AECOM Imagine it. Delivered.

Christchurch City Council
13-Oct-2020

Christchurch Greenhouse Gas Emission Inventories for Financial Years 2018/19 and 2016/17

Christchurch Greenhouse Gas Emission Inventories for Financial Years 2018/19 and 2016/17

Client: Christchurch City Council

Co No.: N/A

Prepared by

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

13-Oct-2020

Job No.: 60624148

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 AS/NZS4801 and OHSAS18001.

Quality Information

Document	Christchurch Greenhouse Gas Emission Inventories for Financial Years 2018/19 and 2016/17
Ref	60624148
Date	13-Oct-2020
Prepared by	Anthony Hume
Reviewed by	Ruth Williams

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
13	13-10-2020	Final Report	Anthony Hume Team Leader Sustainability and Resilience	

Table of Contents

Executive Summary i
1.0 Introduction 1
2.0 Approach to Analysis 1
3.0 2018/19 GHG Emission Inventory Results 5
3.1 2018/19 Transportation GHG Emissions 7
3.2 2018/19 Stationary Energy GHG Emissions 8
3.3 2018/19 Agriculture GHG Emissions 11
3.4 2018/19 Waste GHG Emissions 14
3.5 2018/19 Industrial Processes and Product Use (IPPU) GHG Emissions 15
3.6 2018/19 Forest Carbon Sequestration and GHG Emissions 16
3.7 2018/19 Biogenic GHG Emissions 17
3.8 2018/19 Net GHG Emissions 19
3.9 Comparison of Christchurch District's total gross GHG emissions with other New Zealand Territorial Authorities 20
4.0 2016/17 GHG Emission Inventory Results 23
4.1 2016/17 Transportation GHG Emissions 26
4.2 2016/17 Stationary Energy GHG Emissions 27
4.3 2016/17 Agriculture GHG Emissions 30
4.4 2016/17 Waste GHG Emissions 33
4.5 2016/17 Industrial Processes and Product Use (IPPU) GHG Emissions 34
4.6 2016/17 Forest Carbon Sequestration and GHG Emissions 35
4.7 2016/17 Biogenic GHG Emissions 36
4.8 2016/17 Net GHG Emissions 38
4.9 Comparison of GHG Emission Inventories Between 2016/2017 and 2018/2019 40
5.0 Basic and Basic+ GHG Emissions Reporting (Global Covenant of Mayors for Climate and Energy) 46
6.0 Closing Statement 47
7.0 Limitations 47

Appendix A
Assumptions and Exclusions A

Executive Summary

Christchurch City Council commissioned AECOM New Zealand Limited (AECOM) to complete Community-Scale Greenhouse Gas Emission Inventories for the Christchurch District, including the Banks Peninsula (hereafter referred to as Christchurch) for the financial years 2018/19 and 2016/17. The inventory for the financial year 2016/17 that was reported on in July 2018 by AECOM has been recalculated and updated as part of this AECOM work, in line with current best practice methodology and using improved quality of data. This also enables a more direct comparison to the financial year 2018/19 inventory.

The first part of this report describes the Christchurch greenhouse gas emission inventory during the period 1st July 2018 to 30th June 2019 (2018/19). The second part of the report describes the updated Christchurch greenhouse gas emission inventory during the period 1st July 2016 to 30th June 2017 (2016/17). This is followed by a discussion of changes in greenhouse gas emissions in Christchurch between the 2016/17 and 2018/19 financial year greenhouse gas emission inventories.

This report provides the Council with a snapshot of Christchurch's greenhouse gas (GHG) emission inventory for the 2016/17 and 2018/19 financial year reporting periods, identifying key GHG emission sources and their relative contribution to total GHG emissions. This report also identifies notable changes in GHG emissions between 2016/17 and 2018/19.

The report will:

- Help Council understand Christchurch's local GHG emissions profile
- Help Council track GHG emissions from Christchurch and examine progress toward emission reduction targets
- Enable informed decision making and policy development
- Identify key GHG emission sectors and stakeholders that could be encouraged to reduce local emissions
- Complete Council commitments for Global Covenant of Mayors for Climate and Energy reporting.

The methodology used to calculate the GHG emission inventories follows the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) methodology, published in 2014 by the World Resources Institute (WRI), Cities Climate Leadership Group (C40) and Local Governments for Sustainability (ICLEI). The Global Protocol assesses both direct (production-based) emission sources within the geographic area and indirect emissions (consumption-based emission sources associated with goods and services imported into the geographic area). The GPC method includes GHG emissions from Stationary Energy, Transportation, Waste, Industrial Processes and Product Use (IPPU), Agriculture and Forestry sectors. Key data limitations are detailed throughout the report.

This report provides a high-level baseline data set of GHG emissions for Christchurch and will help the Council to understand Christchurch's GHG emissions inventory and identify key GHG emission sources. Regular reporting (e.g. every 2 years) will help Council to measure GHG emission trends and assess progress toward reducing GHG emissions. GHG emissions are generally reported here in tonnes of carbon dioxide equivalent (tCO_2-e).

2018/2019 GHG Emissions Inventory

During the financial year 2018/19 (2018/19) reporting period Christchurch's total gross GHG emissions were 2,723,016 tonnes of carbon dioxide equivalent (tCO_2-e), which equates to 7.1 tCO_2-e/person in 2018/19. This was below per capita estimates for Dunedin City and New Plymouth, the same as Auckland and above the per capita estimate for Wellington City (see Figure 1).

