Prepared for
Greater Wellington Regional Council
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AECOM

Carterton Emissions Inventory 2021/22

19-Jun-2023

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Carterton Emissions Inventory 2021/22

Client: Greater Wellington Regional Council

Co No.: N/A

Prepared by

AECOM New Zealand Limited
Level 19, 171 Featherston Street, Pōneke|Wellington 6011, PO Box 27277, Pōneke|Wellington 6141, New Zealand
T +64 4 896 6000 F +64 4 896 6001 www.aecom.com

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Reviewed by Adam Swithinbank

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Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
1	19-June-2023	Final	Anthony Hume Associate Director - Practice Leader Sustainability & Resilience	

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Executive Summary

Greenhouse Gas (GHG) emissions for the Carterton Territorial Area (that is covered by the Carterton District Council) have been measured using the Global Protocol for Community Scale Greenhouse Gas Emissions Inventory (GPC) methodology. This approach includes emissions from Stationary Energy, Transport, Waste, Industrial Processes and Product Use (IPPU), Agriculture and Forestry sectors. This document reports greenhouse gas emissions produced in or resulting from activity or consumption within the geographic boundaries of the Carterton District Territorial Area for the 2021/22 financial reporting year and examines greenhouse gas emissions produced from 2018/19 to 2021/22.

The Carterton District Territorial Area is referred to hereafter as Carterton for ease. Greenhouse gas emissions are generally reported in this document in units of carbon dioxide equivalents (CO_2e) and are referred to as 'emissions'.

Major findings of the project include:

2021/22 Emissions Inventory

- In the 2021/22 reporting year (1st July 2021 to 30th June 2022), **Total Gross Emissions** in Carterton were 338,506 tCO_2e.
- **Agriculture** (e.g. emissions from livestock and crops) is by far the largest emitting sector in Carterton, representing 78% of total gross emissions, with enteric fermentation from livestock accounting for 59% of Carterton's total gross emissions.
- **Transport** (e.g., emissions from road and air travel) is the second largest emitting sector in Carterton, representing 16% of total gross emissions, with petrol and diesel consumption accounting for 14% of Carterton's total gross emissions.
- **Stationary Energy** (e.g. emissions relating to electricity and natural gas consumption) is the third-highest emitting sector in the district, accounting for 4% of total gross emissions. **Waste** produced 2% of Carterton's total gross emissions.
- **Net Forestry** emissions were -473,653 in 2021/22 as carbon sequestration (carbon captured and stored in plants or soil by forests) was higher than emissions from forest harvesting (e.g., the release of carbon from timber, roots and organic matter following harvesting). Net Forestry emissions are not included in total gross emissions but in total net emissions.
- **Total Net Emissions** in Carterton were -135,147 tCO_2e. Total net emissions includes sequestration and emissions release from forestry and can fluctuate depending on forestry activity.

Changes in Annual Emissions, 2018/19 to 2021/22

- Between 2018/19 and 2021/22, **Total Gross Emissions** in Carterton decreased from 348,411 tCO_2e to 338,506 tCO_2e, a decrease of 3% (9,905 tCO_2e), largely due to a reduction in transport emissions.
- Over this time the population of Carterton increased by 6.2% (590 people), resulting in **Per Capita Gross Emissions** in Carterton decreasing by 9% between 2018/19 and 2021/22, from 36.3 to 33.3 tCO_2e per person per year.
- Emissions from **Transport** decreased by 14%, between 2018/19 and 2021/22 (8,352 tCO_2e), driven by a reduction in air travel emissions and on-road petrol and diesel consumption.
- Emissions from **Stationary Energy** decreased by 5% between 2018/19 and 2021/22 (739 tCO_2e), mainly due to decreased use of fossil fuel electricity generation in the national grid. Emissions from **Agriculture** decreased by 0.3% (716 tCO_2e). Emissions from **Waste** decreased by 3% between 2019/20 and 2021/22 (167 tCO_2e).
- **Net Forestry** sequestration increased by 150,996 tCO_2e between 2018/19 and 2021/22, from -322,657 tCO_2e to -473,653 tCO_2e. This was mainly driven by an increase in sequestration from commercial forestry due to a 39% increase in the area of exotic forest.

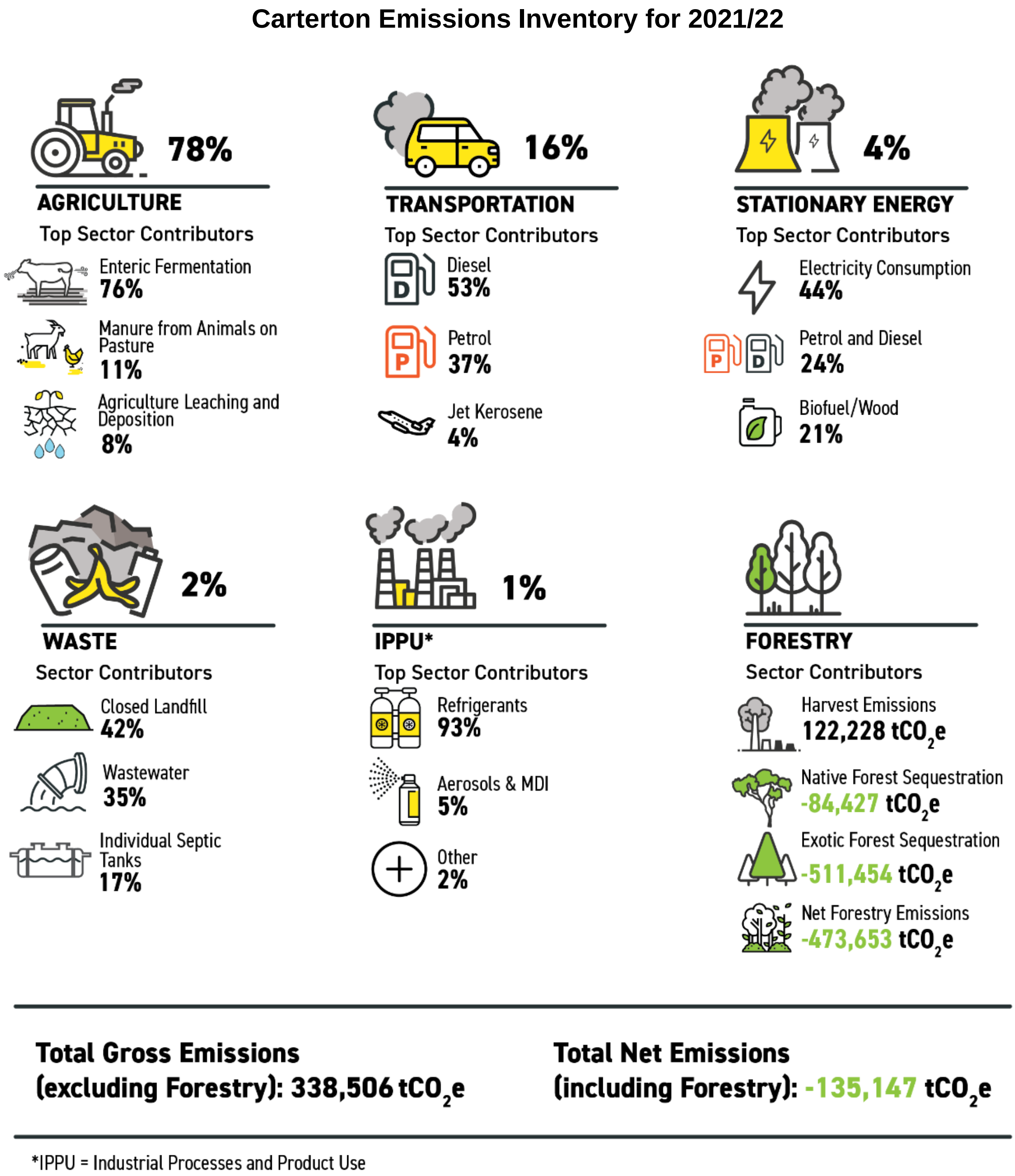

Figure 1: Carterton 2021/22 Emissions Inventory

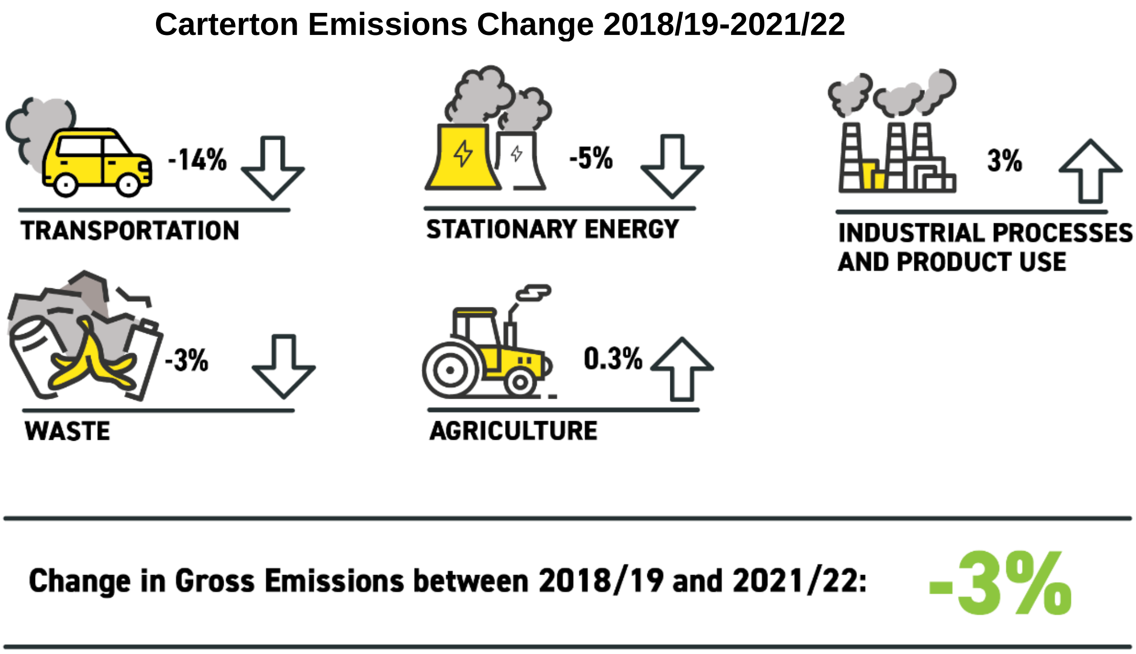

Figure 2: Change in Carterton Emissions Inventory between 2018/19 and 2021/22

1.0 Introduction

AECOM New Zealand Limited (AECOM) was commissioned by the Greater Wellington Regional Council to assist in the development of community-scale greenhouse gas (GHG) footprints for the Carterton District Territorial Area for the 2018/19 to 2021/22 financial years. As part of this work, AECOM recalculated emissions for the 2018/19 financial year, previously calculated by AECOM, using current best-practice methods, updated data, and additional emission sources to enable direct comparison to the other reported years.

This is part of a wider study to develop emissions inventories for each district within the Greater Wellington region. Emissions are reported for the financial year period from 1 July to 30 June for the respective years. The study boundary reported in the following pages incorporates the jurisdiction of the Carterton District Council.

The Carterton District Territorial Area is referred to hereafter as Carterton for ease. Greenhouse gas emissions are generally reported in this document in units of carbon dioxide equivalents (CO_2e) and are referred to as 'emissions'.

2.0 Approach and Limitations

The methodological approach used to calculate emissions follows the Global Protocol for Community Scale Greenhouse Gas Emissions Inventory v1.1 (GPC) published by the World Resources Institute (WRI) 2021. The GPC includes emissions from Stationary Energy, Transport, Waste, Industrial Processes and Product Use (IPPU), Agriculture, and Forestry activities within the district's boundary. The sector calculations for Agriculture, Forestry and Waste are based on Intergovernmental Panel on Climate Change (IPCC) workbooks and guidance for emissions measurement. The sector calculators also use methods consistent with GHG Protocol standards published by the WRI for emissions measurement when needed.

The same methodology has been used for other community-scale GHG footprints around New Zealand, (e.g. the Bay of Plenty region, Hawke's Bay region, Auckland, Christchurch, Dunedin, and the Waikato region) and internationally. The GPC methodology[1] represents international best practice for city and regional level GHG emissions reporting and offers a robust, established method, which enables comparisons between different studies.

