.* Wellington: Ministry for Primary Industries.

Muir PD, Thomson BC, Askin DC. 2008. *A Review of Dressing Out Percentage in New Zealand Livestock*. Report prepared for the Ministry of Agriculture and Forestry by On-Farm Research and Kilu Consulting. Wellington: Ministry of Agriculture and Forestry.

Muir PD, Thomson BC. 2010. *Better Estimation of National Ewe and Beef Cow Liveweights*. Report prepared for the Ministry of Agriculture and Forestry by On-Farm Research. Wellington: Ministry of Agriculture and Forestry.

Muller C, Sherlock RR, Williams PH. 1995. Direct field measurements of nitrous oxide emissions from urine-affected and urine-unaffected pasture in Canterbury. In: *Proceedings of the Workshop on Fertilizer Requirements of Grazed Pasture and Field Crops: Macro and Micronutrients*. Currie LD, Loganathan P (eds). Occasional Report No. 8. Palmerston North: Massey University. pp 243–34.

Pacheco D, Waghorn G, Rollo M. 2018. *Methodology for Splitting Nitrogen between Livestock Dung and Urine*. Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

Pickering A, Gibbs J, Wear S, Fick J, Tomlin H. 2024. *Methodology for Calculation of New Zealand's Agricultural Greenhouse Gas Emissions*. Version 10. Wellington: Ministry for Primary Industries.

Pinares-Patino CS, Ulyatt MJ, Waghorn GC, Lassey KR, Barry TN, Holmes CW, Johnson DE. 2003. Methane emission by alpaca and sheep fed on lucerne hay or grazed on pastures of perennial ryegrass/white clover or birdsfoot trefoil. *Journal of Agricultural Science* 140: 215–226.

Pratt C, Walcroft A, Shilton A, Guieysse B, Chung M, Craggs R, Heubeck S. 2012. *Revised Methane Emission Factors and Parameters for Dairy Effluent Ponds*. Report prepared for the Ministry for Primary Industries by Landcare Research, Massey University and the National Institute of Water and Atmospheric Research. Wellington: Ministry for Primary Industries.

Pronger J, Glover-Clark G, Price R, Campbell D, Schipper L. 2022. *Improving Accounting of Emissions from Drained Organic Soils.* Report prepared for the Ministry for Primary Industries by Manaaki Whenua – Landcare Research. Wellington: Ministry for Primary Industries.

Ritchie H. 2024. *Updating Emissions Calculations for Pigs in the New Zealand Greenhouse Gas Inventory Report*. Report prepared for the Ministry for Primary Industries by NZ Pork. Wellington: Ministry for Primary Industries.

Rollo M, Ledgard S, Longhurst B. 2017. *Final Report: Trends in Dairy Effluent Management*. Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

Saggar S, Clark H, Hedley C, Tate K, Carran A, Cosgrove G. Unpublished. Methane Emissions from Animal Dung and Waste Management Systems, and its Contribution to National Methane Budget. Landcare Research Contract Report: LC0301/02. Prepared for the Ministry of Agriculture and Forestry by Landcare Research in 2003.

Saggar S, Giltrap DL, Davison R, Gibson R, de Klein C, Rollo M, Ettema P, Rys G. 2015. Estimating direct N_2O emissions from sheep, beef, and deer grazed pastures in New Zealand hill country: Accounting for the effect of land slope on the N_2O emission factors from urine and dung. *Agriculture Ecosystems & Environment* 205: 70–78.

Saggar S, Singh J, Giltrap DL, Zaman M, Luo J, Rollo M, Kim D-G, Rys G, van der Weerden TJ. 2013. Quantification of reductions in ammonia emissions from fertiliser urea and animal urine in grazed pastures with urease inhibitors for Agriculture inventory: New Zealand as a case study. *Science of the Total Environment* 465: 136–146.

Sangster C. 2023. *Seasonality of Wool Growth in AIM*. MPI Technical Report. Wellington: Ministry for Primary Industries.

Sherlock RR, de Klein C, Li Z. Unpublished. Determination of N_2O and CH_4 Emission Factors from Animal Excreta, following a Summer Application in Three Regions of New Zealand. A final report of an NzOnet study prepared for the Ministry of Agriculture and Forestry by Landcare Research, AgResearch and Lincoln University in 2003.

Sherlock RR, Jewell P, Clough T. 2008. *Review of New Zealand Specific $Frac_{GASM}$ and $Frac_{GASF}$ Emissions Factors*. Report prepared for the Ministry of Agriculture and Forestry by Landcare Research and AgResearch. Wellington: Ministry of Agriculture and Forestry.

Sise J. 2023. *Minor animal categories.* Report prepared for the Ministry for Primary Industries by AbacusBio. Wellington: Ministry for Primary Industries.

Stats NZ. 2021. *Fertilisers – nitrogen and phosphorus*. Retrieved 12 January 2024.

Stats NZ. 2024. *Agricultural production statistics: Year to June 2023 (final)*. Retrieved 2 December 2024.

Stevens D, Rollo M, Vibart R, Chrystal J, Speirs B, Davison R, Burtt A. 2022. *Sheep and Cattle Birth and Slaughter Dates*. Final report prepared for the Ministry for Primary Industries. Wellington: Ministry for Primary Industries.

Stevens D, Ward J. 2023. *Splitting Emissions Intensity Values between Venison and Velvet Antler in the Deer Industry*. Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

Suttie J. 2012. *Report to the Deer Industry New Zealand: Estimation of Deer Population and Productivity Data 1990 to 2012*. Dunedin: Suttie Consulting Limited.

Swainson N, Muetzel S, Clark H. 2016. Updated predictions of enteric methane emissions from sheep suitable for use in the New Zealand national greenhouse gas inventory. *Animal Production Science* 58: 973–979.

Thomas S, Hume E, Fraser T Curtin D. 2011. *Factors and Activity Data to Estimate Nitrous Oxide Emissions from Cropping Systems, and Stubble and Tussock Burning*. Report prepared for the Ministry of Agriculture and Forestry by Plant and Food Research (formerly Crop and Food Research). Wellington: Ministry of Agriculture and Forestry.

Thomas S, Wallace D, Beare M. 2014. *Pasture Renewal Activity Data and Factors for New Zealand*. Report prepared for the Ministry for Primary Industries by Plant and Food Research. Wellington: Ministry for Primary Industries.

Thomas SM, Fraser T, Curtin D, Brown H, Lawrence E. 2008. *Review of Nitrous Oxide Emission Factors and Activity Data for Crops*. Report prepared for the Ministry of Agriculture and Forestry by Plant and Food Research. Wellington: Ministry of Agriculture and Forestry.

Thomas SM, Ledgard SF, Francis GS. 2005. Improving estimates of nitrate leaching for quantifying New Zealand's indirect nitrous oxide emissions. *Nutrient Cycling in Agroecosystems* 73: 213–226.

Thomas T. Unpublished. Assessment of the Methodology of Potato Area and Yield Activity Estimations used in the NZ National GHG Inventory. Report prepared for the Ministry of Agriculture and Forestry by Plant and Food Research in 2010.

Thomson BC, Muir PD, Davison R, Clark H. 2010. *Review of Population Models within the National Methane Inventory (2010)*. Technical paper prepared for the Ministry of Agriculture and Forestry by On-Farm Research (with cooperation by Meat and Wool New Zealand and AgResearch Ltd). Wellington: Ministry of Agriculture and Forestry.

Thomson BC, Ward KR, Muir PD. 2021. *Purity of Agricultural Lime and Dolomite Used in New Zealand*. Final report prepared for the Ministry for Primary Industries. Wellington: Ministry for Primary Industries.

Ulyatt MJ, Baker SK, McCrabb GJ, Lassey KR. 1999. Accuracy of the SF_6 tracer technology and alternatives for field measurements. *Australian Journal of Agricultural Research* 50: 1329–1334.

van der Weerden A, de Klein C, Kelliher F, Rollo M. 2014. *Reporting to 2006 IPCC Guidelines for N_2O Emissions from Additional Sources of Organic N: Final Report*. MPI Technical Report. Wellington: Ministry for Primary Industries.

van der Weerden T, Cox N, Luo J, Di HJ, Podolyan A, Phillips RL, Saggar S, de Klein CAM, Ettema P, Rys G. 2016a. Refining the New Zealand nitrous oxide emission factor for urea fertiliser and farm dairy effluent. *Agriculture Ecosystems & Environment* 222: 133–137.

van der Weerden T, Luo J, Cox N, Di HJ, Podolyan A, Phillips RL, Saggar S, de Klein CA, Ettema P, Rys G. 2016b. Nitrous oxide emissions from urea fertiliser and effluent with and without inhibitors applied to pasture. *Agriculture Ecosystems & Environment* 219: 58–70.

van der Weerden T, Noble A, Giltrap D, Luo S, Saggar S. 2019. *Meta-analysis of nitrous oxide emission factors for excreta deposited onto pasture: Final report*. Report prepared for the Ministry for Primary Industries by AgResearch in 2019. Wellington: Ministry for Primary Industries.

van der Weerden TJ, Luo J, de Klein CA, Hoogendoorn CJ, Littlejohn RP, Rys GJ. 2011. Disaggregating nitrous oxide emission factors for ruminant urine and dung deposited onto pastoral soils. *Agriculture Ecosystems & Environment* 141(3–4): 426–436.

van der Weerden TJ, Noble AN, Luo J, de Klein CAM, Saggar S, Giltrap D, Gibbs J, Rys G. 2020. Meta-analysis of New Zealand's nitrous oxide emission factors for ruminant excreta supports disaggregation based on excreta form, livestock type and slope class. *Science of The Total Environment* 732.

van der Weerden T, Rutherford A. 2024. *Nitrous oxide emissions from non-manure organic amendments to soils*. Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

Waghorn G, Molano G, Cavanagh A. Unpublished(a). An Estimate of Whole Herd Methane Production from Cows at the Lincoln University Dairy Farm in October 2003. Final report prepared for Landcare Research NZ Ltd in 2003.

Waghorn G, Molano G, Lassey K. Unpublished(b). Estimates of Whole Herd Methane Production from Cows at the Lincoln University Dairy Farm in January and March 2002. A preliminary report prepared for Landcare Research NZ Ltd in 2002.

Welten B, Mercer G, Smith C, Sprosen M, Ledgard S. 2021. *Refining estimates of nitrogen leaching for the New Zealand agricultural greenhouse gas inventory*. Report prepared for the Ministry for Primary Industries.

Wheeler DM, Ledgard SF, de Klein CAM, Monaghan PL, Carey PL, McDowell RW, Johns KL. 2003. OVERSEER® Nutrient budgets – moving towards on-farm resource accounting. In: *Proceedings of the New Zealand Grassland Association 2003*. Palmerston North: New Zealand Grassland Association Inc.

Woods J, Orwin DF. 1988. Seasonal variations in the dimensions of individual Romney wool fibres determined by a rapid autoradiographic technique. *New Zealand Journal of Agricultural* Research 31(3): 311–323.

Chapter 6: Land Use, Land-Use Change and Forestry (LULUCF)

This chapter reports New Zealand's emissions and removals from the Land Use, Land-Use Change and Forestry (LULUCF) sector using the methods and guidance described in volume 4 of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006a). For information on how New Zealand accounts for the contribution of the LULUCF sector towards its Nationally Determined Contribution under the Paris Agreement, refer to annex 9.

6.1 Sector overview

Net emissions summary

2023

In 2023, net emissions from the LULUCF sector were -20,197.1 kilotonnes carbon dioxide equivalent (kt CO_2-e) or -26.4 per cent of New Zealand's gross greenhouse gas emissions. This comprises net emissions of -20,511.0 kt CO_2, emissions of 45.8 kt CO_2-e of methane (CH_4) and 268.0 kt CO_2-e of nitrous oxide (N_2O). The category contributing the most to both removals and emissions is *Forest land remaining forest land*. This is because large removals result from the growth of all forests on this land and there are also large emissions from the sustainable harvest of New Zealand's plantation forests.

1990–2023

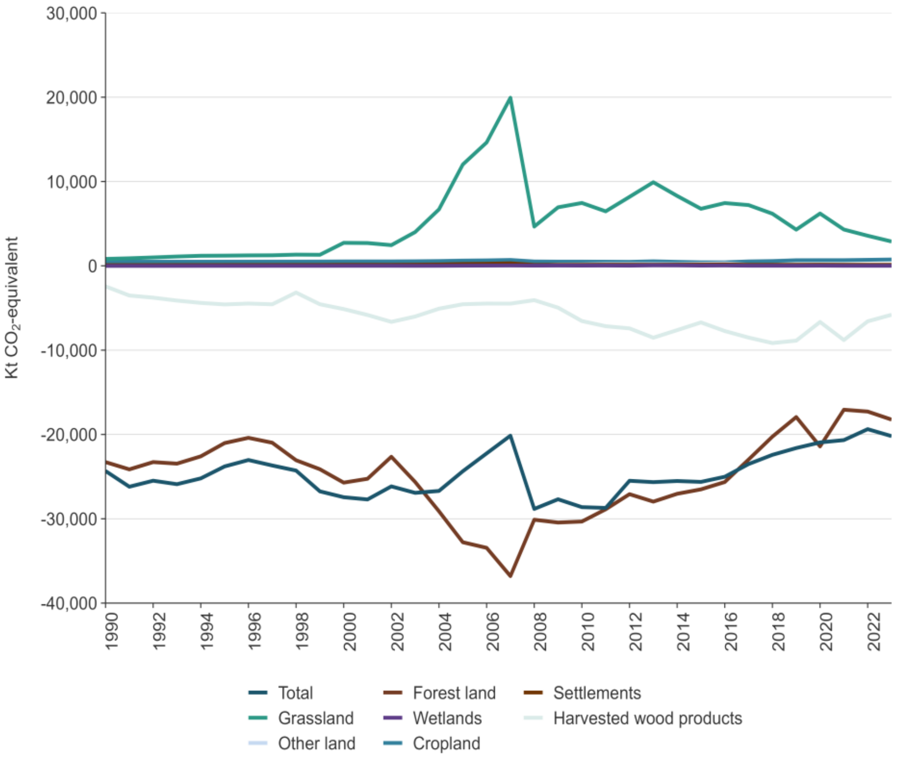
Net emissions in 2023 have increased by 4,136.9 kt CO_2-e (17.0 per cent) from the 1990 level of -24,334.1 kt CO_2-e (see table 6.1.1 and figure 6.1.1). This is largely due to a reduction in removals from *Forest land* and an increase in emissions from *Grassland* (mainly due to emissions from deforestation and conversions among grassland categories) since 1990. The reduction in removals from *Forest land* is driven by high current harvest rates (figure 6.4.3), which are a result of significant afforestation beginning in the 1980s and reaching a peak in the mid-1990s (figure 6.4.1). The planted forests that were established during this period have progressively been reaching harvesting age, and that will continue into the mid-2020s. As the high harvesting rates continue, the average age of the planted forest estate is reduced each year when the harvested forests are replanted. Young forest stands have lower rates of removal than older stands. Harvesting and replanting cycles of New Zealand's planted forests will continue to affect the trajectory of New Zealand's net emissions in the future due to their uneven age-class profile. The increased emissions from harvesting have been compensated for, to some extent, by increased removals in the harvested wood products pool due to inputs into this pool exceeding emissions from decay.

Table 6.1.1 New Zealand's greenhouse gas net emissions for the LULUCF sector by category in 1990 and 2023

Category	Net emissions (kt CO_2-e) 1990	2023	Difference (kt CO_2-e) 1990–2023	Change (%) 1990–2023
Forest land	-23,279.5	-18,235.7	5,043.8	21.7
Cropland	478.3	749.8	271.5	56.8
Grassland	819.9	2,884.2	2,064.3	251.8
Wetlands	-8.3	7.5	15.8	190.4
Settlements	78.5	119.3	40.7	51.9
Other land	14.8	86.1	71.3	482.4
Harvested wood products	-2,437.8	-5,808.3	-3,370.5	-138.3
Total LULUCF	**-24,334.1**	**-20,197.1**	**4,136.9**	**17.0**

Notes: Net emissions are expressed as a negative value in the table to help the reader in clarifying that the value is a removal (of carbon dioxide equivalent from the atmosphere) and not an emission. Columns may not total due to rounding. Percentages presented are calculated from unrounded values.

Figure 6.1.1 New Zealand's annual net emissions from the LULUCF sector from 1990 to 2023



Emissions in the LULUCF sector are primarily driven by the harvest of production forests, deforestation and the decomposition of organic material following these activities. Removals are mainly from the sequestration of carbon that occurs due to plant growth and the production of harvested wood products. Nitrous oxide can be emitted from the ecosystem as a by-product of nitrification and de-nitrification, and the burning of organic matter. Other gases released during biomass burning include CH_4, carbon monoxide (CO), other oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs).

2022–2023

Net emissions from the LULUCF sector decreased between 2022 and 2023 by 824.4 kt CO_2-e (4.3 per cent) (see table 6.1.2).

The largest change occurred in the *Forest land* category, with a decrease in emissions of 952.1 kt CO_2-e, driven by reduced harvesting rates in planted forests between 2022 and 2023 (figure 6.4.3). The *Harvested wood products* category had the second-largest change, with an increase in emissions of 774.0 kt CO_2-e, which was also driven by the drop in harvesting of planted forests, leading to a drop in the inputs to the harvested wood products pool. The *Grassland* category had the third-largest change, with a decrease in emissions of 684.7 kt CO_2-e. This was driven by lower deforestation rates in 2023 compared with 2022.

Table 6.1.2 New Zealand's greenhouse gas net emissions for the LULUCF sector by land use category in 2022 and 2023

Category	(kt CO_2-e) 2022	2023	Difference (kt CO_2-e) 2022–23	Change (%) 2022–23
Forest land	-17,283.6	-18,235.7	-952.1	-5.5
Cropland	709.1	749.8	40.7	5.7
Grassland	3,568.9	2,884.2	-684.7	-19.2
Wetlands	8.1	7.5	-0.6	-7.1
Settlements	118.9	119.3	0.4	0.3
Other land	88.3	86.1	-2.2	-2.5
Harvested wood products	-6,582.3	-5,808.3	774.0	11.8
Total LULUCF	**-19,372.7**	**-20,197.1**	**-824.4**	**-4.3**

6.1.1 National circumstances

New Zealand has a land area of nearly 270,000 square kilometres with extensive coastlines (approximately 19,800 kilometres). This land mass is made up of two main islands, the North Island and South Island, as well as smaller outlying islands. New Zealand has a temperate climate, highly influenced by the surrounding ocean. Around 60 per cent of the land is hilly or mountainous, with around 425,000 kilometres of rivers and streams, and almost 4,000 lakes that are larger than 1 hectare (Ministry for the Environment and Stats NZ, 2017).

Since 1990, approximately 11.1 per cent of New Zealand's total land area has undergone land-use change. Before human settlement, natural forests were New Zealand's predominant land cover, estimated at 85 per cent to 90 per cent of total land area (McGlone, 2009). Natural forest now covers approximately 29 per cent of New Zealand's total land area, having been replaced predominantly by agricultural land uses (Ewers et al., 2006). Demand for accessible land has also led to the modification of a large proportion of New Zealand's vegetated wetland areas to provide pastoral land cover. Just over 10 per cent of wetlands present before European settlement remain across New Zealand (McGlone, 2009). For a summary of land use area in 2023 in New Zealand, see table 6.1.3.

New Zealand forests are either held on privately owned land or in the publicly owned conservation estate (an area of approximately 8.5 million hectares; Ministry for the Environment and Stats NZ, 2018). Consequently, all forests in New Zealand meet the 2006 IPCC Guidelines definition of managed land, which is "land where human interventions and practices have been applied to perform production, ecological or social functions" (IPCC, 2006a). Therefore, both forests planted for timber production and natural forests managed for conservation purposes are considered managed forests.

No timber is legally harvested from natural forests in the publicly owned conservation estate other than in exceptional circumstances where legislation allows. Most other harvesting of natural forests is required by law to be undertaken on a sustainable basis (Forests Act 1949).

Plantation forestry and agricultural industries form the core of New Zealand's economy and are the main determinants of New Zealand's LULUCF emissions profile. Intensive forest management, combined with a temperate climate, fertile soils and high rainfall, means New Zealand has one of the highest rates of exotic forest growth among Annex I countries.

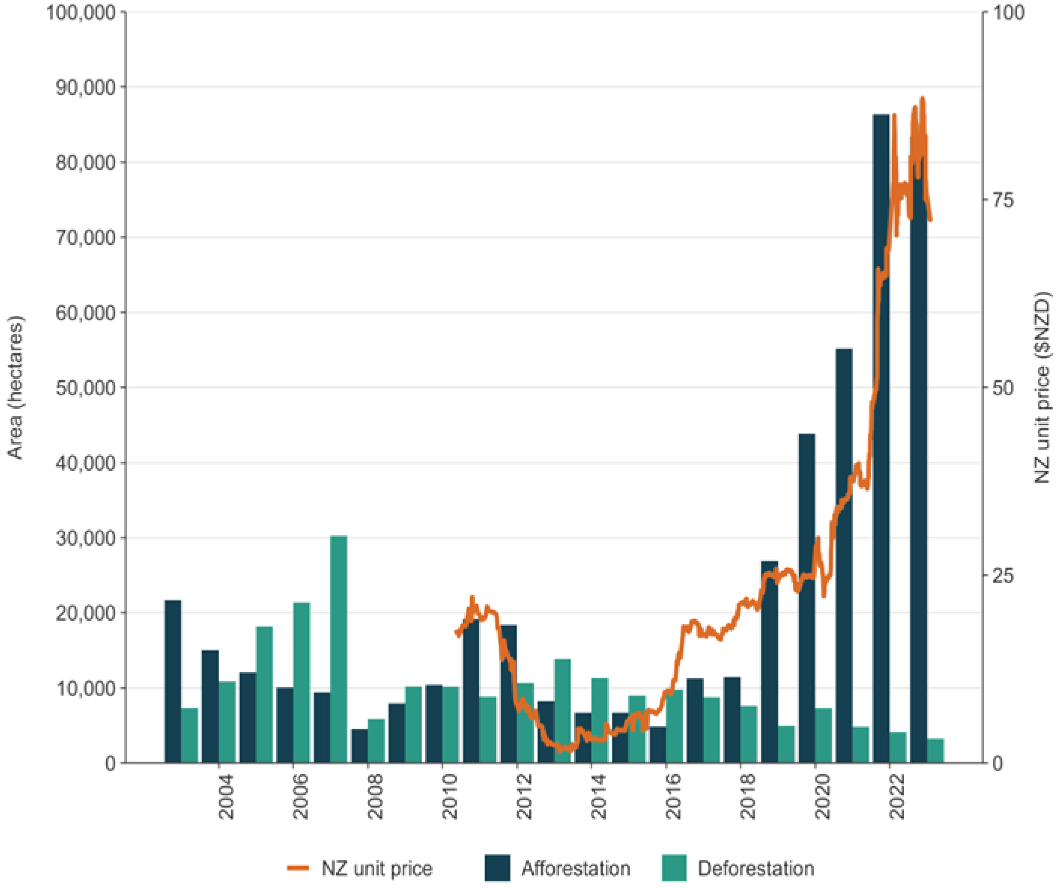
New Zealand's exotic forest plantation estate is intensively managed for production forestry, with rapid-growing genotypes selected and enhanced for optimum growth. Rates of afforestation, reforestation, harvesting and deforestation are strongly influenced by market conditions for harvested timber, competition for land use and introduced government policies. One such policy has been the introduction of the New Zealand Emissions Trading Scheme (NZ ETS) in 2008 and the inclusion of forestry within the scheme (Ministry for Primary Industries, 2015). The forestry component of the NZ ETS was included to encourage new forest planting and disincentivise deforestation. An unintended consequence of this policy was that large-scale deforestation of pre-1990 planted forest occurred in 2007 (30,240 hectares) before the policy's introduction as land owners deforested to avoid potential future liabilities (see figure 6.1.1 and figure 6.1.2). Changes in afforestation and deforestation rates show they correlate strongly with fluctuations in the NZ ETS carbon price (figure 6.1.2). However, afforestation and deforestation rates are also affected by other market conditions and other government initiatives, which are summarised in annex 5, section A5.2.5 'Forest land methodologies'.

Table 6.1.3 Land use in New Zealand in 2023

Category	Land use	Area (kha)	Proportion of total area (%)
Forest land	Pre-1990 natural forest	7,743.944	28.8
	Pre-1990 planted forest	1,433.970	5.3
	Post-1989 planted forest	883.431	3.3
	Post-1989 natural forest	111.520	0.4
	Subtotal	*10,172.865*	*37.8*
Cropland	Annual	389.133	1.4
	Perennial	108.106	0.4
	Subtotal	*497.239*	*1.8*
Grassland	High producing	6,736.718	25.0
	Low producing	6,252.599	23.2
	With woody biomass	1,343.924	5.0
	Subtotal	*14,333.242*	*53.2*
Wetlands	Open water	537.525	2.0
	Vegetated	243.813	0.9
	Subtotal	*781.338*	*2.9*
Settlements		243.451	0.9
Other land		896.950	3.3
Total		**26,925.085**	**100.0**

Note: Areas as at 31 December 2023. Columns may not total due to rounding. Percentages presented are calculated from unrounded values.

Figure 6.1.2 Comparison of afforestation and deforestation rates with the changing NZ ETS unit price, from 2004 to 2023



6.1.2 Methodological tiers and coverage of pools applied in the LULUCF sector

New Zealand uses a combination of Tier 1, Tier 2 and Tier 3 methods, as described in the 2006 IPCC General Guidance and Reporting (IPCC, 2006b), for estimating net emissions for the LULUCF sector. A Tier 1 approach has been used to estimate carbon stock change in the four biomass pools (above-ground and below-ground biomass, dead wood and litter) for all land uses except *Forest land*, *Perennial cropland*, *Vegetated wetland* and *Grassland with woody biomass*, which use Tier 2 or Tier 3 approaches.

For all land uses, Tier 1 approaches are used to estimate carbon stock changes in organic soils, and a Tier 2 modelling approach is applied to estimate soil organic carbon (SOC) changes from mineral soils. This model is described in more detail in annex 5, section A5.2.4 'Mineral soils'.

New Zealand's forests are disaggregated into four reporting categories, to represent the different growth characteristics of the forest types more accurately: pre-1990 planted forest, pre-1990 natural forest, post-1989 planted forest and post-1989 natural forest. The terms 'post-1989' and 'pre-1990' distinguish between forests growing on land that was forested as of 31 December 1989 and those growing on land that was not forested at that date. The terms 'natural' and 'planted' forest are used to identify whether the trees were established from natural regeneration or from managed planting. The term 'harvesting' refers to temporary destocking of forest as part of ongoing forestry land use, whereas 'deforestation' refers to permanent removal of forest as a result of land-use change.

Similarly, the species compositions reported in the *Grassland* category are diverse, ranging from different grass types to woody trees that do not meet New Zealand's forest definition. To allow for this, the *Grassland* category is divided into four types for modelling the net emissions from land-use change.

Calculation of national emission estimates

The methods used to estimate carbon (C) by pool for each land use are summarised in table 6.1.4. Biomass carbon stocks in each land use before conversion, emission factors to estimate carbon stock changes, and annual growth in biomass carbon stocks after land use conversion are summarised in the relevant category sections in this chapter. Activity data are estimated using wall-to-wall mapping from satellite imagery and other ancillary data sets and are described in more detail in section 6.3.1 and annex 5, section A5.2.1.

Table 6.1.4 Relationships between land use, carbon pool and method of calculation used by New Zealand

Reporting category	Living biomass		Dead organic matter		Soils	
Land use	**Above-ground biomass**	**Below-ground biomass**	**Dead wood**	**Litter**	**Soil organic matter** **Mineral soils**	**Organic soils**
Pre-1990 natural forest	Plot measurements; allometric equations	Estimated as the ratio of below-ground biomass to above-ground biomass	Modelled from plot measurements; allometric equations	Plot samples; laboratory analysis of samples collected at plots	Tier 2, country-specific data and model	Not applicable
Pre-1990 planted forest	Modelled through allometric equations, then included in national yield tables	Estimated as the ratio of below-ground biomass to above-ground biomass	Allometric model using plot measurements, included in national yield tables. Harvest residues added to dead wood pool through CRA	Allometric model and percentage of above-ground biomass	Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Post-1989 natural forest	Allometric model	Estimated as the ratio of below-ground biomass to above-ground biomass	Modelled from plot measurements; allometric model	Allometric model and percentage of above-ground biomass	Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Post-1989 planted forest	Modelled through allometric equations, then included in national yield tables	Estimated as the ratio of below-ground biomass to above-ground biomass	Allometric model using plot measurements, included in national yield tables. Harvest residues added to dead wood pool through CRA	Allometric model and percentage of above-ground biomass	Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Cropland – annual	IPCC Tier 1 default parameters	IPCC Tier 1 default parameters (NE)	Tier 2, country-specific data and model	IPCC Tier 1 default parameters		
Cropland – perennial	Country-specific emission factor		IPCC Tier 1 default parameters (NE)		Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Grassland (high and low producing)	IPCC Tier 1 default parameters		IPCC Tier 1 default parameters (NE)		Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Grassland with woody biomass – transitional	Country-specific emission factor				Tier 2, country-specific data and model	IPCC Tier 1 default parameters

Reporting category	Living biomass		Dead organic matter		Soils	
Land use	Above-ground biomass	Below-ground biomass	Dead wood	Litter	Soil organic matter Mineral soils	Organic soils
Grassland with woody biomass – permanent	Country-specific emission factor				Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Wetlands – open water	IPCC Tier 1 default parameters (NE)				Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Wetlands – vegetated	Country-specific emission factor		IPCC Tier 1 default parameters (NE)		Tier 2, country-specific data and model	IPCC Tier 1 default parameters
Settlements	IPCC Tier 1 default parameter (NE)				Tier 2, country-specific data and model	NE
Other land	IPCC Tier 1 default parameter (NE)				Tier 2, country-specific data and model	NE

Note: CRA = Calculation and Reporting Application; NE = not estimated. See the methodology sections for an explanation of soil carbon calculations (annex 5, section A5.2.4) and forest models, C_Change and Forest Carbon Predictor (annex 5, section A5.2.5).

To calculate emissions for the New Zealand LULUCF sector, the following data are used:

- land use and land-use change area data from 1962 to 1989, which provide land in a transition state as at 1990 for each land use (see annex 5, section A5.2.2)
- annual land use and land-use change area data from 1990 to 2023 (see annex 5, section A5.2.2)
- biomass carbon stocks per hectare before land use conversion, and annual growth in biomass carbon stocks per hectare following conversion (described in more detail under each land use category)
- estimates of planted forest harvest area and harvest age-class distribution (see section 6.4 and annex 5, section A5.2.5)
- a forest age profile for pre-1990 planted forests and post-1989 planted forests
- age-based biomass carbon yield tables for pre-1990 planted forests and post-1989 planted and natural forests (see section 6.4.2)
- growth increment for pre-1990 natural forest (see section 6.4.2)
- emission factors and country-level activity data on biomass burning (see section 6.11.8)
- IPCC default conversion factors for converting C to CO_2.

The formula used to calculate emissions from biomass changes on land use conversion is:

$$\left(\begin{array}{c} \textit{Loss of biomass} \\ \textit{present in} \\ \textit{previous crop} \end{array} \times \begin{array}{c} \textit{Activity data} \\ \textit{(Area)} \end{array} \right) + \left(\begin{array}{c} \textit{Annual growth in} \\ \textit{biomass carbon} \\ \textit{stocks in new land} \\ \textit{use} \end{array} \times \begin{array}{c} \textit{Activity} \\ \textit{data (Area)} \end{array} \right) \quad (1)$$

The formula used to calculate emissions from mineral soil changes on land use conversion is:

$$\frac{\textit{Mineral soil carbon at steady state in the new land use} - \textit{Mineral soil carbon at steady state in the previous land use}}{\textit{20 years (transition period)}} \times \left(\textit{Activity data (Area)} \right) \quad (2)$$

For example, the annual change in carbon stock in the first year of conversion of 100 hectares of low producing grassland to perennial cropland would be calculated as follows:

$$\textit{Biomass change} = (-2.867 \times 100) + (0.67 \times 100) = -219.7 \textit{ tonnes C} \quad (1)$$

$$\textit{Mineral soil change} = ((88.44 - 105.98) / 20) \times 100 = -87.7 \textit{ tonnes C} \quad (2)$$

$$\textit{Total carbon stock change} = -307.4 \textit{ tonnes C}$$

$$\textit{Total emissions} = (\textit{carbon stock change} / 1{,}000 \times -1) \times (44/12)$$

$$\textit{Total emissions} = 1.127 \textit{ kt } CO_2$$

These calculations have been performed to produce estimates of annual carbon stock and carbon stock changes since 1990.

Note: New Zealand applies the 2006 IPCC Guidelines (IPCC, 2006a) default transition period of 20 years. The area of all land use categories is reported in the conversion status for 20 years, after which it is reported in the land remaining land categories.

New Zealand Land Use and Carbon Analysis System

New Zealand's LULUCF estimates are calculated using a programme of data collection and modelling called the Land Use and Carbon Analysis System (LUCAS). This data management system stores, manages and retrieves data for international greenhouse gas reporting for the LULUCF sector. Further details on LUCAS, as well as the databases and applications it draws on, are provided in annex 5, section A5.2.9.

6.1.3 Uncertainties in LULUCF

Uncertainty for the LULUCF sector has been calculated as 60.7 per cent using the Approach 1 – propagation of error method as specified in volume 1, chapter 3 of the 2006 IPCC General Guidance and Reporting (IPCC, 2006b). These uncertainties incorporate natural variability, measurement error and model prediction error. Given this uncertainty, net emissions from the LULUCF sector could range from -7,947.3 kt CO_2-e to -32,447.0 kt CO_2-e. Table 6.1.5 shows the three land use categories within the LULUCF sector that make the greatest contribution to uncertainty in the net carbon emissions for the sector. These are given in descending order.

Table 6.1.5 Land use categories making the greatest contribution to uncertainty in the LULUCF sector

Land use category	Uncertainty introduced into emissions for LULUCF (%)
Pre-1990 planted forest	± 48.8
Post-1989 planted forest	± 23.6
Harvested wood products	± 19.6

The greatest contribution of uncertainty to the LULUCF sector arises from pre-1990 planted forest in the *Forest land* category. The age structure of the pre-1990 planted forest estate results in large removals from growth and large emissions from harvesting. The uncertainty is calculated by combining the uncertainty of both the emissions from harvest and those from forest growth. This results in a high uncertainty relative to the net emissions estimate from both the carbon gains and losses.

The second-greatest contribution of uncertainty to the LULUCF sector comes from the post-1989 planted forest in the *Forest land* category. The age structure of the post-1989 planted forest estate also results in large removals from growth and large emissions from harvesting. Because of the uncertainty in these two factors, combined with the large scale of emissions and removals in this category, post-1989 planted forest makes a high contribution of uncertainty to the LULUCF sector.

The *Harvested wood products* category provides the third-greatest contribution to uncertainty in the LULUCF sector. This is driven by large removals in the category and relatively high uncertainty associated with the end-use and discard rates of New Zealand wood (±68.2 per cent).

Further information on uncertainties and the reasons for their relative contributions to the LULUCF sector, as well as details on emission factor and activity data uncertainties for specific land uses and non-CO_2 emissions, are given within the relevant category sections of this chapter.

6.1.4 Recalculations in LULUCF

For the 2025 submission, New Zealand has recalculated its emissions estimates for the LULUCF sector from 1990 to 2022. The recalculations incorporate new activity data from land use mapping. These recalculations have improved the accuracy, consistency and completeness of the LULUCF estimates.

As a result of the recalculations, estimates of net emissions in 2023 have decreased by 0.7 per cent (see table 6.1.6). The impact of these recalculations on net CO_2-e emissions in each land use category is provided in table 6.1.7.

Table 6.1.6 Recalculations to New Zealand's total net LULUCF emissions for 1990 and 2022

Year	Reported net emissions (kt CO_2-e) 2024 submission	2025 submission	Change in estimate (kt CO_2-e)	(%)
1990	-24,324.6	-24,334.1	-9.4	0.0
2022	-19,238.8	-19,372.7	-133.9	-0.7

Table 6.1.7 Recalculations to New Zealand's net LULUCF emissions for 1990 and 2022 by category

Land use category	Net emissions (kt CO_2-e) 2024 submission: 1990 estimate	2025 submission: 1990 estimate	2024 submission: 2022 estimate	2025 submission: 2022 estimate	Change in 1990 estimate (%)	Change in 2022 estimate (%)
Forest land	-23,274.6	-23,279.5	-17,250.8	-17,283.6	0.0	-0.2
Cropland	476.3	478.3	711.9	709.1	0.4	-0.4
Grassland	826.2	819.9	3,665.7	3,568.9	-0.8	-2.6
Wetlands	-8.3	-8.3	8.0	8.1	0.0	0.4
Settlements	78.9	78.5	118.0	118.9	-0.5	0.7
Other land	14.8	14.8	90.7	88.3	0.2	-2.7
Harvested wood products	-2,437.8	-2,437.8	-6,582.3	-6,582.3	0.0	0.0
Total	**-24,324.6**	**-24,334.1**	**-19,238.8**	**-19,372.7**	**0.0**	**-0.7**

Note: Net emissions are expressed as a negative value in the table to help clarify that the value is a removal (of carbon dioxide equivalent from the atmosphere) and not an emission. Columns may not total due to rounding.

The main differences between this submission and previous estimates of New Zealand's LULUCF emissions reported in the 2024 submission are the result of minor changes to the activity data as a result of improvements to the 2020 land use map.

More information on the recalculations is provided in the relevant category-specific recalculations sections below and in chapter 10.

6.1.5 LULUCF planned improvements

The LULUCF sector has a plan of continuous improvement and has introduced several improvements in this submission. Once a year, potential category-specific improvements are ranked in order of priority according to expert review team (ERT) recommendations, key category analysis and contribution to uncertainty in the sector. The improvement priority list is then compared with available resources and capability before a final improvements plan, for the current national inventory report (NIR) and – in the case of the long-term improvements – future NIRs, is agreed on.

Category-specific planned improvements for the 2026 and future submissions are reported separately under each of the relevant category sections of this chapter. The major themes are to:

- continue with method development to implement the 2006 IPCC Guidelines (IPCC, 2006a)
- continue to re-measure the pre-1990 natural forest plot inventory on a continuous basis (on a 10-year cycle). The data collected to date from the complete third measurement cycle will be analysed and integrated into the 2027 submission. The current post-1989 natural forest plot network was re-measured in 2023/24, with analysis and results planned for integration into the 2026 submission
- continue to re-measure the complete planted forest plot network (pre-1990 and post-1989) on a continuous basis (on a five-year cycle). The data will be incorporated into the NIR as they become available
- continue to improve land use mapping by using information collected through the NZ ETS. The NZ ETS provides an ongoing source of mapping information on forest extent and age, along with information on deforestation activity and carbon equivalent forest activities. This will be used as part of a continuous improvement programme to update the 1989, 2007, 2012, 2016 and 2020 land use maps
- confirm mapped areas of deforestation for areas cleared during 2021 and 2022
- incorporate research that refines the extent and identifies nutrient status and drainage depth of drained organic soils, as well as develops suitable emission factors for them, to enable the application of the 2013 Wetlands supplement
- improve the SOC reference stock values for Cropland and Grassland through data being collected as part of a 12-year longitudinal study to measure the impact of management practices on agricultural soils
- improve the Soil Carbon Monitoring System (Soil CMS). This work will improve New Zealand's soil carbon stock change estimates by developing a new modelling approach and addressing key measurement gaps. This work will substantially improve the accuracy of soil carbon estimates and provide a framework to include management effects within land uses. This planned improvement will help address review recommendations L.1 and L.12 2023 (FCCC/ARR/2022/NZL, UNFCCC, 2023). Data will be incorporated into the NIR as they become available.

6.2 Land use definitions and the land representation approach(es) used and their correspondence to the land use, land-use change and forestry categories

6.2.1 Land use category definitions

New Zealand has subdivided the IPCC land use categories into 13 land use classes for reporting as shown in table 6.2.1.

Table 6.2.1 New Zealand's land use categories and land uses

IPCC category	New Zealand land use
Forest land	Pre-1990 natural
	Pre-1990 planted
	Post-1989 natural[1]
	Post-1989 planted[1]
Cropland	Annual
	Perennial
Grassland	High producing
	Low producing
	With woody biomass
Wetlands	Open water
	Vegetated
Settlements	Settlements
Other land	Other land

Note: [1] Mapped as a single land use but stratified into 'post-1989 natural' and 'post-1989 planted' for calculating carbon stock and stock change using data from the plot network.

The land uses were chosen for their conformance with the dominant types in New Zealand, while still enabling reporting under the land use categories specified in the 2006 IPCC Guidelines (IPCC, 2006a). The division of forest land uses into pre-1990 and post-1989 classes was made to support accounting under the Kyoto Protocol and the Paris Agreement (see annex 9, for further information on New Zealand's approach to LULUCF accounting under the Paris Agreement).

The national thresholds used by New Zealand to define *Forest land* are:

- a minimum area of 1 hectare
- a crown cover of at least 30 per cent
- a minimum height of 5 metres at maturity *in situ* (Ministry for the Environment, 2006)
- a minimum forest width of 30 metres from canopy edge to canopy edge.

The definitions of New Zealand's land uses, as they have been mapped, are provided in table 6.2.2. Further details are included in *Land Use and Carbon Analysis System: Satellite imagery interpretation guide for land use classes* (2nd edition) (Ministry for the Environment, 2012).

Table 6.2.2 New Zealand's mapping definitions for each land use

Land use	Definition
Pre-1990 natural forest	Areas that, on 1 January 1990, were and presently include: • tall indigenous forest • self-sown exotic trees, such as wilding pines and grey willows (where managed as forest) • broadleaved hardwood shrubland, kānuka–mānuka (*Leptospermum scoparium–Kunzea* spp.) shrubland and other woody shrubland (≥30 per cent cover, with potential to reach ≥5 metres at maturity *in situ* under current land management within 30–40 years) • areas of bare ground of any size that were previously forested but, due to natural disturbances (e.g., erosion, storms, fire), have temporarily lost vegetation cover • areas that were planted forest at 1990 but are subsequently managed to regenerate with natural species that will meet the forest definition • roads and tracks less than 30 metres in width and other temporarily unstocked areas associated with a forest land use.
Pre-1990 planted forest	Areas that, on 1 January 1990, were and presently include: • radiata pine (*Pinus radiata*), Douglas fir (*Pseudotsuga menziesii*), eucalypts (*Eucalyptus* spp.) or other planted species (with potential to reach ≥5 metre height at maturity *in situ*) established before 1 January 1990 or replanted on land that was forest land as at 31 December 1989 • exotic forest species that were planted after 31 December 1989 on land that was natural forest • riparian or erosion control plantings that meet the forest definition and that were planted before 1 January 1990 • harvested areas within pre-1990 planted forest (assuming these will be replanted, unless deforestation is later detected) • roads, tracks, skid sites and other temporarily unstocked areas less than 30 metres in width associated with a forest land use • areas of bare ground of any size that were previously forested at 31 December 1989 but, due to natural disturbances (e.g., erosion, storms, fire), have lost vegetation cover.
Post-1989 forest	Includes post-1989 planted forest, which consists of: • exotic forest (with the potential to reach ≥5 metre height at maturity *in situ*) planted or established on land that was non-forest land as at 31 December 1989 (e.g., radiata pine, Douglas fir, eucalypts or other planted species) • riparian or erosion control plantings that meet the forest definition and that were planted after 31 December 1989 • harvested areas within post-1989 forest land (assuming these will be replanted, unless deforestation is later detected). Includes post-1989 natural forest, which consists of: • forests arising from natural regeneration of indigenous tree species as a result of management change after 31 December 1989 • self-sown exotic trees, such as wilding conifers or grey willows, established after 31 December 1989 (where managed as forest). Includes areas within post-1989 natural forest or post-1989 planted forest that are: • roads, tracks, skid sites and other temporarily unstocked areas associated with a forest land use • areas of bare ground of any size that were previously forested (established after 31 December 1989) but, due to natural disturbances (e.g., erosion, storms, fire), have lost vegetation cover.
Annual cropland	Includes: • all annual crops • all cultivated bare ground • linear shelterbelts associated with annual cropland.
Perennial cropland	Includes: • all orchards and vineyards • linear shelterbelts associated with perennial cropland.
High producing grassland	Includes: • grassland with high-quality pasture species • linear shelterbelts that are <1 hectare in area or <30 metres in mean width (larger shelterbelts are mapped separately as grassland with woody biomass) • areas of bare ground of any size that were previously grassland but, due to natural disturbances (e.g., erosion), have lost vegetation cover.
Low producing grassland	Includes: • low-fertility grassland and tussock grasslands (e.g., *Chionochloa* and *Festuca* spp.) • mostly hill country

Land use	Definition
	• montane herbfields either at an altitude higher than above-timberline vegetation or where the herbfields are not mixed up with woody vegetation • linear shelterbelts that are <1 hectare in area or <30 metres in mean width (larger shelterbelts are mapped separately as grassland with woody biomass) • other areas of limited vegetation cover and significant bare soil, including erosion and coastal herbaceous sand-dune vegetation.
Grassland with woody biomass	Includes: • grassland with matagouri (*Discaria toumatou*) and sweet briar (*Rosa rubiginosa*), broadleaved hardwood shrubland (e.g., māhoe – *Melicytus ramiflorus*), wineberry (*Aristotelia serrata*), *Pseudopanax* spp., *Pittosporum* spp.), kānuka–mānuka (*Leptospermum scoparium–Kunzea* spp.) shrubland, coastal and other woody shrubland (<5 metres tall and any percentage of cover) where, under current management or environmental conditions (climate and/or soil), it is expected that the forest criteria will not be met over a 30- to 40-year period • above-timberline shrubland vegetation intermixed with montane herbfields (does not have the potential to reach >5 metres in height *in situ*) • grassland with tall tree species (<30 per cent cover), such as golf courses in rural areas (except where the Land Cover Database has classified these as settlements) • grassland with riparian or erosion control plantings (<30 per cent cover) • linear shelterbelts that are >1 hectare in area and <30 metres in mean width • areas of bare ground of any size that previously contained grassland with woody biomass but, due to natural disturbances (e.g., erosion, fire), have lost vegetation cover.
Open water	Includes: • lakes, rivers, dams and reservoirs • estuarine–tidal areas including mangroves.
Vegetated wetland	Includes: • herbaceous and/or non-forest woody vegetation, including trees of any stature, in a wetland context (periodically or permanently flooded) • areas under peat extraction • estuarine–tidal areas including mangroves.
Settlements	Includes: • built-up areas and impervious surfaces • grassland within 'settlements' including recreational areas, urban parklands and open spaces that do not meet the forest definition • major roading infrastructure • airports and runways • dam infrastructure • urban subdivisions under construction.
Other land	Includes: • montane rock and/or scree • river gravels, rocky outcrops, sand dunes and beaches, coastal cliffs, mines (including spoil), quarries • permanent ice and/or snow and glaciers • any other remaining land that does not fall into any of the other land use categories as described in volume 4, section 3.2 of the 2006 IPCC Guidelines (IPCC, 2006a).

6.2.2 Land representation approaches

New Zealand uses a combination of approaches 2 and 3 to determine annual land-use changes occurring between 1 January 1990 and 31 December 2023 (section 2.2.4, IPCC, 2014). This includes wall-to-wall mapping of all land use classes described in table 6.2.3 every four to five years (Approach 3), combined with other non-spatial activity data sets to infer the timing of land-use change between major mapping updates (Approach 2).

An Approach 2 method is used to estimate gross land use transitions before 1990 using a variety of different sources and following the methodology described in Watts (unpublished) and reviewed in Hunter and McNeill (unpublished). This is further described in annex 5, section A5.2.2. Applying this methodology allows for the land use transition matrix for the period 1962 to 1989 to be obtained (see table 6.2.3).

Table 6.2.3 New Zealand's land-use change matrix, from 1962 to 1989 (kha)

1962 land use		Forest land				Cropland		Grassland			Wetlands				
1989 land use		Pre-1990 natural	Pre-1990 planted	Post-1989 planted	Post-1989 natural	Annual	Perennial	High producing	Low producing	With woody biomass	Open water	Vegetated	Settlements	Other land	Net area 31 Dec 1989 (kha)
Forest land	Pre-1990 natural	7,771	-	-	-	-	-	-	-	42	-	-	-	-	7,813
	Pre-1990 planted	302	453	-	-	-	-	-	399	393	-	-	-	-	1,547
	Post-1989 planted	-	-	0	-	-	-	-	-	-	-	-	-	-	0
	Post-1989 natural	-	-	-	0	-	-	-	-	-	-	-	-	-	0
Cropland	Annual	-	-	-	-	325	-	21	9	-	-	-	-	-	355
	Perennial	-	-	-	-	1	59	5	5	-	-	-	-	-	69
Grassland	High producing	84	-	-	-	23	20	4,809	461	346	-	98	-	-	5,840
	Low producing	428	-	-	-	-	-	-	7,447	30	-	-	-	-	7,905
	With woody biomass	78	-	-	-	-	-	-	492	942	-	-	-	-	1,511
Wetlands	Open water	14	-	-	-	-	-	-	-	-	513	-	-	-	527
	Vegetated	-	-	-	-	-	-	-	-	-	-	254	-	-	254
Settlements	Settlements	5	-	-	-	6	-	7	4	1	-	-	185	-	208
Other land	Other land	-	-	-	-	-	-	-	-	-	-	-	-	896	896
Area as at 1 Jan 1962 (kha)		**8,683**	**453**	**-**	**-**	**355**	**78**	**4,842**	**8,816**	**1,753**	**513**	**352**	**185**	**896**	**26,925**
Net change 1 Jan 1962–31 Dec 1989		**-870**	**1,094**	**-**	**-**	**0**	**-9**	**998**	**-911**	**-242**	**14**	**-98**	**23**	**0**	**0**
Net change 1962–1989 (%)		**-10.0**	**241.6**	**-**	**-**	**0.0**	**-11.8**	**20.6**	**-10.3**	**-13.8**	**2.8**	**-27.9**	**12.6**	**0.0**	**0.0**

6.3 Country-specific approaches

6.3.1 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

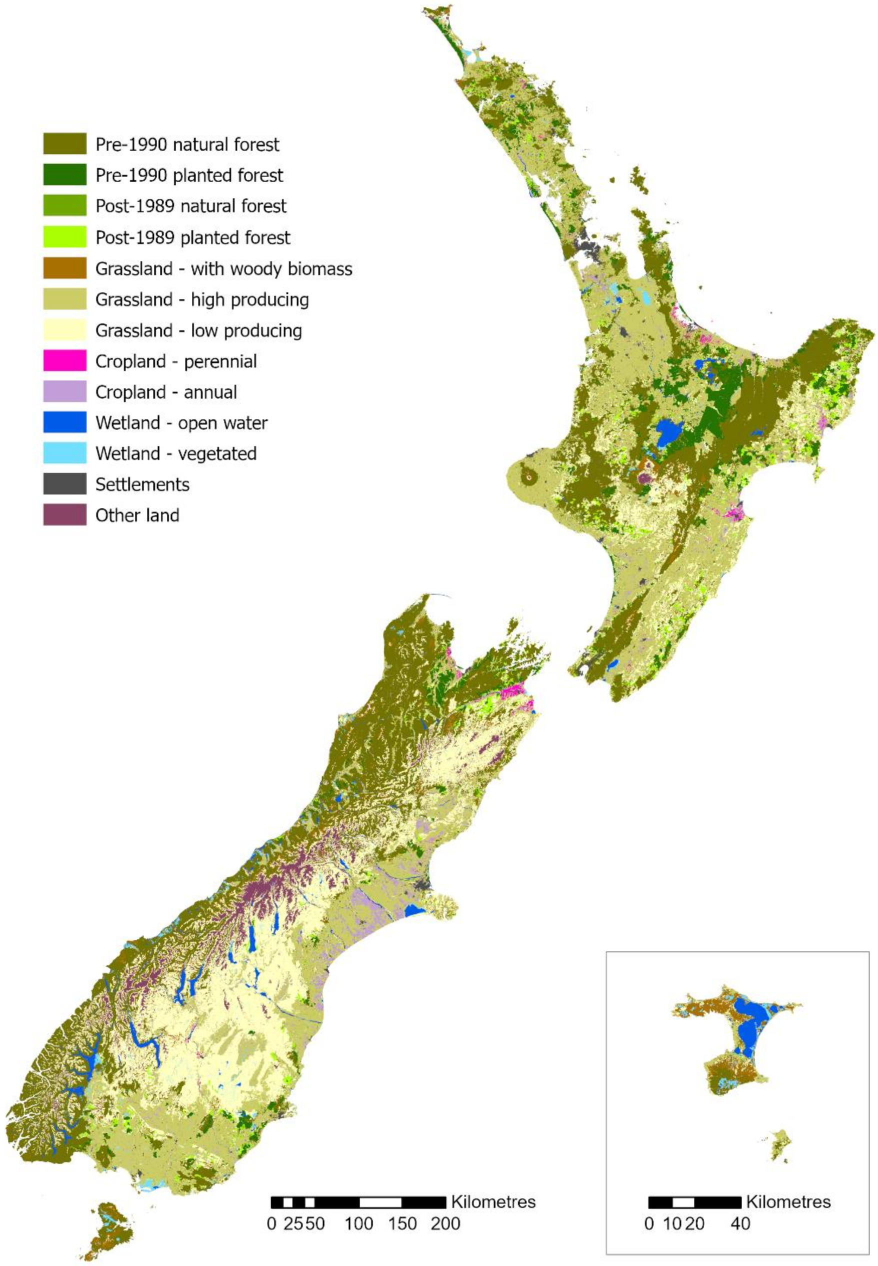
General approach

Areas of land use and land-use change between 1990 and 2023 are based on five wall-to-wall land use maps derived from satellite imagery at nominal mapping dates of 31 December 1989, 31 December 2007, 31 December 2012, 31 December 2016 and 31 December 2020 (see figure 6.3.1). Information on the methods used to compile these land use maps can be found in annex 5, section A5.2.1.

These maps are managed in a single spatial database to ensure consistency in the tracking of land-use change and to ensure any corrections to land use classifications are replicated through the entire time series. Information on the spatial data management system can be found in annex 5, section A5.2.9.

Area information from these maps is interpolated and extrapolated to obtain a complete time series of land-use change occurring between 1990 and 2023 (see annex 5, section A5.2.2). Ancillary data – including aerial photography, additional satellite imagery, data from the NZ ETS and other national survey data – are used to support data interpolation and map production. Further information on the mapping methodology and imagery used, as well as the interpolation and extrapolation process to obtain a complete time series of land-use change occurring between 1990 and 2023 can be found in annex 5, section A5.2.2.

Figure 6.3.1 Land use map of New Zealand as at 31 December 2020



Note: The inset map is of the Chatham Islands, which lie approximately 660 kilometres south-east of the south-eastern corner of the North Island.

Updates for this submission

For this submission, minor improvements to the 2020 land use map have been made. Improvements have also been made to the 1989, 2007, 2012 and 2016 land use maps. This year, improvements have focused on:

- review of land mapped as *Other land* and post-1989 forests on organic soils
- review of unlikely land use changes such as *Settlements* to post-1989 forest classes
- updates to deforestation mapping based on a review of post-1989 forest areas withdrawn from Ministry for Primary Industries (MPI) forestry schemes.

Quality assurance/quality control (QA/QC) and verification

Quality-control and quality-assurance procedures have been adopted for all data collection and data analyses, consistent with the 2006 IPCC Guidelines (IPCC, 2006a) and New Zealand's inventory quality-control and quality-assurance plan. Data quality and data assurance plans are established for each type of data used to determine carbon stock and stock changes, as well as for the mapping of the areal extent and spatial location of land-use changes. Further information on QA/QC procedures specific to mapping can be found in annex 5, section A5.2.1.

Planned improvements

By October 2025, the following improvements will be made to land use activity data:

- confirmation of mapped areas of deforestation for areas cleared during 2021 and 2022
- updates to the 2020 land use map based on forestry mapping entered into the NZ ETS.

Following these improvements, the plan is to complete an accuracy assessment of the map series with a focus on the accuracy of land-use change mapping.

6.3.2 Information on approaches used for reporting harvested wood products

New Zealand applies the production approach to report on the *Harvested wood products* category. To do this, New Zealand has adapted the default Harvested wood products model and uses a Tier 2 method (section 12.2.1.2, IPCC, 2006a), which involves using country-specific activity data and parameters (Wakelin et al., 2020; Wekesa, 2022).

Further information is provided in section 6.10.

6.4 Forest land (4A)

6.4.1 Description

In 2023, *Forest land* contributed -18,235.7 kt CO_2-e of net emissions. Net emissions from *Forest land* have increased by 5,043.8 kt CO_2-e (21.7 per cent) from the 1990 level of -23,279.5 kt CO_2-e (see table 6.4.1). Between 1990 and 2023, *Forest land* is the most significant contributor to carbon stock changes in the LULUCF sector. In 2023, forests comprised 37.8 per cent (10.2 million hectares) of New Zealand's total land area. Note that emissions for the *Harvested wood products* category are reported separately within the common reporting tables (CRTs) and are described further in section 6.10.

In 2023, *Forest land remaining forest land* and *Land converted to forest land* were key categories (based on a trend and level assessment).

Table 6.4.1 New Zealand's land-use change for the *Forest land* category, and associated CO_2-e emissions, in 1990 and 2023

	Net area (ha)			Net emissions (kt CO_2-e)		
Land use category	1990	2023	Change from 1990 (%)	1990	2023	Change from 1990 (%)
Forest land remaining forest land	8,538,327	9,719,064	13.8	-5,325.2	-15,881.8	-198.2
Land converted to forest land	821,678	453,801	-44.8	-17,954.3	-2,353.9	86.9
Total	**9,360,005**	**10,172,865**	**8.7**	**-23,279.5**	**-18,235.7**	**21.7**

Note: Net area in 1990 is as at 1 January 1990; net area in 2023 is as at 31 December 2023. The area of *Land converted to forest land* includes land converted up to 20 years earlier, and net area values include land in a state of conversion (due to land-use change before 1990) and afforestation since 1990. Net emission estimates are for the whole year indicated. Columns may not total due to rounding, and percentages presented are calculated from unrounded values.

New Zealand has applied the following parameters for land to be classified as *Forest land*:

- minimum area of 1 hectare
- potential to reach a minimum height of 5 metres
- potential to reach a minimum crown cover of 30 per cent
- a minimum forest width of 30 metres from canopy edge to canopy edge.

Where the height and canopy cover parameters are not met at the time of mapping, the land has been classified as *Forest land* if the land-management practice(s) and local site conditions (including climate) are such that the forest parameters will be met over a 30- to 40-year timeframe. Note that New Zealand does not report linear shelterbelts under the *Forest land* category because they are not on land managed as forest. They form part of non-forest land uses, namely *Cropland* and *Grassland* (as shelter for crops and/or animals).

New Zealand uses four *Forest land* types: pre-1990 natural forest (predominantly native forest), pre-1990 planted forest (predominantly *Pinus radiata*), post-1989 planted forest and post-1989 natural forest (where post-1989 forests are those established after 31 December 1989). The definitions used for mapping these land uses are given in table 6.2.2.

Table 6.4.2 shows land-use change by forest land type since 1990 and the associated CO_2 emissions from carbon stock change (note: non-CO_2 emissions are reported elsewhere).

Table 6.4.2 Change in land area and associated CO_2 emissions from carbon stock change between 1990 and 2023 for New Zealand's *Forest land*

Land use	Net area (ha) 1990	2023	Change from 1990 (%)	Net emissions (kt CO_2 only) 1990	2023	Change from 1990 (%)
Pre-1990 natural forest	7,812,957	7,743,944	-0.9	-1,360.4	-1,438.3	-5.7
Pre-1990 planted forest	1,547,048	1,433,970	-7.3	-22,333.6	-14,185.3	36.5
Post-1989 planted forest	0	883,431	-	164.1	-2,110.1	-1,386.1
Post-1989 natural forest	0	111,520	-	3.7	-754.6	-20,301.2
Total	**9,360,005**	**10,172,865**	**8.7**	**-23,526.2**	**-18,488.3**	**21.4**

Note: Net area in 1990 is as at 1 January 1990; net area in 2023 is as at 31 December 2023. Net area values include land in a state of conversion to forest (due to land-use change before 1990) and afforestation since 1990. Net emissions estimates are for the whole year indicated. Columns may not total due to rounding. Emissions associated with the conversion of forest to other land uses are reported in the land use category the land is converted to.

Table 6.4.3 shows New Zealand's carbon stock change by carbon pool and forest land type within the *Forest land* category from 1990 to 2023. Over this period, the total carbon stock stored in *Forest land* has increased by 233,508.5 kt C, equivalent to emissions of -856,197.8 tonnes CO_2 since 1990.

Table 6.4.3 New Zealand's net carbon stock change by carbon pool for the *Forest land* category, from 1990 to 2023

Land use	Net carbon stock change 1990–2023 (kt C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2023 (kt CO_2)
Pre-1990 natural forest	11,423.1	1,124.3	-135.2	12,412.3	-45,511.7
Pre-1990 planted forest	116,622.9	16,610.5	-4,389.5	128,843.9	-472,427.7
Post-1989 planted forest	81,878.3	15,612.5	-8,107.5	89,383.2	-327,738.5
Post-1989 natural forest	3,581.8	39.7	-752.5	2,869.1	-10,519.9
Total	**213,506.2**	**33,386.9**	**-13,384.6**	**233,508.5**	**-856,197.8**

Note: Emissions associated with the conversion of forest are reported in the land use category the land is converted to. Columns may not total due to rounding.

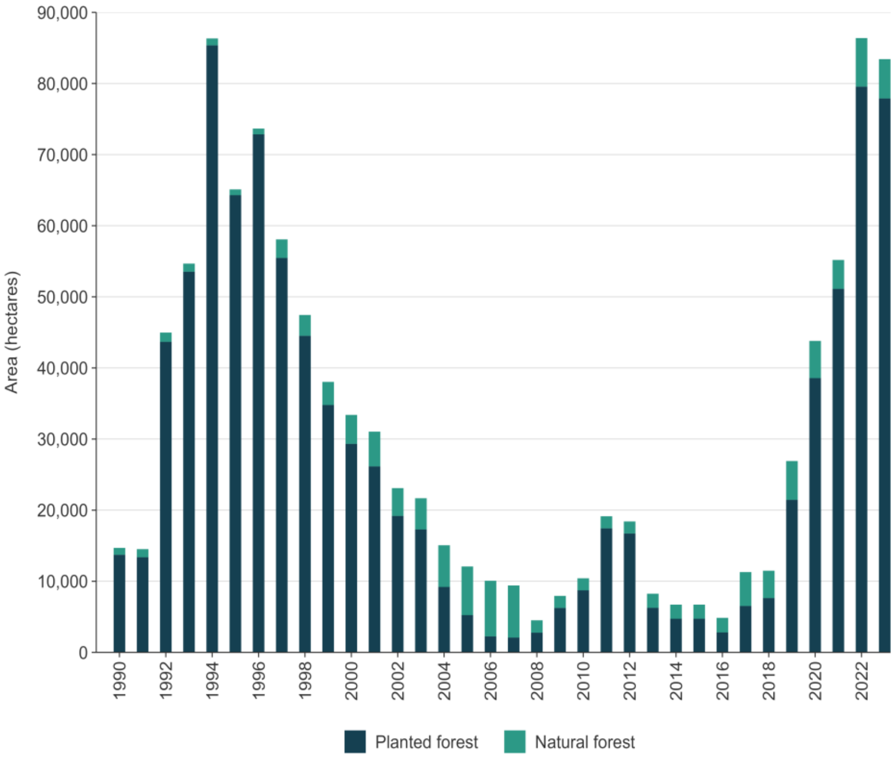
New Zealand's emissions profile in the LULUCF sector is predominantly influenced by plantation forestry. The rapid growth rates of plantation forest relative to natural forest, and the timing of afforestation and harvesting cycles drive the emissions profile and will continue to do so in the future.

6.4.2 Methodological issues

Afforestation/reforestation

Afforestation and reforestation areas of planted and natural forests are derived from a combination of land use mapping, national statistics and forestry scheme data. Annual rates of afforestation and reforestation are shown in figure 6.4.1 and are influenced greatly by market and policy conditions at the time, as described in section 6.1.1. Further details on how the area of afforestation is calculated are provided in annex 5, section A5.2.2.

