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Dunedin City Community Carbon Footprint 2022

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Dunedin City Community Carbon Footprint 2022

Client: Dunedin City Council

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Prepared by

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Executive Summary

Greenhouse Gas (GHG) emissions for the Dunedin City Territorial Area (which is covered by the Dunedin City Council) have been measured using the production-based 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 Dunedin City Territorial Area for 2018/19, 2019/20, 2021/22, and 2021/22 financial reporting years. The 2018/19 footprint has been updated using current best-practice methods, updated data, and additional emission sources to enable direct comparison to the other reported years.

The Dunedin City Territorial Area is referred to hereafter as Dunedin for ease. Greenhouse gas emissions are generally reported in this document in Carbon Dioxide Equivalent (CO_2e) units and are referred to as 'emissions'.

It is important to consider the uncertainty associated with emissions calculations when interpreting a community carbon footprint. At the national level, the New Zealand's Greenhouse Gas Inventory estimates a gross emissions uncertainty of +/- 9%, and a net emissions uncertainty of +/- 27%. It is likely that the uncertainties for these results are similar to that of the national inventory.

Major findings of the project include:

2021/22 Emissions Footprint

- In the 2021/22 financial year (1st July 2021 to 30th June 2022), **total gross emissions** in Dunedin were 1,542,500 tCO_2e.
- **Agriculture** (e.g., emissions from livestock and crops) is the largest source of emissions in Dunedin, accounting for 46% of Dunedin's total gross emissions, with enteric fermentation from livestock the source of 35% of Dunedin's total gross emissions.
- **Transport** (e.g., emissions from road and air travel) is the second largest emitting sector in Dunedin, representing 34% of total gross emissions, with on-road fuel consumption accounting for 19% of Dunedin's total gross emissions. Marine freight journeys to and from Dunedin represent 10% of Dunedin's total gross emissions.
- **Stationary Energy** (e.g., emissions relating to electricity and natural gas consumption) is the third-highest emitting sector in the region, producing 12% of total gross emissions.
- **Waste** (e.g., landfill and wastewater treatment emissions) produced 6% of Dunedin's total gross emissions and **Industrial Processes and Product Use** (IPPU) represented 2% of Dunedin's total gross emissions.
- **Net Forestry** emissions were -493,170 tCO_2e in 2021/22 as carbon sequestration (carbon captured and stored in plants or soil by forests) was greater 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.
- The **total net emissions** in Dunedin were 1,049,330 tCO_2e. The total net emissions include emissions and sequestration (removals) from forestry.

Changes in Emissions, 2018/19 to 2021/22

- Between 2018/19 and 2021/22, **total gross emissions** in Dunedin decreased from 1,697,047 tCO_2e to 1,542,500 tCO_2e, a decrease of 9% (154,546 tCO_2e).
- Over this time, the population of the city increased by 2%, resulting in **per capita gross emissions** in Dunedin reducing by 11% between 2018/19 and 2021/22 (from 13.0 to 11.5 tCO_2e per person per year), in line with the decrease in total gross emissions.
- Emissions from **Agriculture** decreased by 3% between 2018/19 and 2021/22 (19,461 tCO_2e), driven by a reduction in the number of sheep. The reduction in emissions caused by the reduction

in sheep numbers is partly offset by an increase in the number of cattle and related emissions from this source.

- Emissions from **Transport** decreased by 16% between 2018/19 and 2021/22 (95,552 tCO_2e), driven by a reduction in on-road petrol and diesel consumption, marine freight movements, and air travel. It is likely that COVID-19 restrictions and disruptions to international trade impacted emissions from air travel and marine freight transport during these years.
- Emissions from **Stationary Energy** decreased by 12% between 2018/19 and 2021/22 (24,093 tCO_2e), driven by a 16% decrease in electricity consumption emissions (14,663 tCO_2e). During this period, electricity consumption (in kWh) decreased by 3%, while there was a 13% decrease in the emissions intensity of the national electricity grid (tCO_2e/kWh) due to an increase in renewable generation during this time. Coal burning emissions also decreased by 21% (8,892 tCO_2e).
- Emissions from **Waste** decreased by 13% between 2018/19 and 2021/22 (14,906 tCO_2e), driven by a reduction in annual emissions from landfill caused by improvements to landfill gas capture and the gradual decrease in emissions from closed landfill sites.
- **Net Forestry** sequestration increased by 131,833 tCO_2e between 2018/19 and 2021/22, from -361,337 tCO_2e to -493,170 tCO_2e. The rise in net sequestration was caused by a decrease in the amount of forest harvesting (producing emissions), and an increase in the area of exotic (commercial) forestry cover (sequestering emissions). It is important to note that annual forest harvesting emissions follow cyclical planting and market-based trends where in some years less forest is harvested and in other years more forest is harvested.

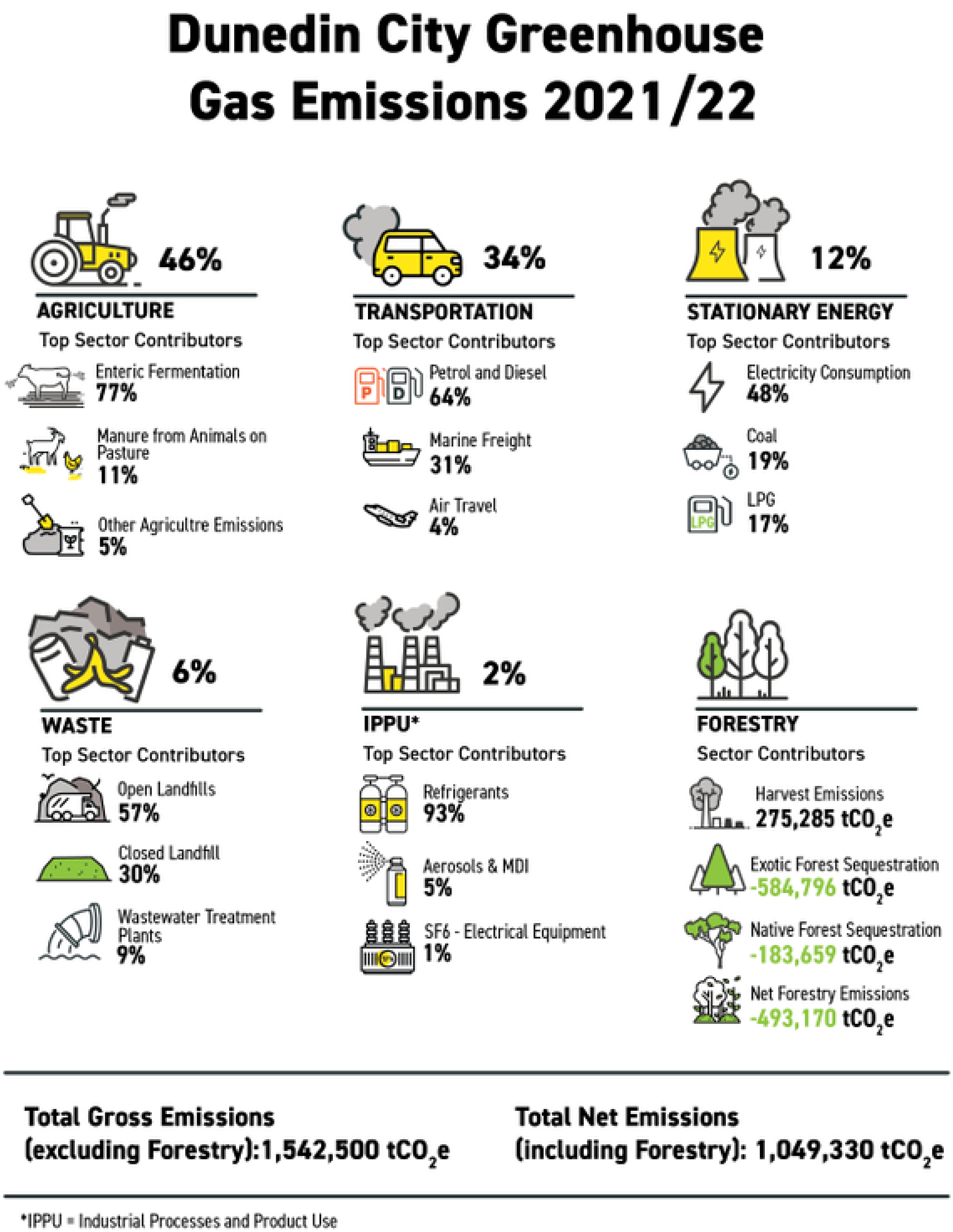

Figure 1: Dunedin City 2021/22 Emissions Footprint

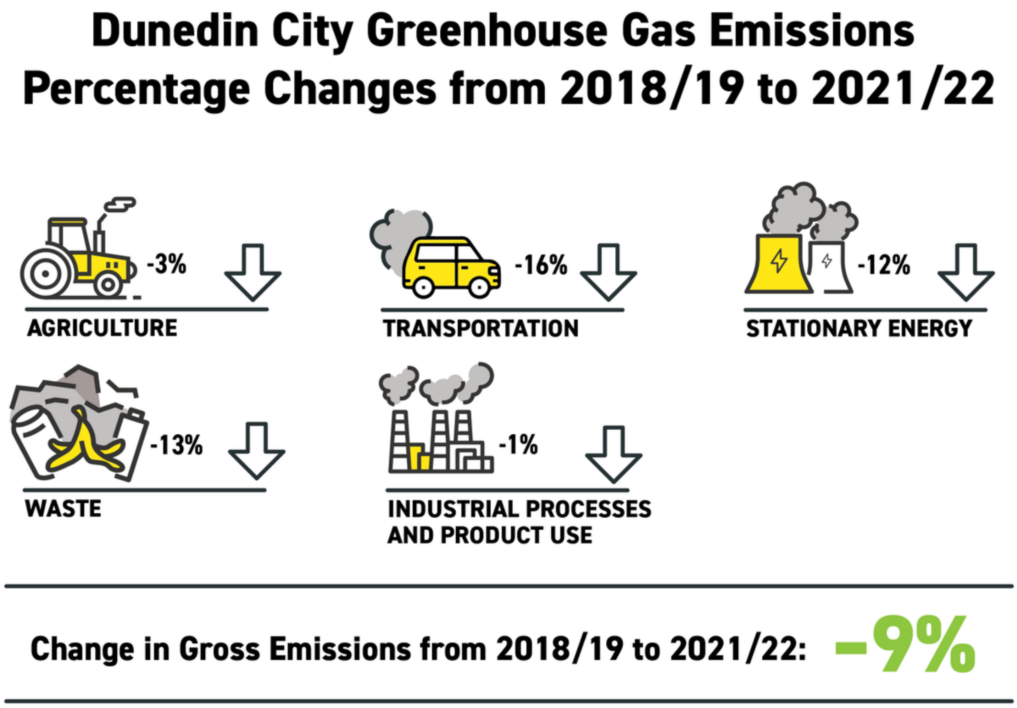

Figure 2: Change in Dunedin Emissions Footprint between 2018/19 and 2021/22

1.0 Introduction

Dunedin City Council commissioned AECOM New Zealand Limited (AECOM) to assist in developing a production-based community-scale greenhouse gas (GHG) footprint for the Dunedin City Territorial Area for the 2019/20, 2020/21 and 2021/22 financial years. As part of this work, AECOM recalculated emissions for the financial year (2018/19) previously calculated by AECOM, using current best-practice methods, updated data, and additional emission sources to enable direct comparison to the other reported years. Emissions are reported from 1st July to 30th June for the respective years. The study boundary incorporates the jurisdiction of the Dunedin City Council.

This inventory will be used to measure the city's emissions and track progress towards Dunedin City Council's city-wide Zero Carbon 2030[1] target. Dunedin aims to achieve net zero emissions of carbon dioxide and other greenhouse gases by 2030 (except biogenic methane) based on the 2018/19 baseline inventory presented here. Dunedin also aims to achieve a 24-47% reduction in biogenic methane emissions below 2016/17 levels by 2050, including a 10% reduction below 2016/17 levels by 2030.