This emissions inventory assesses both direct and indirect emissions sources. Direct emissions are production-based and occur within the geographic area (Scope 1 in the GPC reporting framework). Indirect emissions are produced outside the geographic boundary (Scope 2 and 3) but are allocated to the location of consumption. An example of indirect emissions is those associated with the consumption of electricity, which is supplied by the national grid (these are classed as Scope 2). All other indirect emissions such as cross-boundary travel (e.g. flights) and energy transportation and distribution losses fit into Scope 3.

All major assumptions made during data collection and analysis have been detailed within **Appendix A – Assumptions**. The following aspects are worth noting in reviewing the emissions inventory:

- Emissions are calculated by collecting or estimating data for each emissions source and then converting that data into emissions (tCO_2e) using an emission factor. Emission factors enable an estimate of emissions from a unit of activity data (e.g. litres of fuel used)[2]. This inventory uses applicable emission factors predominantly from the New Zealand Ministry of the Environment (MfE).
- Emissions are expressed on a carbon dioxide-equivalent basis (CO_2e) including climate change feedback using the 100-year Global Warming Potential (GWP) values[3]. Climate change feedbacks are the climate change impacts from GHGs that are increased as the climate changes. For example, once the Earth begins to warm, it triggers other processes on the surface and in the

[1] http://www.ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
[2] https://environment.govt.nz/publications/measuring-emissions-a-guide-for-organisations-2022-quick-guide/
[3] https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf (Table 8.7)

atmosphere. Current climate change feedback guidance is important to estimate the long-term impacts of GHGs.

- GPC reporting is predominately production-based (as opposed to consumption-based) and focused on emissions released within the geographic boundary but includes indirect emissions from energy consumption and cross boundary travel from sources such as air travel. Production-based approaches exclude globally produced emissions relating to consumption (e.g., embodied emissions relating to products produced elsewhere but consumed within the geographic area, such as imported food products, cars, phones, clothes etc.).
- Total emissions are reported as both gross emissions (excluding Forestry) and net emissions (including Forestry).
- Emissions for individual main greenhouse gases for each emissions source are provided in the supplementary spreadsheet information supplied with this report.
- Where location specific data were not accessible, information was calculated based on national or regional level data.
- Transport emissions:
  - Transport emissions associated with air travel, rail, and marine fuel were calculated by working out the emissions relating to each journey arriving or departing the area based on data provided by the relevant operators. Emissions for these sources are then split equally between the destination and origin. Emissions relating to a particular point source (e.g. an airport or port) are allocated to the expected users of that source, not just the area that it is located in. For example, in the Greater Wellington region, the Wellington Airport is treated as a regional airport where it is expected that all territorial authorities will use Wellington Airport for air travel. Therefore, emissions from this source have been allocated to all regional territorial authorities based on population. This is also applicable to marine freight and inter-island marine journeys.
  - All other transport emissions are calculated using the fuel sold in the area (e.g. petrol, diesel, LPG). Fuel sold in an area does not always mean that the fuel is used in that area, however this approach is considered to be a robust and comparable estimate of fuel consumption in a geographic area.
- Solid waste emissions:
  - Solid waste emissions from landfill are measured using the IPCC First Order Decay method that covers landfill activity between 1950 and the present day, as per the GPC reporting requirements. This method accounts for the gradual release of emissions from waste over a long period of time, and so calculates the emissions produced per year from waste in landfill (including emissions from closed landfill sites).
  - Emissions are calculated for waste produced within the geographic boundary, even if they are transported outside the boundary to be entered into landfill. Landfill waste for Carterton is understood to have been disposed of at Bonny Glenn landfill in the Manawatu since the closure of the Carterton Landfill in 2004 and Masterton Landfill in 2006.
- Wastewater emissions:
  - Wastewater treatment plant emissions have been calculated following WaterNZ (2021) guidance. Wastewater emissions include those released directly from wastewater treatment, flaring of captured gas, and discharge onto land/water. Emissions relating to biosolid waste from wastewater treatment sent to landfill have been included in the solid waste emissions source category.
  - Wastewater emissions from populations not connected to centralised wastewater treatment plants have been estimated by assuming that these populations use septic tank systems.
- Industrial Processes and Product Use (IPPU) emissions:

- IPPU emissions are estimated based on data provided in the New Zealand Greenhouse Gas Emissions 1990-2020 report (MfE 2022). Emissions are estimated on a per capita basis applying a national average per person.

- Forestry emissions:
    - This emissions inventory accounts for forest carbon stock changes from afforestation, reforestation, deforestation, and forest management (i.e. it applies land-use accounting conventions under the United Nations Framework Convention on Climate Change rather than the Kyoto Protocol). It treats emissions from harvesting and deforestation as instantaneous rather than accounting for the longer-term emission flows associated with harvested wood products.
    - The emissions inventory considers regenerating (growing) forest areas only. Capture of carbon from the atmosphere is negligible for mature forests that have reached a steady state.

Overall sector data and results for the emissions inventory have been provided to Carterton District Council in calculation table spreadsheets. All assumptions made during data collection and analysis have been detailed within **Appendix A – Assumptions**.

Uncertainty

It is important to consider the level of uncertainty associated with the results, particularly given the different datasets used. Depending on data availability, national, regional, and local datasets are used across the different calculators. At the national level, New Zealand's Greenhouse Gas Inventory shows that for 2020 (the most recent nationwide inventory) an estimate of gross emissions uncertainty was ±8.8%, whereas a net emissions uncertainty estimate was ±26.9% and uncertainty in the gross trend was ±6.4%. These levels of uncertainty should be considered when interpreting the results of this emissions inventory (MfE, 2022[4]).

StatsNZ Regional Inventory

Emissions reported using the GPC method (as reported here) differ from the regional emissions estimates produced by StatsNZ. The differences are due to differences in scope, coverage, data sources, emission factors, and methods[5].

Main differences:

- The StatsNZ approach is entirely based on production, while the GPC approach includes elements of consumption (e.g. where emissions from electricity are allocated to where the electricity is consumed, not where it is generated).
- The StatsNZ method uses a residence approach, while GPC is based on the territory approach.
- This report uses global warming potentials from the IPCC Fifth Assessment Report with climate change feedbacks, while the StatsNZ estimates use those from the Fourth Assessment Report, without climate change feedbacks.
- The StatsNZ estimates also don't include the scope 3 emissions reported here, such as cross boundary air travel and marine freight, or sequestration from forestry.

[4] https://environment.govt.nz/assets/publications/GhG-Inventory/New-Zealand-Greenhouse-Gas-Inventory-1990-2020-Chapters-1-15.pdf
[5] https://www.stats.govt.nz/methods/about-regional-greenhouse-gas-emissions-statistics/

3.0 Emissions Inventory for 2021/22

The paragraphs, figures and tables below outline Carterton's greenhouse gas emissions, referred to as 'emissions' in this assessment. This includes Carterton's total emissions, emissions from each sector, and major emissions sources within each sector. The focus of emissions reporting is on gross emissions.

During the 2021/22 reporting period, Carterton emitted **Total Gross Emissions** of 338,506 tCO_2e. Agricultural emissions are by far the district's most significant contributors to total gross emissions. Note that gross emissions do not account for Forestry sequestration and harvesting emissions. A breakdown of net emissions (i.e. including results from Forestry resources) is reported separately in section 3.7.

The population of Carterton in 2021/22 was approximately 10,175 people, resulting in per capita gross emissions of 33.3 tCO_2e/person. Discussion of per capita emissions is limited to when it is useful for comparing emission figures against other territorial authorities.

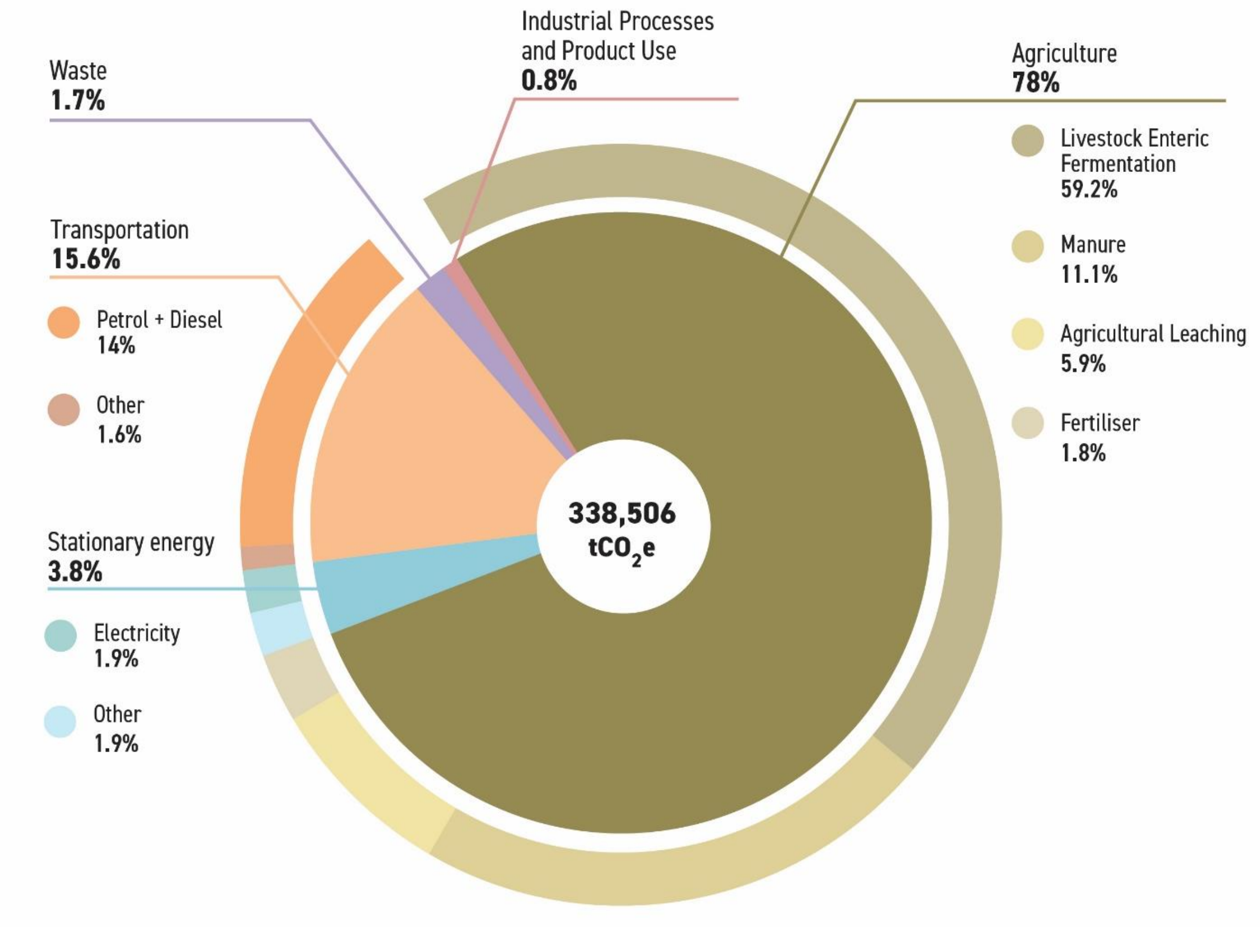

Figure 3: Carterton District's total gross GHG emissions split by sector (tCO_2e).

The emissions inventory comprises emissions from six different sectors, summarised below. Due to rounding, there may be discrepancies between the sum of reported figures and reported totals.

The change in emissions from each emission source between 2018/19 and 2021/22 is presented in section 4.0. This includes analysis of notable changes in emissions.

3.1 Agriculture

Agriculture emitted 264,094 tCO_2e in 2021/22 (78% of Carterton's gross emissions).

Agricultural emissions are the result of both livestock and crop farming within the geographic area. Enteric fermentation from livestock produced 76% of Carterton's agricultural emissions (200,515 tCO_2e). Enteric fermentation GHG emissions are produced by methane (CH_4) released from the digestive process of ruminant animals (e.g., cattle and sheep). The second highest source of Agricultural emissions was produced by unmanaged manure from grazing animals on pasture (28,911 tCO_2e).