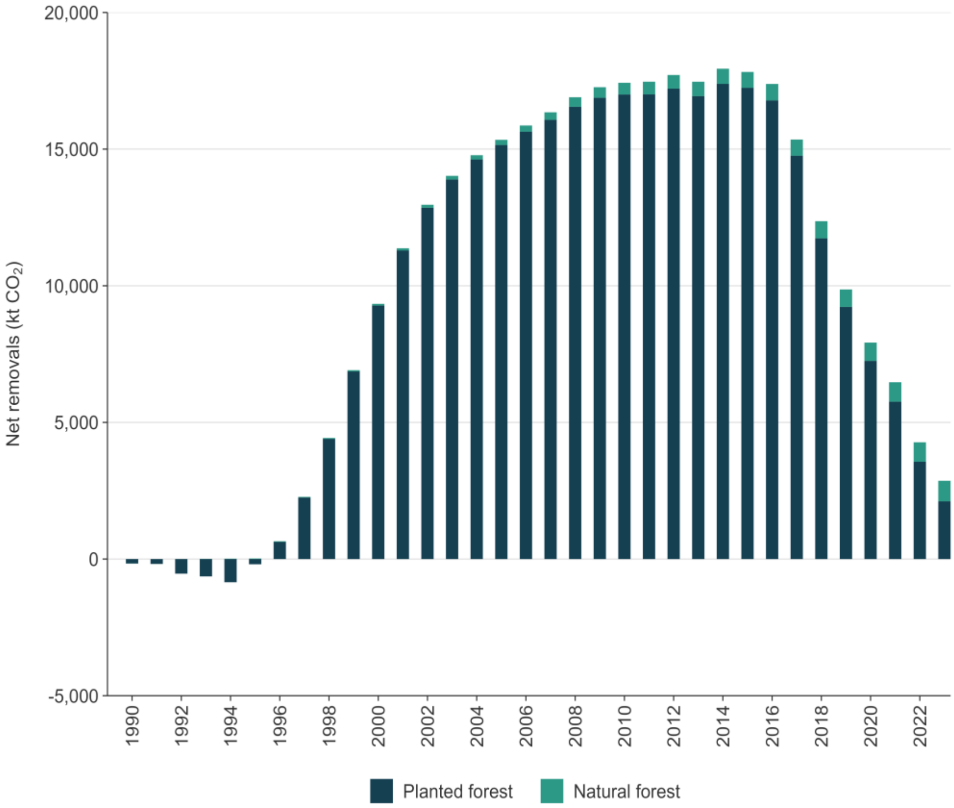
Figure 6.4.1 Annual areas of afforestation and reforestation in New Zealand, from 1990 to 2023



Note: Details on how the afforestation area is calculated are provided in annex 5, section A5.2.2.

Post-1989 planted forests did not become a net sink until 1996 (see figure 6.4.2) when net removals from forest growth surpassed net emissions. These emissions were due to the loss of biomass in carbon stocks associated with the previous land use before conversion, in addition to the loss of soil carbon associated with a land-use change to forestry.

Figure 6.4.2 New Zealand's net carbon dioxide removals by post-1989 planted forests, from 1990 to 2023

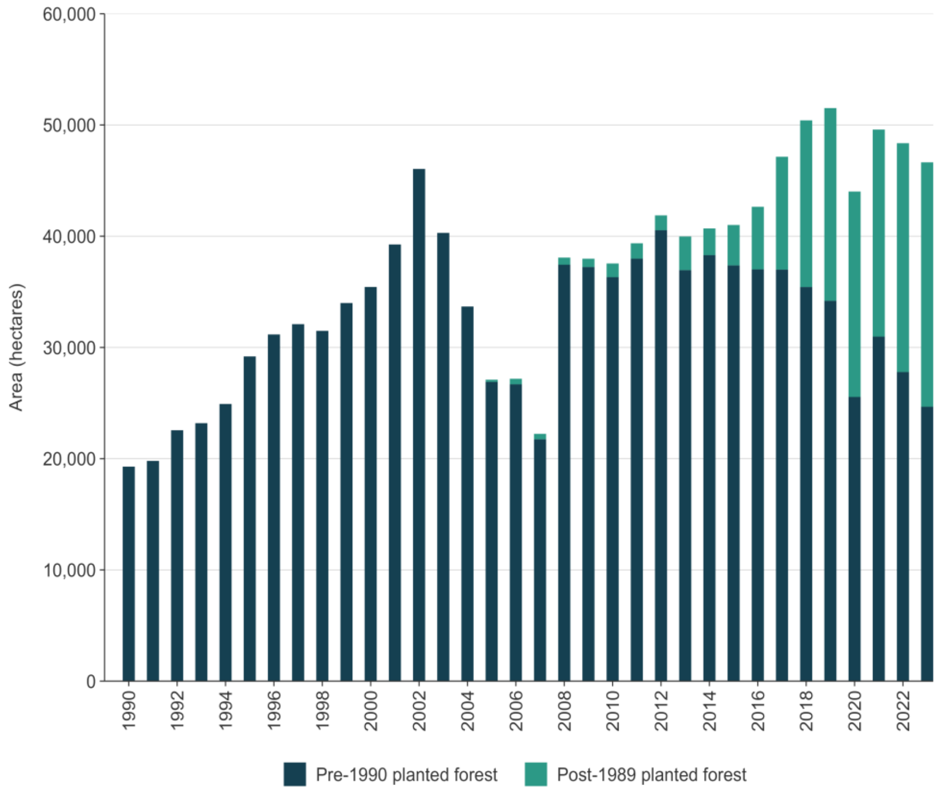


Harvesting

The annual planted forest harvest area (both pre-1990 and post-1989 planted forest combined) from 1990 to 2023 is shown in figure 6.4.3. The method used to calculate the harvest area is outlined in annex 5, section A5.2.5 'Calculation of harvest area'. Emissions from harvesting are dependent on the age of the forest being harvested. To accurately reflect the actual harvest ages that occur, and therefore the associated emissions, a harvest age profile is applied to the harvest area to determine the harvest area by age. Detailed methodology on how the harvest age profile is calculated for post-1989 planted forest and pre-1990 planted forest can be found in annex 5, section A5.2.5 'Calculation of harvest area by age and forest age profile'.

Only a minimal proportion of timber harvested is from the natural forest estate. In 2022, an estimated 0.03 per cent of New Zealand's total forest timber production was from the harvesting of natural forests (Ministry for Primary Industries, 2024b).

Figure 6.4.3 New Zealand's area of planted forest harvest (inclusive of deforestation), from 1990 to 2023



Deforestation

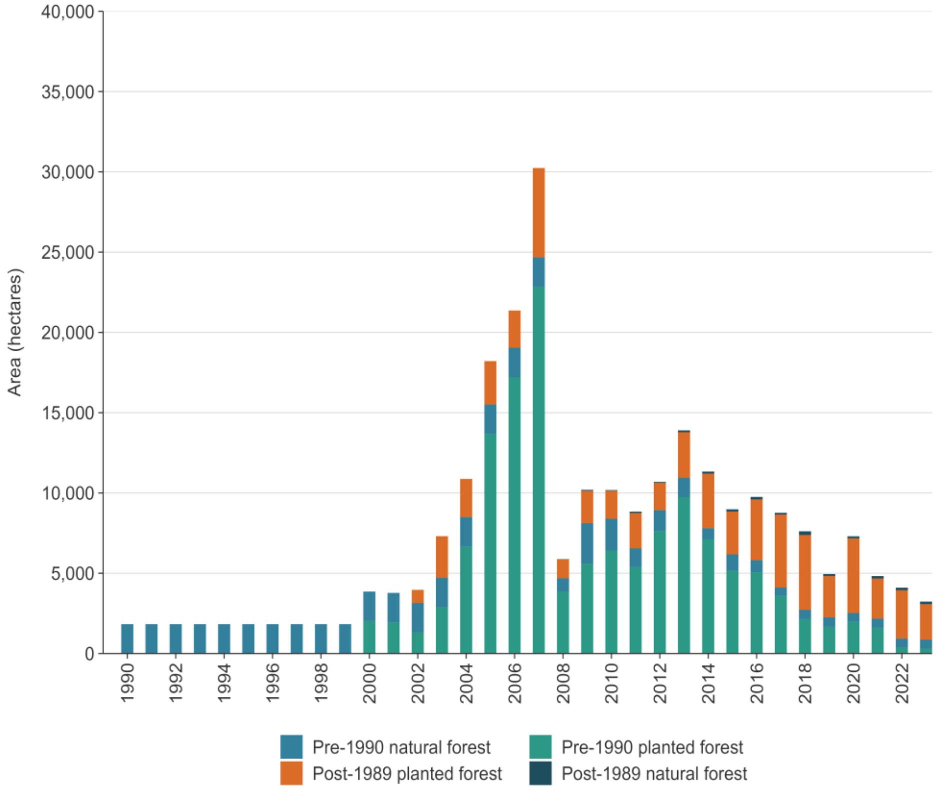
In 2022, an estimated 3,236 hectares of *Forest land* were converted to other land uses, primarily *Grassland*. Table 6.4.4 and figure 6.4.4 show the areas of *Forest land* subject to deforestation since 1990 and in 2023. Figure 6.4.4 also illustrates how planted forest deforestation increased leading up to 2008 and then decreased after the introduction of the NZ ETS in 2008.

Table 6.4.4 New Zealand's *Forest land* subject to deforestation, 1990 and 2023

	Deforestation since 1990			Deforestation in 2023	
Land use	Area of forest in 1990 (ha)	Area (ha)	Proportion of 1990 area (%)	Area (ha)	Proportion of 1990 area (%)
Pre-1990 natural forest	7,812,957	48,407	0.62	570	0.01
Pre-1990 planted forest	1,547,048	136,182	8.80	301	0.02
Post-1989 planted forest	0	62,030	-	2,207	-
Post-1989 natural forest	0	1,850	-	158	-
Total	**9,360,005**	**248,468**	**2.65**	**3,236**	**0.03**

Note: The 2023 areas are as at 31 December 2023; 1990 areas are as at 1 January 1990 and, therefore, differ from 1990 area values in the common reporting tables, which are as at 31 December 1990. Columns may not total due to rounding.

Figure 6.4.4 New Zealand's area of deforestation since 1990, by *Forest land* category



New Zealand assumes instant emissions of all biomass carbon at the time of deforestation, based on the following.

- The majority of deforestation since 2000 has resulted from land conversion to *Grassland*, leading to the rapid removal of all biomass as the land is prepared for farming.
- It is not practical to estimate emissions from residues following deforestation activity given the rapid conversion from one land use to another and the multiple methods of removing residues. Furthermore, estimating biomass residue and decay rates for multiple disposal methods is difficult and costly.

Estimates of deforestation emissions for pre-1990 natural forest are based on the type of vegetation deforested, classed as tall forest or regenerating. This is done using spatial data on land cover (sourced from Land Cover Database version 5 (LCDB5) using the 2008 map year). These forest categories are defined in table 6.4.5. Tall forest deforestation emissions are determined from the average carbon stock per hectare in biomass for tall forests. Regenerating forest deforestation emissions are determined from the average carbon stock per hectare in biomass for regenerating forests. All carbon in biomass, for both tall and regenerating forest, is assumed in the calculations to be an instantaneous emission at the time of deforestation, because no information on the time lag of emissions from dead organic matter or below-ground biomass is currently available. Table 6.4.6 shows the areas of these two forest categories and table 6.4.7 shows the areas of pre-1990 natural forest deforestation split by these two forest types.

Table 6.4.5 Pre-1990 natural forest categories and description

Natural forest category	Description
Tall	Made up of two LCDB5 classes: 1. indigenous forest; tall forest dominated by indigenous conifer, broadleaved or beech species; 2. broadleaved indigenous hardwoods; lowland scrub communities dominated by indigenous mixed broadleaved shrubs.
Regenerating	All other areas mapped as pre-1990 natural forest that fall outside the two LCDB5 classes above. Represents areas recovering from previous disturbances.

Note: LCDB5 = Land Cover Database version 5.

Table 6.4.6 Areas of tall and regenerating pre-1990 natural forest in 1990 and 2023

Pre-1990 forest sub-classification	Area of forest in 1990 (ha)	Area of forest in 2023 (ha)
Tall forest	6,688,090	6,667,201
Regenerating forest	1,124,867	1,076,743
Total	**7,812,957**	**7,743,944**

Table 6.4.7 New Zealand's pre-1990 natural forest deforestation area (ha), for natural forest categories, estimated by type, from 1990 to 2023

Natural forest type	1990–2007	2008–12	2013–17	2018–22	2023 P
Tall forest	9,440	2,641	1,882	1,181	236
Regenerating	23,535	5,182	2,306	1,670	334
Total	**32,974**	**7,823**	**4,189**	**2,851**	**570**

Note: P = provisional estimate. Columns may not total due to rounding.

Estimates of biomass burning emissions associated with deforestation are provided in section 6.11.8.

Deforestation emissions are reported in the relevant *Land converted to* category, as are all emissions from land-use change.

National forest inventory

New Zealand has established a sampling framework for forest inventory purposes based on an 8-kilometre national grid system (8 kilometres north–south by 8 kilometres east–west). The grid has a randomly selected origin and provides an unbiased framework for establishing plots for field and/or Light Detection and Ranging (LiDAR) measurements. The network is subdivided into a 4-kilometre grid for measurement of post-1989 forest. Forest monitoring plots are established and measured where a grid point falls on land mapped as forest land. Figure 6.4.5 and figure 6.4.6 show the distribution of carbon monitoring plots for pre-1990 natural and planted forest and post-1989 natural and planted forest throughout New Zealand. A further description of the plot network can be found in annex 5, section A5.2.5 'National forest inventory'.

Figure 6.4.5 Locations of New Zealand's pre-1990 forest carbon monitoring plots

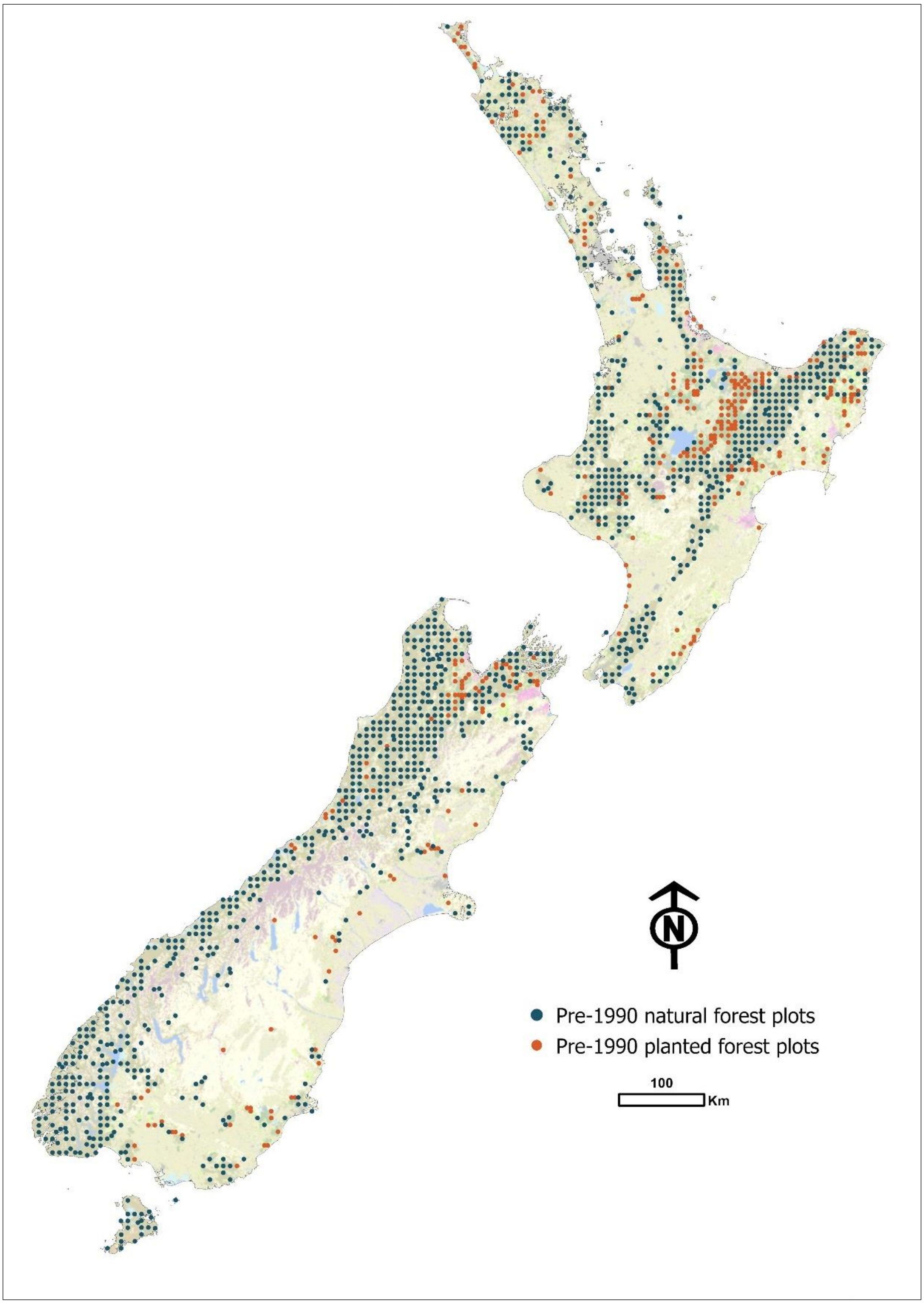
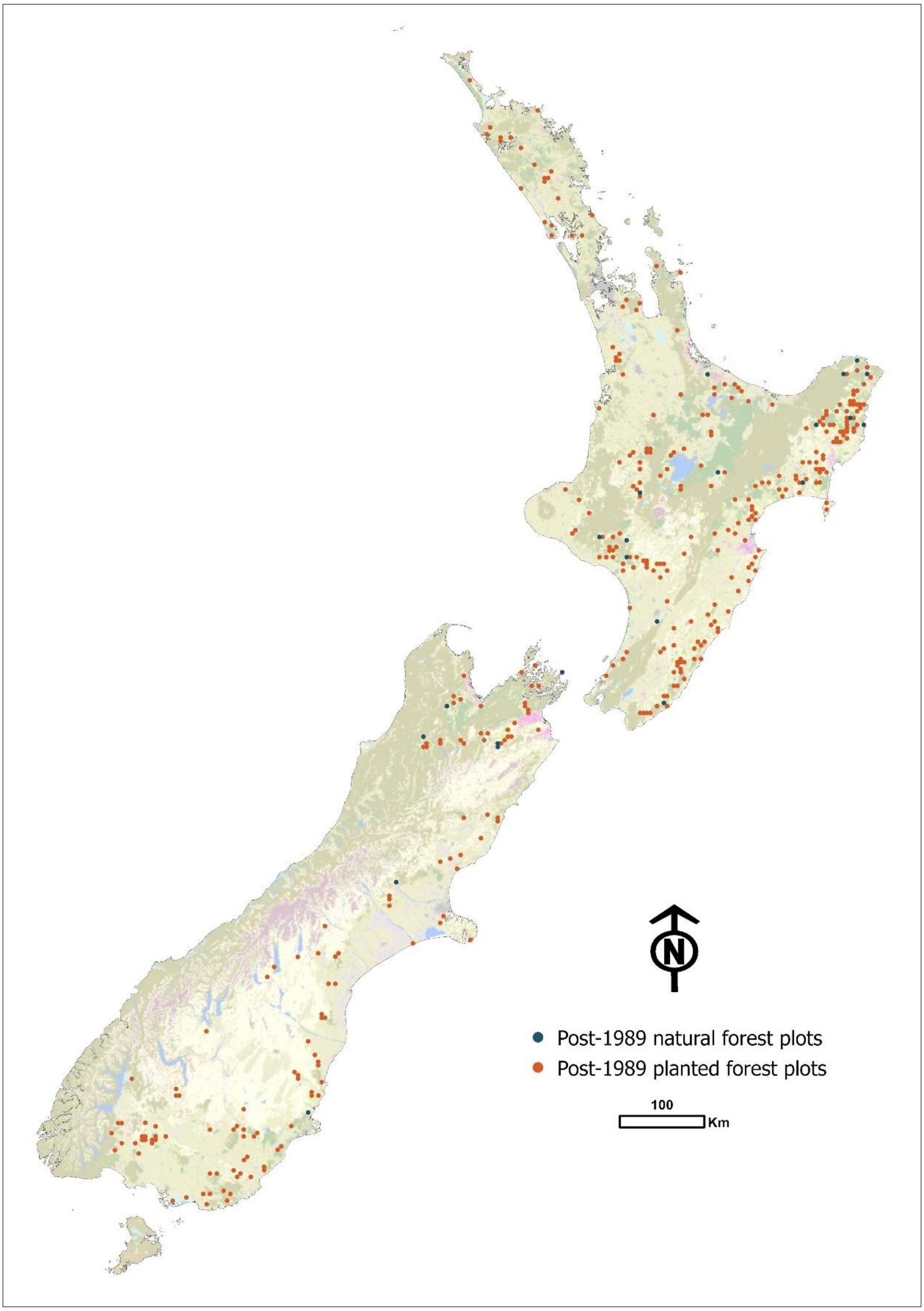


Figure 6.4.6 Locations of New Zealand's post-1989 forest plots



Forest land remaining forest land (4.A.1)

Living biomass and dead organic matter

Emissions and removals for the living biomass and dead organic matter pools have been calculated using Tier 2 and Tier 3 methods. At each forest plot, data are collected to calculate the volumes of trees, shrubs and dead organic matter present. These measurements are then used to estimate the carbon stocks for the biomass pools of:

- living biomass (comprising above-ground biomass and below-ground biomass)
- dead organic matter (comprising dead wood and litter).

The method used to calculate the carbon stock in each biomass pool from the information collected at each plot, for each forest classification, is summarised in table 6.4.8.

Carbon stocks in natural forest are estimated directly from the inventory plots. Further detail on methods can be found in annex 5, section A5.2.5 'National forest inventory'.

The carbon stocks for pre-1990 and post-1989 planted forest are calculated from yield tables derived from the inventory plots, which are then applied to an estimated age-class distribution. The yield tables are based on plots measured in 2021 and 2022 combined with all other plots measured since 2007, which are created using interpolation for multiple measurements (Paul et al., 2024)

A single yield table is applied to the post-1989 planted forest estate and two period-specific yield tables are applied to the pre-1990 planted forest estate based on plant date: pre-1990 forest planted before 1990 and pre-1990 forest planted from 1990 onwards.

The use of period-specific yield tables allows for a more accurate estimate of carbon stock gains and losses from planted forests through time. The planted forest yield tables (presented in annex 5, section A.5.2.5 'Planted forest yield tables') show that pre-1990 planted forests planted after 1990, have the highest total biomass yield when compared with similarly aged pre-1990 planted forests planted before 1990, and post-1989 forests. In general, re-planted pre-1990 forests with younger trees show greater productivity (fast early growth), due to genetic improvements in stock planted recently, relative to stock planted more than 20 years ago (Paul et al., 2024). However, plots with slower growing tree species, such as Douglas fir, cypresses, coastal redwood and slower growing *Eucalyptus* species, are an increasing part of the post-1989 estate, reducing the overall sequestration rate for this forest type, compared with pre-1990 planted forests. Less productive species are likely to be managed on longer rotations, and this can result in older age classes being dominated by relatively slow growing plots, lowering the combined species yield trajectory (Paul et al., 2024).

Where there has been a land-use change between natural forest and planted forest, the associated carbon changes are reported under *Forest land remaining forest land*, provided the forest has already been established for 20 years.

Where pre-1990 forest has undergone a deforestation event, changed to a different land use (such as *Grassland*), and then subsequently undergone another land-use change back to *Forest land*, the land use will be classified as pre-1990 forest. This is in line with the category definitions outlined in table 6.2.2.

Detailed methodology on the plot network, sampling methods and yield table derivation, as well as validation of the yield tables with the measured plot data, can be found in annex 5, section A5.2.5 'National forest inventory' and section A5.2.5 'Forest land model validations'.

Table 6.4.8 Summary of methods used to calculate New Zealand's forest biomass carbon stock from plot data

	Pool		Method	Source
Pre-1990 natural forest	**Living biomass**	Above-ground biomass	Plot measurements; allometric equations	Paul et al. (2021)
		Below-ground biomass	Estimated as the ratio of below-ground biomass to above-ground biomass	Paul et al. (2021); Easdale et al. (2019)
	Dead organic matter	Dead wood	Modelled from plot measurements; allometric equations	Garrett et al. (2019); Paul et al. (2021); Kimberley et al. (2019)
		Litter	Plot samples; laboratory analysis of samples collected at plots	Paul et al. (2021); Garrett (unpublished)
Post-1989 natural forest	**Living biomass**	Above-ground biomass	Plot measurements; allometric equations	Paul et al. (2021)
		Below-ground biomass	Estimated as the ratio of below-ground biomass to above-ground biomass	Paul et al. (unpublished); Easdale et al. (2019)
	Dead organic matter	Dead wood	Modelled from plot measurements; allometric model	Garrett et al. (2019); Paul et al. (unpublished); Kimberley et al. (2019)
		Litter	Allometric model and percentage of above-ground biomass	Paul et al. (unpublished); Garrett (unpublished)
Pre-1990 planted forest	**Living biomass**	Above-ground biomass	Modelled through allometric equations, then included in national yield tables	Paul et al. (2024)
		Below-ground biomass	Estimated as the ratio of below-ground biomass to above-ground biomass	Paul et al. (2024)
	Dead organic matter	Dead wood	Allometric model using plot measurements, included in national yield tables. Harvest residues added to dead wood pool through CRA	Paul et al. (2024)
		Litter	Allometric model and percentage of above-ground biomass	Paul et al. (2024)
Post-1989 planted forest	**Living biomass**	Above-ground biomass	Modelled through allometric equations, then included in national yield tables	Paul et al. (2024)
		Below-ground biomass	Estimated as the ratio of below-ground biomass to above-ground biomass	Paul et al. (2024)
	Dead organic matter	Dead wood	Allometric model using plot measurements, included in national yield tables. Harvest residues added to dead wood pool through CRA	Paul et al. (2024)
		Litter	Allometric model and percentage of above-ground biomass	Paul et al. (2024)

Note: CRA = Calculation and Reporting Application.

Soil organic carbon

Soil organic carbon stocks in *Forest land remaining forest land* are estimated using a Tier 2 method for mineral soils, as described in annex 5, section A5.2.4 'Mineral soils'.

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with the drainage of organic soils in managed forests (section 4.2.3.1, IPCC, 2006a). In New Zealand, natural forests are not drained and, therefore, oxidation processes associated with drainage are not occurring. It is therefore assumed that there are no carbon emissions from organic soils in pre-1990 natural forest land remaining pre-1990 natural forest land. A Tier 1 approach for pre-1990 planted, post-1989 planted and post-1989 natural *Forest land remaining forest land* is applied and is described further in annex 5, section A5.2.4 'Organic soils'.

Non-CO_2 emissions for Forest land

Direct and indirect N_2O emissions from fertilisation of forest land and disturbance associated with land use management conversion are described in section 6.11. Note that the calculations of indirect N_2O are not disaggregated by category and are therefore not included in the emission subtotals for *Forest land*.

Land converted to forest land (4.A.2)

All *Land converted to forest land* since 1 January 1990, either by planting or as a result of human-induced changes in land-management practice (e.g., removing grazing stock and actively facilitating the regeneration of tree species), is included as post-1989 forest. Post-1989 forest is split into two divisions for calculating emissions and removals: post-1989 natural forest and post-1989 planted forest.

The area of land converted to natural and planted forests is derived from a combination of land use mapping, national statistics and forestry scheme data. Further details on how the area of new forest establishment is calculated are provided in annex 5, section A5.2.2.

When non-forest land is converted to forest land, all carbon in living biomass that was present at the time of forest establishment is assumed to be instantly emitted as a result of forest establishment preparation, with the exception of *Grassland with woody biomass*. Conversions from *Grassland with woody biomass* to post-1989 natural forest represent ecological succession and do not involve the clearance of vegetation. A special case yield table (see annex 5, section A5.2.5, table A5.2.18) is used in these instances. This yield table has the same starting carbon stock as *Grassland with woody biomass*, therefore resulting in no net emissions occurring from biomass in the first year after conversion. This does not affect net CO_2 removals by the time the forest reaches the age of 30 years, but affects the year in which reported emissions and removals occur.

Of the non-forest land converted to post-1989 forest between 1990 and 2023, approximately 54.9 per cent has been converted from *Low producing grassland*, 19.1 per cent from *Grassland with woody biomass* and a further 25.4 per cent from *High producing grassland*. Note that the grassland type allocated to afforestation in non-mapped years is proportionally based on previously mapped years. *Grassland with woody biomass* provides the largest source of emissions associated with land-use change to planted forest, due to the amount of biomass present before land use conversion.

Details on the methods, plot network, sampling framework and biomass pools for both post-1989 planted and post-1989 natural forest are provided in annex 5, section A5.2.5 'National forest inventory'.

6.4.3 Uncertainty assessment and time-series consistency

The uncertainty in net carbon emissions from *Forest land* was 62.3 per cent in 2023. The uncertainty in net carbon emissions from *Forest land* accounted for 57.1 per cent of the total uncertainty in emissions from the LULUCF sector. The uncertainty associated with the emissions from each forest class is shown in table 6.4.9. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to the methodology.

Table 6.4.9 Uncertainty in carbon stock change emissions in 2023 from *Forest land*

	Emissions (kt CO_2-e)	Uncertainty in emissions (%)	Contribution to LULUCF uncertainty (%)
Pre-1990 planted forest	-14,185.3	69.4	48.8
Post-1989 planted forest	-2,110.1	225.9	23.6
Pre-1990 natural forest	-1,438.3	250.4	17.8
Post-1989 natural forest	-754.6	35.4	1.3
Total	**-18,488.3**	**62.3**	**57.1**

6.4.4 Category-specific QA/QC and verification

Carbon dioxide emissions from both *Forest land remaining forest land* and *Land converted to forest land* are key categories for both level and trend assessments. In the preparation of this inventory, the data for these emissions underwent Tier 1 QA and QC checks as well as Tier 2 category-specific QA and QC checks. Details of these checks are provided in annex 5, section A5.2.5 'National forest inventory'.

6.4.5 Category-specific recalculations

In this submission, New Zealand has recalculated its emission estimates for the whole LULUCF sector from 1990, including the *Forest land* category. These recalculations used improved activity data, incorporating minor updates to the 2020 land use map. The impact of the recalculations on net CO_2-e emission estimates for the *Forest land* category is provided in table 6.4.10. The differences shown are a result of recalculations for all carbon pools required in reporting for *Forest land* under the LULUCF sector.

Table 6.4.10 Recalculations of New Zealand's estimates for the *Forest land* category in 1990 and 2022

	2024 submission	2025 submission	Change from 2024 submission	Change (%)
Net emissions (kt CO_2-e)				
1990	-23,274.6	-23,279.5	-4.8	-0.0
2022	-17,250.8	-17,283.6	-32.8	-0.2
Area (hectares)				
1990	9,374,620	9,372,869	-1,751	-0.0
2022	10,094,149	10,092,678	-1,470	-0.0

Note: Areas are as at the end of the year indicated.

For *Forest land*, a number of improvements made to both the planted and natural forest activity data led to a recalculation across the time series. These are described in more detail below.

Activity data

The area estimates of afforestation and deforestation were updated for this submission, following updates to forestry scheme data and mapping improvements (see annex 5, section A5.2.2).

All deforestation is mapped up to 2020 and incorporated into the 2020 land use map. Minor corrections to deforestation mapping across the time series were made, leading to minor changes in total deforestation area for each year from 2008 to 2020 inclusive.

For pre-1990 natural forest and post-1989 natural forest, deforestation estimates for 2021 to 2023 were calculated as the average deforestation area for the last three mapped years (2018 to 2020), the same method applied in previous submissions. The updates made to the mapped years have therefore led to a recalculation of the deforestation estimates for 2021 and 2022.

Planted forest deforestation occurring from 2021 to 2023 was estimated using a trend extrapolation approach following the deforestation mapped in earlier years as described in annex 5, section A5.2.2. Mapping updates have resulted in a small reduction in the areas of deforestation estimated for 2021 and 2022.

The overall impact on emissions from changes to activity data for 2022 is a decrease of approximately 32.8 kt CO_2-e.

Planted forest – updates to yield tables and emissions calculations.

In this submission, there are no recalculations associated with planted forest yield tables. Yield tables for both pre-1990 planted forest and post-1989 planted forest were last updated for the 2023 submission (see annex 5, section A.5.2.5 'Planted forest yield tables').

Natural forest – updates to yield tables and emissions calculations

In this submission, there are no recalculations associated with natural forest yield tables. Yield tables for both pre-1990 natural forest and post-1989 natural forest were last updated for the 2022 submission (see annex 5, section A5.2.5 'Natural forest carbon stock change estimates and yield tables').

6.4.6 Category-specific planned improvements

Plot networks and yield tables

New Zealand will continue to measure the pre-1990 natural forest plot network on a 10-year cycle and analyse the data collected as they become available. An updated analysis is anticipated to be ready for the 2027 submission. The current post-1989 natural forest plot network was re-measured in 2023/24, with analysis and results planned for integration into the 2026 submission.

When sufficient data are available, an additional yield table will be developed for post-1989 natural forest. This will be produced by disaggregating data from plots dominated by exotic vegetation (typically *Pinus spp.* or 'wilding pines') from those dominated by native vegetation communities. The current method of including both vegetation types in the one yield table, due to a low sample size for the post-1989 natural forest (a total of 25 plots), limits its applicability in reporting carbon stock change and other areas of conservation and environmental management. At present, these yield tables should always be reported clearly as being the combination of both native and exotic post-1989 natural forest. Providing sufficient funding can be attained, the number of post-1989 natural forest plots surveyed will be increased in future to provide an overall sample large enough to separate into native and exotic communities and two respective yield tables.

The complete planted forest plot network (pre-1990 and post-1989) is being re-measured on a continuous basis (at five-year intervals). These data will be incorporated as they become available.

Natural forest plot data

Work has recently been undertaken to improve the quality of the LUCAS pre-1990 natural forest plot data through a data checking and correction project (Arnst and Vickers, unpublished; Arnst et al., unpublished). These corrections will enhance the robustness and repeatability of all subsequent analyses undertaken using these data. It is anticipated that these data will be included in the 2027 submission, following analysis of the full 10-year measurement cycle completed in 2024.

Electronic data capture by field teams was implemented from 2020 to 2021, supplementing the paper plot sheets previously used. Subsequently, QA/QC on the entire set of stem-related data (i.e., diameter, height, species) has been possible prior to upload into the database, improving on the 10 per cent previously checked manually. Electronic data capture has markedly improved data quality, and any errors in tree stem-related data can be readily identified when data are uploaded to the database.

Mapping and activity data

Mapping of forest areas will be improved through updates to the 2020 land use map. Planned forest-specific mapping improvements include mapping of newly planted forests through data supplied from government-funded forestry scheme mapping, including the NZ ETS, and identified in Sentinel-2 satellite imagery, as well as biennial deforestation mapping updates.

Planted forest model

Quality-assurance and quality-control processes for checking and improving consistency between different data sets are planned for a future submission. Currently, a few inconsistencies require further investigation and remediation. These inconsistencies include:

- the estimated annual volume removed from planted forests, based on the Calculation and Reporting Application model, is not entirely consistent with estimated annual roundwood volume statistics produced by MPI (Ministry for Primary Industries, 2023) for part of the time series (1990 to 2015). Note that a comparison between the two data sources across the time series was carried out and is further described in annex 5, section A5.2.5 'Forest land model validations'
- the pre-1990 planted forest average carbon stock per hectare estimated from the Calculation and Reporting Application model is greater than the average carbon stock per hectare estimated from plots in the forest inventory (further described in annex 5, section A5.2.5 'Forest land model validations')
- the pre-1990 planted forest yield tables have higher carbon stock per hectare estimates on average than plots measured in the planted forest inventory (further described in annex 5, section A5.2.5 'Forest land model validations').

6.5 Cropland (4B)

6.5.1 Description

In 2023, the net emissions from *Cropland* were 749.8 kt CO_2-e, comprising 722.5 kt CO_2 from carbon stock change and 0.1 kt N_2O (24.6 kt CO_2-e) from the nitrogen mineralisation on *Land converted to cropland*. Net emissions from *Cropland* have increased by 271.5 kt CO_2-e (56.8 per cent) from the 1990 level when net emissions were 478.3 kt CO_2-e (see table 6.5.1).

Table 6.5.1 New Zealand's land-use change by *Cropland* category, and associated CO_2-e emissions, 1990 and 2023

Land use category	Net area (ha) 1990	2023	Change from 1990 (%)	Net emissions (kt CO_2-e) 1990	2023	Change from 1990 (%)
Cropland remaining cropland	395,803	369,157	-6.7	352.9	256.1	-27.4
Land converted to cropland	28,302	128,082	352.6	125.4	493.7	293.8
Total	**424,104**	**497,239**	**17.2**	**478.3**	**749.8**	**56.8**

Note: Net area in 1990 is as at 1 January 1990; net area in 2023 is as at 31 December 2023. *Land converted to cropland* includes land converted up to 20 years earlier. Net emission values are for the whole year indicated. Values include carbon dioxide equivalent emissions from nitrous oxide from cultivation of land.

The *Land converted to cropland* category is responsible for the majority of *Cropland* emissions. This category comprised 25.8 per cent of all *Cropland* area in 2023.

Most emissions due to carbon stock change that have occurred in the *Cropland* category since 1990 are in the SOC pool (4,936.1 kt C) (see table 6.5.2). Within the SOC pool, the majority of changes in carbon stocks result from drained organic soils (3,434.1 kt C). This is because organic soils continue to lose carbon even after the 20-year transition period (IPCC, 2006a).

Table 6.5.2 New Zealand's carbon stock change by carbon pool for the *Cropland* category, from 1990 to 2023

Land use	Net carbon stock change 1990–2023 (kt C) by carbon pool: Living biomass	Dead organic matter	Soil organic carbon	Total	Emissions 1990–2023 (kt CO_2)
Annual cropland	-344.7	-13.9	-3,416.8	-3,775.3	13,842.8
Perennial cropland	413.1	-9.3	-1,519.3	-1,115.5	4,090.0
Total	**68.5**	**-23.1**	**-4,936.1**	**-4,890.8**	**17,932.8**

Note: This table includes carbon dioxide emissions from carbon stock change only (so it does not include emissions from nitrous oxide disturbance). The reported dead organic matter losses result from the loss of dead organic matter of woody land use categories on conversion to cropland. Columns may not total due to rounding.

Table 6.5.3 shows land-use change by *Cropland* land use since 1990, and the associated CO_2 emissions from carbon stock change. The *Cropland* category in New Zealand is separated into two land use types: annual and perennial. In 2023, annual cropland accounted for 1.4 per cent of total land area, and perennial cropland accounted for 0.4 per cent of total land area in New Zealand.

Annual crops include cereals, grains, oil seeds, vegetables, root crops and forages. Perennial crops include orchards, vineyards and their associated shelterbelts except where these shelterbelts meet the criteria for the *Forest land* category.

The amount of carbon stored in, emitted by or removed from *Cropland* depends on crop type, management practices, soil properties and climate variables. Annual crops are harvested each year, with little long-term storage of carbon in biomass. Woody vegetation in orchards stores more carbon in biomass, with the amount largely determined by the crop species and presence of shelterbelts.

Table 6.5.3 **New Zealand's land-use change by *Cropland* land use, and associated CO_2 emissions from carbon stock change, from 1990 to 2023**

Land use	Net area (ha) 1990	Net area (ha) 2023	Change from 1990 (%)	Net emissions (kt CO_2 only) 1990	Net emissions (kt CO_2 only) 2023	Change from 1990 (%)
Annual cropland	355,081	389,133	9.6	345.4	659.7	91.0
Perennial cropland	69,023	108,106	56.6	126.1	62.8	-50.2
Total	**424,104**	**497,239**	**17.2**	**471.5**	**722.5**	**53.2**

Note: Net area in 1990 is as at 1 January 1990; net area in 2023 is as at 31 December 2023. This table includes carbon dioxide emissions from carbon stock change only. Columns may not total due to rounding.

A summary of land-use change within the *Cropland* category, by land use type and land conversion status, is provided in table 6.5.4. This shows that land-use change within the *Cropland* category has been dominated by conversions to annual cropland.

Table 6.5.4 **New Zealand's land-use change for the *Cropland* category, from 1990 to 2023**

Cropland category		Net area (ha) 1990	Net area (ha) 2023	Change from 1990 (%)
Cropland remaining cropland	Annual remaining annual	333,599	272,778	-18.2
	Perennial remaining perennial	61,559	90,897	47.7
	Annual to perennial	645	4,469	592.9
	Perennial to annual	0	1,013	-
	Subtotal	*395,803*	*369,157*	*-6.7*
Land converted to cropland	Annual cropland	21,482	115,342	436.9
	Perennial cropland	6,820	12,740	86.8
	Subtotal	*28,302*	*128,082*	*352.6*
Total		**424,104**	**497,239**	**17.2**

Note: This table shows the change between 1 January 1990 and 31 December 2023. Columns may not total due to rounding.

In 2023, *Cropland remaining cropland* and *Land converted to cropland* were identified as key categories for the level and trend assessment in 2023.

6.5.2 Methodological issues

Emissions and removals for the living biomass and dead organic matter pools have been calculated using IPCC Tier 1 emission factors for annual cropland, Tier 2 emission factors for perennial cropland (Davis and Wakelin, unpublished) and activity data as described in section 6.2. Emissions and removals by the SOC pool are estimated using a Tier 2 method for mineral soils and IPCC Tier 1 defaults for organic soils, as described in annex 5, section A5.2.4.

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for the *Cropland* category is provided in table 6.5.5.

Table 6.5.5 Summary of New Zealand's carbon stock change emission factors for the *Cropland* category

Land use	Carbon pool	Steady state carbon stock (t C ha^{-1})	Annual carbon stock change (t C ha^{-1})	Years to reach steady state	Source
Annual	Biomass				
	Living biomass	5.0	NA	1	IPCC default (table 5.9, IPCC, 2006a)
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral	89.77	*	20	New Zealand-specific EF (McNeill and Barringer, unpublished)
	Organic	NE	-5.0 or -10.0**		IPCC Tier 1 default (table 5.6, IPCC, 2006a)
Perennial	Biomass				
	Living biomass	18.76	0.67	28	New Zealand-specific EF (Davis and Wakelin, unpublished)
	Dead organic matter	NE	NE	NA	No IPCC guidelines
	Soils				
	Mineral	88.44	*	20	New Zealand-specific EF (McNeill and Barringer, unpublished)
	Organic	NE	-5.0 or -10.0**		IPCC Tier 1 default (table 5.6, IPCC, 2006a)

Note: EF = emission factor; NA = not applicable; NE = not estimated. * Annual carbon stock change in mineral soils on land undergoing land-use change will depend on the land use category the land has been converted to or from; see annex 5, section A5.2.4 'Mineral soils'. ** The emission factor for organic soils is -5.0 tonnes C ha^{-1} yr^{-1} for cold temperate regions and -10.0 tonnes C ha^{-1} yr^{-1} for warm temperate regions.

Cropland remaining cropland (4.B.1)

For *Cropland remaining cropland*, the Tier 1 assumption is that for annual cropland there is no change in biomass carbon stocks after the first year (IPCC, 2006a, section 5.2.1). The rationale is that the increase in biomass stocks in a single year is equal to the biomass losses from harvest and mortality in that same year. For perennial cropland, there is a change in carbon stocks associated with a land-use change. Where land-use change has occurred between the *Cropland* land use categories, carbon stock changes are reported in *Cropland remaining cropland*.

Living biomass

To estimate carbon stock change in living biomass for annual cropland converted to perennial cropland, New Zealand is using Tier 1 defaults for biomass carbon stocks at harvest (table 5.9, IPCC, 2006a). The Tier 1 method for estimating carbon change assumes carbon stocks in biomass immediately after conversion are zero; that is, the land is cleared of all vegetation before planting crops (5.0 tonnes C ha^{-1} is instantly oxidised in the year of conversion).

To estimate growth after conversion of annual cropland to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 tonnes C ha^{-1} yr^{-1}. This value is based on the New Zealand-specific value of 18.76 tonnes C ha^{-1} (Davis and Wakelin, unpublished) sequestered over 28 years. It is assumed any biomass gains after this 28-year period are compensated for by biomass loss from pruning and other management practices, resulting in a net zero change in biomass stock of perennial cropland remaining perennial cropland.

The assumption of net zero change in biomass stock after 28 years may be overly simplistic, as outlined by the ERT recommendation L.21, 2019 (FCCC/ARR/2019/NZL, UNFCCC, 2020). However, activity data for biomass stock change beyond 28 years, or temporary destocking, are not available annually. Collection of these data is unlikely in the short to medium term because the funding required for research and method development is being prioritised for the *Forest land* category.

The available activity data do not provide information on areas of perennial cropland temporarily destocked; therefore, no losses in carbon stock due to temporary destocking are reported. Consequently, no gains in these areas are reported either when they are restocked.

Dead organic matter

New Zealand does not report estimates of dead organic matter in this category. The notation key NE (not estimated) is used in the CRTs, in accordance with paragraph 37(b) of Decision 24/CP.19 (UNFCCC, 2014). There is insufficient information to provide a basic approach with default parameters to estimate carbon stock change in dead organic matter pools in *Cropland remaining cropland* and, consequently, no Tier 1 method is provided (IPCC, 2006a).

Soil organic carbon

Soil organic carbon stocks in mineral soil for *Cropland remaining cropland* are estimated using a Tier 2 method (see annex 5, section A5.2.4 'Mineral soils'). For organic soils, loss of soil carbon is estimated using the Tier 1 method as described in annex 5, section A5.2.4 'Organic soils'.

Mineral soil carbon change for annual cropland converted to perennial cropland and vice versa is estimated using the IPCC default method of applying a linear rate of change over 20 years (equation 2.25, IPCC, 2006a).

Non-CO_2 emissions

All direct and indirect N_2O emissions occurring from management activities in *Cropland remaining cropland* are reported under the Agriculture sector.

Land converted to cropland (4.B.2)

Living biomass

New Zealand uses a Tier 1 method, and a combination of IPCC default and New Zealand-specific emission factors, to calculate emissions for *Land converted to cropland*. The Tier 1 method multiplies the area of *Land converted to cropland* annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass and dead organic matter immediately after conversion is zero; that is, the land is cleared of all vegetation before planting crops. The amount of biomass cleared when land at steady state is converted is dependent on the land use category undergoing the conversion and is described further under each category-specific section in this chapter.

The Tier 1 method also includes changes in carbon stocks from one year of growth in the year conversion takes place, as outlined in equation 2.5 of the 2006 IPCC Guidelines (IPCC, 2006a).

To estimate growth after conversion to annual cropland, New Zealand uses the IPCC default biomass accumulation rate of 5.0 tonnes C ha^{-1} for the first year following conversion (table 5.9, IPCC, 2006a). After the first year, any increase in biomass stocks in annual cropland is assumed equal to biomass losses from harvest and mortality in that same year and, therefore, after the first year there is no net accumulation of biomass carbon stocks in annual cropland remaining annual cropland (section 5.2.1, IPCC, 2006a).

To estimate growth after conversion to perennial cropland, New Zealand uses the biomass accumulation rate of 0.67 tonnes C ha^{-1} yr^{-1} until 18.76 tonnes C ha^{-1} is reached, as described in the *Cropland remaining cropland* section above. The final eight years of biomass gain are reported in *Cropland remaining cropland* because the 2006 IPCC Guidelines (IPCC, 2006a) default transition period of 20 years has been applied across the entire LULUCF sector.

Dead organic matter

New Zealand reports only losses in dead organic matter associated with the previous land use for this category. The losses are calculated based on the carbon in dead organic matter at the site before conversion to *Cropland*. It is assumed that, immediately after conversion, dead organic matter is zero (all carbon in dead organic matter before conversion is instantly oxidised in the year of conversion). There is insufficient information to estimate gain in carbon stock in dead organic matter pools after land is converted to *Cropland* (IPCC, 2006a). Consequently, where there are no dead organic matter losses associated with the previous land use, the notation key NA (not applicable) is used in the CRTs in accordance with Decision 24/CP.19 (UNFCCC, 2014) because a given source and/or sink category does not result in emissions or removals of a specific gas.

Soil organic carbon

Soil organic carbon stocks in *Land converted to cropland* are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils (see annex 5, section A5.2.4, for further information).

Non-CO_2 emissions

Nitrous oxide emissions from disturbance associated with land use conversion to *Cropland* and land use management are described in section 6.11.

6.5.3 Uncertainty assessment and time-series consistency

The uncertainty in net carbon emissions from *Cropland* was 57.3 per cent in 2023. The uncertainty in net carbon emissions from *Cropland* accounted for 2.0 per cent of the total uncertainty in emissions from the LULUCF sector. The uncertainty associated with the emissions from each *Cropland* class is shown in table 6.5.6. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to methodology.

Table 6.5.6 Uncertainty in net carbon stock change emissions in 2023 for the *Cropland* category

Land use	Emissions (kt CO_2-e)	Uncertainty in emissions (%)	Contribution to LULUCF uncertainty (%)
Annual cropland	659.7	61.1	2.0
Perennial cropland	62.8	147.3	0.5
Total	**722.5**	**57.3**	**2.0**

6.5.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for CO_2 emissions from the *Land converted to cropland* category underwent Tier 1 quality checks. *Cropland remaining cropland* and *Land converted to cropland* were identified as key categories for the level and trend assessment in 2023. As part of verification of the New Zealand-specific above-ground biomass emission factor for perennial cropland, this factor has been compared with the IPCC default for temperate perennial cropland (table 5.1, IPCC, 2006a). The New Zealand value for above-ground biomass of 18.76 tonnes C ha^{-1} is much lower than the default value of 63 tonnes C ha^{-1} provided in the 2006 IPCC Guidelines (IPCC, 2006a). Further research into the differences between the values has shown the IPCC default value is based on just four studies of agroforestry systems where crops are grown in rotation with trees and none of these studies is New Zealand specific. The country-specific emission factor used is based on a New Zealand study, taking into account that New Zealand's main perennial crops are not grown in rotation with trees (i.e., are not part of an agroforestry system) and that a significant proportion of New Zealand's main perennial crops are vine fruit, such as kiwifruit and grapes (Davis and Wakelin, unpublished). This means the country-specific value has lower carbon stocks per hectare in living biomass at maturity than the *Cropland* types included in the study on which the IPCC default value is based.

6.5.5 Category-specific recalculations

Recalculations of the entire time series were carried out for this category as a result of updated activity data resulting from minor improvements to land use mapping. The impact of recalculations on net CO_2-e emission estimates for the *Cropland* category is shown in table 6.5.7.

Table 6.5.7 Recalculations of New Zealand's net emissions from the *Cropland* category in 1990 and 2022

	2024 submission	2025 submission	Change from 2024 submission	Change (%)
Net emissions (kt CO_2-e)				
1990	476.3	478.3	2.0	0.4
2022	711.9	709.1	-2.8	-0.4
Area (hectares)				
1990	426,588	426,841	253	0.1
2022	490,148	489,844	-304	-0.1

Note: Columns may not total due to rounding.

6.5.6 Category-specific planned improvements

A longitudinal study on the impact of management practices on *Grassland* and *Cropland* soils is under way (Manaaki Whenua Landcare Research, 2020). This study will collect time-series data on a network of 500 soil sample plots over 12 years. This is likely to improve the SOC reference values for *Cropland* and help address L.12, 2023 raised in the ERT review report of the 2022 submission (FCCC/ARR/2022/NZL, UNFCCC, 2023). These data are not expected to be available for several years.

In isolation, the above-mentioned study may help improve SOC reference values but will not address review recommendation L.1, 2023 raised in the ERT review report of the 2022 submission (FCCC/ARR/2022/NZL, UNFCCC, 2023). The report questioned whether the estimated SOC reference values were systematically overestimated or underestimated given that land-use change is most likely to occur on a subset of each land use category. The current soils model also assumes land use management practices are static and cannot be updated to include activity data on improvements in soil management practices. However, funding has been acquired to update the Soil CMS and therefore will help address review recommendation L.1, 2023 (FCCC/ARR/2022/NZL, UNFCCC, 2023). This work will improve New Zealand's soil carbon stock change estimates in *Cropland* and other categories by developing a new modelling approach and addressing key measurement gaps. This work will substantially improve the accuracy of soil carbon estimates and provide a framework to include management effects within land uses. The data will be incorporated into the NIR as they become available.

6.6 Grassland (4C)

6.6.1 Description

In 2023, the net emissions from *Grassland* were 2,884.2 kt CO_2-e (see table 6.6.1). These emissions comprise 2,854.1 kt CO_2 emissions from carbon stock change, 0.06 kt N_2O (14.9 kt CO_2-e) and 0.5 kt CH_4 (15.3 kt CO_2-e) emissions from *Biomass burning* and nitrogen mineralisation on *Land converted to grassland*.

Net emissions from *Grassland* have increased by 2,064.3 kt CO_2-e (251.8 per cent) from the 1990 level of 819.9 kt CO_2-e (see table 6.6.1). The majority of this change occurred in post-1989 planted forest that has since been converted to high producing grassland and is the result of deforestation that involves large losses in the living biomass pool.

The *Grassland remaining grassland* and *Land converted to grassland* categories were identified as key categories for the level and trend assessment in 2023.

Table 6.6.1 New Zealand's land-use change for the *Grassland* category, and associated CO_2-e emissions, from 1990 to 2023

	Net area (ha)			Net emissions (kt CO_2-e)		
Land use category	1990	2023	Change from 1990 (%)	1990	2023	Change from 1990 (%)
Grassland remaining grassland	14,904,468	14,040,424	-5.8	309.6	1,327.1	328.7
Land converted to grassland	351,768	292,818	-16.8	510.4	1,557.1	205.1
Total	**15,256,236**	**14,333,242**	**-6.0**	**819.9**	**2,884.2**	**251.8**

Note: Net area in 1990 is as at 1 January 1990; net area in 2023 is as at 31 December 2023. *Land converted to grassland* includes land converted up to 20 years earlier. Net emission estimates are for the whole year indicated. Columns may not total due to rounding.

In New Zealand, the *Grassland* category is used to describe a range of land cover types. In this submission, three types of *Grassland* are used: high producing, low producing, and with woody biomass. Detailed descriptions of each *Grassland* type can be found in table 6.2.2 and are briefly summarised below:

- *High producing grassland* – intensively managed pasture land
- *Low producing grassland* – low-fertility grasses on hill country, areas of native tussock and areas composed of low, shrubby vegetation, both above and below the timberline
- *Grassland with woody biomass* – grassland areas where the cover of woody species is less than 30 per cent and/or does not meet, nor has the potential to meet, the New Zealand forest definition due to the current management regime (e.g., periodically cleared for grazing), or due to characteristics of the vegetation or environmental constraints (e.g., alpine shrubland).

Grassland with woody biomass is a diverse land use and has therefore been disaggregated into two types: permanent (51.1 per cent) and transitional (48.9 per cent), as described in table 6.6.2. A grid-based assessment of *Grassland with woody biomass* was used to determine this disaggregation; this was done through a combination of plot measurements and virtual assessments of grid points where plots did not exist (Wakelin and Beets, unpublished). Separate emission factors for each type of *Grassland with woody biomass* are derived from the LUCAS national plot network (Wakelin and Beets, unpublished). Within the CRTs, reporting on *Grassland with woody biomass* is at the aggregate level.

Table 6.6.2 *Grassland with woody biomass* categories and description

Grassland with woody biomass categories	Description	Expected occurrence
Transitional	Areas of woody shrublands within farmland that do not become forest over a 30- to 40-year timeframe (Trotter and MacKay, unpublished).	Where livestock grazes areas of woody shrubland or where woody shrubland is managed in other ways (e.g., spraying) to prevent it from becoming forest.
Permanent	Land covered by woody vegetation that does not meet the forest definition and is not expected to do so under current ecological, management or environmental conditions.	Where abiotic conditions at a site are conducive to low-stature vegetation; for example, vegetation growing at high altitudes, on low-fertility soil or on frost flats.

In 2023, there were 6,736,718 hectares of *High producing grassland* (25.0 per cent of total land area), 6,252,599 hectares of *Low producing grassland* (23.2 per cent of total land area) and 1,343,924 hectares of *Grassland with woody biomass* (5.0 per cent of total land area). The area of *Grassland with woody biomass* comprises 479,355 hectares of permanent and 864,569 hectares of transitional *Grassland with woody biomass*.

From 1990 to 2023, the net carbon stock change attributed to *Grassland* was a loss of 47,310.3 kt C, equivalent to 173,471.1 kt CO_2 emissions (see table 6.6.3). The majority of these emissions are due to the loss of living biomass carbon stock associated with *Forest land* conversion to *Grassland* (deforestation).

Table 6.6.3 New Zealand's carbon stock change by carbon pool for the *Grassland* category, from 1990 to 2023

Land use	Net carbon stock change 1990–2023 (kt C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2023 (kt CO_2)
Grassland – high producing	-18,785.7	-2,323.8	-9,520.5	-30,630.0	112,310.1
Grassland – low producing	-10,640.7	-1,419.4	720.1	-11,340.0	41,580.1
Grassland – with woody biomass	-3,736.3	-647.6	-956.4	-5,340.3	19,580.9
Total	**-33,162.7**	**-4,390.8**	**-9,756.8**	**-47,310.3**	**173,471.1**

Note: Columns may not total due to rounding.

Grassland remaining grassland

There were 14,040,424 hectares of *Grassland remaining grassland* as at 2023, equivalent to 52.1 per cent of New Zealand's total land area.

Land converted to grassland

In 2023, an estimated 10,176 hectares of land were converted to *Grassland*, while 98,822 hectares of *Grassland* were converted to other land use categories.

The majority (69.3 per cent) of *Land converted to grassland* since 1 January 1990 is land that was previously *Forest land*. The 241,743 hectares of *Forest land* converted to *Grassland* since 1 January 1990 comprise an estimated 132,834 hectares of pre-1990 planted forest, 60,886 hectares of post-1989 planted forest, 46,189 hectares of pre-1990 natural forest and 1,834 hectares of post-1989 natural forest. For more information on deforestation, see annex 5, section A5.2.2. Land-use change of *Forest land* to *Grassland* resulted in net emissions of 1,798.1 kt CO_2 in 2023.

6.6.2 Methodological issues

Emissions and removals from living biomass and dead organic matter have been calculated using a combination of IPCC Tier 1 emission factors and country-specific factors (see table 6.6.4). Emissions and removals from mineral soils are estimated using a Tier 2 method, whereas organic soils are estimated using a Tier 1 method (see annex 5, section A5.2.4).

Table 6.6.4 Summary of New Zealand's biomass emission factors for *Grassland*

Land use	Carbon pool	Steady state carbon stock (t C ha^{-1})	Annual carbon accumulation (t C ha^{-1})	Years to reach steady state	Source
High producing	**Total biomass**	**6.345**	**6.345**	**1**	IPCC (2006a), table 6.4
	Living biomass				
	AGB	1.269	1.269	1	
	BGB	5.076	5.076	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
Low producing	**Total biomass**	**2.867**	**2.867**	**1**	IPCC (2006a), table 6.4
	Living biomass				
	AGB	0.752	0.752	1	
	BGB	2.115	2.115	1	
	Dead organic matter	NE	NA	NA	No IPCC guidelines
With woody biomass – transitional	**Total biomass**	**13.05**	**0.48**	**20**	Wakelin and Beets (unpublished)
	Living biomass				
	AGB	9.35	0.36	20	
	BGB	3.05	0.08	20	
	Dead organic matter				
	Dead wood	0.10	0.004	20	
	Litter	0.55	0.02	20	
With woody biomass – permanent	**Total biomass**	**60.57**	**NO**	**NO**	Wakelin and Beets (unpublished)
	Living biomass				
	AGB	45.18	NO	**NO**	
	BGB	11.71	NO	**NO**	
	Dead organic matter			**NO**	
	Dead wood	3.68	NO	**NO**	
	Litter	0.00	NO	**NO**	

Note: AGB = above-ground biomass; BGB = below-ground biomass; NA = not applicable; NE = not estimated; NO = not occurring. Columns may not total due to rounding. The *High producing grassland* figure is based on the Warm temperate – wet figure from table 6.4 of the 2006 IPCC Guidelines, and the *Low producing grassland* figure is based on the Warm temperate – dry figure from the same table (IPCC, 2006a), with a carbon fraction of 0.47 applied to both. Note that the annual accumulation rates for *Grassland with woody biomass* – transitional do not equal the total biomass steady state carbon stock value over 20 years because the starting stock value at year 1 is 3.54 tonnes C ha^{-1}.

Grassland remaining grassland (4.C.1)

For *Grassland remaining grassland*, the Tier 1 assumption is there is no change in carbon stocks for *Grassland* remaining in the same *Grassland* category (section 6.2.1.1, IPCC, 2006a). The rationale is that, where management practices are static, carbon stocks will be in an approximately steady state; that is, carbon gain through plant growth is roughly balanced by losses from management. New Zealand has reported NA in the CRTs where there is no land-use change at the category level because no emissions or removals are assumed to have occurred. However, a significant area (427,856 hectares) is currently in a state of conversion from one *Grassland* type to another. The carbon stock changes for these land-use changes are reported under *Grassland remaining grassland*.

Living biomass

To calculate carbon stock change in living biomass on land converted from one *Grassland* category to another (e.g., *Low producing grassland* converted to *High producing grassland*), it is assumed the carbon in living biomass immediately after conversion is zero; that is, the land is cleared of all vegetation. In the same year, carbon stocks in living biomass increase by the amount given in table 6.6.4, representing the annual growth in biomass for land converted to another land use.

Dead organic matter

New Zealand does not report estimates of dead organic matter for *High producing grassland* or *Low producing grassland* because there are no Tier 1 defaults provided in the 2006 IPCC Guidelines (IPCC, 2006a). There is insufficient information to develop default coefficients for estimating the dead organic matter pool for these two categories (IPCC, 2006a). The notation key NE is used in the CRTs.

For *Grassland with woody biomass*, an estimate of dead organic matter is derived from the LUCAS national plot network (Wakelin and Beets, unpublished), and estimates of changes in dead organic matter stocks with conversion to and from this land use are reported.

Soil organic carbon

Soil organic carbon stocks in *Grassland remaining grassland* are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils (see annex 5, section A5.2.4).

Non-CO_2 emissions

Direct and indirect N_2O emissions occurring as a result of nitrogen inputs, as well as drainage of managed soils, in *Grassland remaining grassland* are reported under the Agriculture sector.

Land converted to grassland (4.C.2)

Living biomass

New Zealand applies a Tier 1 method to calculate emissions for *Land converted to grassland*. The Tier 1 method multiplies the area of *Land converted to grassland* annually by the carbon stock change per area for that type of conversion.

The Tier 1 method assumes carbon in living biomass immediately after conversion is zero; that is, the land is cleared of all vegetation at conversion and is instantly oxidised. The Tier 1 method also includes changes in carbon stocks from one year of growth from the *Grassland* category that land was converted to in the year conversion takes place, as outlined in equation 2.9 of the 2006 IPCC Guidelines (IPCC, 2006a).

Dead organic matter

For land conversion to *High producing grassland* and *Low producing grassland*, New Zealand reports only losses in dead organic matter. The losses are calculated based on the carbon in dead organic matter at the site before conversion to *Grassland*. It is assumed that, immediately after conversion, the carbon in the dead organic matter pool is zero (all carbon in dead organic matter before conversion is instantly oxidised in the year of conversion). New Zealand applies the Tier 1 default method to high and low producing grassland land uses, which assumes there is no dead wood or litter accumulating in *Land converted to grassland* (IPCC, 2006a). Therefore, where there are no dead organic matter losses associated with the previous land use, the notation key NE is used in the CRTs, in accordance with Decision 24/CP.19 (UNFCCC, 2014).

Where land is converted to *Grassland with woody biomass*, dead organic matter accumulates to 0.65 tonnes C ha^{-1} (see table 6.6.4) over 20 years (the IPCC default period for land to reach steady state (IPCC, 2006a)).

Soil organic carbon

Soil organic carbon stocks in *Land converted to grassland* are estimated using a Tier 2 method for mineral soils and a Tier 1 method for organic soils (see annex 5, section A5.2.4).

Non-CO_2 emissions

Nitrous oxide emissions from disturbance associated with land use conversion to *Grassland* and land use management are described in section 6.11.

6.6.3 Uncertainty assessment and time-series consistency

The uncertainty in net carbon emissions from *Grassland* was 40.9 per cent in 2023. The uncertainty in net carbon emissions from *Grassland* accounted for 5.8 per cent of the total uncertainty in emissions from the LULUCF sector. The uncertainty associated with the emissions from each *Grassland* class is shown in table 6.6.5. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to methodology.