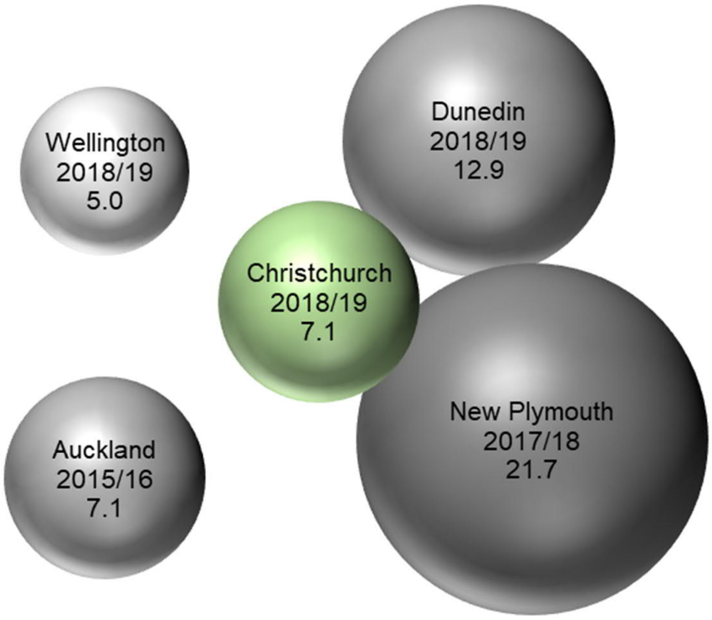

Figure 1 Per capita total gross GHG emissions for selected New Zealand territorial authorities (tCO_2-e/person/year)

Table 1 summarises the 2018/19 GHG emission results for different sectors while Table 2 displays emissions from all calculated emissions sources. High level findings are provided below.

- Transportation (e.g. road, rail and air travel) was the largest GHG emission emitting sector, producing 54.0% of Christchurch's total gross GHG emissions, with petrol and diesel use contributing to 73.4% of the Transportation sector's GHG emissions. Petrol and diesel transportation GHG emissions can be broken down into on-road and off-road usage. On-road transportation consists of all standard transportation vehicles used on roads (e.g. cars, trucks, buses, etc.). Off-road transportation consists of all fuel used for the movement of machinery and vehicles off-roads (e.g. within agriculture, construction and industry). On-road transportation uses of petrol and diesel produced 36.0% of Christchurch's total gross GHG emissions while off-road transportation uses of petrol and diesel produced 3.8% of Christchurch's total gross GHG emissions. Commercial flights from Christchurch Airport was the second highest transportation GHG emission source (11.6% of Christchurch's total gross GHG emissions).
- Stationary Energy (i.e. non-transportation energy use) was the second largest GHG emission emitting sector, producing 19.0% of Christchurch's total gross GHG emissions, with electricity consumed (including associated electricity transmission and distribution losses) contributing to 59.5% of the Stationary Energy sector's GHG emissions.
- Agriculture (e.g. from livestock and crops) was the third highest GHG emission emitting sector, producing 15.3% of Christchurch's total gross GHG emissions, with enteric fermentation (methane from cows, sheep and other animals) contributing to 79.4% of the Agriculture sector's GHG emissions.
- Waste (e.g. gas emitted from landfill sites and wastewater treatment) produced 7.4% of Christchurch's total gross GHG emissions while the Industrial Processes and Product Use (IPPU) sector (e.g. the use of industrial chemicals) produced the remaining 4.2% of Christchurch's total gross GHG emissions.

Table 1 Christchurch District's GHG emissions, by sector, for the financial year 2018/19

Sector	GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	1,470,159	54.0%
Stationary Energy	517,077	19.0%
Agriculture	417,545	15.3%
Waste	202,854	7.4%
Industrial Processes and Product Use	115,381	4.2%
Total Gross GHG Emissions (excl. Forestry)	2,723,016	-
Forestry	-197,733	Not included in total gross GHG emissions
Total Net GHG Emissions (incl. Forestry)	2,525,283	-

Table 2 Christchurch District's GHG emissions, by sector and source, for the financial year 2018/19

GHG Emission Sector/Source		GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	Petrol (On-Road)	522,258	19.2%
	Diesel (On-Road)	457,784	16.8%
	Jet Kerosene (Commercial Flights)	315,769	11.6%
	Diesel (Off-Road)	93,668	3.4%
	Marine Light Fuel Oil (Freight Cargo)	55,523	2.0%
	Rail (Diesel)	14,783	0.5%
	Petrol (Off-Road)	6,109	0.2%
	LPG (Off-Road Mobile Uses)	2,411	0.1%
	Aviation Gas (Local Flights)	1,159	0.04%
	Marine Diesel (Tourism Vessels and Local Ferries)	692	0.03%
	Biodiesel (Vehicle Use)	3	0.0001%
Stationary Energy	Electricity Consumed	284,524	10.4%
	LPG (Stationary Use)	97,979	3.6%
	Petrol & Diesel (Stationary Use)	54,978	2.0%
	Coal	49,623	1.8%
	Electricity Transmission and Distribution Losses	23,363	0.9%
	Biofuel (Wood)	6,480	0.2%
	Biogas-Methane Recovered (WWTP[1] and Landfill)	130	0.005%
	Biodiesel (Stationary Use)	0.18	0.00001%

[1] Bromley Wastewater Treatment Plant

Agriculture – See Section 3.3 for a breakdown of Sources	Agriculture	417,545	15.3%
Waste	Closed Landfill Sites	143,874	5.3%
	Open Landfill Sites	33,542	1.2%
	Wastewater Treatment	14,683	0.5%
	Composting	10,755	0.4%
Industrial Processes and Product Use	Industrial Processes and Product Use	115,381	4.2%
Total Gross GHG Emissions		**2,723,016**	
Forestry	Harvest GHG Emissions	284,524	Not included in total gross GHG emissions
	Native Forest Sequestration	-108,965	
	Exotic Forest Sequestration	- 373,292	
Total Net GHG Emissions		**2,525,283**	

2016/2017 GHG Emission Inventory

During the financial year 2016/17 (2016/17) reporting period Christchurch's total gross GHG emissions were 2,665,643 tonnes of carbon dioxide equivalent (tCO_2-e) which equates to 7.1 tCO_2-e/person in 2016/17. This was below per capita estimates for Dunedin City and New Plymouth, the same as Auckland and above the per capita estimate for Wellington City.