Table 1 Agriculture emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Enteric Fermentation	200,515	59.2%	75.9%
Unmanaged Manure on Pasture	28,911	8.5%	10.9%
Agricultural Leaching and Deposition (manure, urine, and fertiliser)	19,910	5.9%	7.5%
Managed Manure	8,527	2.5%	3.2%
Fertilisers on Land	6,231	1.8%	2.4%
Total	**264,094**	**78.0%**	**100%**

Livestock was responsible for the majority of the Agriculture sector's GHG emissions. Sheep account for 41% of agricultural emissions in Carterton, with dairy cattle accounting for 32% and non-dairy cattle accounting for 22%. In 2021/22, there were an estimated 199,404 sheep in Carterton, 20,665 dairy cattle and 23,067 non-dairy cattle.

Table 2 Agriculture emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Sheep	109,324	32.3%	41.4%
Dairy Cattle	83,941	24.8%	31.8%
Non-Dairy Cattle	59,162	17.5%	22.4%
Fertliser	7,830	2.3%	3.0%
Other Livestock	3,838	1.1%	1.5%
Total	**264,094**	**78.0%**	**100.0%**

3.2 Transport

Producing 52,883 tCO_2e in 2021/22, Transport was Carterton's second-highest emitting sector 16% of total gross emissions). Air travel and marine travel emissions relating to the Wellington Airport and CentrePort have been split between all territorial authority areas in the region (see below).

Table 3 Transport energy emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Diesel	27,946	8.3%	52.8%
Petrol	19,523	5.8%	36.9%
Jet Kerosene (Air Travel)	2,054	0.6%	3.9%
Marine Freight	1,930	0.6%	3.6%
Marine (Inter-Island Ferries)	922	0.3%	1.7%
Rail (Diesel)	412	0.1%	0.8%
LPG	86	<0.1%	0.2%
Aviation Gas (Air Travel)	11	<0.1%	<0.1%
Total	**52,883**	**15.6%**	**100%**

Most of the Transport emissions in 2021/22 can be attributed to petrol and diesel, which produced 27,946 tCO_2e and 19,523 tCO_2e respectively (collectively 90% of the sector's emissions and 14% of total gross emissions). Diesel and petrol transport emissions are broken down into on-road and off-road use. On-road transport consists of all standard road vehicles used on public roads (cars, trucks, buses, etc.). Off-road transport consists of all fuel used for vehicle movement off roads (agricultural tractors and vehicles, forklifts, etc.). On-road transport produced 41,942 tCO_2e in 2021/22 (79% of Transport emissions and 12% of total gross emissions) and off-road transport produced 5,613 tCO_2e (11% of Transport emissions).

Table 4 Petrol and diesel emissions – on-road and off-road

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Diesel - On-Road	22,599	6.7%	42.7%
Petrol - On-Road	19,343	5.7%	36.6%
Diesel - Off-Road	5,348	1.6%	10.1%
Petrol - Off-Road	179	0.1%	0.3%
Petrol and Diesel Total	**47,469**	**14.0%**	**89.8%**

The next largest emission source for Carterton in 2021/22 is jet kerosene (aircraft jet fuel), contributing 4% of the sector's emissions and 0.6% of total gross emissions (2,054 tCO_2e). Jet kerosene emissions are based on the fuel consumed by aircraft journeys to and from Wellington, with emissions split equally between the origin and destination location. The Wellington Airport has been considered to be a regional airport so emissions from jet kerosene have been split between all territorial authorities in the Greater Wellington Region based on population. It is important to note that jet kerosene emissions for Carterton in 2021/22 were 58% lower than in 2018/19, largely due to the restriction on international travel through Wellington Airport due to the COVID-19 pandemic (see section 7.0), it is likely that this will increase in 2022/23.

The remaining Transport emissions are attributed to marine freight, inter-island ferries, rail, aviation gas (used by small aircraft), and LPG use for transport (e.g., forklifts).

Emissions from marine freight have been divided between all territorial authorities in the Greater Wellington region based on relative population sizes. It is understood that imports and exports through this port are not exclusively related to activities in the Greater Wellington region; however, to ensure that these emissions are reflected in community carbon footprints as per the GPC requirements, this approach is appropriate. A similar consideration has been applied to aircraft emissions relating to Wellington Airport and inter-island ferry journeys. All assumptions have been detailed in the appendix.

3.3 Stationary Energy

Stationary Energy produced 12,893 tCO_2e in 2021/22, contributing 4% to Carterton's total gross emissions.

Table 5 Stationary Energy emissions by emission source

Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Electricity Consumption	5,715	1.7%	44.3%
Stationary Petrol & Diesel Use	3,111	0.9%	24.1%
Biofuel / Wood	2,687	0.8%	20.8%
LPG	683	0.2%	5.3%
Electricity Transmission & Distribution Losses	606	0.2%	4.7%
Coal	91	0.0%	0.7%
Total:	**12,893**	**3.8%**	**100%**

Electricity consumption was the cause of 44% of Stationary Energy emissions in 2021/22 (5,715 tCO_2e) and 2% of Carterton's total gross emissions (6,321 tCO_2e when including transmission and distribution losses related to the consumption). Electricity consumption emissions depend on the amount of consumption (in kWh), and the emissions intensity of the national grid (tCO2e/kWh). The emissions intensity of the national grid is determined by overall national electricity generation in a particular year (e.g. from fossil fuels or renewable sources). Overall, national electricity generation can fluctuate year on year based on factors such as low rainfall reducing hydropower generation levels, resulting in changes to electricity consumption emissions even when consumption levels haven't changed. This can be seen between 2020/21 and 2021/22 where, despite no significant change in consumption, electricity consumption emissions were 34% higher in 2020/21 than in 2021/22 due to increased use of fossil fuel generation that year caused by reduced hydro generation (see Section 4.2).

Stationary petrol and diesel use accounted for 24% of Stationary Energy emissions in 2021/22 (3,111 tCO_2e). The burning of biofuel / wood generated 21% of Stationary Energy emissions in 2021/22 (2,687 tCO_2e). The use of LPG and burning of coal produced the remaining Stationary Energy emissions.

Biogenic CO_2 emissions from biofuels have not been included in these totals and are reported separately in Section 3.10.

3.4 Waste

Waste originating in Carterton (solid waste and wastewater) produced 5,818 tCO_2e in 2021/22.

Table 6 Waste emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Closed Landfill Sites	2,447	0.7%	42.1%
Wastewater Treatment Plants	2,047	0.6%	35.2%
Individual Septic Tanks	986	0.3%	17.0%
Open Landfill Sites	337	0.1%	5.8%
Total:	**5,818**	**1.7%**	**100%**

Wastewater treatment (treatment plants and individual septic tanks) accounted for 52% of total waste emissions in 2021/22 (3,034 tCO_2e). About half of the households in Carterton (53%) are connected to wastewater treatment plants, producing total emissions of 2,047 tCO_2e in wastewater emissions. Wastewater treatment plant emissions increased by 34% between 2018/19 and 2021/22 due to an increase in processed biosolids, however it is unclear as to why this increase has occurred. Households not connected to centralised wastewater treatment plants (i.e., using individual septic tanks) produced 986 tCO_2e in wastewater emissions. Better data on wastewater treatment in Carterton would improve the accuracy of the results for this emission source

Landfill waste produced 48% of waste emissions (2,784 tCO_2e in 2021/22). Solid waste emissions include emissions from open (operating) landfill sites and closed landfill sites. Open landfill sites produced 337 tCO_2e in 2021/22, and closed landfill sites produced 2,447 tCO_2e in 2021/22. Both open and closed landfills emit landfill (methane) gas from the breakdown of organic materials disposed of in the landfill for many years after waste enters the landfill.

Landfill emissions are those that are the result of waste produced in Carterton and emitted in the reporting year, calculated based on all the waste sent to landfill over time. It is noted that the waste produced in Carterton is sent to Bonny Glenn Landfill in the Manawatu since the Carterton Landfill closed in 2004 and the Masterton Landfill closed in 2006.

3.5 Industrial Processes and Product Use (IPPU)

IPPU in Carterton produced 2,817 tCO_2e in 2021/22, contributing 0.8% to Carterton's total gross emissions. This sector includes emissions associated with the consumption of industrial products and synthetic gases containing GHGs for refrigerants, foam blowing, fire extinguishers, aerosols, metered dose inhalers and Sulphur Hexafluoride for electrical insulation and equipment production. No known industrial processes (as defined in the GPC requirements) are present in Carterton (e.g., aluminum manufacture).

IPPU emissions do not include energy use for industrial manufacturing, which is included in the relevant Stationary Energy sub-category (e.g., coal, electricity and/or petrol and diesel). These emissions are based on nationally reported IPPU emissions and apportioned based on population due to the difficulty of allocating emissions to particular geographic locations. Addressing IPPU emissions is typically a national policy issue.

The most significant contributor to IPPU emissions is refrigerants, which produced 93% of IPPU emissions (2,621 tCO_2e).

Table 7 Industrial processes and product use emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Refrigerants and Air Conditioning	2,621	0.8%	93.0%
Aerosols	146	<0.1%	5.2%
SF6 - Electrical Equipment	29	<0.1%	1.0%
Foam Blowing	11	<0.1%	0.4%
SF6 - Other	6	<0.1%	0.2%
Fire Extinguishers	4	<0.1%	0.2%
Total	**2,817**	**0.8%**	**100%**

3.6 Forestry

Net Forestry emissions include:

- Sequestration of carbon from the atmosphere from native forests (e.g. mānuka and kānuka) and exotic forest (e.g. pine) sequesters (captures) while the trees are growing to maturity and,
- emissions released due to harvesting of forests via the release of carbon from organic matter and soils following harvesting.

When forest sequestration exceeds emissions from harvesting in a particular year, the extra carbon sequestered by forest results in net-negative Forestry emissions. Conversely, when emissions from harvesting exceed the amount of carbon sequestered by native and exotic forests, then Forestry emissions will be a net-positive source of emissions.

Total sequestration in 2021/22 was 595,881 tCO_2e (mostly from exotic forests), while harvesting emissions were 122,228 tCO_2e. This meant that Forestry in Carterton was a net negative source of emissions in 2021/22 (rather than a positive source of emissions, where harvesting emissions exceed sequestration). Total Forestry emissions in 2021/22 were therefore -473,653 tCO_2e. It is noted that the harvesting of exotic forests can be cyclical in nature. Some years will have higher sequestration, and some years will have higher harvesting emissions determined by the age of forests, commercial operators, and the global market.

Table 8 Forestry emissions by emission source (including sequestration)

Sector / Emissions Source	tCO_2e
Harvest Emissions	122,228
Native Forest Sequestration	-84,427
Exotic Forest Sequestration	-511,454
Total	**-473,653**

3.7 Net Emissions

Net emissions differ from gross emissions because they include emissions related to forestry activity (harvesting emissions and sequestration). The cyclical nature of harvesting and planting regimes influences the observed forestry emissions, which in 2021/22 were a net-negative source of emissions. During the 2021/22 reporting period, sequestration was greater than gross emissions meaning that total net emissions in Carterton were -135,147 tCO_2e. Due to large-scale commercial (exotic) forestry in Carterton it is likely that the total net emissions figure will change year-to-year dependent on planting and harvesting activity and is unlikely to stay negative in the medium to long term.

Figure 4 shows total gross emissions and total net emissions in 2021/22, and the impact of forestry sequestration and harvesting.