Table 6.6.5 Uncertainty in carbon stock change emissions in 2023 for *Grassland*

	Emissions (kt CO_2-e)	Uncertainty in emissions (%)	Contribution to LULUCF uncertainty (%)
Grassland – low producing	1,792.7	63.0	5.6
Grassland – high producing	663.4	22.1	0.7
Grassland – with woody biomass	398.0	65.2	1.3
Total	**2,854.1**	**40.9**	**5.8**

6.6.4 Category-specific QA/QC and verification

Emissions from the *Grassland remaining grassland* and *Land converted to grassland* categories are key categories (level and trend). In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

6.6.5 Category-specific recalculations

Recalculations of the entire time series were carried out for this category as a result of updates to activity data, including deforestation estimates. The impact of recalculations on net CO_2-e emission estimates for the *Grassland* category is shown in table 6.6.6. The recalculation indicates a 2.6 per cent reduction in emissions for 2022, which is primarily driven by a small reduction in the planted forest deforestation estimates for 2022 (see table A9.4.3, annex 9).

Table 6.6.6 **Recalculations of New Zealand's net emissions from the *Grassland* category in 1990 and 2022**

	2024 submission	2025 submission	Change from 2024 submission	Change (%)
Net emissions (kt CO_2-e)				
1990	826.2	819.9	-6.2	-0.8
2022	3,665.7	3,568.9	-96.8	-2.6
Area (hectares)				
1990	15,237,917	15,239,673	1,756	0.0
2022	14,419,970	14,421,888	1,918	0.0

6.6.6 Category-specific planned improvements

A longitudinal study on the impact of management practices on soil carbon stocks in *Grassland* and *Cropland* is under way, along with improvements to the Soil CMS. This is further described in section 6.5.6.

6.7 Wetlands (4D)

6.7.1 Description

In 2023, there were 7.5 kt CO_2-e net emissions from *Wetlands*, compared with net emissions of -8.3 kt CO_2-e from *Wetlands* in 1990 (see table 6.7.1). This changing trend, from net remover in 1990 to net emitter in 2023, is due to a shift in land-use change patterns that has been observed since 1990, when compared with the changes that had occurred before 1990.

As of 2023, there were 7,238 hectares in a state of conversion to *Wetlands* (see table 6.7.1). These lands have been converted to *Wetlands* during the previous 20 years but have not yet reached steady state.

Removals from the *Wetlands* category are driven by increases to mineral soil carbon stocks following conversions to wetland (4.4 kt CO_2-e of removals in 2023 from mineral soils), while emissions are driven by the extraction of peat each year.

Table 6.7.1 **New Zealand's land-use change for the *Wetlands* category, and associated CO_2-e emissions, in 1990 and 2023**

	Net area (ha)			Net emissions (kt CO_2-e)		
Land use category	1990	2023	Change from 1990 (%)	1990	2023	Change from 1990 (%)
Wetlands remaining wetlands	770,745	774,100	0.4	11.5	22.5	95.3
Land converted to wetlands	10,276	7,238	-29.6	-19.8	-15.0	24.1
Total	**781,021**	**781,338**	**0.0**	**-8.3**	**7.5**	**190.4**

Note: Net area in 1990 is as at 1 January 1990; net area in 2023 is as at 31 December 2023. *Land converted to wetlands* includes land converted up to 20 years earlier. Net emission values are for the whole year indicated. Columns may not total due to rounding.

New Zealand's *Wetlands* are currently mapped into two types: open water, which includes artificially flooded lands, lakes and rivers; and vegetated wetland, which includes herbaceous vegetation that is periodically flooded, and estuarine and tidal areas. Flooded lands, a category of *Wetlands*, are defined in the 2006 IPCC Guidelines (IPCC, 2006a, p 7.19) as:

> … water bodies where human activities have caused changes in the amount of surface area covered by water, typically through water level regulation. … Regulated lakes and rivers that do not have substantial changes in water area in comparison with the pre-flooded ecosystem are not considered as Flooded Lands.

The majority of New Zealand's hydroelectric schemes are based on rivers and lakes where the main pre-flooded ecosystem was a natural lake or river; therefore, they are not defined as flooded lands.[50]

In 2023, there were 537,525 hectares of open water and 243,813 hectares of vegetated wetlands. Together, these two land use types make up 2.9 per cent of the total New Zealand land area.

In 2016, a study was commissioned to identify and map current and historical (from 1990) horticultural peat mining areas, peat type and quantity, and post-mining activities (Clarkson, unpublished). This work estimated there were 273 hectares under peat extraction in 2015. Due to a lack of further information, this area is assumed to be constant from 1990 to 2023. The results of this study have been incorporated into New Zealand's 2016 land use map.

From 1990 to 2023, the net carbon stocks in *Wetlands* decreased by 9.3 kt C, equivalent to emissions of 34.1 kt CO_2 in total since 1990 (see table 6.7.2).

Table 6.7.2 New Zealand's carbon stock change by carbon pool for the *Wetlands* category, from 1990 to 2023

Land use	Net carbon stock change 1990–2023 (kt C)				Emissions 1990–2023
	Living biomass	Dead organic matter	Soils	Total	(kt CO_2)
Wetlands – vegetated	-18.9	-2.7	14.6	-7.0	25.7
Wetlands – open water	-111.0	-7.1	115.9	-2.3	8.5
Total	**-129.9**	**-9.8**	**130.4**	**-9.3**	**34.1**

Note: Columns may not total due to rounding.

6.7.2 Methodological issues

Wetlands remaining wetlands (4.D.1)

Living biomass and dead organic matter

New Zealand applies Tier 1 methods for estimating CO_2 emissions in *Wetlands remaining wetlands* (following the guidance provided in section 7.1 of the 2006 IPCC Guidelines (IPCC, 2006a)). Improvements planned for methods in the wetlands category are outlined in section 6.7.6. Chapter 7 of the 2006 IPCC Guidelines (IPCC, 2006a) provides guidance for estimating emissions from flooded land and extraction from peat land. Recultivation of peat land is included under the Agriculture sector.

Due to the current lack of data on biomass carbon stock change in *Wetlands remaining wetlands*, New Zealand has not prepared estimates for change in living biomass or dead organic matter for this category. New Zealand reports the notation key NE in the CRT for this category. However, carbon stock changes associated with changes between the two wetland subcategories (*Wetlands – vegetated* and *Wetlands – open water*) are reported under *Wetlands remaining wetlands*.

50 An exception occurred in the creation of the Clyde Dam. The Clutha River in the South Island was dammed, creating Lake Dunstan. The area flooded was mostly low producing grassland.

Soil organic carbon

Soil organic carbon stocks in *Wetlands remaining wetlands* are estimated using a Tier 2 method for mineral soils and Tier 1 methods for organic soils (see annex 5, section A5.2.4). For open water, the SOC stock at equilibrium is assumed to be the same value as that of low producing grassland.

For mineral soils, as with living biomass and dead organic matter, there are no emissions for wetlands in steady state, so the notation key NE is used, in accordance with Decision 24/CP.19 (UNFCCC, 2014).

For organic soils, IPCC good practice guidance is limited to the estimation of carbon emissions associated with peat extraction. In New Zealand, oligotrophic Sphagnum peat is mined for horticultural use (Clarkson, unpublished). Carbon dioxide emissions from the extraction of horticultural peat are estimated from two sources: on-site emissions from peat production and off-site emissions from its subsequent use. Tier 1 default emission factors are applied. Non-CO_2 emissions are not estimated because there is no method for estimating N_2O emissions from the extraction of nutrient-poor peat and no CH_4 emissions occur from this activity. As such, the ERT recommendation L.7, 2017 (FCCC/ARR/2017/NZL, UNFCCC, 2018) cannot be addressed. During the review of the 2021 submission, the ERT considered that this issue had been resolved given there is no method for estimating these emissions in the 2006 IPCC Guidelines (IPCC, 2006a). New Zealand is following the methodology for reporting N_2O emissions from *Wetlands remaining* wetlands, in line with volume 4, section 7.2.1.2 of the 2006 IPCC Guidelines (IPCC, 2006a).

Activity data

The *Vegetated wetland* category includes areas of forest that are part of the wetland ecosystem. Where the forest area has been judged to be part of the wetland ecosystem, it has been classed as vegetated wetland.

Land converted to wetlands (4.D.2)

Between 1990 and 2023, 10,942 hectares of land were converted to *Wetlands*, while 10,625 hectares of *Wetlands* were converted to other land uses (mainly *Grassland*, at 8,809 hectares). This resulted in a net decrease in total area reported under *Wetlands* of 317 hectares. The wetland losses were mainly related to the conversion of vegetated wetland to grassland (8,270 hectares). Increases in the area of wetland open water (10,963 hectares) are mainly due to the development of irrigation ponds in the Canterbury and Otago regions. However, on visual inspection of the 2020 land use map, it was determined that approximately 1,000 hectares of new open water have resulted from new lakes forming within the Southern Alps, often at the foot of glaciers.

Emissions from *Land converted to peat extraction* are reported in the CRTs as NE because the areas under peat extraction have remained static since 1990. For *Land converted to flooded land*, the area is included in the area mapped as *Land converted to open water* (this category includes naturally occurring open water (natural lakes) as well as intentionally flooded land). This means emissions for *Land converted to flooded land* are reported as IE (included elsewhere), and these emissions are captured under *Land converted to open water* instead.

Living biomass and dead organic matter

New Zealand uses a combination of Tier 1 and Tier 2 methods to calculate emissions from *Land converted to wetlands* (equation 7.10, IPCC, 2006a). The Tier 1 method assumes the carbon in living biomass and dead organic matter present before conversion is lost in the same year as the conversion takes place. All emissions from land-use change to *Wetlands* from the removal of the previous vegetation are instantly emitted.

For open water wetlands, the carbon stocks in living biomass and dead organic matter following conversions are equal to zero. For *Vegetated wetlands*, a Tier 2 method is used that includes changes in carbon stocks from the year of conversion into this category, as outlined in equation 2.9 of the 2006 IPCC Guidelines (IPCC, 2006a). When land is converted to *Vegetated wetlands*, living biomass accumulates 1.4 tonnes C ha^{-1} yr^{-1} (see table 6.7.3) over 20 years (the IPCC default period for land to reach steady state (IPCC, 2006a)). This rate of accumulation is based on a literature review of carbon stocks in New Zealand wetland vegetation (Easdale et al., 2022). Due to the methods used in the review, the above-ground component of the estimated accumulation rate is based on biomass estimates of living and dead plant material as well as coarse dead wood for the woody vegetation types that are included in the *Vegetated wetland* category (Easdale et al., 2022).

Table 6.7.3 Summary of New Zealand's biomass emission factors for *Wetlands*

Land use	Carbon pool	Steady state carbon stock (t C ha^{-1})	Annual carbon accumulation (t C ha^{-1})	Years to reach steady state	Source
Open water	**Total biomass**	**NE**	**NE**	**NE**	No IPCC guidelines
	Living biomass				
	AGB	NE	NE	NE	
	BGB	NE	NE	NE	
	Dead organic matter	NE	NE	NE	
Vegetated	**Total biomass**	**27.6**	**1.4**	**20**	Easdale et al. (2022)
	Living biomass				
	AGB	20.2	1	20	
	BGB	7.4	0.4	20	
	Dead organic matter				
	Dead wood	NE	NE	NE	
	Litter	NE	NE	NE	

Note: AGB = above-ground biomass; BGB = below-ground biomass; NE = not estimated. Columns may not total due to rounding.

Soil organic carbon

Soil organic carbon stocks in *Land converted to wetlands* are estimated using a Tier 2 method, as described in annex 5, section A5.2.4.

Non-CO_2 emissions

Non-CO_2 emissions from drainage of soils and wetlands

New Zealand has not prepared estimates for this category. The notation key NE is used in the CRTs where either no activity data are available to report on this activity or no Tier 1 methodology exists within the accepted guidelines for providing estimates. Use of this notation key is in accordance with Decision 24/CP.19 (UNFCCC, 2014).

6.7.3 Uncertainty assessment and time-series consistency

The uncertainty in net carbon emissions from *Wetlands* was 127.1 per cent in 2023 and accounted for 0.1 per cent of the total uncertainty in emissions from the LULUCF sector. The uncertainty associated with the emissions from each *Wetland* class is shown in table 6.7.4. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to methodology.

Table 6.7.4 Uncertainty in carbon stock change emissions in 2023 for *Wetlands*

	Emissions (kt CO_2-e)	Uncertainty in emissions (%)	Contribution to LULUCF uncertainty (%)
Wetlands – open water	-5.5	241.8	0.1
Wetlands – vegetative	-5.1	39.7	0.0
Peat extraction	18.0	18.9	0.0
Total	**7.3**	**127.1**	**0.1**

6.7.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data and emission factor for carbon change underwent Tier 1 quality checks.

6.7.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for *Wetlands* is shown in table 6.7.5.

Table 6.7.5 Recalculations for New Zealand's net emissions from the *Wetlands* category in 1990 and 2022

	2024 submission	2025 submission	Change from 2024 submission	Change (%)
Net emissions (kt CO_2-e)				
1990	-8.3	-8.3	0.0	0.0
2022	8.0	8.1	0.0	0.4
Area (hectares)				
1990	780,805	780,896	91	0.0
2022	780,998	781,083	84	0.0

6.7.6 Category-specific planned improvements

The following improvements are planned for the *Wetlands* category.

- Research is under way to identify activity data, nutrient status, drainage depth and suitable emission factors for drained organic soils to enable the application of the 2013 *Wetlands* supplement in future submissions.

6.8 Settlements (4E)

6.8.1 Description

In 2023, the net emissions from *Settlements* were 119.3 kt CO_2-e, an increase of 51.9 per cent from net emissions in 1990 (see table 6.8.1). This change in emissions is mainly from the category of *Land converted to settlements* and results from the drainage of organic soils. *Settlements* was not a key category in 2023.

Table 6.8.1 New Zealand's land-use change for the *Settlements* category, and associated CO_2-e emissions, from 1990 to 2023

Land use category	Net area (ha) 1990	2023	Change from 1990 (%)	Net emissions (kt CO_2-e) 1990	2023	Change from 1990 (%)
Settlements remaining settlements	191,414	223,267	16.6	66.8	79.8	19.5
Land converted to settlements	16,624	20,185	21.4	11.8	39.5	235.7
Total	**208,037**	**243,451**	**17.0**	**78.5**	**119.3**	**51.9**

Note: Net area at 1990 is as of 1 January 1990; net area at 2023 is as of 31 December 2023. *Land converted to settlements* includes land converted up to 20 years earlier. Net emission values are for the whole year indicated. Columns may not total due to rounding.

From 1990 to 2023, the net carbon stock change for *Settlements* decreased by 1,150.4 kt C, equivalent to emissions of 4,218.2 kt CO_2 in total since 1990 (see table 6.8.2). These carbon stock losses are predominantly due to the loss of carbon from organic soils associated with drainage when land is converted to *Settlements*.

Table 6.8.2 New Zealand's carbon stock change by carbon pool for the *Settlements* category, from 1990 to 2023

Land use	Net carbon stock change 1990–2023 (kt C) Living biomass	Dead organic matter	Soils	Total	Emissions 1990–2023 (kt CO_2)
Settlements	-468.6	-34.8	-647.0	-1,150.4	4,218.2

The *Settlements* land use category, as described in volume 4, chapter 3.2 of the 2006 IPCC Guidelines, includes "all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories" (IPCC, 2006a, p 3.7). *Settlements* include trees grown along streets, in public and private gardens, and in parks associated with urban areas.

In 2023, there were 243,451 hectares of *Settlements* in New Zealand, an increase of 35,414 hectares since 1990. This category comprised 0.9 per cent of New Zealand's total land area in 2023. The largest area of change to *Settlements* between 1990 and 2023 came from high producing grassland, with 26,998 hectares between 1990 and 2023.

The emissions in the *Settlements remaining settlements* category are all from anthropogenic drainage of organic soils for establishment of settlements. Carbon in living biomass and dead organic matter for this land use category is estimated as zero but, because zero is not a valid entry for biomass gains in the Greenhouse Gas Inventory Reporting Tool, the notation key NA is reported for biomass gains instead. The carbon stock in mineral soil for this land use is assumed to be in steady state, so this is also reported as zero.

6.8.2 Methodological issues

Settlements remaining settlements (4.E.1)

New Zealand applies Tier 1 methods for estimating emissions from the *Settlements remaining settlements* category. The assumptions are that there is no change in carbon stocks for living biomass, dead organic matter, or mineral soils. The Tier 1 method for organic soils conversely assumes emissions are constant if they are drained. Where organic soils occur in this category, they are assumed to be drained. See annex 5, section A5.2.4 'Organic soils', for further information on the methods applied to organic soils.

Because this is not a key category, New Zealand is not currently investigating methods to move to a higher tier of reporting for this category.

Land converted to settlements (4.E.2)

Living biomass and dead organic matter

New Zealand has applied a Tier 1 method for estimating carbon stock change with land conversion to *Settlements* (equation 2.16, IPCC, 2006a). This is the same as that used for other areas of land use conversion (e.g., *Land converted to cropland*). The default assumptions for a Tier 1 estimate are that all living biomass and dead organic matter present before conversion are lost in the same year as the conversion took place. Furthermore, carbon stocks in living biomass and dead organic matter following conversion are equal to zero (sections 8.3.1 and 8.3.2, IPCC, 2006a).

Soil organic carbon

Soil organic carbon stocks in mineral soil for *Land converted to settlements* are estimated using a Tier 2 method (see annex 5, section A5.2.4 'Mineral soils'). For organic soils, loss of soil carbon is estimated using the Tier 1 method applied to *Settlements remaining settlements*.

6.8.3 Uncertainty assessment and time-series consistency

The uncertainty in net carbon emissions from *Settlements* was 65.5 per cent in 2023. The uncertainty in net carbon emissions from *Settlements* accounted for 0.4 per cent of the total uncertainty in emissions from the LULUCF sector. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to methodology.

6.8.4 Category-specific QA/QC and verification

In the preparation of this inventory, the activity data for these emissions underwent Tier 1 quality checks.

6.8.5 Category-specific recalculations

Recalculations were carried out for this category (see table 6.8.3). Recalculations in the *Settlements* category are largely due to emissions associated with small mapping changes to the areas of deforestation that have been converted to *Settlements* as well as the introduction of the 2020 land use map.

Table 6.8.3 Recalculations for New Zealand's net emissions from the *Settlements* category in 1990 and 2022

	2024 submission	2025 submission	Change from 2024 submission	Change (%)
Net emissions (kt CO_2-e)				
1990	78.9	78.5	-0.4	-0.5
2022	118.0	118.9	0.8	0.7
Area (hectares)				
1990	209,319	209,166	-153	-0.1
2022	242,694	242,683	-10	-0.0

6.8.6 Category-specific planned improvements

During the review of the 2021 submission, the ERT recommended that New Zealand calculate N_2O emissions associated with the drainage of organic soils in settlements. Although there is no default method in the IPCC 2006 Guidelines (IPCC, 2006a) for N_2O emissions associated with drainage for this land use category, New Zealand considers that most of its *Settlements* area can be assimilated to *Grassland* when it comes to soil carbon. Therefore, the default methods applied to *Grassland* should also be applied to *Settlements*. Given the changes to the CRT reporting environment leading up to this submission, the emissions resulting from drained organic soils in *Settlements* have not been included in the total emissions for LULUCF. It is planned that this will be included in the 2026 submission.

6.9 Other land (4F)

6.9.1 Description

In 2023, the net emissions from *Other land* were 86.1 kt CO_2-e (see table 6.9.1). This is 71.3 kt CO_2-e (482.4 per cent) higher than the 1990 level of 14.8 kt CO_2-e. The majority of these emissions occur in the *Land converted to other land* category. This is primarily because the area of land estimated as having been converted to *Other land* has been steadily increasing since 1990.

Other land is defined in section 3.2 of the 2006 IPCC Guidelines (IPCC, 2006a) as including bare soil, rock, ice and all land areas that do not fall into any of the other five land use categories. This means this category includes any land that has not been actively classified into one of the other categories. It consists mostly of steep, rocky terrain at high elevation, often covered in snow or ice. This category is 3.3 per cent of New Zealand's total land area.

Analysis of the change in area between 1990 and 2023 shows that, of the 8,053 hectares converted from *Other land* to other land use categories, 2,940 hectares were converted to post-1989 planted forest, 686 hectares to post-1989 natural forest and 1,427 hectares to *Grassland with woody biomass*. *Land converted to other land* is dominated by quarries, with the largest individual site in the region of Otago measuring approximately 1,400 hectares. Also included in this change are coastal areas where sand dunes have advanced into previously vegetated areas, some areas of new rural roading not associated with settlements, and areas that have been cleared of vegetation but where the future land use is uncertain. In some cases, these uncertain areas undergo a subsequent land-use change to *Settlements*.

Between 1 January 1990 and 31 December 2023, there were 9,322 hectares of *Land converted to other land*; most (5,803 hectares) of this was from the *Grassland* categories. This is likely to be mainly due to conversion of *Grassland* to roads, mines and quarries.

In 2023, *Land converted to other land* was not a key category.

Table 6.9.1 New Zealand's land-use change for the land use category *Other land*, from 1990 to 2023

Land use category	Net area (ha) 1990	Net area (ha) 2023	Net area (ha) Change from 1990 (%)	Net emissions (kt CO_2-e) 1990	Net emissions (kt CO_2-e) 2023	Net emissions (kt CO_2-e) Change from 1990 (%)
Other land remaining other land	895,681	890,430	-0.6	0.1	3.7	3,197.4
Land converted to other land	0	6,520	0.0	14.7	82.4	461.8
Total	**895,681**	**896,950**	**0.1**	**14.8**	**86.1**	**482.4**

Note: Net area at 1990 is as of 1 January 1990; net area at 2023 is as of 31 December 2023. *Land converted to other land* includes land converted up to 20 years earlier. The net emission values for *Other land remaining other land* are due to N_2O emissions from nitrogen mineralisation as a result of land-use change. Columns may not total due to rounding.

6.9.2 Methodological issues

Other land remaining other land (4.F.1)

A summary of the New Zealand emission factors and other parameters used to estimate greenhouse gas emissions for *Other land* is provided in table 6.9.2.

Table 6.9.2 Summary of New Zealand emission factors for the land use category *Other land*

Other land greenhouse gas source category	Steady state carbon stock (t C ha^{-1})	Years to reach steady state	Carbon stock change on conversion to *Other land* (t C ha^{-1})	Reference
Biomass	NE	NA	Instantaneous loss of previous land use carbon stock	IPCC Tier 1 default assumption (section 9.3.1, IPCC, 2006a)
Soils (mineral)	58.37	20	Linear change over the conversion period between new and previous stock values	Annex 5, section A5.2.4 of this submission

Note: NA = not applicable; NE = not estimated.

Living biomass and dead organic matter

All of New Zealand's land area in the *Other land* category is classified as 'managed'. New Zealand considers all land to be managed, because all land is under some form of management plan, regardless of the intensity and/or type of land-management practices. Reporting for the category *Other land remaining other land* is not mandatory. New Zealand applies the Tier 1 approach to this category, which assumes carbon accumulation and loss for the biomass pool is zero in all years subsequent to the year of conversion (section 9.3.1, IPCC, 2006a).

Soil organic carbon

Soil organic carbon stocks in *Other land remaining other land* are estimated using a Tier 2 method for mineral soils (see annex 5, section A5.2.4 'Mineral soils'). The steady state mineral SOC stock in *Other land* is estimated to be 58.37 tonnes C ha^{-1}. This is based on only three samples so has an associated uncertainty of ±70.7 per cent (McNeill and Barringer, unpublished). The 2006 IPCC Guidelines provide a default value for soil carbon in *Other land* of 0 tonnes C ha^{-1} (section 9.3.3.2, IPCC, 2006a). However, due to the hierarchical structure of defining land use classes, *Other land* is defined as "any other remaining land that does not fall into any of the other land use categories", which can result in the SOC measured potentially being greater than zero.

Land converted to other land (4.F.2)

Living biomass and dead organic matter

New Zealand uses a Tier 1 method to calculate emissions for *Land converted to other land* (equation 2.16, IPCC, 2006a). This is the same as the method used for other areas of land use conversion (e.g., *Land converted to cropland*). The Tier 1 method assumes the carbon in living biomass and dead organic matter present before conversion is lost and instantly oxidised in the same year as the conversion takes place and that carbon stocks in living biomass and dead organic matter following conversion are equal to zero. There is no Tier 1 method for calculating carbon accumulation in living biomass or dead organic matter for *Land converted to other land*.

Soil organic carbon

Soil organic carbon stocks in *Land converted to other land* before conversion are estimated using a Tier 2 method (see annex 5, section A5.2.4 'Mineral soils'). The IPCC default method of a linear change over a 20-year period is used to estimate the change in SOC stocks between the original land use and other land for any given period.

6.9.3 Uncertainty assessment and time-series consistency

The uncertainty in net carbon emissions from *Other land* was 85.5 per cent in 2023. Emissions from *Other land* accounted for 0.3 per cent of the net emissions from the LULUCF sector. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to methodology.

6.9.4 Category-specific QA/QC and verification

In the preparation of this inventory, the data for these emissions underwent Tier 1 quality checks.

6.9.5 Category-specific recalculations

The impact of recalculations on net CO_2-e emission estimates for the *Other land* category is shown in table 6.9.3. Recalculations were carried out for this category as a result of mapping data, as described section 6.2 and annex 5, section A5.2.2. Recalculations in the *Other land* category are due to corrections incorporated into the 2020 land use map that improve mapping of *Other land* where it transitions unrealistically to a land use class with a high soil carbon value. Additionally, emissions associated with small mapping changes to the areas of deforestation that have been converted to *Other land* have increased the 2021 emission estimate.

Table 6.9.3 Recalculations for New Zealand's net emissions from the *Other land* category in 1990 and 2022

	2024 submission	2025 submission	Change from 2024 submission	Change (%)
Net emissions (kt CO_2-e)				
1990	14.8	14.8	0.0	0.2
2022	90.7	88.3	-2.5	-2.7
Area (hectares)				
1990	895,835	895,640	-195	-0.0
2022	897,126	896,909	-217	-0.0

6.9.6 Category-specific planned improvements

The reference SOC value, based on only three estimates, is high compared with the 2006 IPCC Guidelines (IPCC, 2006a) default value and has a relatively high uncertainty. Further soil sampling in land classified as *Other land* is required to improve soil carbon estimates in this land use category.

6.10 Harvested wood products (4G)

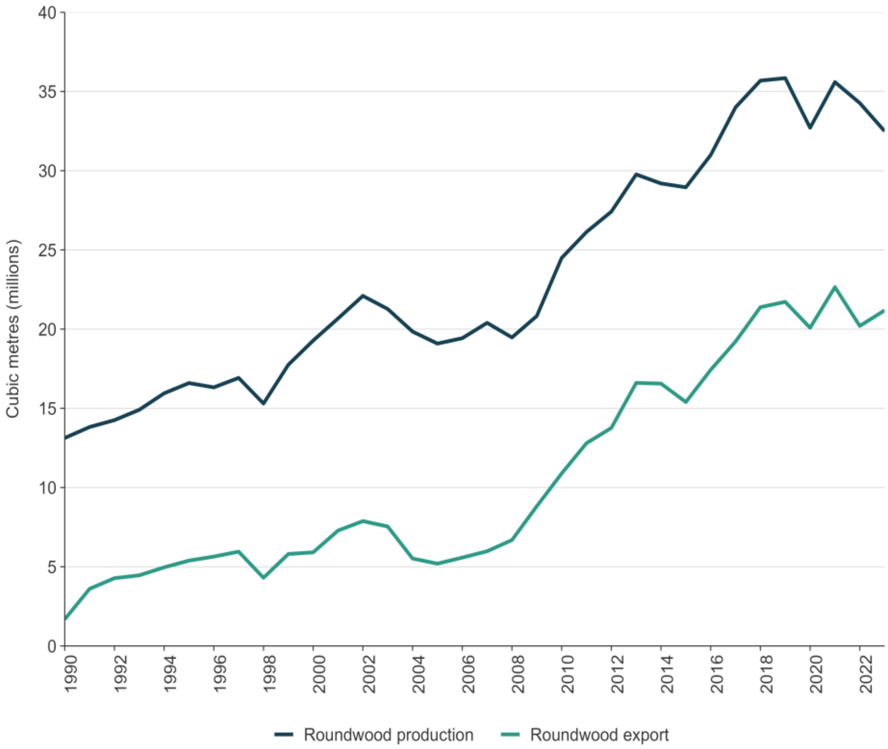
6.10.1 Description

In 2023, the net emissions from *Harvested wood products* were -5,808.3 kt CO_2-e. This is 3,370.5 kt CO_2-e (138.3 per cent) lower than the 1990 level of -2,437.8 kt CO_2-e. The decrease in emissions in the *Harvested wood products* category is driven by the increase in harvesting and production of roundwood that has occurred since 1990, as shown in figure 6.10.1.

Net emissions in the *Harvested wood products* category are driven by the harvesting of planted forests to produce roundwood, resulting in changes to the carbon stock of this pool. The harvested wood products pool gains carbon as new harvested wood products are created. Losses from the harvested wood products pool occur due to products being discarded. To account for these losses through time, a decay profile, or half-life, is applied for each product type.

Between 2022 and 2023 net emissions in the *Harvested wood products* category increased by 774.0 kt CO_2-e. The reason for this change was a decrease in harvesting compared with 2022.

Figure 6.10.1 Volume of roundwood produced and exported, from 1990 to 2023



New Zealand has a large planted-forest estate that provides the majority of wood products consumed domestically and exported in either product or raw material form. New Zealand currently processes around 40 per cent of its annual harvest (Ministry for Primary Industries, 2024b). The remaining harvest is exported in raw material form. New Zealand is currently the largest exporter of industrial roundwood followed by Germany and Czechia (Food and Agriculture Organization, 2024). New Zealand's planted forests are dominated by radiata pine (*Pinus radiata*), which is used in a wide range of applications including timber-frame construction, packaging, furniture, joinery and interior fittings, decking, general external outdoor products, concrete formwork, printing and writing paper, corrugated materials, tissue products, newsprint, kitchen and bathroom cabinets, flooring, posts and poles (Wekesa, 2022; Wekesa et al., 2022).

In 2023, *Harvested wood products* was a key category (level and trend assessment).

6.10.2 Methodological issues

New Zealand has selected the production approach to report *Harvested wood products* in the NIR. To do this, New Zealand has adapted the default *Harvested wood products* model and uses a Tier 2 method (section 12.2.1.2, IPCC, 2006a), which involves using country-specific activity data and parameters (Wakelin et al., 2020).

Activity data

Activity data on roundwood production volume, roundwood export volume and the production of New Zealand processed wood products are sourced from MPI (Ministry for Primary Industries, 2024a, 2024b, 2024c; Wekesa et al., 2022). Additional data on New Zealand wood product production and export that are not available from the published MPI statistics are sourced from the Food and Agriculture Organization of the United Nations (FAO) statistical database (the FAOSTAT database), which contains data that MPI provides to the FAO. The FAOSTAT database provides more granular breakdowns of semi-finished wood products produced in New Zealand, to which specific carbon fractions can then be applied.

Activity data for the period 1900 to 1960 are populated using the IPCC model method, which assumes that consumption is correlated with population growth. New Zealand used the default value for Oceania for the annual rate of increase for the period 1900 to 1960. This information is used to initialise *Harvested wood products* stocks at 1 January 1990.

A large proportion (approximately 60 per cent) of New Zealand's harvest was exported as raw materials in the form of logs or wood chips in 2023, as shown in figure 6.10.1 (Ministry for Primary Industries, 2024b). Note that the exported volume of *Harvested wood products* described in CRT 4.Gs2 does not sum to 60 per cent of all exported products. This is because this table includes only products produced in New Zealand and does not include the volume of raw logs exported that are then processed offshore.

MPI provides data on the export quantity of raw materials but provides no information on the conversion of these materials to products or their expected half-lives. Research was completed in 2016 to provide information on harvested wood products from exported logs in New Zealand's three main export markets (China, South Korea and India). This research provides activity data for the conversion of New Zealand-produced raw materials to harvested wood products in export markets (Manley and Evison, 2016).

Further research was commissioned in 2017 to update the model assumptions that are used for calculating harvested wood product volume and associated emissions to include the activity data and half-lives of the 2016 report (Wakelin and Kimberley, unpublished). Note that the model also includes export variables to Japan, which was historically a large export market but has reduced and is projected to continue to reduce over time. It also includes 'Other countries', which account for a small volume of exports that are sold to other markets. Details of product volume and half-lives for these export markets can be found in annex 5, section A5.2.6.

Activity data for exported log volumes and *Harvested wood products* to individual countries are periodically published by MPI (Ministry for Primary Industries, 2024b, 2024c). The proportion of exported roundwood to product type in these export markets is obtained by applying the ratios of product type produced (sawnwood, wood panels or paper), as identified in the 2016 report (Manley and Evison, 2016), to the volume of timber exported to each of the export markets.

Emission factors

The default wood carbon content value of 50 per cent, from table 12.4 of the 2006 IPCC Guidelines (IPCC, 2006a), is used in the *Harvested wood products* model (IPCC, 2006a). This value is consistent with the planted forest model that uses a country-specific value of 50 per cent. A country-specific wood density value of 420 kilograms per cubic metre is used for sawnwood produced from coniferous species (Jones, 2005). This value is used to reflect coniferous species' contribution to New Zealand roundwood, which makes up around 98 per cent of annual harvest. A country-specific wood density value of 500 kilograms per cubic metre is used for sawnwood produced from non-coniferous species (Jones, 2005). Non-coniferous species (mainly *Eucalyptus*) make up around 2 per cent of annual harvest. The default IPCC bark factor (11 per cent; annex 4A.1, IPCC, 2006a) is used for conifers and is considered appropriate for New Zealand. Wood-based panels and paper products all use IPCC defaults because no country-specific value is available (see table 6.10.1).

Exported raw logs are first converted to tonnes of carbon, based on the carbon fractions for coniferous species and for non-coniferous species, as outlined above. This carbon is then apportioned into each export market and wood product combination (sawnwood, panels and paper).

Table 6.10.1 Conversion factors for *Harvested wood products* produced from New Zealand wood in New Zealand

Category	Factor (t C/m^3 or t C/t*)	Source
Sawnwood, other industrial roundwood (coniferous)	0.210	Country specific (Jones, 2005)
Sawnwood, other industrial roundwood (non-coniferous)	0.250	Country specific (Jones, 2005)
Veneer sheets	0.210	Country specific (Jones, 2005)
Plywood	0.267	IPCC default (IPCC, 2014)
Particle board	0.269	IPCC default (IPCC, 2014)
Fibreboard (compressed)	0.315	IPCC default (IPCC, 2014)
Insulating board/other fibreboard	0.075	IPCC default (IPCC, 2014)
Paper products	0.450*	IPCC default (IPCC, 2014)

Note: * Indicates where factors are given in tonnes of carbon per tonne of product.

Half-lives

Half-lives determine the discard rate of products from service in the *Harvested wood products* category. Overall, sawnwood and wood-based panels made and consumed in New Zealand are used to manufacture long-lived wood products, whereas short-lived products are manufactured overseas (Wekesa, 2022; Wekesa et al., 2022). These findings are used in this submission instead of default half-life values used previously. New Zealand uses a weighted half-life of 33.6 years for *Sawnwood*, 32.4 years for *Wood-based panels for domestically processed and consumed harvested wood products*, whereas weighted half-life values of 23.6 years for *Sawnwood* and 20.7 years for *Sawnwood panels* are used for harvested wood products produced in New Zealand and exported overseas (Wakelin, unpublished (f)). A default half-life value of two years was used for domestically produced and processed *Paper and paperboard* consumed in the domestic and export markets (IPCC, 2014). These half-lives are used to increase the accuracy of the estimates over the default categories (*Solid wood* and *Paper and paperboard*) (table 12.2, IPCC, 2006a).

Most of New Zealand's exported logs are converted into construction and packaging material (Manley and Evison, 2016). The weighted half-lives for China and India are significantly lower than the IPCC default half-lives for *Sawnwood* and *Panels*, as demonstrated in table 6.10.2. These findings are included in New Zealand's *Harvested wood products* estimates and provide an improvement on the default assumption where exported raw materials were discarded at the same rate as domestic production. Further information on the half-lives for conversions of exported logs is provided in annex 5, section A5.2.6.

Table 6.10.2 Weighted half-lives for harvested wood products produced in export markets

Country	Weighted half-lives (years) Sawnwood	Wood panels	Paper
China	8.3	8.3	2
India	1.4	10.4	2
South Korea	15.5	23.9	2
Japan	3.1	2.8	2
Other	8.3	8.3	2
IPCC default	35	25	2

6.10.3 Uncertainty assessment and time-series consistency

The uncertainty in net carbon emissions from *Harvested wood products* was 68.2 per cent in 2023, which accounted for 19.6 per cent of the total uncertainty in emissions from the LULUCF sector. Uncertainty in the *Harvested wood products* estimates is introduced by activity data, conversion factors and decay parameters. The contribution to total uncertainty is driven by large removals in this pool and high uncertainty associated with the end-use and discard rates of New Zealand wood. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to the methodology.

6.10.4 Category-specific QA/QC and verification

Activity data for roundwood are sourced from annual statistics produced by MPI. However, as section 6.4 describes, the methodology for estimating above-ground biomass losses on harvest uses the LUCAS model, which combines harvest area by age with yield table carbon values. To ensure consistency between MPI roundwood volume statistics and LUCAS harvest estimates, a comparison between the two data sources across the time series was carried out and is further described in annex 5, section A5.2.5 ‘Forest land model validations’.

The results show a relatively good match between the two data sources between 2013 and 2020. This is because roundwood volume is now used to determine the total destocking area over this period. However, the two data sources deviate in earlier years. LUCAS above-ground biomass losses from harvest are greater than those estimated from roundwood volume statistics from 1996 to 2012 and are slightly lower from 1990 to 1994.

The implications of these earlier differences are that New Zealand may be reporting more carbon losses from harvesting and deforestation than carbon gains from roundwood creation and inputs into the harvested wood products pool across most of the time series.

Work is under way to establish how best to address this inconsistency through the time series.

6.10.5 Category-specific recalculations

Recalculations of the entire time series were carried out for this category as a result of updated activity data. The impact of recalculations on net CO_2-e emission estimates for *Harvested wood products* is shown in table 6.10.3.

Table 6.10.3 Recalculations for New Zealand's net emissions from the *Harvested wood products* category in 1990 and 2022

	2024 submission	2025 submission	Change from 2024 submission	Change (%)
Net emissions (kt CO_2-e)				
1990	-2,437.8	-2,437.8	0.0	0.0
2022	-6,582.3	-6,582.3	0.0	0.0

6.10.6 Category-specific planned improvements

Data are now available on country-specific end-use products and half-lives of roundwood logs processed and consumed in New Zealand (Wekesa, 2022; Wekesa et al., 2022). These data should be incorporated into the uncertainty model to improve the accuracy of estimates. This enhancement should be prioritised for inclusion in future submissions.

6.11 Non-CO_2 emissions (4(I–IV))

In 2023, net N_2O emissions from soils associated with land-use change reported in the LULUCF sector were 242.8 kt CO_2-e (see table 6.11.1). This is 26.4 kt CO_2-e (9.8 per cent) lower than the 1990 level of 269.2 kt CO_2-e. This is primarily due to a reduction in direct emissions from nitrogen mineralisation/immobilisation.

Table 6.11.1 Nitrous oxide emissions from soils associated with land-use change reported in the LULUCF sector, from 1990 to 2023

	Net emissions (kt N_2O)		Net emissions (kt CO_2-e)		
Emissions source	1990	2023	1990	2023	Change from 1990 (%)
Direct emissions from nitrogen mineralisation/immobilisation	0.6	0.4	165.1	117.7	-28.7
Direct emissions from drainage of organic and mineral soils	0.3	0.4	67.0	98.7	47.4
Indirect emissions from leaching and runoff	0.1	0.1	37.2	26.5	-28.7
Total	**1.0**	**0.9**	**269.2**	**242.8**	**-9.8**

Note: Columns may not total due to rounding. Direct nitrous oxide emissions reported in this table are for *Forest land* only. Nitrous oxide emissions on *Cropland* and *Grassland* are reported under the Agriculture sector.

6.11.1 Direct N_2O emissions from nitrogen fertilisation of forest land and other land (4(I))

New Zealand's activity data on nitrogen fertilisation are not currently disaggregated by land use and, therefore, all direct N_2O emissions from nitrogen fertilisation of *Forest land* and *Other land* are reported in the Agriculture sector under the category *Direct N_2O emissions from managed soils* (3.D.a). The notation key IE is reported in the CRTs for the LULUCF sector.

6.11.2 Emissions from drainage and rewetting of organic and mineral soils (4(II))

Description

New Zealand reports on N_2O emissions, as a result of oxidation of organic matter, from the drainage of organic soils. Nitrous oxide emissions on *Cropland* and *Grassland* are reported under the Agriculture sector. Direct N_2O emissions from drained organic soils in *Forest land* are estimated to be 0.4 kt N_2O in 2023, compared with 0.3 kt N_2O in 1990. The notation key NE is reported in the CRTs for rewetted mineral soils.

Methodological issues

To estimate N_2O emissions associated with the drainage of organic soils on forest land, New Zealand uses the Tier 1 method outlined in the 2006 IPCC Guidelines (equation 11.1, IPCC, 2006a). The Tier 1 default value for temperate, nutrient-poor forest soils of 0.1 kg N_2O-N ha^{-1} is applied. Note that the area of pre-1990 natural forest remaining pre-1990 natural forest on organic soils is assumed to be in its natural, undisturbed state, and therefore is presumed to be undrained.

6.11.3 Direct N_2O emissions from nitrogen mineralisation/immobilisation (4(III))

Description

Direct N_2O emissions from nitrogen mineralisation/immobilisation are minor in New Zealand, estimated at 0.4 kt N_2O in 2023, compared with 0.6 kt N_2O in 1990. Note that N_2O emissions on *Cropland remaining cropland* from nitrogen mineralisation/immobilisation are reported under the Agriculture sector. Direct N_2O emissions from nitrogen mineralisation/immobilisation associated with land-use change for all other land use categories are reported under the LULUCF sector.

Nitrous oxide emissions result from the mineralisation of soil organic matter with land-use change. This mineralisation results in an associated conversion of nitrogen previously in the soil organic matter to ammonium and nitrate. Microbial activity in the soil converts some of the ammonium and nitrate present to N_2O. An increase in this microbial substrate caused by a net decrease in soil organic matter can therefore be expected to give an increase in net N_2O emissions (section 11, IPCC, 2006a).

Methodological issues

To estimate N_2O emissions from disturbance associated with land-use change, New Zealand uses the method outlined in the 2006 IPCC Guidelines (equation 11.2 and equation 11.8, IPCC, 2006a).

The inputs to these equations are:

- loss of carbon in mineral soils
- EF_1 – the emission factor for calculating emissions of N_2O from nitrogen in the soil. New Zealand uses a country-specific value of 0.01 kg N_2O – N/kg N (Kelliher and de Klein, 2006)
- C:N ratio – the IPCC default ratio of carbon to nitrogen in soil organic matter (15:1) is used (IPCC, 2006a, p 11.16).

Where an area of land is converted to a land use with a higher original mineral SOC stock than the category it is converted from, no N_2O emissions have been estimated as occurring because there is no associated loss of SOC. For instance, *Cropland* converted to *Forest land* is estimated not to result in net N_2O emissions because this land use conversion is associated with a net gain in SOC in New Zealand (see annex 5, section A5.2.4, table A5.2.8). In these situations, the notation key NO (not occurring) is reported in the CRTs.

6.11.4 Indirect N_2O emissions from leaching and runoff (4(I))

Indirect N_2O emissions from leaching and runoff are associated with mineralisation of nitrogen from loss of soil carbon in mineral and drained and/or managed organic soils through land-use change or management practices. Emissions on *Cropland remaining cropland* from leaching and runoff are reported under the Agriculture sector. Indirect N_2O emissions from leaching and runoff for all other land use categories are reported under the LULUCF sector.

Indirect emissions from leaching and runoff in all land use categories excluding *Cropland remaining cropland* were estimated as 0.1 kt N_2O in 2023, which is 28.7 per cent lower than reported in 1990.

Methodological issues

New Zealand applies the Tier 1 method outlined in the 2006 IPCC Guidelines (equation 11.10, IPCC, 2006a) for estimating N_2O emissions from leaching and runoff. The following are the inputs to this equation.

- F_{SOM} – annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching and runoff occur, kg N yr^{-1}, is calculated using the method described in section 6.11.3 above.
- EF_5 – emission factor for N_2O emissions from N leaching and runoff, kg N_2O–N (kg N leached and runoff)$^{-1}$ uses the default emission factor of 0.0075 provided in table 11.3 of the IPCC Guidelines (IPCC, 2006a).
- $Frac_{LEACH\text{-}(H)}$ – fraction of all N added to and/or mineralised in managed soils in regions where leaching and runoff occur that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$ uses the default value of 0.30 provided in table 11.3 of the IPCC Guidelines (IPCC, 2006a).

6.11.5 Indirect N_2O emissions from atmospheric deposition of N volatilised from managed soil (4(I))

Description

New Zealand cannot separate the sources of nitrogen between *Cropland*, *Grassland* and *Other land* uses. For this reason, it reports all *Indirect N_2O emissions from atmospheric deposition of N volatilised from managed soil* within CRT 3.D.b in the Agriculture sector and uses the notation key IE within CRT 4(I) of the LULUCF sector.

6.11.6 Uncertainty assessment and time-series consistency for N_2O emissions in soils associated with land-use change

The uncertainty in net N_2O emissions from nitrogen in soils associated with land-use change in 2023 is outlined in table 6.11.2. The methods used to calculate the uncertainty are further described in annex 5, section A5.2.8.

Table 6.11.2 Net N_2O emissions from nitrogen in soils associated with land-use change in 2023

	Emissions (kt CO_2-e)	Uncertainty in emissions (%)	Contribution to LULUCF uncertainty (%)
Direct N_2O emissions from N mineralisation/immobilisation	117.7	85.5	0.5
Direct N_2O emissions from drainage and rewetting	98.7	86.5	0.4
Indirect emissions from leaching and runoff	26.5	126.8	0.2

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to methodology.

6.11.7 Category-specific planned improvements for N_2O emissions in soils associated with land-use change

Nitrous oxide emissions associated with the drainage of organic soils in *Settlements* are planned to be included in the 2026 submission because New Zealand considers that most of its *Settlements* area can be assimilated to *Grassland* when it comes to soil carbon. This is covered in section 6.8.6.

6.11.8 Biomass burning (4(IV))

Description

Non-CO_2 emissions from *Biomass burning* in 2023 were 1.6 kt CH_4 (45.8 kt CO_2-e) and 0.1 kt N_2O (25.2 kt CO_2-e) (see table 6.11.3).

Table 6.11.3 Non-CO_2 emissions from *Biomass burning*

Emissions	1990	2023	Change from 1990 (%)
CH_4 emissions (kt CH_4)	2.8	1.6	-41.0
N_2O emissions (kt N_2O)	0.1	0.1	8.1

Biomass burning can occur as a result of wildfires or controlled burning and results in emissions of CO_2, CH_4, N_2O, CO and NO_x. *Biomass burning* is not a significant source of emissions for New Zealand because the practice of controlled burning is limited, and wildfires are not common due to New Zealand's temperate climate and vegetation.

The two types of biomass burning (wildfire and controlled burning) that occur in New Zealand are reported in two main land use categories: *Forest land* and *Grassland*. Emissions reported in *Forest land* are further separated by forest type, and emissions from *Grassland* are reported from the controlled burning of tussock land (in ecosystems dominated by *Chionochloa* spp.) and from wildfires in exotic pasture grassland.

Methodological issues

New Zealand employs Tier 2 methodologies to estimate emissions from *Biomass burning*. A combination of country-specific carbon fractions (Beets, unpublished), emission factors (Thomas et al., 2011) and combustion factors (Payton and Pearce, 2009; Wakelin, unpublished(a), (e)) is employed along with the 2006 IPCC Guidelines default carbon fractions, emission factors, combustion factors and equations to derive emissions (sections 2.4, 4.2.4 and 6.2.4, IPCC, 2006a). These variables are summarised in table 6.11.4 and table 6.11.5, and further information on their application is provided in annex 5, section A5.2.7.

Table 6.11.4 Summary of *Biomass burning* carbon fractions and emission factors

	Biomass burning implied emission factors derived from 2006 IPCC Guidelines (IPCC, 2006a) and New Zealand-specific carbon fractions							
	Grassland/savannah		GWB/shrubland		Forest land			
	Controlled burning	Wildfire	Controlled burning	Wildfire	Controlled burning		Wildfire	
					Planted forest	Natural forest	Planted forest	Natural forest
Carbon fraction	0.44	0.44	0.44	0.44	0.51*	0.47	0.51*	0.47
C:N ratio	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CO emission factor	0.06	0.06	0.06	0.06	0.09	0.10	0.09	0.10
CH_4 emission factor	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
N_2O emission factor	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04
NO_x emission factor	0.27	0.27	0.27	0.27	0.18	0.19	0.18	0.19

Note: GWB = grassland with woody biomass. Values are rounded to two decimal places. *0.51 New Zealand-specific carbon fraction for planted forests (Beets, unpublished).

Table 6.11.5 **Summary of *Biomass burning* combustion factor values**

Combustion factor values (proportion of pre-fire biomass consumed) for fires (table 2.6, IPCC, 2006a)			
Vegetation type			**Value**
Forest	Other temperate forests	Post-logging slash burn	0.62
		Felled and burned (land clearing fire)	0.51
	All 'other' temperate forests		0.45
GWB and shrubland	Shrubland (general)		0.95
	All shrubland		0.72
	GWB New Zealand specific		0.70*
Grassland	All savannah/grasslands (early dry season burns)		0.74
	All savannah/grasslands (mid/late dry season burns)		0.77
	Average of IPCC savannah/grasslands		0.755
	Controlled grassland burn New Zealand specific		0.555**

Note: GWB = grassland with woody biomass. *Wakelin (unpublished(e)), **Payton and Pearce (2009).

For all land uses, CO_2 emissions are captured in the general stock change calculation following the 2006 IPCC Guidelines (IPCC, 2006a). Carbon dioxide emissions resulting from *Biomass burning* are reported as IE, where emissions are captured in the stock change calculation within the land use category.

In *Grassland*, CO_2 emissions from biomass burning are assumed to be equal to subsequent regrowth. The assumption of equivalence is accepted as reasonable in this scenario as per the 2006 IPCC Guidelines, section 2.4 and section 6.2.4 (IPCC, 2006a).

In *Cropland*, CH_4 and N_2O emissions from controlled burning are reported as IE. This is because emissions from the burning of crop stubble associated with controlled burning in *Cropland* are reported under the Agriculture sector and reported within 3.F.

Both CO and NO_x are also released from biomass burning and are reported in relevant aggregate land use categories. Carbon monoxide and NO_x emissions from biomass burning are captured as part of the biomass burning model and reported in the CRTs.

Controlled burning emissions are reported within:

- *Grassland* converted to *Forest land* (due to site preparation for conversion)
- *Forest land remaining forest land* (from the clearing of vegetation (natural forest) before the establishment of exotic planted forest and the burning of post-harvest slash before restocking)
- *Forest land* converted to *Grassland* (from controlled burning associated with deforestation)
- *Grassland remaining grassland* (due to savanna (tussock) and pastureland management practices).

Emissions of CO_2 from wildfires in *Forest land remaining forest land* are included in the general stock change calculation. In *Forest land remaining forest land*, burned stands are either harvested (so emissions are included with the harvesting emissions) or left to grow on at reduced stocking. Carbon dioxide emissions are reported when the stand is harvested or deforested (with no reduction in stock when compared with an unburned stand). For both natural and planted forests, emissions from areas burned are captured within the forest plot networks that New Zealand uses to estimate carbon stock change. In these cases, to avoid double counting of CO_2 emissions, the notation key IE is used.

Wildfire activity data are sourced from Fire and Emergency New Zealand (FENZ). Historically, burned areas were estimated and allocated by field staff to vegetation types: grass, tussock, gorse, scrub, wetland, plantation forest and indigenous forest. The process (since 2017) now involves mapping the burn area. This area is overlaid on the 2020 land use map to determine what type of land cover has been burned.

Activity data for controlled burning for *Forest land* are estimated based on a 2011 survey of forest owners (Wakelin, unpublished(d)). Activity data (area of land-use change) for *Grassland with woody biomass* converted to forest are based on annual land-use changes, as estimated in section 6.2, and an estimate of area burned from a survey of forest owners. Earlier estimates of controlled burning in planted forest (Forest Industry Training and Education Council, 2005; Robertson, 1998) were used, in addition to the 2011 survey, to provide activity data throughout the time series. Further details of the survey findings and extrapolation can be found in annex 5, section A5.2.7.

Activity data are combined with emission factors derived from the national forest plot network (see table 6.4.8) to estimate non-CO_2 emissions from burning associated with the clearing of vegetation before the establishment of exotic planted forest. Below-ground biomass is assumed not to burn. Further detailed information on the methodology applied can be found in annex 5, section A5.2.7.

Biomass burning is not a key category for New Zealand.

Uncertainties and time-series consistency

The uncertainty in CH_4 and N_2O net emissions from *Biomass burning* was 51.4 per cent in 2023. Emissions from *Biomass burning* accounted for 0.1 per cent of the net emissions from the LULUCF sector.

Time-series consistency is ensured by applying consistent methods and full recalculations in the event of any refinement or improvement to methodology.

Category-specific QA/QC and verification

Quality-control and quality-assurance measures are applied to the *Biomass burning* activity data and emission factors. The biomass burning data set is verified whenever new data are supplied. The *Biomass burning* parameters (burning and emission factors), assumptions and data set have been reviewed (Payton and Pearce, 2009; Thomas et al., 2011; Wakelin, unpublished(b), (c), (d), (e); Wakelin et al., unpublished).

Category-specific recalculations

Wildfire activity data for 2018 to 2023 have been updated for this submission, to incorporate mapping of the 2023 wildfire extent, and updates have been made to the vegetation classification from the land use map. New estimates for controlled burning in *Grassland remaining grassland* have required recalculations across the time series.

Category-specific planned improvements

The assumption that controlled burning of post-harvest residues on afforested land does not occur will be revisited in a future submission, due to the increasing harvest rate in these forests as they reach maturity.

Chapter 6: References

Arnst E, Hayman E, Richardson S. Unpublished. Natural Forest Plot Data Corrections 2023–2024. Contract report LC4306 prepared for the Ministry for the Environment by Manaaki Whenua Landcare Research New Zealand Ltd in 2024.

Arnst E, Vickers S. Unpublished. Natural Forest Plot Data Corrections 2022–2023. Contract report LC4306 prepared for the Ministry for the Environment by Manaaki Whenua Landcare Research New Zealand Ltd in 2023.

Beets PN. Unpublished. Carbon Fraction of Radiata Pine Biomass Components. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2017.

Clarkson B. Unpublished. Peat Extraction in New Zealand Wetlands. Contract report LC2710 prepared for the Ministry for the Environment by Landcare Research New Zealand Ltd in 2016.

Davis MR, Wakelin SJ. Unpublished. Perennial Cropland Biomass: Sampling Requirements. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Limited (trading as Scion).

Easdale TA, Richardson SJ, Marden M, England JR, Gayoso-Aguilar J, Guerra-Carcamo JE, Brandon AM. 2019. Root biomass allocation in southern temperate forests. *Forest Ecology and Management* 453: 117542.

Easdale TA, Burge OR, Wiser S, Richardson SJ. 2022. *Carbon Assessment of Wetland Vegetation*. Contract report LC4173 prepared for the Ministry for the Environment by Landcare Research New Zealand Ltd.

Ewers RM, Kliskey AD, Walker S, Rutledge D, Harding JS, Didham RK. 2006. Past and future trajectories of forest loss in New Zealand. *Biological Conservation* 133(3): 312–325.

Food and Agriculture Organization of the United Nations. 2024. *Forestry Production and Trade Data*. Retrieved 3 November 2024.

Forest Industry Training and Education Council. 2005. *Best Practice Guidelines for Land Preparation*. Revised edn. Rotorua: Forest Industry Training and Education Council.

Garrett LG. Unpublished. Natural Forests Soils: Data Checking and Carbon Content of the Mineral Soil. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion).

Garrett LG, Kimberley MO, Oliver GR, Parks M, Pearce SH, Beets PN, Paul TSH. 2019. Decay rates of above- and below-ground coarse woody debris of common tree species in New Zealand's natural forest. *Forest Ecology and Management* 438: 96–102.

Hunter G, McNeill S. Unpublished. Review of LUCAS Land Use Backcasting 1962–1989. Contract report prepared for the Ministry for the Environment by Landcare Research New Zealand Ltd in 2010.

IPCC. 2006a. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006b. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *General Guidance and Reporting*. *Volume 1.* Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2013. Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

IPCC. 2014. Hiraishi T, Krug T, Tanabe K, Srivastava N, Baasansuren J, Fukuda M, Troxler TG (eds). *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*. Switzerland: IPCC.

Jones T. 2005. Wood properties of commercial tree species. In: M Colley (ed.) *NZIF 2005 Forestry Handbook*. Wellington: New Zealand Institute of Forestry. pp 204–207.

Kelliher FM, de Klein CAM. 2006. *Review of New Zealand's Fertiliser Nitrous Oxide Emission Factor (EF1) Data*. Report prepared for the Ministry for the Environment by Landcare Research and AgResearch. Wellington: Ministry for Primary Industries.

Kimberley MO, Beets PN, Paul TSH. 2019. Comparison of measured and modelled change in coarse woody debris carbon stocks in New Zealand's natural forest. *Forest Ecology and Management* 434 (2019): 18–28.

Land Cover Database v5.0 _ Land Cover Database version 5.0, Mainland New Zealand. Retrieved 11 November 2021.

Manaaki Whenua Landcare Research. 2020. *A National Soil Carbon Monitoring System for Agricultural Land*. Retrieved 4 December 2020.

Manley B, Evison D. 2016. *Material Flow and End-use of Harvested Wood Products Produced from New Zealand Log Exports*. Wellington: Ministry for Primary Industries.

McGlone MS. 2009. Postglacial history of New Zealand wetlands and implications for their conservation. *New Zealand Journal of Ecology* 33: 1–23.

McNeill SJ, Barringer JRF. Unpublished. Respecification and Reclassification of the 2013 MfE Soil CMS Model. Prepared for the Ministry for the Environment by Landcare Research New Zealand Ltd.

Ministry for Primary Industries. 2015. *Forestry in the emissions trading scheme*. Retrieved 12 February 2022.

Ministry for Primary Industries. 2023. *Wood processing data: Quarterly production, stock and roundwood removals, June 2023 quarter production*. Wellington: Ministry for Primary Industries. Retrieved 15 August 2023.

Ministry for Primary Industries. 2024a. *Wood processing data: Roundwood removals, year ended 31 March, 1951 to most recent*. Wellington: Ministry for Primary Industries. Retrieved 1 March 2024.

Ministry for Primary Industries. 2024b. *Wood processing data: Quarterly production, stock and roundwood removals, June 2024 quarter production*. Wellington: Ministry for Primary Industries. Retrieved 15 August 2024.

Ministry for Primary Industries. 2024c. *Wood Product Markets: Quarterly trade, June 2024 quarterly exports*. Retrieved 14 November 2024.

Ministry for the Environment. 2006. *New Zealand's Initial Report under the Kyoto Protocol*. Wellington: Ministry for the Environment. Retrieved 14 July 2011.

Ministry for the Environment. 2012. *Land Use and Carbon Analysis System: Satellite imagery interpretation guide for land use classes* (2nd edn). Wellington: Ministry for the Environment.

Ministry for the Environment and Stats NZ. 2017. *New Zealand's Environmental Reporting Series: Our fresh water 2017*. Retrieved 16 February 2024.

Ministry for the Environment and Stats NZ. 2018. *New Zealand's Environmental Reporting Series: Our land 2018*. Retrieved 16 February 2024.

Paul TSH, Beets PN, Kimberley MO. Unpublished. Carbon Stocks in New Zealand's Post-1989 Natural Forest: Analysis of the 2018/2019 forest inventory data. Contract report prepared for the Ministry for the Environment by the New Zealand Forest Research Institute Ltd (trading as Scion) in 2020.

Paul TSH, Kimberley MO, Beets PN. 2021. Natural forests in New Zealand: A large terrestrial carbon pool in a national state of equilibrium. *Forest Ecosystems* 8(1): 1–21.

Paul TSH, Wakelin SJ, Dodunski C. 2024. *The National Forest Inventory 2018–2022 Analysis: Yield tables and carbon stocks in planted forests in New Zealand based on a five-year inventory cycle*. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion). Rotorua: Scion.

Payton IJ, Pearce HG. 2009. Fire-induced Changes to the Vegetation of Tall-tussock (*Chionochloa rigida*) Grassland Ecosystems*. Science for Conservation 290*. Wellington: Department of Conservation.

Robertson KA. 1998. Loss of organic matter and carbon during slash burns in New Zealand exotic forests. *New Zealand Journal of Forestry Science* 28(2): 221–241.

Thomas S, Hume E, Fraser T, Curtin D. 2011. *Factors and Activity Data to Estimate Nitrous Oxide Emissions from Cropping Systems, and Stubble and Tussock Burning*. Report prepared for the Ministry of Agriculture and Forestry by Plant and Food Research (formerly Crop and Food Research) technical paper no. 2012/16. Wellington: Ministry of Agriculture and Forestry.

Trotter C, MacKay A. Unpublished. Potential Forest Land. Contract report 04/05-0410-L prepared for Landcare Research New Zealand Ltd.

UNFCCC. 2014*.* FCCC/CP/2013/10/Add.3. Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013: Addendum – Part 2: Action taken by the Conference of the Parties at its nineteenth session.

UNFCCC. 2018. FCCC/ARR/2017/NZL. Report of the individual review of the annual submission of New Zealand submitted in 2017. Centralised Review.

UNFCCC. 2020. FCCC/ARR/2019/NZL. Report of the individual review of the annual submission of New Zealand submitted in 2019. In-country Review.

UNFCCC. 2023. FCCC/ARR/2022/NZL. Report of the individual review of the annual submission of New Zealand submitted in 2022. Centralised Review.

Wakelin SJ. Unpublished(a). Scientific Research Underpinning New Zealand's Carbon Inventory in Planted Forests. Objective 9 – UNFCCC planted forest carbon inventory methodology. Milestone 2 – Review of shrubland clearance assumptions in the national carbon inventory. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2004.

Wakelin SJ. Unpublished(b). Review of LULUCF Biomass Burning Assumptions in New Zealand's Greenhouse Gas Inventory. Contract report prepared for the Ministry for the Environment by Ensis in 2006.

Wakelin SJ. Unpublished(c). Apportioning Wildfire Emissions to Forest Sub-categories in the National Greenhouse Gas Inventory. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2011.

Wakelin SJ. Unpublished(d). Controlled Biomass Burning Emissions for the 2011 Greenhouse Gas Inventory. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2012.

Wakelin SJ. Unpublished(e). Review of Emissions from Prescribed Burning of Standing Vegetation in New Zealand. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2018.

Wakelin SJ. Unpublished(f). Annual updating of the Harvested Wood Products carbon accounting model. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2023.

Wakelin SJ, Beets PN. Unpublished. Emission Factors for Managed and Unmanaged Grassland with Woody Biomass. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2013.

Wakelin SJ, Clifford VR, Anderson SAJ, Pearce HG. Unpublished. Review of LULUCF Non-carbon Emissions in New Zealand's Greenhouse Gas Inventory. Contract report 17342 prepared for Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2009.

Wakelin SJ, Kimberley M. Unpublished. Harvested Wood Products Model for UNFCCC and Kyoto Protocol Reporting. Contract report prepared for the Ministry for the Environment by New Zealand Forest Research Institute Ltd (trading as Scion) in 2017.

Wakelin SJ, Searles N, Lawrence D, Paul TSH. 2020. Estimating New Zealand's harvested wood products carbon stocks and stock changes. *Carbon Balance and Management* 15(10).

Watts D. Unpublished. Land Use Backcasting: Data and methodology. Wellington: Ministry for the Environment.

Wekesa A. 2022. The Estimation and Modelling of Carbon Stocks from Harvested Wood Products in New Zealand. Doctoral thesis, University of Canterbury. Retrieved 24 February 2023.

Wekesa, A, Manley, B, Evison, D. 2022. *Improved Data on Harvested Wood Products*. Wellington: Ministry for Primary Industries. Retrieved 1 August 2023.

Chapter 7: Waste

7.1 Sector overview

7.1.1 The Waste sector in New Zealand

In 2023, the Waste sector contributed 3.8 per cent of New Zealand's gross greenhouse gas emissions, most of which was biogenic methane (CH_4) from municipal landfills. The sector's emissions came from solid waste disposal, biological treatment of solid waste, incineration and open burning, and wastewater treatment and discharge.

In New Zealand, most solid waste is disposed to land making it the largest source of waste emissions accounting for 77.4 per cent of the sector's emissions as of 2023. The majority of the country's household and commercial waste is placed in managed municipal landfills. Before 2010, some household waste was also disposed of in unmanaged or uncategorised sites. Unmanaged sites include numerous smaller landfills, including those located on farms and those used for the disposal of construction and demolition materials or industrial waste. One major exception to disposal to land is the management of farm waste, of which half is estimated to be disposed of by open burning. Figure 7.1.1 shows the sources of and disposal practices for solid waste in New Zealand.