Table 3 summarises the 2016/17 GHG emission results for different sectors while Table 4 displays emissions from all calculated emissions sources. High level findings are provided below.

- Transportation (e.g. road, rail and air travel) was the largest GHG emission emitting sector, producing 53.5% of Christchurch's total gross GHG emissions, with petrol and diesel use contributing to 73.9% of the Transportation sector's GHG emissions. Petrol and diesel transportation GHG emissions can be broken down into on-road and off-road usage. On-road transportation consists of all standard transportation vehicles used on roads (e.g. cars, trucks, buses, etc.). Off-road transportation consists of all fuel used for the movement of machinery and vehicles off-roads (e.g. within agriculture, construction and industry). On-road transportation uses of petrol and diesel produced 36.0% of Christchurch's total gross GHG emissions while off-road transportation uses of petrol and diesel produced 3.5% of Christchurch's total gross GHG emissions. Commercial flights from Christchurch Airport was the second highest transportation GHG emission source (11.4% of Christchurch's total gross GHG emissions).
- Stationary Energy (i.e. non-transportation energy use) was the second largest GHG emission emitting sector, producing 18.1% of Christchurch's total gross GHG emissions, with electricity consumed (including associated electricity transmission and distribution losses) contributing to 51.7% of the Stationary Energy sector's GHG emissions.
- Agriculture (e.g. from livestock and crops) was the third highest emitting sector, producing 15.4% of Christchurch's total gross GHG emissions, with enteric fermentation (methane from cows, sheep and other animals) contributing to 79.4% of the Agriculture sector's GHG emissions.
- Waste (e.g. gas emitted from landfill sites and wastewater treatment) produced 8.6% of Christchurch's total gross GHG emissions while the Industrial Processes and Product Use (IPPU) sector (e.g. the use of industrial chemicals) produced the remaining 4.4% of Christchurch's total gross GHG emissions.

Table 3 Christchurch District's GHG emissions, by sector, for the financial year 2016/17

Sector	GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	1,425,197	53.5%
Stationary Energy	483,079	18.1%
Agriculture	410,970	15.4%
Waste	228,571	8.6%
Industrial Processes and Product Use	117,825	4.4%
Total Gross GHG Emissions (excl. Forestry)	**2,665,643**	-
Forestry	-300,264	Not included in total gross GHG emissions
Total Net GHG Emissions (incl. Forestry)	**2,365,379**	-

Table 4 Christchurch District's GHG emissions, by sector and source, for the financial year 2016/17

GHG Emission Sector/Source		GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	Petrol (On-Road)	530,117	19.9%
	Diesel (On-Road)	428,248	16.1%
	Jet Kerosene (Commercial Flights)	302,609	11.4%
	Diesel (Off-Road)	87,362	3.3%
	Marine Light Fuel Oil (Freight Cargo)	54,298	2.0%
	LPG (Off-Road Mobile Uses)	11,850	0.4%
	Petrol (Off-Road)	7,088	0.3%
	Rail (Diesel)	1,817	0.1%
	Aviation Gas (Local Flights)	1,159	0.04%
	Marine Diesel (Tourism Vessels and Local Ferries)	651	0.02%
	Biodiesel (Vehicle Use)	-	-
Stationary Energy	Electricity Consumed	231,039	8.7%
	Petrol & Diesel (Stationary Use)	99,739	3.7%
	LPG (Stationary Use)	79,716	3.0%
	Electricity Transmission and Distribution Losses	18,842	0.7%
	Coal	47,146	1.8%
	Biofuel (Wood)	6,524	0.2%
	Biogas-Methane Recovered (WWTP[2] and Landfill)	74	0.003%
	Biodiesel (Stationary Use)	0.01	0.0000002%

[2] Bromley Wastewater Treatment Plant

GHG Emission Sector/Source		GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Agriculture – See Section 4.3 for a breakdown of Sources	Agriculture	410,970	15.4%
Waste	Closed Landfill Sites	170,479	6.4%
	Open Landfill Sites	31,035	1.2%
	Wastewater Treatment	14,272	0.54%
	Composting	12,786	0.48%
Industrial Processes and Product Use	Industrial Processes and Product Use	117,825	4.4%
Total Gross GHG Emissions		**2,665,643**	
Forestry	Harvest GHG Emissions	185,825	Not included in total gross GHG emissions
	Native Forest Sequestration	-108,965	
	Exotic Forest Sequestration	- 377,123	
Total Net GHG Emissions		**2,365,379**	

Comparison of GHG Emission Inventories Between 2016/2017 and 2018/2019

The inventory for the financial year 2016/17 that was reported on in July 2018 by AECOM has been recalculated and updated in this report in line with current best-practice methodology and using improved quality of data. Christchurch's total gross GHG emissions increased from 2,665,643 tCO_2-e in 2016/17 to 2,723,016 tCO_2-e in 2018/19, a rise of 57,373 tCO_2-e (2.2%). Per capita GHG emissions did not change between these reporting periods 7.1 tCO_2-e per person per year in both financial years.

Between 2016/17 and 2018/19, total net GHG emissions in Christchurch increased from 2,365,379 tCO_2-e to 2,525,283 tCO_2-e, an increase of 6.8% (159,904 tCO_2-e). The sector with the largest real increase in GHG emissions was the Transportation sector, increasing by 44,962 tCO_2-e (3.2%) between 2016/17 and 2018/19. The largest real decrease in GHG emissions was the Waste sector, decreasing by 25,718 tCO_2-e (11.3%) between 2016/17 and 2018/19.

Changes in GHG emissions between 2016/17 and 2018/19 are covered in detail in section 4.9. High level findings are provided below.