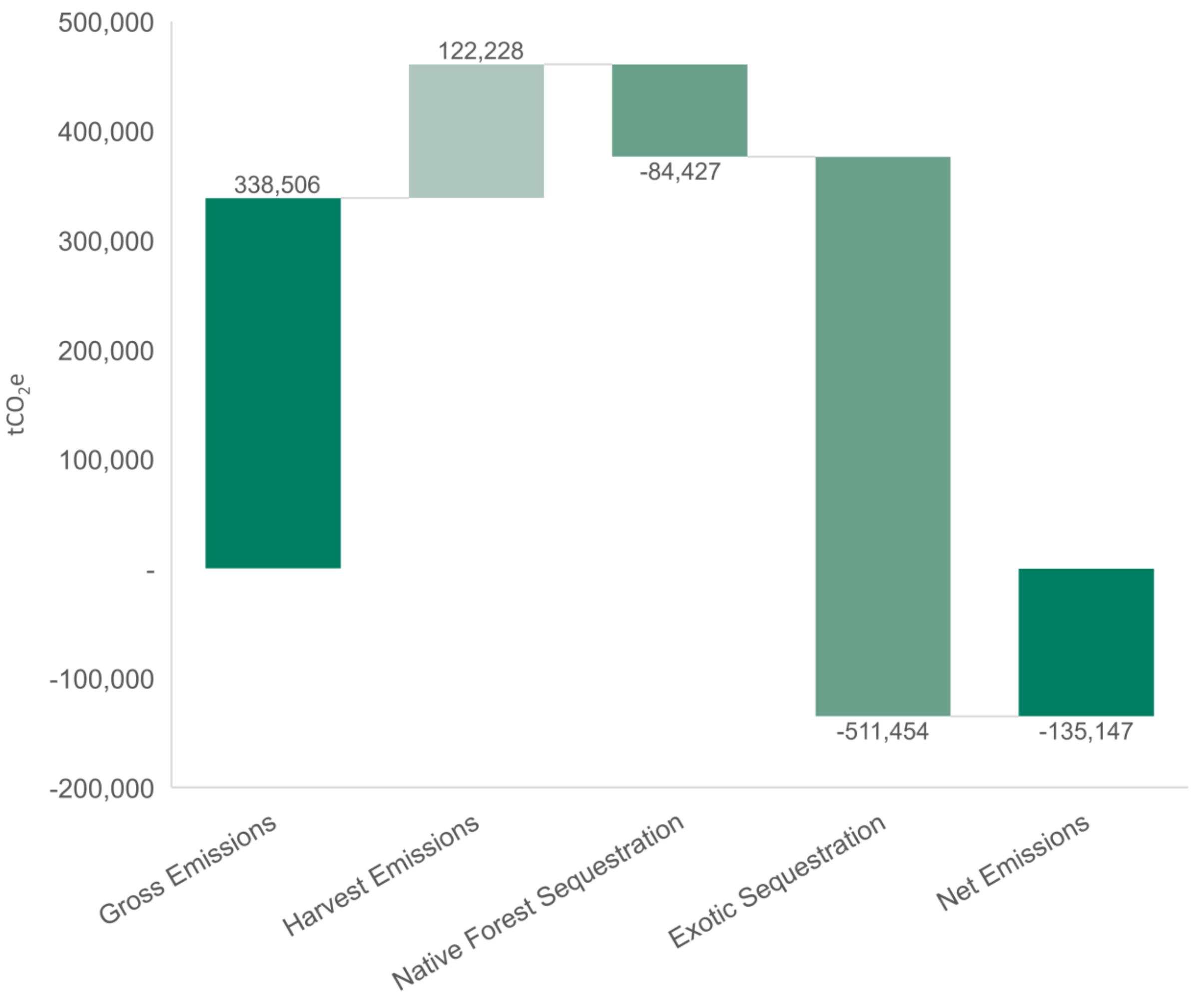

Figure 4 Total gross emissions and total net emissions in 2021/22, showing the impact of forestry sequestration and harvesting

3.8 Territorial Authorities in the Greater Wellington Region

The Greater Wellington regional area contains several territorial authorities including Wellington City Council, Carterton District Council, Kāpiti Coast District Council, Hutt City Council, Upper Hutt City Council, Masterton District Council, Carterton District Council, and South Wairarapa District Council.

Figure 5 shows the Greater Wellington Region total gross emissions divided by territorial authority. Figure 6 shows total gross emissions for the territorial authorities in the Greater Wellington Region, split by sector.

Wellington City is the highest emitting territorial authority in the region, representing 23% of Greater Wellington's total gross emissions. Wellington City's emissions inventory is predominantly transport-related emissions with the next largest emitting territorial authorities; Masterton and South Wairarapa containing significant agricultural emissions. Of the eight territorial authorities within the Greater Wellington region, Upper Hutt has the lowest total gross emissions, with emissions mostly from Transport and Stationary Energy. Carterton has the fourth lowest total gross emissions, with emissions mostly from Agriculture.

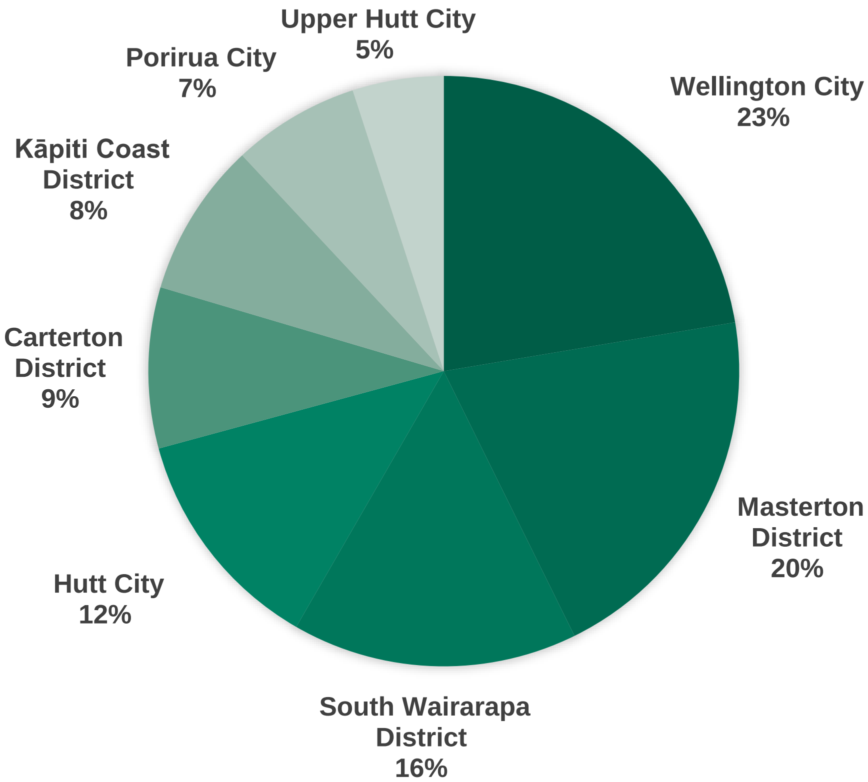

Figure 5 Greater Wellington's total gross emissions divided by territorial authority (tCO_2e).

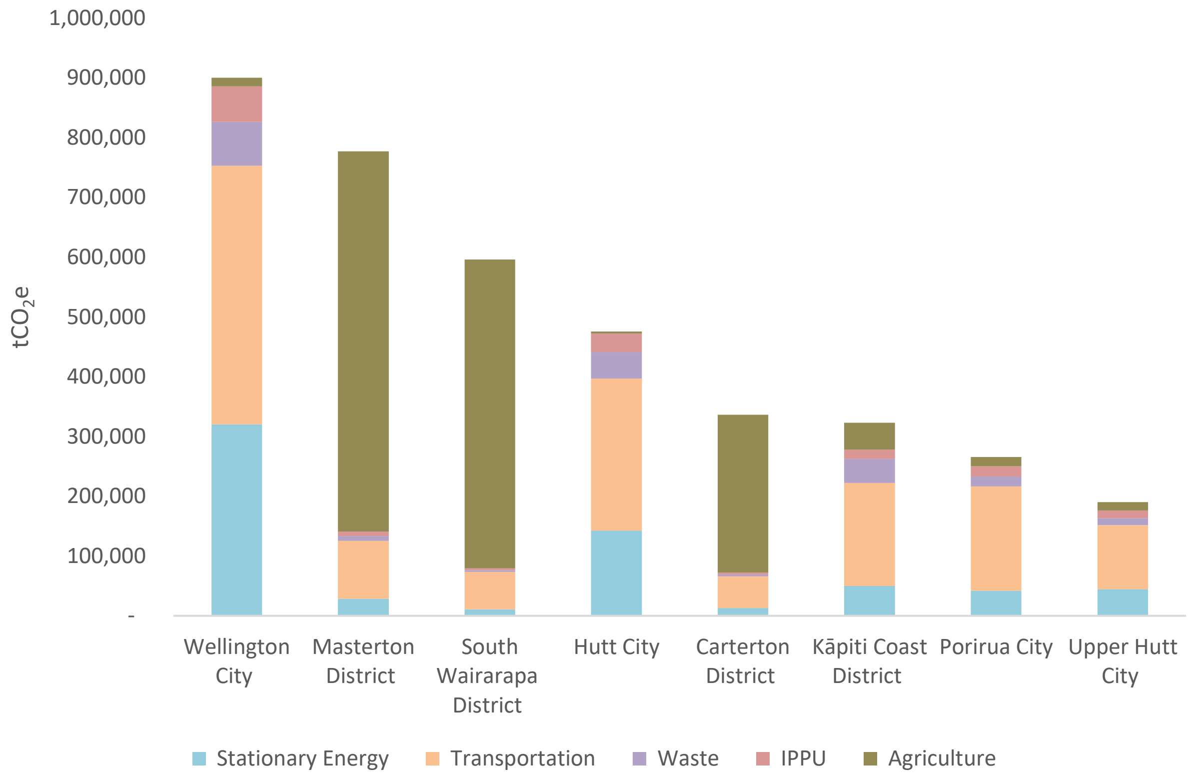

Figure 6 Total gross emissions by territorial authority in the Greater Wellington region (tCO_2e).

When comparing emissions inventories from different areas, a per capita figure can be useful because it provides a common reference point to understand the difference in emissions. Figure 7 shows emissions per capita for the territorial authorities within the Greater Wellington Region.

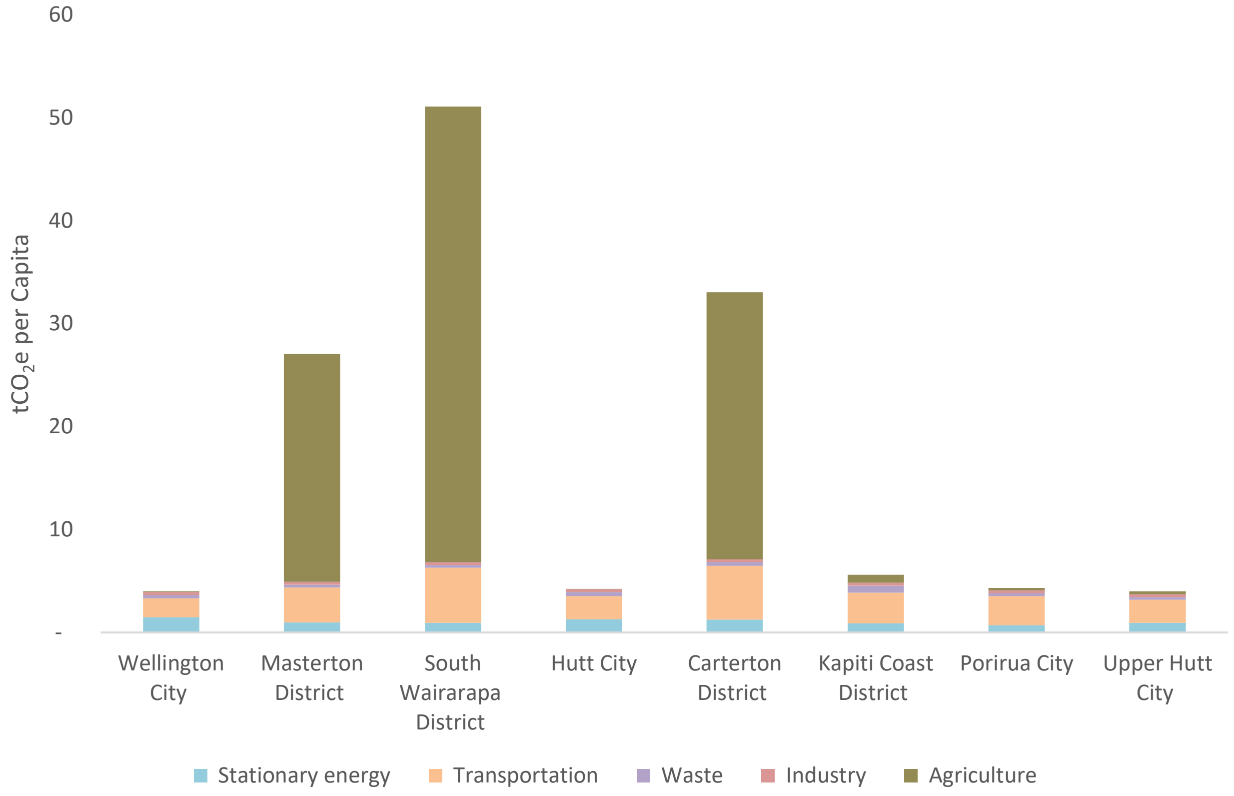

Figure 7 Total gross emissions per capita for the territorial authorities within the Greater Wellington Region (tCO_2e).