Emissions from composting activities are included and account for 2.8 per cent of the sector's emissions. There is currently one large-scale anaerobic digestion plant processing municipal organic waste in New Zealand, which started operating towards the end of 2022. No other emission sources for direct greenhouse gases are applicable to New Zealand.

Incineration and open burning made up a small portion of the sector's emissions, 6.1 per cent. Municipal waste is not incinerated in New Zealand. Incineration is used only on a small scale, mainly for hazardous waste, clinical waste and sewage sludge, and has declined over time due to environmental regulation and the availability of other disposal options.

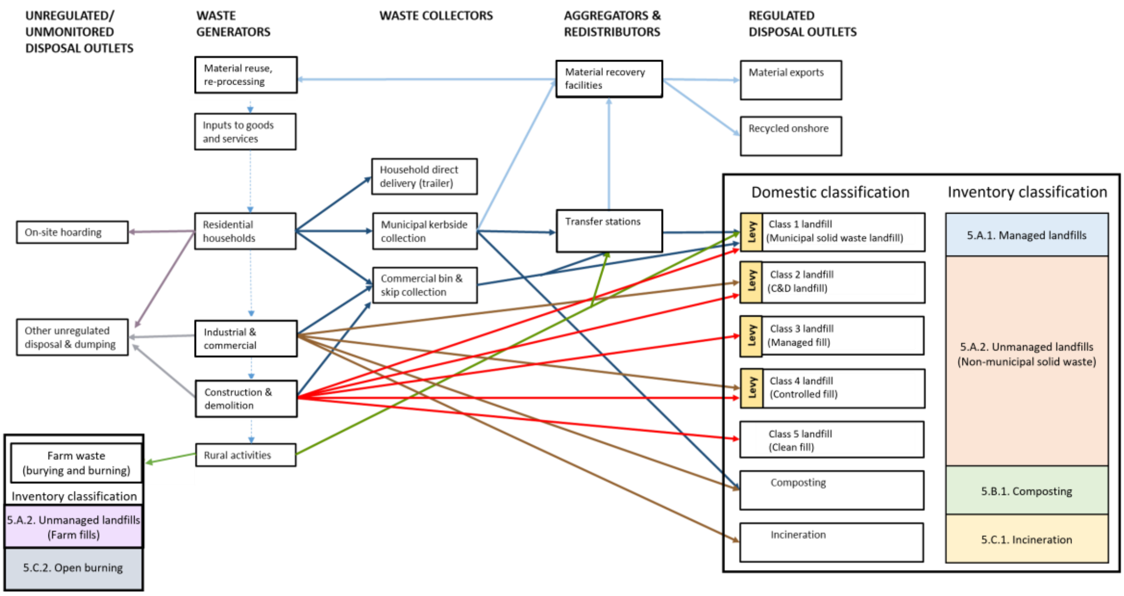
Most wastewater treatment in New Zealand is aerobic and includes domestic and industrial wastewater, all releasing CH_4 emissions. It contributed to 13.8 per cent of the sector's CH_4 emissions. Methane emissions from domestic wastewater are mainly from rural septic tank usage. Wastewater emissions are also produced by some municipal treatment plants that use semi-aerobic processes, and from industries in New Zealand, in particular, the meat and the pulp and paper industries.

In 2023, the sector's emissions decreased by 11.0 per cent from 1990. This is a result of several government policies including the introduction of a levy on the disposal of waste to municipal and non-municipal landfills in 2009 via the Waste Minimisation Act 2008, the inclusion of most municipal landfills in the New Zealand Emissions Trading Scheme (NZ ETS), and resource consent requirements for certain landfills.

The Government has reaffirmed its commitment to working with the sector to reduce emissions through the second emissions reduction plan (Ministry for the Environment, 2024). In 2024, the Ministry for the Environment published this plan, outlining the actions required to meet New Zealand's emissions budget for 2026–30. Chapter 13 of the plan specifically addresses measures for the waste sector, and any resulting impacts will be reflected in future greenhouse gas inventories.

New Zealand reports emissions from Tokelau, which is a dependent territory of New Zealand. Due to the application of different methods and the complexity of integrating emissions within the main sectors, Tokelau emissions are reported for all activities under the ‘Other’ sector of the Inventory. Therefore, all emissions reported in this sector exclude Tokelau. Please refer to chapter 8 and annex 7 for details of methods applied and the emissions for Tokelau.

Figure 7.1.1 Sources of and disposal practices for solid waste in New Zealand



7.1.2 Emissions summary

The Waste sector in New Zealand produces mainly CH_4 (91.9 per cent) followed by nitrous oxide (N_2O) (5.3 per cent) and carbon dioxide (CO_2) emissions (2.8 per cent). The Waste sector produces 7.3 per cent of gross CH_4 emissions in New Zealand. There are also emissions of CO_2 from the disposal of solid waste, but these are of biogenic origin and are not reported.

2023

In 2023, emissions from the Waste sector contributed 2,916.6 kilotonnes carbon dioxide equivalent (kt CO_2-e) or 3.8 per cent of New Zealand’s gross greenhouse gas emissions. The largest source category is *Solid waste disposal*, as shown in table 7.1.1.

1990–2023

In 2023, emissions from the Waste sector decreased by 11.0 per cent (361.0 kt CO_2-e), from 3,277.6 kt CO_2-e in 1990.

Annual emissions peaked at 3,830.2 kt CO_2-e in 2002 and have generally been in decline since that time. Growth in population and economic activity since 1990 has resulted in increasing volumes of solid waste and wastewater for the whole of the time series. Ongoing improvements in the management of solid waste disposal at municipal landfills have meant total Waste sector emissions have been trending down since 2005, despite increasing volumes of solid waste and wastewater. The reduction in emissions is primarily the result of increased CH_4 recovery through the installation of landfill gas (LFG) capture systems, driven by National Environmental Standards for Air Quality introduced in 2004 and by the inclusion of the waste sector in the NZ ETS in 2013. These legislative tools have been complemented by local government efforts to improve kerbside collections, including for organic waste, across the country, and by a central government waste work programme that includes product stewardship, plastic phase-outs and investment in resource recovery infrastructure for organic materials. Trends in annual emissions are shown in chapter 2, figure 2.2.11 and in figure 7.1.2 and figure 7.1.3.

2022–2023

Between 2022 and 2023, emissions from the Waste sector decreased by 0.7 per cent (20.5 kt CO_2-e). This decrease is largely the result of decreases in CH_4 emissions in the *Managed waste disposal sites* category mainly due to increasing LFG capture and changes in the composition of waste, with a reduction in the proportion of garden, food and paper waste disposed to those sites.

Table 7.1.1 New Zealand's greenhouse gas emissions for the Waste sector by source category in 1990 and 2023

	Emissions (kt CO_2-e)		Difference (kt CO_2-e)	Change (%)	Share (%)	
Source category	**1990**	**2023**	**1990–2023**	**1990–2023**	**1990**	**2023**
Solid waste disposal (5.A)	2,630.4	2,256.8	-373.7	-14.2	80.3	77.4
Biological treatment of solid waste (5.B)	4.8	81.6	76.8	1,598.3	0.1	2.8
Incineration and open burning of waste (5.C)	319	176.9	-142.1	-44.5	9.7	6.1
Wastewater treatment and discharge (5.D)	323.3	401.3	77.9	24.1	9.9	13.8
Waste sector total	**3,277.6**	**2,916.6**	**-361.0**	**-11.0**	**-**	**-**

Note: Percentages presented are calculated from unrounded values. Columns may not total due to rounding.

Figure 7.1.2 Profile of emissions from New Zealand's Waste sector by source category from 1990 to 2023

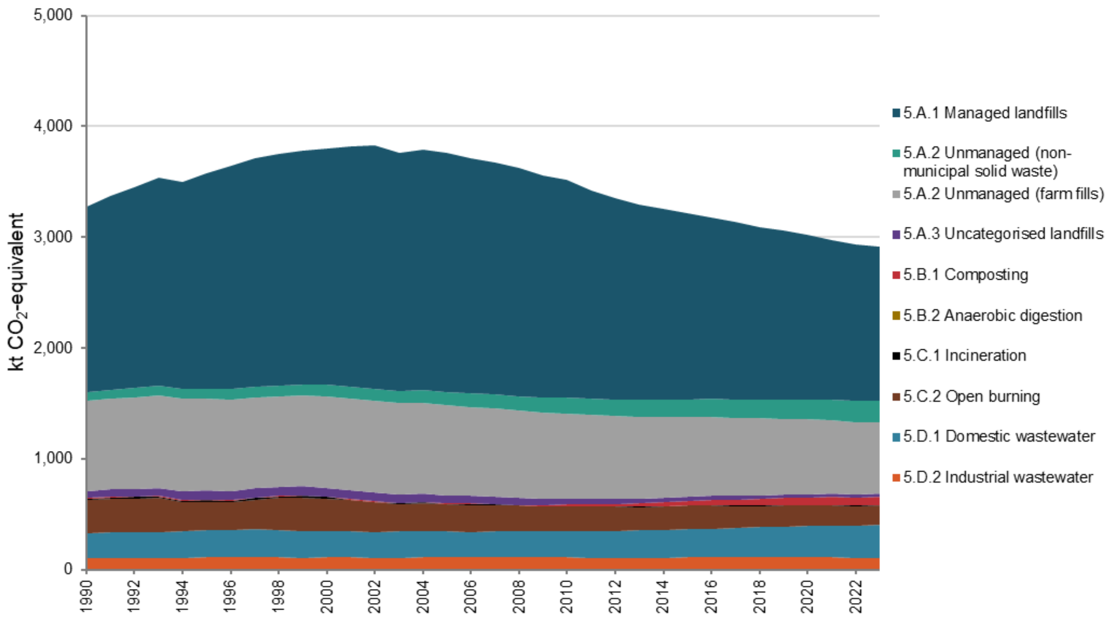
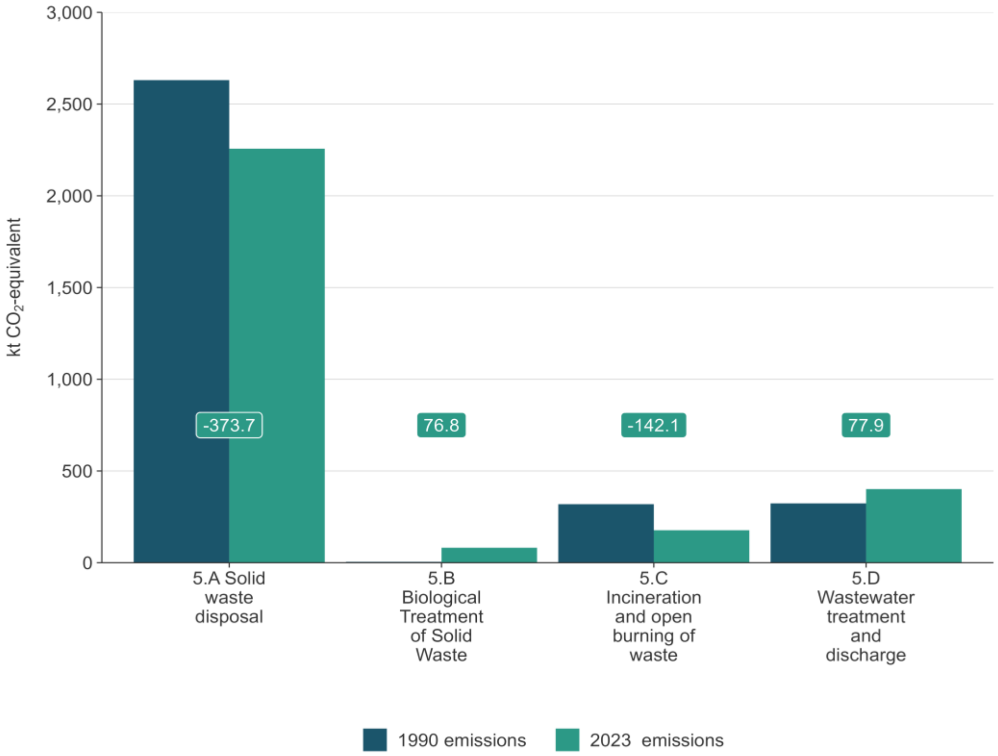


Figure 7.1.3 New Zealand's emissions from the Waste sector by source category, from 1990 to 2023



7.1.3 Key categories for Waste sector emissions

Details of New Zealand's key category analysis are in chapter 1, section 1.4. The key categories in the Waste sector are listed in table 7.1.2.

Table 7.1.2 Key categories in the Waste sector

CRF category code	IPCC category	Gas	Criteria for identification
5.A.	Waste – Solid waste disposal	CH_4	L1, T1
5.C.	Waste – Incineration and open burning of waste	CO_2	T1
5.D.	Waste – Wastewater treatment and discharge	CH_4	L1

Note: L1 means a key category is identified under the level analysis – approach 1, and T1 is trend analysis – approach 1. See chapter 1, for more information.

7.1.4 Methodological issues for the Waste sector

New Zealand uses Tier 2 methodologies for estimating emissions from the *Solid waste disposal* source category, which is a key category, and for some wastewater emissions. Tier 1 methodologies are used to estimate other emissions from the Waste sector.

Activity data have come from a variety of sources. Municipal solid waste disposal data were obtained from mandatory reporting under the Waste Minimisation Act 2008 and the NZ ETS for the years available (2010 onwards). Non-municipal waste disposal data were also derived from mandatory reporting under the Act from 2022 onwards. For all other sources, activity data were collected through targeted surveys. Interpolation based on gross domestic product (GDP) or population is used for other years.

Human population and animal production statistics provided by Stats NZ are also used for estimating emissions from the Waste sector.

Country-specific emission factors have been used where available, including parameters for municipal waste (Eunomia, unpublished(a)) and for treatment of some types of industrial wastewater (Cardno, unpublished).

Specific methodological issues are discussed under each source category in this chapter.

7.1.5 Uncertainties

The uncertainties for emission estimates are discussed under each category in this chapter. For most sources, they conform to the default scale of uncertainties in the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC, 2006a). Higher uncertainties are reported for wastewater going into rivers and seawater due to uncertainty in the emission factors associated with indirect N_2O emissions.

7.1.6 Verification

Where available, data from different sources were used for verification. All municipal and non-municipal landfills report their activity data either monthly, quarterly or annually under the requirements of the Waste Minimisation Act 2008. In addition, most municipal landfills also report activity data and estimated emissions (by mass balance) under the NZ ETS. These data sources are used as primary sources or for verification, as appropriate.

7.1.7 Recalculations and improvements

Improvements and recalculations made to estimates in the Waste sector have resulted in a 24.8 per cent (1,079.2 kt CO_2-e) decrease in emissions in 1990 and a 15.9 per cent (555.6 kt CO_2-e) decrease in emissions in 2022.

For the 2025 submission, three source categories have undergone significant updates:

- *Managed waste disposal sites – Anaerobic* (5.A.1): Updates have been made to emission factors and parameters, incorporating revised data on waste composition, the fraction of CH_4 in LFG, CH_4 generation rates and LFG recovery rates. These updates have been included in the Inventory to address three outstanding expert review recommendations from the 2022 assessment and review report (UNFCCC, 2023).
- *Unmanaged waste disposal sites* (5.A.2): Newly available activity and composition data, along with methodological improvements, have been incorporated into this category. Since 2022, non-municipal landfills are now required to monitor and report the waste they accept as part of the waste levy requirements under the Waste Minimisation Act 2008. Methodological adjustments were implemented to correct overestimations in previous submissions and to align with domestic landfill classifications for non-municipal landfills**.
- *Anaerobic digestion at biogas facilities* (5.B.2): For the first time, activity data and methodologies for the *Anaerobic digestion* category are included in this submission. These updates account for the commissioning of New Zealand's first large-scale food waste-to-bioenergy anaerobic digestion plant, which began operating in October 2022.[51] The facility is projected to process approximately 75,000 tonnes of food scraps annually.

** After the Inventory was finalised, a potential underestimate of emissions was identified in a Waste sector category (*Unmanaged waste disposal sites*). Preliminary analysis suggests that this may revise the decrease in Waste sector emissions from 11 per cent to 7 per cent between 1990 and 2023, and from 0.7 per cent to 0.5 per cent between 2022 and 2023. However, the impact on New Zealand's overall emissions totals is expected to be minor. Any adjustments will be made in future submissions, once a full review has been completed.

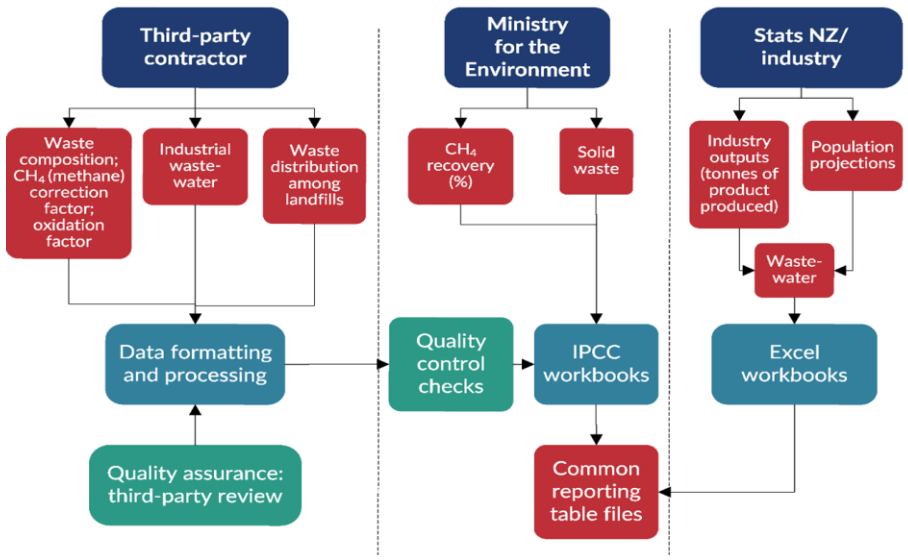
[51] See Ecogas. *Reporoa Organics Processing Facility*. Retrieved 5 February 2025.

Further details can be found under methodological issues within this chapter for each source category and in chapter 10.

7.1.8 Quality-assurance/quality-control (QA/QC) processes

Figure 7.1.4 shows a flow diagram for data in the Waste sector, including quality-assurance and quality-control processes. Tier 1 quality checks were carried out on all data for key categories in this sector.

Figure 7.1.4 Tier 1 quality checks for the Waste sector



7.2 Solid waste disposal (5.A)

7.2.1 Description

In New Zealand, the majority of solid waste from household, industrial and commercial sectors[52] is disposed of in landfills. However, approximately half of the farm waste is disposed of through open burning. The primary types of landfill sites in New Zealand are:

1. municipal landfills (Class 1): these primarily accept household and commercial waste but also handle industrial and other types of solid waste
2. non-municipal landfills (Classes 2, 3–4, 5 and industrial monofills): these significant landfills predominantly accept construction and demolition, commercial, inert and industrial waste
3. farm fills: these are used for the disposal of both household and farm waste, in addition to the common practice of open burning on farms

These landfill categories correspond to the Inventory categories outlined in table 7.2.1. All operational municipal landfill sites are managed according to IPCC Guidelines (IPCC, 2006a). However, emissions from uncategorised municipal landfills, which were operational before 2010, continue occurring due to first order decay.

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[52] The use of 'industrial and commercial' is in a general sense in this report, which is different from how these terms are used in a domestic policy setting.

Table 7.2.1 **Landfill emissions in the common reporting tables**

CRF category code	Landfill type using New Zealand terminology	Comment
5.A.1.a (Anaerobic)	Managed municipal landfills (Class 1)	Includes all currently operational municipal landfill sites and all sites with gas recovery
5.A.1.b (Semi-aerobic)	–	No semi-aerobic landfill sites identified in New Zealand
5.A.2 (Unmanaged)	Non-municipal landfills (Classes 2–5)	Includes industrial monofills
5.A.2 (Unmanaged)	Farm fills	Disposal to land of about half of farm waste
5.A.3 (Uncategorised)	Other municipal landfills (now closed)	While disposal is prior to 2010 only, emissions continue to be reported due to decay over time

Since 1990, a range of initiatives have been implemented to improve solid waste management practices in New Zealand, including:

- resource consent requirements: all municipal landfills must meet the conditions set under the Resource Management Act 1991
- National Environmental Standards for Air Quality (2004): enacted under the Resource Management Act 1991, these standards require large landfills to capture LFG, significantly increasing the adoption of LFG recovery technology
- New Zealand Waste Strategy: initially published in 2002 and updated in 2010 and 2023, this strategic document provides guidance for local governments and the waste sector (Ministry for the Environment, 2002a, 2010, 2023[53]).
- Solid Waste Analysis Protocol (2002): this protocol, updated in 2022, provides a consistent system for classifying, sampling and estimating the composition of solid waste (Ministry for the Environment, 2002b)
- Waste Minimisation Act 2008: this Act introduced a levy on the disposal of municipal solid waste disposal, initially set at NZ$10 per tonne in 2009 and progressively increased to NZ$60 per tonne by July 2024. Since 2022, the levy has also applied to non-municipal landfills. Additionally, from 1 July 2024, new waste data regulations came into effect under the Waste Minimisation Act 2008
- local government waste management plans: under the Waste Minimisation Act 2008, local governments are required to prepare waste management and minimisation plans every six years, supported by funding for waste minimisation services.

In addition, most municipal landfills are now mandatory participants in the NZ ETS, with obligations to report and surrender emission units for CH_4 emissions, estimated through mass balance methods.

These initiatives have led to significant improvements in waste management since 1990. Many small, poorly located and substandard municipal landfills have been closed, with municipalities now relying on larger, more modern regional facilities. In 2023, there were 40 active[54] municipal landfill sites, a significant reduction from 327 in 1995 and 563 in 1971. This shift has been driven by the policy initiatives outlined above, which have encouraged consolidation into fewer, better-managed landfills. The overall volume of waste disposed of in landfills has increased over time, largely due to population growth, especially in non-municipal fills (see table 7.2.3 and table 7.2.4). The increased disposal activity and reduction in the number of landfills means the operating facilities are larger.

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53 More information can be found about the new waste strategy and other developments at environment.govt.nz/what-government-is-doing/areas-of-work/waste/waste-legislation-review.

54 Ministry for the Environment. *Waste statistics*. Retrieved 4 February 2025.

Non-municipal landfills and farm fills are required to comply with regional policies and plans under the Resource Management Act 1991. Historically, these facilities were not required to monitor or report the waste they accepted, nor were they required to pay the waste levy or participate in the NZ ETS. However, since July 2022, non-municipal landfills have been included in the waste levy system.

In 2023, the *Solid waste disposal* source category contributed 2,256.8 kt CO_2-e (77.4 per cent) of total emissions from the Waste sector. Emissions from *Solid waste disposal* in 2023 were 373.7 kt CO_2-e (14.2 per cent) below the 1990 level of 2,630.4 kt CO_2-e. While there is year-to-year variation, this net decrease is the result of two trends. First, population and economic growth have driven ongoing increases in the total amount of municipal waste generated. Secondly, changing composition over time and improved landfill management practices, particularly LFG recovery, have offset this increase, resulting in emissions peaking in 2002.

Methane emissions from *Solid waste disposal* were identified as a key category in the 2023 level assessment and trend assessment.

7.2.2 Methodological issues

Choice of activity data

The quality and availability of activity data for *Solid waste disposal* vary significantly. For municipal landfills prior to 2010, data were primarily derived from occasional surveys, rather than consistent annual data collection. Since 2010, however, high-quality activity data have been reported monthly and annually through the waste levy system.

For non-municipal landfills, activity data used in this report were sourced exclusively from the levy system, replacing previous survey-based data collection, which was of limited quality and led to significant overestimations.

Municipal landfills (5.A.1.a and 5.A.3)

Annual waste placement data for municipal landfills have been estimated using the following methods:

- back-casting from a 1982 national survey, using real (inflation-adjusted) GDP, for the years before 1982
- national surveys conducted in 1982, 1995, 1998, 2002 and 2006
- linear interpolation for the years between these surveys
- linear interpolation for the years 2007 to 2009
- annual data collected under the Waste Minimisation Act 2008 since 2010.

A regression analysis established that there was a correlation between real GDP and the amount of waste landfilled up to 2002. The transition from national surveys to using data collected under the Waste Minimisation Act 2008 involves linear interpolation. Other methods were explored, but this approach gave the most robust estimates (Eunomia Research and Consulting and Waste Not Consulting, unpublished).

Additional data for landfill emissions were collected through a 2009 survey (SKM, unpublished(b)) of 25 landfills operating at the time, all of which either had or planned to install LFG recovery systems by 2012. These sites provided annual waste placement data.

While some of these landfills have since closed and no longer accept waste, they continue to generate CH_4 emissions. Since 2009, one large landfill has opened and an existing site installed an LFG recovery system in 2018. These sites are included in the emissions estimates.

From 2010 onwards, all municipal landfills report waste placement volumes under the Waste Minimisation Act 2008. The number of managed landfills is detailed in table 7.2.2.

Table 7.2.2 Landfill categories in 2023

Landfill type	Sites with LFG recovery	Sites without LFG recovery	Total
Open landfills under the NZ ETS and waste levy	17	23	40
Closed landfills (still emitting)	10	16	26
Total	27	39	66

Note: LFG = landfill gas; NZ ETS = New Zealand Emissions Trading Scheme.

For the period from 1950 to 1995, waste placement at *Uncategorised waste disposal sites* (5.A.3) is estimated as a fixed fraction (10 per cent) of the difference between the national total and sites with LFG recovery, as shown in the equation below:

$$\text{disposal for } 5.A.3 = 10\% \times (\text{national total} - \text{disposal for LFG sites})$$

Between 1995 and 2010, the 10 per cent fraction gradually declines to zero. From 2010 onwards, activity data for uncategorised sites are reported as 'not occurring'.

Waste placement from 1950 to 2023 is presented in table 7.2.3. Landfill sites that have had LFG recovery systems at any point since 1950 are categorised as 'sites with LFG recovery', even though no sites had such systems before 1985.

Table 7.2.3 Solid waste deposited to municipal and uncategorised landfills, from 1950 to 2023

Year	Sites with LFG recovery (kt)	Sites without LFG recovery (kt)	Uncategorised sites (kt)	Total (kt)
1950	33.7	74.7	8.3	116.6
1951	77.5	164.7	18.3	260.6
1952	77.5	118.7	13.2	209.4
1953	77.5	127.3	14.1	219
1954	77.5	195.3	21.7	294.5
1955	181.7	180.3	20.0	382.1
1956	181.7	202.7	22.5	407
1957	181.7	241.8	26.9	450.4
1958	181.7	267.1	29.7	478.5
1959	181.7	281.5	31.3	494.5
1960	181.7	349.3	38.8	569.9
1961	181.7	438.5	48.7	668.9
1962	181.7	447.2	49.7	678.6
1963	447.9	297.3	33.0	778.2
1964	447.9	369.1	41.0	858
1965	447.9	477.2	53.0	978.1
1966	447.9	566.8	63.0	1,077.6
1967	495.8	486	54.0	1,035.8
1968	495.8	485.2	53.9	1,034.9
1969	495.8	489.1	54.3	1,039.2
1970	654.1	497.4	55.3	1,206.9

Year	Sites with LFG recovery (kt)	Sites without LFG recovery (kt)	Uncategorised sites (kt)	Total (kt)
1971	654.1	554.4	61.6	1,270.1
1972	672.5	746.9	83.0	1,502.5
1973	672.5	889.1	98.8	1,660.4
1974	844.5	839.4	93.3	1,777.1
1975	844.5	736.6	81.8	1,662.9
1976	984.9	578.2	64.2	1,627.4
1977	984.9	713	79.2	1,777.2
1978	984.9	588.6	65.4	1,639.0
1979	984.9	581.8	64.6	1,631.4
1980	984.9	572.1	63.6	1,620.6
1981	984.9	581.8	64.6	1,631.4
1982	984.9	937.7	104.2	2,026.8
1983	984.9	1,017.6	113.1	2,115.7
1984	1,156.5	943.2	104.8	2,204.5
1985	1,259.1	930.9	103.4	2,293.4
1986	1,259.1	1,010.9	112.3	2,382.3
1987	1,342.7	1,015.6	112.8	2,471.1
1988	1,432.6	1,014.7	112.7	2,560.0
1989	1,432.6	1,094.7	121.6	2,648.9
1990	1,432.6	1,174.7	130.5	2,737.8
1991	1,432.6	1,254.7	139.4	2,826.6
1992	1,432.6	1,334.7	148.3	2,915.5
1993	1,650.5	1,218.5	135.4	3,004.4
1994	1,687.5	1,265.2	140.6	3,093.2
1995	1,687.5	1,345.2	149.5	3,182.1
1996	1,735.0	1,186.0	122.1	3,043.1
1997	1,671.2	1,126.0	106.8	2,904.1
1998	1,605.0	1,067.2	92.8	2,765.0
1999	1,605.0	1,134.5	89.8	2,829.3
2000	1,605.0	1,202.6	85.9	2,893.5
2001	1,748.3	1,136.9	72.6	2,957.8
2002	1,797.0	1,159.7	65.3	3,022.0
2003	1,694.9	1,297.1	63.5	3,055.5
2004	1,746.2	1,289.1	53.7	3,089.0
2005	1,954.3	1,129.2	38.9	3,122.5
2006	2,384.2	751.2	20.6	3,156.0
2007	2,244.9	739.8	15.1	2,999.8
2008	2,189.3	645.4	8.7	2,843.5
2009	2,143.9	539.8	3.6	2,687.2
2010	2,338.7	193.8	NO	2,532.5
2011	2,330.1	182.4	NO	2,512.5
2012	2,335.8	179.1	NO	2,515.0
2013	2,524.2	161.2	NO	2,685.4
2014	2,776.8	156.2	NO	2,933.1
2015	3,053.9	168.5	NO	3222.4
2016	3,232.9	172.1	NO	3,404.9
2017	3,349.1	145.2	NO	3,494.3
2018	3,610.1	95.1	NO	3,705.3

Year	Sites with LFG recovery (kt)	Sites without LFG recovery (kt)	Uncategorised sites (kt)	Total (kt)
2019	3,405.8	92.4	NO	3,498.2
2020	3,297.5	85.8	NO	3,383.3
2021	3,425.4	112.3	NO	3,537.7
2022	3,472.4	127.8	NO	3,600.2
2023	3,371.2	139.1	NO	3,510.3

Note: LFG = landfill gas; NO = not occurring. Columns may not total due to rounding.

Non-municipal landfills and farm fills (5.A.2)

Non-municipal landfills primarily accept construction and demolition, inert and industrial waste. While household waste is not intended to be accepted, some may receive incidental amounts of green waste or putrescibles. These landfills are categorised under the Waste Disposal Levy as follows:

- Class 2: Construction and demolition disposal facilities
- Class 3–4: Controlled fill facilities, receiving inert waste material from construction and demolition including earthworks
- Class 5: Cleanfill facilities, receiving natural excavated material such as clay, soil and rock
- industrial monofills: Waste from a single industrial process.

In previous submissions, activity data for non-municipal landfills were derived from a limited number of facilities, obtained through direct contact with landfill operators and regional councils. Large data gaps were addressed by correlating waste quantities with regional GDP. However, mandatory reporting under the Waste Minimisation Act 2008 has improved data collection. As of January 2022, Class 2 landfills began reporting waste volumes, with other landfill classes starting in January 2023. These data revealed that earlier estimates for non-municipal landfills significantly underestimated disposal volumes, particularly for Class 3–4, Class 5 and industrial monofills.

A regression analysis demonstrated a strong correlation between real GDP and waste volumes. Consequently, real GDP is now used as a proxy to estimate waste disposal volumes since 1950, relying exclusively on data collected through the levy. Waste quantities are calculated for each landfill class and aggregated to provide a national total.

Farm fills are used to dispose of various farming wastes, including scrap metal, timber, plastic wraps, batteries and demolition materials. Farmers may also dispose of household waste, green waste, offal and crops.

The data used to estimate activity and emissions from farm fills stem from surveys conducted in the Canterbury region (2012 to 2013) and in the Waikato and Bay of Plenty regions (2014) (GHD, 2013, 2014; Tonkin and Taylor Ltd, unpublished(b)). These survey results were extrapolated to estimate national waste quantities based on the number of farms in each region and year. Farming practices across the country are similar, so this extrapolation is unlikely to introduce significant bias. However, the sample size is limited, and changes in farm sizes and waste disposal practices (e.g., the introduction of the levy) have not been fully accounted for.

Waste quantities were averaged for surveyed farm types: dairy, livestock, arable, viticulture and other horticulture. These regional estimates were combined to provide a national total, with adjustments for differences in farm type prevalence over time (Tonkin and Taylor Ltd, unpublished(b)).

The number and type of farms were estimated using data from the Agriculture Production Survey, ensuring consistency with data from the Agriculture sector, including livestock numbers.

A key update in the 2021 submission was the revision of farm waste disposal methods. It was assumed that farm waste is evenly split between disposal in farm fills and open burning, with each method accounting for 47 per cent of the total, while 6 per cent is disposed of by other means. This contrasts with previous submissions, which assumed open burning accounted for only 2 per cent of farm waste, based on a 2013 report from Tonkin and Taylor Ltd (unpublished(b)) suggesting that most farm waste was buried. However, open burning is a prevalent practice in New Zealand, supported by frequent complaints to regional councils and survey findings from GHD (2013, 2014), which indicated that almost every farm has a burn pile or similar setup.

Because wood waste constitutes a large proportion of CH_4 emissions from farm fills, it is crucial to account for wood waste that is burned rather than buried. This balanced approach will be reviewed once more precise data become available.

In 2022, Eunomia (unpublished(c)) consulted experts nationwide and confirmed that the assumption of an even split between burial and burning remains valid.

Table 7.2.4 presents the waste placement data for farm fills (excluding open burning or other disposal methods) and non-municipal landfills from the beginning of the model in 1950 to 2023.

Table 7.2.4 Solid waste deposited to unmanaged landfills, from 1950 to 2023

Year	Farm fills (kt)	Non-municipal landfills (kt)	Total waste disposed (kt)
1950	853.9	3,664.1	4,518.0
1951	853.4	3,798.5	4,651.9
1952	853.9	3,937.9	4,791.8
1953	856.2	4,082.3	4,938.5
1954	867.2	4,231.8	5,099.1
1955	873.9	4,386.8	5,260.7
1956	801.1	4,547.4	5,348.5
1957	800.2	4,713.8	5,513.9
1958	785.2	4,886.1	5,671.4
1959	788.3	5,064.7	5,853.0
1960	727.6	5,249.7	5,977.3
1961	692.0	5,441.4	6,133.4
1962	688.1	5,640.0	6,328.1
1963	683.7	5,845.7	6,529.4
1964	678.1	6,058.8	6,736.9
1965	666.5	6,279.5	6,946.0
1966	661.1	6,508.2	7,169.3
1967	644.8	6,745.1	7,389.9
1968	632.4	6,990.4	7,622.9
1969	627.8	7,244.6	7,872.4
1970	617.9	7,507.9	8,125.8
1971	613.6	7,780.6	8,394.2
1972	593.8	8,063.0	8,656.9

Year	Farm fills (kt)	Non-municipal landfills (kt)	Total waste disposed (kt)
1973	597.7	8,355.6	8,953.3
1974	600.1	8,658.6	9,258.8
1975	634.3	8,972.5	9,606.7
1976	641.0	9,297.5	9,938.5
1977	648.5	9,634.2	10,282.7
1978	656.4	9,982.8	10,639.2
1979	666.3	10,014.6	10,680.9
1980	676.3	10,234.1	10,910.4
1981	685.8	10,365.5	11,051.4
1982	699.2	10,848.1	11,547.3
1983	716.4	10,948.9	11,665.3
1984	724.8	11,331.2	12,056.0
1985	745.4	11,874.3	12,619.7
1986	755.0	12,066.1	12,821.1
1987	764.2	12,392.7	13,156.9
1988	776.1	12,513.0	13,289.1
1989	782.0	12,468.6	13,250.7
1990	769.1	12,488.8	13,257.9
1991	763.4	12,507.9	13,271.2
1992	754.2	12,371.5	13,125.7
1993	769.3	12,506.9	13,276.2
1994	659.9	13,306.2	13,966.1
1995	653.3	13,987.3	14,640.7
1996	627.7	14,647.9	15,275.6
1997	674.1	15,176.7	15,850.8
1998	720.4	15,492.4	16,212.8
1999	766.8	15,625.5	16,392.3
2000	733.8	16,465.5	17,199.3
2001	700.8	16,938.1	17,638.9
2002	667.8	17,516.0	18,183.8
2003	627.5	18,341.6	18,969.1
2004	632.3	19,209.0	19,841.4
2005	613.1	19,994.3	20,607.4
2006	614.6	20,664.8	21,279.4
2007	602.7	21,239.1	21,841.8
2008	576.4	21,887.0	22,463.4
2009	564.3	21,615.6	22,179.9
2010	569.8	21,604.4	22,174.3
2011	552.1	21,916.5	22,468.6
2012	553.5	22,407.8	22,961.3
2013	539.5	22,920.3	23,459.9
2014	540.1	23,552.7	24,092.8
2015	526.1	24,437.3	24,963.3
2016	528.2	25,345.1	25,873.4
2017	498.7	26,293.2	26,791.9
2018	483.8	27,186.7	27,670.5
2019	472.4	28,140.2	28,612.6
2020	470.0	28,806.8	29,276.8

Year	Farm fills (kt)	Non-municipal landfills (kt)	Total waste disposed (kt)
2021	474.3	28,691.3	29,165.5
2022	449.9	30,003.7	30,453.6
2023	441.6	30,852.7	31,294.3

Note: Columns may not total due to rounding. It is assumed that an equal and additional amount of farm waste that is buried in farm fills is burned (see section 7.4).

Choice of methods

Estimations of CH_4 emissions from *Solid waste disposal* to land were calculated using the first order decay (FOD) model, in accordance with the Tier 2 method outlined in the 2006 IPCC Guidelines (IPCC, 2006a). This method assumes that the degradable organic component in waste decays slowly through decades, during which CH_4 and CO_2 are formed.

Municipal landfills (5.A.1.a)

Municipal landfills employ a multi-phase FOD model consistent with the IPCC (2006a) Guidelines, using country-specific parameters.

For each of the 27 landfill sites that had LFG recovery at any point, the multi-phase FOD model has been applied to estimate CH_4 emissions. This model incorporates site-specific data, such as waste placement volumes, decay rates (k-values) based on local climate conditions, and LFG recovery efficiency rates that reflect the landfill's operational status (either open or closed). These 27 sites, still operational, account for approximately 90 per cent of the waste disposed at municipal landfills, as shown in table 7.2.3.

Municipal waste at sites outside of these 27 landfills is typically disposed of in smaller landfills that have never had gas recovery systems. In 1990, more than 300 such sites existed, and by 2023, approximately 23 were still in operation. This number includes very small sites serving small and remote communities. The FOD model has also been applied to estimate the total CH_4 emissions from these landfills as a whole, using the same approach as the sites with LFG recovery, except that all of these sites are assumed to have a wet climate and zero LFG recovery.

Non-municipal landfills and farm fills (5.A.2)

Most non-municipal landfills and privately owned industrial landfills are permitted to receive inert materials, though some may also receive up to 5 per cent to 10 per cent green waste, depending on local resource consent conditions. Construction and demolition landfills and some industrial monofills may receive a wider range and/or a higher proportion of organic materials. Limited information is available regarding the historical management practices at these sites. The FOD model has been applied to estimate total CH_4 emissions from non-municipal landfills.

For farm fills, the FOD model has been used to estimate CH_4 emissions based on the proportion of farm waste landfilled. Survey data on waste composition from dairy, livestock, arable and viticulture farms (GHD, 2013, 2014) were used to determine weighted average values for the degradable organic carbon (DOC) content of waste from these farming sectors. Data for viticulture and arable farms were used to estimate the DOC content for other horticultural farm types (GHD, 2013).

Choice of emission factors and parameters

Municipal landfills (5.A.1.a)

Waste composition

Many municipal landfills in New Zealand accept both commercial and industrial waste, in addition to household waste. However, there is insufficient data to determine the exact proportion of waste disposed of at municipal landfills that originates from commercial and industrial sources. While government regulations requiring disposal facility operators to report the source of waste they receive were agreed upon in 2023, these regulations came into effect in 2024, and the first full set of data will be available in 2025. Where composition surveys have been conducted at sites that accept commercial and industrial waste, these data have been incorporated into the overall waste composition estimates.

Waste composition estimates have been derived from national surveys conducted in 1995 and 2004 (Ministry for the Environment, 1997; Waste Not Consulting, unpublished(a)). Further estimates have been made for the years 2006, 2008, 2012, 2016, 2018 to 2019 and 2021 to 2023, based on individual landfill surveys (Eunomia, unpublished(a), unpublished (d); MWH, 2017; Waste Not Consulting, unpublished(b), unpublished(c)). These surveys were conducted using the Solid Waste Analysis Protocol (Ministry for the Environment, 2002b), adapted to landfill type, to ensure consistent sampling and analysis methodologies. The 2018 surveys, conducted by territorial authorities at 18 disposal facilities and transfer stations, covered 66 per cent of the total waste disposed of at the surveyed municipal landfills that year.

No reliable waste composition data are available for the period prior to 1995. For the years 1950 to 1994, the 1995 survey data were used, with adjustments made to account for the introduction of disposable nappies in the 1960s (Eunomia Research and Consulting and Waste Not Consulting, unpublished). Linear interpolation was applied for the years between survey years, and waste composition from 2018 onwards is assumed to be consistent with the 2018 data. Additional individual landfill surveys conducted after 2018 were used to refine the composition estimates, though the impact of these adjustments was minimal.

Table 7.2.5 presents the estimated waste composition data for the period from 1950 to 2023, which have been applied to all municipal landfills.

Table 7.2.5 Estimated composition of waste disposed to municipal landfills, from 1950 to 2023

Year	Food (%)	Garden (%)	Paper (%)	Wood (%)	Textile (%)	Nappies (%)	Sludge (%)	Inert (%)	Notes
1950–60	17.2	11.0	16.3	7.1	0.5	0.0	2.9	45.0	No nappies
1961–69	17.2	11.0	16.3	7.1	0.5	1.0	2.9	44.0	Based on interpolation
1970–79	17.2	11.0	16.3	7.1	0.5	2.0	2.9	43.0	Interpolation
1980–94	17.2	11.0	16.3	7.1	0.5	2.7	2.9	42.3	As for 1995
1995–2003	17.2	11.0	16.3	7.1	0.5	2.7	2.9	42.3	National survey
2004	14.1	9.2	14.9	13.9	3.9	2.7	2.9	38.4	National survey
2005	14.9	9.2	13.4	13.4	3.9	2.9	2.9	39.4	Based on interpolation
2006	15.6	9.3	12.0	13.0	3.9	3.0	2.9	40.4	Based on survey data
2007	16.4	9.3	10.5	12.5	3.9	3.2	2.9	41.4	Based on interpolation
2008	17.1	9.4	9.0	12.0	3.8	3.3	2.9	42.4	Based on survey data
2009	17.0	9.1	9.4	12.0	4.3	3.2	3.2	41.8	Based on interpolation
2010	16.9	8.9	9.8	11.9	4.7	3.2	3.4	41.1	Based on interpolation
2011	16.9	8.6	10.3	11.9	5.2	3.1	3.7	40.5	Based on interpolation
2012	16.8	8.3	10.7	11.9	5.6	3.0	3.9	39.9	Based on survey data
2013	15.5	7.9	9.9	12.0	5.5	2.9	3.6	42.8	Based on interpolation

Year	Food (%)	Garden (%)	Paper (%)	Wood (%)	Textile (%)	Nappies (%)	Sludge (%)	Inert (%)	Notes
2014	14.2	7.5	9.1	12.1	5.4	2.8	3.2	45.7	Based on interpolation
2015	12.9	7.0	8.3	12.2	5.3	2.7	2.9	48.6	Based on interpolation
2016	11.6	6.6	7.5	12.4	5.2	2.6	2.6	51.5	Based on survey data
2017	10.3	6.2	6.7	12.5	5.1	2.6	2.3	54.4	Based on interpolation
2018	9.0	5.7	5.9	12.6	5.0	2.5	1.9	57.3	Based on survey data
2019	9.0	5.7	5.9	12.6	5.0	2.5	1.9	57.3	Based on survey data
2020	9.0	5.7	5.9	12.6	5.0	2.5	1.9	57.3	Assumed same as 2019
2021	9.0	5.7	5.9	12.6	5.0	2.5	1.9	57.3	Based on survey data
2022	9.0	5.7	5.9	12.6	5.0	2.5	1.9	57.3	Based on survey data
2023	9.0	5.7	5.9	12.6	5.0	2.5	1.9	57.3	Based on survey data

Changes in waste composition over time result in varying amounts of decomposable degradable organic carbon (DDOC) being introduced into landfills. See table 7.2.6 for the specific values used for DDOC and other relevant variables.

Methane correction factor, oxidation factor and fraction of methane in landfill gas (F)

The CH_4 correction factor used is 1.0 for all managed landfill sites, both landfills with LFG recovery and those without. A default IPCC oxidation factor of 10 per cent has been applied to these sites.

For sites other than managed landfills, where the mix of shallow and deep disposal areas is unknown, a survey conducted in 1971 estimated that larger operational sites at the time were approximately half deep (over 5 metres) and half shallow. The application of cover material at these sites was also variable. Therefore, for uncategorised landfills, a CH_4 correction factor of 0.6 and an oxidation factor of zero have been applied.

The fraction of CH_4 in LFG (F) is set at 50 per cent for both municipal and uncategorised landfills. This value was revised from a previous estimate of 57 per cent, which was based on LFG monitoring data from the United Kingdom. This earlier value was assumed to be applicable due to similarities in landfill management practices between New Zealand and the United Kingdom. However, it was decided that, in the absence of country-specific analyses to account for CO_2 absorption in seepage water, the default IPCC value will be used for the fraction of CH_4 in LFG.

Methane generation rates

The parameters used to determine the quantity and rate of CH_4 generation are provided in the study by Eunomia (unpublished(a)). Table 7.2.6 outlines these parameters in detail.

Table 7.2.6 Parameters by waste type that determine the quantity and rate of methane generation

Parameter	Food	Garden	Paper	Wood	Textile	Nappies	Sludge[b]
DDOC	0.11[a]	0.09	0.16	0.06	0.20 (1950s) to 0.08 (2020 onwards)	0.04	0.025
DOCf[c]	0.7	0.56	0.5	0.14	0.5	0.5	0.5
DOC (=DDOC/DOCf)	0.16	0.16	0.32	0.43	0.40 (1950s) to 0.16 (2020 onwards)	0.08	0.05
k-value wet sites (>700 mm rain/year)	0.19	0.1	0.06	0.03	0.06	0.06	0.19
k-value dry sites	0.06	0.05	0.04	0.02	0.04	0.04	0.19

Note: DDOC = decomposable degradable organic carbon; DOC = degradable organic carbon; DOCf = DOC fraction. All parameters are from Eunomia (unpublished(a)) except: (a) DDOC for food is from IPCC (2019); (b) all values for sludge are from IPCC (2006a) default wet temperate; and (c) all DOCf values are from IPCC (2019) except for garden waste (Eunomia, unpublished(a)).

Eunomia (unpublished(a)) recommended the use of DOC fraction (DOCf) values that align with the 2019 IPCC refinement to the 2006 Guidelines, with one adjustment for garden waste to account for the presence of woody branches (IPCC, 2019). DOC values are derived from the ratio of DDOC to DOCf, rather than being explicitly provided. The DDOC values for all materials differ from the IPCC (2006a) defaults, reflecting global trends in material characteristics.

- For food waste, the most appropriate DDOC is the IPCC default (IPCC, 2019).
- For paper, the DDOC is lower than the IPCC (2006a) default to reflect the more resistant types of paper (such as magazines and newsprint), which degrade more slowly due to their high lignin content.
- For wood, the DDOC is specific to New Zealand and significantly lower than the IPCC (2006a) defaults but closer to the values from the 2019 IPCC refinement to the 2006 Guidelines (IPCC, 2019). This adjustment accounts for the mix of treated and untreated wood disposed of in New Zealand landfills, as well as the varying degradability of these materials.
- For textiles, DDOC values are adjusted to reflect the increasing prevalence of synthetic fibres over time.
- For nappies, DDOC is set lower than the IPCC default, which is based on the Swedish anaerobic digestion model, because there is no specific source or justification for the default in the IPCC methodology.

Decay rates (k-values) are determined by climate and material composition, using the IPCC default values (2006a). While the k-values used in the past four submissions of the Inventory were derived from Eunomia (unpublished(a)), it was decided to revert to the default IPCC values, due to the limited number of site-specific models available to calibrate decay rate performance accurately.

Methane recovery

Country-specific CH_4 recovery rates were gathered from a range of open and closed facilities, varying in size from small to large. These data were provided to the Ministry for the Environment through a voluntary survey conducted in 2024. To estimate LFG collection efficiency for each site, several assumptions were made regarding the following parameters.

- Gas capture cover type and capture rate: Coverage values for all sites were derived from the survey data. For sites that provided comprehensive data, site-specific recovery rates were applied. For non-participatory landfills or those that did not provide sufficient quality data, a default recovery rate of 20 per cent was applied, based on IPCC default values. Assumed capture rates (without losses) for each cover type were estimated based on international LFG modelling (Gregory, 2017).
- Capture rate losses: Assumptions were made regarding loss rates at each site’s LFG system at different stages of its life cycle. A 10 per cent loss in capture rate was assumed once gas collection begins but before flaring is introduced. This loss increases to 10 per cent to 20 per cent after flaring starts. After LFG collection ceases (assumed to be 15 years after flaring begins), the loss rate drops to zero.
- Cover type losses after filling: Expert judgement was applied to assumptions regarding the transition from operational areas to permanently capped areas once landfill operations cease. It is assumed that operational areas reduce by 100 per cent (to 0 hectares) in the year following the cessation of operations. The area covered by temporary caps is expected to decrease to zero over time, while the area covered by permanent caps is expected to increase to 100 per cent.

- Capture rate before operations: A capture rate of 0 per cent is assumed before the implementation of LFG systems.

In general, higher recovery rates are associated with modern, large and well-managed facilities that have more efficient systems compared with other sites. While the Ministry for the Environment aims to collect additional country-specific capture data regularly, to revise these assumptions, it is important to note these data cannot be made publicly available because they are commercially sensitive.

Summary of parameters used

Table 7.2.7 summarises the parameter values applied for estimating CH_4 emissions for solid waste disposed to municipal landfills.

Table 7.2.7 Summary of parameters for municipal landfills

Parameter	Values	Source	Reference
Managed landfills			
k-value (by waste type and rainfall)	0.030–0.185	IPCC default	IPCC (2006a)
Methane correction factor	1	IPCC default	IPCC (2006a)
Oxidation factor	10 per cent	IPCC default	IPCC (2006a)
Recovery efficiency	30–80 per cent (site specific) 0 per cent (no recovery)	Site specific	Eunomia (unpublished(d))
DDOC (kt C/kt waste)	0.05–0.43	Country specific	Eunomia (unpublished(a)), IPCC (2006a)
DOCf that decomposes	0.14–0.7	Country specific	Eunomia (unpublished(a)), IPCC (2006a)
Fraction of methane in landfill gas (F)	0.5	Country specific	IPCC (2006a)
Uncategorised landfills			
k-value (multi-phase by waste type)	0.030–0.185	IPCC default	IPCC (2006a)
Methane correction factor	0.6	IPCC default	IPCC (2006a)
Oxidation factor	0	IPCC default	IPCC (2006a)
DOC (kt C/kt waste) (by waste type)	0.15–0.43	IPCC default	IPCC (2006a)
DOCf that decomposes	0.5	IPCC default	IPCC (2006a)
Fraction of methane in landfill gas (F)	0.5	IPCC default	IPCC (2006a)
All landfill sites			
Starting year	1950	IPCC default	IPCC (2006a)
Delay time	6 months	IPCC default	IPCC (2006a)

Note: DDOC = decomposable degradable organic carbon; DOC = degradable organic carbon; DOCf = DOC fraction; IPCC = Intergovernmental Panel on Climate Change.

Non-municipal landfills and farm fills (5.A.2)

Waste composition

Waste composition estimates for non-municipal landfills (Class 2–5 landfills and industrial monofills) are derived from voluntary waste survey data compiled in 2024 (Eunomia, unpublished(d)) and expert judgement. The waste survey follows the updated version of the Solid Waste Analysis Protocol (Ministry for the Environment, 2002b), adapted to non-municipal landfills, and the waste categories were mapped to the corresponding IPCC waste types (IPCC, 2006a).

The primary waste types disposed of in non-municipal landfills include soil, rubble, concrete, wood and green waste. Custom DOC values were applied (Eunomia, unpublished(c)), with the exception of rubber and sludge, which used the IPCC default values. Wood waste, which uses a custom DDOC value, consists largely of wood processing waste. Studies have shown that this type of waste contains a higher lignin content, which breaks down more slowly and less completely (Eunomia, unpublished(a)), leading to lower CH_4 generation.

For farm fills, the DOC for bulk municipal solid waste is applied to some farm waste, based on results from the non-natural rural waste survey (GHD, 2013). This approach is appropriate because the farm waste is expected to be a mixture of domestic refuse, inert materials (e.g., scrap metal and glass) and waste specific to the farming activities. Because this mixture is similar to municipal solid waste, using the DOC values for bulk municipal solid waste is considered suitable (Tonkin and Taylor Ltd, unpublished(b)).

Other parameters

The majority of non-municipal landfills and farm fills are shallow, with less than 5 metres depth of waste. These are estimated to account for 90 per cent of the waste disposed, with a CH_4 correction factor value of 0.4. The other 10 per cent (approximately) goes to fills that are assumed to be:

- for non-municipal landfills, an unknown mix that would have an average CH_4 correction factor value of 0.6; this gives an overall average of 0.42 for these sites
- for farm fills with deeper pits that have an average depth greater than 5 metres, the CH_4 correction factor value is 0.8 and the average for all farm fills is 0.44.

Default k-values for a wet temperate climate are used. No oxidation is assumed to occur in the cover for these unmanaged sites.

Summary of parameters used

Table 7.2.8 summarises the parameter values applied for estimating CH_4 emissions for solid waste disposed to non-municipal landfills and farm fills.

Table 7.2.8 Summary of parameters for non-municipal landfills and farm fills

Parameter	Values	Source	Reference
Non-municipal landfills			
k-value	0.030–0.185	IPCC default	IPCC (2006a)
Methane correction factor	0.42	Country specific	Tonkin and Taylor Ltd (unpublished(b))
DOC (kt C/kt waste)	0.04–0.39	Country specific	Eunomia (unpublished(c)), IPCC (2006a)
Farm fills			
k-value	0.09	IPCC default	IPCC (2006a)
Methane correction factor	0.44	Country specific	Tonkin and Taylor Ltd (unpublished(b))
DOC (kt C/kt waste)	0.214–0.331	Country specific	GHD (2013, 2014)
All sites			
Oxidation factor	0	IPCC default	IPCC (2006a)
Starting year	1950	IPCC default	IPCC (2006a)
Delay time	6 months	IPCC default	IPCC (2006a)
Fraction of DOC that decomposes	0.5	IPCC default	IPCC (2006a)
Fraction of CH_4 in gas	0.5	IPCC default	IPCC (2006a)

Note: DOC = degradable organic carbon.

7.2.3 Uncertainty assessment and time-series consistency

Uncertainties

For emission factors and activity data used for most of the *Solid waste disposal* category, the uncertainty estimate is ±40 per cent (see table 7.2.9). This is consistent with the ranges provided in the 2006 IPCC Guidelines (IPCC, 2006a).

For managed municipal landfills, the emission factor uncertainty is set at this level because, while better-quality parameters are used in this category, most of the parameters are based on international data and are not site specific.

For non-municipal landfills, the uncertainty in activity data is estimated to be ±90 per cent. While country-specific activity data are now available for non-municipal landfills, these are limited to a few reporting years. However, this uncertainty is expected to decrease as more data are reported in the coming years. In contrast, information on the volume of waste disposed of in farm fills remains limited due to the informal nature of their management.

For farm fills, the uncertainty in activity data is estimated to be ±140 per cent. Information on the amount of waste placed in these sites is limited, given the nature of the management of such fills.

The overall uncertainty in activity data for *Solid waste disposal* is calculated using approach 1[55] for adding uncertainties together. The overall uncertainty in the emission factor is set as the same as the uncertainty for the underlying categories because they are consistent.

Table 7.2.9 Uncertainty in emissions from *Solid waste disposal*

Emissions category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Managed landfills	±40	±40
Unmanaged landfills (Class 2–5)	±90	±40
Unmanaged landfills (farm fills)	±140	±40
Uncategorised landfills	±40	±40
Overall uncertainty in methane emissions	**±79.9**	**±40**

Time-series consistency

As a result of substantial changes in waste disposal practices over time, the basis for calculating emissions has changed significantly. Notable changes include closure of the majority of the smaller landfill sites that were operating in 1990, the move to waste levy and NZ ETS reporting, and the ongoing improvement in the quality and completeness of activity data for *Solid waste disposal*. These changes have occurred gradually and affect CH_4 emissions over a long period. Therefore, there is little effect on the apparent consistency of data or the implied emission factors.

7.2.4 Category-specific QA/QC verification

Solid waste disposal is a key category. In the preparation of this submission, the data for this category underwent Tier 1 quality checks.

55 The approach 1 is based upon error propagation and is used to estimate uncertainty in individual categories, in the inventory as a whole, and in trends between a year of interest and a base year.

7.2.5 Category-specific recalculations

Significant recalculations are included in the 2025 submission. Updates to the *Managed waste disposal sites – Anaerobic* (5.A.1.a) include:

- adoption of country-specific CH_4 recovery rates, derived from measurements at municipal landfills with gas capture systems
- updates to waste composition values based on recent site-specific measurements
- revisions to decay rates (k-values) and the fraction of CH_4 in LFG (F) returning to the default IPCC values.

Updates to the *Unmanaged waste disposal sites* (5.A.2) include:

- adoption of country-specific activity data based on reporting through the waste levy system
- revisions to the previous model to incorporate New Zealand's landfill site classifications
- implementation of trend extrapolation techniques using recent data obtained through the levy system.

As a result of these changes, emissions have been reduced by 1,078.3 kt CO_2-e in 1990 and by 556.2 kt CO_2-e in 2022. Detailed descriptions of these recalculations are provided in chapter 10.

7.2.6 Category-specific planned improvements

Two areas within the *Solid waste disposal* category are being considered for future improvements.

- Solid waste management data surveys are currently being conducted as part of the National Waste Data Reporting Programme, with results expected in 2025. The findings will enhance understanding of solid waste generation, treatment methods (including recycling, composting, incineration and disposal) and how these practices influence the composition of solid waste.
- Emissions of carbon monoxide, nitrogen oxides and non-methane volatile organic compounds from landfills have not been estimated in this or previous submissions. These emissions are considered likely to be immaterial, but the inventory agency will consider estimating them for future submissions. This improvement will depend on the availability of budget, resources and data.

7.3 Biological treatment of solid waste (5.B)

7.3.1 Description

New Zealand has experienced an increase in commercial-scale composting of solid waste in recent years. Anecdotal evidence also suggests a rise in household and community-scale composting, in some cases supported by local government waste minimisation programmes, like the Compost Collective.[56] These initiatives educate and empower communities to adopt composting practices. Emissions from composting were first reported in the 2019 submission under category 5.B.1.

[56] For more information, see compostcollective.org.nz. Retrieved 6 March 2023.

In October 2022, the country's first large-scale anaerobic digestion plant commenced operations, with the capacity to process up to 75,000 tonnes of food scraps annually. Apart from this, no other forms of biological treatment of solid waste are currently practised in New Zealand.

In 2023, *Biological treatment of solid waste* accounted for 81.6 kt CO_2-e (2.8 per cent) of Waste sector emissions. This was an increase of 76.8 kt CO_2-e (1,598.3 per cent) above the 1990 level of 4.8 and an increase of 5.1 kt CO_2-e (6.7 per cent) from 2022.

7.3.2 Methodological issues

Choice of activity data

Composting (5.B.1.)

Activity data for composting are estimated using expert judgement, with reference to evidence of commercial-scale composting operating across New Zealand. In 1990, it is estimated that an equivalent of 1 per cent of total municipal solid waste was composted (see the total solid waste reported in table 7.2.3). Between 1991 and 2008, composting activity was assumed to have grown by 2 per cent per annum. From 2009 to 2018, grow rates were estimated to have increased significantly (ranging from 10 per cent to 40 per cent per annum), to align with reported volumes for 2019 (Eunomia, unpublished(b)), reflecting the expansion of commercial-scale composting. Activity data for composting can be derived from table 7.2.3 using this description.

The decreasing proportion of food and garden waste disposed of in managed landfills between 2012 and 2018 (see table 7.2.5) is consistent with the trend towards increased composting, though casualty has not been established.

Anaerobic digestion (5.B.2)

New Zealand's first large-scale anaerobic digestion plant, located in Reporoa in the central North Island, began operations in October 2022.[57] The facility is projected to process up to 75,000 tonnes of food scraps annually at full capacity, generating energy in the form of electricity, heat and biogas.

Waste volumes processed at the facility were provided by the plant operator for the years since the plant has been functioning. In its first year of operation (from October 2022), 792 tonnes of wet waste were processed, increasing to 29,473 tonnes in 2023, marking a growth of 3,621 per cent.

Choice of methods

Direct emissions from *Composting* and *Anaerobic digestion* are estimated using the Tier 1 default methodology outlined in the 2006 IPCC Guidelines (IPCC, 2006a).

Default CH_4 emission factors already account for CH_4 recovery in *Anaerobic digestion*, while default N_2O emission factors are assumed negligible and are not estimated (IPCC, 2006a).

57 See Ecogas. *Reporoa Organics Processing Facility*. Retrieved 5 February 2025.

Choice of emission factors

IPCC default parameters are used, as detailed in table 7.3.1.

Table 7.3.1 Emission factors applied to estimate emissions from *Composting* and *Anaerobic digestion*

Emissions category	Emission factor (g/kg)	Source
Compost (CH_4)	4.0	IPCC (2006a)
Anaerobic digestion (CH_4)	0.8	IPCC (2006a)
Compost (N_2O)	0.24	IPCC (2006a)
Anaerobic digestion (N_2O)	Assumed negligible	IPCC (2006a)

The emission factors are sourced from table 4.1, chapter 4 of volume 5 of the 2006 IPCC Guidelines (IPCC, 2006a).

7.3.3 Uncertainty assessment and time-series consistency

Uncertainties

In accordance with the 2006 IPCC Guidelines (IPCC, 2006a), uncertainties in activity data can exceed ±>100 per cent when data quality is poor or limited. For *Composting*, an uncertainty of ±100 per cent is applied, reflecting the limited availability of high-quality data. For *Anaerobic digestion*, an uncertainty in activity data of ±90 per cent has been estimated, consistent with the approach used for the municipal and non-municipal landfill subcategories, because data were obtained directly from the facility operator.

Uncertainties in emission factors are derived from the variability of the emission factors relative to the IPCC default (IPCC, 2006a). For composting and anaerobic digestion, the default CH_4 emission factor has an uncertainty of approximately ±100 per cent. The N_2O emission factor for composting exhibits a range of +150 per cent to -75 per cent, so the uncertainty is given as ±150 per cent. In contrast, the N_2O emission factor for anaerobic digestion is considered negligible, and its uncertainty is reported as ‘not applicable’.

Table 7.3.2 summarises the uncertainties associated with *Composting* and *Anaerobic digestion*.

Table 7.3.2 Uncertainty in emissions from *Composting and Anaerobic digestion*

Emissions category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Composting (CH_4)	±100	±100
Composting (N_2O)	±100	±150
Anaerobic digestion (CH_4)	±90	±100
Anaerobic digestion (N_2O)	NA	NA

Note: NA = not applicable.

Time-series consistency

Time-series consistency is maintained by applying consistent models and parameters across the entire reporting period.

7.3.4 Category-specific QA/QC and verification

Given the relatively small contributions of these emissions, basic quality-assurance and quality-control checks were applied. Detailed quality-assurance and quality-control efforts for the Waste sector are primarily focused on categories such as *Solid waste disposal* to land and *Wastewater treatment and discharge*.

7.3.5 Category-specific recalculations

Emissions from *Composting* (5.B.1.a) have not changed in 1990 and 2022, compared with the previous submission. No recalculations have been conducted for *Anaerobic digestion*, because this is the first year of reporting this category.

7.3.6 Category-specific planned improvements

No specific improvements are currently planned for the *Composting* and *Anaerobic digestion* source categories.