- The Transportation sector's contribution to Christchurch's total gross GHG emissions increased between 2016/17 and 2018/19 by 3.2%. The largest increases in GHG emissions from the Transportation sector were from on-road, air and rail transportation.
- The Stationary Energy sector's contribution to Christchurch's total gross GHG emissions increased between 2016/17 and 2018/19 by 7.0%. The largest increase in GHG emissions from the Stationary Energy sector was from electricity consumed (including associated electricity transmission and distribution losses).
- The Agriculture sector's contribution to Christchurch's total gross GHG emissions increased between 2016/17 and 2018/19 by 1.6%.
- The Waste sector's contribution to Christchurch's total gross GHG emissions reduced between 2016/17 and 2018/19 by 11.3%. Increased use and efficiency of landfill gas capture has driven down the Waste sector's GHG emissions.
- The Industrial Process and Product Use (IPPU) sector's contribution to Christchurch's total gross GHG emissions reduced between 2016/17 and 2018/19 by 2.1%. A nationwide reduction in IPPU GHG emissions have driven the reduction in IPPU GHG emissions in Christchurch.

- The net negative impact of the Forestry sector on Christchurch's total net GHG emissions decreased by 34.1% between 2016/17 and 2018/19. Sequestration of carbon by native and exotic forests in Christchurch decreased by 1.0% between 2016/17 and 2018/19 while forestry harvesting GHG emissions increased by 53.1%.

1.0 Introduction

Christchurch City Council commissioned AECOM New Zealand Limited (AECOM) to complete Community-Scale Greenhouse Gas Emission Inventories for the Christchurch District, including Banks Peninsula (hereafter referred to as Christchurch) for financial years 2018/19 and 2016/17. The inventory for the financial year 2016/17 that was reported on in July 2018 by AECOM has been recalculated and updated, as part of this AECOM work, in line with current best practice methodology and using improved quality of data. This also enables a more direct comparison to the financial year 2018/19 inventory.

2.0 Approach to Analysis

The methodology used to calculate the GHG emission inventories follows the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) published in 2014 by the World Resources Institute (WRI), Cities Climate Leadership Group (C40) and Local Governments for Sustainability (ICLEI). The GPC approach assesses both direct (production-based) GHG emission sources within the geographic area and indirect (consumption-based) GHG emission sources associated with goods and services imported into the geographic area. The GPC method includes GHG emissions from Stationary Energy, Transportation, Waste, Industrial Processes and Product Use (IPPU), Agriculture and Forestry sectors. Key data limitations are detailed throughout the report.

All of the GHG emission calculations involved in these inventories have been developed by AECOM and are based on Intergovernmental Panel on Climate Change (IPCC) workbooks and guidance for GHG emissions measurement. Where necessary, AECOM's GHG emissions calculations also use methods consistent with guidance published by New Zealand's Ministry for the Environment (MfE) or other authoritative sources.

AECOM's GHG emission calculation methods have been used in the calculation of all reported GHG emissions, except for GHG emissions from Christchurch's wastewater treatment plant operations where the measurement method has been adapted to incorporate specific data from the main Christchurch wastewater treatment plant located in Bromley.

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

A methodology based on the GPC reporting standards and guidance from the IPCC has been used for other community scale GHG emission inventories around New Zealand, (e.g. Wellington City, Auckland, Dunedin City and New Plymouth District) and also internationally. The GPC methodology[3] represents international best practice for district, city and regional level GHG emission inventory reporting.

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

- GHG emissions are expressed on a carbon dioxide-equivalent basis (CO_2-e) including climate change feedback using the 100-year Global Warming Potential (GWP) values[4]. Climate change feedbacks are the climate change impacts from GHGs that increase or decrease as the climate changes and are specific to each GHG gas. For example, as the Earth warms, different GHG gases trigger different processes on the surface and in the atmosphere, which can accelerate warming, and create more extreme or more mild weather patterns which in turn affect future

[3] http://www.ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
[4] https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf (Table 8.7)

global temperatures and weather patterns. Current climate change feedback guidance is important to estimate the long-term impacts of GHG's.

- GPC reporting is 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 GHG emissions relating to consumption (e.g. embodied GHG emissions relating to products produced elsewhere but consumed within the geographic area).
- Total GHG emissions are reported as gross GHG emissions (excluding Forestry) and net GHG emissions (including Forestry).
- Where location specific data was not accessible, information was calculated via a per capita break-down of national or regional level data.
- Transportation GHG emissions
  - Transportation GHG emissions associated with air, rail and marine activity were calculated using the Induced Activity method. Fuel consumption data was determined from the number of journeys taken, distance travelled and consumption rates for the appropriate transport mode.
  - The reported marine light fuel oil figure reports GHG emissions from cargo activities and does not include small marine vessels (e.g. private and fishing vessels) or cruise ships. Accurate data on cruise ship fuel consumption is not available and so is not reported.
- Stationary Energy GHG emissions
  - Stationary Energy is energy used by activities other than for transportation. Stationary Energy demand (e.g. for electricity and LPG) is broken down by the sub-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[5]. Additional to agriculture, forestry and fishing, the industrial sector may also include mining, food processing, textiles, chemicals, metals, mechanical/electrical equipment and building and construction activities, when relevant.
- Solid Waste GHG emissions
  - Solid Waste GHG emissions from landfill are measured using the IPCC First Order Decay method that covers landfill activity between 1950 and the present day. Solid Waste GHG emissions were calculated for the currently operating landfill at Kate Valley, and three closed landfill sites; Burwood, Bexley and Sawyers Arms.
- Wastewater Treatment GHG emissions
  - The majority of Wastewater in Christchurch (approximately 90%) is treated at the Bromley wastewater treatment site. The GHG emissions associated with Bromley, including biogas combustion GHG emissions (CH_4 and N_2O) have been calculated by Council using nitrous oxide GHG emission factor produced by Beca Consultants. Biogenic tCO_2 resulting from combustion of biogas has been calculated by AECOM following the same method used by council for the calculation of CH_4 and N_2O.There are also several smaller sites, including sites at Lyttelton, Diamond Harbour and Akaroa, whose GHG emissions have not been included. Wastewater treatment GHG emissions from individual septic tanks have been calculated by AECOM and included in this report. as per 2006 Guidelines for National Greenhouse Gas Inventories. Wastewater treatment GHG emissions calculations include N_2O emissions from treated wastewater released into aquatic systems (e.g. the Christchurch ocean outfall) and in line with New Zealand's national GHG inventory.