The Greater Wellington region has a 7.1 tCO_2e/per capita figure for total gross emissions which is lower than the national value of 15.7 tCO_2e/per capita. Upper Hutt has the lowest equal per capita total emissions at 4.0 tCO_2e/per capita. South Wairarapa and Carterton have the largest per capita total gross emissions at 51.4 tCO_2e/per capita and 33.3 tCO_2e/per capita respectively, both due to high Agriculture emissions in the district. Masterton has the third highest per capita emissions at 27.4 tCO_2e/per capita, again due to Agriculture emissions in the district. South Wairarapa, Carterton and Masterton also have the highest per capita transport emissions in the region (5.3 tCO_2e/per capita, 5.2 tCO_2e/per capita and 3.4 tCO_2e/per capita, respectively). Wellington City has the highest Stationary Energy emissions per capita in the region (1.5 tCO_2e/per capita).

3.9 Total Gross Emissions by Greenhouse Gas

Each greenhouse gas has a different level of impact on climate change, this is accounted for when converting quantities of each gas into units of carbon dioxide equivalent (CO_2e).

Table 9: Carterton total gross emissions, by greenhouse gas

Greenhouse Gas	Tonnes	Tonnes of CO_2e
Carbon Dioxide (CO_2)	63,678	63,678
Biogenic Methane (CH_4)	6,350	215,885
Non-biogenic Methane (CH_4)	23	765
Nitrous Oxide (N_2O)	186	55,401
Other / Unknown Gas (in CO_2e)	2,777	2,777
Total	**73,013**	**338,506**

By far the largest source of emissions in tonnes is carbon dioxide (CO_2) at 63,678 tonnes. Due to the greater global warming impact of methane per tonne, methane represents 9% of the total tonnage of GHG emissions from Carterton but represents 64% of CO_2e. Nitrous oxide represents 0.3% of the total tonnage of GHG emissions from Carterton but represents 16% of CO_2e.

3.10 Biogenic Emissions

Biogenic carbon dioxide and methane emissions are stated in Table 10 and Table 11, respectively.

Biogenic CO_2 emissions result from the combustion of biomass materials that store and sequester CO_2, including materials used to make biofuels (e.g., trees, crops, vegetable oils, or animal fats). Biogenic CO_2 emissions from plants and animals are excluded from gross and net emissions as they are considered to be part of the natural carbon cycle.

Table 10: Biogenic CO_2 in Carterton (Excluded from gross emissions)

Biogenic Carbon Dioxide (CO_2) (Excluded from gross emissions)		
Biofuel	26,383	t CO_2
Landfill Gas	389	t CO_2
Total Biogenic CO_2	**26,771**	**t CO_2**

Biogenic CH_4 emissions (e.g., produced by farmed cattle via enteric fermentation) are included in gross emissions due to their relatively large impact on global warming relative to biogenic CO_2. Biogenic methane represents 9% of the gross total tonnage of GHG emissions in Carterton but represents 64% of total gross GHG emissions when expressed in CO_2e. This is caused by the higher global warming impact of methane per tonne, compared to carbon dioxide. The total tonnage of each GHG and the contribution of each GHG to total gross emissions when expressed in CO_2e is shown in Table 9.

The importance of biogenic CH_4 is highlighted in NZ's Climate Change Response (Zero Carbon) Amendment Act. The Act includes specific targets to reduce biogenic CH_4 by between 24% and 47% below 2017 levels by 2050, and by 10% below 2017 levels by 2030. More information on the Act is available here: https://www.mfe.govt.nz/climate-change/zero-carbon-amendment-act.

Table 11: Biogenic Methane in Carterton (Included in gross emissions)

Biogenic Methane (CH_4) (Included in gross emissions)		
Enteric Fermentation (Livestock)	5,898	t CH_4
Manure Management (Livestock)	251	t CH_4
Wastewater Treatment	83	t CH_4
Landfill Gas	82	t CH_4
Biofuel	36	t CH_4
Total Biogenic CH_4	**6,350**	**t CH_4**

4.0 Annual Emissions Change from 2018/19 to 2021/22

Alongside calculating Carterton's emissions inventory for 2021/22, Carterton's emissions inventory for 2019/20 and 2020/21 has been calculated, and the previously published 2018/19 inventory has been recalculated. The 2018/19 inventory has been updated to account for updates in data and calculation best-practice and to align with the other reporting years. This section displays the results of the 2018/19, 2019/20, 2020/21 and 2021/22 emissions inventories with a focus on gross emissions and documents the change in emissions from 2018/19 to 2021/22.

An analysis of the impact of the COVID-19 pandemic on Carterton's emissions is found in Section 6.0. This section is cautious in examining the interpretation of changes, due to the inventory only assessing one financial year (2018/19) prior to the COVID-19 pandemic disruptions.

Table 12 Change in Carterton total gross and net emissions from 2018/19 to 2021/22

	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Total Net Emissions (including Forestry)	25,755	13,772	-126,745	-135,147	N/A[6]
Total Gross Emissions (excluding Forestry)	348,411	361,848	346,908	338,506	-3%

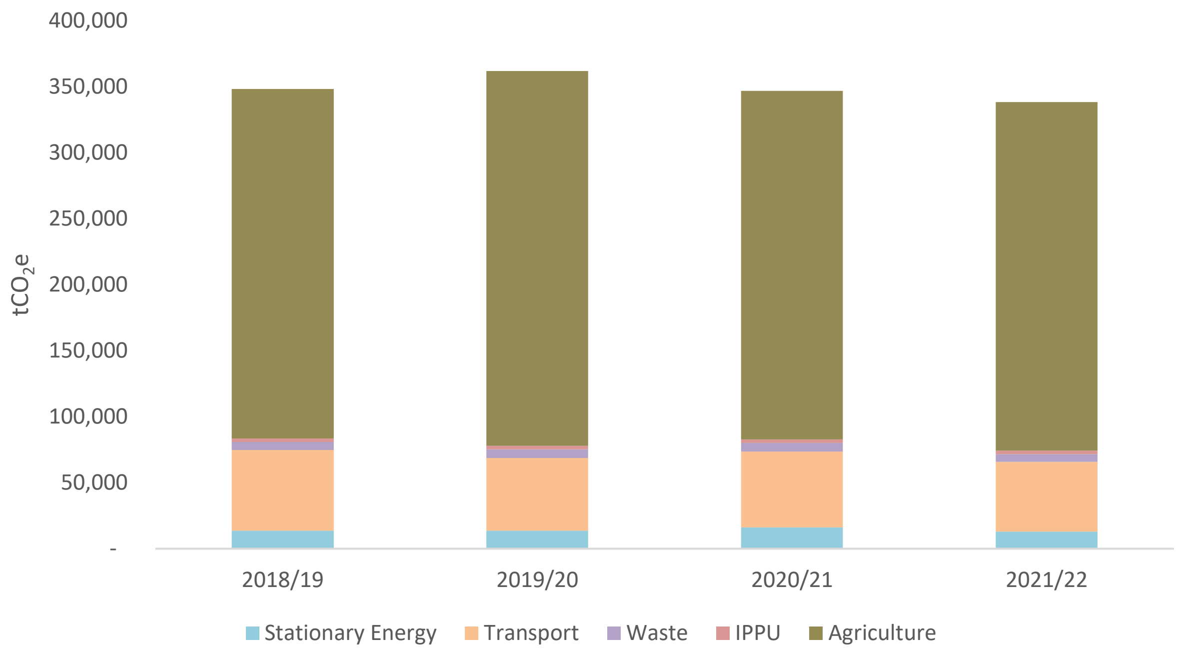

Figure 8 Change in Carterton total gross emissions from 2018/19 to 2021/22

Annual total gross emissions decreased by 3% from 348,411 tCO_2e in 2018/19 to 338,506 tCO_2e in 2021/22. The decrease in gross was driven by a reduction in Transport emissions primarily related to air travel and on-road fuel use. The impact of COVID-19 pandemic restrictions can be especially seen in air travel emissions where emissions were 58% lower in 2021/22 compared to 2018/19.

[6] A percentage change figure has been omitted as it can be misleading in this situation where total net emissions have gone from a positive to a negative figure due to changes in net forestry sequestration

Annual total net emissions in Carterton decreased by 625% from 25,755 tCO_2e in 2018/19 to -160,091 tCO_2e. The decrease in total net emissions was driven by 39% increase in exotic forest area meaning an increase in sequestration.

The population of Carterton increased by 6.2% between 2018/19 and 2021/22 (590 people). Combined with the decrease in total gross emissions, per capita emissions between 2018/19 and 2021/22 decreased from 36.3 to 33.3 tCO_2e per person per year. A discussion of the decoupling of gross emissions from population growth and GDP is found in Section 5.0.

The sections below outline the change in emissions between 2018/19 and 2021/22 for each sector and emissions source, highlighting the changes that have had the largest impact on total gross emissions. Due to rounding, there may be discrepancies between the sum of reported figures and reported totals.

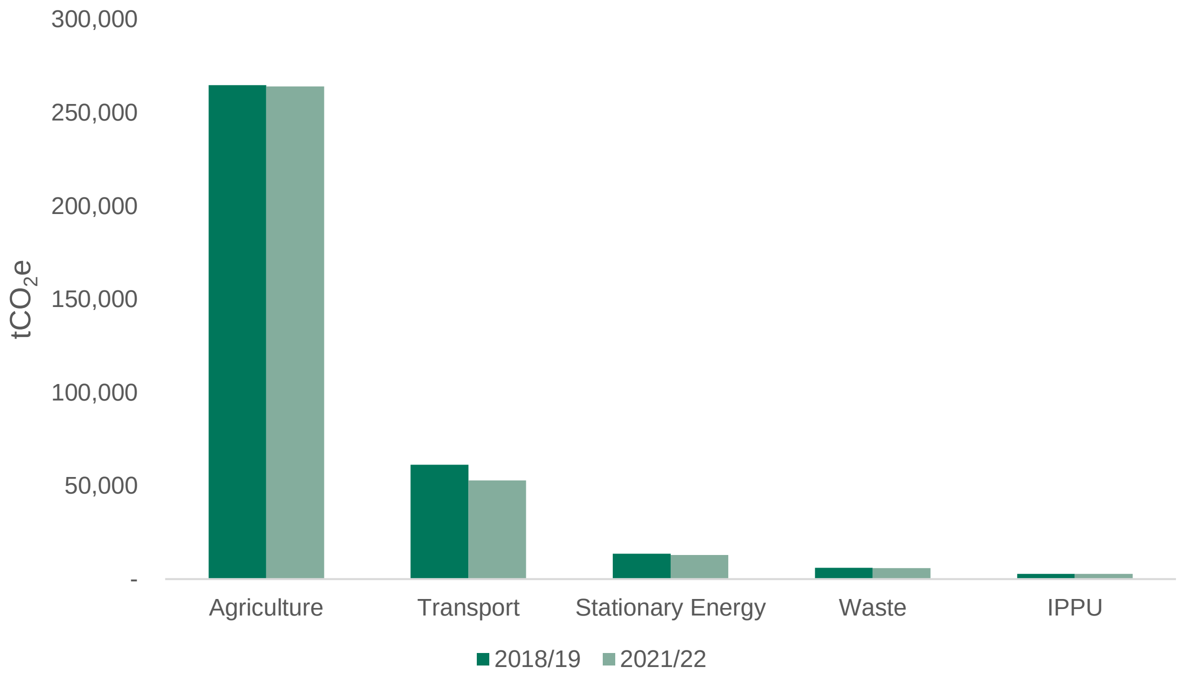

Figure 9 Emissions for each sector of Carterton gross emissions inventory for 2018/19 and 2021/22

4.1 Agriculture

Table 13 Change in Carterton's Agriculture emissions from 2018/19 to 2021/22

Sector / Emissions Source	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Livestock Enteric Fermentation	200,942	215,479	200,515	200,515	-0.2%
Unmanaged Manure on Pasture	29,277	31,176	28,911	28,911	-1%
Agricultural Leaching and Deposition (Manure, Urine, and Fertiliser)	20,131	21,394	19,910	19,910	-1%
Managed Manure	8,153	9,338	8,527	8,527	5%
Fertilisers on Land	6,308	6,458	6,231	6,231	-1%
Total	**264,810**	**283,845**	**264,094**	**264,094**	**-0.3%**

The Agriculture sector's emissions remained relatively stable between 2018/19 and 2021/22 with a decrease of 0.3% (716 tCO_2e).