The Dunedin City Territorial Area is referred to hereafter as Dunedin for ease. Greenhouse gas emissions are generally reported in this document in Carbon Dioxide Equivalent (CO_2e) units 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 city'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 methods have been used for other community-scale GHG footprints around New Zealand (e.g., the Bay of Plenty region, Hawke's Bay region, Auckland, Christchurch, Wellington, and the Waikato region) and internationally. The GPC methodology[2] represents international best practice for the city and regional GHG emissions reporting and has been applied in previous Dunedin City Council emission footprints.

This emissions footprint 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 consumption location. An example of indirect emissions is those associated with electricity consumption, which is supplied by the national grid (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 footprint:

- 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 atmosphere. Current climate change feedback guidance is essential to estimate the long-term impacts of GHGs.
- GPC reporting is predominately production-based (as opposed to consumption-based) but includes indirect emissions from energy consumption. Policymakers generally prefer production-based

[1] https://www.dunedin.govt.nz/dunedin-city/climate-change/zero-carbon
[2] http://www.ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
[3] https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf (Table 8.7)

emissions reporting due to robust, established methods 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.).

- Emissions for individual leading greenhouse gases for each emissions source are provided in the supplementary spreadsheet information supplied with this report.
- Where location-specific data was not accessible, emissions were calculated based on national or regional data.
- Population figures align with Dunedin's population projection figures used in Dunedin's 10 Year Planning and Development documents[4].
- Agriculture Emissions
  - Agriculture emissions are based on Dunedin City's livestock numbers and fertiliser use data from the Agricultural Census (StatsNZ). The latest data from this source for Dunedin is from 2017. To estimate the change in livestock and fertiliser use since 2017, regional (Otago) agricultural data from StatsNZ (2021) has been used. The 2021 figure has been applied to 2022 due to lack of data for this year.
- Stationary Energy Emissions
  - Stationary energy demand (e.g. electricity use, natural gas, etc.) is broken down by emission source and the sector in which it is consumed. Stationary energy demand is reported in the following categories: industrial (which includes agriculture, forestry, and fishing); commercial; and residential.
  - South Island LPG sales data has been allocated to Dunedin on a per capita basis. 'Auto' and 'Forklift' sales represent transport uses of LPG. All other sales represent stationary energy uses of LPG.
- Transport emissions:
  - Transport emissions associated with air travel, rail, and marine fuel that cross Dunedin's geographic boundary were calculated by working out the emissions relating to each journey arriving or departing Dunedin based on data provided by the relevant operators. Emissions for these sources are then split equally between the destination and origin.
  - It is understood that air travel and marine journeys departing and arriving at Dunedin Airport and Port Otago do not just serve the Dunedin population and Dunedin commercial interests, however all emissions have been allocated to Dunedin. This approach ensures that all emissions are accounted for in regional emissions reporting. Dunedin's emissions from these sources are therefore higher than if emissions were split between all areas benefitting from these transport hubs. The same approach is used for emissions related to transport hubs outside of Dunedin, such as Auckland Airport which serves and benefits Dunedin through long-haul international flights for Dunedin's residents and tourists, these emissions have not been included in Dunedin's emissions inventory.
  - All other transport emissions are calculated based on the fuel sold or consumed 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 (this includes emissions from landfill sites that are currently closed).

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[4] https://www.dunedin.govt.nz/council/annual-and-long-term-plans/10-year-plan-2021-2031/section-4/significant-forecasting-assumptions

- Emissions are calculated for waste produced within the geographic boundary, even if transported outside the boundary to be entered into a landfill. Landfill waste for Dunedin is mainly disposed of at Green Island Landfill located within Dunedin, with some waste transported to other landfill sites outside Dunedin. Emissions from landfill waste not disposed of at Green Island have been estimated based on historical waste data due to an inability to obtain data from private operators.

- 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. This population estimate has been based on 2017/18 data and has been assumed to be unchanged since then.
- Industrial Processes and Product Use (IPPU) emissions:
  - IPPU emissions have been estimated based on data provided in the New Zealand Greenhouse Gas Emissions 1990-2020 report (MfE 2022). Emissions are calculated per capita, applying a national average per person.
- Forestry emissions:
  - This emissions footprint 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 footprint considers regenerating (growing) forest areas only. The 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 footprint have been provided to Dunedin City Council in calculation table spreadsheets. All assumptions made during data collection and analysis have been detailed within **Appendix A – Assumptions**.

It is important to consider the uncertainty associated with the results, particularly given the different datasets used. National, regional, and local datasets are used across the other calculators depending on data availability. At the national level, New Zealand's Greenhouse Gas Inventory shows that for 2020 (the most recent nationwide inventory), an estimate of the gross emissions uncertainty was +/- 8.8%, the net emissions uncertainty estimate was +/- 26.9%, and the uncertainty in the gross emissions trend was +/-6.4%. These levels of uncertainty should be considered when interpreting the results of this community carbon footprint (MfE, 2022[5]).

StatsNZ Regional Footprint

Due to differences in emission factors and methodology used between the StatsNZ Regional Footprints and this community carbon footprint (based on the GPC requirements and available data), caution should be taken when comparing reported emissions. One example is where this footprint uses updated emission factors for methane and nitrous oxide following guidance from the IPCC and in line with other district and regional-level GHG inventories in New Zealand. This difference is especially relevant for the Agriculture sector.

[5] https://environment.govt.nz/assets/publications/GhG-Inventory/New-Zealand-Greenhouse-Gas-Inventory-1990-2020-Chapters-1-15.pdf

3.0 Community Carbon Footprint for 2021/22

The paragraphs, figures and tables below outline Dunedin's greenhouse gas emissions, referred to as 'emissions' in this assessment. This includes Dunedin'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, Dunedin emitted **total gross emissions** of 1,542,500 tCO_2e. Note that gross emissions do not account for Forestry sequestration and harvesting emissions. Agriculture and Transport emissions are the city's most significant contributors to total gross emissions.

The population of Dunedin in 2021/22 was approximately 133,726 people, resulting in per capita gross emissions of 11.5 tCO_2e/person. Discussion of per capita emissions is limited to when it is useful for comparing emission figures against other territorial authorities. A breakdown of net emissions (i.e., including results from Forestry resources) is reported separately.

Table 1 Total net and gross emissions

Total emissions	tCO_2e
Total Net Emissions (including Forestry)	1,049,330
Total Gross emissions (excluding Forestry)	1,542,500

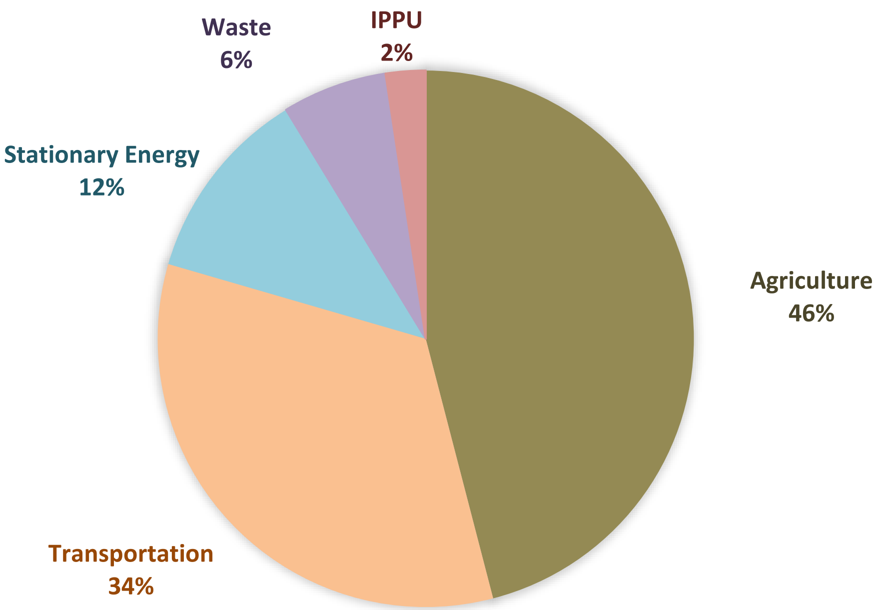

Figure 3: Dunedin City's total gross GHG emissions split by sector (tCO_2e).

Net emissions differ from gross emissions because they include emissions related to forestry activity (harvesting emissions and forestry sequestration). The cyclical nature of harvesting and planting regimes influences the observed forestry emissions. During the 2021/22 reporting period, Dunedin emitted **total net emissions** of 1,049,330 tCO_2e.

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

3.1 Agriculture

Agriculture emitted 708,856 tCO_2e in 2021/22 (46% of Dunedin's gross emissions). Table 2 provides the total emissions, percentage of the total gross emissions, and percentage of the sector total for each sector/emissions source.

Agricultural emissions are the result of both livestock and crop farming. Enteric fermentation from livestock produced 77% of Dunedin's agricultural emissions (544,475 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 from nitrous oxide (N_2O) released by unmanaged manure from grazing animals on pasture (79,987 tCO_2e).

Table 2 Agriculture emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Livestock Enteric Fermentation	544,475	35.3%	76.8%
Unmanaged Manure on Pasture	79,987	5.2%	11.3%
Agricultural Leaching and Deposition	52,069	3.4%	7.3%
Managed Manure	21,286	1.4%	3.0%
Fertilisers on Land	11,039	0.7%	1.6%
Total	**708,856**	**46.0%**	**100%**

Livestock was responsible for 98% of the Agriculture sector's GHG emissions (see Table 3). Sheep represent 85% of the total number of livestock in Dunedin in 2021/22 and 51% of agricultural emissions. Cattle (dairy and non-dairy) represent 13% of the total number of livestock in Dunedin in 2021/22 and 46% of agricultural emissions, this is due to their greater emissions footprint compared to sheep per animal.

It is important to note that GPC reporting standards do not include emissions related to the consumption of products created outside the Dunedin City boundary, including agriculture products (e.g. meat and dairy).

Table 3 Agriculture emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Sheep	358,080	23%	51%
Dairy Cattle	191,529	12%	27%
Non-dairy Cattle	131,970	9%	19%
Other livestock	14,185	1%	2%
Fertiliser (other)	13,093	1%	2%
Total	**708,856**	**46%**	**100%**

3.2 Transport

The second highest emitting sector in Dunedin, Transport, produced 517,379 tCO2e in 2021/22 (34% of Dunedin's gross total emissions). Table 4 provides the total emissions, percentage of the total gross emissions, and percentage of the sector total for each sector/emission source.

Table 4 Transport energy emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Diesel	216,594	14.0%	41.9%
Marine Freight	160,389	10.4%	31.0%
Petrol	114,412	7.4%	22.1%
Jet Kerosene (Air Travel)	18,494	1.2%	3.6%
Rail	4,218	0.3%	0.8%
Marine Diesel (Local)	1,872	0.1%	0.4%
LPG	1,178	0.1%	0.2%
Aviation Gas (Air Travel)	223	<0.1%	<0.1%
Total	**517,379**	**33.5%**	**100%**

Most of the Transport emissions in 2021/22 can be attributed to diesel and petrol, which produced 261,594 tCO_2e and 114,412 tCO_2e respectively (collectively 64% of the sector's emissions and 22% of total gross emissions). Diesel and petrol transport emissions are broken down into on-road and off-road use (see Table 5). On-road transport consists of all standard road vehicles (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 288,511 tCO_2e in 2021/22 (56% of Transport emissions and 19% of total gross emissions) and Off-road transport produced 43,674 tCO_2e (8% of Transport emissions). An extra breakdown of on-road emissions by vehicle type and class is appended to this report.

Table 5 Petrol and diesel emissions – on-road and off-road

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Diesel (On-road)	175,149	11.4%	33.9%
Petrol (On-road)	113,362	7.3%	21.9%
Diesel (Off-road)	41,445	2.7%	8.0%
Petrol (Off-road)	1,050	0.1%	0.2%
Petrol and Diesel Total	**331,006**	**21.5%**	**64.0%**

The next largest emission source for Dunedin in 2021/22 is marine freight, contributing 31% of the sector's emissions and 10% of total gross emissions (160,389 tCO_2e). Marine freight emissions are the result of freight movements to and from Port Otago.