[5] Stats NZ: Retrieved from http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/industrial-classification.aspx#gsc.tab=0

- Industrial Processes and Product Use (IPPU) GHG emissions
  - Due to data confidentiality, the inventory reports all the known industrial product use GHG emissions as one single value and does not break-down GHG emissions by product type. The availability of data for the GHG emissions associated with IPPU is also restricted due to confidentiality issues and constraints in communication from relevant stakeholders.
  - Industry and solvent related GHG emissions are estimated based on data provided in the New Zealand Greenhouse Gas Emissions 1990-2017 report (Ministry for the Environment 2019). These GHG emissions are estimated on a per capita basis applying a national average per person.
- Forestry GHG emissions:
  - This inventory accounts for forest carbon stock changes from afforestation, reforestation, deforestation and forest management (i.e. it applies land-use accounting conventions under the UN Framework Convention on Climate Change rather than the Kyoto Protocol). It treats GHG emissions from harvesting and deforestation as instantaneous rather than accounting for the longer-term GHG emission flows associated with harvested wood products.
  - The inventory considers regenerating (growing) forest areas only. Capture of carbon from the atmosphere is treated as negligible for mature forests that have reached a steady state.

Sector source data and results for the GHG emissions inventory have been provided to Christchurch City Council in calculation table spreadsheets. All assumptions made during data collection and analyses have been detailed within Appendix A – Assumptions and Exclusions.

2018/19 GHG Emission Inventory Results

3.0 2018/19 GHG Emission Inventory Results

During the financial year 2018/19 (2018/19) reporting period the Christchurch District emitted a total gross 2,723,016 tonnes of carbon dioxide equivalent (tCO_2-e) and a net 2,525,283 tCO_2-e.

The Christchurch District's population in 2018/19 was approximately 385,500 people, resulting in per capita gross GHG emissions of 7.1 tCO_2-e/person in 2018/19. The Transportation sector's GHG emissions were the largest contributor to the inventory for Christchurch, followed by the Stationary Energy sector (refer to Table 5).

Throughout this report a consistent colour scheme has been used to display GHG emissions from each of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) sector categories. The colour scheme follows the recommended GPC reporting framework to ensure consistency of reporting in New Zealand and internationally.

Table 5 Christchurch District's GHG emissions, by sector, for the financial year 2018/19

Sector	GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	1,470,159	54.0%
Stationary Energy	517,077	19.0%
Agriculture	417,545	15.3%
Waste	202,854	7.4%
Industrial Processes and Product Use	115,381	4.2%
Total Gross GHG Emissions (excl. Forestry)	2,723,016	-
Forestry	-197,733	Not included in total gross GHG emissions
Total Net GHG Emissions (incl. Forestry)	2,525,283	-

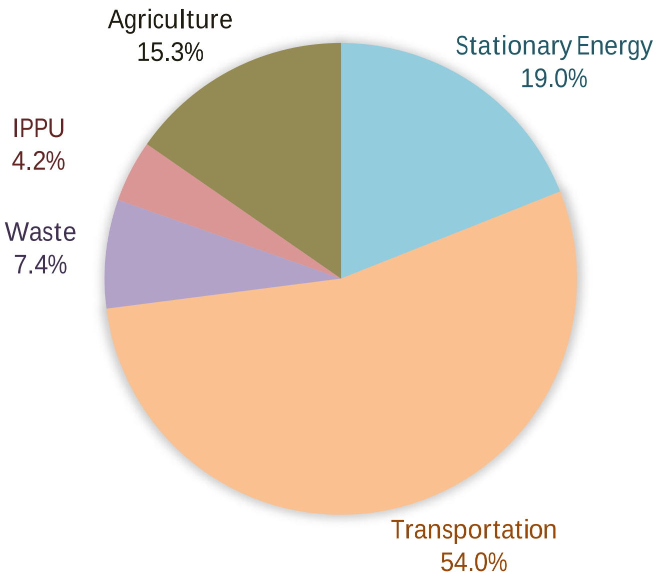

Figure 2 Christchurch District's gross GHG emissions, by sector, for the financial year 2018/19

Table 6 Christchurch District's GHG emissions, by sector and source, for the financial year 2018/19

GHG Emission Sector/Source		GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	Petrol (On-Road)	522,258	19.2%
	Diesel (On-Road)	457,784	16.8%
	Jet Kerosene (Commercial Flights)	315,769	11.6%
	Diesel (Off-Road)	93,668	3.4%
	Marine Light Fuel Oil (Freight Cargo)	55,523	2.0%
	Rail (Diesel)	14,783	0.5%
	Petrol (Off-Road)	6,109	0.2%
	LPG (Off-Road Mobile Uses)	2,411	0.1%
	Aviation Gas (Local Flights)	1,159	0.04%
	Marine Diesel (Tourism Vessels and Local Ferries)	692	0.03%
	Biodiesel (Vehicle Use)	3	0.0001%
Stationary Energy	Electricity Consumed	284,524	10.4%
	LPG (Stationary Use)	97,979	3.6%
	Petrol & Diesel (Stationary Use)	54,978	2.0%
	Coal	49,623	1.8%
	Electricity Transmission and Distribution Losses	23,363	0.9%
	Biofuel (Wood)	6,480	0.2%
	Biogas-Methane Recovered (WWTP[6] and Landfill)	130	0.005%
	Biodiesel (Stationary Use)	0.18	0.00001%
Agriculture – See Section 3.3 for a breakdown of Sources	Agriculture	417,545	15.3%
Waste	Closed Landfill Sites	143,874	5.3%
	Open Landfill Sites	33,542	1.2%
	Wastewater Treatment	14,683	0.5%
	Composting	10,755	0.4%
Industrial Processes and Product Use	Industrial Processes and Product Use	115,381	4.2%
Total Gross GHG Emissions		**2,723,016**	
Forestry	Harvest GHG Emissions	284,524	Not included in total gross GHG emissions
	Native Forest Sequestration	-108,965	
	Exotic Forest Sequestration	- 373,292	
Total Net GHG Emissions		**2,525,283**	