Sheep represent 80% of total livestock in Carterton in 2021/22 and 41% of agricultural emissions. Emissions related to sheep decreased by 10% (12,155 tCO_2e) due to an 10% reduction in the number of sheep (from 221,622 sheep to 199,404 sheep).

Non-dairy cattle represent 9% of total livestock in Carterton in 2021/22 and 22% of agricultural emissions, this is due to their greater emissions footprint compared to sheep. Emissions related to non-dairy cattle increased by 4% (2,317 tCO_2e) due to a 2% increase in the number of non-dairy cattle (from 22,515 cattle to 23,067 cattle).

Dairy cattle represent 8% of total livestock in Carterton in 2021/22 and 32% of agricultural emissions. Emissions related to dairy cattle increased by 13% (9,575 tCO_2e) due to a 12% increase in the number of dairy cattle (from 18,491 cattle to 20,665 cattle).

4.2 Transport

Table 14 Change in Carterton Transport emissions from 2018/19 to 2021/22

Sector / Emissions Source	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Diesel	28,887	27,553	29,477	27,946	-3%
Petrol	23,475	20,549	22,372	19,523	-17%
Jet Kerosene (Air Travel)	4,848	3,594	1,346	2,054	-58%
Marine Freight	2,264	1,771	2,396	1,930	-15%
Marine (Inter-Island Ferries)	1,181	1,201	1,241	922	-22%
Rail (Diesel)	490	249	412	412	-16%
LPG	81	81	86	86	7%
Aviation Gas (Air Travel)	10	11	11	11	3%
Total	**61,236**	**55,008**	**57,341**	**52,883**	**-14%**

Transport emissions decreased by 14% between 2018/19 and 2021/22 (8,352 tCO_2e). This was driven by a 4,677 tCO_2e decrease in on-road fuel use emissions and a 2,794 tCO_2e reduction Jet Kerosene in (aircraft fuel) emissions.

Jet Kerosene emissions decreased by 58% due to a reduction in flights, especially of international flights, with international passenger numbers down 91% and domestic passenger numbers down 39% between 2019/20 and 2021/22[7]. This is likely the impact of COVID-19-related restrictions on travel and the slow pace of recovery of the aviation industry. It is expected that emissions from this source will increase in 2022/23.

On-road fuel use emissions (petrol and diesel) decreased by 10%, with an 17% decrease in on-road petrol emissions. This is partly due to the impacts of COVID-19 with restrictions on travel in both 2019/20 and 2021/22 in Greater Wellington. Improvements in the efficiency of private and commercial vehicles may have also contributed to this decrease.

Marine freight emissions decreased by 15% between 2018/19 and 2021/22 (335 tCO_2e). It is, however, important to note that maritime freight emissions for Wellington tend to fluctuate year-to-year based on distance travelled by vessels, size of vessels, and the number of visits in a particular year (for example, emissions from marine freight in 2021/22 are 9% higher than in 2019/20).

Emissions related to the inter-island ferries decreased by 22% between 2018/19 and 2021/22 (259 tCO_2e), this is due to a change in fuel use for some journeys by one of the operators of this service, from heavy fuel oil to diesel, which has a lower emissions impact.

[7] https://www.wellingtonairport.co.nz/business/investor-services/traffic-reports/

4.3 Stationary Energy

Table 15 Change in Carterton's Stationary Energy emissions from 2018/19 to 2021/22

Sector / Emissions Source	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Electricity Consumption	6,361	6,470	8,637	5,715	-10%
Stationary Petrol & Diesel Use	3,240	3,077	3,294	3,111	-4%
Biofuel / Wood	2,684	2,684	2,685	2,687	0%
LPG	639	646	679	683	7%
Electricity Transmission and Distribution Losses	556	566	803	606	9%
Coal	153	191	94	91	-41%
Total:	**13,632**	**13,633**	**16,192**	**12,893**	**-5%**

Emissions from Stationary Energy decreased by 5% between 2018/19 and 2021/22 (739 tCO_2e). This was driven by a decrease in electricity consumption emissions due to changes in the emissions intensity of the national grid.

Electricity consumption in Carterton (in kWh) increased by 3% between 2018/19 and 2021/22. However, emissions from this source decreased by 10% due to a decrease in the emissions intensity of the national electricity grid (tCO_2e/kWh). The emissions intensity of the national grid decreased due to a reduction in coal and gas generation as renewable generation sources made up a greater proportion of national generation (especially hydropower). It is important to note that the emissions intensity of New Zealand's national grid fluctuates year on year, primarily driven by water levels in the hydropower system (as can be seen in the increase in emissions from 2019/20 to 2020/21 and subsequent decrease again in 2021/22).

Other notable changes can be seen in stationary petrol and diesel use which decreased by 4% (129 tCO_2e) between 2018/19 and 2021/22. The 41% decrease in coal use represents transitions away from coal use for energy to lower emission options.

4.4 Waste

Table 16 Change in Carterton Waste emissions from 2018/19 to 2021/22

Sector / Emissions Source	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Closed Landfill	2,945	2,765	2,600	2,447	-17%
Wastewater Treatment Plants	1,527	2,248	2,462	2,047	34%
Individual Septic Tanks	929	948	969	986	6%
Open Landfill	584	647	473	337	-42%
Total	5,985	6,608	6,504	5,818	-3%

Total Waste emissions reduced by 3% between 2018/19 and 2021/22 (167 tCO_2e); this was driven by a reduction of emissions from closed landfill sites and improvements in the landfill gas capture system at Bonny Glen Landfill.

Emissions from Individual Septic Tanks are determined based on an estimate of the population of Carterton not connected to centralised wastewater treatment plants. Emissions from this source increased by 6% due to an increase in the forecast of the population not connected to centralised wastewater treatment, in line with population growth.

Wastewater treatment plant emissions increased by 34% (520 tCO_2e) due to an increase in processed biosolids, however it is unclear as to why this increase has occurred. Better data on wastewater treatment in Carterton would improve the accuracy of the results for this emission source

4.5 Industrial Processes and Product Use (IPPU)

Table 17 Change in Carterton IPPU emissions from 2018/19 to 2021/22

Sector / Emissions Source	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Refrigerants and Air Conditioning	2,542	2,556	2,583	2,621	3%
Aerosols	160	149	144	146	-9%
SF6 - Electrical Equipment	25	27	28	29	13%
Foam Blowing	11	12	11	11	3%
SF6 - Other	5	5	6	6	2%
Fire Extinguishers	4	4	4	4	1%
Total	**2,749**	**2,754**	**2,776**	**2,817**	**2%**

IPPU emissions remained relatively unchanged between 2018/19 and 2021/22. The only notable change is a decrease in aerosol emissions which may be due to a decrease in the quantity used or an increase in the use of lower emissions-impacting aerosols. Note that national-level data is used for this sector and is portioned out using a population approach; actual emissions for Carterton are unknown.

4.6 Forestry

Table 18 Change in Carterton Forestry emissions from 2018/19 to 2021/22

Sector / Emissions Source	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Total Harvest Emissions	110,047	92,226	122,228	122,228	11%
Native Forest Sequestration	-84,427	-84,427	-84,427	-84,427	0%
Exotic Forest Sequestration	-348,277	-355,875	-511,454	-511,454	47%
Total	**-322,657**	**-348,076**	**-473,653**	**-473,653**	**47%**

Net Forestry sequestration (emissions released minus sequestration) increased by 150,996 tCO_2e between 2018/19 and 2021/22, from -322,657 tCO_2e to -473,653 tCO_2e. Sequestration from exotic forestry increased by 47% (163,177 tCO_2e) owing to a 39% increase in exotic forest area. Harvesting emissions increased by 11% (12,181 tCO_2e) and native forestry sequestration did not change.

Forestry harvesting emissions increased due to an increase in Carterton's proportion of Greater Wellington's land area covered by exotic trees of harvestable age (used to estimate Carterton's proportion of the Greater Wellington region's commercial harvesting). Forestry emissions are influenced by the cyclical nature of harvesting and planting regimes, where some years will have higher sequestration and some years will have higher harvesting emission. This depends on the age of forests and the demand for lumber and timber. Improved and updated data sources may impact the estimation of emissions from this source in the future.

Sequestration by native forests remained unchanged during this time as the same data has been used for each year; however, it is unlikely that there have been significant changes.

5.0 Decoupling of GHG emissions from population growth and GDP

Decoupling of emissions is when emissions grow less rapidly than the growth of an economy (measured in Gross Domestic Product (GDP)). The term decoupling expresses the desire to mitigate emissions without harming economic well-being. The exact drivers for the decoupling of emissions from GDP are generally difficult to pinpoint. New policies, for restructuring the way to meet demand for energy, food, transportation, and housing will all contribute. Both direct local actions (e.g. landfill gas reductions) and indirect national trends (e.g. changes to emissions from electricity generation) can contribute to emissions decoupling. A complete discussion of the decoupling of emissions is beyond this project's scope.

Figure 10 shows the changes in gross emissions when compared to changes in other metrics of interest between 2018/19 and 2021/22. For example, total gross emissions have decreased by 3%, whilst the population in Carterton has increased by 6%, resulting in an 8% reduction in total gross emissions per capita. Similarly, Gross Domestic Product (GDP) in Carterton has increased by around 6%, resulting in an 8% decrease in the GHG emissions ratio to GDP. The data suggests that potentially a high-level, decoupling of the emissions covered by this assessment from economic growth has occurred between 2018/19 and 2021/22 in Carterton. However, it is noted that emissions calculated as part of this assessment are based on production based emissions. Emissions calculated as part of a consumption based assessment may present a different outcome.

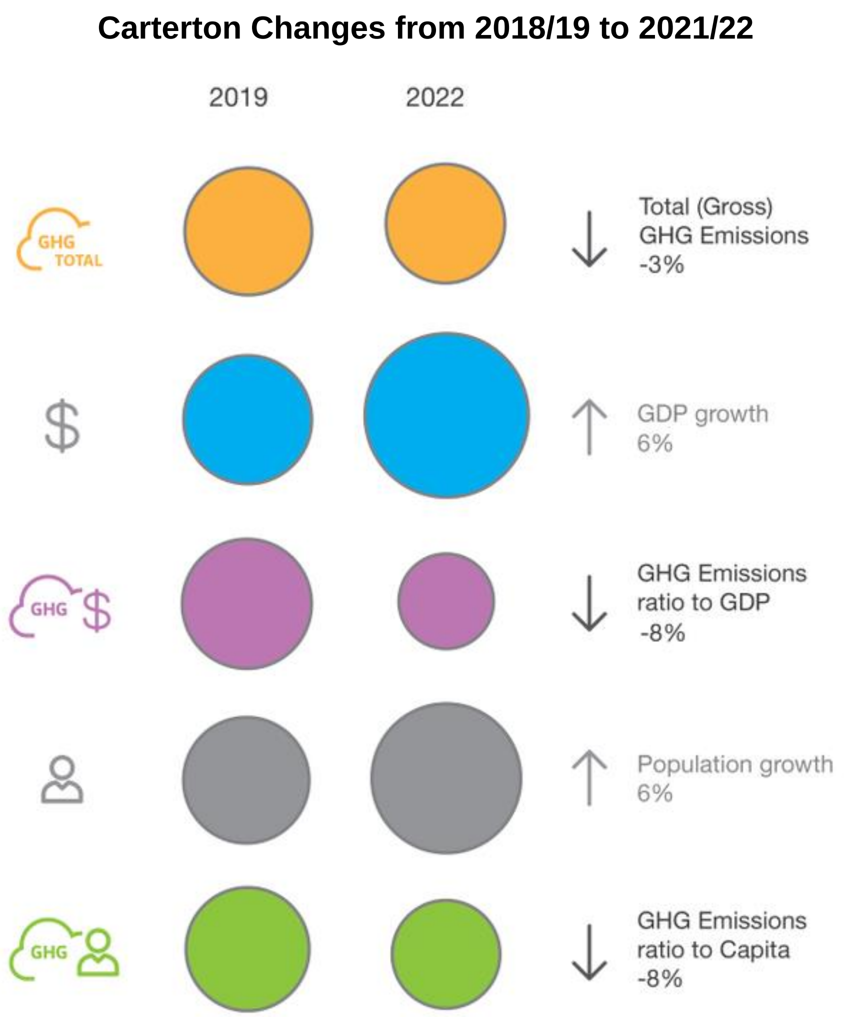

Figure 10 Change in total gross emissions compared to other metrics of interest

6.0 Update to the 2018/19 Emissions Inventory

Improvements to the methodology, improvements in available data, and updates to emission factors since the 2018/19 Community Carbon Footprint (Emissions Inventory) was first published in 2020, have meant that the 2018/19 inventory results are required to be updated to allow direct comparison with the 2019/20, 2020/21, and 2021/22 inventories.