The remaining Transport emissions are attributed to air travel (jet kerosene and aviation gas), rail and local marine transport (port vessels and local ferries), rail, and LPG use for transport (e.g., forklifts).

It is understood that marine freight and air travel journeys departing and arriving at Dunedin do not just serve the Dunedin population and commercial interests, however all emissions have been allocated to Dunedin. The same approach has been taken for transport hubs outside Dunedin such as Auckland Airport which serve and benefit Dunedin's population and tourists through long-haul international flights but are not included in Dunedin's emissions inventory. This approach ensures that all emissions are accounted for in regional emissions reporting. Dunedin's emissions from these sources may therefore be different if emissions were split between all areas benefitting from these transport hubs. All assumptions have been detailed in Appendix A.

3.3 Stationary Energy

Producing 181,671 tCO_2e in 2021/22, Stationary Energy was Dunedin's third-highest emitting sector (12% of total gross emissions). Table 6 provides the total emissions, percentage of the total gross emissions, and percentage of the sector total for each sector/emission source.

Table 6 Stationary Energy emissions by emission source

Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Electricity Consumption	78,920	5.1%	43.4%
Coal	34,250	2.2%	18.9%
LPG	30,943	2.0%	17.0%
Stationary Petrol & Diesel Use	23,846	1.5%	13.1%
Electricity Transmission & Distribution Losses	8,370	0.5%	4.6%
Biofuel / Wood	5,303	0.3%	2.9%
Landfill Biogas (used for energy generation)	39	<0.1%	<0.1%
Total:	**181,671**	**11.8%**	**100%**

Electricity consumption was the cause of 43% of Stationary Energy emissions in 2021/22 (78,920 tCO_2e) and 5% of Dunedin's total gross emissions (87,290 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 (tCO_2e/kWh), which is determined by the methods of overall national electricity generation in a particular year. The emissions intensity of the national grid can fluctuate year on year resulting in changes to electricity consumption emissions even when consumption levels haven't changed (e.g., despite no significant change in consumption, electricity consumption emissions in 2020/21 were 121,808 tCO_2e, 54% higher than in 2021/22).

The use of coal accounted for 19% of the Stationary Energy emissions in 2021/22 (34,250 tCO_2e). Use of LPG generated 17% of Stationary Energy emissions in 2021/22 (30,943 tCO_2e). The burning of petrol and diesel, biofuels, and landfill biogas used for energy generation, produced the remaining Stationary Energy emissions.

Biogenic carbon dioxide (CO_2) emissions from biofuels and landfill gas burning for energy generation have not been included in these totals and are reported separately in Section 3.9. Emissions of other greenhouse gasses produced by these emission sources (e.g. methane and nitrous oxide) have been included in these totals and converted to units of carbon dioxide equivalence (CO_2e) as per GPC guidance.

3.4 Waste

Waste originating in Dunedin (solid waste and wastewater) produced 97,567 tCO_2e in 2021/22, which comprises 6% of Dunedin's total gross emissions. Table 7 provides the total emissions, percentage of the total gross emissions, and percentage of the sector total for each sector/emission source.

Table 7 Waste emissions by emission source

Sector / Emissions Source	tCO_2e	% of Total Gross Emissions	% of Sector Total
Waste in Open Landfill Sites	55,475	3.6%	56.9%
Waste in Closed Landfill Sites	29,472	1.9%	30.2%
Wastewater Treatment Plants	8,901	0.6%	9.1%
Individual Septic Tanks	3,720	0.2%	3.8%
Total:	**97,567**	**6.3%**	**100%**

Solid waste produced the bulk of waste emissions (84,946 tCO_2e in 2021/22), making up 87% of total waste emissions. Solid waste emissions include emissions from open landfills and closed landfills. Open landfill sites produced 55,475 tCO_2e in 2021/22, and closed landfill sites produced 29,472 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.

Open landfill emissions include emissions from waste produced in Dunedin and predominantly sent to the currently open Green Island landfill. Emissions from waste transported out of Dunedin and disposed of in other open landfill sites has also been estimated and included in the results.

Emissions relating to the combustion of landfill gas used for energy generation have been included in the Stationary Energy sector results.

Emissions from diverted and composted green waste have not been calculated due to a lack of reliable data. It is likely that this would be a small emissions source for Dunedin.

Wastewater treatment (treatment plants and individual septic tanks) accounted for 13% of total waste emissions in 2021/22 (12,621 tCO_2e). The majority of households in Dunedin (85% in 2021/22) are connected to wastewater treatment plants, producing total emissions of 8,901 tCO_2e in wastewater emissions. Households not connected to centralised wastewater treatment plants (i.e., using individual septic tanks) produced 3,720 tCO_2e in wastewater emissions. Due to methane production, septic tanks have a higher emissions intensity per quantity of wastewater compared to the wastewater treatment plants in Dunedin.

3.5 Industrial Processes and Product Use (IPPU)

IPPU in Dunedin produced 37,027 tCO_2e in 2021/22, contributing 2% to Dunedin'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 Dunedin (e.g., aluminium 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.

Table 8 provides the total emissions, percentage of the total gross emissions, and percentage of the sector total for each sector/emission source. The most significant contributor to IPPU emissions is refrigerants, which produced 93% of IPPU emissions (34,448 tCO_2e).

Table 8 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	34,448	2.2%	93.0%
Aerosols	1,919	0.1%	5.2%
SF6 - Electrical Equipment	375	<0.1%	1.0%
Foam Blowing	151	<0.1%	0.4%
SF6 - Other	74	<0.1%	0.2%
Fire extinguishers	59	<0.1%	0.2%
Total	**37,027**	**2.4%**	**100%**

3.6 Forestry

Planting of native forests (e.g. mānuka and kānuka) and exotic forest (e.g. pine) sequesters (captures) carbon from the atmosphere while the trees are growing to maturity. Harvesting of forests emits emissions 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 reduces annual total emissions. Conversely, when emissions from harvesting exceed the amount of carbon sequestered by native and exotic forests, then total gross emissions will increase.

Sequestration in 2021/22 was 768,455 tCO_2e (mostly from exotic forests), while harvesting emissions were 275,285 tCO_2e. This meant that Forestry in Dunedin was a net negative source of emissions in 2021/22 (rather than a positive source of emissions, where harvesting exceeds sequestration). Total Forestry emissions in 2021/22 were -493,170 tCO_2e. It is noted that the harvesting of exotic (commercial) 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 9 Forestry emissions by emission source (including sequestration)

Sector / Emissions Source	tCO_2e
Harvest Emissions	275,285
Native Forest Sequestration	-183,659
Exotic Forest Sequestration	-584,796
Net Total	**-493,170**

3.7 Comparison with other Cities in Aotearoa/New Zealand – Total and Per-Capita Emissions

It can be helpful to put Dunedin's emissions inventory in context by comparing it to the emissions inventory of other cities in Aotearoa/New Zealand. This section presents Dunedin's emissions inventory alongside the emissions inventory for different cities in Aotearoa/New Zealand. It is essential to note the differences between the cities (e.g., population size and land area), the time period covered, and that slightly different methodologies and assumptions may have been used to calculate emissions, when comparing Dunedin's emissions inventory with other cities. These considerations will impact the comparability of these inventories.

Wellington, Christchurch, Tauranga, and Hamilton have been chosen as comparable cities to Dunedin. Due to Auckland's much larger population and land area, a comparison with Auckland has not been made. Total gross emissions and total gross emissions per capita are displayed and discussed below.

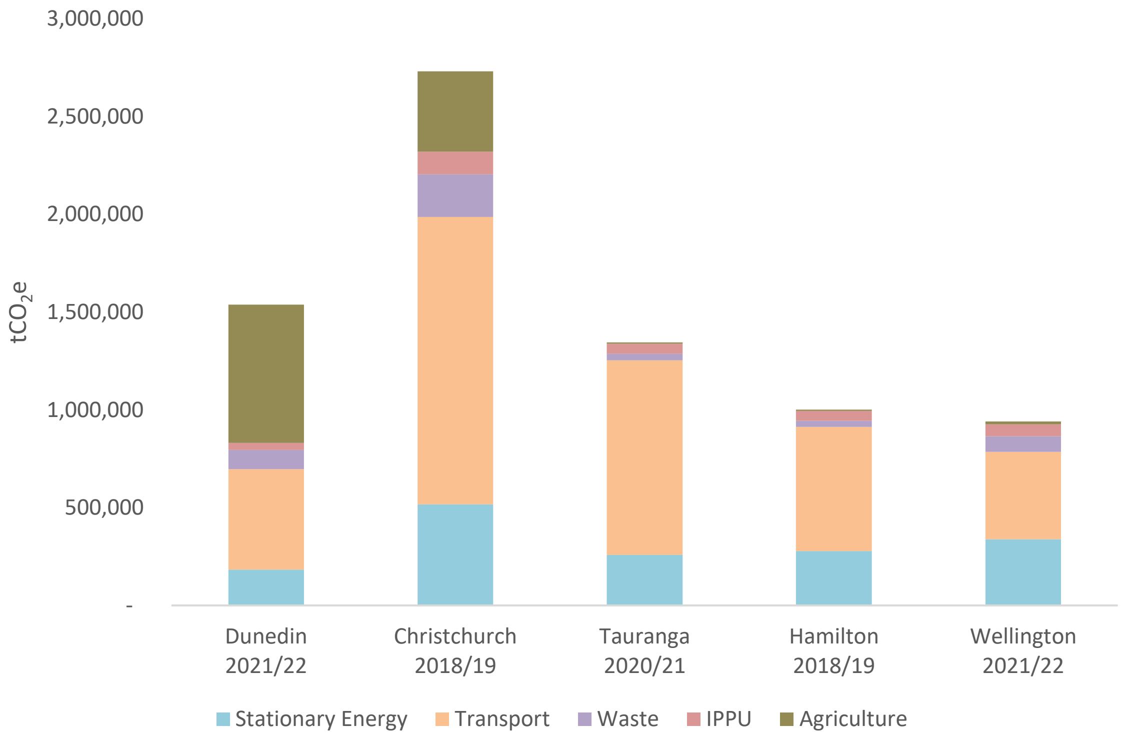

Figure 4 Total gross emissions for Dunedin and comparable cities (tCO_2e).

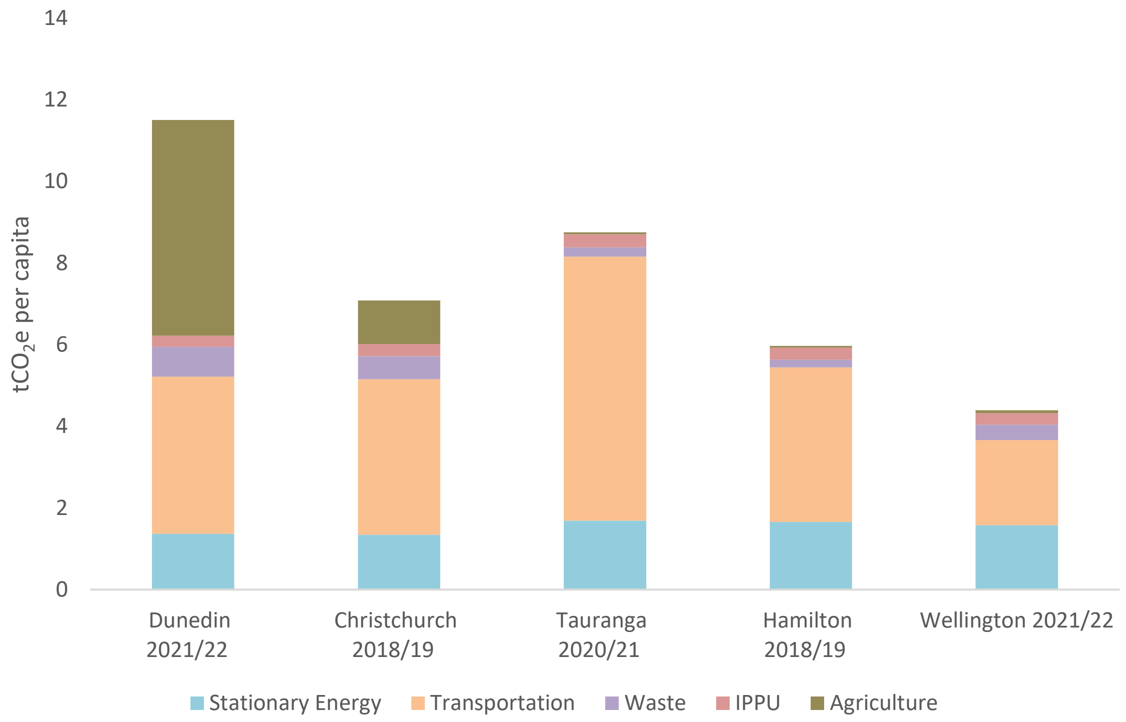

Figure 5 Total per capita gross emissions for Dunedin and comparable cities (tCO_2e).