[6] Bromley Wastewater Treatment Plant

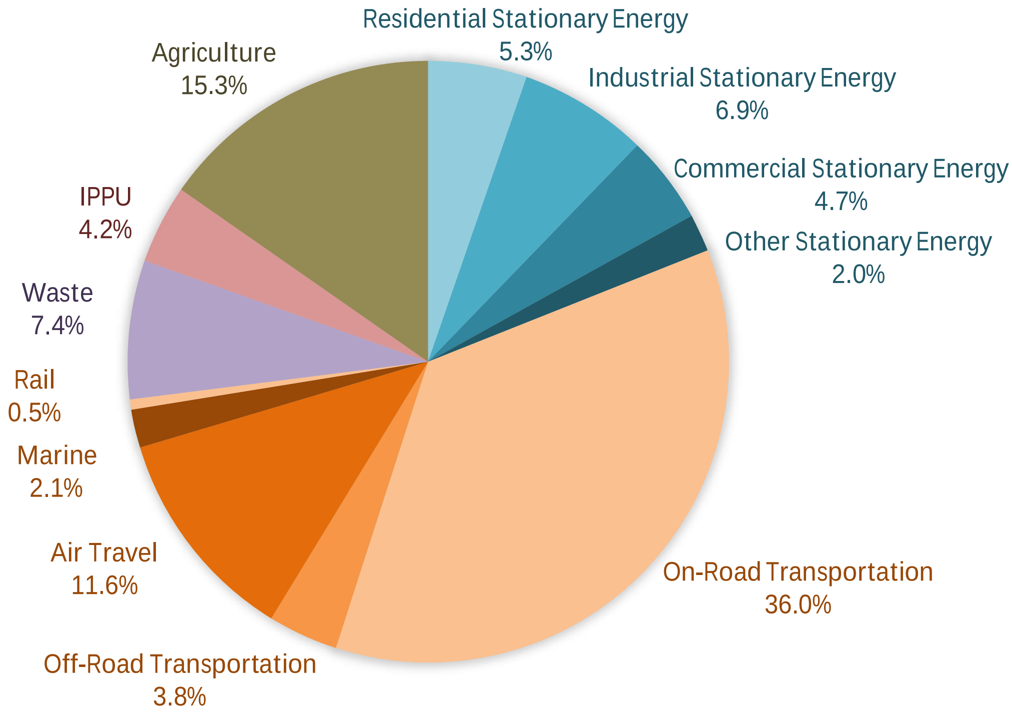

Figure 3 Christchurch District's gross GHG emissions, by source, for the financial year 2018/19

The Christchurch GHG emission inventory for 2018/19 includes GHG emissions for six different category sources which are summarised below.

3.1 2018/19 Transportation GHG Emissions

The Transportation sector was the highest GHG emission emitting sector, producing 1,470,159 tCO_2-e in 2018/19 (54.0% of Christchurch's total gross GHG emissions). The largest contributor to the Transportation sector's GHG emissions was from petrol and diesel, which produced 1,079,818 tCO_2-e (73.4% of the Transportation sector's GHG emissions and 39.7% of Christchurch's total gross GHG emissions). Petrol contributed to 35.9% of the Transportation sector's GHG emissions (528,367 tCO_2-e) while diesel contributed to 37.5% of the Transportation sector's GHG emissions (551,452 tCO_2-e).

Petrol and diesel transportation GHG emissions can be broken down into on-road and off-road usage. On-road transportation consists of all standard transportation vehicles used on roads (e.g. cars, trucks, buses, etc.). Off-road transportation consists of all fuel used for the movement of machinery and vehicles off-roads (e.g. within agriculture, construction and industry).

On-road transportation (petrol and diesel) produced 980,041 tCO_2-e (66.7% of the Transportation sector's GHG emissions and 36.0% of Christchurch's total gross GHG emissions). Off-road transportation (petrol, diesel and LPG) produced 102,188 tCO_2-e (7.0% of the Transportation sector's GHG emissions and 3.8% of Christchurch's total gross GHG emissions).

The second largest source of the Transportation sector's GHG emissions was from air travel (jet kerosene and aviation gas) which produced 316,928 tCO_2-e (21.6% of the Transportation sector's GHG emissions and 11.6% of Christchurch's total gross GHG emissions). The rest of the Transportation sector's GHG emissions were from rail, marine and biodiesel transportation producing a total of 71,001 tCO_2-e (4.8% of the Transportation sector's GHG emissions).

Table 7 Christchurch District's Transportation GHG emissions, by source, for the financial year 2018/19

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Transportation	Petrol (On-Road)	522,258	1,470,159	35.5%
	Diesel (On-Road)	457,784		31.1%
	Air Travel (Jet Kerosene and Aviation Gas)	316,928		21.6%
	Diesel (Off-Road)	93,668		6.4%
	Marine (Freight Cargo, Tourism Vessels and Local Ferries)	56,215		3.8%
	Rail (Diesel)	14,783		1.0%
	Petrol (Off-Road)	6,109		0.4%
	LPG (Off-Road Mobile Uses)	2,411		0.2%
	Biodiesel (Vehicle Use)	3		0.0002%