7.4 Incineration and open burning of waste (5.C)

7.4.1 Description

There is no incineration of municipal waste in New Zealand for energy production or otherwise. Incineration is used on a small scale for disposal of clinical waste, hazardous wastes and sewage sludge. The practice of incinerating clinical waste has declined through the time series, due to more stringent environmental regulation and the use of alternative technologies such as sterilisation. In the context of New Zealand's greenhouse gas inventory, the term 'clinical wastes' refers to a combination of clinical, medical and quarantine wastes.

Waste incineration is regulated under the Resource Management Act 1991. In addition, in 2004, a national environmental standard was introduced that required consents for all existing low-temperature incinerators, such as those historically used in schools and sometimes in hospitals.

There is no open burning of waste at municipal or non-municipal landfill facilities in New Zealand. It is common for farms to practise open burning of rural waste (GHD, 2014) and, while limited information is available on the extent of the practice, emissions from open burning are reported here. It is assumed an equal amount of farm waste that is buried (see table 7.2.4) is burned.

On its website, the Ministry of Education indicates that waste incineration is still practised in a small number of primary schools located in remote rural areas. Although information is not available on the exact number of schools practising waste incineration, it is estimated that around 10 per cent of the total number of schools in New Zealand still incinerate their waste production (P Guiney, Ministry of Education, pers. comm., 4 December 2019). Emissions from this source are not estimated for this submission and are reported as 'not estimated'. See chapter 1, section 1.7, for more information.

Where data are available, the burning of waste materials, including waste oil, wood chips and tyres for fuelling boilers and cement kilns, is reported under the Energy sector in the *Manufacturing industries and construction* category.

In 2023, *Incineration and open burning of waste* accounted for 176.9 kt CO_2-e (6.1 per cent) of Waste sector emissions (see table 7.4.1). This was a decrease of 142.1 kt CO_2-e (44.5 per cent) below the 1990 level of 319.0 kt CO_2-e, and a decrease of 3.3 kt CO_2-e (1.8) from 2022.

Table 7.4.1 Emissions from *Incineration and open burning of waste* (5.C)

	Emissions (kt CO_2-e) 1990–2023		Difference (kt CO_2-e) 1990–2023	Change (%) 1990–2023
Source category				
Incineration (5.C.1)	14.3	2	-12.3	-86.2
Open burning (5.C.2)	304.8	175	-129.8	-42.6
Total (5.C)	**319**	**176.9**	**-142.1**	**-44.5**

Note: Percentages presented are calculated from unrounded values.

Carbon dioxide emissions from the *Incineration and open burning of waste* source category were identified as a key category in the 2023 trend assessment.

7.4.2 Methodological issues

Choice of activity data

Waste incineration (5.C.1)

Limited information was available from individual site operators on the amount of waste burned between 1990 and 2008. For most sites, these activity data needed to be inferred because the only evidence available was the capacity of equipment and the amounts allowed by consent conditions. For the years after 2008, it has generally been assumed that facilities are continuing in operation at the same rates, in the absence of better information.

Table 7.4.2 presents activity data for incineration.

Table 7.4.2 Amounts of waste incinerated, from 1990 to 2023

Year	Clinical wastes (kt)	Hazardous wastes (kt)	Sewage sludge (kt)	Total waste incinerated (kt)
1990	21.5	0.3	4.4	26.2
1991	21.5	0.3	4.4	26.2
1992	21.5	0.3	4.4	26.2
1993	21.3	0.3	4.4	26.0
1994	21.3	0.3	4.4	26.0
1995	21.0	0.3	4.4	25.7
1996	20.3	0.3	4.4	25.0
1997	20.3	0.3	4.4	25.0
1998	20.0	0.3	4.4	24.7
1999	18.9	0.3	4.4	23.6
2000	17.8	0.3	4.4	22.4
2001	9.3	0.3	4.4	13.9
2002	8.2	0.3	4.4	12.9
2003	7.3	0.3	4.4	12.0
2004	7.2	0.3	4.4	11.9
2005	5.3	0.3	4.4	10.0
2006	3.2	0.3	4.4	7.9
2007	0.6	0.3	4.4	5.3
2008	0.6	0.3	4.5	5.4
2009	0.6	0.3	4.5	5.4
2010	0.6	0.3	4.5	5.4
2011	0.6	0.3	4.5	5.4

Year	Clinical wastes (kt)	Hazardous wastes (kt)	Sewage sludge (kt)	Total waste incinerated (kt)
2012	0.6	0.3	4.5	5.4
2013	0.6	0.3	4.5	5.4
2014	0.6	0.3	4.5	5.4
2015	0.6	0.3	4.5	5.4
2016	0.6	0.3	4.5	5.4
2017	0.6	0.3	4.5	5.4
2018	0.6	0.3	4.5	5.4
2019	0.6	0.3	4.5	5.4
2020	0.6	0.3	4.5	5.4
2021	0.6	0.3	4.5	5.4
2022	0.6	0.3	4.5	5.4
2023	0.6	0.3	4.5	5.4

Note: Columns may not total due to rounding.

Open burning of waste (5.C.2)

Little information is available on the quantities of farm wastes burned. A change introduced in the 2021 submission is that the methods of disposal of farm waste are evenly split between disposal to land in farm fills and disposal by open burning, at 47 per cent farm fills, 47 per cent open burning and 6 per cent other.

Refer to section 7.2.2 for a discussion on farm waste landfilling and open burning. In summary, because open burning is a significant and common practice (GHD, 2013, 2014) it is being considered to be equal in volume to disposal to land. The amount of waste disposed to farm fills reported in table 7.2.4 is additional and equal to the amount that is disposed by open burning.

Choice of methods

Waste incineration (5.C.1)

Estimates of direct emissions from the incineration of waste are made using the default Tier 1 methodology (IPCC, 2006a). The data used were collected and collated in 2007, and the sources used included information previously collected for purposes of air quality regulation and consent data from regional councils and site operators (SKM, unpublished(a)).

Open burning of waste (5.C.2)

Estimates of direct emissions from the open burning of rural waste are made using the default Tier 1 methodology (IPCC, 2006a). Farm waste comprises a mix of household and other wastes, which have a composition and diversity similar to general municipal solid waste (Tonkin and Taylor Ltd, unpublished(b)). Therefore, emissions from CH_4 and N_2O were estimated using default emission factors for bulk municipal solid waste.

Emissions of CO_2 were calculated using the same composition of farm waste as is landfilled, for consistency. Table 7.4.3 shows the parameters that determine dry-matter content, total carbon content and fossil carbon content (IPCC defaults), which are then weighted against composition.

Table 7.4.3 Values applied to estimate carbon dioxide emissions from open burning of rural waste

Waste type	Composition (%)	Dry-matter content (%)	Total carbon content (%)	Fossil carbon content of total carbon (%)
Paper/card	1	90	46	1
Textiles	19.7	80	50	20
Food waste	15.1	40	38	0
Wood	41	85	50	0
Garden and park waste	NA	40	49	0
Nappies	NA	40	70	10
Rubber and leather	0.3	84	67	20
Plastics	10.4	100	75	100
Metal	2.4	100	NA	NA
Glass	0.4	100	NA	NA
Other, inert	9.6	90	3	100
Weighted average	**NA**	**79.7**	**44.8**	**24**

Source: Dry-matter content, total carbon content and fossil carbon content values are from table 2.4 in IPCC, 2006a

Note: NA = not applicable.

Choice of emission factors

Waste incineration (5.C.1)

The parameters used to calculate emissions from incineration are detailed in table 7.4.4.

Table 7.4.4 Parameter values applied to estimate emissions from *Incineration*

Parameter	Hazardous waste	Clinical wastes	Sewage sludge	Source
Dry-matter content in waste (%)	50 (table 2.6)	65 (table 2.6)	10 (section 2.3.2)	IPCC (2006a)
Fraction of carbon	0.275 (wet) (table 2.6)	0.6 (dry) (table 5.2)	0.45 (dry) (table 5.2)	IPCC (2006a)
Fraction of fossil carbon in total carbon	1 (table 2.6)	0.4 (table 5.2)	0 (table 5.2)	IPCC (2006a)
Oxidation factor	1	1	1	IPCC (2006a), table 5.2
Molar ratio to convert from carbon to carbon dioxide	44/12	44/12	44/12	
Overall carbon dioxide emission factor (kg/kt)	0.5	0.57	0.16	
Methane emission factor (kg/kt) as directly referenced	NA	NA	9.7 (section 5.4.2)	IPCC (2006a)
Methane energy factor (kg gas/TJ)	30 (table 2.3, Industrial wastes)	300 (table 2.4, Municipal/ Industrial wastes)	NA	IPCC (2006b)
Methane (MJ/kg waste)	12.8	16.8	NA	Ministry of Commerce (1993)
Methane emission factor (kg/kt) calculated as a quotient of the above parameters	2.34	17.86	NA	
Nitrous oxide emission factor (kg/kt)	100	60	900	IPCC (2006b), table 5.6

Note: NA = not applicable.

These parameters are as given in the 2006 IPCC Guidelines (IPCC, 2006a, 2006b), noting that:

- some parameters have been chosen as the closest available to the specific type of waste
- where a range is given, the mid-point is used
- methane emission factors for hazardous and clinical waste (IPCC, 2006b) have been converted from a terajoule basis to a kt basis using factors from the *New Zealand Energy Information Handbook* (Ministry of Commerce, 1993), which only had gross calorific values.

While the incineration of clinical waste has decreased over time, it remains a significant proportion of the material incinerated in New Zealand (SKM, unpublished(a)). There is no IPCC default category that specifies medical or quarantine waste. The composition of medical and quarantine wastes is closest to clinical waste, so the emission factors for clinical waste have been used and the activity data for these waste types are combined into the category for clinical wastes.

Open burning of waste (5.C.2)

Parameters are used as detailed in table 7.4.5.

Table 7.4.5 Parameters used to estimate emissions from *Open burning of waste*

Parameter	Value	Source
Carbon dioxide		
Dry-matter content (%)	79.7	Calculated (see table 7.4.3)
Total carbon content (%)	44.8	Calculated (see table 7.4.3)
Fossil carbon content (%)	24	Calculated (see table 7.4.3)
Oxidation factor (%)	58	IPCC default
Conversion factor	44/12	
Other gases		
Methane emission factor (kg/kt wet waste)	6500	IPCC default
Nitrous oxide emission factor (kg/kt dry waste)	150	IPCC default

To calculate N_2O emissions, the activity data are converted using the weighted average dry-matter content in table 7.4.3 because the default emission factor is presented in terms of dry waste.

7.4.3 Uncertainty assessment and time-series consistency

Uncertainties

Consistent with the IPCC recommendation for uncertainties relating to activity data (IPCC, 2006a), estimated uncertainty for the amount of wet waste incinerated ranges from ±10 per cent to ±50 per cent, and uncertainty of ±50 per cent is applied (see table 7.4.6).

The data collected for the composition of waste are not detailed. Therefore, following the recommendation for uncertainties relating to emission factors (IPCC, 2006a), the estimated uncertainty for default CO_2 factors is ±40 per cent. Default factors used in the calculation of CH_4 and N_2O emissions have a much higher uncertainty (IPCC, 2006a); for this reason, the estimated uncertainty for default CH_4 and N_2O factors is ±100 per cent.

Table 7.4.6 Uncertainty in emissions from *Incineration and open burning of waste*

Emissions category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Waste incineration and open burning (CO_2)	±50	±40
Waste incineration and open burning (CH_4)	±50	±100
Waste incineration and open burning (N_2O)	±50	±100

Time-series consistency

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or emission factors have occurred, a full time-series recalculation is conducted.

7.4.4 Category-specific QA/QC and verification

Quality-assurance and quality-control checks are carried out where possible. Detailed quality-assurance and quality-control efforts for the Waste sector focus on the *Solid waste disposal* to land and *Wastewater treatment and discharge* categories. Activity data for the *Open burning of waste* category are derived from the landfill data.

7.4.5 Category-specific recalculations

Emissions from *Incineration* decreased by 0.3 kt CO_2-e (2.3 per cent) in 1990 and by 0.3 kt CO_2-e (14.8 per cent) in 2023. This is due to adjustments to the fraction of carbon and fraction of fossil carbon in the total carbon.

Emissions from *Open burning of waste* showed negligeable increases (<0.00001 per cent) in 1990 and 2022. These are attributed to a minor reduction in the total number of farm holdings throughout the time series.

7.4.6 Category-specific planned improvements

No specific improvements are planned for this category. Over time, surveys by local authorities on disposal of waste in the farm sector may provide a better understanding of open burning in the farm sector. Further work is needed to understand the ratio of farm waste disposed to open burning or landfills. Anecdotal evidence suggests that incineration of medical waste may be occurring at lower volumes than is assumed (M Geesink, Northland District Health Board, pers. comm., 11 November 2020). Changes will be made when evidence becomes available to confirm this, noting that emissions from incineration are under 1 per cent of the Waste sector and that other incineration sources (eg, rural schools) are currently not estimated.

7.5 Wastewater treatment and discharge (5.D)

7.5.1 Description

In 2023, *Wastewater treatment and discharge* contributed 401.3 kt CO_2-e (13.8 per cent) of emissions from the Waste sector. This was an increase of 77.9 kt CO_2-e (24.1 per cent) from the 1990 level of 323.3 kt CO_2-e and is due to increases in the volume of industrial and domestic wastewater handled over this period.

Small amounts of industrial wastewater are applied as organic amendments to agricultural soils, as well as an extremely small amount of sewage sludge (van der Weerden et al., 2014). Any emissions from this practice are likely to be insignificant and are reported as 'not estimated' under the Agriculture sector (see chapter 5, section 5.5.2). Table 7.5.1 presents emissions from *Wastewater treatment and discharge*.

Sludge amounts are reported as 'included elsewhere' for domestic and industrial wastewater because most of the sludge is sent to landfills, and activity data and emissions from its disposal are reported in the *Solid waste disposal* source category (Tonkin and Taylor Ltd, unpublished(a)).

Table 7.5.1 Emissions from *Wastewater treatment and discharge* (5.D)

	Emissions (kt CO_2-e) 1990–2023		Difference (kt CO_2-e) 1990–2023	Change (%)1990–2023
Source category				
Domestic wastewater (5.D.1)	222.4	296.2	73.8	33.2
Industrial wastewater (5.D.2)	100.9	105.1	4.2	4.1
Total (5.D)	**323.3**	**401.3**	**77.9**	**24.1**

Note: Percentages presented are calculated from unrounded values.

Methane emissions from the *Wastewater treatment and discharge* source category were identified as a key category in the 2023 level assessment.

Domestic wastewater (5.D.1)

Wastewater from almost every town in New Zealand with a population over 1,000 is collected and treated in municipal wastewater treatment plants. There are approximately 317 municipal wastewater treatment plants in New Zealand and around a further 50 government or privately owned treatment plants serving populations of more than 1,000 people (SCS Wetherill Environmental, unpublished).

Although most of the wastewater treatment processes are aerobic, a significant number of wastewater treatment plants use partially anaerobic processes, such as oxidation ponds or septic tanks. Small communities and individual rural dwellings are served mainly by simple septic tanks. While the part of the population using septic tanks is small, compared with the national population, this treatment type produces the most CH_4 emissions from domestic wastewater. This is because emissions from other treatment types are small or the CH_4 is destroyed.

Industrial wastewater (5.D.2)

The major sources of industrial wastewater in New Zealand are the meat and the pulp and paper industries. Most of the industrial wastewater treatment is aerobic, and most of the CH_4 generated from anaerobic treatment is flared.

In June 2015, the methodologies and input data used to calculate the industrial wastewater emissions were reviewed, to capture any changes in industry activity and ensure current best practice and knowledge were reflected (Cardno, unpublished). This is discussed further under section 7.5.2.

7.5.2 Methodological issues

Choice of activity data

Domestic wastewater (5.D.1)

Estimates for CH_4 emissions are derived from combining the population connected to each treatment plant in New Zealand with the treatment methods for each plant (Beca Infrastructure Ltd, unpublished).

The population using each municipal treatment plant and an estimation of the population using septic tanks were determined (Beca Infrastructure Ltd, unpublished; SCS Wetherill Environmental, unpublished). Emissions from the wastewater treatment plants are calculated for 1997, 2001, 2006 and every year from 2013 onward. Emissions from the years before 1997 are calculated based on a fixed aggregate methane correction factor from 1997. Emissions from the remaining years are interpolated.

Emissions are proportional to the population treated by each plant, and population data are updated based on the population growth rate of the district in which the plant is located, using the latest population data. This information is obtained from Stats NZ. For intermediate years, data are interpolated. Years before 1997 are driven by national population growth using the methane correction factor from 1997.

In 2023, the population connected to treatment plants was estimated to be about 4.2 million. The connected population excludes people connected to rural septic tanks, estimated at 515,034 people in 2023, and approximately 57,268 people using other aerobic plants. The total population of New Zealand was 5.2 million, therefore, the remaining population of 369,961 people is not accounted for. This is a result of incomplete data on the wastewater treatment plants in New Zealand and the populations connected to each of these plants being estimated. To account for emissions from the remaining population, CH_4 emissions for the *Domestic wastewater* source category were scaled up proportionately based on the population for which emissions are known. An assumption is made to apply the average emission factor for wastewater treatment for this otherwise unaccounted-for population.

Indirect N_2O emissions from the disposal of treated domestic wastewater are estimated using per capita protein consumption and national population estimates, less the population using septic tanks because there is no liquid effluent from septic tanks. Activity data for *Domestic wastewater* are reported in table 7.5.2. Also included in table 7.5.2 is an aggregate CH_4 correction factor that is determined by the sum of the CH_4 correction factor for various treatment types, weighted by the population served by each type.

Table 7.5.2 Activity data and key factors for domestic wastewater from 1990 to 2023

Year	National population	Aggregate methane correction factor	Domestic wastewater total organic product (kt)
1990	3,410,400	Same as 1997	137.2
1991	3,516,000	Same as 1997	141.7
1992	3,552,200	Same as 1997	143.5
1993	3,597,800	Same as 1997	145.7
1994	3,648,300	Same as 1997	148.2
1995	3,706,700	Same as 1997	150.9
1996	3,762,300	Same as 1997	153.5
1997	3,802,700	0.0425	155.5
1998	3,829,200	Interpolated	154.6

Year	National population	Aggregate methane correction factor	Domestic wastewater total organic product (kt)
1999	3,851,100	Interpolated	153.6
2000	3,873,100	Interpolated	152.7
2001	3,916,200	0.0378	151.7
2002	3,989,500	Interpolated	155
2003	4,061,600	Interpolated	158.4
2004	4,114,300	Interpolated	161.8
2005	4,161,000	Interpolated	165.2
2006	4,209,100	0.032	168
2007	4,245,700	Interpolated	170.5
2008	4,280,300	Interpolated	172.3
2009	4,332,100	Interpolated	174.1
2010	4,373,900	Interpolated	175.9
2011	4,399,400	Interpolated	177.8
2012	4,425,900	Interpolated	179.7
2013	4,477,400	0.0316	181.7
2014	4,564,400	0.0316	185.2
2015	4,663,700	0.0318	189.2
2016	4,767,600	0.0317	193.3
2017	4,859,500	0.0318	196.8
2018	4,941,200	0.0319	200.0
2019	5,040,400	0.0321	203.9
2020	5,103,700	0.0321	206.9
2021	5,116,500	0.0324	207.5
2022	5,160,600	0.0329	209.1
2023	5,308,500	0.0328	214.5

Industrial wastewater (5.D.2)

The following industries are identified as having organic-rich wastewaters that are treated anaerobically (in order of significance): meat processing, pulp and paper, and other industries described below. Table 7.5.3 reports the activity data for the amount of total organic product in wastewater (TOW) across the main industries.

Table 7.5.3 Total organic product producing methane from industrial wastewater, from 1990 to 2023

Year	Meat industries TOW (kt)	Pulp and paper industry TOW (kt)	All other industries TOW (kt)	Total industrial TOW (kt)
1990	55.6	76.7	20.2	152.5
1991	59.2	76.3	18.8	154.2
1992	64.1	72.7	17.2	154.1
1993	59.3	79.3	15.7	154.3
1994	62.1	80.0	14.4	156.5
1995	64.5	83.3	13.3	161.1
1996	65.7	79.9	11.9	157.6
1997	66.6	82.7	10.3	159.7
1998	68.7	81.1	9.2	158.9
1999	61.4	81.9	7.8	151.1
2000	65.8	89.4	6.4	161.6
2001	67.7	84.2	4.9	156.8

Year	Meat industries TOW (kt)	Pulp and paper industry TOW (kt)	All other industries TOW (kt)	Total industrial TOW (kt)
2002	65.0	87.1	5.5	157.6
2003	70.1	80.2	5.0	155.3
2004	73.8	90.5	6.1	170.5
2005	72.6	91.9	5.9	170.4
2006	71.3	86.5	6.4	164.3
2007	72.5	86.7	6.7	166.0
2008	72.8	85.8	7.7	166.2
2009	68.3	87.0	7.7	163.0
2010	66.6	91.2	7.5	165.3
2011	65.6	87.9	4.1	157.6
2012	65.7	84.9	3.3	153.9
2013	67.9	79.1	4.3	151.3
2014	68.7	77.5	5.5	151.8
2015	72.4	78.6	4.0	155.0
2016	69.2	78.4	5.4	153.0
2017	71.2	78.6	4.9	154.7
2018	72.7	77.2	5.2	155.2
2019	73.0	77.7	5.1	155.8
2020	73.8	71.8	5.7	151.2
2021	74.6	68.2	4.6	147.4
2022	72.7	61.0	6.6	140.3
2023	74.2	50.6	6.2	131.0

Note: TOW = total organic product in wastewater. Columns may not total due to rounding.

Table 7.5.4 reports the activity data for the total nitrogen in effluent from industrial wastewater.

Table 7.5.4 Nitrogen (N) in effluent from industrial wastewater, from 1990 to 2023

Year	Meat industries (excl poultry) N in effluent (kt)	Poultry N in effluent (kt)	Dairy processing N in effluent (kt)	Leather & skins N in effluent (kt)	Total industrial N in effluent (kt)
1990	1.4	0.1	0.2	1.2	2.8
1991	1.5	0.1	0.2	1.2	2.9
1992	1.6	0.1	0.2	1.2	3.1
1993	1.4	0.1	0.2	1.2	2.9
1994	1.5	0.1	0.2	1.2	3.0
1995	1.6	0.1	0.2	1.2	3.1
1996	1.6	0.1	0.2	1.2	3.2
1997	1.6	0.1	0.2	1.2	3.2
1998	1.7	0.1	0.2	1.2	3.2
1999	1.5	0.1	0.3	1.2	3.1
2000	1.6	0.1	0.3	1.2	3.2
2001	1.6	0.1	0.3	1.2	3.3
2002	1.5	0.2	0.3	0.6	2.6
2003	1.6	0.2	0.3	0.6	2.7
2004	1.7	0.2	0.3	0.6	2.8
2005	1.7	0.2	0.3	0.6	2.8
2006	1.7	0.2	0.3	0.6	2.8
2007	1.7	0.2	0.3	0.6	2.8

Year	Meat industries (excl poultry) N in effluent (kt)	Poultry N in effluent (kt)	Dairy processing N in effluent (kt)	Leather & skins N in effluent (kt)	Total industrial N in effluent (kt)
2008	1.7	0.2	0.4	0.6	2.8
2009	1.6	0.2	0.4	0.6	2.7
2010	1.5	0.2	0.4	0.6	2.7
2011	1.5	0.2	0.4	0.6	2.7
2012	1.5	0.2	0.4	0.6	2.7
2013	1.5	0.2	0.5	0.6	2.8
2014	1.5	0.2	0.5	0.6	2.9
2015	1.6	0.2	0.5	0.6	2.9
2016	1.5	0.3	0.5	0.6	2.9
2017	1.5	0.3	0.5	0.6	2.9
2018	1.6	0.3	0.5	0.6	3.0
2019	1.6	0.3	0.5	0.6	3.0
2020	1.6	0.3	0.5	0.6	3.0
2021	1.6	0.3	0.5	0.6	3.0
2022	1.6	0.3	0.5	0.6	2.9
2023	1.6	0.3	0.5	0.6	3.0

Note: Columns may not total due to rounding.

Meat industry

Methane emissions from the meat industry are calculated from an estimate of the wastewater output from meat processing. This estimate is based on the total production (kills) from the different producers in the meat industry and uses data that is as consistent as possible with the data for kills used in the Agriculture sector.

Poultry processing is calculated separately from other meat processing because its fraction of waste treated in anaerobic ponds and the unit chemical oxygen demand (COD) load are higher than for other meat processing (Cardno, unpublished).

Rendering loads are not separated out to simplify the inventory calculations because there are only a few standalone rendering plants in New Zealand, and the rest are combined with meat processing plants. Therefore, the unit COD load only includes rendering operations (Cardno, unpublished).

Nitrous oxide emissions from the meat industry are calculated using the same activity data as for CH_4 emissions.

Pulp and paper industry

Estimated pulp and paper wastewater output is based on paper, paperboard and pulp production. This information is obtained from the Ministry for Primary Industries.

Wine industry

Methane emissions from wastewater for the wine industry are based on the outputs obtained from New Zealand Wine, which reports on the grape and wine sector. For the purpose of this assessment, an average industry wastewater discharge metric of 2.7 cubic metres of water per tonne of grapes processed is assumed. This value is derived from national data. Note that this value is significantly lower than IPCC default values (Beca Ltd, unpublished).

Wool scouring industry

Methane emissions from wastewater for the wool scouring industry are based on the outputs obtained by SCS Wetherill Environmental (unpublished) for the years up to 2000. From 2001 to 2012, the SCS estimates have been prorated against the industry's output data and applied to the output data for these years. After 2012, the wool scouring industry used only aerobic treatment of wastewater and, consequently, no emissions are reported for 2013 onwards (Beca Ltd, unpublished).

Dairy processing industry

The dairy processing industry predominantly uses aerobic treatment. Only one factory uses anaerobic treatment. The emissions from the wastewater treatment process are recovered and most of the captured biogas (consisting of 55 per cent CH_4) is used in boilers. The remainder is flared (Beca Infrastructure Ltd, unpublished). Emissions from the biogas recovered from the Tirau dairy processing plant (*Industrial wastewater*) for energy recovery are reported as 'included elsewhere' under the Waste sector, and actual emissions are reported in *1.A.2.e – Biomass* under the Energy sector.

Nitrous oxide emissions from dairy industry wastewater are included, based on the review of methods for industrial wastewater by Cardno (unpublished). Emission estimates are based on the total litres of milk processed, consistent with data reported under the Agriculture sector. The production data are then converted from litres to kilograms by multiplying by 1.031 (the weight of 1 litre of milk) for the activity data used in the emissions calculations.

Leather and skins industry

Methane emissions from wastewater for the leather and skins industry, also known as tanneries and fellmongers, are based on the outputs obtained by SCS Wetherill Environmental (unpublished) for the years up to 2001. From 2002, all wastewater from the tanneries is accounted for in domestic wastewater because all tanneries now discharge to the municipal wastewater system; however, some fellmongers still use aerobic treatment (Cardno, unpublished).

Nitrous oxide emissions from wastewater for the leather and skins industry are based on the outputs obtained by SCS Wetherill Environmental (unpublished). Emissions reduced in 2002 to account for the tanneries that discharge entirely to the domestic system.

Choice of methods

Methods used to calculate emissions from wastewater handling are summarised in table 7.5.5. For domestic wastewater, the TOW is estimated for each individual treatment plant based on the population in the district served by the plant.

Table 7.5.5 Methods used for calculating emissions from wastewater treatment

Emissions category	Gas	Comment	Method	Source
Domestic wastewater (5.D.1)	CH_4		Tier 2	SCS Wetherill Environmental (unpublished), Beca Infrastructure Ltd (unpublished)
Domestic wastewater (5.D.1)	N_2O	Based on average per capita protein intake	Tier 1	IPCC (2006a)
Industrial wastewater (5.D.2) – Meat industry	CH_4		Tier 1	IPCC (2006a)
Industrial wastewater (5.D.2) – Pulp and paper industry	CH_4		Tier 1	IPCC (2006a)

Emissions category	Gas	Comment	Method	Source
Industrial wastewater (5.D.2) – Wine industry	CH_4		Tier 2	Beca Ltd (unpublished)
Industrial wastewater (5.D.2) – Wool scouring industry	CH_4		Tier 1	IPCC (2006a)
Industrial wastewater (5.D.2)	N_2O	Based on chemical oxygen demand from CH_4 emissions	Tier 2	Cardno (unpublished)

Wine industry

A Tier 2 approach is used to estimate emissions from the wine industry. Information on the wastewater treatment practices of the industry was obtained from a survey (Beca Ltd, unpublished). Default values from the 2006 IPCC Guidelines (IPCC, 2006a) are used where New Zealand-specific information is not available.

Nitrous oxide emissions

Direct emissions of N_2O from domestic wastewater plants are typically minor and only occur in advanced centralised treatment plants. Good practice guidelines (IPCC, 2006a) advise that the estimation of direct N_2O emissions is only necessary where advanced centralised treatment plants account for a major proportion of wastewater treatment. Although one wastewater treatment plant in Auckland serves about a million people, direct N_2O emissions are not estimated because they are likely to be small.

However, indirect emissions of N_2O may occur after disposal of effluent into waterways, lakes or the ocean. New Zealand reports indirect emissions of N_2O from domestic wastewater.

The 2006 IPCC Guidelines (IPCC, 2006a) indicate that, compared with domestic wastewater, the N_2O emissions from industrial wastewater are believed to be insignificant. Yet, in New Zealand, these emissions have greater significance, because the meat and dairy processing industries produce nitrogen-rich wastewaters.

The IPCC does not provide a method for calculating N_2O emissions from industrial wastewater and, consequently, a New Zealand-derived method has been applied. The total nitrogen load is calculated by adopting the COD load, as determined in calculating CH_4 emissions from the same wastewater and using an estimated ratio of COD to nitrogen in the wastewater for each of the different producers in the meat, dairy processing and leather and skins industries.

Choice of emission factors

Domestic wastewater (5.D.1)

Methane emissions from domestic wastewater treatment

Table 7.5.6 summarises the parameter values applied for estimating CH_4 emissions from domestic wastewater treatment.

Table 7.5.6 Parameter values applied by New Zealand for estimating methane emissions for domestic wastewater treatment

Parameter	Value	Source	Reference
Methane correction factors			
Handling systems methane correction factor	Range of 0–0.65	New Zealand specific	SCS Wetherill Environmental (unpublished)
Aggregated methane correction factor	Range of 0.032–0.043	New Zealand specific	SCS Wetherill Environmental (unpublished)
BOD (kg BOD/person/year)	26	New Zealand specific	Beca Infrastructure Ltd (unpublished)
Correction factor for BOD	Range of 1.8–14.9	New Zealand specific	Beca Infrastructure Ltd (unpublished)
Maximum methane-producing capacity (kg CH_4/kg BOD)	0.625	New Zealand specific	SCS Wetherill Environmental (unpublished)

Note: BOD = biochemical oxygen demand.

Methane correction factors for handling systems

Methane correction factors for the different handling systems in New Zealand were estimated by SCS Wetherill Environmental (unpublished). These factors range from zero up to 0.65 for the different types of anaerobic treatment. The different treatment types are added together, weighted by the population for each type of treatment, to give an aggregated CH_4 correction factor ranging between 0.032 and 0.043. Table 7.5.2 shows the aggregate CH_4 correction factor applied across the time series.

Adjustments to biochemical oxygen demand

New Zealand uses a value of 26 kilograms biochemical oxygen demand (BOD) per person per year. This is equivalent to the IPCC high-range default value for the Oceania region of about 70 grams per person per day (IPCC, 2006a). This value has been determined as a typical value for wastewater treatment methods adopted in New Zealand (Beca Infrastructure Ltd, unpublished).

This value has been increased by 25 per cent for most treatment plants, to allow for the additional wastewater that they take from commercial and industrial activity within the municipal area. Ten of the treatment plants have been identified as accepting much larger amounts of industrial and/or commercial wastewater. The correction factor for BOD for these plants ranges from 77 per cent to 1,390 per cent above the amount of domestic wastewater (Beca Infrastructure Ltd, unpublished). No adjustment to the BOD is made for septic tanks.

Recovery

Methane removal via flaring or for energy production is known to occur at eight plants in New Zealand. All CH_4 generated at these plants is flared or used for energy production and, consequently, no CH_4 emissions are reported for those plants (Beca Infrastructure Ltd, unpublished).

Nitrous oxide emissions from domestic wastewater

Table 7.5.7 summarises the parameter values applied for estimating N_2O emissions from domestic and commercial wastewater treatment.

Table 7.5.7 Parameter values applied by New Zealand for estimating nitrous oxide emissions from domestic and commercial wastewater treatment

Parameter	Value	Source	Reference
Per capita protein consumption (kg/person/year)	36.135	New Zealand specific	Beca Infrastructure Ltd (unpublished)
Fraction of nitrogen in protein	0.16	IPCC default	IPCC (2006a)
Fraction of non-consumed protein	1.4	IPCC default	IPCC (2006a)
Fraction of industrial and commercial co-discharged protein	1.25	IPCC default	IPCC (2006a)
Nitrogen removed with sludge (kg)	0	IPCC default	IPCC (2006a)
Emission factor	0.005	IPCC default	IPCC (2006a)
Direct N_2O emissions from wastewater treatment plants	0	IPCC default	IPCC (2006a)

A value of 36.135 kilograms of protein per person per year is used. This figure was the maximum value reported by New Zealand to the Food and Agriculture Organization of the United Nations.

Recovery

There is no recovery of emissions reported for this source.

Industrial wastewater (5.D.2)

Methane emissions from industrial wastewater treatment – Meat industry

Table 7.5.8 summarises the parameter values applied for estimating CH_4 emissions from wastewater treatment by the meat industry.

Table 7.5.8 Parameter values applied by New Zealand for estimating methane emissions from wastewater treatment by the meat industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	50	New Zealand specific	SCS Wetherill Environmental (unpublished)
Methane correction factor	Range of 0–0.55	New Zealand specific	SCS Wetherill Environmental (unpublished)
Maximum methane-producing capacity (kg CH_4/kg COD)	0.25	IPCC default	IPCC (2006a)
Overall emission factor	0.036 (meat excluding poultry) 0.0344 (poultry)	New Zealand specific	Cardno (unpublished)

Note: COD = chemical oxygen demand.

Recovery

There is no recovery of emissions reported for this source.

Methane emissions from industrial wastewater treatment – Pulp and paper industry

Table 7.5.9 summarises the parameter values applied for estimating CH_4 emissions from wastewater treatment by the pulp and paper industry.

Table 7.5.9 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the pulp and paper industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	36	New Zealand specific	Beca Infrastructure Ltd (unpublished)
Methane correction factor	Range of 0–0.8	New Zealand specific	Beca Infrastructure Ltd (unpublished)
Maximum methane-producing capacity (kg CH_4/kg COD)	0.25	IPCC default	IPCC (2006a)
Overall emission factor	0.0117	New Zealand specific	Cardno (unpublished)

Note: COD = chemical oxygen demand.

Recovery

There is no recovery of emissions reported for this source.

Methane emissions from industrial wastewater treatment – Wine industry

Table 7.5.10 summarises the parameter values applied for estimating CH_4 emissions from wastewater treatment by the wine industry.

Table 7.5.10 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the wine industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	12.42	New Zealand specific	Beca Infrastructure Ltd (unpublished)
Methane correction factor	Range of 0–0.5	New Zealand specific	Beca Infrastructure Ltd (unpublished)
Maximum methane-producing capacity (kg CH_4/kg COD)	0.25	IPCC default	IPCC (2006a)
Overall emission factor	0.0167	New Zealand specific	Cardno (unpublished)

Note: COD = chemical oxygen demand.

Recovery

There is no recovery of emissions reported for this source.

Methane emissions from industrial wastewater treatment – Wool scouring industry

Table 7.5.11 summarises the parameter values applied for estimating CH_4 emissions from wastewater treatment by the wool scouring industry.

Table 7.5.11 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the wool scouring industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	22	New Zealand specific	SCS Wetherill Environmental (unpublished)
Methane correction factor	0.29	New Zealand specific	SCS Wetherill Environmental (unpublished)
Maximum methane-producing capacity (kg CH_4/kg COD)	0.25	IPCC default	IPCC (2006a)
Overall emission factor	0.0065	New Zealand specific	SCS Wetherill Environmental (unpublished)

Note: COD = chemical oxygen demand.

Recovery

There is no recovery of emissions reported for this source.

Methane emissions from industrial wastewater treatment – Leather and skins industry

Table 7.5.12 summarises the parameter values applied for estimating CH_4 emissions from wastewater treatment by the leather and skins industry.

Table 7.5.12 Parameter values applied by New Zealand for estimating methane emissions for wastewater treatment by the leather and skins industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	180	New Zealand specific	SCS Wetherill Environmental (unpublished)
Methane correction factor	Range of 0–0.55	New Zealand specific	SCS Wetherill Environmental (unpublished)
Maximum methane-producing capacity (kg CH_4/kg COD)	0.25	IPCC default	IPCC (2006a)
Overall emission factor	0.0124	New Zealand specific	SCS Wetherill Environmental (unpublished)

Note: COD = chemical oxygen demand.

Recovery

There is no recovery of emissions reported for this source.

Nitrous oxide emissions from industrial wastewater treatment – Meat industry

Table 7.5.13 summarises the parameter values applied for estimating N_2O emissions from wastewater treatment by the meat industry.

Table 7.5.13 Parameter values applied by New Zealand for estimating nitrous oxide emissions for wastewater treatment for the meat industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	50	New Zealand specific	SCS Wetherill Environmental (unpublished)
Ratio of total nitrogen to biodegradable COD (TN:COD_b)	0.09	New Zealand specific	Cardno (unpublished)
Overall emission factor	Range of 0.0013–0.0019	New Zealand specific	Cardno (unpublished)

Note: COD = chemical oxygen demand; COD_b = COD of total biodegradable material; TN = total nitrogen.

Recovery

There is no recovery of emissions reported for this source.

Nitrous oxide emissions from industrial wastewater treatment – Dairy processing industry

Table 7.5.14 summarises the parameter values applied for estimating N_2O emissions from wastewater treatment by the dairy processing industry.

Table 7.5.14 Parameter values applied by New Zealand for estimating nitrous oxide emissions for wastewater treatment for the dairy processing industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	2	New Zealand specific	Cardno (unpublished)
Ratio of total nitrogen to biodegradable COD (TN:COD$_b$)	0.044	New Zealand specific	Cardno (unpublished)
Overall emission factor	0.0028	New Zealand specific	Cardno (unpublished)

Note: COD = chemical oxygen demand; TN = total nitrogen.

Recovery

There is no recovery of emissions reported for this source.

Nitrous oxide emissions from industrial wastewater treatment – Leather and skins industry

Table 7.5.15 summarises the parameter values applied for estimating N_2O emissions from wastewater treatment by the leather and skins industry.

Table 7.5.15 Parameter values applied by New Zealand for estimating nitrous oxide emissions for wastewater treatment for the leather and skins industry

Parameter	Value	Source	Reference
Degradable organic component (kg COD/tonne of product)	180	New Zealand specific	SCS Wetherill Environmental (unpublished)
Ratio of total nitrogen to biodegradable COD (TN:COD$_b$)	0.08	New Zealand specific	SCS Wetherill Environmental (unpublished)
Overall emission factor	0.02	New Zealand specific	SCS Wetherill Environmental (unpublished)

Note: COD = chemical oxygen demand; TN = total nitrogen.

Recovery

There is no recovery of emissions reported for this source.

7.5.3 Uncertainty assessment and time-series consistency

Uncertainties

Table 7.5.16 Uncertainty in emissions from wastewater

Emissions category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Domestic and industrial wastewater (CH_4)	±10	±40
Domestic and industrial wastewater (N_2O)	±10	±90

Methane emissions

The parameters used to estimate CH_4 emissions from domestic and industrial wastewater (see table 7.5.16) have an estimated uncertainty of ±40 per cent (SCS Wetherill Environmental, unpublished). This stems from uncertainties in:

- the factors used to calculate emissions from the different wastewater treatment processes
- the quantities of wastewater handled by the different wastewater treatment plants
- the accuracy and completeness of the data relating to each plant
- the factors used to calculate the degradable organic content in the wastewater
- the wastewater treatment methods.

Nitrous oxide emissions

Large uncertainties are associated with the IPCC default emission factors for N_2O emissions from wastewater treatment effluent (IPCC, 2006a). The uncertainty is estimated to be ±90 per cent based on the ranges experienced in collecting and applying similar data internationally, and expert judgement on the application of this experience to New Zealand (Law et al., 2012).

Time-series consistency

Time-series consistency is ensured by the use of consistent models and parameters across the period. Where changes to methodologies or emission factors have occurred, the entire time series has been recalculated.

7.5.4 Category-specific QA/QC and verification

In the preparation for this inventory submission, the data for the *Wastewater treatment and discharge* category underwent Tier 1 quality checks.

7.5.5 Category-specific recalculations

Emissions from domestic and industrial wastewater treatment

Emissions from *Domestic wastewater* decreased by 0.5 kt CO_2-e (0.2 per cent) in 1990 and increased by 1.0 kt CO_2-e (0.3 per cent) in 2022. This is the result of revising population data using the latest estimates available and applying these consistently across the time series where possible. Emissions from *Industrial wastewater* did not change in 1990 and 2022. More details on recalculations are provided in chapter 10.

7.5.6 Category-specific planned improvements

No specific improvements are planned for this source category.

Chapter 7: References

Beca Infrastructure Ltd. Unpublished. National Greenhouse Gas Inventory from Wastewater Treatment and Discharge. Report commissioned by the Ministry for the Environment in 2007.

Beca Ltd. Unpublished. Industrial Wastewater Greenhouse Gas (GHG) Estimates from the Pulp and Paper, Wool Scouring and Wine Industries for New Zealand's GHG Inventory. Report commissioned by the Ministry for the Environment in 2013.

Cardno. Unpublished. Greenhouse Gas Emissions from Industrial Wastewater Treatment. Report commissioned by the Ministry for the Environment in 2015.

Eunomia Research and Consulting and Waste Not Consulting. Unpublished. Incorporating Waste Minimisation Act Data into New Zealand's Greenhouse Gas Estimates. Report commissioned by the Ministry for the Environment in 2014.

Eunomia. Unpublished(a). Improvements to Estimates of Greenhouse Gas Emissions from Landfills. Report commissioned by the Ministry for the Environment in 2020.

Eunomia. Unpublished(b). Data updated from National Resource Recovery Project situational analysis report (2019). Commissioned by the Ministry for the Environment in 2020.

Eunomia. Unpublished(c). Waste Data Improvements for Non-Municipal Landfills and Farm Waste. Report commissioned by the Ministry for the Environment in 2022.

Eunomia. Unpublished(d). New Zealand's National Recycling Rate: Options and estimates. Report commissioned by the Ministry for the Environment in 2024.

GHD. 2013. *Non-natural Rural Wastes: Site survey analysis*. GHD Ltd for the Canterbury Regional Council, published as Canterbury Regional Council Report No R13/52. Retrieved 9 November 2017.

GHD. 2014. *Rural Waste Surveys Data Analysis: Waikato and Bay of Plenty*. GHD Ltd for the Waikato Regional Council, published as Waikato Regional Council Report No 3114554. Retrieved 9 November 2017.

Gregory RG. 2017. Landfill gas modelling: combining scientific rigour and commercial key performance indicators for reliable forecasting. International Waste Working Group, Conference Proceedings Sardinia, TUHH 2017.

IPCC. 2006a. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste*. IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006b. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy*. IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2019. Calvo Buendia E, Tanabe K, Kranjc A, Baasansuren J, Fukuda M, Ngarize S, Osako A, Pyrozhenko Y, Shermanau P, Federici S (eds). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5. Waste*. IPCC National Greenhouse Gas Inventories Programme. Switzerland: Intergovernmental Panel on Climate Change.

Law Y, Ye L, Pan Y, Yuan Z. 2012. Nitrous oxide emissions from wastewater treatment processes. *Philosophical Transactions of the Royal Society 'B'* 367(1593): 1265–1277.

Ministry for the Environment. 1997. *National Waste Data Report*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2002a. *The New Zealand Waste Strategy*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2002b. *Solid Waste Analysis Protocol*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2010. *The New Zealand Waste Strategy: Reducing Harm, Improving Efficiency*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2022. *Te hau mārohi ki anamata – Towards a productive, sustainable and inclusive economy: Aotearoa New Zealand's first emissions reduction plan*. Wellington: Ministry for the Environment.

Ministry for the Environment. 2024. *Our journey towards net zero: New Zealand's second emissions reduction plan 2026–30*. Wellington: Ministry for the Environment.

Ministry of Commerce. 1993. *New Zealand Energy Information Handbook: Energy Data, Conversion Factors, Definitions*. Taylor Baines and Associates.

MWH. 2017. *National Waste Disposal Survey. Final Report.* MWH for the Ministry for the Environment, published as National Waste Disposal Survey Final Report 2017 No CR275. Retrieved 9 November 2017.

SCS Wetherill Environmental. Unpublished. National Greenhouse Gas Inventory from the Waste Sector 1990–2020. Report commissioned by the Ministry for the Environment in 2002.

SKM. Unpublished(a). Greenhouse Gases from the Waste Incineration Sector. Report commissioned by the Ministry for the Environment in 2007.

SKM. Unpublished(b). Estimates of Landfill Methane Recovered in New Zealand 1990–2012. Report commissioned by the Ministry for the Environment in 2009.

Tonkin and Taylor Ltd. Unpublished(a). National Greenhouse Gas Emissions from Wastewater Sludge. Report commissioned by the Ministry for the Environment in 2011.

Tonkin and Taylor Ltd. Unpublished(b). GHG Estimates from Non-municipal Landfills New Zealand. Report commissioned by the Ministry for the Environment in 2014.

UNFCCC. 2023. FCCC/ARR/2022/NZL. *Report on the Individual Review of the Annual Submission of New Zealand Submitted in 2022*. Centralised Review.

van der Weerden A, de Klein C, Kelliher R, Rollo M. 2014. *Reporting to 2006 IPCC Guidelines for N_2O Emissions from Additional Sources of Organic N: Final report*. Wellington: Ministry for Primary Industries.

Waste Not Consulting. Unpublished(a). Waste Composition and Construction Waste Data. Report commissioned by the Ministry for the Environment in 2006.

Waste Not Consulting. Unpublished(b). Reviewing the 2008 National Waste Composition Estimate and Producing a 2012 Estimate. Report commissioned by the Ministry for the Environment in 2013.

Waste Not Consulting. Unpublished(c). Update of National Average Waste Composition for Class 1 Landfills. Report commissioned by the Ministry for the Environment in 2020.

Chapter 8: Tokelau (other) sector

Beginning with the 2019 submission, New Zealand's national inventory includes emissions from Tokelau, which is an overseas dependent territory of New Zealand. See chapter 2, table 2.2.2 for the contribution of emissions from Tokelau. Generally, in New Zealand's inventory, net and gross emissions are reported as a total of emissions from New Zealand's mainland territory, plus emissions from Tokelau where applicable. Because emissions from Tokelau are small, and the methodology used varies greatly between Tokelau's inventory and the inventory for New Zealand's mainland territory, emissions from Tokelau are reported in the Other sector (CRT sector 6).

Methodological issues for Tokelau are detailed in chapter 8, separately from the sectoral chapters that focus on methods for New Zealand's mainland territory only. Annex 7 provides the common reporting tables (CRTs) of the time series for emissions and activity data, and information on methods and emission factors for each sector and category contributing to the gross emissions from Tokelau.

New Zealand ratified the United Nations Framework Convention on Climate Change (the Convention) on 16 September 1993 and the Paris Agreement on 4 October 2016. The extension to Tokelau (as of 13 November 2017) of New Zealand's ratification of the Convention and of the Paris Agreement requires New Zealand to include Tokelau in the obligatory climate change reporting managed by the Ministry for the Environment. Delivering on this obligation, among other things, means that New Zealand's national greenhouse gas (GHG) inventory shall include the GHG estimates from Tokelau.

To maintain transparency of the inventory and visibility of the GHG data from Tokelau, CRT sector 6 (Other) is used to present emissions from Tokelau's own sectors in the CRTs. This chapter provides an overview of Tokelau's economy and industry. It includes information on emissions trends, roles and responsibilities, quality-assurance and quality-control planning, methodological notes in regard to the GHG emissions from Tokelau.

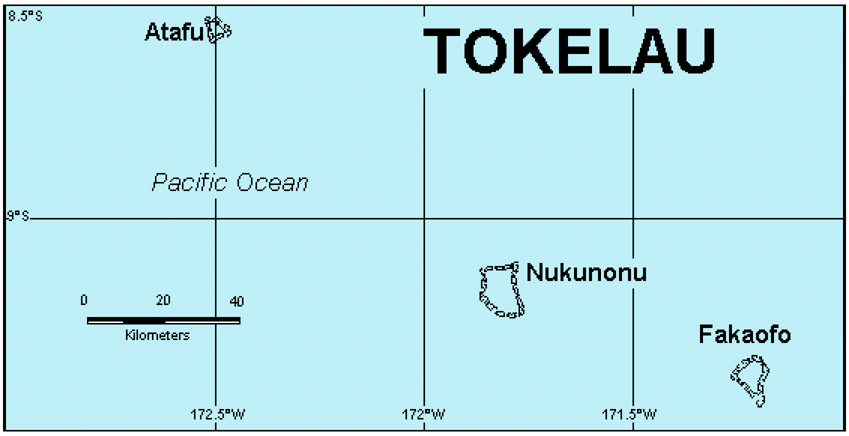
8.1 Tokelau overview

8.1.1 Geography

Tokelau is a non-self-governing territory[58] of New Zealand and is made up of three small coral atolls: Atafu, Nukunonu and Fakaofo. The total land area is 12 square kilometres within an Exclusive Economic Zone (EEZ) covering 318,990 square kilometres. Atafu, the northern atoll, has a surface area of 3.5 square kilometres; Nukunonu, the central atoll, is 4.7 square kilometres and Fakaofo, the southern atoll, is 4 square kilometres (figure 8.1.1).

[58] In the United Nations Charter (United Nations, 1945), a non-self-governing territory is defined as a territory "whose peoples have not yet attained a full measure of self-government". Tokelau has been on the United Nations list of non-self-governing territories since 1946, following the declaration of the intention by New Zealand to transmit information on the Tokelau Islands under Article 73e of the United Nations Charter.

Figure 8.1.1 Map of Tokelau



Source: Tokelau Islands Maps

From Atafu in the north to Fakaofo in the south, Tokelau extends for less than 200 kilometres. The atolls are about 3 to 5 metres above sea level. The maximum width of any island (motu) on the atolls' rims is 200 metres. Tokelau is, therefore, particularly vulnerable to natural hazards.

8.1.2 Preparing the Tokelau inventory estimates

Censuses of dwellings and population

Tokelauans have New Zealand citizenship.

Tokelau has carried out independent censuses of population and dwellings five yearly; detailed data are available on the number of inhabitants, livestock, housing and some appliances. Only the past four censuses in Tokelau (2006, 2011, 2016 and the 2019 mini census) have used a precise definition of who is a 'de jure Tokelauan'[59] and the people who actually lived in Tokelau during the Census night ('de facto' population). The de facto population has been used for the purposes of estimating emissions, which was 1,295 people in 2019 (Tokelau National Statistics Office, 2020). From 1990 to 2019, the population was fluctuating but generally declined for both de facto and de jure measures. Around 15,000 of the people who identify as Tokelauan live overseas, most of whom live in New Zealand.

Tokelau has a subsistence economy in which the sharing (inati) of essential resources plays an important and significant role. The inhabitants are dependent on local natural resources, particularly fishing in the lagoon and deep sea, growing coconuts and breadfruit, and keeping domesticated pigs and chickens.

The coral atolls provide a subsistence lifestyle within a fragile environment. Tokelau imports most of its foodstuffs from Samoa. The Tokelau economy is dependent on two major financial resources: economic and administrative assistance from New Zealand, and income from fisheries. New Zealand provides general budget support to help the delivery of essential services, consistent with its constitutional and United Nations Charter obligations.

[59] A 'de jure' census tallies people according to their regular or legal residence.

Reporting arrangements

Including Tokelau in New Zealand's inventory reporting is a gradual process. This requires building the expert capacity and establishing connections with the various organisations and businesses in Tokelau that participate in data collection and processing. Estimates include emissions from the largest Tokelau contributors, which are the Energy, Industrial Processes and Product Use (IPPU), Agriculture and Waste sectors, using Intergovernmental Panel on Climate Change (IPCC) Tier 1 methodologies with default emission factors for all reported categories (IPCC, 2006a–d). The Land Use, Land-Use Change and Forestry sector is not estimated because Tokelau has no planted or managed forests, and any emissions are expected to be negligible.

New Zealand and Tokelau signed a memorandum of understanding (MoU) on 18 January 2018 to establish the relationship between Tokelau and New Zealand regarding the governance of international climate change reporting relating to the inclusion of Tokelau in New Zealand's national inventory system. According to the MoU, both New Zealand's central inventory agency (the Ministry for the Environment) and Tokelau's Ministry of Climate, Oceans and Resilience, formerly known as the Climate Change Division within the Office of the Council for the Ongoing Government of Tokelau, have roles in inventory reporting.

New Zealand's Ministry for the Environment takes responsibility for:

- coordination of communications between New Zealand and Tokelau officials, as well as communications with project consultants in New Zealand and overseas
- coordination with other New Zealand government agencies participating in the inventory production, should their consulting or advice be required for the project
- initial consultation on developing a national GHG inventory system for Tokelau, together with the relevant instructive materials, principles, protocols and procedures of Tier 1 statistics, and methodological guidance for the inventory
- technical advice on various aspects of the project regarding the subject matter, the legal background (the Convention reporting guidance), software issues, and the quality-assurance and quality-control issues associated with changes in the national inventory system
- production of the complete set of the data tables in agreed formats
- final integration of the Tokelau GHG inventory component into the joint inventory submission to the Convention
- submitting the joint inventory to the Convention and coordinating communication with the Convention associated with the inventory submission and review
- publication of the joint inventory report and the CRTs online, as well as all supplementary materials.

Tokelau's Ministry of Climate, Oceans and Resilience takes responsibility for:

- coordinating the project implementation in Tokelau by communicating with the relevant agencies, organisations and individuals involved in Tokelau's GHG inventory; coordinating their efforts and delegating responsibilities to ensure sufficient information and support are provided to those agencies, organisations and individuals to enable the GHG inventory production
- providing timely advice on all cultural aspects of the project and helping to resolve any matters associated with potential cultural issues

- ensuring that the agreed project schedule is fully complied with, and the relevant timeframes are met, which includes submission of Tokelau's GHG data and information to New Zealand's national inventory compiler within the agreed timeframe
- coordinating Tokelau's efforts in activity data collection for the inventory reporting and data processing
- producing a peer-reviewed draft of the Tokelau chapter that is consistent with Paris Agreement reporting requirements as agreed under the Convention (UNFCCC, 2018a), chapter II of the Paris Agreement's modalities, procedures and guidelines (UNFCCC, 2018b), including the use of the 2006 IPCC Guidelines (IPCC, 2006a–d) and following the common reporting tables in Annex I to decision 5/CMA.3 (UNFCCC, 2021).

Both the Ministry for the Environment and Ministry of Climate, Oceans and Resilience are responsible for adhering to the principles and protocols for producers of Tier 1 statistics (Stats NZ, 2007).

Methodological issues

Methods and emission factors

Tier 1 methodological approaches with default emission factors are used for estimating emissions from all Tokelau source categories.

Tokelau is in a different climate zone from New Zealand and has a different lifestyle and different technologies. There are also differences in the scale of operations, especially in the Agriculture sector, which do not allow applying New Zealand's definition of a farm to Tokelau. For estimating emissions from Tokelau, the 2006 IPCC default emission factors for Oceania with a warm climate are used, whereas New Zealand uses default emission factors associated with a temperate climate.

The calorific values for fuels used for Tokelau are also different from those used for New Zealand because those fuels are coming from different sources. Relevant emission factors used for estimating emissions and references to the methods are included in sections 8.2 to 8.15 dedicated to the inventory sectors reported by Tokelau.

Activity data

The Tokelau National Statistics Office collects and processes activity data from Tokelau for the preparation of the inventory. Table 8.1.1 contains the key sources of the activity data from Tokelau used in Tokelau's GHG inventory.

Table 8.1.1 Key sources for activity data in Tokelau

Item	Name/abbreviation	Explanation	Used where
1	Census	Tokelau Census of Population and Dwellings 2006, 2011, 2016, 2019 (mini census) www.tinyurl.com/TokelauCensus	Census data; interpolations for populations of people and livestock; solid and water waste disposal (flush toilets), number of private aluminium boats and outboard motors, home appliances.
2	Archives NZ	Archives New Zealand, Wellington	Historic Census records going back to 1951, at five-year intervals (Tokelau National Statistics Office collation and analysis).
3	HIES	Tokelau Household Income and Expenditure Survey 2015/16 www.tinyurl.com/TokelauHIES	Population and dwellings data supplementary to Census, in partnership with Pacific Community (SPC).

Item	Name/abbreviation	Explanation	Used where
4	SNZ, Stats NZ	Stats NZ, Wellington www.stats.govt.nz	Major partner in collection, analysis and publication of Tokelau Census data.
5	TNSO	Tokelau National Statistics Office, Apia www.tokelau.org.nz/Stats.html	Joint collection, analysis and publication of Tokelau Census data.
6	DoE	Tokelau Department of Energy	Estimate of diesel use for 24/7 power generation in 2004, plus before and after installation of solar panels in July–September 2012 (personal communication Mr Robin Pene, DoE director).
7	PPS	Petroleum Product Supplies Ltd Apia	Fuel prices and volumes supplied for shipping and on-atoll use of diesel, petrol, kerosene and lubricant oil.
8	DoF	Tokelau Department of Finance	Paid invoices and payment records to PPS, Origin, and on-atoll stores.
9	2018 vehicle survey	Photo survey of Tokelau motorised vehicles on-atoll, August–December 2018	Personal communication JA Jasperse, TNSO.
10	Origin	Origin Energy Samoa Ltd, Apia	Prices and volumes supplied for on-atoll use of propane for cooking.
11	PCTrade-Green	Excel version of PCTrade package developed by Stats NZ, Christchurch	Used for analysing cargo shipping manifests, providing number of return voyages Apia–Tokelau over time, imports of goods, and exports of recyclables to date (2014 – June 2019 data available).
12	DoH	Tokelau Department of Health	Anecdotal information on inhalers, laser gas, fire extinguishers.
13	TSS	Tokelau Department of Transport and Support Services, Apia	Cargo shipping manifests for analysis of imports of all goods, and export of recyclables.
14	2014 Imports study	Jasperse JA. 2016. *Analysis of 2014 imports into Tokelau from Samoa, Part 2: Stores' invoices reconciled with cargo manifests, and quality of life implications*, Tokelau National Statistics Office	Various Energy and Waste sector data, for example, calculation of per capita protein consumption www.tokelau.org.nz/Bulletin/September+2016/2014+imports+final.html
15	EDNRE	Tokelau Department of Economic Development, Natural Resources and Environment	Anecdotal information on waste disposal and export.
16	PCRAFI	Koroisamanunu, Iva; Joy Papao; Mereoni Ketewai; and Arieta Sokota: *Mission Preliminary Report (Fieldwork undertaken from 8 August – 2 September 2013). SOPAC technical note (PR193)*, May 2014. Water and Sanitation Programme and Disaster Reduction Programme. Applied Geoscience and Technology Division (SOPAC), Suva, Fiji Islands	Information on drinking water, wastewater and sanitation.
17	MiCORE	Tokelau Ministry of Climate, Oceans and Resilience	Partner to Memorandum of Understanding with New Zealand Ministry for the Environment leading to the present inventory.

Tokelau's data and information in the common reporting tables

The methodologies for estimating emissions in Tokelau and New Zealand differ, so adding Tokelau and New Zealand's activity data at a category level and estimating combined emissions within each category is currently not possible. Due to limitations of the CRT, including specific categories for Tokelau consistently across all inventory sectors is also not possible.

Tokelau requested New Zealand's inventory team to maintain visibility of the data from Tokelau in the CRT, so that Tokelau officials could use them for other reporting and policy purposes. Reporting Tokelau as a different inventory sector provides this visibility. Therefore, CRT sector 6 (Other) is used to present emissions from Tokelau by sector in the CRT. Currently, the CRT environment does not allow the creation of lower-level categories in sector 6. To avoid double counting in the CRT, the data and information are aggregated for each of the Energy, IPPU, Agriculture and Waste sectors. In addition, annex 7 includes detailed tables with time series from 1990 to 2023 for each category reported for Tokelau. For comparability reasons, these tables are presented in a similar format to the CRT entry tables, and the table names follow the CRT naming convention for emission categories. The executive summary and chapter 2 of this National Inventory Report include comparisons between Tokelau and New Zealand's emissions.

8.1.3 Emissions reporting

Due to the small land size area, small population and absence of industry, Tokelau has a very low impact on the environment and emits very small amounts of GHGs. In relative terms, emissions have increased overall since 1990, due to increasing per capita consumption despite a decrease in population. Tokelau produces mainly carbon dioxide (CO_2) emissions (54.5 per cent) and methane (CH_4) emissions (39.4 per cent) followed by hydrofluorocarbons (HFCs) (5.0 per cent) and nitrous oxide (N_2O) emissions (1.1 per cent). Emissions from HFCs largely come from the use of air conditioning.

The total amount of all GHGs from all sources in Tokelau in 2023 was 4.20 kilotonnes carbon dioxide equivalent (kt CO_2-e), contributing around 0.006 per cent to New Zealand's gross emissions. This is below the significance threshold in accordance with paragraph 32, chapter II of the Annex to the decision 18/CMA.1 (UNFCCC, 2018b).

Emissions from Tokelau have increased since 1990, mainly due to increases in CO_2 emissions from the *Electricity generation* category (see figure 8.1.4 and figure 8.3.2).

The emissions in Tokelau are limited to:

- CO_2 from boat engines and vehicles
- CO_2 from back-up power generators
- fluorinated gases from the use of refrigerants
- CH_4 and N_2O from livestock (pigs and poultry)
- CH_4, CO_2 and N_2O from waste.

2023

In 2023, emissions from Tokelau contributed 0.006 per cent (4.20 kt CO_2-e) of New Zealand's gross GHG emissions.

The largest source category was *Domestic navigation* (emissions from marine vessels within Tokelau), which contributed 63.2 per cent (1.43 kt CO_2-e) of all energy emissions and 34.1 per cent of gross emissions from Tokelau.

Carbon dioxide dominated emissions from Tokelau, contributing 54.5 per cent (2.29 kt CO_2-e) of its total emissions in 2023. At 2.25 kt CO_2, the Energy sector contributed 98.3 per cent of total CO_2 emissions, mostly from *Domestic navigation*; with the remaining 1.7 per cent (0.04 kt) coming from *Open burning of waste* in the Waste sector.

Methane emissions contributed 39.4 per cent (1.65 kt CO_2-e) to the total emissions from Tokelau. The Agriculture sector in Tokelau contributed 55.8 per cent of CH_4 emissions (0.92 kt CO_2-e), which mostly came from *Manure management*. A significant portion of CH_4 emissions, 43.9 per cent (0.73 kt CO_2-e), came from the Waste sector, largely from *Solid waste disposal*. The Energy sector contributed the remaining 0.4 per cent of CH_4 emissions (0.01 kt CO_2-e), which mostly came from *Domestic navigation*.

Nitrous oxide emissions contributed 1.1 per cent (0.05 kt CO_2-e) to the total emissions from Tokelau. The IPPU sector (*Medical applications*) contributed the largest amount of N_2O, 52.1 per cent (0.02 kt CO_2-e) of the total N_2O. The Energy sector contributed a further 26.0 per cent (0.01 kt CO_2-e), which comes largely from *Domestic navigation*. The Waste sector contributed the remaining 21.8 per cent of N_2O (0.01 kt CO_2-e) from *Open burning of waste*.

Emissions of fluorinated gases from Tokelau consisted of HFC emissions only, contributing 5.0 per cent (0.21 kt CO_2-e) to the total emissions from Tokelau. These emissions largely result from the use of air conditioning. Emissions of perfluorocarbons (PFCs), nitrogen trifluoride and sulphur hexafluoride do not occur in Tokelau.

Figure 8.1.2 and figure 8.1.3 show emissions from Tokelau by gas and by sector.