Of these five cities, Dunedin had the second highest total gross emissions, behind only Christchurch, whose inventory covers a much larger population. This is mainly the effect of Dunedin's Agriculture emissions compared to the other cities due to the Dunedin geographic area covering more rural areas than the other cities. When excluding Agriculture emissions, Dunedin's total gross emissions are the lowest of these cities, although Dunedin's population is also the smallest of these cities (the population covered by the emissions inventory).

From a per capita perspective, Dunedin had a 11.5 tCO_2e/per capita figure for total gross emissions, which is lower than the national value of 15.7 tCO_2e/per capita. This is mainly due to differences in Stationary Energy and Agriculture per capita, where Dunedin had 1.4 tCO_2e/per capita for Stationary Energy and 5.3 tCO_2e/per capita for Agriculture, compared to 4.1 tCO_2e/per capita and 9.0 tCO_2e/per capita respectively in the National inventory.

Of the five cities compared above, Dunedin had the highest per capita emissions; this is again mainly due to differences in Agriculture emissions. When excluding Agriculture emissions, Dunedin's total gross emissions per capita are very similar to those for Christchurch and Hamilton. Wellington's lower per capita emissions are mainly the result of lower on-road transport emissions per capita. High marine freight emissions per capita in Tauranga (New Zealand's largest port by volume) contribute to Tauranga's high Transport emissions per capita.

3.8 Total Gross Emissions by Greenhouse Gas

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

Table 10: Dunedin's total gross emissions by greenhouse gas

Greenhouse Gas	Tonnes	Tonnes of CO_2e
Carbon Dioxide (CO_2)	679,354	679,354
Biogenic Methane (CH_4)	19,373	658,670
Non-biogenic Methane (CH_4)	242	8,235
Nitrous Oxide (N_2O)	529	157,522
Other / Unknown Gas (in CO_2e)	38,719	38,719
Total	**738,216**	**1,542,500**

Figure 6 illustrates Dunedin's total gross emissions by greenhouse gas in tonnes of the individual gas, and when converted to units of carbon dioxide equivalents (CO_2e).

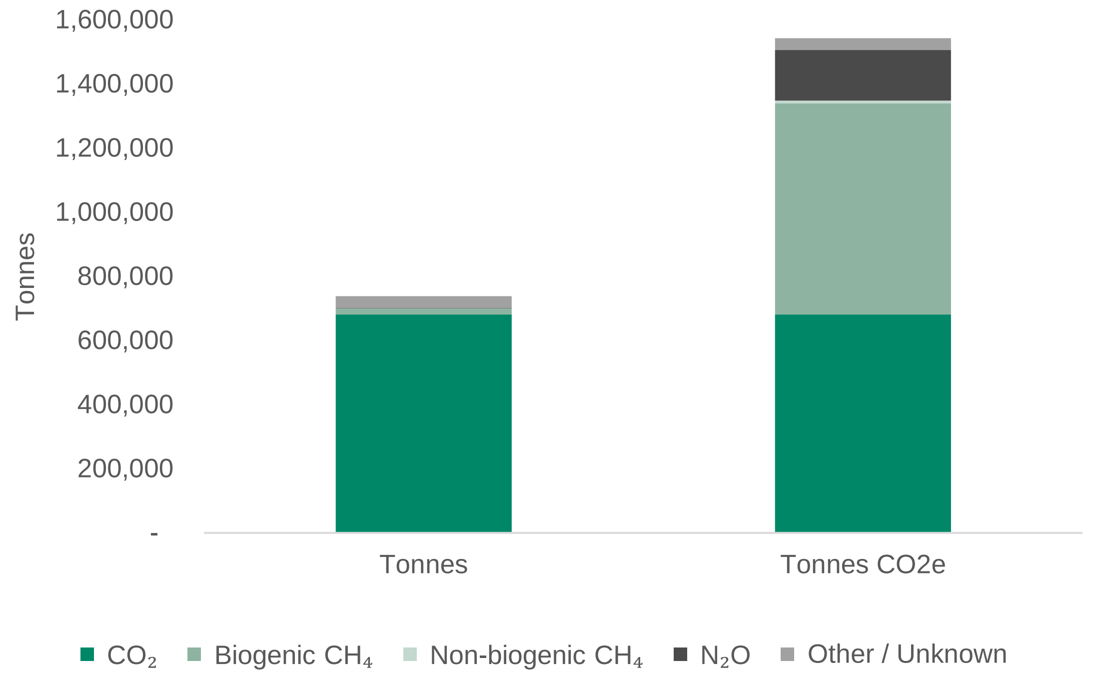

Figure 6: Dunedin's total gross emissions by greenhouse gas (in tonnes, and converted into tonnes of CO_2 equivalent units)

By far, the largest source of emissions in tonnes in Dunedin in 2021/22 is carbon dioxide (CO_2), representing 92% of emitted greenhouse gases (679,354 tonnes). However, due to the greater global warming impact of methane and nitrous oxide, methane represents 43% of the climate change impact of greenhouse gasses in Dunedin (in tCO_2e), while nitrous oxide represents 10% of the tCO_2e. Carbon dioxide represents 44% of the climate change impact of greenhouse gases produced in Dunedin (in tCO_2e).

The largest sources of carbon dioxide emissions are on-road transport (280,054 tonnes), and marine freight (157,003 tonnes). The largest sources of methane are agriculture (16,577 tonnes or 563,610 tCO_2e) and solid waste (2,498 tonnes or 84,946 tCO_2e). The largest source of nitrous oxide emissions is agriculture (469 tonnes or 139,778 tCO_2e).

Table 11 shows Dunedin's emissions by sector, broken down by greenhouse gas (converted to CO_2e).

Table 11: Dunedin's gross emissions by sector, broken down by greenhouse gas (converted to tonnes of carbon dioxide equivalent units (tCO_2e))

Emissions Source	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	Other / Unknown	Total
Agriculture	5,468	563,610	139,778	-	708,856
Transportation	503,992	2,803	8,891	1,693	517,379
Stationary Energy	169,893	7,877	3,901	-	181,671
Waste	-	92,614	4,953	-	97,567
IPPU	-	-	-	37,027	37,027
Total	**679,354**	**666,905**	**157,522**	**38,719**	**1,542,500**

3.9 Biogenic Emissions

Biogenic carbon dioxide and methane emissions are stated in Table 12 and Table 13, respectively.

Biogenic Carbon Dioxide (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 part of the natural carbon cycle.

Table 12: Biogenic CO_2 in Dunedin (Excluded from gross emissions)

Emissions Source	Biogenic tCO_2
Biofuel / Wood	80,562
Landfill Biogas (used for energy generation)	5,998
Total Biogenic CO_2	**86,560**

Biogenic methane (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 3% of the total gross tonnage of GHG emissions in Dunedin but 43% 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 10.

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 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 13: Biogenic Methane in Dunedin (Included in gross emissions)

Emissions Source	Biogenic tCH_4
Enteric Fermentation	16,014
Landfill Biogas	2,498
Manure Management	563
Wastewater Treatment	226
Biofuel / Wood	72
Total Biogenic CH_4	**19,373**

4.0 Emissions change from 2018/19 to 2021/22

Alongside calculating Dunedin's emissions footprint for 2021/22, Dunedin's emissions footprint for 2019/20 and 2020/21 have also been calculated, and the previously published 2018/19 footprint has been updated. It can be helpful to update previous footprints when methodologies, data sources, and emission factors are updated; this enables direct comparison between footprints for different years. Detail on the update to the 2018/19 footprint can be found in section 6.0.

This section displays the results for the 2018/19, 2019/20, 2020/21, and 2021/22 years with a focus on gross emissions and the change in emissions from 2018/19 to 2021/22. The updated 2018/19 footprint is to be used as a baseline by Dunedin City Council against which to track emissions changes over time.

Table 14 Change in Dunedin's Total Gross and Net emissions from 2018/19 to 2021/22

	2018/19 (tCO_2e)	2019/20 (tCO2e)	2021/22 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Total Net Emissions (including forestry)	1,335,709	1,097,490	1,218,358	1,049,330	-21%
Total Gross Emissions (excluding forestry)	1,697,047	1,621,684	1,646,955	1,542,500	-9%

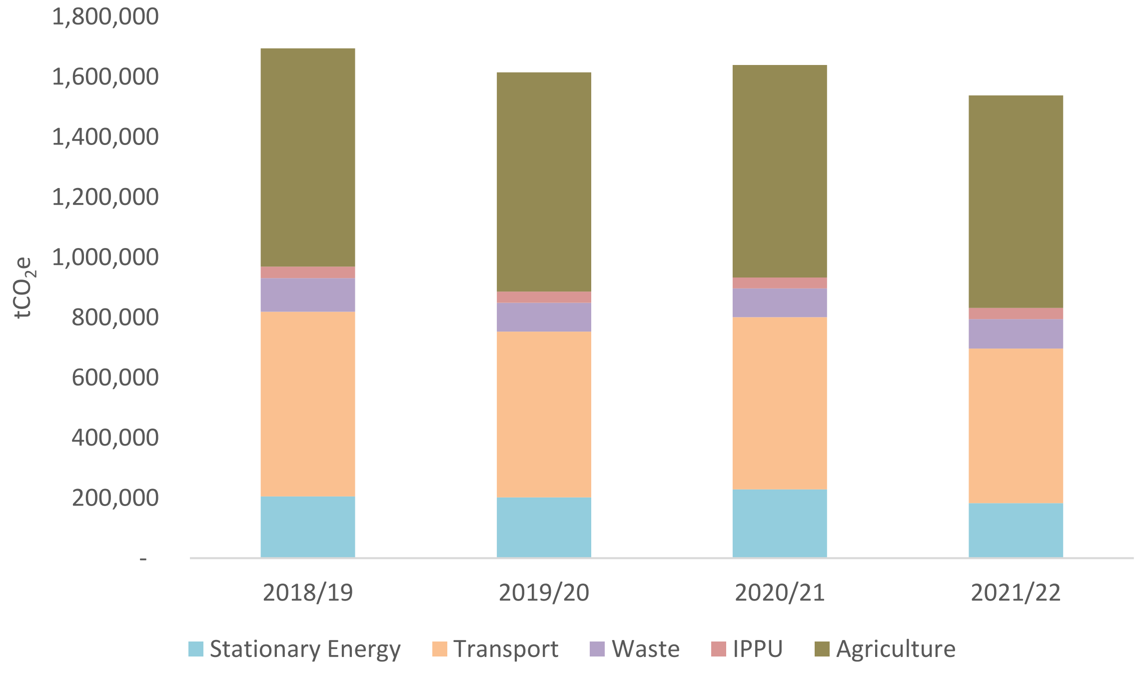

Figure 7 Change in Dunedin's total gross emissions from 2018/19 to 2021/22

Annual total gross emissions decreased by 9% (154,546 tCO2e) from 1,697,047 tCO_{2}/e in 2018/19 to 1,542,500 tCO_2e in 2021/22. The decrease in total gross emissions was driven by a reduction in Transport emissions primarily related to decreases in petrol and diesel fuel consumption, air travel and marine freight movements. Sales of petrol and diesel decreased, however the kilometres travelled by vehicles increased by 2%, suggesting that changes to the vehicle fleet may be the cause of the decrease in petrol and diesel emissions. It is likely that COVID-19 restrictions and disruptions to international trade impacted emissions from air travel and marine freight transport during these years.