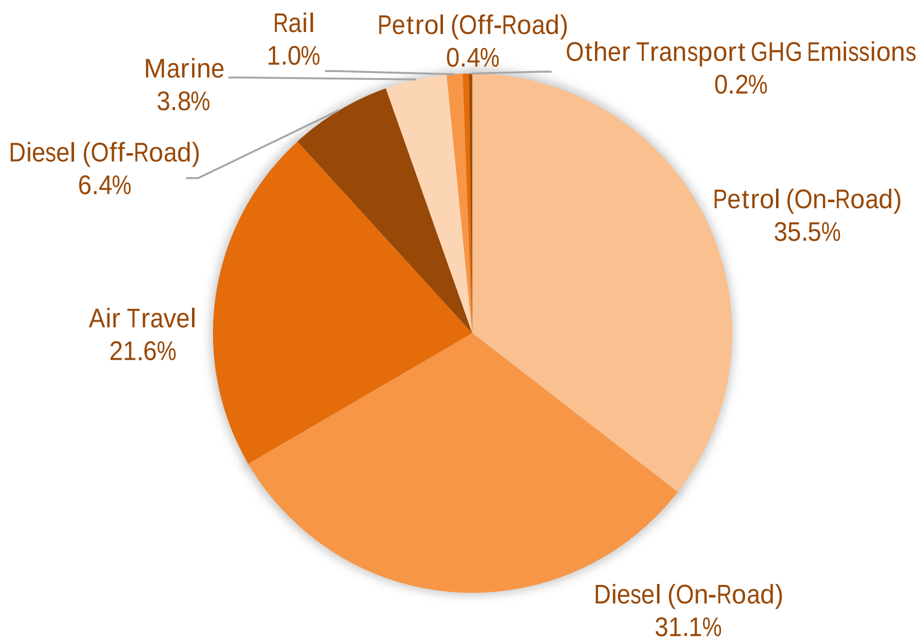

Figure 4 Christchurch District's Transportation source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2018/19

3.2 2018/19 Stationary Energy GHG Emissions

The Stationary Energy sector was Christchurch's second highest emitting sector producing 517,077 tCO_2-e in 2018/19 (19.0% of Christchurch's total gross GHG emissions). The largest contributor to the Stationary Energy sector's GHG emissions was from electricity consumed (including associated electricity transmission and distribution losses) producing 307,887 tCO_2-e (59.5% of the Stationary Energy sector's GHG emissions and 11.3% of Christchurch's total gross GHG emissions).

The second largest source of the Stationary Energy sector's GHG emissions was bottled LPG use which produced 97,979 tCO_2-e (18.9% of the Stationary Energy sector's GHG emissions and 3.6% of Christchurch's total gross GHG emissions).

GHG emissions from petrol and diesel use in stationary energy activities produced 54,978 tCO_2-e (10.6% of the Stationary Energy sector's GHG emissions and 2.0% of Christchurch's total gross GHG emissions).

Recovered biogas (methane) has been used for energy generation and flaring at Kate Valley landfill, Burwood landfill and Bromley wastewater treatment plant.

GHG emissions from the combustion of recovered biogas (methane), from landfill and wastewater treatment, used for energy generation are included in the Stationary Energy sector (a requirement of the GPC standard).

GHG emissions from flaring of recovered biogas (methane) from landfill and wastewater treatment are generally included in the Waste sector. However, due to difficulties in separating out data for recovered biogas (methane) used for energy generation and recovered biogas (methane) used for flaring, GHG emissions from flaring of recovered biogas (methane) from landfill and wastewater treatment are included in the Stationary Energy sector.

Combustion of biogas (methane) for energy generation and flaring of biogas (methane) results in carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) GHG emissions. Carbon dioxide GHG emissions are biogenic GHG emissions (i.e. generated from organic materials) and have been excluded from the total gross GHG emissions but are reported in the biogenic emissions section of this inventory (section 3.7), following GPC guidance. Methane and nitrous oxide GHG emissions from the combustion of biogas (methane) collected at the Bromley wastewater treatment plant, Kate Valley landfill and Burwood landfill and used for energy generation and flaring, are reported in the Stationary Energy sector. Methane GHG emissions from the combustion of biogas (methane) are also biogenic and so are additionally reported in the biogenic emissions section of this inventory (section 3.7), following GPC guidance.

The Stationary Energy sector's GHG emissions are also broken down by sub-sector. Stationary Energy GHG emissions are reported for the following sub-sectors within the Stationary Energy sector: industrial; commercial; and residential. GHG emissions from petrol and diesel used for stationary energy and from the recovery and combustion of biogas (methane) for stationary energy use are not broken down into these sub-sectors.

- The Industrial Stationary Energy sub-sector produced 189,081 tCO2-e (36.6% of the Stationary Energy sector's GHG emissions and 6.9% of Christchurch's total gross GHG emissions). Industrial stationary energy is energy used within all industrial settings (e.g. mining, food processing, textiles, chemicals, metals, mechanical/electrical equipment and building and construction activities), and includes agriculture, forestry and fishing activities.
- The Residential Stationary Energy sub-sector produced 143,967 tCO_2-e (27.8% of the Stationary Energy sector's GHG emissions and 5.3% of Christchurch's total gross GHG emissions). Residential stationary energy is energy used in homes (e.g. for heating, lighting and cooking).
- The Commercial Stationary Energy sub-sector produced 128,922 tCO_2-e (24.9% of the Stationary Energy sector's GHG emissions and 4.7% of Christchurch's total gross GHG emissions). Commercial stationary energy is energy used in all non-residential and non-industrial settings (e.g. in retail, hospitality, education and healthcare).
- The remaining Stationary Energy sector's GHG emissions from diesel, petrol and combustion of biogas (methane) produced 55,108 tCO_2-e (10.7% of the Stationary Energy sector's GHG emissions and 2.0% of Christchurch's total gross GHG emissions) and were not allocated to the above Stationary Energy sub-sector categories.