The previous 2018/19 inventory results and updated 2018/19 inventory results are presented in Table 19. The previous 2018/19 inventory reported the three Wairarapa councils in one combined inventory. For the purposes of comparison to the previous inventory, all three emission inventories for the Wairarapa councils (Masterton, South Wairarapa and Carterton) for 2018/19 have been combined in Table 20.

Critical reasons for the change to results between these inventories are outlined below:

- Stationary Energy emissions have been adjusted due to improvements in data and methodology changes, notably the natural gas and electricity data and emission factors, and a difference in the allocation of diesel and petrol sales to stationary energy purposes.
- Transportation emissions have been adjusted due to data improvements and methodology changes, most notably in how the Wellington Region's petrol and diesel sales have been allocated to the territorial authorities within the Region (from a population approach to a vehicle kilometre travelled approach). The marine freight and inter-island ferry calculations have also been updated based on best-practice guidance for cross-boundary transport emissions.
- Waste emissions have been adjusted due to updates to the estimate of landfill gas capture system efficiency at the open landfill sites, the estimate of historical waste (1950-1999), and the population not connected to centralised wastewater treatment. Wastewater treatment plant emissions calculations have been updated to align with WaterNZ guidance (2021).
- IPPU emissions have been adjusted due to a change in data and emission factors provided by the Ministry for the Environment (MfE).
- Agriculture emissions have been adjusted due to improvements in data based on regional trends since the 2017 territorial authority-level census and changes in MfE emission factors.
- Forestry emissions have been adjusted due to improvements in published data and emission factors.

Table 19 Reported GHG emissions in Wairarapa for 2018/19, showing the change in emissions between those previously reported (2020) and the updated results (2023)

	2018/19 previous inventory (2020) – tCO_2e	2018/19 updated inventory (2023) – tCO_2e
Stationary Energy	59,293	54,486
Transportation	271,511	251,423
Waste	39,950	32,269
IPPU	14,219	13,546
Agriculture	1,349,348	1,439,551
Forestry	-1,380,860	-1,403,853
Total Net Emissions (incl. forestry)	**353,460**	**387,422**
Total Gross Emissions (excl. forestry)	**1,734,320**	**1,791,275**

Future emissions inventories for Carterton may also require adjustments to the emission results reported here due to improvements to the inventory process.

7.0 Impact of the COVID-19 pandemic on GHG Emissions

COVID-19 impacted New Zealand and the entire world during 2020 and 2021; causing widespread government-imposed restrictions on businesses and individuals and huge shifts in behaviours and economic markets. Restrictions in New Zealand relating to COVID-19 began in mid-March 2020 with many personal and business restrictions continuing past the end of 2019/20 and throughout 2021/22.[8]

Globally, carbon dioxide emissions from fossil fuels (the largest contributor to greenhouse gas emissions) in 2020 decreased by 7% compared to 2019[9]. Emissions from the transportation sector account for the largest share of this decrease. Surface transport, e.g. car journeys, fell by approximately half at the peak of COVID-19 restrictions in April 2020 (when restrictions were at their maximum, particularly across Europe and the U.S. Globally, emissions recovered to near 2019 levels and are expected to continue to increase.

In New Zealand, national daily carbon dioxide emissions are estimated to have fallen by up to 41% during the level 4 lockdown in April 2020[10]. National gross emissions decreased by 3% from 2018/19 to 2019/20, which was largely driven by a decrease in fuel use in road transport due to COVID-19 pandemic restrictions, a decrease in fuel use in manufacturing industries and construction due to COVID-19 restrictions, and a decrease in fuel use from domestic aviation also due to COVID-19 restrictions.

Total gross emissions in Carterton decreased by 9,905 tCO_2e (3%) between 2018/19 (pre-COVID-19) and 2021/22. A 14% decrease in Transport emissions (8,352 tCO_2e) accounts for the vast majority of this change. Notably, Transport emissions reduced by 10% between 2018/19 and 2019/20, driven by reduced road and air transport fuel use (see Figure 11). Air travel emissions in particular have been impacted by COVID-19 with emissions 72% lower in 2020/21 than in 2018/19 especially due to a reduction in international flights. It is expected that air travel emissions will rise to near pre-COVID-19 levels in 2022/23 in the Wellington Region. On-road transport emissions were also impacted by COVID-19, especially through restrictions on travel for periods of time in 2019/20 and 2021/22.

Despite changes in Stationary Energy, Agriculture, Waste, and IPPU emissions, these sectors are not judged to have been significantly affected by COVID-19. Of note, electricity consumption has increased during this time with annual emissions affected by the sources of national generation of electricity in each year. We cannot say with confidence whether energy consumption, or other changes have been significantly affected by COVID-19.

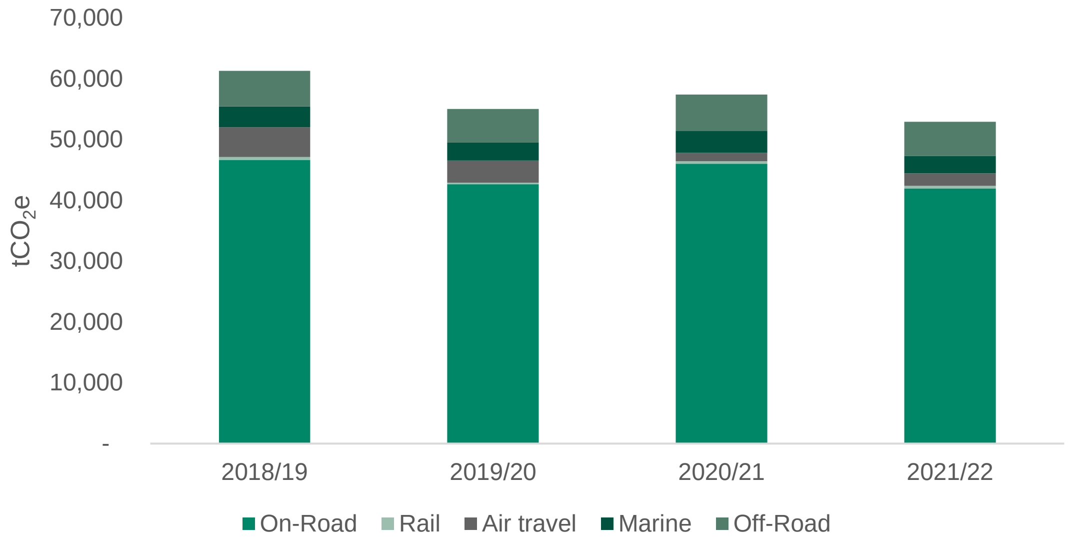

Figure 11 Carterton Transport emissions for 2018/19, 2019/20, 2020/21 and 2021/22 (tCO_2e)

[8] https://covid19.govt.nz/alert-system/history-of-the-covid-19-alert-system/
[9] Pierre Friedlingstein et al. - Global Carbon Budget 2020 (2020)
[10] Corinne Le Quere et al. – Temporary Reduction in Daily Global CO_2 Emissions During the COVID-19 Forced Confinement

8.0 Closing Statement

Carterton GHG emissions inventory provides information for decision-making and action by the council, Carterton stakeholders, and the wider community. We encourage the council to use the results of this study to update current climate actions plans and set emission reduction targets.

The emissions inventory developed for Carterton covers emissions produced in the Stationary Energy, Transport, Waste, IPPU, Agriculture, and Forestry sectors using the GPC reporting framework. Sector-level data allows Carterton to target and work with the sectors that contribute the most emissions to the inventory.

Understanding of the extensive and long-lasting effects of climate change is improving all the time. It is recommended that this full emissions inventory be updated regularly (every two or three years) to inform ongoing positive decision making to address climate change issues. Use of real-time data for major emissions sources and consideration of consumption-based emissions, can also add to understanding of emissions across the region.

The accuracy of any emissions inventory is limited by the availability, quality, and applicability of data. Areas where data could be improved for future inventories include forestry (forest cover and harvesting), agriculture (especially livestock numbers), wastewater, and on and off-road transport fuel use.

9.0 Limitations

Where this Report indicates that information has been provided to AECOM by third parties, AECOM has made no independent verification of this information except as expressly stated in the Report. AECOM assumes no liability for any inaccuracies in or omissions to that information. This Report was prepared between January 2023 and May 2023 and is based on the information reviewed at the time of preparation. AECOM disclaims responsibility for any changes that may have occurred after this time. This Report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This Report does not purport to give legal advice.

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Appendix A

Assumptions and Data Sources

Sector / Category	Assumption and Data Sources
General	
Geographical Boundary	LGNZ local council mapping boundaries have been applied. The emissions inventory for each territorial authority covers the entirety of the territorial authority area.
Population	Population figures are provided by StatsNZ. Financial year populations have been used, these are based on the average population from the two calendar years (e.g. the average of 2020 and 2021 calendar year populations for 2020/21).
Climate Change Feedback	Emissions are expressed on a carbon dioxide-equivalent basis (CO_2e) including climate change feedback using the 100-year Global Warming Potential (GWP) values. Climate change feedbacks are the climate change impacts from GHGs that are increased as the climate changes. For example, once the Earth begins to warm, it triggers other processes on the surface and in the atmosphere. Current climate change feedback guidance is important to estimate the long-term impacts of GHGs. Emissions for individual main greenhouse gases for each emissions source are provided in the supplementary spreadsheet information supplied with this report.
GPC Production Approach	GPC reporting is predominately production-based (as opposed to consumption-based) but includes indirect emissions from energy consumption. Production-based emissions reporting is generally preferred by policy-makers due to robust established methodologies such as the GPC, which enables comparisons between different studies. Production-based approaches exclude globally produced emissions relating to consumption (e.g., embodied emissions relating to products produced elsewhere but consumed within the geographic area such as imported food products, cars, phones, clothes etc.). A breakdown of emissions by scope (1, 2 and 3) is included in the supplementary spreadsheet information supplied with this report.
Emission Factors	All emission factors have detailed source information in the calculation tables within which they are used. Where possible, the most up to date, NZ-specific emission factors have been applied. AR5 Global Warming Potential (GWP) figures for greenhouse gases have been used accounting for climate change feedbacks.
Transport Emissions	
Petrol and Diesel:	Total petrol and diesel sales data was provided by Wellington City Council for Wellington City Council, Carterton District Council, Kāpiti Coast District Council, Hutt City Council and Upper Hutt City Council. Total petrol and diesel sales data was provided by Masterton District Council for South Wairarapa District Council, Masterton District Council and Carterton District Council. Sales data have then been then apportioned out to the territorial authorities within the region based on the total distance travelled by vehicles in each territorial authority in the financial year (known as Vehicle Kilometres Travelled or VKT). Allocating fuel consumption across a region based on VKT does not account for the likely makeup of the vehicle fleet of a particular geographic area (e.g. where a more rural area

	may use more diesel, or a more urban area may have more hybrid or electric vehicles travelling). Fuel sold in an area does not always mean that the fuel is used in that area, however this approach is considered to be a robust and comparable estimate of fuel consumption in a geographic area. Total petrol and diesel fuel use was then divided by likely end use. The division into transport and stationary energy end use (and within transport, on-road and off-road) was calculated using fuel end use data provided by the Energy Efficiency and Conservation Authority (EECA) in April 2020. - On-road transport is defined as all standard transportation vehicles used on roads e.g. cars, bikes, buses. - Off-road transport is defined as machinery for agriculture, construction and other industry used off-roads. - Stationary energy petrol and diesel use is defined as fuel not used for transport either on or off roads. Petrol and diesel used for stationary energy has been reported in the Stationary Energy sector.
Rail Diesel	Consumption was calculated by KiwiRail using the Induced Activity method for system boundaries. The following assumptions were made: - Net Weight is product weight only and excludes container tare (the weight of an empty container) - The Net Tonne-Kilometres (NTK) measurement has been used. NTK is the sum of the tonnes carried, multiplied by the distance travelled. - National fuel consumption rates have been used to derive litres of fuel for distance. - Type of locomotive engine used, and jurisdiction topography, have not been incorporated in the calculations. Using the induced activity method, the trans-boundary routes were determined, and the number of stops taken along the way derived. The total litres of diesel consumed per route was then split between the departure territorial authority, arrival territorial authority and any territorial authority the freight stopped at along the way. If the freight travelled through but did not stop within a territorial authority, no emissions were allocated. Data was not available for 2021/22 therefore the 2020/21 value has been used for 2021/22. This data is subject to commercial confidentiality.
Jet Kerosene (Scheduled Flights)	Calculated using the Induced Activity method as per rail diesel. An estimate of fuel use was calculated for flights arriving and departing from Wellington Airport: - The schedule of flights arriving and departing from Wellington Airport containing details on the aircraft used for each flight was used to calculate fuel consumption. - Flight distances and aircraft fuel burn rates were used for these calculations. - As per the induced activity method, only 50% of emissions calculated per one-way arrival and departure were allocated to Wellington Airport. The remaining 50% of each leg was allocated to the originating or destination airport. An estimation of fuel use from military, freight, private, and other flights for 2020/21 and 2021/22 have been estimated based on data provided in 2020. Wellington Airport has been treated as a regional airport, so emissions have been split between the territorial authorities in the region on a population basis.