A reduction in electricity consumption emissions due to changes in the emissions intensity of the national grid (tCO_2e/kWh), reduction in the number of sheep in Dunedin, and improvements to solid waste landfill gas capture also notably impacted total gross emissions.

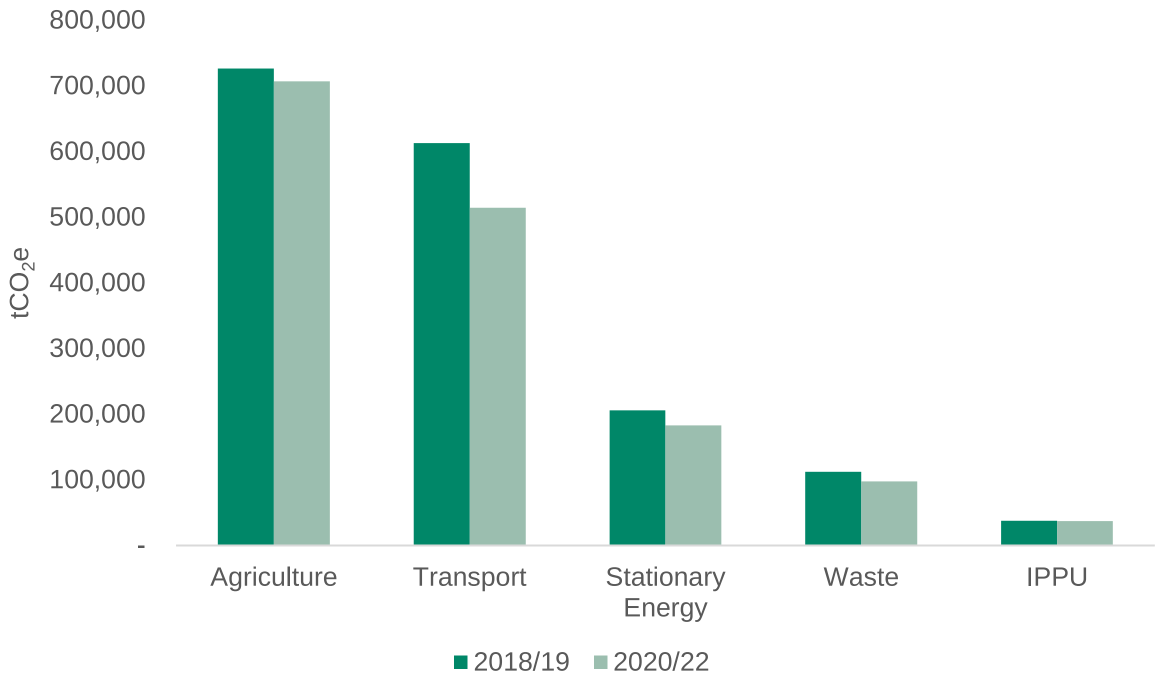

Figure 8 Emissions for each sector of Dunedin's gross emissions footprint for 2018/19 and 2021/22

Annual total net emissions in Dunedin decreased by 21% (286,379 tCO_2e) from 1,335,709 in 2018/19 to 1,049,330 tCO_2e in 2021/22. The decrease in net emissions was driven by the 9% (154,546 tCO_2e) reduction in total gross emissions (driven by changes in Transport, Stationary Energy, Agriculture, and Waste) and a net increase in sequestration from Forestry (due to a decrease in annual forest harvesting and an increase in the area of exotic (commercial) forestry cover).

The population of Dunedin increased by 2% between 2018/19 and 2021/22, resulting in per capita gross emissions in Dunedin reducing by 11% between 2018/19 and 2021/22 (from 13.0 to 11.5 tCO2e per person per year) as total gross emissions decreased during this period. A discussion of the decoupling of gross emissions from population growth and GDP is found in Section 7.0.

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.

4.1 Agriculture

Table 15 Change in Dunedin'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	557,334	560,331	544,475	544,475	-2%
Unmanaged Manure on Pasture	82,448	82,638	79,987	79,987	-3%
Agricultural Leaching and Deposition	54,138	53,975	52,069	52,069	-4%
Managed Manure	20,808	20,930	21,286	21,286	2%
Fertilisers on Land	13,590	12,381	11,039	11,039	-19%
Total	**728,318**	**730,255**	**708,856**	**708,856**	**-3%**

The Agriculture sector's emissions decreased by 3% between 2018/19 and 2021/22 (19,461 tCO_2e). This decrease is driven by a decrease in Livestock Enteric Fermentation emissions (12,858 tCO_2e) due to a reduction in the total number of sheep in Dunedin (see Table 16 and Table 17).

Sheep represent 85% of total livestock in Dunedin in 2021/22 and 51% of agricultural emissions. Emissions related to sheep decreased by 8% (52,814 tCO_2e) due to an 8% reduction in the number of sheep (from 702,162 sheep to 649,349 sheep).

Cattle (dairy and non-dairy) represent 13% of total livestock in Dunedin in 2021/22 and 46% of agricultural emissions, this is due to their greater emissions footprint compared to sheep. Emissions related to cattle increased by 3% (13,464 tCO_2e) due to a 4% increase in the number of cattle (from 96,056 cattle to 98,607 cattle).

Another notable change is in Fertilisers on Land which decreased by 19% due to a reduction in the amount of liming and dolomite fertiliser used in Dunedin.

Table 16 Change in Dunedin's Livestock emissions from 2018/19 to 2021/22

	2018/19 (tCO_2e)	2021/22 (tCO_2e)	% Change in Emissions (2018/19 to 2021/22)
Sheep	377,877	358,080	-8%
Dairy Cattle	181,387	191,529	6%
Non-dairy Cattle	128,648	131,970	3%
Other livestock	15,055	14,185	-6%
Total	**702,966**	**695,764**	**-2%**

Table 17 Change in Dunedin's Livestock numbers from 2018/19 to 2021/22

	Number of Animals (2018/19)	Number of Animals (2021/22)	% Change in Number of Animals (2018/19 to 2021/22)
Sheep	702,162	649,349	-8%
Dairy Cattle	45,102	47,152	5%
Non-dairy Cattle	50,954	51,455	1%
Other livestock	14,983	14,401	-4%
Total	**813,202**	**762,357**	**-6%**

4.2 Transport

Table 18 Change in Dunedin's 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	237,707	226,696	236,871	216,594	-9%
Marine Freight	191,429	169,794	175,594	160,389	-16%
Petrol	144,638	130,780	136,243	114,412	-21%
Jet Kerosene (Air Travel)	30,054	20,315	20,315	18,494	-38%
Rail	4,557	4,427	4,218	4,218	-7%
Marine Diesel (Local)	3,067	1,807	1,807	1,872	-39%
LPG	1,134	1,124	1,163	1,178	4%
Aviation Gas (Air Travel)	346	245	245	223	-36%
Total	**612,931**	**555,188**	**576,454**	**517,379**	**-16%**

Emissions from Transport decreased by 16% between 2018/19 and 2021/22 (95,552 tCO_2e), driven by a reduction in emissions from petrol and diesel consumption (51,339 tCO_2e), marine freight movements (31,040 tCO_2e), and air travel (11,683 tCO_2e).

Petrol and diesel fuel emissions have been calculated based on fuel sales in the Dunedin, Clutha, and Waitaki areas, and apportioned between the three territorial authorities based on the vehicle kilometres travelled (VKT) in each area. Sales of both diesel and petrol decreased between 2018/19 and 2021/22, by 4% and 17% respectively. During the same period, total VKT for the three areas increased by 8%, while VKT in Dunedin increased by 2%, therefore Dunedin represented a smaller proportion of total sales using this approach. This results in a 9% (21,113 tCO_2e) reduction in diesel emissions and a 21% (30,226 tCO_2e) reduction in petrol emissions in Dunedin. A possible explanation for emissions from petrol and diesel to decrease while the distance travelled by vehicles increased could be improvements in the fuel efficiency and types of vehicles in Dunedin compared to the other areas. The COVID-19 related 'lockdowns' had short but significant impacts on fuel consumption with fast rebounds to normal levels, but it is more likely that longer term trends in individual and commercial transport, vehicle efficiency, and societal changes, are responsible for the trends seen in petrol and diesel used for transport.

Marine freight fuel emissions decreased by 16% between 2018/19 and 2021/22 (31,040 tCO_2e). This aligns with a 15% decrease in freight volumes through the Port during the same period[6]. COVID-19 related disruptions to international trade may have impacted freight movements during this time.

Jet Kerosene (jet aircraft fuel) emissions decreased by 38% (11,560 tCO_2e) due to a reduction in flights, especially of international flights and flights to/from Auckland, with total passenger numbers down 29% between 2018/19 and 2020/21 and no international flights since 2020[7]. The discrepancy between the change in passenger numbers and change in fuel emissions is explained by higher fuel consumption per passenger of the longer flights to Auckland and international destinations, compared to the majority of flights to and from Dunedin. This is likely the impact of COVID-19-related restrictions on travel and the slow pace of recovery of the aviation industry to pre-COVID-19 levels.

Note that emissions from cruise ships visiting Dunedin have not been estimated due to a lack of reliable data available to calculate these emissions. This is only relevant to 2018/19 and 2019/20 as there were no cruise ship visits in 2020/21 and 2021/22.

4.3 Stationary Energy

Table 19 Change in Dunedin'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	93,583	94,862	121,808	78,920	-16%
Coal	43,142	39,751	34,250	34,250	-21%
LPG	29,772	29,532	30,550	30,943	4%
Stationary Petrol & Diesel Use	26,308	25,038	26,159	23,846	-9%
Electricity Transmission and Distribution Losses	8,174	8,296	11,324	8,370	2%
Biofuel / Wood	4,755	5,029	5,303	5,303	12%
Landfill Biogas (used for energy generation)	30	45	44	39	30%
Total	**205,764**	**202,553**	**229,437**	**181,671**	**-12%**

Emissions from Stationary Energy decreased by 12% between 2018/19 and 2021/22 (24,093 tCO_2e). This was predominantly driven by a 16% decrease in electricity consumption emissions (14,663 tCO_2e).

Electricity consumption emissions are impacted by the amount of electricity consumed and the way in which the electricity is generated. Between 2018/19 and 2021/22 there was a 3% decrease in electricity consumption (in kWh) combined with a 13% decrease in the emissions intensity of the national electricity grid (tCO_2e/kWh), resulting in a 16% decrease in electricity consumption emissions. 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

[6] https://www.portotago.co.nz/assets/Uploads/PortOtago-AR-2022-Web.pdf
[7] https://www.dunedinairport.co.nz/assets/Dunedin-Annual-Report-2021-Glossy-FINAL-with-AR.pdf

fluctuates year on year, primarily driven by water levels in the hydropower system (as can be seen in the increase in emissions from 2018/19 to 2020/21 and subsequent decrease again in 2021/22).

Other notable changes can be seen in coal consumption emissions which decreased by 21% (8,892 tCO_2e), likely driven by a change in fuel use at the Dunedin Energy Centre from coal to biofuels (woodchips). Unlike with electricity consumption emissions, this is a local change that is outside of the direct influence of activities outside the Dunedin boundary and is likely to be part of a longer-term trend.

LPG emissions are estimated based on data covering the South Island and allocated to Dunedin on a per capita basis, this means that the 4% increase in LPG emissions follows the trend for the South Island as a whole.