Figure 8.1.2 Tokelau's emissions by gas in 2023

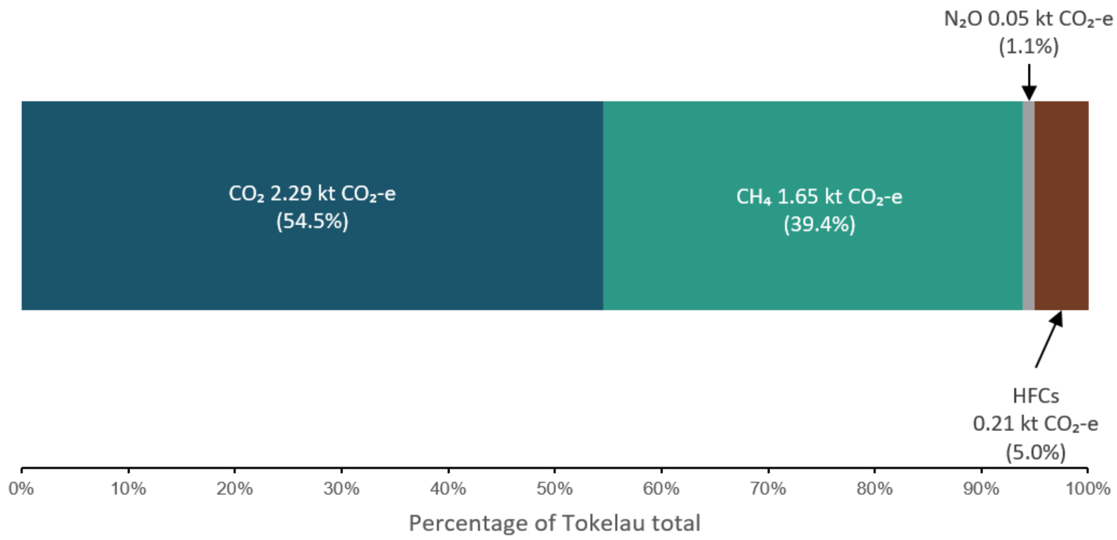
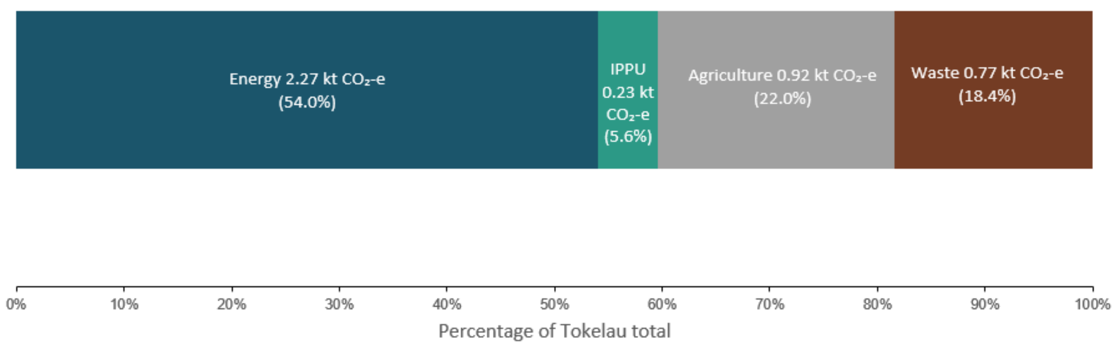


Figure 8.1.3 Tokelau's emissions by sector in 2023



1990–2023

In 1990, total emissions from Tokelau were 3.37 kt CO_2-e. Between 1990 and 2023, total emissions increased by 24.7 per cent (0.83 kt CO_2-e) to 4.20 kt CO_2-e (table 8.1.2 and figure 8.1.4). From 1990 to 2023, the average annual increase in gross emissions was 0.89 per cent.

The emissions increased largely due to changes in the Energy sector. The emission categories that contributed the most to this change were *Domestic navigation* and *Electricity generation*.

The changes in *Domestic navigation* are a result of Tokelau gaining ownership and use of the ferry *Mataliki* in 2016, cargo vessel *Kalopaga* in 2018 and *Fetu o te Moana* in 2019, leading to an increasing number of sea voyages between the atolls, which increased transport emissions.

The changes in Tokelau's Energy sector emissions from *Electricity generation* drive the overall emissions trend observed across most of the time series. Initially, up until 2003, emissions from this source were relatively stable. A significant increase in emissions was then observed (of nearly 400 per cent) due to an increase in the use of diesel generators for electricity production occurring between 2003 and 2011. This was followed by a significant drop in emissions occurring in 2012 and 2013 (by 82.5 per cent), when solar electricity generation began. Toward the end of the time series, diesel generator use increased again as the generation from solar power decreased, with emissions increasing accordingly.

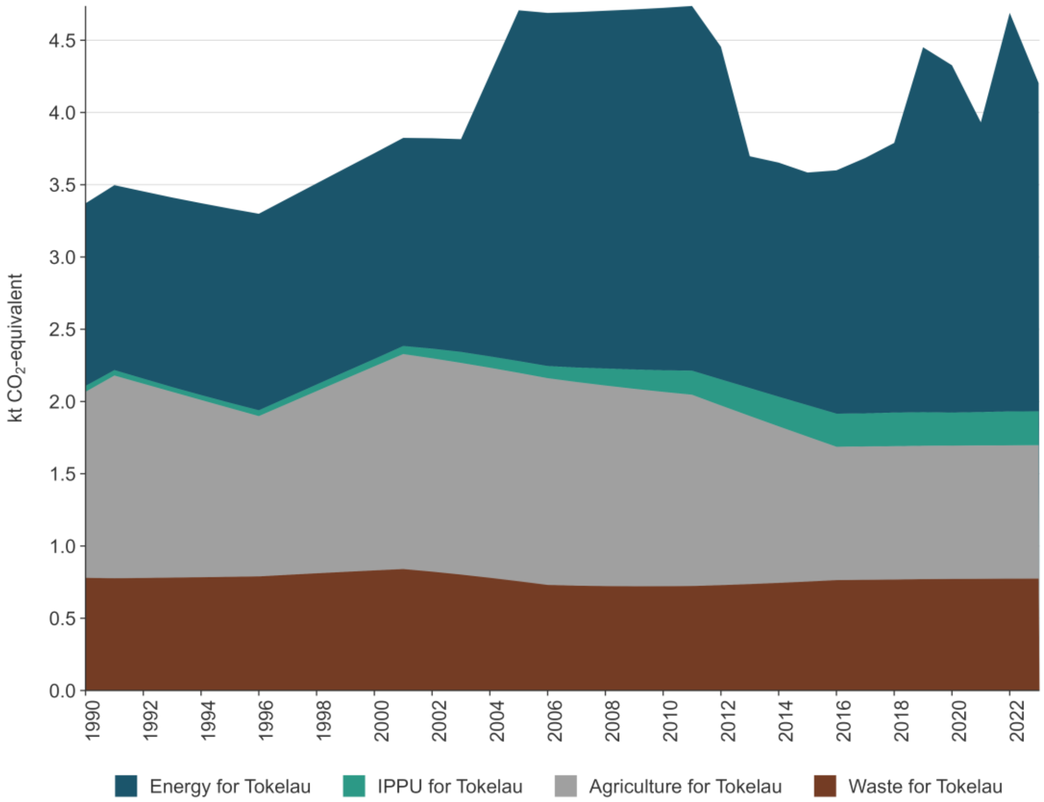
Emissions from Tokelau's IPPU sector have also increased mainly due to the introduction of air conditioning after 2006. Emissions from Tokelau's Agriculture sector decreased slightly as a result of a reduced population of pigs.

Table 8.1.2 Gross emissions from Tokelau by gas in 1990 and 2023

	Emissions (kt CO_2-e)		Difference (kt CO_2-e)	Change (%)
Direct greenhouse gas emissions	**1990**	**2023**	**1990–2023**	**1990–2023**
CO_2	1.30	2.29	0.99	76.6
CH_4	2.00	1.65	-0.34	-17.2
N_2O	0.08	0.05	-0.03	-39.7
HFCs	NO	0.21	0.21	NA
PFCs	NO	NO	NA	NA
SF6	NO	NO	NA	NA
NF3	NO	NO	NA	NA
Gross, all gases	**3.37**	**4.20**	**0.83**	**24.7**

Note: Emissions from the Land Use, Land-Use Change and Forestry sector are not estimated for Tokelau. The percentage change for hydrofluorocarbons (HFCs) is not applicable (NA) because HFC production or use was not occurring (NO) in 1990. Columns may not total due to rounding. Presented percentages are calculated from unrounded values.

Figure 8.1.4 Emissions by sector for Tokelau (kt CO_2-e), from 1990 to 2023



2022–2023

Total Tokelau emissions in 2023 were 0.49 kt CO_2-e (10.4 per cent) lower than emissions in 2022. The decrease in emissions is largely in the *Electricity generation* category, which is the result of reduced diesel due to fuel conservation initiatives and problems with the diesel electricity generators. The diesel generators have been in greater demand following issues with solar electricity generation since 2022. This decrease in emissions from *Electricity generation* is slightly offset by a small increase in the *Domestic navigation* category, due to an increase in shipping trips.

Key categories

Emission categories from Tokelau have been included in the key category analysis, along with all categories reported in New Zealand's inventory. None of the emission categories from Tokelau are key categories (either level or trend) in the 2025 submission.

8.1.4 Recalculations and improvements

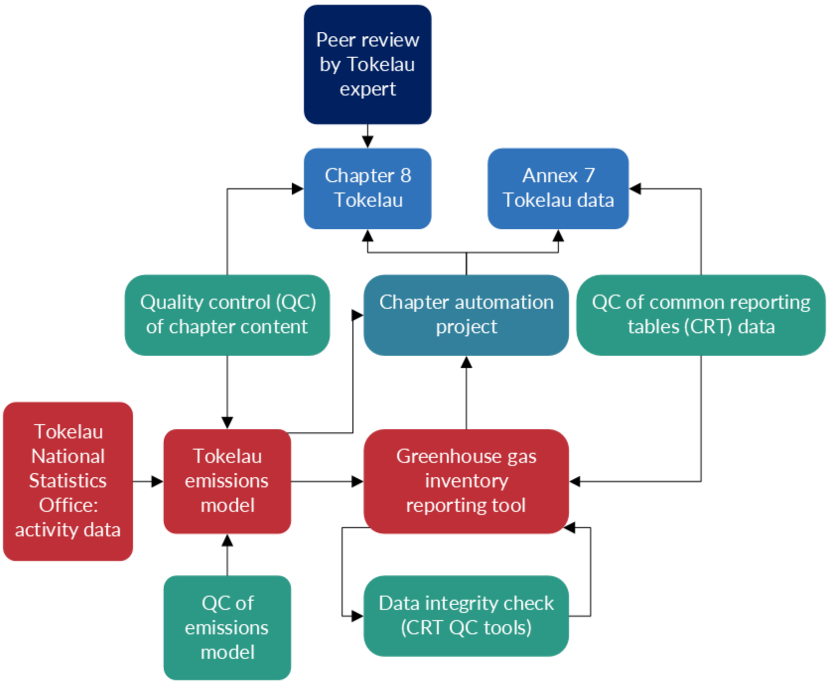
One minor recalculation has been made in the Tokelau emission estimates since the 2024 submission. Improvements made to estimates in Tokelau have resulted in a decrease of 0.03 per cent (0.001 kt CO_2-e) in estimated Tokelau emissions in 1990 and an increase of 0.1 per cent (0.004 kt CO_2-e) in estimated Tokelau emissions in 2022. This change is due to updates in New Zealand's medical emissions data, which are assumed to be the same per capita in Tokelau.

8.1.5 Quality-assurance/quality-control (QA/QC) processes

Tokelau's activity data undergo quality-control processes at the Tokelau National Statistics Office. Tokelau's emissions estimates undergo quality-assurance and quality-control processes that are similar to those of other inventory sectors.

Figure 8.1.5 presents an overview of the compilation process for Tokelau and its integration into New Zealand's inventory. It also shows where quality-assurance and quality-control steps are applied.

Figure 8.1.5 Data processing, quality-assurance and quality-control processes applied to the inventory data from Tokelau and its integration into New Zealand's inventory



8.2 Energy emissions from Tokelau (6. Tokelau_1)

8.2.1 Overview of Tokelau's Energy sector

The total amount of all energy emissions in Tokelau in 2023 was 2.27 kt CO_2-e. This contributed 54.0 per cent to the total emissions from Tokelau and 0.003 per cent to New Zealand's gross emissions including Tokelau. The categories that contributed to the energy emissions were *Domestic navigation*, *Electricity generation* and *Other – Residential*.

For all energy categories, emissions were estimated using the IPCC Tier 1 methodological approach with IPCC default emission factors (IPCC, 2006a). Default IPCC uncertainty values were used for all estimates (IPCC, 2006a).

Tokelau predominately uses diesel oil and petrol (for back-up generators and transport) and liquefied petroleum gas (LPG) (for cooking purposes). Solid fuels are not used in Tokelau, other than on a small scale, for instance the husks of locally grown coconuts. Emissions from solid fuels are, therefore, not estimated.

Small amounts of other fossil fuels are imported by Tokelau, which are assumed to be combusted. These include gasoline, other kerosene and lubricants. Their combustion is accounted for under *Domestic navigation – Gas/diesel oil*. Around 40 drums (205-litre capacity per drum) of oil are imported annually, the bulk of which is assumed to be mixed with petrol for 'outboard' engine use and combusted, with only a few drums used to lubricate cars and other engines. Because none of those are recycled, combustion is the most likely outcome. After every five roundtrips, oil changes carried out in Apia during servicing of the ferries *Mataliki* and *Kalopaga* have the more significant amount of waste oil but this remains in Samoa.

For consistency with New Zealand's Energy sector, gross calorific values were used for Energy sector estimates from Tokelau. The relevant IPCC default emission factors were adjusted accordingly by multiplying them by 0.95 and 0.90 for liquid and gaseous fuels respectively.

8.2.2 Reference approach

The reference approach calculations were performed according to the methods described in the 2006 IPCC Guidelines. Equations 6.1 to 6.4 from chapter 6 in the 2006 IPCC Guidelines were used for calculating consumption and estimating emissions (IPCC, 2006a). Gross calorific values were used for all calculations.

In 2023, total CO_2 emissions from the reference approach in Tokelau were 1.99 kt, which differs from the sectoral approach by 2.3 per cent. The average variation of differences between the sectoral and reference approach across the time series was 2.2 per cent.

8.2.3 International bunker fuels

No fuel is used for international navigation in Tokelau, because only domestic voyages are made by Tokelau's vessels. All international voyages use the fuel loaded in Samoa and no refuelling is done in Tokelau for the international routes.

Tokelau has no domestic or international aviation transportation.

8.3 Stationary combustion: Public electricity and heat production

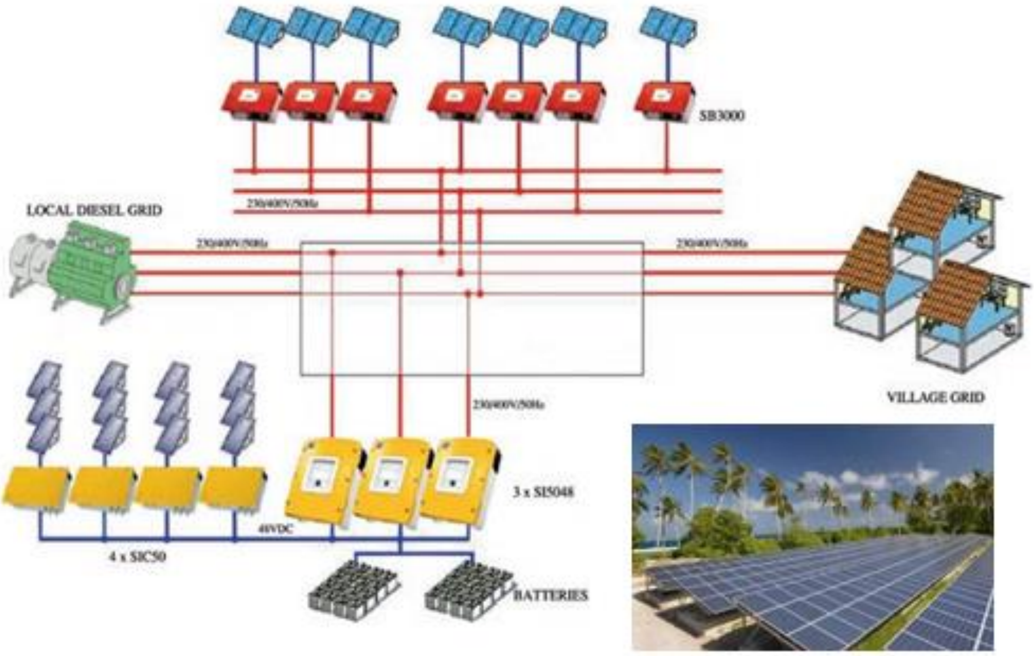
8.3.1 Description

The main source of emissions from this category in Tokelau includes electricity production from back-up generators. Tokelau uses liquid fossil fuels for these purposes, therefore, only liquid fossil fuels are reported in the *Energy industries* category.

Like most small Pacific Island nations and territories, Tokelau has been heavily reliant on the importation of fossil fuels for energy generation. Imports increased significantly in 2004, when electric power became available for households 24 hours a day, 7 days a week. Before that, electricity was generated between 6 pm and 10 pm daily, and annual diesel consumption was about 20 per cent of the value in 2011.

In 2012, the installation of 4,000 solar photovoltaics (PV) systems across the three atolls was completed (figure 8.3.1). Each of the three Tokelau atolls now has a significant array of solar PV systems that cater for a significant proportion of local electric power requirements.

Figure 8.3.1 Cluster block diagram for Tokelau's solar project



Source: International Renewable Energy Agency (2013)

Tokelau received wide media coverage for its installation of solar PV units.[60] The change resulted in a significant drop in liquid fossil fuels consumption for electricity production in Tokelau (by around 82.5 per cent) and a decrease in the total energy emissions by 36.4 per cent between 2011 and 2013. However, some power generation using diesel remains necessary as a back up, during the failure of solar PV units, prolonged cloudy spells, and to meet the steadily increasing demand from households and the public sector. In 2022, Tokelau's reliance on diesel generators has increased in part due to Nukunonu's solar panel batteries overheating due to low maintenance. A project that was planned to upgrade the solar panel batteries was deferred due to COVID-19.

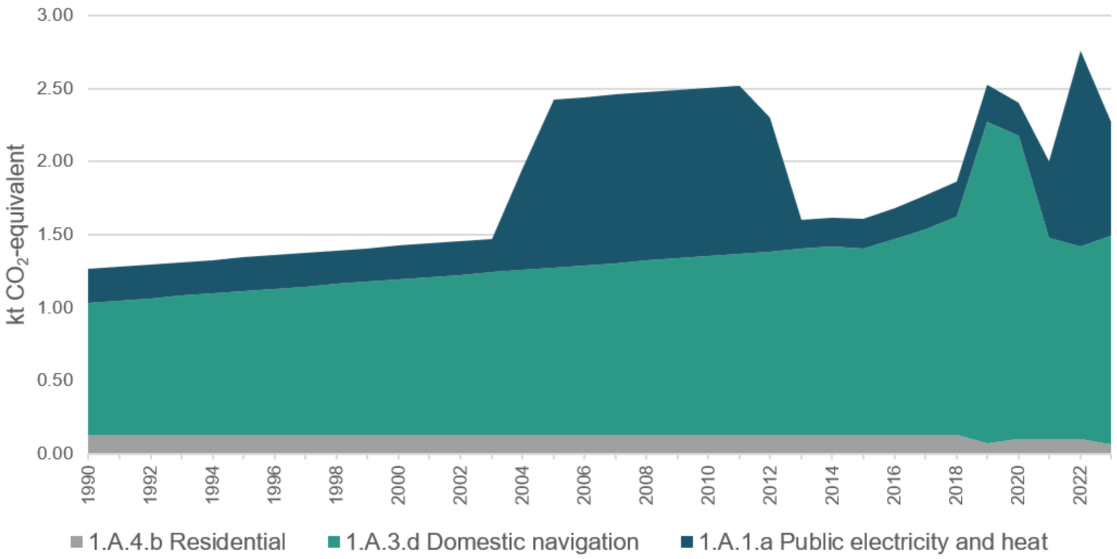
Energy emission trends

For Tokelau, the *Electricity generation* category accounted for 100 per cent of the emissions from the *Energy industries* category for the entire time series. In 2023, emissions from the *Energy industries* category totalled 0.78 kt CO_2-e (34.2 per cent of all energy emissions from Tokelau). Emissions from energy industries increased by 0.54 kt CO_2-e (136.1 per cent) since the 1990 level of 0.23 kt CO_2-e.

The increase in emissions in 2004 was due to continuously generating electricity from fossil fuels, which was later offset by the installation of solar PV units in 2012. After 2012, solar energy dominated electricity production until the end of the time series when demand increased for diesel generation because the generation from solar power decreased. Figure 8.3.2 shows emission trends in the Energy sector by category for Tokelau.

60 See Roorda et al. (2015) *Evaluation of the Tokelau Country Programme*, page 46.

Figure 8.3.2 Energy emissions by category for Tokelau (kt CO_2-e), from 1990 to 2023



8.3.2 Methodological issues

Activity data

The sources of activity data for the *Energy industries* category are included in table 8.1.1. Key sources for the energy supply and consumption data are the Tokelau Department of Energy and Petroleum Product Supplies Ltd (Apia, Samoa). The Tokelau Department of Energy provided background data for estimates of diesel use for power generation around the time that electricity changed to 24 hours a day, 7 days a week in Tokelau in 2004 (item 6 in table 8.1.1). Based on purchase information, the Department of Finance provided the data on fuel prices and volumes supplied by Petroleum Product Supplies Ltd for shipping and on-atoll use of diesel, petrol, kerosene and lubricant oil (item 7 in table 8.1.1). Only liquid fossil fuels (i.e., gas and diesel oil) are used in the *Energy industries* category. All fossil fuels in Tokelau are imported and activity data are mostly obtained from analysis of invoices from main suppliers and shipping manifests.

In the course of the analysis of available data, discrepancies were discovered between the fuel imports shown on shipping manifests and the more reliable financial fuel purchase data that were audited. Detailed data were not available for each year from 1990 to 2023 (or data reliability was not high), so a trade-off was made between data granularity and data quality. The biggest and most reliably recorded data variations are reflected in the time series.

For electricity generation, two important events occurred: first, the changeover to 24 hour, 7 days a week electricity in 2004 (from 6 pm to 10 pm before that, at an estimated 20 per cent of the 24 hour, 7 days a week value in 2011); and second the introduction of solar PV-powered plants in 2012. The change during 2012, due to the installation of solar PV-powered plants, was reasonably well documented and, therefore, reflected in the time series. For the years 1990 to 2003, 2005 to 2011 and 2013 to 2015, the activity data (and corresponding emissions) are shown as constant. In 2022, Tokelau's reliance on diesel generators has increased due to an increase in demand and a decrease in the availability of solar power. Use of diesel generators subsequently decreased in 2023 due to fuel conservation initiatives and problems with the generators.

The diesel data for 2013 to 2015 were entirely based on analysis during 2018 of fuel purchases, when, for the first time, Tokelau's analysts could clearly separate out the diesel used on-atoll and for shipping. The methodology for such analyses that was put in place for the 2019 inventory submission has been refined in each subsequent submission.

Diesel is delivered on 'dangerous goods sailings' to Tokelau in the ships' fuel bunkers. On arrival, it is pumped into drums on a barge, for shipping to shore and transport to the generator sites.

Methods and emission factors

An IPCC Tier 1 method was applied for estimating emissions from the *Electricity generation* category. The method required the data on the amount of LPG combusted in the source category and a default emission factor from table 2.2, section 2.3.2.1, volume 2 of the 2006 IPCC Guidelines. Default emission factors from the 2006 IPCC Guidelines were converted from net calorific values to gross calorific values using the Organisation for Economic Co-operation and Development (OECD) and International Energy Agency (IEA) assumptions to make these conversions:

$$\textit{Gross Emission Factor (liquid fuels)} = 0.95 \text{ x } \textit{Net Emission Factor}$$

Equations 2.1 and 2.2 from section 2.3.1.1 in the 2006 IPCC Guidelines were used for estimating emissions (IPCC, 2006a).

8.3.3 Uncertainty assessment and time-series consistency

For this submission, it was not possible to develop Tokelau-specific uncertainty values, therefore, for emission factors, default uncertainty values provided in the 2006 IPCC Guidelines were used for CO_2 and CH_4 (for public power, co-generation and district heating) (IPCC, 2006a). Because no quantified default emission factor is provided for N_2O, New Zealand's emission factor uncertainty across the Energy sector for N_2O was used for this category.

For activity data, due to the lack of detailed pre-2018 fuel data, an upper level of the default uncertainty range for the main activity electricity and heat production associated with data extrapolation from the 2006 IPCC Guidelines was applied (IPCC, 2006a). Table 8.3.1 shows the use of uncertainties for the *Energy industries* category.

Table 8.3.1 Uncertainties for the *Energy industries* category

Gas	Fuel type	Activity data (AD) uncertainty (%)	Emission factor (EF) uncertainty (%)	Source
CO_2	Liquid fuels	10	±7	AD: page 2.41, IPCC, 2006a (table 2.15) EF: page 2.38, IPCC, 2006a
CH_4	Liquid fuels	10	±50.0	AD: page 2.41, IPCC, 2006a (table 2.15) EF: page 2.38, IPCC, 2006a (table 2.12)
N_2O	Liquid fuels	10	±50.0	AD: page 2.41, IPCC, 2006a (table 2.15) EF: New Zealand's value is used (table 3.2.1, chapter 3)

For the *Electricity generation* category, time-series consistency is maintained by using a combination of actual and inferred data for diesel consumed depending on the information available. For all years before 2019, except 2011 and 2015, diesel use is assumed based on the typical use of the diesel electricity generators.

8.3.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.3.5 Category-specific recalculations

There were no changes to estimates for the *Energy industries* category.

8.3.6 Category-specific planned improvements

No improvements are planned for energy industries. Some areas identified for possible improvements are better monitoring of diesel fuel landing on-atoll at the power sites, and clearly separating fuel used for power generation from heavy machinery and diesel-powered vehicles. Data on gross electricity production from oil were acquired in late 2019 from the International Renewable Energy Agency; these could provide additional detail and verification of energy use back to their base year 2000. Future imports of coolants (ethylene glycol) for the solar PV-powered plants may also be considered in future.

8.4 Stationary combustion: Other sectors – Residential

8.4.1 Description

Tokelau has no significant industry. All energy is used by domestic and fishing activities and community–government activities (e.g., meeting halls and offices, village freezers, building projects, stevedoring). Therefore, emissions associated with energy consumption in Tokelau (except fishing) are included in the category *Other sectors – Residential*. The small amount of emissions associated with communal activities are not easily distinguishable from those coming from residential activities and are therefore included in the *Other sectors – Residential* category. Emissions from fishing are included in *Domestic navigation*. This is because it is difficult to distinguish fuel use for fishing from fuel use for domestic navigation in Tokelau, because families use the same boats for both purposes.

According to the 2016 Tokelau Census, every household has a fridge and a freezer, and some households now have air conditioning. Most households (over 60 per cent) also own a washing machine, a computer and a television. The United Nations Development Programme, under the Tokelau Energy Sector Support Project, has in the past funded a programme of replacing old inefficient fridges and freezers with new ones. Home appliances in Tokelau mainly use the power provided by solar PV-powered plants, supplemented as needed by back-up diesel-powered generators. Emissions associated with the use of diesel-powered back-up generators are included in the *Energy industries* category.

Gas cooking using imported natural gas (LPG) is the preferred method used by about 72.0 per cent of households, replacing kerosene stoves. The use of kerosene stoves dropped from 56.6 per cent of households in 2006 to 23.6 per cent in 2016 (2016 Tokelau Census). Associated activity data and emissions are included in the *Other sectors – Residential* category.

In 2023, emissions from the *Other sectors – Residential* category were 0.06 kt CO_2-e (2.7 per cent of all energy emissions from Tokelau).

8.4.2 Methodological issues

Activity data

The sources of activity data for the *Other sectors – Residential* category are included in table 8.1.1. The key data source for the category is paid invoices from Origin Energy Samoa Ltd (Apia, Samoa) providing prices and volumes of propane supplied on-atoll for cooking.

Methods and emission factors

An IPCC Tier 1 method was applied for estimating emissions from the *Other sectors – Residential* category. The method required the data on the amount of LPG combusted in the source category and a default emission factor from table 2.2, section 2.3.2.1, volume 2 of the 2006 IPCC Guidelines. Default emission factors from the 2006 IPCC Guidelines were converted from net calorific values to gross calorific values using the OECD and IEA assumptions to make these conversions:

$$\text{Gross Emission Factor (gaseous fuels)} = 0.90 \text{ x Net Emission Factor}$$

Equations 2.1 and 2.2 from section 2.3.1.1 in the 2006 IPCC Guidelines were used for estimating emissions (IPCC, 2006a).

8.4.3 Uncertainty assessment and time-series consistency

For this submission, it was not possible to develop Tokelau-specific uncertainty values, therefore, for emission factors, default uncertainty values provided in the 2006 IPCC Guidelines were used for CO_2 and CH_4 (for commercial, institutional and residential combustion) (IPCC, 2006a). Because no quantified default emission factor is provided for N_2O, New Zealand's emission factor uncertainty across the Energy sector for N_2O was used for this category.

For activity data, a mid-range level of default uncertainty range associated with data extrapolation from the 2006 IPCC Guidelines was applied (IPCC, 2006a). Table 8.4.1 shows the use of uncertainties for the *Other sectors – Residential* category.

Table 8.4.1 Uncertainties for the *Other sectors – Residential* category

Gas	Fuel type	Activity data (AD) uncertainty (%)	Emission factor (EF) uncertainty (%)	Source
CO_2	Liquid fuels	20	±7	AD: page 2.41, IPCC, 2006a (table 2.15) EF: page 2.38, IPCC, 2006a
CH_4	Liquid fuels	20	±50.0	AD: page 2.41, IPCC, 2006a (table 2.15) EF: page 2.38, IPCC, 2006a (table 2.12)
N_2O	Liquid fuels	20	±50.0	AD: page 2.41, IPCC, 2006a (table 2.15) EF: New Zealand's value (table 3.2.1, chapter 3)

For the *Other sectors – Residential* category, time-series consistency is maintained by keeping activity data constant at 2018 amounts and using actual data since 2018 for which data is available.

8.4.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.4.5 Category-specific recalculations

There were no changes to estimates for the *Other sectors – Residential* category.

8.4.6 Category-specific planned improvements

No improvements are planned for the *Other sectors – Residential* category. One area identified for possible future improvement is to consider additional LPG imports purchased from Aute Gas (Apia, Samoa), for Nukunonu. However, the difference is likely to be small, compared with the current approach (where Nukunonu is taken as the average between the fuel purchases from Origin, by Atafu and Fakaofo). For future submissions, further analysis of activity data from Tokelau, to reflect year-to-year variations, will be considered as far as resources allow.

8.5 Mobile combustion: Domestic navigation

8.5.1 Description

The only means of transport to and from Tokelau is by sea because there is no air transportation. All travel and supplies to Tokelau originate and terminate in Samoa, Tokelau's closest neighbour. A direct trip from any of the three atolls to the nearest port, Apia, usually takes between 26 hours and 40 hours. There are no ports and terminals in Tokelau, and no offshore anchorage is available; barges that can enter the fringe reef are used for loading and offloading ships.

The passenger ferries and cargo ships arriving from Apia (distance around 500 kilometres) generally visit the three atolls in succession: they are 60 kilometres and 90 kilometres apart, respectively. A round trip is about 1,300 kilometres using diesel from Apia. Up until 2018, the fraction (300/1300) is used to estimate *Domestic navigation* within Tokelau. For 2023, actual data on the number of inter-atoll trips was used.

Until recently, the main forms of road transport on the atolls were trucks, pick-ups, motorbikes and a range of golf carts. Some vehicles are electric, fuelled by solar PV energy. Solar-powered streetlights ensure safety on the roadways. The private importation of other vehicles has increased recently.

The number of petrol cars has been very small in Tokelau. In 2023 there were only about 40 cars (in addition to the vehicles above) and 30 motorbikes, with the entire network of unsealed roads being about 10 kilometres. Census 2001 and prior recorded only four registered cars. Aluminium boats with an outboard motor are widely used by families. Emissions from fuels used for road transport are orders of magnitude lower than from boats, and it was not possible to distinguish the small amounts of fuels used by cars from the total amount used by boats and cars. That is why emissions from road transport are included under the *Domestic navigation* category.

According to its 2016 census, Tokelau has 176 aluminium boats with 160 outboard motors, which use most of the imported petrol to travel within and outside the large lagoons. Most of the diesel use is by the ferries travelling to and from Samoa. *Fetu o te Moana* is a new search and rescue vessel delivered in 2019 that also provides general inter-atoll transport.

For Tokelau, the *Domestic navigation* category accounted for 100 per cent of the emissions from the *Transport* category for the entire time series. In 2023, emissions from the *Domestic navigation* category totalled 1.43 kt CO_2-e (63.2 per cent of all energy emissions from Tokelau).

8.5.2 Methodological issues

Activity data

The sources of activity data for the *Transport* category are included in table 8.1.1. Activity data sources for the category are:

- paid invoices from Petroleum Product Supplies Ltd (Apia, Samoa) with data on fuel prices and volumes supplied for shipping and on-atoll use: diesel, petrol, kerosene and lubricant oil
- the Tokelau Department of Finance's invoices and payment records to Petroleum Product Supplies Ltd, Origin and on-atoll stores
- a photo survey of Tokelau motorised vehicles on-atoll, August–December 2018.

Additional energy data related to cargo manifests were obtained from an *Analysis of 2014 Imports into Tokelau from Samoa, Part 2: Stores' invoices reconciled with cargo manifests, and quality of life implications* (Jasperse, 2016). Only liquid fossil fuels (gas and diesel oil) are used for fuelling Tokelau's transport.

Due to large discrepancies between different sources of raw data, reliable statistics on fuel consumption across the period 1990 to 2023 are not available. Some anecdotal transport data exist for the number of roundtrips Apia–Tokelau during the years 1990 to 2014. Actual records are available after this period.

Methods and emission factors

A Tier 1 method was applied for estimating emissions from the *Domestic navigation* category. The method required the data on the amount of fuel combusted in the source category and a default emission factor from tables 3.5.2 (for CO_2) and 3.5.3 (for non-CO_2 gases), section 3.5.1.2, volume 2 of the 2006 IPCC Guidelines. Default emission factors from the 2006 IPCC Guidelines were converted from net calorific values to gross calorific values using the OECD and IEA assumptions to make these conversions:

$$\textit{Gross Emission Factor (liquid fuels)} = \textit{0.95 x Net Emission Factor}$$

Equation 3.5.1 in section 3.5.1.1 in the 2006 IPCC Guidelines was used for estimating emissions (IPCC, 2006a).

8.5.3 Uncertainty assessment and time-series consistency

For this submission, it was not possible to develop Tokelau-specific uncertainty values, therefore, for emission factors, default uncertainty values provided in the 2006 IPCC Guidelines were used for CO_2 (for diesel) and CH_4 (upper value) (IPCC, 2006a). For N_2O, New Zealand's emission factor uncertainty across the Energy sector was used for this category, which is within the default uncertainty range. For activity data, due to discrepancies between different data sources, an upper level of default uncertainty range associated with incomplete surveys from the 2006 IPCC Guidelines was applied (IPCC, 2006a). Table 8.5.1 shows the use of uncertainties for *Domestic navigation* (diesel).

Table 8.5.1 Uncertainties for the *Domestic navigation* (diesel) category

Gas	Fuel type	Activity data (AD) uncertainty (%)	Emission factor (EF) uncertainty (%)	Source
CO_2	Liquid fuels	±50	±1.5	Section 3.5.1.7, IPCC, 2006a
CH_4	Liquid fuels	±50	±50.0	Section 3.5.1.7, IPCC, 2006a
N_2O	Liquid fuels	±50	±50.0	New Zealand's value is used (table 3.2.1, chapter 3), section 3.5.1.7, IPCC, 2006a

For the *Domestic navigation* category, time-series consistency is maintained by estimating activity data for years before 2018 when detailed data became available.

8.5.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.5.5 Category-specific recalculations

There were no changes to estimates for the *Domestic navigation* category.

8.5.6 Category-specific planned improvements

No improvements are planned for *Transport*. For future submissions, further analysis of activity data to reflect year-to-year variations will be considered as far as resources allow.

8.6 Emissions from Industrial Processes and Product Use in Tokelau (6. Tokelau_2)

8.6.1 Overview of Tokelau's Industrial Processes and Product Use sector

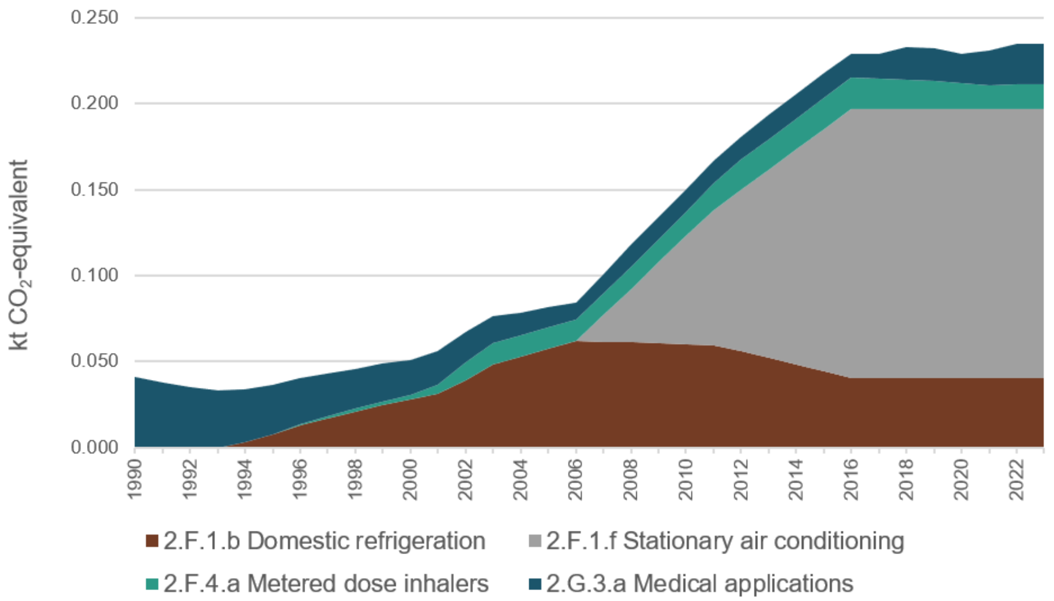
Tokelau has no significant industry. The emissions associated with the IPPU sector come from the following activities:

- use of refrigeration and air conditioning – HFCs
- use of metered dose inhalers – HFC-134a and HFC-227ea
- medical applications of N_2O.

Thus, the source categories included in this report are *Refrigeration and air conditioning* (2.F.1), *Metered dose inhalers* (2.F.4) and *Medical applications* (2.G.3).

The total amount of all IPPU emissions in Tokelau in 2023 was 0.23 kt CO_2-e. They contributed 5.6 per cent to the total emissions from Tokelau and 0.0003 per cent to New Zealand's gross emissions including Tokelau. The biggest contributor to the total IPPU HFC emissions is *Stationary air conditioning* followed by *Domestic refrigeration*, with 66.6 per cent and 17.3 per cent of IPPU emissions from Tokelau, respectively. Figure 8.6.1 shows emission trends in the IPPU sector by category for Tokelau.

Figure 8.6.1 Industrial Processes and Product Use emissions by category for Tokelau (kt CO_2-e) from 1990 to 2023



8.7 Emissions from Refrigeration and air conditioning in Tokelau

8.7.1 Description

Due to a very small number of air-conditioned vehicles in Tokelau, all emissions from this category are reported in *Stationary air conditioning* (2.F.1.f).

Because most fridge and freezer appliances are installed in households, the emissions associated with refrigeration are reported in *Domestic refrigeration* (2.F.1.b). Emissions from fridge and freezer appliances are based on the number of those appliances, however, no HFCs were used before 1994. To account for the phase-in of HFCs, it has been assumed that the proportion of appliances using HFCs increased 10 per cent per year, starting at 10 per cent of appliances in 1994 and reaching 100 per cent of appliances in 2003. This phase-in is reflected in figure 8.6.1. Emissions continue to change after 2003 due to changes in the overall number of appliances.

8.7.2 Methodological issues

Activity data

The data for the number of appliances are sourced from:

- Tokelau Census of Population and Dwellings (2006, 2011, 2016) (item 1 in table 8.1.1) for 2006 to 2016 data points
- Archives New Zealand (Wellington, New Zealand) for historic Census records going back to 1950, mostly at five-year intervals
- Tokelau Household Income and Expenditure Survey 2015/16 for population and dwellings data supplementary to the Census

- Tokelau Department of Health for anecdotal information on inhalers, laser gas and fire extinguishers
- Tokelau Department of Transport and Support Services (Apia, Samoa) for cargo shipping manifests for analysis of imports of all goods
- Stats NZ (Wellington, New Zealand), which helped in the collection, analysis and publication of Tokelau Census data
- Tokelau National Statistics Office, which performed collection, analysis and publication of Tokelau Census data with subsequent data collation and analyses.

The raw data on the number of appliances used in Tokelau obtained from the Census have been further analysed and cross-referenced through other sources (e.g., see those listed in table 8.1.1); available data points are increased by equal increments between the data collection years.

Method and emission factors

For both air conditioning and domestic refrigeration, the following assumptions were made:

- no chemicals are imported or exported, except as a component of each sort of equipment; emissions are assumed to be derived from current equipment only
- HFCs and PFCs are neither produced nor exported or disposed of in Tokelau, therefore, the net consumption is essentially equal to imports
- a composite default emission factor of 15 per cent can be used for estimating emissions for both domestic refrigeration and stationary air conditioning
- assumed percentage of new equipment exported (0 per cent for Tokelau)
- assumed percentage of new equipment imported (100 per cent for Tokelau)
- the HFC emissions from stationary air conditioning did not occur until 2006
- the HFC emissions from domestic refrigeration did not occur until 1994 (the same as for New Zealand)
- the average charge for fridges and freezers has the upper limit of the mass of gas of 0.5 kilograms (from table 7.9 of volume 3 of the 2006 IPCC Guidelines (IPCC, 2006b))
- the average charge for an air conditioning unit is 10 kilograms of refrigerant gas (default value from the 2006 IPCC Guidelines (IPCC, 2006a))
- for air conditioning units and fridges and freezers, Tokelau reports the same set of HFCs as New Zealand. These are HFC-32, HFC-125 and HFC-134a for air conditioning units, and HFC-134a for refrigeration.

The Tier 1a method from the 2006 IPCC Guidelines is used for estimating emissions from category 2.F.1 in Tokelau (IPCC, 2006b). In this method, activity data are represented by a net consumption value (equation 7.1 from volume 3 of the 2006 IPCC Guidelines), while the emission factor is a value that represents a weighted average of several parameters, as shown below in table 7.9 from volume 3 of the 2006 IPCC Guidelines (IPCC, 2006b).

The calculation formula for net consumption within the Tier 1a method is as follows.

EQUATION 7.1

CALCULATION OF NET CONSUMPTION OF A CHEMICAL IN A SPECIFIC APPLICATION

$$\textit{Net Consumption} = \textit{Production} + \textit{Imports} - \textit{Exports} - \textit{Destruction}$$

Net consumption values for each HFC are then used to calculate annual emissions for applications exhibiting prompt emissions, as follows.

EQUATION 7.2A

CALCULATION OF EMISSIONS OF A CHEMICAL FROM A SPECIFIC APPLICATION

$$\textit{Annual Emissions} = \textit{Net Consumption} \bullet \textit{Composite EF}$$

8.7.3 Uncertainty assessment and time-series consistency

Because a composite emission factor was used for both the 2.F.1.b and 2.F.1.f categories, the uncertainty level for activity data is assumed at a level of ±32 per cent (see table 8.7.1). The 2006 IPCC Guidelines (IPCC, 2006b) do not provide a default value for the composite factors, so New Zealand's value for uncertainties to describe refrigerant leakages was used for both categories.

Table 8.7.1 Uncertainties for the *Refrigeration and air conditioning* category

Gas	Category	Activity data uncertainty (%)	Emission factor uncertainty (%)	Source
HFCs	2.F.1	±24	Not applicable	New Zealand's value is used (table 4.7.4, chapter 4)

Time-series consistency is maintained by interpolating the number of air conditioning and refrigeration units in between census years, which are generally five years apart.

8.7.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.7.5 Category-specific recalculations

There were no changes to estimates for the *Stationary air conditioning* and *Domestic refrigeration* categories.

8.7.6 Category-specific planned improvements

No improvements are planned for the next inventory submission.

8.8 Emissions from Metered dose inhalers and Medical applications in Tokelau

8.8.1 Description

The *Metered dose inhalers* (2.F.4.a) and *Medical applications* categories (2.G.3.a) contribute negligible amounts of HFC (HFC-134a and HFC-227ea) and N_2O emissions respectively to the total emissions from the IPPU sector in Tokelau. They are reported by scaling New Zealand's emissions from the same category by Tokelau's de facto population.

In 2023, the *Metered dose inhalers* category contributed 6.0 per cent to total IPPU emissions from Tokelau, and the category *Medical applications* contributed 10.1 per cent to the sector, which amounted to 0.04 kt CO_2-e from both categories.

8.8.2 Methodological issues

Activity data

Only anecdotal evidence associated with the activity data for both categories is available from Tokelau's Department of Health (see table 8.1.1). They are reported by scaling New Zealand's emissions from the same category by Tokelau's de facto population for the entire time series to each gas.

Method and emission factors

For both categories, a Tier 1a methodology was applied because New Zealand applied this methodology for estimating emissions from 2.F.4 and Tier 1 methodology for 2.G.3 (IPCC, 2006b). In addition, population ratios from population statistics of Tokelau and New Zealand have been calculated for each year of the time series except the years when the emissions were not occurring (until 1995 for HFC-134a and 2011 for HFC-227ea).

For 2.F.4.a, a product life factor of 100 per cent was used. For 2.G.3a, it was assumed that N_2O is used as a propellant in pressurised and aerosol food products, none of the N_2O is reacted during the process and all of the N_2O is emitted to the atmosphere. Therefore, a default emission factor of 1.0 was used for this category.

8.8.3 Uncertainty assessment and time-series consistency

For consistency of reporting, the same uncertainty values for categories 2.G.3.a were applied for Tokelau and New Zealand (see section 4.8.3 in chapter 4 and table 8.8.1). The same uncertainty for 2.F.1 has also been applied to 2.F.4, in the absence of further information.

Table 8.8.1 Uncertainties for the *Other product manufacture and use* category

Category	Uncertainty in activity data (%)	Uncertainty in emission factors
N_2O from other product uses	±30 (2002–12) ±5 (2013–18) For simplicity, an average of 15% has been used	Not applicable.

Time-series consistency is maintained by scaling data for New Zealand based on a per capita equivalent across the entire time series.

8.8.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.8.5 Category-specific recalculations

For the *Metered dose inhalers* category, there was no change in estimates for 1990 and a 2.2 per cent (0.0003 kt CO_2-e) increase in 2022. For the *Medical applications* category, there was a 2.6 per cent decrease in 1990 and an 18.2 per cent (0.004 kt CO_2-e) increase in 2022. Both changes were due to updates in the emissions data for New Zealand, which is assumed to be the same per capita for Tokelau.

8.8.6 Category-specific planned improvements

No improvements are planned for the next inventory submission.

8.9 Emissions from the Agriculture sector in Tokelau (6. Tokelau_3)

Fish, rather than locally produced plants or animals, are the most important food source in Tokelau. The low fertility of the coral soil means few crops are supported. Food needs are not met by locally grown produce and are heavily supplemented by imports.

Cultivated food crops are limited to breadfruit (*Artocarpus altilis*), giant swamp taro 'pulaka' (*Cyrtosperma chamissonis*), taro palagi (*Xanthosoma sagittifolium*), giant taro (*Alocasia macrorrhizos*), banana (*Musa* sp. [2 varieties]), papaya (*Carica papaya*), pumpkin (*Cucurbita* sp.) and coconut (*Cocos nucifera*).

A small amount of subsistence agriculture occurs in Tokelau. Coconuts are used for human and livestock consumption. Fakaofo grows small amounts of swamp taro. The villages have breadfruit trees and some banana patches; the women's committees run community gardens and grow pandanus 'fala' (*Pandanus odoratissimus*) for traditional crafts (e.g., mats, hats, fans).

A previous United Nations Development Programme-sponsored project for the establishment of keyhole gardens[61] by Tokelau youth has been abandoned.

No industrial-scale farming occurs in Tokelau. Tokelau atolls do not have any large agricultural and horticultural development that would fall under New Zealand's definition of a farm. There are no cows, sheep or deer, with agricultural livestock represented by small numbers of pen-kept pigs and free range chickens only.

Tokelau also has no pasture and no managed agricultural soils, therefore, emissions from the *Direct N_2O emissions from managed soils* and *Indirect N_2O emissions from managed soils* categories are discounted and reported as 'not occurring' (NO). However, it may be possible to estimate emissions from agricultural soils in a future submission.

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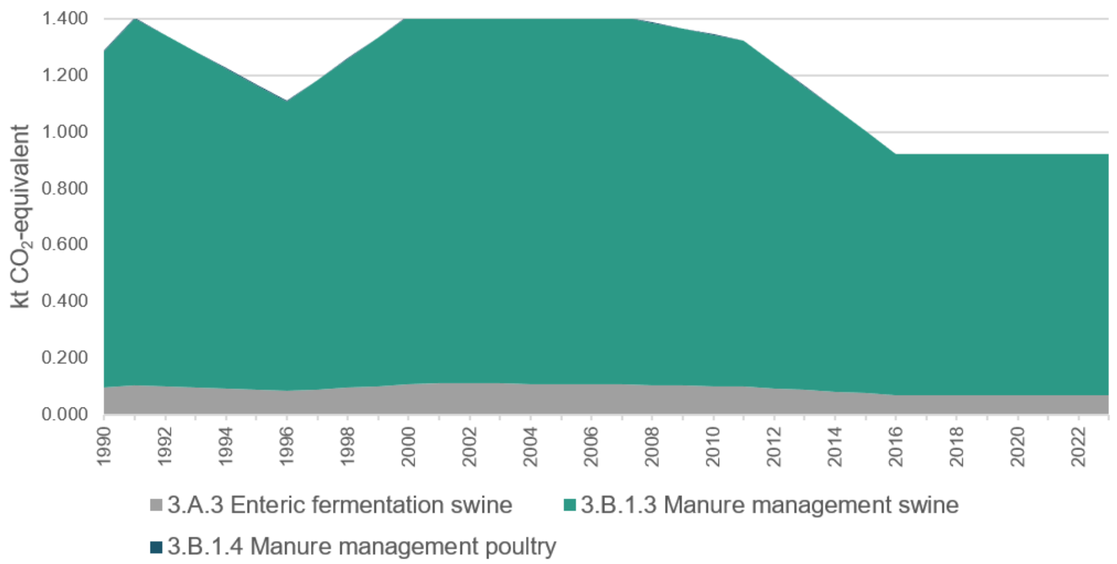
[61] A keyhole garden is a small (around 2.5 metre diameter) circular raised garden with a keyhole-shaped indentation on one side. Moisture and nutrients flow from an active compost pile placed in the centre of a round plant bed.

This submission includes agricultural emissions from Tokelau associated with enteric fermentation and manure management from swine and poultry.

Total emissions from the Agriculture sector in Tokelau amounted to 0.92 kt CO_2-e in 2023. This makes the sector the second biggest emitter in Tokelau (22.0 per cent of the total emissions from Tokelau) at 0.001 per cent of New Zealand's gross emissions. Figure 8.9.1 shows emission trends in the Agriculture sector by category for Tokelau.

Figure 8.9.1 Agriculture emissions by category for Tokelau (kt CO_2-e), from 1990 to 2023



Note: The emissions contribution from 3.B.1.4 *Manure management poultry* is too small to be shown in the figure.

8.10 Emissions from Enteric fermentation in Tokelau

8.10.1 Description

The only domestic farm animals kept are pigs (in community pens) and chickens (free range) (table 8.10.1). There is potential to generate energy from the piggery waste and reduce the effluent pollution of the lagoon.

Table 8.10.1 Number of livestock in Tokelau (2016)

Atoll	Households	Pigs	Chickens
Atafu	88	742	270
Fakaofo	85	419	50
Nukunonu	83	536	305
Tokelau	256	1,697	625

Because the 2006 IPCC Guidelines do not provide a default emission factor for enteric fermentation for poultry, this category is reported as 'not estimated' (NE). Therefore, only swine (pigs) are included under the *Enteric fermentation* (3.A.3) category.

The *Enteric fermentation – Swine* category contributed 7.5 per cent to the total Agriculture emissions in Tokelau in 2023, and amounted to 0.07 kt CO_2-e.

8.10.2 Methodological issues

Activity data

Animal population figures were obtained from the Tokelau Census data (see table 8.1.1). The animal population between the census years is calculated by equal increments between the data collection points, to obtain the average animal population (AAP) per year.

An average pig weight of 80 kilograms is used.

Methods and emission factors

Tier 1 methodology with a default emission factor of 1.5 kg CH_4/head/year from table 10.10 in volume 4 of the 2006 IPCC Guidelines was used for calculating emissions from this category (IPCC, 2006c). Tokelau's allocation by climate zone is 100 per cent to a warm climate.

The following equation was used for calculating emissions from swine.

$$Emissions\ (kt\ CH_4)\ = AAP\ (Swine)\ 1.5\ [kg\ CH_4\ head^{-1} year^{-1}]\ /10\text{^}6[kg/kt]$$

8.10.3 Uncertainty assessment and time-series consistency

Section 10.2.3 (volume 4) of the 2006 IPCC Guidelines states that the uncertainty associated with animal populations will vary widely, depending on the source, but should be within ±20 per cent (IPCC, 2006c). The default emission factor uncertainty is ±30 per cent to 50 per cent (default mid-range is ±40 per cent).

For this category, the default uncertainty value of ±20 per cent for activity data and an upper range default emission factor uncertainty of ±50 per cent were used.

Time-series consistency was maintained by interpolating the number of animals in between census years (which are generally five years apart).

8.10.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.10.5 Category-specific recalculations

There were no changes to estimates for the *Enteric fermentation* categories.

8.10.6 Category-specific planned improvements

No improvements are planned for the next inventory submission.

8.11 Emissions from Manure management in Tokelau

8.11.1 Description

The 2006 IPCC Guidelines provide default emission factors for *Manure management* (3.B.1) for both swine and poultry, therefore, both animal types are included in reporting from this category (IPCC, 2006c).

Manure management – Swine contributed 92.4 per cent to the total Agriculture emissions in Tokelau in 2023 and amounted to 0.85 kt CO_2-e. *Manure management – poultry* was very small, at 0.1 per cent (0.0005 kt CO_2-e).

8.11.2 Methodological issues

Activity data

The activity data entries for *Manure management* are exactly the same as for *Enteric fermentation* (see section 8.10). The assumption is that all poultry are dry layers.

Methods and emission factors

A Tier 1 methodology with default emission factors provided in table 10.15 in volume 4 of the 2006 IPCC Guidelines was used for estimating emissions from the *Manure management* category. The Tier 1 method is based on animal population data and does not require distinguishing between different manure management systems. Equation 10.22 from volume 4 of the 2006 IPCC Guidelines was applied, in conjunction with the default emission factors from table 10.14 in volume 4 of 2006 IPCC Guidelines for Oceania with a warm climate. These are 18.5 kg CH_4/head/year for swine and 0.03 kg CH_4/head/year for poultry (IPCC, 2006c).

8.11.3 Uncertainty assessment and time-series consistency

Default uncertainty values for activity data and emission factors were used for this category. Section 10.2.3 in volume 4 of the 2006 IPCC Guidelines states that the uncertainty associated with populations will vary widely, depending on the source, but should be within ±20 per cent (IPCC, 2006c). The default emission factor uncertainty for *Manure management* is ±30 per cent.

Time-series consistency was maintained by interpolating the number of animals in between census years (which are generally five years apart).

8.11.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.11.5 Category-specific recalculations

There were no changes to estimates for the *Manure management* category.

8.11.6 Category-specific planned improvements

No improvements are planned for the next inventory submission.

8.12 Emissions from the Waste sector in Tokelau (6. Tokelau_5)

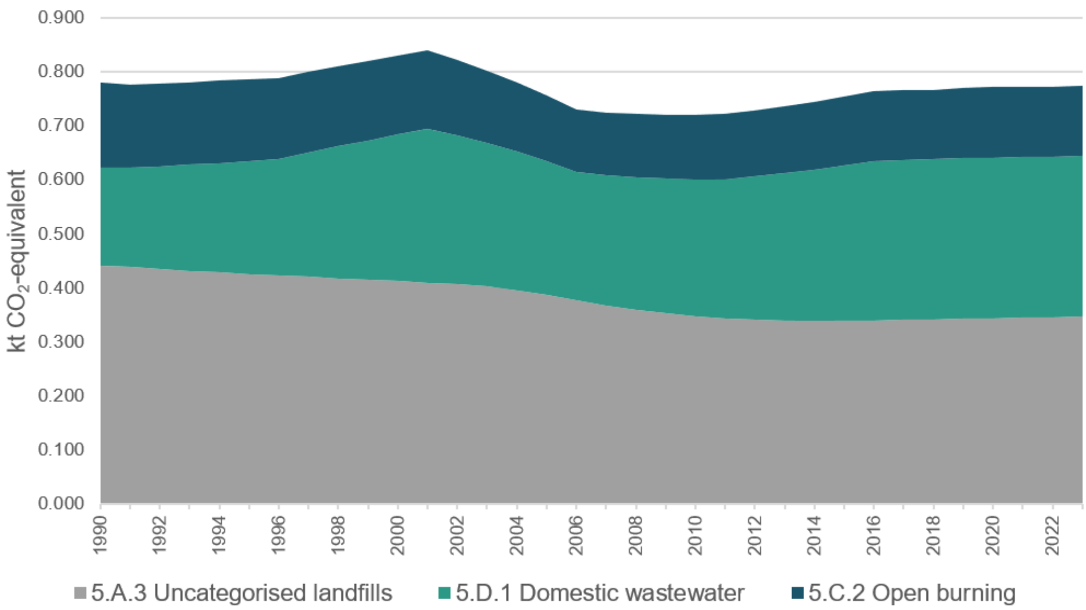
The total amount of all Waste sector emissions in Tokelau in 2023 was 0.77 kt CO_2-e, making the Waste sector the third-biggest emitter in Tokelau. The Waste sector contributed 18.4 per cent to the total emissions from Tokelau and 0.001 per cent to New Zealand's gross emissions including Tokelau.

The sources of emissions in the Waste sector in Tokelau were from the categories *Solid waste disposal*, *Wastewater treatment and discharge* and *Incineration and open burning of waste*, which contributed 44.8 per cent, 38.5 per cent and 16.8 per cent, respectively, to the total emissions from the Waste sector in Tokelau.

The raw data related to the Waste sector were obtained from multiple sources (see items 1 to 5, 11, and 13 to 16 in table 8.1.1). The data were compiled, analysed and processed by the Tokelau National Statistics Office to produce activity data. The human population data were used as a driver for estimates in all of the Waste categories.

Emissions from all categories reported in the Waste sector for Tokelau were estimated using a Tier 1 methodological approach (IPCC, 2006d). Figure 8.12.1 shows emission trends in the Waste sector by category for Tokelau.

Figure 8.12.1 Waste sector emissions by category for Tokelau (kt CO_2-e), from 1990 to 2023



8.13 Emissions from Solid waste disposal in Tokelau

8.13.1 Description

According to the 2016 Tokelau Census, most household rubbish is collected by village workers. Fakaofo had the highest proportion of households where all rubbish was collected (72.9 per cent). Of all private occupied dwellings, 98.8 per cent had at least some of their household rubbish collected. Most of the collected rubbish is either burned on the reef or buried in centralised areas of the islands. Exceptions are the organic waste, which is fed daily to pigs, large beer bottles that are exported for recycling to Apia (Samoa) and metal waste that is collected and sold as scrap in Apia under an MoU with a Samoan company.[62]

Where village workers do not collect household rubbish, households use alternative methods for disposal. The most common methods are burning, burial and disposing of in the garden. Tokelau has no dedicated categorised landfills, therefore, solid waste disposal is reported for uncategorised landfills only.

The *Solid waste disposal* category contributed 44.8 per cent to the total Waste emissions in Tokelau in 2023, which amounted to 0.35 kt CO_2-e.

8.13.2 Methodological issues

Activity data

- The total amount of solid waste is based on the 2006 IPCC default of 690 kg/person/year for Oceania (IPCC, 2006d). This is likely to be an overestimate, however, a country-specific value is not available.
- Solid waste is assumed to be half buried and the other half burned. As above, this does not account for exported solid waste or organic waste fed to pigs and will be an overestimate.
- The composition of solid waste for the landfill calculations is based on the 2006 IPCC default (67.5 per cent food, 6 per cent paper/cardboard, 2.5 per cent wood, and the remaining 24 per cent is 'inert') (IPCC, 2006d). This does not take into account the food waste that is fed to animals or used for composting and gardens, nor data on waste composition, such as disposable nappies, and will likely be an overestimate overall.

Methods and emission factors

A Tier 1 methodology has been applied to estimate emissions from this category. The Tier 1 approach is to use all default values. It is assumed that 50 per cent of waste is buried (landfilled) and the other 50 per cent is burned. Any amounts of waste shipped offshore are additional and are not counted. Table 8.13.1 sums up the information about parameters used for calculating emissions from this category.

Table 8.13.1 Summary of parameters for uncategorised landfills in Tokelau

Parameter	Values	Source	Reference
Bulk MSW DOC (kt C/kt waste)	0.14	IPCC default	IPCC, 2006d (worksheets for SWDS)
k-value	0.17	IPCC default	Table 3.2, IPCC, 2006d
Methane correction factor	0.6	IPCC default	Table 3.1, IPCC, 2006d
Oxidation factor	0 per cent	IPCC default	Table 3.2, IPCC, 2006d
Starting year	1950	IPCC default	Section 3.6, p 3.24, IPCC, 2006d
Delay time	6 months	IPCC default	Section 3.2.3, p 3.19, IPCC, 2006d
Fraction of DOC that decomposes	0.5	IPCC default	Section 3.2.3, p 3.13, IPCC, 2006d
Fraction of CH_4 in gas	0.5	IPCC default	Section 3.2.3, p 3.15, IPCC, 2006d
Amount of waste per person per year	690 kg	IPCC default for Oceania	Annex 2A.1, IPCC, 2006d
Amount of waste landfilled	50 per cent	Assumption	

Note: DOC = degradable organic carbon; MSW = municipal solid waste; SWDS = solid waste disposal sites.

[62] See Government of Tokelau. 2017. *Solid Waste Management: MOU Signed between Tokelau EDNRE and Pacific Recycle Co. Ltd*. Retrieved 9 March 2018.

8.13.3 Uncertainty assessment and time-series consistency

The same uncertainty data for uncategorised landfills were used for Tokelau and New Zealand (see table 7.2.9, chapter 7; for methodological notes, refer to the uncertainties for the *Solid waste disposal* category, section 7.2.3, chapter 7; and table 8.13.2).

Table 8.13.2 Uncertainty in emissions from the *Solid waste disposal* category

Emissions category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Uncategorised landfills	±140	±40

Time-series consistency is maintained by interpolating the population data in between census years, which are generally five years apart.

8.13.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.13.5 Category-specific recalculations

There were no changes to estimates for the *Solid waste disposal* category.

8.13.6 Category-specific planned improvements

No improvements are planned for the next inventory submission.

8.14 Emissions from Incineration and open burning in Tokelau

8.14.1 Description

Because Tokelau has no major incineration facilities, all emissions associated with waste burning are reported in the *Open burning of waste* category. Carbon dioxide, CH_4 and N_2O are reported in this category.

The composition of solid waste for CO_2 from open burning is the same as for landfills, except that the 24 per cent 'inert' is considered to be 'other inert' for open burning purposes (and not disaggregated into glass, metal, plastic and so on). Keeping the 24 per cent in 'other inert' is likely to result in an overestimate.

The emission factors for open burning of solid waste for CH_4 and N_2O are the IPCC defaults for municipal solid waste and are based on a generic waste composition. It is not clear if this will over- or under-estimate emissions.

The category *Incineration and open burning* contributed 16.8 per cent to the total Waste sector emissions in Tokelau in 2023, which amounted to 0.13 kt CO_2-e.

8.14.2 Methodological issues

Activity data

The calculations are based on Tokelau's population data and assume that 50 per cent of the waste is landfilled and the other 50 per cent is burned. This information is reported as 'non-biogenic' open burning because only fossil carbon is reported, and the emission factors for CH_4 and N_2O are for municipal solid waste, which does not distinguish biogenic and non-biogenic waste.

Methods and emission factors

A Tier 1 methodology with default 2006 IPCC parameters was used for calculating emissions from this category.