	Fuel use by aircraft using Kāpiti Coast Airport has also been accounted for using the same methodology, with all emissions allocated to Kāpiti Coast District.
Aviation Gas (General Aviation)	Aviation gas is mostly used by small aircraft for relatively short flights. Data for Wellington Airport was not available at the time of writing, so an assumption has been made based on similar sized airports in New Zealand. This is the same assumption used in the previous 2019/20 inventory. Wellington Airport has been treated as a regional airport, so emissions have been split between the territorial authorities in the region on a population basis. Fuel use by aircraft using Kāpiti Coast Airport has also been accounted for using the same methodology, with all emissions allocated to Kāpiti Coast District. There are a number of small aerodromes and runways across the region. Due to the difficulty of obtaining data, emissions related to flights from these locations have been excluded. It is likely that these emissions would have been very small in relation to other sources, and so would fit below the materiality threshold.
Marine Fuels - Freight	Calculated using the Induced Activity method as per rail diesel and jet kerosene. An estimate of fuel use was calculated for flights arriving and departing from CentrePort (Wellington Port): - The schedule of vessels arriving and departing from Wellington Port containing details on size of the vessel was used to calculate fuel consumption. - Shipping distances and vessel fuel burn rates were used for these calculations. - As per the induced activity method, only 50% of emissions calculated per one-way arrival and departure were allocated to Wellington Port. The remaining 50% of each leg was allocated to the originating or destination Port. International shipping passing through CentrePort was split by weight of cargo into 'Logs' and 'All other cargo'. Emissions generated by 'All other cargo' has been allocated on a per capita basis between all territorial authorities in the Wellington Region. Emissions generated by 'logs' was split between territorial authorities, proportionally, by the percentage share of district forest area of harvest age (>26 years old).
Marine Fuels (Local)	Port operational vessels: - Fuel use has been provided directly from Wellington Port (CPL) for 2020/21 - The 2020/21 figure has also been used for 2019/20 and 2021/22 - All emissions from this source have been allocated to Wellington City Local ferries: - Diesel fuel use has been provided directly by the ferry operator - Electricity use has been provided directly by the ferry operator (beginning in 2021/22) - All emissions from this source have been allocated to Wellington City Private use, other commercial operators, and commercial fishing: - Most small private boats use fuel purchased at vehicle gas stations so this consumption will be included in off-road transport petrol and diesel emissions. - No data was available to determine emissions from other commercial operators, and commercial fishing

Marine Fuels – Inter-island Ferries	Data has been provided by the ferry operators in commercial confidence. Assumptions of fuel use have been used where data was not provided.
Cruise Ships	No reliable data was available to determine the emissions from cruise ships (only relevant to 2019/20 as there were no cruise ship visits in 2020/21 and 2021/22).
LPG	Total North Island consumption data was used and then split on a per capita basis to determine the territorial authority's consumption. National LPG end use data has been used to breakdown consumption into stationary energy and transport usage, these are then reported separately in their respective categories.
Stationary Energy Emissions	
Consumer Energy End Use	Stationary energy demand (e.g. electricity use, natural gas, etc.) is broken down by the sector in which they are consumed. We report stationary energy demand in the following categories: industrial (which includes agriculture, forestry, and fishing); commercial; and residential. These sectors follow the Australia New Zealand Standard Industrial Classification 2006 definitions. In addition to agriculture, forestry and fishing, the industrial sector includes mining, food processing, textiles, chemicals, metals, mechanical/electrical equipment and building and construction activities. Emissions from petrol and diesel used for stationary energy are not broken down into these sectors. Energy demand used for transport is reported in the transport sector.
Electricity Consumption	Electricity demand has been calculated using grid demand trends from the EMI website (www.emi.ea.govt.nz) to obtain raw grid exit point data for each territorial authority area. Reconciled demand has been used as per EMI's confirmation. The breakdown into sectors is based on NZ average consumption per sector (residential, commercial, and industrial).
Public Transport Electricity	Electricity used in the public transport system is included in the Transport sector (where known).
Private Transport Electricity	Electricity used for private transport (e.g. electric cars, electric bikes, electric micro-mobility) has not been separated from other stationary energy electricity consumption due to a lack of reliable data.
Coal Consumption	National coal consumption data has been provided by MBIE for all years (2022). Regional industrial coal data has been provided by EECA. National residential and commercial coal consumption has been divided between territorial authorities on a per capita basis. Regional industrial coal consumption has been divided between territorial authorities on a per capita basis, where relevant.

Biofuel and Wood Consumption	National biofuel consumption data has been provided by the Ministry for Business, Innovation and Employment (MBIE 2021). Biofuel consumption has been divided between territorial authorities on a per capita basis. Biofuel emissions are broken down into Biogenic emissions (CO_2) and Non-Biogenic emissions (CH_4 and N_2O). The latest year's data available is for 2019. 2019/20, 2020/21, and 2021/22 use the 2019 figure, adjusted for population change.
LPG Consumption	North Island LPG sales data (tonnes) has been provided by the LPG Association for 2020 and 2021. Data interpolated between known data points or copied from the most recent data point where data is not available. 'Auto' and 'Forklift' sales represent transport uses of LPG. All other sales represent stationary energy uses of LPG. Sales have been divided between territorial authorities on a per capita basis. The breakdown into sectors (Residential, Commercial, and Industrial) is based on NZ average consumption per sector as per MfE data.
Petrol and Diesel (Stationary Energy End Use)	Total petrol and diesel sales data was provided by Wellington City Council for Wellington City Council, Carterton District Council, Kāpiti Coast District Council, Hutt City Council and Upper Hutt City Council. Total petrol and diesel sales data was provided by Masterton District Council for South Wairarapa District Council, Masterton District Council and Carterton District Council. Sales data have then been then apportioned out to the territorial authorities within the region based on the total distance travelled by vehicles in each territorial authority in the financial year (known as Vehicle Kilometres Travelled or VKT). Allocating fuel consumption across a region based on VKT does not account for the likely makeup of the vehicle fleet of a particular geographic area (e.g. where a more rural area may use more diesel, or a more urban area may have more hybrid or electric vehicles travelling). Fuel sold in an area does not always mean that the fuel is used in that area, however this approach is considered to be a robust and comparable estimate of fuel consumption in a geographic area. Total petrol and diesel fuel use was then divided by likely end use. The division into transport and stationary energy end use (and within transport, on-road and off-road) was calculated using fuel end use data provided by the Energy Efficiency and Conservation Authority (EECA) in April 2020. - On-road transport is defined as all standard transportation vehicles used on roads e.g. cars, bikes, buses. - Off-road transport is defined as machinery for agriculture, construction and other industry used off-roads. - Stationary energy petrol and diesel use is defined as fuel not used for transport either on or off roads. Petrol and diesel used for stationary energy has been reported in the Stationary Energy sector.
Natural Gas Consumption	Natural gas consumption data has been provided by FirstGas. Territorial Authorities supplied by gas from each Point of Connection (POC) have been confirmed by FirstGas.

Biogenic Emissions (CO_2)	Some carbon dioxide (CO_2) emissions are considered to be biogenic. These are CO_2 emissions where the carbon has been recently derived from CO_2 present in the atmosphere (for example, some agricultural and waste emissions). These emissions are not included in calculating total CO_2e.
Agricultural Emissions	
Agriculture	Territorial authority livestock numbers and fertiliser data taken from the Agricultural Census (StatsNZ). The last territorial authority census was in 2017. Regional agricultural data from StatsNZ (2021) has been used to estimate the change in livestock and fertiliser use since 2017. Due to the gap in data for 2021/22, the 2020/21 figure has been used for 2021/22.
Solid Waste Emissions	
Landfill Emissions	Landfill waste volume and landfill gas capture system information has been provided by the respective council departments. Solid waste emissions from landfill are measured using the IPCC First Order Decay method that covers landfill activity between 1950 and the present day, as per the GPC reporting requirements. This method accounts for the gradual release of emissions from waste over a long period of time, and so calculates the emissions produced per year from waste in landfill (including emissions from closed landfill sites). Waste volume: - Where information is not available, waste volumes have been estimated based on historical national data on a per capita basis. Landfill gas capture system efficiency: - Efficiency and coverage of the system used in the emissions calculations has been provided by the respective councils based on recorded or estimated data. Landfill gas flaring / burning for energy generation: - There is biogas energy generation at Southern Landfill which is a site used by some councils in the Wellington Region. The percentage of landfill gas flared or burned for energy generation used in the calculations has been taken from data provided by WCC in relation to the calculation of Southern Landfill's Unique Emissions Factor (UEF) for 2019/20 and 2021/22. - Emissions relating to burning of landfill gas for energy generation have been included in the Stationary Energy sector. Emissions are allocated to territorial authorities based on where the waste was produced, even if the waste is disposed in landfill outside the territorial authority: - Information on the origin and destination of waste produced in each territorial area has been provided by the respective councils based on recorded or estimated data.
Wastewater Emissions	
Wastewater Treatment	All wastewater emissions have been calculated following the WaterNZ (2021) guidance. Wastewater Treatment Plants: - Calculation of emissions includes emissions released directly from wastewater treatment, flaring of captured gas and from discharge onto land/water. - Where data was not available assumed values have been used based on the WaterNZ (2021) guidance - Emissions relating to discharge of biosolids sent to landfill (if present) have been included in the Solid Waste emissions source.

	- Emissions are allocated to territorial authorities based on where the wastewater was produced, even if the wastewater is treated outside the territorial authority. Individual Septic Tanks: - Populations not connected to known centralised wastewater treatment plants are assumed to be using septic tanks.
Industrial Emissions	
Industrial Processes	It is assumed that there are no significant non-energy related emissions of greenhouse gasses from industrial processes in the Region (e.g. aluminium manufacture).
Industrial Product Use	National data covering industrial product use (e.g., fire extinguishers, refrigerants) have been estimated based on data provided in the New Zealand Greenhouse Gas Emissions 1990-2020 report (MfE 2022). Emissions are estimated on a per capita basis applying a national average per person.
Forestry Emissions	
Exotic Forestry Harvested and Exotic Forest coverage	Harvested forestry, and forest cover information for each territorial authority has been derived from Landcare Research data. This emissions inventory accounts for forest carbon stock changes from afforestation, reforestation, deforestation, and forest management (i.e., it applies land-use accounting conventions under the United Nations Framework Convention on Climate Change rather than the Kyoto Protocol). It treats emissions from harvesting and deforestation as instantaneous rather than accounting for the longer-term emission flows associated with harvested wood products. The emissions inventory considers regenerating (growing) forest areas only. Capture of carbon from the atmosphere is negligible for mature forests that have reached a steady state.
Native Forest	Native forest land area for each territorial authority has been provided by Landcare Research.