4.4 Waste

Table 20 Change in Dunedin's 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)
Open Landfill	63,003	49,334	50,887	55,475	-12%
Closed Landfill	37,345	34,421	31,810	29,472	-21%
Wastewater Treatment Plants	8,405	8,653	8,901	8,901	6%
Individual septic tanks	3,720	3,720	3,720	3,720	0%
Total	**112,473**	**96,128**	**95,318**	**97,567**	**-13%**

Total Waste emissions reduced by 13% between 2018/19 and 2021/22 (14,906 tCO_2e); this was driven by improvements to landfill gas capture at open landfills and a reduction in landfill gas emissions from closed landfill sites.

The majority of Dunedin's waste is processed at the Green Island landfill. At Green Island the total landfill gas (CH_4) produced annually increased by 2% between 2018/19 and 2021/22 due to increases in annual waste volumes sent to landfill over the last 20 years. However, improvements to landfill gas capture systems have meant that 30% more landfill gas (CH_4) was captured and used for energy generation or flared in 2021/22 compared to 2018/19. This resulted in a 12% (7,529 tCO_2e) reduction in emissions from open landfill sites from 2018/19 to 2021/22.

Closed landfill site emissions made up 30% of Dunedin's Waste emissions in 2021/22. Closed landfill sites continue to emit landfill gas long after they have closed but, as no additional waste enters these sites, annual emissions from this source will fall over time. Annual emissions from closed landfill sites reduced by 21% (7,873 tCO_2e) between 2018/19 and 2021/22.

Emissions relating to the combustion of landfill gas used for energy generation have been included in the Stationary Energy sector results.

Emissions from wastewater treatment plants increased by 6% between 2018/19 and 2021/22, mainly driven by an increase in population connected to the Green Island wastewater treatment plant. Note that data was not available for the 2021/22 year, so the 2020/21 value has been used.

Emissions from Individual Septic Tanks are determined based on an estimate of the population of Dunedin not connected to centralised wastewater treatment plants. Note that this population estimate is based on data from 2017/18 and has been assumed to be unchanged since then so there is no reported change in emissions from this source.

4.5 Industrial Processes and Product Use (IPPU)

Table 21 Change in Dunedin's 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	34,742	34,742	34,321	34,448	-1%
Aerosols	2,186	2,186	1,912	1,919	-12%
SF6 - Electrical Equipment	345	345	374	375	9%
Foam Blowing	152	152	150	151	-1%
SF6 - Other	74.8	74.8	73.3	73.6	-2%
Fire extinguishers	61	61	59	59	-2%
Total	**37,561**	**37,561**	**36,890**	**37,027**	**-1%**

IPPU emissions decreased between 2018/19 and 2021/22 by 1% (534 tCO_2e). A decrease in refrigerant and aerosol emissions mainly drives the decrease in IPPU emissions. This may be a decrease in the quantity used or an increase in the use of lower emissions-impacting refrigerants and aerosols. Note that national-level data is used for this sector and is portioned out using a population approach; actual emissions related to IPPU for the city are unknown.

4.6 Forestry

Table 22 Change in Dunedin's 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)
Exotic Forest Sequestration	- 526,686	- 572,195	- 584,796	- 584,796	11%
Native Forest Sequestration	- 183,659	- 183,659	- 183,659	- 183,659	0%
Forest Harvest Emissions	349,008	231,659	339,858	275,285	-21%
Total	**-361,337**	**-524,194**	**-428,596**	**-493,170**	

Net Forestry sequestration and 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 emissions. 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.

Annual net Forestry sequestration increased by 131,833 tCO_2e between 2018/19 and 2021/22, from -361,337 tCO_2e to -493,170 tCO_2e. The rise in annual net sequestration was caused by a decrease in the amount of forest harvesting (producing emissions), and an increase in the area of exotic (commercial) forestry cover (sequestering emissions).

Annual forestry harvesting emissions decreased by 21% between 2018/19 and 2021/22. Note that annual forest harvesting emissions fluctuate year to year as described above. For context, annual harvesting emissions in 2021/22 were higher than most years from 2014/15 to 2021/22, and 2018/19 were larger than all but one year in the period from 2014/15 to 2021/22.

The area of Dunedin covered by exotic forestry increased by 6% between 2018/19 and 2021/22 with the area of land covered by forestry of peak sequestration age (6-40 years old) increasing by 14%. This resulted in an increase of annual sequestration from exotic forestry of 11%.

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 Net Zero 2030 Goal Tracking

Like the New Zealand's national emissions reduction target, Dunedin city's emissions reductions target is in two parts (the 'split gas approach').

Split gas emissions reduction targets:

- Dunedin aims to achieve net zero emissions of carbon dioxide and other greenhouse gases by 2030 (except biogenic methane[8]) based on the 2018/19 baseline inventory presented here (*i.e. Total Net Emissions excluding Biogenic Methane).*
- Dunedin also aims to achieve a 24-47% reduction in biogenic methane emissions below 2016/17 levels by 2050, including a 10% reduction below 2016/17 levels by 2030 (*i.e. Total Biogenic Methane Emissions*).

Table 23 presents the results of this inventory using the split gas approach as per the emissions reduction targets, alongside total gross and total net emissions.

Split gas emissions reduction tracking:

- Total Net Emissions (Excluding Biogenic Methane):
  - Total Net Emissions (Excluding Biogenic Methane) decreased by 40% (259,472 tCO_2e) between 2018/19 and 2021/22.
  - This increase was driven by a 131,833 tCO_2e increase in net sequestration from Forestry due to an increase in the area of exotic forestry cover and a decrease in commercial harvesting following national trends. As mentioned above, net 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 emissions. Due to the variable nature of net forestry emissions, net sequestration cannot be relied upon to achieve long-term reductions in total net emissions.
  - The decrease in Transport emissions had the next largest impact on Total Net Emissions (Excluding Biogenic Methane). It is also important to note that Transport emissions have the potential to increase if flights and marine freight journeys return to pre-COVID-19 pandemic levels.
- Total Biogenic Methane Emissions:
  - Total Biogenic Methane Emissions decreased by 4% (26,907 tCO_2e) between 2018/19 and 2021/22.
  - This was driven by a reduction in enteric fermentation emissions from sheep due to a reduction in the number of sheep in Dunedin. This decrease has been slightly offset by an increase in the number of cattle in Dunedin.

Reducing emissions across the board will need to be achieved for Dunedin to be able to reach the city's emissions reductions targets. It is therefore important that total gross emissions remain the focus of attention while considering Dunedin's emissions progress.

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[8] See section 3.9

Table 23 Change in Dunedin's total emissions from 2018/19 to 2021/22 (split gas approach)

	2018/19 (tCO_2e)	2019/20 (tCO_2e)	2020/21 (tCO_2e)	2021/22 (tCO_2e)	% Change (2018/19 to 2021/22)
Total Gross Emissions (including biogenic methane)	1,697,047	1,621,684	1,646,955	1,542,500	-9%
Total Net Emissions (including biogenic methane)	1,335,709	1,097,490	1,218,358	1,049,330	-21%
Total Net Emissions (excluding biogenic methane)	650,132	424,922	561,938	390,661	-40%
Total Biogenic Methane Emissions (tCO_2e)	685,577	672,568	656,420	658,670	-4%

6.0 Update to the 2018/19 Emissions Footprint

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

The previous 2018/19 inventory results and updated 2018/19 inventory results are presented in Table 24.

Reasons for the change to results between these footprints are outlined below:

- Stationary Energy emissions have been adjusted due to improvements in data and changes to emission factors. This is especially the case for electricity, where the data source has been adjusted to align with the Dunedin Energy Study.
- There were no significant changes to the Transportation sector. Changes in emissions are due to changes in emission factors and an adjustment of allocation of petrol and diesel fuel use between transportation and stationary uses.
- Waste emissions have been adjusted due to updates to waste composition information for open landfill sites and changes to wastewater calculations. Wastewater calculations have been updated to align with WaterNZ guidance (2021) and the estimate of population using septic tanks has been updated.
- 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 changes in data and emission factors. Forest harvesting data has been adjusted based on data provided by the two main forestry harvesting organisations located within Dunedin.

Table 24 Reported GHG emissions in Dunedin for 2018/19, showing the change in emissions between those previously reported (2020) and the updated results (2022)

	2018/19 previous inventory (2020) – tCO_2e	2018/19 updated inventory (2022) – tCO_2e
Stationary Energy	200,464	205,764
Transportation	613,793	612,931
Waste	120,157	112,473
IPPU	39,544	37,561
Agriculture	599,051	728,318
Forestry	- 407,349	- 361,337
Total Net Emissions (incl. forestry)	**1,165,660**	**1,335,709**
Total Gross Emissions (excl. forestry)	**1,573,008**	**1,697,047**

Future community carbon footprints for Dunedin may also require adjustments to the emission results reported here due to improvements to the inventory process.

7.0 Decoupling of GHG emissions from population growth and GDP

Figure 9 shows the changes in gross emissions compared to other metrics of interest between 2018/19 and 2021/22. For example, total gross emissions have decreased by 9% between 2018/19 and 2021/22 whilst the population of the city increased by 2%, resulting in per capita gross emissions in Dunedin reducing by 11% between 2018/19 and 2021/22 (from 13.0 to 11.5 tCO_2e per person per year), more than the decrease in total gross emissions. Similarly, Gross Domestic Product (GDP) in Dunedin has increased by 2%, resulting in a 11% decrease in the GHG emissions ratio to GDP.

Decoupling is when emissions grow less rapidly than GDP (a measure of economic growth). 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 9 Change in total gross emissions compared to other metrics of interest

8.0 Closing Statement

Dunedin’s GHG emissions footprint provides information for decision-making and action by the DCC, Dunedin stakeholders, and the wider community. We encourage the DCC to use the results of this study to update current climate action plans, set emission reduction targets, and track changes in emissions over time.

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

Understanding of climate change's extensive and long-lasting effects is always improving. It is recommended that this emissions footprint be updated regularly (every two or three years) to inform ongoing positive decision-making to address climate change issues.

The availability, quality, and applicability of data limit the accuracy of any emissions footprint. Areas where data could be improved for future footprints include Forestry, Agriculture, Solid Waste, Wastewater, off-road transport fuel use, Aviation Gas, Marine Freight, LPG, and IPPU.

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 **October 2022 and November 2022** 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	Assumptions and Exclusions
General	
Geographical Boundary	LGNZ local council mapping boundaries have been applied
Population	Population figures up to 2017 are provided by StatsNZ. Population figures for 2018-2022 align with Dunedin's population projection figures used in Dunedin's 10 Year Planning and Development documents (https://www.dunedin.govt.nz/council/annual-and-long-term-plans). 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.).
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.

Biogenic Emissions	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.
Transport Emissions	
Petrol and Diesel:	Total petrol and diesel consumption in Dunedin City was calculated from aggregated petrol and diesel sales data for Dunedin City, Clutha District, and Waitaki District, which was then apportioned out to these territorial authorities 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	Fuel consumption was calculated by Kiwi Rail 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.
Jet Kerosene	Calculated using the Induced Activity method as per rail diesel. An estimate of fuel use was calculated for scheduled passenger flights arriving and departing from Dunedin Airport: - The schedule of flights arriving and departing from Dunedin 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 Dunedin Airport. The remaining 50% of each leg was allocated to the originating or destination airport. It is understood that air travel journeys departing and arriving at Dunedin Airport do not just serve the Dunedin population and Dunedin commercial interests, however all emissions have been allocated to Dunedin. This approach ensures that all emissions are accounted for in regional emissions reporting. Dunedin's emissions from these sources are therefore higher than if emissions were split between all areas benefitting from these transport hubs. Jet kerosene emissions from military, freight, and private aircraft have not been calculated due to a lack of available data.
Aviation Gas	Aviation gas is mostly used by small aircraft for relatively short flights. Data for Dunedin Airport was not available at the time of writing, so an assumption has been made based on data provided for the 2014/15 year and adjusted for the following years based on the number of flight movements at Dunedin Airport.
Marine Diesel – Freight	Calculated using the Induced Activity method as per rail diesel and jet kerosene. An estimate of fuel use was calculated for journeys arriving and departing from Port Otago: - The schedule of vessels arriving and departing from Port Otago 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 Dunedin Port. The remaining 50% of each leg was allocated to the originating or destination Port.