The emission factor for CO_2 was the weighted average of calculated factors from table 8.14.1 and a 58 per cent oxidation factor for open burning. For other gases, the following 2006 IPCC default emission factors were used (from volume 5): for CH_4, the default emission factor for municipal solid waste in section 5.4.2 (6,500 kg CH_4/gigagrams (Gg) wet waste); for N_2O, the default emission factor for open burning of municipal solid waste from table 5.6 (150 kg N_2O/Gg dry waste) (IPCC, 2006d). Converted waste volume to dry weight by using dry matter conversion was calculated for CO_2 (56.1 per cent). Table 8.14.1 shows waste type and the composition data based on default 2006 IPCC parameters used in estimating emissions from *Open burning of waste*.

Table 8.14.1 Composition data and carbon content used for estimating emissions from *Open burning of waste*

Waste type	Landfill composition (%)	CO_2 incineration composition (%)	Dry matter (%)	Total carbon (%)	Fossil carbon (%)
Paper/card	6.0	6.0	90	43	1
Textiles	0	0	80	50	20
Food waste	67.5	67.5	40	38	0
Wood	2.5	2.5	85	50	0
Garden and park waste	0	0	40	49	0
Nappies	0	0	40	70	10
Rubber and leather	part of inert	0	84	67	20
Plastics	part of inert	0	100	75	100
Metal	part of inert	0	100	NA	NA
Glass	part of inert	0	100	NA	NA
Other, inert	24.0	24.0	90	3	100
Calculated weighted average			**56.13**	**30.20**	**24.06**

Note: NA = not applicable.

Percentages in table 8.14.1 are defaults from table 2.3 and table 2.4 in volume 5, 2006 IPCC Guidelines (IPCC, 2006d).

An assumption was made that 'inert' waste for landfills is classified entirely as 'other inert' waste for incineration (the impact of this assumption is that emissions are slightly higher than distributing the 24 per cent over the various inert types due to the high fossil carbon percentage).

8.14.3 Uncertainty assessment and time-series consistency

The same uncertainty data for *Open burning of waste* were used for Tokelau (see table 8.14.2) and New Zealand (see table 7.4.6, chapter 7; for methodological notes, refer to uncertainties in emissions from *Incineration and open burning*, section 7.4.3, chapter 7).

Table 8.14.2 Uncertainty in emissions from *Open burning of waste* for Tokelau

Emissions category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Waste open burning (CO_2)	±50	±40
Waste open burning (CH_4)	±50	±100
Waste open burning (N_2O)	±50	±100

Time-series consistency was maintained by interpolating the population data in between census years (which are generally five years apart).

8.14.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.14.5 Category-specific recalculations

There were no changes to estimates for the *Open burning and incineration* category.

8.14.6 Category-specific planned improvements

No improvements are planned for the next inventory submission.

8.15 Emissions from Wastewater treatment and discharge in Tokelau

8.15.1 Description

In the absence of industrial plants in Tokelau, all emissions associated with wastewater treatment and discharge are reported in the *Domestic wastewater* category (5.D.1). The category uses the same population values as in the *Solid waste disposal* and *Open burning of waste* categories (see above). The category includes emissions of CH_4 and N_2O.

The *Domestic wastewater* category contributed 38.5 per cent to the total of Waste sector emissions from Tokelau in 2023, which amounted to 0.30 kt CO_2-e.

8.15.2 Methodological issues

A Tier 1 methodology with the 2006 IPCC default emission factors (except the protein consumption value) for all gases was applied for estimating emissions from this category.

Assumptions for estimating CH_4 emissions from wastewater:

- 60 grams biochemical oxygen demand (BOD) per person per day (as for Canada, Europe, Russia and Oceania), which calculates as 21.9 kg/person/year

- for population, the same time series as in categories 5.A.3 and 5.C was used
- despite having no wastewater collection system, a correction factor for industrial BOD discharged in sewers of 1.25 is used (default for collected systems) to account for any industrial and commercial activity in Tokelau, such as fishing. No other estimates of industrial wastewater are made (effectively 5.D.2 *Industrial wastewater* is 'included elsewhere' (IE) and included in 5.D.1 *Domestic wastewater*)
- in 2016, most Tokelauans had access to a private toilet in their homes using septic tanks: 72.9 per cent of private occupied dwellings had an indoor flush toilet, and 21.6 per cent of dwellings had an outdoor flush toilet. Atafu had the highest proportion of dwellings with an indoor toilet (87.4 per cent), and Nukunonu had the highest proportion of households with an outdoor toilet (34.9 per cent) (Census 2016, similar to values for 2011 and 2006). The percentage of open water toilets gradually reduced from 65 per cent of dwellings in 1991 to nil by 2016.

Table 8.15.1 sums up default parameters used for estimating CH_4 emissions for Tokelau wastewater treatment. The default BOD correction factor for collected systems is used to account for industrial and commercial water because there is no separate estimate.

Table 8.15.1 Parameters for estimating methane emissions for Tokelau wastewater treatment

Parameter	Value	Source	Reference
Methane correction factors			
Septic system	0.5	IPCC default	Table 6.3, section 6.2.2.2, IPCC, 2006d
Sea, river and lake discharge	0.1	IPCC default	Table 6.3, section 6.2.2.2, IPCC, 2006d
Weighted average methane correction factor	0.233	Calculated	
Maximum methane producing capacity (kg CH_4/kg BOD)	0.6	IPCC default	Table 6.2, section 6.2.2.2, IPCC, 2006d
Biochemical oxygen demand (kg BOD/person/year)	21.9	IPCC default for Oceania	IPCC, 2006d (worksheets for SWDS)
Correction factor for BOD	1.25	IPCC default for collected systems	Section 6.2.2.3, p 6.14, IPCC, 2006d

Note: BOD = biochemical oxygen demand; SWDS = solid waste disposal sites.

Assumptions for estimating nitrous oxide emissions from wastewater

Table 8.15.2 shows the parameters used to calculate N_2O emissions from wastewater. It is assumed that septic tanks do not discharge to the sea and that only the population using open water toilets contribute to the nitrogen in effluent calculation.

Protein consumption of 32.45 kg/person/year has been calculated based on known consumption compiled by the Tokelau National Statistics Office. The fraction of industrial and commercial co-discharged protein accounts for any commercial and industrial activities because there is no separate estimate.

Table 8.15.2 Parameter values applied for estimating nitrous oxide emissions for Tokelau wastewater treatment

Parameter	Value	Source	Reference
Per capita protein consumption (kg/person/year)	32.448	Tokelau specific	Developed by Tokelau's National Statistics Office using imports data (see table 8.1.1)
Fraction of nitrogen in protein	0.16	IPCC default	Section 6.3.1.3, p 6.25, IPCC, 2006d
Fraction of non-consumed protein	1.1	IPCC default for developing countries	Table 6.11, section 6.3.3, IPCC, 2006d
Fraction of industrial and commercial co-discharged protein	1.25	IPCC default	Table 6.11, section 6.3.3, IPCC, 2006d
Nitrogen removed with sludge (kg)	0	IPCC default	Section 6.3.1.3, p 6.25, IPCC, 2006d
Emission factor	0.005	IPCC default	Table 6.11, section 6.3.3, IPCC, 2006d
Emissions from wastewater treatment plants	0	IPCC default	IPCC (2006d)

8.15.3 Uncertainty assessment and time-series consistency

The same uncertainty data for *Domestic wastewater* were used for Tokelau and New Zealand (see table 7.5.16, chapter 7; for methodological notes, refer to uncertainties in emissions from *Domestic wastewater* in section 7.5.3, chapter 7). Table 8.15.3 shows uncertainties for activity data and emission factors used by Tokelau for *Domestic wastewater*.

Table 8.15.3 Uncertainty in emissions from *Domestic wastewater*

Emissions category	Uncertainty in activity data (%)	Uncertainty in emission factors (%)
Domestic and industrial wastewater (CH_4)	±10	±40
Domestic and industrial wastewater (N_2O)	±10	±90

Time-series consistency is maintained by interpolating the population data and the use of open water toilets in between census years, which are generally five years apart.

8.15.4 Category-specific QA/QC and verification

Quality control of the activity data and calculations was applied to each category for Tokelau. No verification was possible because no alternative data were available.

8.15.5 Category-specific recalculations

There were no changes to estimates for the *Domestic wastewater* category.

8.15.6 Category-specific planned improvements

No improvements are planned for the next inventory submission.

Chapter 8: References

Government of Tokelau. 2017. *Solid Waste Management: MOU Signed between Tokelau EDNRE and Pacific Recycle Co. Ltd*. Retrieved 9 March 2018.

IPCC. 2006a. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. *Volume 2. Energy*. IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2006b. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. *Volume 3. Industrial Processes and Product Use*. IPCC National Greenhouse Gas Inventories Programme. Japan: Published for the IPCC by the Institute for Global Environmental Strategies.

IPCC. 2006c. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. *Volume 4. Agriculture, Forestry and Other Land Use*. IPCC National Greenhouse Gas Inventories Programme. Japan: Published for the IPCC by the Institute for Global Environmental Strategies.

IPCC. 2006d. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. *Volume 5. Waste*. IPCC National Greenhouse Gas Inventories Programme. Japan: Published for the IPCC by the Institute for Global Environmental Strategies.

International Renewable Energy Agency. 2013. *Renewable energy opportunities and challenges in the Pacific Islands region.* Retrieved 31 January 2019.

Jasperse JA. 2016. *Analysis of 2014 imports into Tokelau from Samoa, Part 2: Stores' invoices reconciled with cargo manifests, and quality of life implications*. Apia, Samoa: Tokelau National Statistics Office. Retrieved 28 February 2019.

Koroisamanunu I, Papao J, Ketewai M and Sokota A. 2014. *Mission Preliminary Report (Fieldwork undertaken from 8 August – 2 September 2013). SOPAC technical note (PR193), May 2014*. Suva, Fiji: Water and Sanitation Programme and Disaster Reduction Programme. Applied Geoscience and Technology Division (SOPAC).

Roorda M, Carpenter D, Laing A, McGillivray M. 2015. *Evaluation of the Tokelau Country Programme.* Prepared for the Ministry of Foreign Affairs and Trade by Adam Smith International. Retrieved 31 January 2019.

Stats NZ. 2007. *Principles and Protocols for Producers of Tier 1 Statistics.* Retrieved 31 January 2019.

Tokelau Islands Maps. *South Pacific Literatures and Cultures.* Retrieved 31 January 2019.

Tokelau National Statistics Office. 2020. *Final count: 2019 Tokelau Population Count.* Retrieved 31 January 2022.

UNFCCC. 2018a. FCCC/CP/2018/10/Add.1. *Decision 1/CP.24 Preparations for the implementation of the Paris Agreement and the first session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.*

UNFCCC. 2018b. FCCC/PA/CMA/2018/3/Add.2. *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on the third part of its first session, held in Katowice from 2 to 15 December 2018. Addendum 2. Part two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement.*

UNFCCC. 2021. CCC/PA/CMA/2021/10/Add.2. *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its third session, held in Glasgow from 31 October to 13 November 2021. Addendum Part two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its third session.*

United Nations. 1945. *Charter of the United Nations, 1945*. Retrieved 31 January 2019.

Chapter 9: Indirect carbon dioxide and nitrous oxide emissions

New Zealand elected not to report indirect carbon dioxide emissions in its 2025 inventory submission. Indirect nitrous oxide emissions are reported in the Agriculture sector (chapter 5) and the Land Use, Land-Use Change and Forestry sector (chapter 6).

Chapter 10: Recalculations and improvements

This chapter summarises the recalculations and improvements made to the Inventory following the 2024 submission. Further details on the recalculations and improvements for each sector are provided in chapters 3 to 8.

Recalculations of estimates reported in previous submissions of the Inventory are carried out for several reasons including:

- improved activity data
- updated parameters for estimating emissions including methodologies
- incorporating new evidence that enables the reporting of previously unreported emissions because of insufficient data
- correcting errors.

It is good practice to recalculate the whole time series from 1990 to the latest reporting year, to ensure consistency across the time series. This means some estimates of emissions and/or removals reported in this submission are different from estimates reported in the previous submission. There may be exceptions to recalculating the entire time series and, where this has occurred, explanations are provided.

10.1 Explanations and justifications for recalculations, including in response to the review process

Key reasons for recalculations in the 2025 submission of the Inventory are given in the sectoral chapters and summarised in table 10.1.1.

Table 10.1.1 Explanations and justifications for recalculations

Sector	Explanation of recalculation	Underpinning IPCC principle	Additional justification
Energy	Historical energy demand data in the national energy balance tables are revised from year to year. This may result in minor revisions to activity data and recalculations to the corresponding emissions for some years in some categories.	Accuracy	
	Updated data sourced from field operators have been used to improve the accuracy of emissions estimates for geothermal activities.	Accuracy	
IPPU	Updated lubricant activity data.	Accuracy	Improved data availability
	Correction of minor calculation errors for hydrofluorocarbon foam blowing manufacturing chemicals re-exported.	Accuracy	Correction of errors
	Error correction in commercial refrigerant-related emissions.	Accuracy	Correction of errors
	Minor error correction in stationary refrigerant-related emissions.	Accuracy	Correction of errors
	Transport refrigeration net equipment stock adjustments.	Accuracy	Improved data availability
	Minor error correction in transport refrigerant-related emissions.	Accuracy	Correction of errors

Sector	Explanation of recalculation	Underpinning IPCC principle	Additional justification
Agriculture	Improvements to donkey, poultry, alpaca and llama population estimates.	Accuracy	Improved data availability
	Update to the estimated deer populations, mature hind liveweight and velvet antler production.	Accuracy	
	Update to the emissions calculations for pigs.	Accuracy	Improved data availability
	Inclusion of a seasonal adjustment to wool growth.	Accuracy	
	Inclusion of emissions from non-manure organic amendments to soil.	Completeness	Accuracy
	Error corrections and improvements to model code.	Accuracy	Correction of errors
LULUCF	Updated activity data arising from regular mapping improvements.	Accuracy	Improved data availability
Waste	Estimated emissions from *Managed waste disposal sites* (5.A.1.a) decreased by 360.7 kilotonnes carbon dioxide equivalent (kt CO_2-e) (17.7 per cent) in 1990 and have increased by 294.1 kt CO_2-e (26.2 per cent) in 2022. This is due to the effects of updating emissions factors and parameters, incorporating revised data on waste composition, the fraction of methane in landfill gas, methane generation rates, and landfill gas recovery rates.	Accuracy	Key category improvement: *Solid waste disposal*
	Estimated emissions from *Unmanaged landfills* (5.A.2) have decreased by 717.0 CO_2-e (89.8 per cent) in 1990 and by 850.9 CO_2-e (81.8 per cent) in 2022. This is due to methodological updates and the inclusion of newly available activity and composition data obtained through the expansion of the waste levy under the Waste Minimisation Act 2008 (Ministry for the Environment, 2024).	Accuracy	Key category improvement: *Solid waste disposal*
	Estimated emissions from *Incineration* (5.C.1) decreased by 0.3 kt CO_2-e (2.3 per cent) in 1990 and by 0.3 kt CO_2-e (14.8 per cent) in 2022. This is due to adjustments to the fraction of carbon and fraction of fossil carbon in the total carbon.	Completeness	
	Estimated emissions from *Open burning of waste* (5.C.2) have increased by 0.004 CO_2-e (0.00004 per cent) in 1990 and decreased by 4.2 CO_2-e (2.2 per cent) in 2021. This is due to updates to activity data for farm fills, after revisions to the number and type of farms reported in the latest agricultural production statistics (Stats NZ, 2023).[63]	Accuracy	
Tokelau	One minor recalculation has been made in the Tokelau emission estimates since the 2024 submission. Improvements made to estimates in Tokelau have resulted in a decrease of 0.03 per cent (0.001 kt CO_2-e) in estimated Tokelau emissions in 1990 and an increase of 0.1 per cent (0.004 kt CO_2-e) in estimated Tokelau emissions in 2022. This change is due to updates in New Zealand's medical emissions data, which are assumed to be the same per capita in Tokelau (figure 10.2.8).	Consistency	

10.2 Implications for emissions and removal levels and trends, including time-series consistency

10.2.1 New Zealand's gross emissions

The impact of recalculations on New Zealand's gross emissions is shown in figure 10.2.1. Recalculations have resulted in a decrease of 1.9 per cent (1,279.3 kilotonnes carbon dioxide equivalent (kt CO_2-e)) in gross emissions in 1990 and a decrease of 0.5 per cent (412.2 kt CO_2-e) in gross emissions in 2022.

63 See Stats NZ. 2023b. *Agricultural production statistics: Year to June 2022 (final)*. Retrieved 28 February 2025.

The greatest contribution to the decrease in gross emissions estimates across the time series came from improvements made in the Waste sector. This decrease is mainly the result of improving emissions estimates for *Solid waste disposal – Unmanaged waste disposal sites.*

Figure 10.2.1 Effect of recalculations on New Zealand's gross greenhouse gas emissions estimates, from 1990 to 2022

10.2.2 New Zealand's net emissions

The effect of recalculations on net emissions estimates, which include the Land Use, Land-Use Change and Forestry (LULUCF) sector is shown in figure 10.2.2. There was a decrease of 2.9 per cent (1,288.7 kt CO_2-e) in net emissions in 1990 and a decrease of 0.9 per cent (546.2 kt CO_2-e) in net emissions in 2022.

The changes in net emissions were a result of the combined effect of the improvements made to gross emissions estimates, described above, and to the LULUCF sector estimates. The improvements to the LULUCF sector that contributed to the recalculations for net emissions were due to updated activity data arising from regular mapping improvements.

Figure 10.2.2 **Effect of recalculations on New Zealand's net greenhouse gas emissions estimates, from 1990 to 2022**

The following tables show the category that had the largest impact on the recalculations across the time series by sector. Table 10.2.1 shows the recalculations for the category that increased emissions estimates the most for each sector.

Table 10.2.1 **Recalculations that led to the greatest increase in emissions estimates in each sector**

Sector	Category with the largest increase in estimated emissions across the entire time series	Largest single increase in emissions for the category (kt CO_2-e)	Year of the largest increase in estimated emissions
Energy	Energy industries – Public electricity and heat production	186.1	2022
IPPU	Other (please specify) – Carbon dioxide consumption	55.4	2019
Agriculture	Option A – Dairy cattle	474.3	2017
LULUCF	Forest land remaining forest land – Pre-1990 planted forest remaining pre-1990 planted forest	790.6	2022
Waste	Managed waste disposal sites – Anaerobic	294.1	2022
Tokelau	Other (please specify) – Tokelau_2. Industrial Processes and Product Use	0.004	2022

Table 10.2.2 shows the recalculations for the category that reduced emissions estimates the most for each sector.

Table 10.2.2 Recalculations that led to the greatest decrease in emissions estimates in each sector

Sector	Category with the largest reduction in estimated emissions across the entire time series	Largest single decrease in emissions for the category (kt CO_2-e)	Year of the largest decrease in estimated emissions
Energy	Petroleum refining – Liquid fuels	-47.5	2019
IPPU	Commercial refrigeration – HFC-134a	-45.4	2022
Agriculture	Option A – Non-dairy cattle	-349.7	2016
LULUCF	Forest land remaining forest land – Post-1989 forest remaining post-1989 forest	-1,039.4	2022
Waste	Solid waste disposal – Unmanaged waste disposal sites	-886.8	2013
Tokelau	Other (please specify) – Tokelau_2. Industrial Processes and Product Use	-0.001	1990

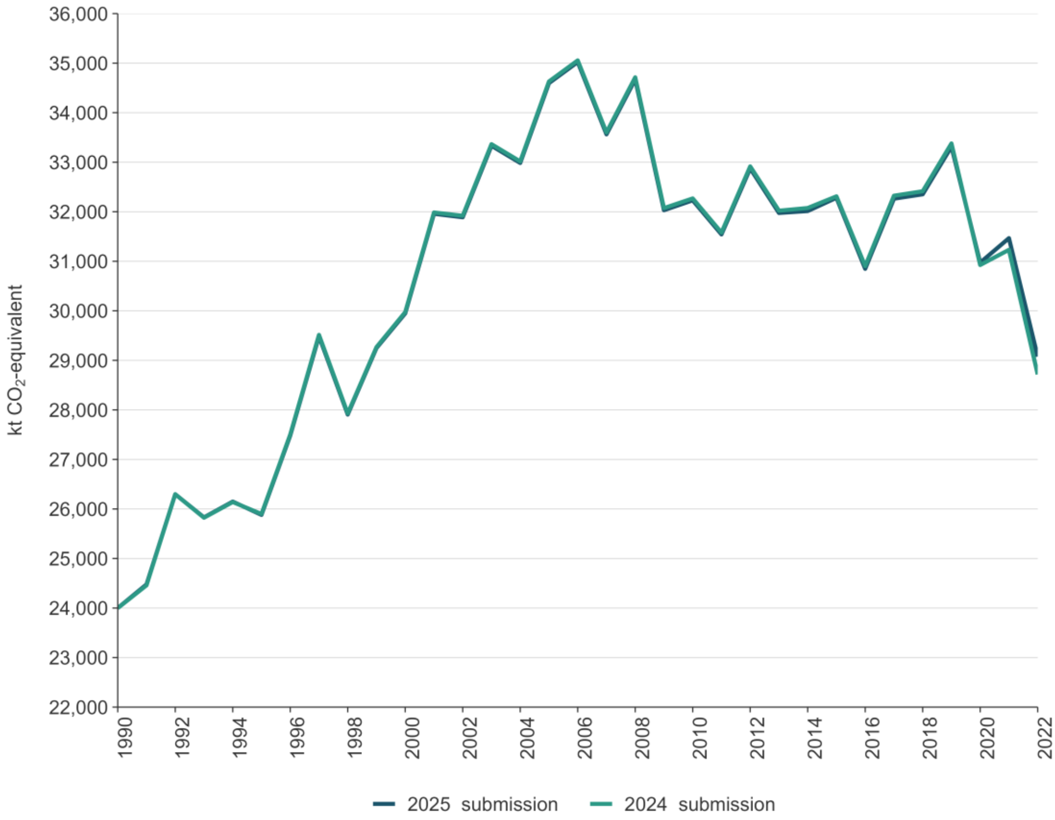
The following sections detail the effect of and reasons for recalculations for each sector and summarise the improvements.

10.2.3 Energy

Improvements and recalculations made to the Energy sector have resulted in an increase of 0.01 per cent (1.4 kt CO_2-e) in estimated energy emissions for 1990 and an increase of 1.3 per cent (359.9 kt CO_2-e) in estimated energy emissions for 2022 (figure 10.2.3).

The improvements include a methodological improvement, a refinement to the implementation of software code and various changes to the underlying energy activity data. Further details on source-specific improvements are provided in their corresponding sections in chapter 3.

Figure 10.2.3 Effect of changes to activity data on emissions estimates from New Zealand's Energy sector, from 1990 to 2022



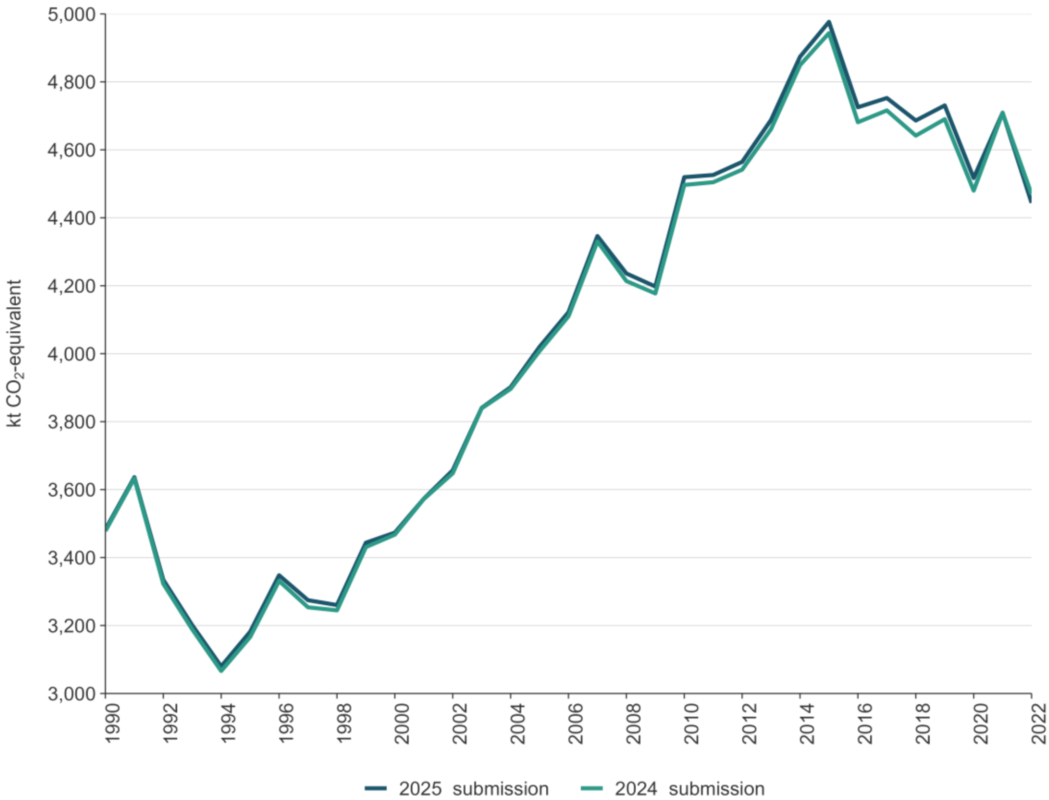
10.2.4 Industrial Processes and Product Use

For the Industrial Processes and Product Use (IPPU) sector, several improvements in the *Refrigeration and air conditioning* category were made, to better account for changes in stocks held by importers and users. These included:

- changes to activity data for the early retirement of heat pumps (a reduction)
- changes to activity data for refrigerant recycling (a reduction)
- changes to activity data for early retirement of air conditioners (an increase) with a consequent spike in disposal trends
- reassessment of historical emissions between 2014 and 2020.

Improvements and recalculations made to the IPPU sector have resulted in an increase of 0.1 per cent (4.9 kt CO_2-e) in estimated IPPU emissions in 1990 and a decrease of 0.6 per cent (25.2 kt CO_2-e) in estimated IPPU emissions in 2022 (figure 10.2.4).

Figure 10.2.4 Effect of recalculations on emissions estimates from the IPPU sector, from 1990 to 2022



10.2.5 Agriculture

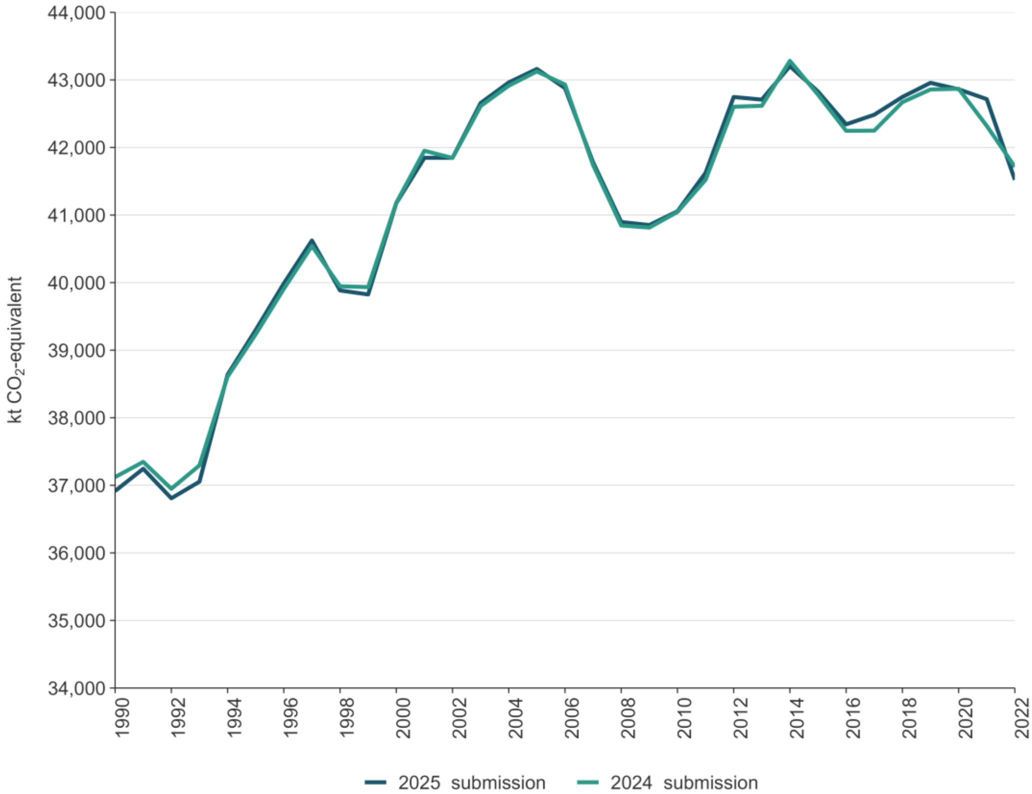
The following improvements and corrections were made to the Agriculture sector.

- Minor species population values were improved. For details, see chapter 5, section 5.2.5.
- Deer population and productivity statistics were improved. For details, see chapter 5, section 5.2.5.
- Emissions calculations for pigs were improved. For details, see chapter 5, section 5.2.5 and section 5.3.5.
- Emissions from non-manure organic amendments to soils were included in reporting. For details, see chapter 5, section 5.5.5.

- Sheep energy requirements were improved by implementing seasonality of wool growth. For details, see chapter 5, section 5.2.5.
- Revisions were made to agricultural statistics, using the latest available activity data from sources described in chapter 5, section 5.1.4.
- A number of error corrections and improvements to the model code were made. For details, see below.

Improvements and recalculations made to the Agriculture sector have resulted in a decrease of 0.6 per cent (206.4 kt CO_2-e) in estimated agriculture emissions in 1990 and a decrease of 0.5 per cent (191.3 kt CO_2-e) in estimated agriculture emissions in 2022 (figure 10.2.5).

Figure 10.2.5 Effect of recalculations on emissions estimates from New Zealand's Agriculture sector, from 1990 to 2022



The improvements implemented for the Agriculture sector in the 2025 submission of the Inventory were as follows.

Improvements to minor species population estimates

Emissions estimates in all categories relating to donkeys, poultry, llamas and alpacas since 1990 reported in the 2025 submission have been enhanced by a methodological update to population estimates.

The emissions from minor species were estimated using New Zealand activity data, and Intergovernmental Panel on Climate Change (IPCC) emission factors (EFs) and methodologies. Where possible, New Zealand has used country-specific methods and EFs to estimate emissions for these minor livestock species.

Recent research carried out by AbacusBio (Sise, 2023) has used industry data, data from Stats NZ, other agricultural databases and additional information provided from industry stakeholders to improve the population assumptions for donkeys, poultry, llamas and alpacas.

The following recommendations from Sise (2023) were implemented in the 2025 submission of the Inventory.

- Update the donkey population to 1,500 (previously 141).
- Use disaggregated Stats NZ data to calculate the poultry population.
- Use the modelled alpaca and modelled llama population levels for 2009 to 2022, with information from both the alpaca and llama registries used to provide population estimates from 2023 onwards.

These changes increase total annual agricultural emissions reported in 2022 by 1.0 kt CO_2-e, less than 0.01 per cent of total agricultural emissions (table 10.2.3).

Table 10.2.3 Emissions impact of changing minor species population estimates

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agriculture*	2024 (1990–2022) emissions estimate	37,121.5	41,712.7	4,591.2	12.4
	2024 (1990–2022) emissions estimate with updated minor species populations	37,122.1	41,713.6	4,591.5	12.4
	Difference in emissions estimates	0.6	1.0		

Updating deer population and productivity statistics

Emissions estimates in all categories relating to deer since 1990 reported in the 2025 submission have been improved by an updated method to estimate the class populations, an updated mature hind liveweight, and a new source of activity data for velvet antler production.

Recent research carried out by AgResearch (Stevens and Ward, 2023) has developed a methodology to assign deer animals reported in the Stats NZ Agricultural Production Survey data to venison or velvet production as well as to age and sex. The research also used industry data to improve estimates of the mature weight of hinds and stags, stag slaughter date, and suggest a more accurate source of velvet antler production.

The following recommendations from Stevens and Ward (2023) were implemented in the 2025 submission of the Inventory.

- Update the methodology to assign deer animals reported in the Stats NZ Agricultural Production Survey data to class, including the adoption of separate classes for the venison and velvet value streams.
- Update the values used for hind liveweight to a maximum of 110 kilograms (kg).
- Use the Deer Industry New Zealand record of velvet antler production.
- Add an additional slaughter for stag populations at 25 months.

These changes decrease total annual agricultural emissions reported in 2022 by 72.6 kt CO_2-e or around 0.2 per cent of total agricultural emissions (table 10.2.4).

Table 10.2.4 Emissions impact of updating the deer population and productivity statistics

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agriculture*	2024 (1990–2022) emissions estimate	37,121.5	41,712.7	4,591.2	12.4
	2024 (1990–2022) emissions estimate with updated deer calculations	37,105.2	41,640.1	4,534.9	12.2
	Difference in emissions estimates	-16.4	-72.6		

Updating emissions calculations for pigs

Emissions estimates in all categories relating to pigs have been improved by several updates to the emissions calculations. Emissions from pigs were estimated using activity data and a combination of IPCC and country-specific EFs and methodologies.

The 2024 submission of the Inventory applied New Zealand-specific EFs for pigs developed by Hill (2012), in conjunction with default EFs provided by the IPCC. The methodology was based on a 2009 survey of New Zealand pig farmers. Changes to the commercial New Zealand pork industry have occurred since then, such as improvements in genetic selection, animal housing, feed, husbandry, and herd management.

Recent research carried out by NZ Pork (Ritchie, 2024) resurveyed commercial pig farmers in New Zealand to gather current data on relevant industry characteristics and practices. The survey was conducted in 2022. This has led to several recommendations for updates to EFs and other relevant data. The following recommendations were implemented in the 2025 Inventory submission.

- An enhanced Tier 1 methodology for pigs was implemented that differentiates between breeding and growing pigs in the calculation of methane emissions and nitrogen excretion.
- Updated enteric fermentation EFs for pigs were used (see chapter 5, section 5.2.5).
- Updated EFs and manure management system proportions were implemented for calculating methane emissions from manure management (see chapter 5, section 5.3.5).
- Updated EFs and manure management system proportions were used in the calculation of nitrous oxide (N_2O) emissions (see chapter 5, section 5.3.5).

These changes decrease total annual agricultural emissions reported in 2022 by 4.7 kt CO_2-e or around 0.01 per cent of total agricultural emissions (table 10.2.5).

Table 10.2.5 Emissions impact of updating the pig calculations

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agriculture*	2024 (1990–2022) emissions estimate	37,121.5	41,712.7	4,591.2	12.4
	2024 (1990–2022) emissions estimate with updated pig calculations	37,108.32	41,708.0	4,599.7	12.4
	Difference in emissions estimates	-13.2	-4.7		

Seasonality of wool growth

Emissions estimates in all categories relating to sheep have been improved by an update to monthly wool growth.

Monthly wool growth estimates are used in the calculation of total energy required and nitrogen retained by sheep. In the previous method, wool growth was constant through the year, and in the case of the calculation of the energy required for wool growth, constant for the entire time series.

Recent research carried out internally by the Ministry for Primary Industries (MPI) analysed data in several published papers, to determine an appropriate seasonal adjustment to wool growth (Sangster, 2023). The research resulted in fitting a sinusoidal curve to published monthly wool growth data to develop a seasonal adjustment (Woods and Orwin, 1988).

The model now apportions the annual wool yield to sheep class and month using a calculated seasonal adjustment and accounts for the slower wool growth in lambs. The same wool growth distribution is used for both the energy requirements for wool growth and nitrogen retention calculations.

These changes decrease total annual agricultural emissions reported in 2022 by 132.7 kt CO_2-e, or around 0.3 per cent of total agricultural emissions (table 10.2.6).

Table 10.2.6 Emissions impact of introducing seasonality into wool growth

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agriculture*	2024 (1990–2022) emissions estimate	37,121.5	41,712.7	4,591.2	12.4
	2024 (1990–2022) emissions estimate with updated wool calculations	36,977.9	41,580.0	4,602.0	12.4
	Difference in emissions estimates	-143.6	-132.7		

Emissions from non-manure organic amendments to soils

Emissions estimates in *Agricultural soils* have been improved by the inclusion of emissions from non-manure organic amendments to soil.

In 2014, research into non-manure organic fertiliser inputs estimated emissions for this source in 2013 were 0.07 kt of N_2O, or 20.0 kt CO_2-e. This represented 0.05 per cent of New Zealand's total agricultural greenhouse gas (GHG) emissions, or 0.02 per cent of national total GHG emissions in 2012 (van der Weerden et al., 2014). Because this is lower than the threshold of 0.05 per cent of national total GHG emissions (excluding LULUCF) and, as such, is considered an 'insignificant source' by the United Nations Framework Convention on Climate Change (UNFCCC) for reporting GHG emissions, New Zealand has not included activity data for these non-manure organic sources in previous submissions of the Inventory. Instead, New Zealand has reported these as 'NE' or 'not estimated'.

Recent research carried out by AgResearch (van der Weerden and Rutherford, 2024) has used industry data (sheep and cattle meat, dairy processing companies, commercial compost producers and retailers, commercial blood and bone producers and retailers, vegetable processing companies, wine producers, and brewery companies) to estimate the quantities of organic nitrogen amendments applied to agricultural land.

The *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2019) retained the default value of 1 per cent for nitrogen (N) additions to agricultural soils. However, the refinement also provides additional EF values disaggregated by N type and climate, where climate is disaggregated into wet and dry. New Zealand falls into this 'wet climate' category, according to the IPCC definition.

The emissions from non-manure organic amendments to soil are calculated using the 2019 IPCC direct N_2O emissions factor for non-manure organic fertiliser (EF_1) of 0.006, to ensure calculations are using the latest scientific knowledge. This provides a more appropriate value for organic N amendments to soils in wet climates rather than remaining with the aggregated value of 1 percent that is applied to all N inputs, from synthetic fertiliser to compost, across all climatic zones.

These changes increase total annual agricultural emissions reported in 2022 by 12.4 kt CO_2-e, or around 0.03 per cent of total agricultural emissions (table 10.2.7).

Table 10.2.7 Emissions impact of including non-manure organic amendments to soil

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agriculture*	2024 (1990–2022) emissions estimate	37,121.5	41,712.7	4,591.2	12.4
	2024 (1990–2022) emissions estimate with non-manure organic fertiliser	37,123.6	41,725.1	4,601.5	12.4
	Difference in emissions estimates	2.1	12.4		

Corrections and improvements to the Agriculture inventory model

Each year, the Agriculture inventory compilation team identifies changes to improve alignment between the model code and the written methodology (Pickering et al., 2024). Improvements to the input data and methodology have also been implemented, in response to comments from international reviewers.

The main changes are related to milk consumed by young animals, energy requirements for gestation, sheep, beef and mature dairy cow liveweight estimates, and dairy cattle monthly milk production estimates.

One of the improvements this year is using the monthly milk production data published by the Dairy Companies Association of New Zealand to inform the milk produced in a given month as a proportion of total annual milk produced for dairy cattle. The Dairy Companies Association of New Zealand values are similar to that of the fixed proportions that were previously used, so this is a minor improvement.

The total impact of these changes is an increase of 368.2 kt CO_2-e of emissions reported in 2022 (table 10.2.8). This corresponds to an increase in reported total agricultural emissions of around 0.9 per cent.

Table 10.2.8 Emissions impact of improvements and corrections to model code

		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agriculture*	2024 (1990–2022) emissions estimate	37,121.5	41,712.7	4,591.2	12.4
	2024 (1990–2022) emissions estimate with corrections and data improvements	37,089.7	42,080.9	4,991.2	13.5
	Difference in emissions estimates	-31.8	368.2		

Revisions to agricultural statistics

Since the publication of the Agriculture sector estimates in the 2024 submission of the Inventory, Stats NZ updated its livestock numbers in the *Agricultural production statistics: Year to June 2022 (final)*, which included revisions to the 2022 data (Stats NZ, 2023). This revision was released alongside its *Agricultural production statistics: Year to June 2023 (final)* on 3 May 2024 (Stats NZ, 2024). Updates were made to sheep, beef, dairy cattle and poultry numbers as well as changes in regional totals. The updated data reflect lower livestock populations, which result in lower emissions estimates.

Additionally, data for fertiliser use in 2022 provided by MPI was revised, resulting in more fertiliser use in 2022 in the 2025 submission compared with the 2024 submission. The impact of this revision on total emissions is significantly less than the impact of the livestock population data revision.

The total impact of these changes is a decrease of 365.2 kt CO_2-e of emissions reported in 2022 (table 10.2.9). This corresponds to a decrease in reported total agricultural emissions of around 0.9 per cent.

Table 10.2.9 Emissions impact of revision to agricultural statistics

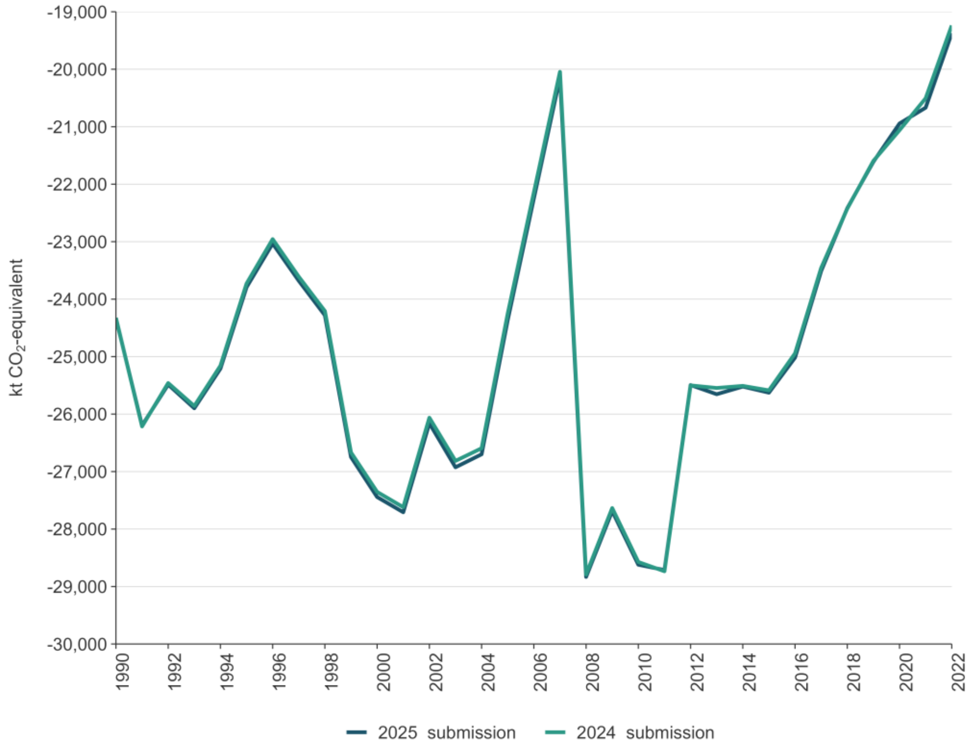
		1990 (kt CO_2-e)	2022 (kt CO_2-e)	Change in emission outputs between 1990 and 2022 (kt CO_2-e)	Percentage change in emission outputs between 1990 and 2022 (%)
Total emissions from *Agriculture*	2024 (1990–2022) emissions estimate	37,121.5	41,712.7	4,591.2	12.4
	2024 (1990–2022) emissions estimate with corrections and data improvements	37,121.5	41,347.5	4,226.0	11.4
	Difference in emissions estimates	0	-365.2		

10.2.6 Land use, land-use change and forestry

No methodological improvements were applied in the LULUCF sector for this submission. However, improvements were made to emissions estimates, as a result of updates to activity data arising from regular mapping improvements.

Improvements made to the LULUCF sector have resulted in an increase of 0.04 per cent (9.4 kt CO_2-e) in estimated net LULUCF removals in 1990 and an increase of 0.7 per cent (133.9 kt CO_2-e) in estimated net LULUCF removals in 2022 (figure 10.2.6).

Figure 10.2.6 **Effect of improvements on net emissions estimates from New Zealand's LULUCF sector, from 1990 to 2022**



Note: Net emissions are expressed as a negative value to clarify that the value is a removal and not an emission.

10.2.7 Waste

Improvements and recalculations made to estimates in the Waste sector have resulted in a 24.8 per cent (1,079.2 kt CO_2-e) decrease in emissions in 1990 and a 15.9 per cent (555.6 kt CO_2-e) decrease in emissions in 2022 (figure 10.2.7).

For the 2025 submission, three source categories have undergone significant updates.

- *Managed waste disposal sites* (5.A.1): Updates have been made to emission factors and parameters, incorporating revised data on waste composition, the fraction of methane in landfill gas, methane generation rates and landfill gas recovery rates. These updates have been included in the Waste sector estimates to address three outstanding expert review recommendations (UNFCCC, 2023).
- *Unmanaged waste disposal sites* (5.A.2): Newly available activity and composition data, along with methodological improvements, have been incorporated into this category. Since 2022, non-municipal landfills have been required to monitor and report the waste they accept as part of the waste levy requirements under the Waste Minimisation Act 2008. Methodological adjustments were implemented to correct overestimations in previous submissions and to align with domestic landfill classifications for non-municipal landfills.
- *Anaerobic digestion at biogas facilities* (5.B.2): For the first time, activity data and methodologies for the *Anaerobic digestion at biogas facilities* category are included in this submission. These updates account for the commissioning of New Zealand's first large-scale food waste-to-bioenergy anaerobic digestion plant, which began operating in October 2022.[64] The facility is projected to process approximately 75,000 tonnes of food scraps annually.

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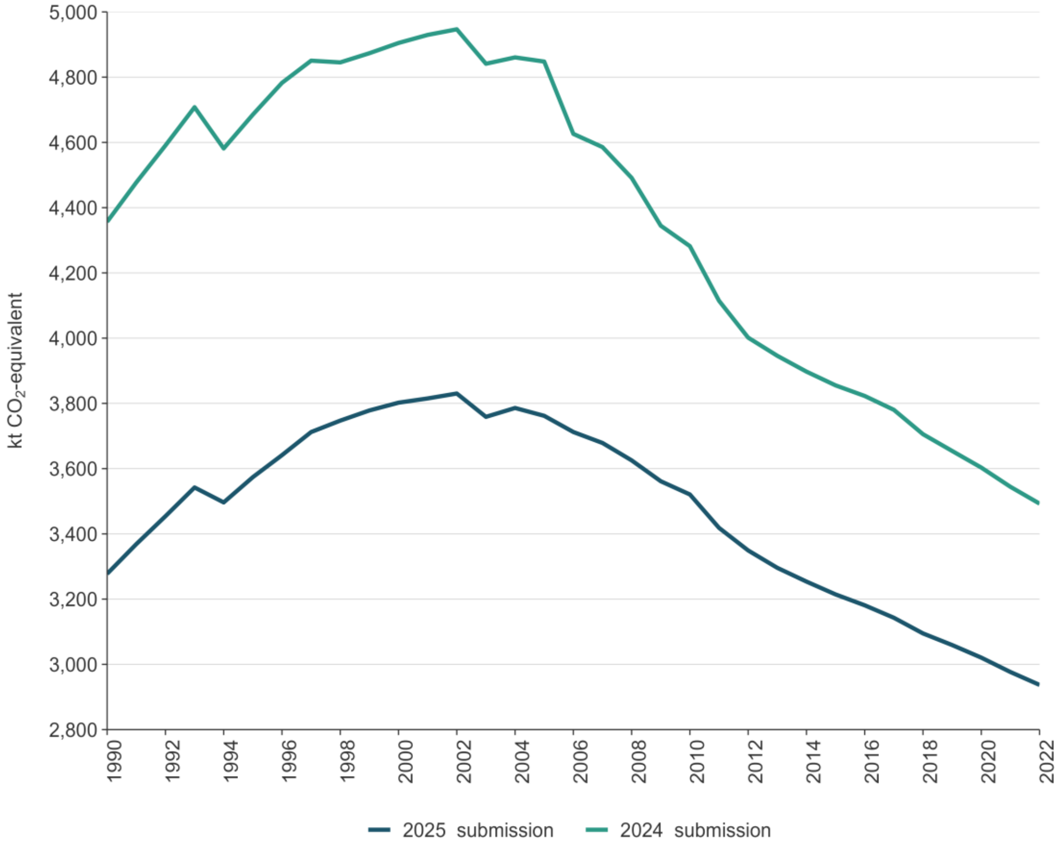
64 See Ecogas. *Reporoa Organics Processing Facility*. Retrieved 5 February 2025.

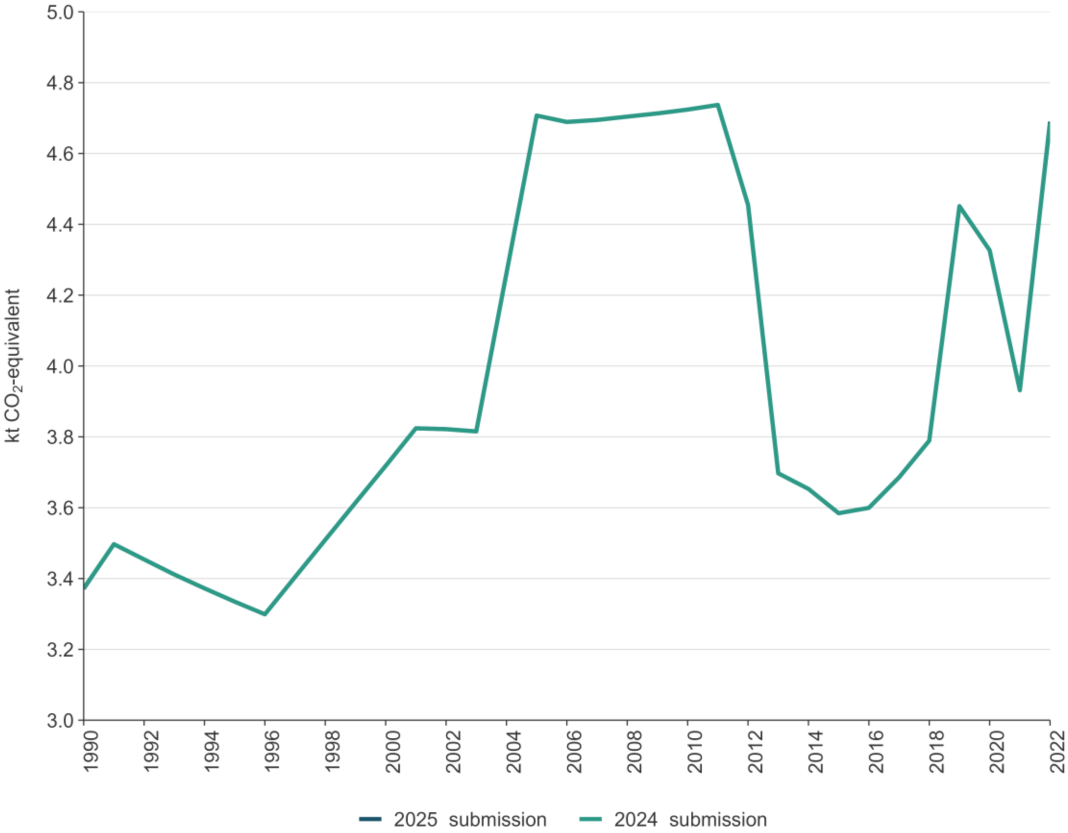
Figure 10.2.7 Effect of recalculations on emissions estimates from New Zealand's Waste sector, from 1990 to 2022



10.2.8 Other sector (Tokelau)

One minor recalculation has been made in the Tokelau emission estimates since the 2024 submission. Improvements made to estimates in Tokelau have resulted in a decrease of 0.03 per cent (0.001 kt CO_2-e) in estimated Tokelau emissions in 1990 and an increase of 0.1 per cent (0.004 kt CO_2-e) in estimated Tokelau emissions in 2022 (figure 10.2.8). This change is due to updates in New Zealand's medical emissions data, which are assumed to be the same per capita in Tokelau.

Figure 10.2.8 Effect of recalculations on emissions estimates from the Tokelau sector, from 1990 to 2022



Note: Due to the small size of the recalculation, the 2025 submission line is obscured by the 2024 submission line.

10.3 Areas of improvement and/or capacity building in response to the review process

New Zealand has made improvements to the 2025 submission of the Inventory to take into account the findings from the reviews of previous submissions.

Table 3 of the report on the individual review of New Zealand's greenhouse gas inventory submitted in 2022 (UNFCCC, 2023), which can be found here, contains an assessment of progress in addressing recommendations provided by the expert review teams (ERTs) during the reviews of earlier submissions. These recommendations are detailed in table 10.3.1 along with New Zealand's latest responses to those recommendations.

Table 10.3.1 New Zealand's response to the status of the recommendations included in table 3 of UNFCCC (2023)

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
General			All recommendations from previous review reports have been resolved.	NA
Energy				
E.1	1.A.1.a Public electricity and heat production – liquid fuels – CO_2, CH_4 and N_2O (E.4, 2021) (E.23, 2019) Transparency	Include information on trends in liquid fuel consumption, especially by explaining the values for 2001 (reported as "NO") and 1992 and 2008 (where consumption and emissions were significantly higher than in other years since 1990).	Resolved. The Party explained in its NIR (p.82) that emissions from public electricity and heat production fluctuate considerably from year to year and that particularly dry meteorological conditions result in an increase in fossil fuel electricity production to compensate for the shortfall in hydroelectric generation. In addition, as the storage capacity of hydro reservoirs is limited to around 10 per cent of New Zealand's production, fossil fuel electricity generation is used to balance supply and demand. Information provided in the NIR (table 10.2.2) indicates that AD were checked with the data system manager at the Ministry of Business, Innovation and Employment and found to be correct.	NA
E.2	1.A.1.a Public electricity and heat production – gaseous fuels – CO_2 (E.18, 2021) Convention reporting adherence	Check the value of the CO_2 IEF for gaseous fuels in 2005 and either justify the inconsistency in the NIR or correct the value for the emission estimates in 2005.	Resolved. The Party reported in its NIR (p.84) that AD for natural gas consumption for electricity generation have been updated. This resulted in revised CO_2 IEFs for the entire time series. The ERT has not identified any issues with the CO_2 IEF reported for 2005.	NA
E.3	1.A.2.e Food processing, beverages and tobacco – gaseous fuels – CO_2 (E.19, 2021) Transparency	Explain in the NIR the reasons why the AD for gaseous fuels were revised for 2013 and why the CO_2 IEF was lower between 1996 and 2012 after the recalculation performed for the 2021 submission. Report in the NIR why the CO_2 IEF was lower for 2003.	Resolved. The Party recalculated the CO_2 EF for gaseous fuels and reported revised emission estimates in CRF table 1.A(a)s2. According to the NIR (p.77), the GHG reporting data system was streamlined and simplified and a number of minor inconsistencies and errors were corrected. During the review,	NA

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
			the Party confirmed that the CO_2 EF was one of the inconsistencies addressed.	
E.4	1.A.3.b Road transportation – liquid and gaseous fuels – CO_2, CH_4 and N_2O (E.8, 2021) (E.29, 2019) Comparability	Report as "NO", instead of "IE", the AD and emissions for biomass for light- and heavy- duty trucks and buses, and diesel, liquified petroleum gas and biomass for motorcycles for before 2000.	Not resolved. The Party has not yet changed the notation keys reported in CRF table 1.A(a)s3. During the review, the Party clarified that the notation keys will be changed for the next annual submission.	Resolved. The notation keys have been updated.
E.5	1.A.3.b Road transportation – liquid and gaseous fuels – CO_2 (E.9, 2021) (E.30, 2019) Convention reporting adherence	Continue to estimate the CO_2 emissions on the basis of fuel sold, but report the CO_2 emissions for before 2000 disaggregated by vehicle mode (cars, light-duty trucks, heavy- duty trucks and buses, and motorcycles) using the data collected for the estimation of CH_4 and N_2O emissions as a good practice to verify the CO_2 estimates obtained with a tier 1 approach.	Addressing. The Party stated in the NIR (p.393) that a project for disaggregating the data is under way and that key milestones of the system code reconfiguration have been reached. The Party plans to implement the changes for the next annual submission.	Resolved. Carbon dioxide emissions have been disaggregated by mode based on vehicle kilometres travelled data. Since vehicle kilometres travelled data do not exist prior to 2001, disaggregating CO_2 by mode for this period is not possible.
E.6	1.A.4 Other sectors – gaseous fuels – CO_2 (E.20, 2021) Transparency	Explain in the NIR the reasons for the lower CO_2 IEFs between 1996 and 2012 after the recalculation performed for the 2021 submission. Report in the NIR the reason for the lower value of the CO_2 IEF for 2003.	Resolved. The Party recalculated the CO_2 EF for gaseous fuels and reported revised emission estimates in CRF table 1.A(a)s2. According to the NIR (p.77), the GHG reporting data system was streamlined and simplified and a number of minor inconsistencies and errors were corrected. During the review, the Party confirmed that the CO_2 EF was one of the inconsistencies addressed.	NA
E.7	1.A.4.a Commercial/institutional – liquid fuels – CO_2 (E.21, 2021) Transparency	Report fully and transparently on recalculations in the NIR in accordance with paragraphs 43–45 of the UNFCCC Annex I inventory reporting guidelines.	Resolved. During the 2021 review, the Party explained that there was a reallocation of AD from commercial/Institutional (category 1.A.4.a) to road transportation (category 1.A.3.b). However, this reallocation was subsequently reversed in the national oil data system. No issues were identified with the reporting of the recalculations.	NA
E.8	1.B.1.a Coal mining and handling – solid fuels – CH_4 (E.12, 2021) (E.15, 2019) (E.14, 2017) (E.17, 2016) (E.31, 2015) Completeness	Estimate CH_4 emissions from abandoned underground mines (subcategory 1.B.1.a.i.3) or, if these emissions are considered insignificant, report them as "NE" and provide a quantitative estimate of the likely level of the emissions in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.	Addressing. The Party reported in its NIR (p.104) that a contractor was employed to review all the coal reports within the Ministry of Business, Innovation and Employment's online coal mine databases and extract details relevant to estimating emissions from abandoned coal mines. On the basis of the preliminary outcome, further research is needed for making a realistic estimate of emissions.	Not resolved. Progress has been made in identifying old mines from historical mine records in the South Island, but these data still require significant manual processing before they can be used to meaningfully assess methane fugitive emissions.
E.9	1.B.2.c Venting and flaring – gaseous fuels – CO_2 (E.15, 2021) (E.35, 2019) Comparability	Report the AD from the Kapuni gas treatment plant for subcategory 1.B.2.c.1.ii venting – gas as confidential, "IE" or "NE", as appropriate, in CRF table 1.B.2 and review the information on AD reported in the documentation box of the same table.	Addressing. The Party reported AD in CRF table 1.B.2 for venting (category 1.B.2.c.ii). However, in the NIR (p.110), and in the documentation box of CRF table 1.B.2, it stated that no AD are available. During the review, the Party clarified that the AD from the Kapuni gas treatment plant are confidential and that the value reported in CRF table 1.B.2.c.ii for venting is only a	Resolved. The notation keys have been changed to 'C'.

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
			placeholder that was introduced during the upgrading of the data system. The Party stated its intention to report the AD as "C" in its next annual submission.	
IPPU				
I.1	2. General (IPPU) (I.1, 2021) (I.1, 2019) (I.1, 2017) (I.1, 2016) (I.2, 2015) (37, 2014) (42, 2013) Transparency	Include in the NIR detailed information and methodological descriptions on how plant- specific data are estimated.	Resolved. The Party improved the relevant methodological descriptions in its NIR. In response to the recommendation, the Party clarified that information on plant-specific data and methods as well as references to emissions trading scheme regulations were first added to the 2018 submission and have been updated over several NIRs.	NA
I.2	2. General (IPPU) – HFCs, PFCs and SF_6 (I.2, 2021) (I.17, 2019) (I.16, 2017) (I.20, 2016) (I.23, 2015) Transparency	Include in the NIR all the information indicated in the section "Reporting and documentation" of the 2006 IPCC Guidelines for categories 2.F product use as substitutes for ozone-depleting substances and 2.G other product manufacture and use.	Resolved. During the review, the Party explained that for product use as substitutes for ozone-depleting substances (category 2.F), most of the specific documentation listed in the 2006 IPCC Guidelines (e.g. vol. 3, chap. 7, table 7.10, p.7.60) is either unavailable or not relevant to the methods used by the Party, including, for example, a schedule for phasing out chlorofluorocarbons and hydrochlorofluorocarbons. The Party also explained that data provided by some manufacturers are confidential and are used in stock models at the national level. The ERT finds that the level of detail in the NIR is sufficiently transparent given New Zealand's methodological choice and national circumstances. For other product manufacture and use (category 2.G), the documentation listed in the 2006 IPCC Guidelines (vol. 3, chap. 8, table 8.6, p.8.22) is provided and used in the modelling. Information on archiving, including the models used, is summarized in the NIR and in a separate report (Verum Group, 2021) that is referenced in the NIR as unpublished, but which the Party provided to the ERT during the review.	NA
I.3	2. General (IPPU) (I.3, 2021) (I.23, 2019) Convention reporting adherence	Correct the inconsistency in the reporting of key categories within the NIR, including in the annexes to the NIR, wherein cement production (CO_2) was reported as a key category in both the level and trend assessment in NIR table 4.1.2, but as a key category in the level assessment only in NIR section 4.2.1 and as a key category in the trend assessment only (including and excluding LULUCF) in CRF table 7.	Not resolved. The Party corrected the inconsistency in the reporting of key categories between NIR table 4.1.2 and section 4.2.1, noting that cement is a key category by level and trend, but continued to report the category as key in the trend assessment only in CRF table 7.	Resolved. Key category analysis and estimation of uncertainties have been repeated in the subsequent submissions and these discrepancies have been removed. New Zealand uses a different approach to the key category analysis than that reported in CRT table 7. It is described in chapter 1, section 1.4.

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
I.4	2. General (IPPU) – CO_2 (I.4, 2021) (I.26, 2019) Transparency	Explain how the AD for the chemical and metal industries (categories 2.B and 2.C) are obtained.	Resolved. The description in the NIR (sections 4.3.2 and 4.4.2) has been updated, which explained how the AD for chemical and metal industries are obtained.	NA
I.5	2.A.2 Lime production – CO_2 (I.6, 2021) (I.6, 2019) (I.23, 2017) Transparency	Update the description in the NIR to correctly reflect the AD and EFs used and to clarify the assumptions and methods applied for 1990–2013 and 2014 onward.	Resolved. The Party reported in the NIR (table 10.2.1) that consistent AD are now used for the entire time series. The ERT noted that the NIR includes some changes in the methodological description for estimating emissions from lime production.	NA
I.6	2.A.2 Lime production – CO_2 (I.7, 2021) (I.24, 2019) Accuracy	Review and, if necessary, revise the CO_2 EF for kiln dust, noting that it cannot be the same as the CO_2 EF for calcium oxide because the dust contains a mixture of calcium oxide and magnesium oxide.	Resolved. During the review, the Party reported that both companies producing lime in New Zealand reported zero or insignificant amounts of magnesium oxide in kiln dust and therefore no amendment to the CO_2 EF is considered necessary. The ERT considers that the recommendation has been fully addressed and emphasizes the need to reflect such details in future NIRs for the sake of transparency.	NA
I.7	2.B.1 Ammonia production – CO_2 (I.13, 2021) (I.27, 2019) Comparability	Subtract the total quantities of oil and gas used (fuel plus feedstock) in ammonia production from the quantity reported under energy use in the energy sector, include the emissions accordingly in the IPPU sector and explain this reallocation in the NIR.	Addressing. During the review, the ERT asked New Zealand to clarify its response that “the recommendation cannot be implemented because information submitted by the plant operators is subject to an obligation to keep gas consumption data confidential”. The Party clarified that there was a misunderstanding on the exact requirement of the recommendation and explained that feedstock gas used for ammonia production was not included in the emissions reported for the energy sector and that appropriate notation keys will be used in future annual submissions to reflect any confidentiality issues.	Resolved. This recommendation has been actioned. An explanation is provided in chapter 4.
I.8	2.C.1 Iron and steel production – CO_2 (I.14, 2021) (I.11, 2019) (I.26, 2017) Completeness	Estimate CO_2 emissions from electric steel production at the Pacific Steel plant, either by using a carbon balance or by applying an appropriate EF, and report these emissions under category 2.C.1.	Not resolved. The Party reported in its NIR (table 10.2.1) that the plant was closed in 2015. The ERT notes that the fact that the plant was closed in 2015 does not address the completeness issue for 1990–2015, assuming that the plant was in operation during that complete time period.	Resolved. New Zealand estimates CO_2 emissions from electric steel production at the Pacific Steel plant using an approximate carbon balance. This is described in the chapter 4, section 4.4.2.
I.9	2.C.1 Iron and steel production – CH_4 (I.25, 2021) Completeness	Investigate all the potential CH_4 sources and report CH_4 emissions from iron and steel production under category 2.C.1 for the entire time series using a methodology consistent with the decision tree in the 2006 IPCC Guidelines (vol. 3, chap. 4, p.4.20, figure 4.8). Include a description of the methodologies, AD and EFs used for the estimates. Alternatively, report the emissions as “NE” and demonstrate in the NIR that the likely level of emissions is below the significance	Addressing. During the review, the Party stated that it approached the steel company with a request for any available updated information on AD and that discussions with the steel company are ongoing.	Resolved. The steel company confirmed that their manufacturing processes do not generate or emit methane. As such, they do not test emissions for methane or have any data on methane.

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
		threshold indicated in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.		
I.10	2.C.1 Iron and steel production – CO_2 (I.26, 2021) Transparency	Investigate the source of significant changes in the CO_2 IEFs for steel production across the time series and include in the NIR information concerning the trend and the reasons for the changes.	Addressing. Information on the changes in the CO_2 IEFs for steel production across the time series was not included in the NIR. During the review, the Party stated that it approached the steel company with a request for any available updated information on changes affecting the IEFs and that, providing no issues arise, the information will be included in its next annual submission.	Resolved. New Zealand has updated the text (chapter 4, section 4.4.2) to explain that changes of input mixture across time are the direct cause of changes in the IEFs.
I.11	2.C.4 Magnesium production – SF_6 (I.15, 2021) (I.14, 2019) (I.28, 2017) Transparency	State in the NIR that, for SF_6 emissions from magnesium casting, a country-specific uncertainty is used rather than the IPCC default uncertainty and explain the reason for its use.	Not resolved. The ERT could not find a statement in the NIR indicating that, for SF_6 emissions from magnesium casting, a country-specific uncertainty is used rather than the IPCC default uncertainty. During the review, the Party stated that an explanation is provided in the NIR (section 4.4.2), which states that, for such a small emissions source (estimated at 120 kg SF_6 or less than 3 kt CO_2 eq/year), only approximate estimates of the quantities of SF_6 used are available.	Resolved. New Zealand has updated the text (chapter 4, section 4.4.3) to explain that it uses a country-specific uncertainty value for AD in SF_6 emissions from magnesium casting.
I.12	2.D.1 Lubricant use – CO_2 (I.16, 2021) (I.28, 2019) Transparency	Improve the information on the CO_2 EF for lubricant use, including the source of the EF.	Resolved. The Party reported in its NIR information on the CO_2 EF for lubricant use (section 4.5.2) and that the EF is the IPCC default (table 10.2.2).	NA
I.13	2.F Product uses as substitutes for ozone- depleting substances – HFCs (I.17, 2021) (I.18, 2019) (I.30, 2017) Transparency	Explain, in section 4.7.3 of the NIR, which approach (other than a combination of uncertainties) was used to derive the uncertainty of 35 per cent presented in NIR table A2.1.1.	Resolved. The Party reported in its NIR (table 10.2.1) that an explanation was provided to the previous ERT and the approach is briefly explained in the NIR (section 4.7.3). During the review, the Party explained that the uncertainties are ±20 per cent for household refrigerators, 30 per cent for self-contained refrigerators, 30 per cent for remote cabinets, 40 per cent for dairy refrigeration, 70 per cent for cool stores, 50–80 per cent for three refrigerated transport components and 30 per cent for other air conditioning. The overall uncertainty is recalculated for each annual submission if the shares of these equipment types change. For other subapplications, the estimates do not change from year to year. The Party also explained that further information is available in a separate report (Verum Group, 2021).	NA
I.14	2.F Product uses as substitutes for ozone- depleting substances – HFCs (I.18, 2021) (I.29, 2019) Transparency	Explain in the NIR the model used to estimate emissions for this category in more detail, including the assumptions made.	Resolved. The Party reported in its NIR (table 10.2.2) that such explanations are expanded on in the NIR (section 4.7.2) and will be further improved in future annual submissions. During the review, the Party informed the ERT that additional information is available in a separate report (Verum Group, 2021), referenced in the NIR.	NA

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I.15	2.F Product uses as substitutes for ozone- depleting substances – HFCs (I.19, 2021) (I.29, 2019) Transparency	Improve QA/QC for this category by comparing the results of the bottom-up model with the results of a top-down approach as the import data are based on comprehensive annual surveys, to allow for a clear comparison of the two results, as recommended in the 2006 IPCC Guidelines (vol. 3, chap. 7.1.4.1).	Resolved. During the review, the Party explained that the 2006 IPCC Guidelines (vol. 3, chap. 7) recommend comparing equipment-based estimates, at the sub-application level, with a mass balance approach, where applicable. The bottom-up stock models used by New Zealand are unique to each sub-application and have varying – and sometimes high – uncertainty related to the quality of statistical data from the equipment. Data on the total supply of each refrigerant inform the calculation of usage for new installations and the replacement of refrigerants currently in use. Consequently, the available top-down data contribute to the calculation of emissions for each sub-application and cannot be used for a straight comparison with the results of the bottom-up models.	NA
I.16	2.F.1 Refrigeration and air conditioning – HFCs (I.20, 2021) (I.19, 2019) (I.17, 2017) (I.37, 2016) Transparency	Describe in the NIR the methodology used to derive the 2 per cent decline in refrigerant charge in vehicle air-conditioning systems and demonstrate that this methodology is in line with the splicing techniques in the 2006 IPCC Guidelines.	Resolved. The Party included this description in its NIR (table 10.2.2 and section 4.7.2). During the review, the Party stated that further details are available in a separate report (Verum Group, 2021), referenced in the NIR, that is available to the ERT.	NA
I.17	2.F.1 Refrigeration and air conditioning – HFCs (I.21, 2021) Accuracy	Update the average charge of HFC-134a for the years from 2010 onward by taking into consideration the cars added to the fleet in recent years on the basis of data available from importers and/or from fleet statistics.	Resolved. The Party reported in its NIR (section 4.7.2) that it imports a wide variety of vehicles, many of them used cars, and that obtaining more accurate and up-to-date statistics on their refrigerant charge is not feasible. However, on the basis of data from importers, the average charge in new vehicles added to the fleet reduced by 2 per cent/year from 2010 to 2020.	NA
I.18	2.F.1 Refrigeration and air conditioning – HFCs (I.23, 2021) (I.31, 2019) Transparency	Explain in the NIR, for category 2.F.1.e mobile air conditioning, the trend in HFC-134a filled into new manufactured products, especially the decrease between 2003 and 2004.	Resolved. During the review, the Party explained that responses to enquiries to importers indicate that this trend continued from 2004 to 2005 and that obtaining more accurate and up-to-date statistics is not feasible.	NA
I.19	2.G.2 SF_6 and PFCs from other product use – SF_6 (I.24, 2021) (I.22, 2019) (I.21, 2017) (I.23, 2016) (I.26, 2015) Transparency	Include in the NIR an explanation of the analysis of SF_6 emissions from SF_6 use in shoe and double-glazed window manufacturing based on the information that was provided to the ERT during the 2015 review in the responses to questions and a background report.	Resolved. The Party reported in its NIR (section 4.8.2) that, following enquiries, it has been confirmed that there is no use of SF_6 in New Zealand for those applications.	NA

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Agriculture				
A.1	3.A Enteric fermentation – CH_4 (A.16, 2021) Accuracy	Using the data and results of research, improve the model trends or changes in death rates over the time series used for estimating emissions from enteric fermentation for dairy cattle, beef cattle, sheep and deer, and document any recalculations in the NIR.	Addressing. For its 2022 submission, the Party continued to apply the fixed death rate values in the characterization of the monthly livestock population for New Zealand's tier 2 model for estimating emissions from enteric fermentation for dairy cattle, beef cattle, sheep and deer. During the review, the Party clarified that the relevant country-specific research is ongoing and that updated information on death rates for daily-cattle will be used for its 2023 annual submission. The Party also clarified that research into birth and slaughter dates for beef cattle and sheep has just been finalized and these data could be used to revise death rates for beef cattle and sheep for its 2024 annual submission.	Resolved. New research findings for dairy cattle were included in the 2023 submission as a part of an improved dairy cattle population model. New research findings for beef cattle were included in the 2024 submission as a part of an improved beef cattle population and liveweight model. New research findings for sheep were incorporated in the updated proportion of lambs held over to a second slaughter date in the 2024 submission.
A.2	3.A.1 Cattle – CH_4, N_2O (A.17, 2021) Accuracy	Review whether a lactation length of six months and a milk yield of 800 l for beef cows are appropriate for the emission estimates and provide further justification for these values in the NIR or recalculate emissions using more appropriate values for milk yield for beef cows.	Not resolved. The Party did not provide any information to justify the appropriateness of a lactation length of six months and milk yield of 800 l for estimating emissions for beef cows. During the review, the Party clarified that there are currently no data available to justify the values and that, owing to the delay in receiving the 2021 review report, it is unlikely that the issue will be resolved before the 2023 submission. New Zealand will engage with sectoral experts to determine whether the assumed values are still appropriate and, in the event that they are found not to be, identify next steps for addressing the issue.	Not resolved. New Zealand currently does not have data to provide further justification for these values in its reporting. Investigation is required to determine (a) if the values are appropriate, and, if not, (b) what values should be used instead, or (c) if new research is required to determine the values.
A.3	3.A.1 Cattle – CH_4 (A.18, 2021) Transparency	Include a clearer description in the NIR of how productivity data for milk production from the Livestock Improvement Corporation are matched with terrestrial livestock data, including for those instances where Livestock Improvement Corporation data combine geographically close regions to obtain a single value (productivity data) that is then used for livestock population in these regions.	Not resolved. The Party did not update the description of how Livestock Improvement Corporation productivity data are matched with terrestrial livestock data in its NIR (p.161). During the review, the Party clarified that this was not done owing to the delay in receiving the 2021 review report. A clearer description will be included in the 2023 submission.	Resolved. A clearer description has been added in chapter 5, section 5.1.4.
A.4	3.A.1 Cattle – CH_4, N_2O (A.19, 2021) Accuracy	Incorporate the data and results of the ongoing research in order to provide more up-to-date data on the proportion of dry cows and update the parameter POPdnmct (total number of dairy cows and heifers not in milk or calf in year t), recalculate the emission estimates and explain the recalculations in the NIR.	Not resolved. New Zealand did not provide additional information on the results of the ongoing research aimed at updating the data on the proportion of dry cows and the parameter POPdnmct. During the review, the Party clarified that the research is being finalized and the results will be used once available, hopefully as part of improvements for the 2023 submission.	Resolved. Additional investigation has confirmed that POPdnmct is based on survey data collected annually by the Agricultural Production Survey. Additional information is now provided in annex 5, section A5.1.1, table A5.1.3.

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A.5	3.A.1 Cattle – CH_4 (A.20, 2021) Accuracy	Improve the methodology related to the instantaneous gain of 10 per cent of the weight of mature cows to account for their higher energy requirements and recalculate the associated emission estimates. Document clearly these recalculations in the NIR.	Addressing. New Zealand continued to assume that growing heifer live weight gain linearly increases from 9 per cent when a heifer is born to 90 per cent when it becomes a mature heifer at 638 days old. After 638 days, growing heifers join the class of mature milking cows and make an instantaneous jump in weight to the full mature dairy cow weight. During the review, the Party clarified that the instantaneous weight gain is related to the fact that growing heifers are moving up into the next subcategory of cattle. The Party specified that ongoing research to improve the methodology for estimating dairy cattle population will address this issue and the results will be incorporated into its 2023 submission.	Resolved. The weight gain method was adjusted to address this recommendation as a part of the improved estimates of within-year dairy cattle population change included in the 2023 NIR submission.
A.6	3.A.4 Other livestock – CH_4 (A.9, 2021) (A.13, 2019) Accuracy	Implement the planned methodological changes regarding revising the assumptions about the population of dairy goats and the total goat population, recalculate the emission estimates and explain them in the NIR.	Resolved. In its NIR (table 10.2.2, p.392), the Party stated that it used revised estimates of the dairy goat population for the 2020 inventory. This resulted in an updated CH_4 EF for enteric fermentation for the whole time series in the 2020 inventory (CRF table 3.A.s1). During the review, the Party clarified that data from recent research (Burggraaf et al., 2019) have now been adopted in the methodology regarding the proportion of dairy goats in the overall farmed population and emission estimates have been recalculated accordingly. The ERT noted that a reference to this research was provided in the NIR (p.177).	NA
A.7	3.B.1 Cattle – N_2O (A.21, 2021) Transparency	Correct the description of N excretion in the first two months of life for dairy cattle in section 5.1 of the New Zealand Ministry for Primary Industries technical report in order to resolve the inconsistency with section 5.1.1.2 of the same technical report.	Not resolved. The inconsistency in the technical report (New Zealand Ministry for Primary Industries, 2022) remains: it is stated on page 97 that for dairy cattle in the first two months of their life, N excretion is set to zero, whereas it is stated on pages 97–98 of the same report that for dairy cattle less than one year old, N excretion is calculated on the basis of N intake through milk powder and its protein content, as shown in equation 5.3 in the report (p.98). During the review, the Party clarified that the recommendation was not implemented because of the delay in receiving the 2021 review report and that the report by the Ministry for Primary Industries will be updated to ensure consistency.	Resolved. Section 5.2 (previously section 5.1) of the Ministry for Primary Industries technical report on the methodology for calculation of New Zealand's agricultural greenhouse gas emissions has been updated for consistency (Pickering et al., 2024).
A.8	3.B.4 Other livestock – CH_4 (A.12, 2021) (A.16, 2019) Accuracy	Revise the calculation procedures for the CH_4 EF for deer and explain the revisions in the NIR. If three studies from 2003 are still used as the basis for the calculation, consider using a more appropriate average value than a simple arithmetic average, such as a	Resolved. The Party continued to apply a simple arithmetic average of CH_4 yield value of 0.000914788 kg CH_4/kg faecal dry matter, which was obtained on the basis of two studies for sheep and three studies for cattle. During the review, the Party clarified that the current procedure for calculating the CH_4 EF	NA

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		weighted average, to estimate the CH_4 EF for deer; and justify that the obtained value is more appropriate than the IPCC default value.	for deer remains appropriate given the information available. As deer weights are approximately halfway between those of sheep and beef and the values for sheep and beef are based on robust, country-specific research, basing the CH_4 EF for deer on the average of those two values is likely to be more accurate than using the IPCC default value. The ERT considers the arguments provided by New Zealand to be relevant and robust and thus considers the issue to have been resolved.	
A.9	3.D.a.2.a Animal manure applied to soils – N_2O (A.22, 2021) Transparency	Provide additional information describing the manure management systems used for dairy cattle in the NIR, including the information from Rollo et al. (2017).	Not resolved. New Zealand continued to report that "some manure is also collected but not stored; rather it is daily spread directly onto pasture (e.g. swine manure and some dairy manure)" (NIR p.200), and did not include detailed information from Rollo et al. (2017) justifying its stance that this manure management practice does not fall under the definition of the manure management system daily spread, or on reporting "NO" for dairy cattle in CRF tables 3.B(a)s2 and 3.B(b). During the review, the Party clarified that the recommendation was not implemented because of the delay to the 2021 review report; however, more information will be provided in its 2023 submission in order to resolve this issue.	Resolved. A clearer description has been added in chapter 5, section 5.5.2 under Organic nitrogen fertilisers. A report by Rollo et al. (2017) found that only 8 per cent of dairy farms use land application of manure, with direct pumping from a sump. In all cases, manure that was collected was stored for least one or two days before spreading to pasture via irrigation. Therefore, it does not meet the definition of daily spread and the notation key 'NO' is reported in 3.B(b).1.a of the CRT.
A.10	3.D.a.2.c Other organic fertilizers applied to soils – N_2O (A.23, 2021) Completeness	Undertake an updated analysis of the AD related to N applied to soils for non-manure components of organic fertilizers and estimate and report N_2O emissions for this subcategory. If the emissions are considered to fall below the threshold of significance, report in the NIR information in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines on the likely level of N_2O emissions, demonstrating that they are below 0.05 per cent of the national total and do not exceed 500 t CO_2 eq.	Addressing. New Zealand did not report updated information to justify that N_2O emissions from other organic fertilizers applied to soils are below the threshold of significance in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. During the review, the Party clarified that it continued to refer to van der Weerden et al. (2014), in which the reported results illustrate a yearly breakdown of the contribution of organic amendments as a percentage of total GHG emissions, which ranges from 0.01 to 0.025 per cent. The Party also clarified that, according to the same report, the results should be reviewed in five years, but such a review was not undertaken owing to resource constraints. The Party further clarified that it had listed the need to review the results in van der Weerden et al. (2014) as a priority in the current annual budget round. The ERT considers that the results and information used to evaluate emissions from the organic sources in the aforementioned 2014 report are a robust justification for considering that N_2O emissions from other organic fertilizers applied to soils are below the threshold of significance, as required by paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, but that such results	Resolved. Research completed in 2024 (van der Weerden and Rutherford, 2024) quantified the non-manure organic nitrogen applied to soils. Although the emissions from this source fall below the threshold for significance, New Zealand now reports emissions from non-manure organic fertilisers. See chapter 5, section 5.5.5, for more detail.

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			and information should be reviewed, as referred to in the same report.	
A.11	3.D.b Indirect N_2O emissions from managed soils – N_2O (A.15, 2021) (A.19, 2019) Transparency	Revise the description in the NIR of the country-specific values for FracLEACH and for the fraction of applied organic N fertilizer materials and of urine and dung N deposited by grazing animals that volatilizes as ammonia and nitrogen oxides in kg N volatilized.	Addressing. To estimate indirect N_2O emissions from managed soils, New Zealand used the FracLEACH value, which is further disaggregated for two land-use systems: cropping and grassland. The updated FracLEACH value for cropping systems was applied. In its NIR (p.217), the Party gave a brief description of the methodology used to derive the value, provided a reference (Welten et al., 2021) and clarified that, as the field investigations were ongoing at the time of compiling the NIR, the FracLEACH value for grazing systems was not updated. During the review, the Party clarified that the results of the research to evaluate the country-specific FracLEACH values was partially applied for the 2022 submission and that the remaining findings are scheduled to be applied for the 2023 submission.	Resolved. These values have been revised, based on recent research. Information on the country-specific FracLEACH parameter used in the Inventory is included in chapter 5, section 5.5.2 (under Indirect nitrous oxide emissions from managed soils – Nitrogen leaching and runoff (CRT 3.D.2.b)).
LULUCF				
L.1	4. General (LULUCF) – CO_2 and N_2O (L.1, 2021) (L.10, 2019) Accuracy	Either provide evidence that the estimated SOC changes do not result in systematic over- or underestimations, given that land-use changes occur randomly across the entire SOC variability of a land-use category or subcategory, or replace the current method with one consistent with good practice as defined in the 2006 IPCC Guidelines (vol. 4, chap. 2.3.3.1).	Addressing. The Party reported in its NIR (p.396) that to undertake a robust study to collect this information would likely cost between NZD 400,000 and 600,000/year. At a minimum, this is more than five times the annual research budget for the LULUCF sector. Following decision tree 2.4 in volume 4 of the 2006 IPCC Guidelines, there are insufficient resources to implement such research in the near future without a significant increase in funding. During the review, the Party clarified that it recently assigned a multi-year budget to conduct work on improving mineral soil estimates and that, owing to the nature of the research required, results will not be available for reporting purposes for several years yet. The ERT considers that the recommendation has not yet been fully addressed because the Party has neither verified the accuracy of SOC change estimates produced by the model nor applied an alternative method consistent with the 2006 IPCC Guidelines. The ERT noted that the country-wide application of the IPCC default methodology for SOC in mineral soils together with either IPCC default values (tier 1) or country-specific values (tier 2) for reference SOC stocks and SOC change factors would resolve the issue.	Addressing. New Zealand has begun a multi-year programme to conduct work on improving mineral soil estimates. Due to the nature of the research required, however, results will not be available for reporting purposes for several years yet.

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L.2	4. General (LULUCF) – CO_2 (L.2, 2021) (L.11, 2019) Convention reporting adherence	Provide a comparison across the available time series of data of roundwood statistics reported by the Ministry for Primary Industries and the quantities estimated by the LUCAS model based on the harvested area as allocated to age classes and provide justification for any discrepancies.	Resolved. The Party added an additional section in annex 3 to the NIR (vol. 2, pp.95–96) describing forest land model validations and, specifically, the differences between LUCAS model harvest losses and the roundwood statistics reported by the Ministry for Primary Industries.	NA
L.3	4. General (LULUCF) – CO_2 (L.3, 2021) (L.12, 2019) Convention reporting adherence	Replace "IE" with estimates of biomass carbon stock losses only for the year in which an area conversion occurs, and with "NO" for any year in which conversion of additional areas does not occur, in CRF tables 4.A and 4.B.	Resolved. The Party reported "NO" in its NIR (p.396) for annual biomass carbon stocks where conversions did not occur during the time series (e.g. for conversions of post-1989 forest to cropland). Where a land-use conversion had previously occurred but there were some years in the time series when conversion of additional areas did not occur, the annual biomass carbon stocks were reported as "NA" since the methodology does not require the Party to estimate annual biomass stock changes in such years. Perennial biomass carbon stocks were reported as "NA" where biomass carbon gain occurred owing to conversion to land uses that do not host any perennial biomass carbon stock. The ERT agrees with the use of "NA" in these circumstances.	NA
L.4	Land representation – CO_2, CH_4 and N_2O (L.8, 2021) (L.16, 2019) Accuracy	Investigate how to use the results of the accuracy assessment, once available, to adjust the reported AD for the land representation.	Addressing. The Party reported in its NIR (p.397), with reference to annex A3.2.2 to the NIR, that a confusion matrix for the 2012 map was developed, demonstrating that mapping errors and biases were very limited for all land categories, except grassland and grassland with woody biomass. The Party also reported that a new land-use map using imagery acquired in 2020–2021 is being produced. Once that is complete, an accuracy assessment of the map series with a focus on the accuracy of land-use change mapping will be conducted. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet completed the accuracy assessment, in particular for land-use change categories where small land-area errors are associated with large errors in emission estimates.	Addressing. A new land use map for 2020 has been completed and an accuracy assessment of the map series from 1990 to 2020, with a focus on the accuracy of land-use change mapping, is planned.
L.5	4.A Forest land – CO_2 (L.10, 2021) (L.17, 2019) Transparency	Provide information on the actual age of harvest of forest plantations as derived from information collected through the National Exotic Forest Description.	Resolved. The Party added information on the actual age of harvest and on the actual age profile of forest plantations (figure A.3.2.11) in annex 3.2.5 to the NIR.	NA

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L.6	4.A Forest land – CO_2 (L.26, 2021) Transparency	Include in the NIR the definitions of tall and regenerating forests, their respective areas and how this distinction and the associated calculations result in complete estimates of CSC, in particular in the event of natural disturbances.	Resolved. The Party reported in its NIR the definitions (table 6.3.5, p.255) and areas (table 6.3.6, p.255) of tall and regenerating forests. Forest areas are classified spatially as either tall or regenerating and, accordingly, CSC is calculated separately. Natural disturbances affect the carbon stocks measured in the national forest inventory plot network and therefore are implicitly included in the CSC calculations.	NA
L.7	4.A.1 Forest land remaining forest land – CO_2 (L.11, 2021) (L.4, 2019) (L.5, 2017) Accuracy	Update the below-ground biomass ratios, noting that choosing a value above the median in the range of 9–33 per cent without further documentation entails the risk of overestimation of removals from forest land remaining forest land, or, if that update is not possible, report in the NIR on the progress on the ongoing work to update the below-ground biomass ratios.	Resolved. The Party reported below-ground biomass ratios in its NIR (vol. 2, table A3.2.10, p.87) that were updated on the basis of peer-reviewed literature (Easdale et al., 2019).	NA
L.8	4.A.1 Forest land remaining forest land – CO_2 (L.12, 2021) (L.18, 2019) Completeness	Report estimates of above-ground biomass CSCs, noting that those estimates should include all gains and losses in tall natural forest remaining tall natural forest; however, carbon stock losses as a result of stand-replacing disturbances (such as storms or destructive wildfires) that lead to a subsequent regeneration of the natural forest, and carbon stock gains up to the average carbon stock of tall forests, should be reported within the regenerating natural forest category, including the entire transition of regenerating natural forest to tall natural forest.	Resolved. The Party reported in its NIR (p.88) and in CRF table 4.A estimates of CSC for tall and regenerating forests.	NA
L.9	4.A.1 Forest land remaining forest land – CO_2 (L.13, 2021) (L.19, 2019) Accuracy	Provide evidence that national circumstances make the collection of data on SOC in mineral soils and on its variation across time in forest land remaining forest land impracticable or, if this is not possible, plan activities to be implemented in the next few years to collect the data needed to apply a tier 2 method to estimate SOC changes in mineral soils of tall natural forest remaining tall natural forest.	Resolved. The Party reported in its NIR (pp.397–398) that undertaking a robust study to collect this information would likely cost between NZD 400,000 and 600,000/year. At a minimum, this is more than five times the annual research budget for the LULUCF sector. In line with guidance in the 2006 IPCC Guidelines (vol. 4, chap. 2, figure 2.4), there are insufficient resources to implement such research in the near future. To do so would require a significant increase in funding. During the review, the Party clarified that it recently assigned a multi-year budget to conduct work on improving mineral soil estimates. However, results will not be available for reporting purposes for several years yet.	NA

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L.10	4.A.2 Land converted to forest land – N_2O (L.14, 2021) (L.20, 2019) Transparency	Report disaggregated information for the two subcategories of post-1989 natural forest and post-1989 plantations.	Not resolved. The Party reported in CRF table 4(III) information on N_2O emissions from land converted to forest land but that information was not disaggregated by forest type. During the review, New Zealand stated that it has identified a solution to disaggregate reporting in CRF table 4(III) and it is currently investigating how to implement this. The ERT considers that the recommendation has not yet been addressed because the Party has not yet reported in CRF table 4(III) information on land converted to forest land disaggregated by forest type.	Not resolved. New Zealand was unable to implement the solution to disaggregate this information by forest type. A new solution is now being sought.
L.11	4.B.1 Cropland remaining cropland – CO_2 (L.15, 2021) (L.21, 2019) Completeness	Identify the main subdivisions for New Zealand's perennial cropland on the basis of the harvesting cycle and the biomass carbon stock at the end of the harvesting cycle, and build an age–class distribution for each subdivision; estimate and report annual biomass carbon stock gains and losses accordingly; and report the estimation and all additional information in the NIR.	Not resolved. The Party reported in its NIR (p.398) that emissions from cropland remaining cropland are low relative to those for other categories, such as forest land and harvested wood products. The category is therefore a low research priority and funding is unable to be directed to this at present. The ERT considers that the recommendation has not yet been addressed because the Party has not yet estimated CSCs in perennial biomass associated with the ageing and replanting of perennial crops. The ERT noted that the use of historical statistical data on perennial crop area allows for an age–class distribution to be built and used to estimate annual carbon stock gains and losses associated with the ageing of perennial crop plantations and the renewal of those at the end of the production cycle.	Not resolved. Emissions from *Cropland remaining cropland* are low relative to those for other categories, such as *Forest land* and *Harvested wood products*. The category is therefore a low research priority and funding is unable to be directed to this at present.
L.12	4.B.1 Cropland remaining cropland – CO_2 (L.16, 2021) (L.22, 2019) Completeness	Plan the activities needed to collect data and prepare estimates of SOC changes in cropland associated with changes in management practices.	Addressing. The Party reported in its NIR (p.271) that a longitudinal study on the impact of management practices on grassland and cropland soils is under way. Time-series data on a network of 500 soil sample plots over 12 years will be collected, but the data are not expected to be available for several years. During the review, New Zealand clarified that the baseline data for this study will be collected by 2023/2024 and that the 12-year timeline is for the resampling of those 500 sample plots, which will inform and refine estimates of SOC changes within one land use over time. New Zealand also clarified that it aims to use these baseline data to improve its mineral SOC stock change estimates for all agricultural land uses by its 2026 submission, and that improvements to its reporting on management practices may also be made before the resampled data are available. The ERT considers that the recommendation has not yet been fully addressed because, while the Party has secured dedicated funding and commenced a multi-year research programme, it has not yet collected the necessary data	Addressing. A longitudinal agricultural land soils study is currently under way. This study includes a collection of baseline data for the national 500 soils programme, and a 12-year timeline for resampling the 500 sites will inform and refine estimates of change through time within one land use. New Zealand also aims to improve mineral SOC stock change estimates for all agricultural land uses with the baseline data.

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			to estimate and report SOC changes in mineral soils associated with agricultural management changes as required for the IPCC default methodology for cropland remaining cropland.	
L.13	4.C.2 Land converted to grassland – CO_2 (L.17, 2021) (L.23, 2019) Convention reporting adherence	Report "NE" for biomass carbon stock losses for wetlands converted to grassland, providing relevant references to the 2006 IPCC Guidelines for justification, or revise the methodology by assigning a biomass carbon stock value to wetlands before conversion, in particular for the subcategory vegetated wetlands.	Resolved. The Party reported this subcategory as "NE" in CRF table 4.C because the 2006 IPCC Guidelines (vol. 6, chap. 6.7.2) do not provide default values for above-ground biomass or dead organic matter and the country has no country-specific data. During the review, the Party clarified that, following its 2022 submission, a literature review was conducted on available research on biomass carbon stocks in vegetated wetlands. This research will allow New Zealand to assign biomass carbon stock values to vegetated wetlands before conversion, and the results will be used for its 2023 submission.	NA
L.14	4.D Wetlands – CO_2 (L.18, 2021) (L.6, 2019) (L.7, 2017) Completeness	Continue the ongoing work to improve estimates for wetlands and report the emissions for subcategories 4.D.1.1 (peat extraction remaining peat extraction) and 4.D.2.1 (land converted to peat extraction).	Resolved. Although the Party reported in its NIR (p.280) that information from land converted to peat extraction was reported as "NE" in the CRF tables because the areas under peat extraction have remained the same since 1990, the ERT noted that in CRF table 4.D, it is reported that "New Zealand does not have activity data available to reliably report on this activity", so reporting this subcategory as "NE" is appropriate.	NA
L.15	4.E.2 Land converted to settlements – CO_2 (L.27, 2021) Accuracy	Assess the share of impervious surfaces within the settlements category and estimate soil CSC for land converted to settlements on the basis of this share and in accordance with the 2006 IPCC Guidelines.	Not resolved. The Party did not report any relevant information in its NIR. During the review, the Party clarified that research on settlements is low priority and it has not been possible to direct funding to this area. The ERT considers that the recommendation has not yet been addressed because the Party has not yet applied, as a first step, the IPCC default method and values to calculate SOC losses for land converted to settlements.	Not resolved. Research on settlements is low priority, due to the small emissions associated with this category. Therefore, it has not been possible to direct funding into this area.
L.16	4.F Other land – CO_2, CH_4 and N_2O (L.20, 2021) (L.27, 2019) Accuracy	Reclassify all other land with significant SOC content under the most appropriate land-use category and recalculate the land representation and SOC changes for the revised area of conversion to and from other land.	Not resolved. The Party reported in its NIR (section 6.8.6, p.287) that the mapping of other land in 1990 was based on low 30 m resolution Landsat satellite imagery, meaning that some areas of lower productive grassland and bare ground without a typical grassland spectral signature could have been incorrectly classed as other land. Subsequent land-use change has highlighted that the 1990 classification should be reviewed and updated. This is a scheduled improvement activity. The Party also reported that the country-specific reference SOC value, based only on three estimates, is high compared with the default value in the 2006 IPCC Guidelines (vol. 4, chap. 2) and has a relatively high uncertainty. Further soil sampling in land classified as other land is required to improve soil carbon estimates for this land-use	Addressing. New Zealand aims to narrow the definition of *Other land* and ensure estimates of mineral SOC stock changes are aligned with this category, through improving mapping and additional sampling. At present, remapping work is under way to reclassify land with significant SOC currently classified as *Other land*.

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
			category. However, while this action is listed as a planned improvement, it has not yet received funding and is unlikely to be implemented before the next annual submission. During the review, New Zealand, stated that it aims to narrow its definition of other land and ensure estimates of mineral SOC stock changes are more representative for this category through improving mapping and additional soil sampling. The ERT considers that the recommendation has not yet been addressed because the Party has not yet separated land without significant SOC stocks in mineral soils from land with significant SOC. Mixing of both types within a single category results in a high likelihood of overestimating SOC gains in conversion to vegetated land uses and SOC losses in conversion from vegetated land uses to other land. That is because conversion of other land to other vegetated land uses occurs exclusively on other land with significant SOC stocks.	
L.17	4.F.2 Land converted to other land – CO_2 (L.21, 2021) (L.28, 2019) Accuracy	Verify the occurrence of the conversion of land with organic soils to other land and, if SOC losses are not reported for organic soils converted to other land, report "NA" in the CRF table.	Not resolved. The Party reported in its NIR (p.399) that improving the 1990 classification of other land is a scheduled activity. The ERT considers that the recommendation has not yet been addressed because the Party has not yet reported on the goal of the scheduled activity (expected by the ERT to be a classification of land cover and soil types) or the timescale for achieving that goal.	Addressing. A review of the 2020 land use map has revealed approximately 8 hectares of *Land converted to other land* on organic soils. These appear to be a result of mapping errors in the organic soil map. Work is under way to correct these errors.
L.18	4(II) Emissions/removals from drainage and rewetting and other management of organic/mineral soils – N_2O (L.22, 2021) (L.29, 2019) Completeness	Report N_2O emissions from drainage of non-agricultural organic soils in CRF table 4(II) for each land category for which an SOC loss in organic soils is reported in CRF tables 4.A, 4.D and 4.E.	Addressing. The Party reported in CRF table 4(II) carbon stock losses from drained organic soils in forest land. During the review, the Party clarified that, during the review of its 2021 submission, the previous ERT acknowledged that there is no default value in the 2006 IPCC Guidelines that can be applied for wetlands or settlements. However, the ERT suggested that, because New Zealand considers that most of its settlement area can be counted as grassland when it comes to soil carbon, the EFs for grassland should be applied to settlements. For the 2022 submission, these emissions were calculated but not included in the CRF tables or emission totals. As there is no reporting category for these emissions in the CRF tables, assistance was sought on how they could be reported. Unfortunately, the response to this request was not received in time to incorporate the emission estimates into the submission. Therefore, the value of 23.2 kt CO_2 eq emissions resulting from drained organic soils in settlements has not been included in the total emissions for LULUCF, but this is planned for the 2023 submission. The ERT	Addressing. Emissions from drained organic soils in *Forest land* have been calculated for the 2025 submission (see chapter 6, section 6.11.2). Note that during the review of the 2021 submission, the ERT acknowledged that there is no default method in the 2006 IPCC Guidelines (IPCC, 2006) that can be applied to *Wetlands* or *Settlements*. However, the ERT suggested that, because New Zealand considers most of its *Settlements* area can be assimilated to *Grassland* when it comes to soil carbon, the emission factors for *Grassland* should be applied to *Settlements*. For this submission, these emissions have been calculated but not included in the CRT or emission totals. For more information, see chapter 6, section 6.8.6.

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
			considers that the recommendation has not yet been fully addressed because the Party has not yet included in its inventory the estimated N_2O emissions caused by the drainage of organic soils in the settlements land-use category.	
L.19	4(IV) Indirect N_2O emissions from managed soils – N_2O (L.25, 2021) (L.31, 2019) Completeness	Report indirect N_2O emissions from leaching and run-off of N mineralization associated with SOC losses in mineral soils in CRF table 4(IV).	Resolved. The Party reported in CRF table 4(IV) indirect N_2O emissions from leaching and run-off for all land-use categories other than cropland remaining cropland.	NA
L.20	4(V) Biomass burning – CO_2 (L.28, 2021) Transparency	Transparently describe in the NIR how CO_2 emissions from wildfires are captured in the estimates for planted forests by the general stock change calculation, specifying in particular what share of salvage logging is assumed, whether it is entirely or partly deducted from the estimated 'non-salvage' harvest area, and whether age distribution is impacted by wildfire.	Resolved. The Party reported in its NIR (p.297) that CO_2 emissions from wildfires in forest land remaining forest land are included in the general stock change calculation. In forest land remaining forest land, burned stands are either harvested (so emissions are included with the harvesting emissions) or left to grow at reduced stocking. For both natural and planted forests, emissions from areas burned are captured within the forest plot networks that New Zealand uses to estimate CSC. In these cases, to avoid double counting of CO_2 emissions, "IE" is reported in CRF table 4(V).	NA
L.21	4(V) Biomass burning – N_2O (L.29, 2021) Transparency	Provide explanations in the NIR on how the Fire and Emergency New Zealand database is fed, whether by remote sensing data or field reports, together with information on the time series of annually burned area.	Resolved. The Party reported in its NIR (p.298) that wildfire AD are sourced from Fire and Emergency New Zealand, which maintains a database in which wildfire events are recorded. Historically, burned areas were estimated and allocated by field staff by vegetation type: grass, tussock, gorse, scrub, wetlands, plantation forest and indigenous forest. The process was updated in 2017 and now involves mapping the burned area and overlaying land-cover categories to identify vegetation types. The ERT noted that a reference to the online information on wildfire compiled by Fire and Emergency New Zealand would further enhance the transparency of the inventory.	NA
Waste				
W.1	5. General (waste) – CO_2 (W.1, 2021) (W.17, 2019) Transparency	Include more information on current waste management, such as an overview of MSW generation and its treatment method (recycling, composting, incineration or disposal) in NIR section 7.1.1, and its impact on the composition of waste disposed to landfill.	Not resolved. The previous ERT noted that the Party did not indicate how management practices impact the composition of waste disposed to landfill. During the review, the Party indicated that no changes were made to NIR section 7.1.1 compared with the 2021 submission.	Addressing. New Zealand is in the process of collecting quantitative and qualitative data to improve the information provided under chapter 7, section 7.1.1, regarding the impact of waste management practices on the composition of waste disposed to landfills. This information is being collected through the implementation of New Zealand's first emissions reduction plan (Ministry for the

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
				Environment, 2022) and it is expected to be available for inclusion in a future submission.
W.2	5.A Solid waste disposal on land – CH_4 (W.3, 2021) (W.4, 2019) (W.5, 2017) (W.4, 2016) (W.7, 2015) Accuracy	Provide substantive justification for the country-specific values for CH_4 recovery efficiency, including justification for the factors that can enhance the recovery, or revise the estimates for CH_4 recovery at SWDS for which metered data are not available to 20 per cent, in order to be consistent with the 2006 IPCC Guidelines.	Resolved. The Party provided in its NIR (p.318) a reference to an unpublished study in which these country-specific values on CH_4 recovery are justified (see ID# W.12 in table 5).	NA
W.3	5.A Solid waste disposal on land – CH_4 (W.13, 2021) Transparency	Include information in the NIR on the consolidation of MSW landfill sites – from numerous small and poorly managed to fewer large-scale and well-managed landfills – and any additional information on the changing trends in waste generation and waste management in the country.	Resolved. The Party provided in its NIR (p.308) an explanation of the waste policies that resulted in the disposal of solid waste to fewer larger and better managed landfills.	NA
W.4	5.A.3 Uncategorised waste disposal sites – CH_4 (W.14, 2021) Transparency	Provide additional information in NIR section 7.1.1 on current waste management practices, including a higher-resolution version of figure 7.1.1 and an overview of MSW generation and its treatment method (recycling, composting, incineration, or disposal), and the impact of such practices on the composition of waste disposed to landfill.	Addressing. The Party indicated that no changes were made to NIR figure 7.1.1 because the previous ERT was insufficiently explicit on what improvements would be useful for future reviews. According to the current ERT, figure 7.1.1 should be an introductory figure, allowing the reader to understand the main waste generation, pre-treatment and disposal methods and to assess completeness. The figure should preferably contain some quantitative information for a recent year (preferably the latest reported year of the annual submission). The figure may be simplified; intermediate actors (waste collectors, aggregators and redistributors) do not need to be included. Terms should be consistent with text in the NIR and in the 2006 IPCC Guidelines (e.g. MSW instead of residential households).	Addressing. New Zealand is collecting quantitative and qualitative data to improve the resolution of figure 7.1.1 in chapter 7 regarding municipal waste disposal generation and its treatment methods (recycling, composting, incineration or disposal). This information is being collected through the implementation of New Zealand's first emissions reduction plan (Ministry for the Environment, 2022) and it is expected to be available for inclusion in a future submission.
W.5	5.B.1 Composting – CH_4 (W.15, 2021) Convention reporting adherence	Correct the text in the NIR (p.381) to refer to the correct number in table 7.2.3 (which reflects total MSW) and provide a description of the AD on composting used for the estimates.	Resolved. The Party provided in its NIR (p.322) a reference to the correct NIR table 7.2.3 (solid waste deposited to municipal and uncategorized landfills from 1950 to 2020).	NA
W.6	5.C.1 Waste incineration – CO_2 (W.8, 2021) (W.21, 2019) Convention reporting adherence	Investigate historical data on waste incineration in schools and revise the estimates, if appropriate.	Addressing. The Party reported the incineration of MSW (category 5.C.1) in CRF table 5.C as "NO". The Party stated in the NIR (p.302) that MSW is generally not incinerated in New Zealand. The Party provided in annex 6 to the NIR an explanation of why emissions from waste incineration in schools are below the significance threshold. In annex 6.2 to the NIR, estimated emissions were reported to be 0.04 kt CO_2 eq/year,	Resolved. New Zealand has investigated historical data on waste incineration in schools. There is no additional data on the practice of incinerating waste in rural schools. New Zealand has corrected its reporting of this source in CRF table 5.C so

ID#	Issue/problem classification[1]	Recommendation from previous review report	ERT assessment and rationale	New Zealand response
			which is less than 1 per cent of the significance threshold for 2020. It is unlikely that emissions in the past would have exceeded the significance thresholds in specific years of the time series 1990–2020. During the review, the Party clarified that it incorrectly reported "NE" under subcategory 5.C.2.2.a instead of subcategory 5.C.1.2.a in CRF Reporter. The ERT considers the use of "NE" for reporting under subcategory 5.C.1.2.a to be appropriate as emissions for this subcategory are below the significance threshold.	that it is in accordance with the explanation provided in chapter 7.
W.7	5.C.1 Waste incineration – CO_2, CH_4 and N_2O (W.16, 2021) Transparency	Include information in the NIR to clarify how clinical waste is defined in line with national circumstances.	Resolved. In the NIR (section 7.4.1, p.323), New Zealand clarified the term clinical waste: "clinical wastes refers to a combination of clinical, medical and quarantine wastes". The ERT considers that this definition of clinical waste is consistent with the terminology in the 2006 IPCC Guidelines.	NA
W.8	5.C.2 Open burning of waste – CO_2, CH_4 and N_2O (W.17, 2021) Transparency	Clarify in the NIR that farm fills are disposed of in two different treatment pathways (i.e. under unmanaged landfill and under open burning) and that the AD for both pathways have the same value, and provide some basis on which to justify why the same value of AD is applied for both farms fills and open burning.	Resolved. The Party described in the NIR (pp.312–313 and 325) the two treatment pathways for this uncollected waste, providing justification for assuming a 50:50 split between both treatment options in the absence of better information and expressing the need to understand the split.	NA
W.9	5.D Wastewater treatment and discharge – N_2O (W.10, 2021) (W.22, 2019) Accuracy	Revise the reporting of N_2O emissions from industrial wastewater and sewage sludge applied to soils in the agriculture and waste chapters of the NIR and in CRF table 3.D, and explain any recalculations in the NIR.	Not resolved. During the review, the Party indicated that this is a low-priority issue owing to the expected small scale of emissions. Therefore, New Zealand has not yet taken action to address the recommendation.	Not resolved. It has not been prioritised due to the negligible emissions associated with sludge.
W.10	5.D Wastewater treatment and discharge – CH_4 and N_2O (W.11, 2021) (W.23, 2019) Accuracy	Clarify and report consistent information on the final treatment or disposal of sludge, including incineration and disposal in municipal landfills; review the estimates; and explain any recalculations in the NIR.	Addressing. The Party did not report a clear and consistent overview of final treatment and disposal of sludge in the NIR. The ERT considers that the overview should provide information on all sludge treatment and removal options (reuse, landfilling, biological treatment, incineration), ensuring that the total amount of sludge treated is consistent with the total amount of biochemical oxygen demand removed as sludge in the calculation of emissions from wastewater treatment and discharge (see ID# W.15 in table 5).	Addressing. Volumes of sludge disposed of in managed landfills have been updated according to Eunomia (unpublished). Further improvements will be included a future submission.
W.11	5.D.2 Industrial wastewater – CH_4 (W.12, 2021) (W.24, 2019) Comparability	Estimate and report the amount of CH_4 flared and for energy recovery, respectively, in CRF table 5.D, noting that the amount of CH_4 for energy recovery, if occurring, should probably be reported as "IE" in that table and the estimates reported under the energy sector.	Resolved. The Party reported CH_4 flared as "NE" and CH_4 utilized for energy production as "IE" in CRF table 5.D. On the basis of a number of submissions from Parties included in Annex I to the Convention in a similar situation, the ERT considers that "NE" is appropriate for reporting CH_4 flared.	NA

Note: [1]References in parentheses are to the paragraph(s) and the year(s) of the previous review report(s) in which the issue or problem was raised. Issues are identified in accordance with paras. 80–83 of the UNFCCC review guidelines and classified as per para. 81 of the same guidelines. Problems are identified and classified as problems of transparency, accuracy, consistency, completeness or comparability in accordance with para. 69 of the Article 8 review guidelines in conjunction with decision 4/CMP.11. AD = activity data; CH_4 = methane; CO_2 = carbon dioxide; CRF = common reporting format; CRT = common reporting table; CSC = carbon stock change; EF = emission factor; ERT = expert review team; eq = equivalent; GHG = greenhouse gas; HFCs = hydrofluorocarbons; IE = included elsewhere; IEF = implied emission factor; IPCC = Intergovernmental Panel on Climate Change; IPPU = Industrial Processes and Product Use; kg = kilogram; kt = kilotonne; l = litre; LUCAS = Land Use and Carbon Analysis System; LULUCF = Land Use, Land-Use Change and Forestry; m = metre; MSW = municipal waste disposal; N = nitrogen; NA = not available; NE = not estimated; NIR = National Inventory Report; NO = not occurring; N_2O = nitrous oxide; NZD = New Zealand dollars; PFCs = perfluorocarbons; QA/QC = quality assurance and quality control; SF6 = sulphur hexafluoride; SOC = soil organic carbon; SWDS = solid waste disposable sites; t = tonnes; UNFCCC = United Nations Framework Convention on Climate Change.

Table 5 of the report on the individual review of New Zealand's greenhouse gas inventory submitted in 2022 (UNFCCC, 2023), which can be found here, contains new recommendations related to the review of the 2022 submission. These recommendations, along with New Zealand's latest responses to date, are detailed in table 10.3.2.

Table 10.3.2 New Zealand's response to the additional findings made during the individual review of the 2022 annual submission

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?[2]	New Zealand response
General		No general findings additional to those included in table 3 were made by the ERT during the review.		
Energy				
E.10	1. General (energy sector) – gaseous fuels – CO_2	On the basis of information provided in the NIR (pp.75 and 91) and an annex to the NIR (annex 4, table A4.1), the CO_2 EFs for liquid fuels are based on regular measurements from the only refinery in New Zealand. During the review, the Party clarified that these CO_2 EFs are not based on actual measurements of calorific value and carbon content, but are calculated on the basis of the fuel density. The Party stated that the refinery used to provide approximately 75 per cent of all liquid fuels consumed in New Zealand, but that dropped to 52 per cent in 2021 and the refinery ceased operation in 2022. As of April 2022, the facility is being converted into an import terminal without refinery activities. The ERT recommends that New Zealand review the carbon content and calorific values of the imported liquid fuels in accordance with good practice guidance provided in the 2006 IPCC Guidelines or equivalent international standards and recalculate its estimates on the basis of any changes to the CO_2 EFs.	Yes. Accuracy	Resolved. MBIE now collects fuel property information from liquid fuel importers on a monthly basis. This is used to calculate an annual weighted average carbon content and calorific value for each fuel type. The updated densities and calorific values are published in MBIE's oil statistics, which are available online: www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/oil-statistics. These data are then directly used to prepare the emissions estimates for the National Inventory Report.
IPPU		No findings for the IPPU sector additional to those included in table 3 were made by the ERT during the review.		
Agriculture				
A.12	3.B.1 Cattle – CH_4	New Zealand stated in its NIR (p.185) that, to determine CH_4 emissions from dairy cattle manure in anaerobic lagoons, the default MCF value of 0.76 at an average annual temperature of 15°C was used. However, the ERT noted that New Zealand also stated in its NIR (p.193) that the "current value [sic] for the MCF is 0.74, based on the 2006 IPCC default value for uncovered anaerobic lagoons at an annual temperature of 15 degrees Celsius". The ERT also noted that, in CRF table 3.B(a)s2, New Zealand reported "NA" for the MCF value for anaerobic lagoons used to store and treat manure generated by dairy cattle. In response to a request for clarification of the MCF value for anaerobic lagoons used in the estimates of CH_4 emissions from manure management of dairy cattle, and to specify the range of average annual temperatures used to select the MCF values for the entire reporting period, the Party clarified that the MCF value used is from the 2006 IPCC Guidelines (vol. 4, chap. 10, table 10.17) and	Yes. Transparency	Addressing. Section 5.3.2 in chapter 5 has been corrected to state an MCF value of 0.74 is used. CRT 3.B.1.1 *Dairy cattle* has been updated to report the MCF for the entire reporting period. Research is under way to improve this section of the Agriculture inventory, starting with a nationwide farm survey of dairy manure and effluent management practices.

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?[2]	New Zealand response
		that value (0.74) is correctly stated in the NIR (p.193). The Party also clarified that the MCF value was selected on the basis of an annual average temperature of 15°C, which is a conservative estimate given that average historical temperatures have typically been lower. To confirm this statement, the Party provided the ERT with the data on average annual temperatures for 1990–2020 from the National Institute of Water and Atmospheric Research for the Waikato region, which is a more northern and warmer region of New Zealand where the majority of its dairy cattle are farmed. Additionally, New Zealand stated that the annual temperature ranges from 10°C in the south to 16°C in the north and the MCF for anaerobic lagoon was selected on the basis of the higher end of that range. The ERT recommends that New Zealand (1) correct the omission in the reporting of the MCF value for anaerobic lagoons used to store and treat dairy cattle manure; (2) report the MCF value for anaerobic lagoons in CRF table 3.B(a)s2 for the entire reporting period; and (3) provide the reference source and brief description of the climate data used as the basis for selecting an appropriate MCF value for anaerobic lagoon manure management system from the 2006 IPCC Guidelines (vol. 4, chap. 10, table 10.17).		
LULUCF		No findings for the LULUCF sector additional to those included in table 3 were made by the ERT during the review.		
Waste				
W.12	5.A Solid waste disposal on land – CH_4	The Party reported in its NIR (p.318) that CH_4 recovery from SWDS was estimated assuming a 68 per cent recovery efficiency for SWDS that were open in the latest reporting year and a 52 per cent recovery efficiency for sites that were closed. These recovery efficiencies were justified by referring to an unpublished study by consulting group Eunomia, which cites these percentages as being the instantaneous recovery efficiency (the ratio of CH_4 recovery and predicted generation, using a model for emissions from landfill named the MELMod model) at SWDS in the United Kingdom of Great Britain and Northern Ireland and argues that, with respect to waste composition and biodegradation of organic material, there are no substantial differences between SWDS in the United Kingdom and New Zealand. Also, site management practices appear to be similar. In the absence of more of the data used by operators (to arrive at alternative lifetime capture rates), it is unclear to Eunomia why the rates would differ so widely between active sites in the two countries. The ERT noted that the justification of Eunomia's argument that United Kingdom CH_4 recovery efficiencies are applicable to New Zealand is insufficient. Collection efficiency is dependent on the permeability of the cover soil, the part of the SWDS where CH_4 is collected (with emphasis on freshly deposited waste), well density (gas well/ha) and screening for surface emissions, among other factors. After 2000, the United Kingdom developed strict regulations on this, and it is not clear whether similar regulations exist in New Zealand and, if so, whether they have been successfully implemented. The ERT noted	Yes. Accuracy	Resolved. Country-specific methane recovery rates were gathered from a range of open and closed facilities, varying in size from small to large. These data were provided to the Ministry for the Environment through a voluntary survey conducted in 2024. To estimate landfill gas efficiency for each site, several assumptions were made regarding: 1) gas capture cover type and capture rate, 2) capture rate losses, 3) cover type losses after filling, and 4) capture rate before landfill operations. Details are described in chapter 7, section 7.2.2.

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?[2]	New Zealand response
		that the assumption of a 68/52 per cent recovery rate is not in accordance with the 2006 IPCC Guidelines (vol. 5, chap. 3, pp.3.18–3.19), which indicate that CH_4 recovery should be measured (either directly or indirectly from energy generation). If no measurement data are available, recovery might be estimated on the basis of installed capacity (assuming 35 per cent of this capacity is actually used) or a default recovery of 20 per cent can be assumed for the part of the waste where CH_4 is collected. The ERT also noted that, according to the Eunomia study, SWDS operators do have available measurements of CH_4 collected. However, owing to commercial confidentiality and administrative simplicity, these data are not reported to the competent authorities and so are not available to the GHG inventory team. The ERT recommends that the Party quantify CH_4 recovery on the basis of amounts measured by the SWDS operators. As long as this information is not available, a recovery efficiency of 20 per cent can be assumed for the part of the waste where CH_4 is collected or, alternatively, recovery can be estimated as 35 per cent of available collection capacity in accordance with the 2006 IPCC Guidelines (vol. 5, chap. 3, pp.3.18–3.19). The ERT also encourages the Party to build up an institutional framework, so that measurements of CH_4 collection by the SWDS operators become available to the inventory team.		
W.13	5.A Solid waste disposal on land – CH_4	The Party reported in its NIR (pp.317–318) that CH_4 generation in SWDS was estimated assuming country-specific values for the decay rate constant. This is justified by referring to the unpublished Eunomia study, wherein it is suggested that decay rate constant values from a model for landfill gas named the GasSim model be used because the United Kingdom and New Zealand have similar waste composition and management practices and both, being islands, have a maritime climate. According to the Eunomia study, the use of the GasSim factors allows for maritime climate to be taken into account, which is not the case for the default decay rate constant values from the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.17). However, it is indicated in the study that these values should be further verified in New Zealand using a similar benchmarking process to that undertaken in the United Kingdom to identify whether the appropriate factors are being used as New Zealand sites typically have higher temperatures and higher rainfall than those in the United Kingdom. The 2006 IPCC Guidelines (vol. 1, chap. 2, p.2.12 and table 2.2) give guidance on what information can be used for developing country-specific model parameters. Other specific studies, census, surveys, measurement and monitoring data can also be used. However, the factors must be representative and standard methods must be used. The ERT noted that the assumptions in GasSim are not transparent and the details of the validation of GasSim in British landfills are not available for review. The ERT agrees that the model from the 2006 IPCC Guidelines has its limitations and that GasSim might result in a better prediction for both the United Kingdom and New Zealand. However, an open and scientific discussion on the accuracy of GasSim's prediction is needed before	Yes. Accuracy	Resolved. While the k-values used in the past four submissions of the Inventory were derived from Eunomia (unpublished), it was decided to revert to the default IPCC values due to the limited number of site-specific models available to calibrate decay rate performance accurately.

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?[2]	New Zealand response
		results from the GasSim model can be accepted for GHG inventory purposes. The ERT agrees with the opinion expressed in the Eunomia study that a benchmarking process would provide valuable information on biodegradation in SWDS in New Zealand. The ERT recommends that the Party either justify that the decay rate constant values from the GasSim model are appropriate for New Zealand's circumstances, for example by undertaking a benchmarking process to ensure that the values are appropriate for the country's climatic conditions, or quantify CH_4 generation from SWDS using the default decay rate constant values from the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.17).		
W.14	5.A Solid waste disposal on land – CH_4	The Party reported in its NIR (p.317) that CH_4 emissions from SWDS are estimated assuming a fraction of CH_4 in landfill gas of 0.57. This is justified by referring to the unpublished Eunomia study, wherein reference is made to Golder Associates (2014), according to which the fraction of CH_4 in landfill is based on 50,000 landfill gas monitoring data sets supplied by SWDS in the United Kingdom for 2010–2012. The ERT noted that the value of 0.57, as proposed by Golder Associates (2014), is based on available analyses of the composition of recovered landfill gas. The 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.15) indicate that, in SWDS, CO_2 is absorbed in seepage water and the neutral condition of the SWDS transforms much of the absorbed CO_2 to bicarbonate. Therefore, if the fraction of CH_4 in landfill gas is based on measurements of CH_4 concentrations measured in emitted landfill gas, it is good practice to adjust for the CO_2 absorption in seepage water. During the review, the Party confirmed that while the value of 0.57 was based on experimental data, CO_2 absorption was not accounted for in Golder Associates (2014). The ERT recommends that the Party either adjust the county-specific value of 0.57 for CO_2 absorption in seepage water or revert to the default value of 0.5 from the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.15).	Yes. Accuracy	Resolved. The fraction of methane in landfill gas (F) was set at 50 per cent for both municipal and uncategorised landfills. This value was revised from a previous estimate of 57 per cent, which was based on landfill gas monitoring data from the United Kingdom. This earlier value was assumed to be applicable due to similarities in landfill management practices between New Zealand and the United Kingdom. However, it was decided that, in the absence of country-specific analyses to account for CO_2 absorption in seepage water, the default IPCC value will be used for the fraction of methane in landfill gas.
W.15	5.D Wastewater treatment and discharge – CH_4 and N_2O	The Party reported in its NIR (p.329) that sludge amounts are reported as "IE" for both domestic and industrial wastewater because most of the sludge is sent to SWDS, and that AD and emissions from sludge disposal are reported in the solid waste disposal source category (see NIR p.316). In addition, emissions from sludge treatment and disposal are mentioned in the NIR for the energy (p.86) and agriculture (p.201) sectors, as well as for the waste sector under the category incineration (p.325). The ERT noted that this is not in agreement with the 2006 IPCC Guidelines. Where statistics on sludge removal are not available, the amount of TOW removed as sludge in equations 6.1 and 6.4 of the 2006 IPCC Guidelines (vol. 5, chap. 6) is zero. In this case, all organic material (TOW) is assumed to be completely converted to gases (i.e. CO_2, CH_4, N and N_2O) and reported under wastewater treatment and discharge (category 5.D) and CH_4 and N_2O emissions from sludge treatment and disposal are included in the total emissions for category 5.D, assuming the EFs for category 5.D (see the 2006 IPCC Guidelines, vol. 5, chap. 6.6.1). When sludge is included in other categories, the calculation of emissions for category 5.D should be corrected for the corresponding amount of TOW removed as sludge, as indicated in equations 6.1 and	Yes. Accuracy	Not resolved. New Zealand plans to collect information on the mass of sludge removed and organic matter content in dry sludge, to revise its current estimates. This has not yet been prioritised due to the negligible emissions associated with sludge.

ID#	Finding classification	Description of finding with recommendation or encouragement	Is finding an issue/problem?[2]	New Zealand response
		6.4 of the 2006 IPCC Guidelines (vol. 5, chap. 6, pp.6.11 and 6.18, under "completeness" and "reporting and documentation"). Failure to make this correction results in double counting of emissions. Therefore, if New Zealand has information on the mass of sludge removed and an estimate of the organic matter in dry sludge, the amount of TOW removed as sludge might be calculated as the product of (1) the total dry mass of sludge, (2) the average organic matter content in sludge and (3) a conversion of organic matter to chemical oxygen demand. When one assumes that organic matter can be described as cellulose ($C(H_2O)_n$), the oxidation proceeds via $C(H_2O)_n + n\ O_2 \rightarrow n\ CO_2 + n\ H_2O$ and the conversion of 1 kg organic matter corresponds to 32/30 kg chemical oxygen demand. The ERT recommends that the Party revise its estimates to prevent double counting of emissions by either removing emissions from sludge treatment and discharge for all sectors other than for category 5.D, or correcting the calculation of emissions for category 5.D using equations 6.1 and 6.4 from the 2006 IPCC Guidelines and an amount of TOW removed as sludge that corresponds to the AD for emissions from sludge treatment and disposal for categories 5.A and 5.C and in the energy and agriculture sectors. If New Zealand were to choose the first option, the issues in ID# W.9 and W.10 in table 3 would automatically be resolved as well.		

Note: [2]Recommendations made by the expert review team during the review are related to issues as defined in para. 81 of the United Nations Framework Convention on Climate Change review guidelines or problems as defined in para. 69 of the Article 8 review guidelines (UNFCCC, 2023). AD = activity data; CO_2 = carbon dioxide; CH_4 = methane; CRF = common reporting format; CRT = common reporting table; EFs = emission factors; ERT = expert review team; GHG = greenhouse gas; IE = included elsewhere; IPCC = Intergovernmental Panel on Climate Change; IPPU = Industrial Processes and Product Use; kg = kilogram; LULUCF = Land Use, Land-Use Change and Forestry; MBIE = Ministry of Business, Innovation and Employment; MCF = methane conversion factor; N = nitrogen; NA = not available; NIR = National Inventory Report; N_2O = nitrous oxide; SWDS = solid waste disposable sites; TOW = total organic product in wastewater.

Chapter 10: References

Easdale TA, Richardson SJ, Marden M, England JR, Gayoso-Aguilar J, Guerra-Carcamo JE, Brandon AM. 2019. Root biomass allocation in southern temperate forests. *Forest Ecology and Management* 453: 117542.

Eunomia. Unpublished. Improvements to Estimates of Greenhouse Gas Emissions from Landfills. Contract report prepared for the Ministry for the Environment in 2020.

Hill, J. 2012. *Recalculate Pork Industry Emissions Inventory*. Report prepared for the Ministry of Agriculture and Forestry by Massey University and the New Zealand Pork Industry Board. Wellington: Ministry of Agriculture and Forestry.

IPCC. 2006. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* IPCC National Greenhouse Gas Inventories Programme. Japan: Institute for Global Environmental Strategies for IPCC.

IPCC. 2019. Calvo Buendia E, Tanabe K, Kranjc A, Baasansuren J, Fukuda M, Ngarize S, Osako A, Pyrozhenko Y, Shermanau P, Federici S (eds). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Switzerland: IPCC.

Ministry for the Environment. 2022. *Te Hau Mārohi ki Anamata: Towards a Productive, Sustainable and Inclusive Economy – Aotearoa New Zealand's First Emissions Reduction Plan.* Wellington: Ministry for the Environment.

Ministry for the Environment, 2024. *Waste Minimisation Act 2008*. Retrieved 27 February 2025.

Pickering A, Gibbs J, Wear S, Fick J, Tomlin H. 2024. *Methodology for Calculation of New Zealand's Agricultural Greenhouse Gas Emissions*. Version 10. Wellington: Ministry for Primary Industries. Retrieved 13 January 2025.

Ritchie H. 2024. *Updating Emissions Calculations for Pigs in the New Zealand Greenhouse Gas Inventory Report*. Report prepared for the Ministry for Primary Industries by NZ Pork. Wellington: Ministry for Primary Industries.

Rollo M, Ledgard S, Longhurst B. 2017. *Final Report: Trends in Dairy Effluent Management.* Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

Sangster C. 2023. *Seasonality of Wool Growth in AIM*. MPI Technical Report. Wellington: Ministry for Primary Industries.

Sise J. 2023. *Minor Animal Categories*. Report prepared for the Ministry for Primary Industries by AbacusBio. Wellington: Ministry for Primary Industries.

Stats NZ. 2023. *Agricultural production statistics: Year to June 2022 (final)*. Retrieved 28 February 2025.

Stats NZ. 2024. *Agricultural production statistics: Year to June 2023 (final)*. Retrieved 28 February 2025.

Stevens D, Ward J. 2023. *Splitting Emissions Intensity Values between Venison and Velvet Antler in the Deer Industry*. Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

UNFCCC. 2023. FCCC/ARR/2022/NZL. *Report on the Individual Review of the Annual Submission of New Zealand Submitted in 2022.* Centralised Review.

van der Weerden A, de Klein C, Kelliher F, Rollo M. 2014. *Reporting to 2006 IPCC Guidelines for N_2O Emissions from Additional Sources of Organic N: Final Report.* MPI Technical Report. Wellington: Ministry for Primary Industries.

van der Weerden T, Rutherford A. 2024. *Nitrous Oxide Emissions from Non-manure Organic Amendments to Soils*. Report prepared for the Ministry for Primary Industries by AgResearch. Wellington: Ministry for Primary Industries.

Welten B, Mercer G, Smith C, Sprosen M, Ledgard S. 2021. *Refining Estimates of Nitrogen Leaching for the New Zealand Agricultural Greenhouse Gas Inventory.* Contract report prepared for the Ministry for Primary Industries.

Woods J, Orwin DF. 1988. Seasonal variations in the dimensions of individual Romney wool fibres determined by a rapid autoradiographic technique. *New Zealand Journal of Agricultural Research* 31(3): 311–323.