	Data: - The 2018/19 emissions calculated from vessel schedule (Port Otago website) alongside vessel info and journey distances. The schedule available covered a 68-day period in 2020, this has been extrapolated and adjusted to represent the 2018/19 reporting year. - The 2021/22 emissions calculated from vessel schedule (Port Otago website) alongside vessel info and journey distances. The schedule available covered a 60-day period in 2022, this has been extrapolated and adjusted to represent the 2021/22 reporting year. - We have used the reported change in bulk cargo and container tonnage processed at Port Otago between 2015 and 2021 to estimate emissions between 2015 and 2021.
Marine Diesel (Local)	Port operational vessels: - Fuel use has been provided directly from Port Otago for 2018/19, 2020/21, and 2021/22 from the Port's Annual Reports. - All emissions from this source have been allocated to Dunedin 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
Cruise Ships	No reliable data was available to determine the emissions from cruise ships (only relevant to 2018/19 as there were no cruise ship visits in 2020/21 and 2021/22)
LPG	Total South 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	The Dunedin City boundary is mostly covered by Aurora Energy network, there are some smaller towns on the northern and western fringes which are supplied by Otagonet. - Data for the Aurora Energy Network has been provided by Aurora, broken down into residential and non-residential usage. - An estimate of consumption on the Otagonet network has been estimated based on estimates conducted by the University of Otago as part of the Dunedin Energy Study. The breakdown of non-residential use into the commercial and industrial sectors is based on NZ average consumption per sector.
Private Transport Electricity	Electricity used for private transport (e.g., electric busses, 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	Coal consumption data provided by the University of Otago from their Dunedin Energy Study data. This data includes coal used by multiple organisations, and in residential settings in Dunedin, not just the University of Otago.
Biofuel and Wood Consumption	Biofuel and wood burning consumption data are directly provided by the University of Otago from their Dunedin Energy Study data. This data includes biofuel and wood burned by multiple organisations, and in residential settings in Dunedin, not just the University of Otago. The carbon dioxide (CO_2) emissions produced from the burning of biofuels have been excluded from the emissions totals as they are considered to be biogenic (but are reported separately). Only the methane and nitrous oxide emissions have been included in the reported CO_2e figures for biofuels.
LPG Consumption	South 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. 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 consumption in Dunedin City was calculated from aggregated petrol and diesel sales data for Dunedin City, Clutha District, and Waitaki District, which was then apportioned out to these territorial authorities 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	There is no natural gas connection in the Dunedin City Territorial Area.
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.

Solid Waste Emissions	
Landfill Emissions	Landfill waste volume and landfill gas capture system information has been provided by Dunedin City Council. Solid waste emissions from landfill are measured using the IPCC First Order Decay method that covers landfill activity between 1950 and the present day. Waste volume: - Where information is not available, waste volumes have been estimated based on historical national data on a per capita basis. - Waste volume transported outside of Dunedin by a private company has been estimated based on total waste volume produced in Dunedin prior to waste being transported out of Dunedin. Landfill gas flaring / burning for energy generation: - Emissions relating to burning of landfill gas for energy generation have been included in the Stationary Energy sector. The carbon dioxide (CO_2) emissions produced from the burning of landfill gas have been excluded from the emissions totals as they are biogenic (but are reported separately). Only the methane and nitrous oxide emissions have been included in the reported CO_2e figures for landfill gas. 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.
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. - The population not connected to centralised wastewater treatment has been estimated based data from the 2017/18 year and applied to all years as the population not connected to centralised wastewater

	treatment has been assumed to be unchanged. This will need to be updated for future inventories as it is not likely that all new housing since 2017/18 is connected to centralised wastewater treatment.
Industrial Processes and Product Use Emissions	
Industrial processes	It is assumed that there are no significant non-energy related emissions of greenhouse gasses from industrial processes in the Dunedin City area (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 and data provided by two commercial operators representing approximately 70% of commercial forestry in Dunedin. This emissions footprint 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 footprint 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.

Appendix B

Additional Transport Emissions Breakdown

Additional Transport Emissions Analysis – Dunedin City

This section details the additional analysis undertaken to further breakdown Dunedin’s transport sector Greenhouse Gas (GHG) emissions. The focus of this additional analysis addresses on-road and off-road transport emissions which together represent 22% of Dunedin’s total gross emissions in the2021/22 financial year. Within on-road transport emissions this assessment particularly looks at the relative contribution of each vehicle type (Cars, Commercial Vehicles, Buses) to the region’s transport emissions.

Key findings:

- Cars represent 48% of Dunedin on-road transport emissions, and 9% of Dunedin total gross emissions.
- Light commercial vehicles represent 31% of Dunedin’s on-road transport emissions and 6% of Dunedin’s total gross emissions.
- Heavy commercial vehicles represent 18% of Dunedin’s on-road transport emissions and 4% of Dunedin’s total gross emissions.
- Electric vehicles currently represent 0.02% of Dunedin on-road transport emissions (65 tCO_2e), based on emissions related to the electricity consumed.
- Cars represent 73% of all Vehicle Kilometres Travelled (VKT) in Dunedin but represent 48% of all on-road emissions in Dunedin. This is due to the higher average tCO_2e per VKT of commercial vehicles compared to cars.
- 25-50+ tonne heavy vehicles represent 4% of all Vehicle Kilometres Travelled (VKT) in Dunedin but represent 14% of all on-road emissions in Dunedin.
- Diesel is the predominant fuel for off-road transport use, representing 95% of off-road transport emissions in Dunedin.
- Nationally, agriculture is the highest producing sector of off-road transport emissions, producing 27% of all off-road transport emissions. The next largest off-road transport producing sectors are building and construction, commercial, and industrial uses. Data specific to Dunedin was not available at the time of writing.

1.0 Methodology

The basis for this assessment is the results presented in the Dunedin Community Carbon Footprint for the financial year 2021/22 (July 1st to June 30th). The emissions for on-road and off-road transport have been calculated directly based on the sale of petrol and diesel in Dunedin, and then these have been broken down by sector and vehicle type using data provided by Waka Kotahi and the Energy Efficiency and Conservation Authority (EECA).

Data provided by Waka Kotahi covering Vehicle Kilometres Travelled (VKT) and emissions (by gas) for each territorial authority by vehicle class in 2018/19 has been used to assess the relative contribution of vehicle class types to on-road transport emissions in Dunedin.

Emissions related to energy use from electric vehicles (EVs) in the Community Carbon Footprint is included in the Stationary Energy sector and not included in transport emissions, due to lack of available data at the time of calculation. Total emissions presented here include the EV emissions contribution. These emissions have been calculated using an average electricity consumption per km travelled and based on the carbon intensity of the national electricity grid in 2021/22.

All calculated emissions have been converted to tonnes of CO_2 equivalent (tCO_2e) to allow direct comparison with the results of the Community Carbon Footprint.

Off-road transport data is limited at the local level, so this assessment utilises national data provided by the EECA to determine the relative contribution of emission sources within the on-road transport emissions source.

Definition of on-road vehicle categories[1]:

- Light duty vehicles:
  - Cars: passenger cars and sports utility vehicles (SUVs). This includes passenger cars and SUVs used for commercial purposes (e.g. taxis).
  - Light commercial vehicles: Utes and vans with gross vehicle mass up to 3.5 tonnes
- Heavy duty vehicles:
  - Heavy commercial vehicles: commercial vehicles with gross vehicle mass higher than 3.5 tonnes
  - Buses with gross vehicle mass higher than 3.5 tonnes

2.0 Key Limitations

On-road transport

- The reported emissions are for the financial year 2021/22 however the data underlying the breakdown of on-road transport emissions is based on calendar year 2019 data. There may be some differences between these years regarding the vehicle fleet make-up, but it expected that the proportions used are representative. Notably, electric and hybrid vehicle use is likely to have increased since 2019.

Off-road transport

- Calculations have been based on national-level data resulting in a lower level of confidence in their applicability to the territorial authority's off-road emissions given the variation in off-road transport uses across the country.
- In the Community Carbon Footprint, recreational marine fuel usage is included in 'off-road transport' due to the lack of data able to separate this marine fuel consumption from other on-land fuel consumption. This recreational marine fuel is estimated and included in 'off-road transport' here for consistency.

Marine freight transport, air travel, and rail

- These emissions sources have not been broken down further in this assessment.

[1] https://www.nzta.govt.nz/assets/Highways-Information-Portal/Technical-disciplines/Air-quality/Planning-and-assessment/Vehicle-emissions-prediction-model/VEPM-6.3-technical-report-2022.pdf

3.0 Transport Emissions Summary

The paragraphs, figures and tables below outline Dunedin greenhouse gas emissions from transport. During the 2021/22 reporting period, transport in Dunedin emitted 517,379 tCO_2e, representing 34% of Dunedin's total gross emissions.

On-road transport is the largest contributor to Transport emissions, representing 56% of Transport emissions and 19% of Dunedin total gross emissions. This is followed by marine transport (all relating to marine freight) and off-road transport.

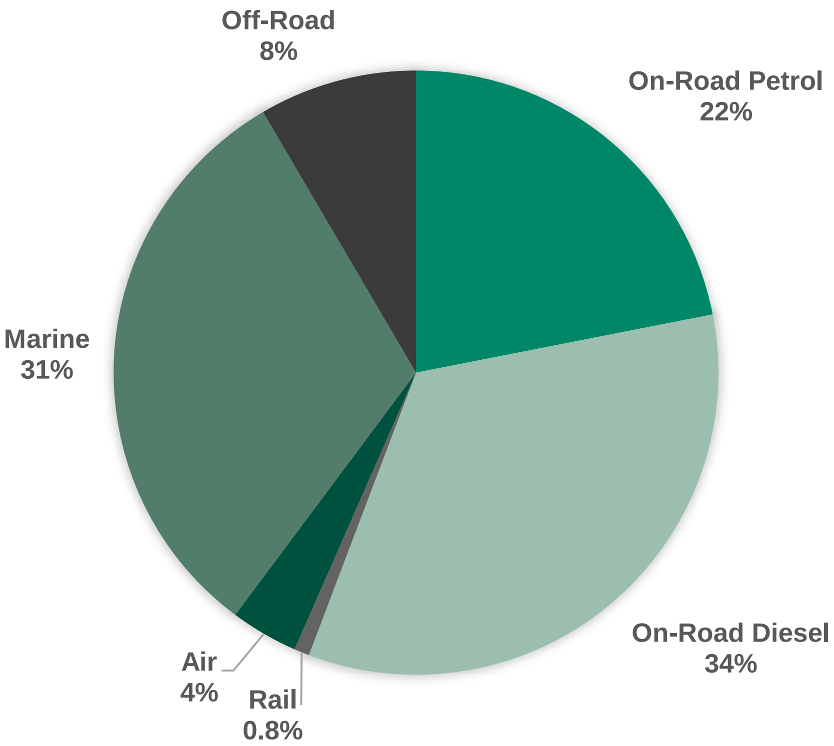

Figure 1 Dunedin – transport emissions (tCO_2e)

4.0 On-Road Transport Emissions Breakdown

On-road transport emissions are those relating to cars, commercial vehicles (including utes, trucks, and large commercial vehicles), and buses on-roads.

Table 1 and Figure 2 detail on-road transport emissions per vehicle category. The results show that cars in Dunedin tend to be fuelled by petrol while Commercial Vehicles and Buses almost exclusively use diesel.

Low emission Electric Vehicle (EV) use is currently low within the Dunedin resulting in an extremely small contribution to on-road transport emissions (68 tCO_2e). Note that sales and use of electric vehicles have likely increased since 2019 (the most recent year available for the dataset used), however emissions will likely still represent an extremely small contribution to on-road transport emissions.

In Dunedin, the largest contributor to on-road transport emissions are commercial vehicles, representing 49% of on-road transport emissions, and 9% percent of Dunedin's total gross emissions. Cars represent 48% of on-road transport emissions, and 9% percent of Dunedin total gross emissions. A further breakdown of commercial vehicle types is provided below.

Table 1 On-road transport emissions by vehicle type and fuel type (tCO_2e)

Vehicle Type	Petrol	Diesel	Electric	Total	% of Total
Cars	106,609	32,119	65	**138,792**	**48%**
Commercial Vehicles	6,753	135,976	1	**142,729**	**49%**
Buses	-	7,054	3	**7,057**	**2%**
Total	**113,362**	**175,149**	**68**	**288,578**	**100%**
% of Total	**39%**	**61%**	**0.02%**		

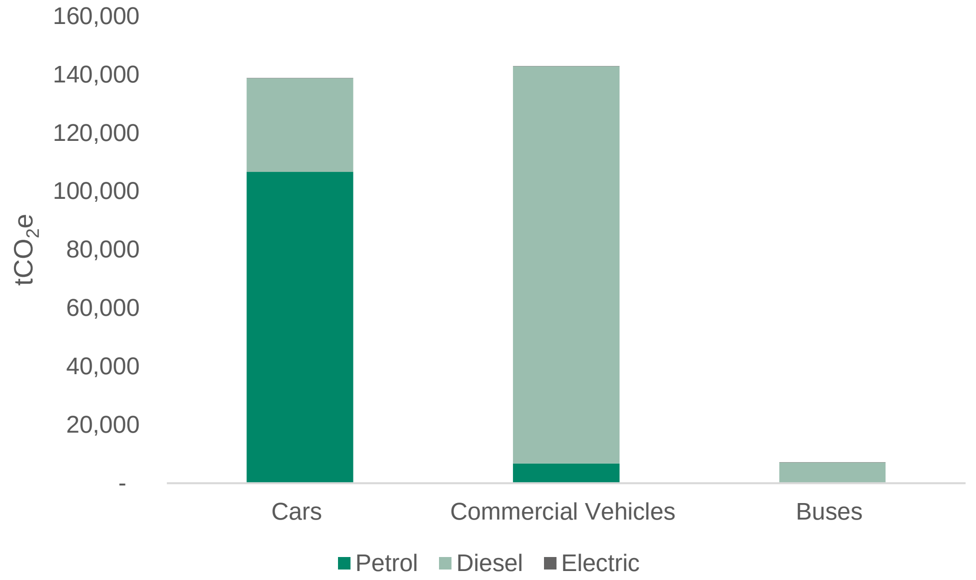

Figure 2 On-road transport emissions by vehicle type and fuel type

In Dunedin, 77% of total car emissions are from petrol, while commercial vehicles are primarily diesel (95% of total commercial vehicle emissions). Buses are almost mostly diesel fuelled and contribute 2% of total vehicle emissions to the city. The busses category includes all busses including public transport, school busses, and private commercial busses (including tourist coaches).

Emissions from these vehicle types can be broken down further by vehicle class. Table 2 and Figure 3 detail on-road transport emissions per vehicle class.

Table 2 On-road transport emissions by vehicle class (tCO_2e)

Vehicle Class	GHG Emissions (tCO_2e)	% of Total
Cars	138,792	48%
Light Commercial Vehicles <3.5 Tonne	90,003	31%
Heavy Vehicles 3.5-25 Tonne	11,110	4%
Heavy Vehicles 25-50+ Tonne	41,616	14%
Bus Urban 15-18 Tonne	6,408	2%
Bus Coach >18 Tonne	648	<1%
Total	**288,578**	**100%**

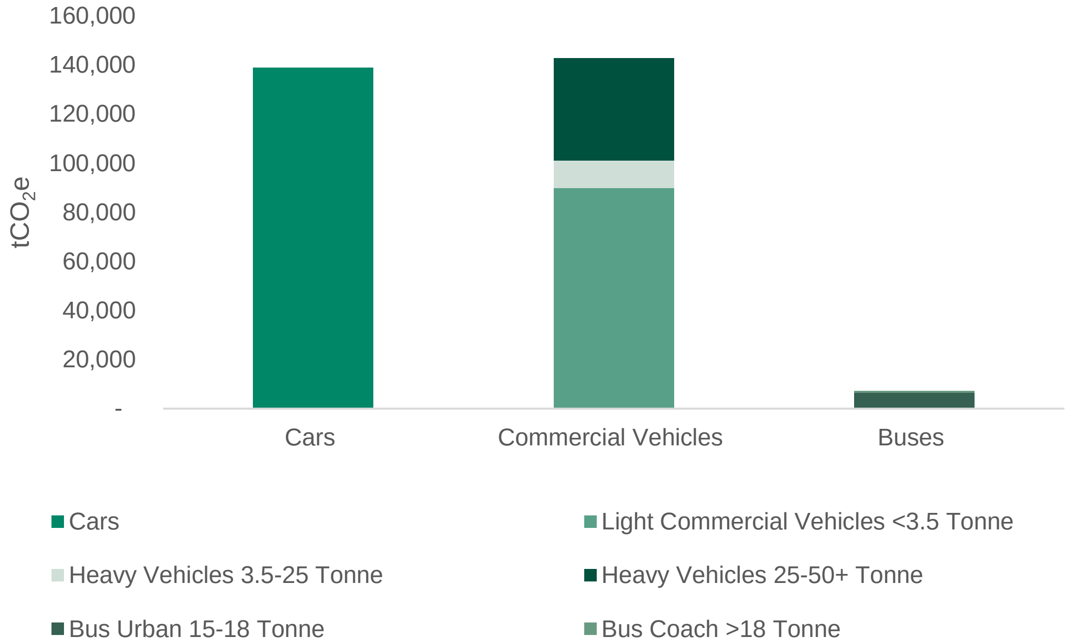

Figure 3 On-road transport emissions by vehicle class

Alongside total transport emissions, we can also look at emissions compared to distance travelled by different vehicle types. Table 3 shows the emissions per vehicle class as above but also includes the Vehicle Kilometres Travelled (VKT) by each vehicle class in Dunedin and shows the average GHG emissions per VKT for each vehicle class. The average GHG emissions per VKT figure was calculated from the distance travelled (as per the Waka Kotahi data) and reported emissions (calculated from fuel sales and broken-down using Waka Kotahi emissions data).

Cars represent 73% of all VKT in Dunedin but represent 48% of all on-road emissions in Dunedin. This is due to the relatively low average tCO_2e per VKT of cars compared to heavier vehicles (which is also partly due to the use of petrol rather than diesel for cars). Despite 25-50+ tonne heavy vehicles representing 4% of all VKT in Dunedin these vehicles represent 14% of all on-road emissions in Dunedin. It is important to note that these figures do not take into account the weight of freight, or the number of people, being moved per vehicle, where larger vehicles may be more efficient per tonne of freight moved than smaller vehicles, or where busses may be more efficient per person than cars.

Efforts to reduce the kilometres travelled by all vehicles should be considered to reduce emissions from on-road transport. This could include enabling and encouraging increased public transport use or diverting freight from roads onto rail and marine transport options. Efforts to improve the fuel efficiency of all vehicles should also be considered.

Table 3 On-road transport vehicle class VKT, emissions, and calculated average emissions per VKT

Vehicle Type	Vehicle Kilometres Travelled (VKT)	GHG Emissions (tCO_2e)	Average tCO_2e per VKT
Cars	679,216,121	138,792	0.0002
Light Commercial Vehicles <3.5 Tonne	183,069,239	90,003	0.0005
Heavy Vehicles 3.5-25 Tonne	20,642,365	11,110	0.0005
Heavy Vehicles 25-50+ Tonne	38,422,659	41,616	0.0011
Bus Urban 15-18 Tonne	5,371,689	6,408	0.0012
Bus Coach >18 Tonne	809,998	648	0.0008
Total	**927,532,071**	**288,578**	

5.0 Off-Road Transport Emissions Breakdown

The off-road transport emissions breakdown by sector is presented in Table 4 and Figure 4. The total off-road petrol and diesel figures are based on the Community Carbon Footprint for Dunedin. These totals have then been allocated to sectors based on the *Off-road liquid fuel insights- Quantifying off-road diesel and petrol use in New Zealand*, July 2021 produced by the Energy Efficiency and Conservation Authority (EECA). It is important to note that the EECA figures used are from 2019 and are based on values for the entirety of New Zealand and are therefore not specific to uses of off-road transport fuels in Dunedin.

The allocation of petrol and diesel to these sectors should be used for context only as they are not robustly reflective of fuel use in Dunedin.

Diesel is the predominant fuel for off-road transport use, representing 95% of off-road transport emissions. Nationally, agriculture is the highest producing sector for off-road transport emissions, producing 27% of all off-road transport emissions. The next largest off-road transport producing sectors are building and construction, commercial, and industrial uses. These figures would likely be significantly different if data for Dunedin was available.

Table 4 Off-road transport emissions by sector type and fuel type (tCO_2e)

Sector Type	Diesel	Petrol	Total	% of Total
Agriculture	11,535	162	**11,697**	**27%**
Fishing & Hunting	1,799	1	**1,800**	**4%**
Forestry & Logging	3,089	0	**3,089**	**7%**
Building & Construction	7,546	1	**7,547**	**17%**
Mining	3,206	-	**3,206**	**7%**
Industrial	5,513	9	**5,522**	**13%**
Commercial	5,826	103	**5,929**	**14%**
Recreational marine	1,955	1,886	**3,841**	**9%**
Marina Refuelling Stations	1,017	25	**1,041**	**2%**
Total	**41,485**	**2,189**	**43,674**	
% of Total	**95%**	**5%**	**-**	

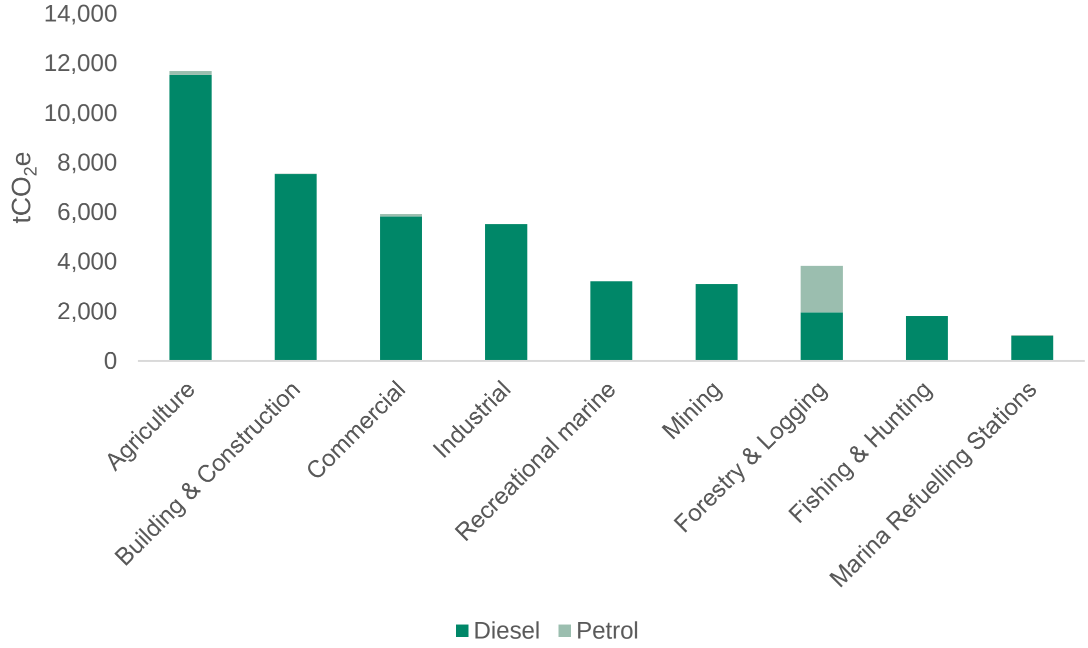

Figure 4 Off-road transport emissions by sector type and fuel type (tCO_2e)