Table 8 Christchurch District's Stationary Energy GHG emissions, by source, for the financial year 2018/19

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Stationary Energy	Electricity Consumed	284,524	517,077	55.0%
	LPG (Stationary Use)	97,979		18.9%
	Petrol & Diesel (Stationary Use)	54,978		10.6%
	Coal	49,623		9.6%
	Electricity Transmission and Distribution Losses	23,363		4.5%
	Biofuel (Wood)	6,480		1.3%
	Biogas-Methane Recovered (WWTP[7] and Landfill)	130		0.03%
	Biodiesel (Stationary Use)	0.18		0.00004%

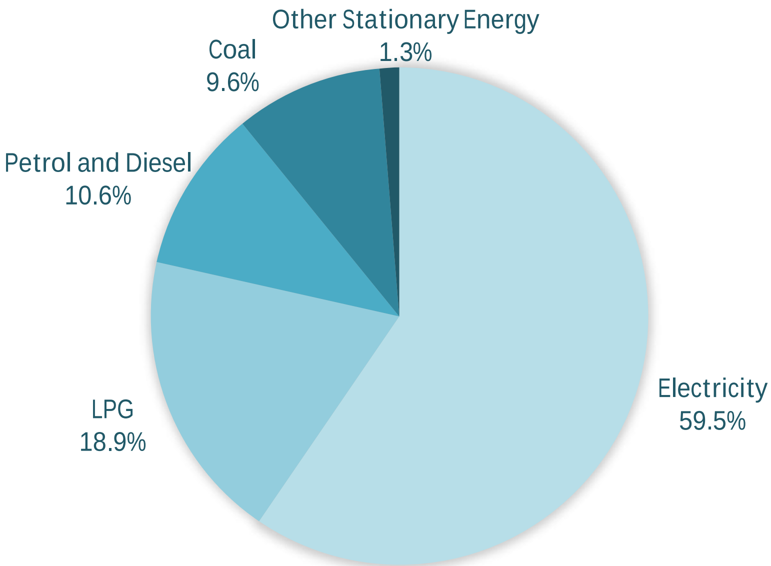

Figure 5 Christchurch District's Stationary Energy source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2018/19

[7] Bromley Wastewater Treatment Plant

Table 9 Christchurch District's Stationary Energy GHG emissions, by sub-sector, for the financial year 2018/19

Sector/Sub-Sector		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Stationary Energy	Industrial	189,081	517,077	36.6%
	Residential	143,967		27.8%
	Commercial	128,922		24.9%
	Other Stationary Energy	55,108		10.7%

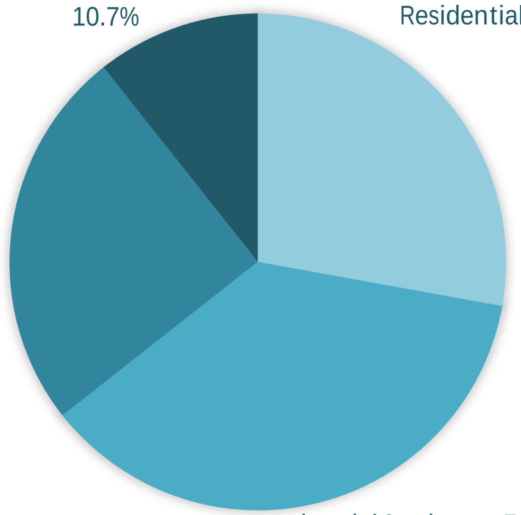

Figure 6 Christchurch District's Stationary Energy sub-sector GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2018/19

3.3 2018/19 Agriculture GHG Emissions

The Agriculture sector was Christchurch's third highest emitting sector producing 417,545 tCO_2-e in 2018/19 (15.3% of Christchurch's total gross GHG emissions). Livestock produced the majority of the Agriculture sector's GHG emissions, 408,946 tCO_2-e (97.9% of the Agriculture sector's GHG emissions and 15.0% of Christchurch's total gross GHG emissions). Sheep are farmed in the largest numbers across Christchurch, accounting for 71.3% of farmed livestock (253,331 animals). Dairy cattle make up 14.4% of farmed livestock (51,273 animals). Non-dairy cattle make up 10.2% of farmed livestock (36,307 animals) while small numbers of other livestock make up the remaining 4.0% (e.g. pigs, goats, deer and horses).

Enteric fermentation from livestock produced 331,625 tCO_2-e (79.4% of the Agriculture sector's GHG emissions and 12.2% of Christchurch's total gross GHG emissions). The second largest source of the Agriculture sector's GHG emissions was from nitrous oxide (N_2O) being released by manure from grazing animals on pasture producing 49,502 tCO_2-e (11.9% of the Agriculture sector's GHG emissions and 1.8% of Christchurch's total gross GHG emissions). The remaining Agriculture sector's GHG emissions are in Table 10.

Agriculture sector GHG emissions can also be broken down into livestock type and crops and fertiliser, see Table 11. Dairy cattle produced 189,545 tCO2-e (45.4% of the Agriculture sector's GHG emissions and 7.0 % of Christchurch's total gross GHG emissions), sheep produced 126,770 tCO2-e (30.4% of the Agriculture sector's GHG emissions and 4.7% of Christchurch's total gross GHG emissions), and non-dairy cattle produced 84,091 tCO2-e (45.4% of the Agriculture sector's GHG emissions and 3.1% of Christchurch's total gross GHG emissions). Crops and fertiliser produced 8,599 tCO2-e (2.1% of the Agriculture sector's GHG emissions and 0.3% of Christchurch's total gross GHG emissions). Small numbers of other livestock (e.g. pigs, goats, deer and horses) make up the remaining 8,541 tCO2-e (2.0% of the Agriculture sector's GHG emissions and 0.3% of Christchurch's total gross GHG emissions).

The measurement of GHG emissions in the agriculture sector considers both direct and indirect GHG emissions from N_2O. Direct sources include those where N_2O is emitted directly to the atmosphere from cultivated soils and fertiliser applied and/or grazed grassland systems (e.g. Enteric Fermentation). Indirect GHG emissions sources result from either the movement of nitrogen from agricultural systems into ground water or surface water through drainage and surface runoff (e.g. Leaching), or ammonia or nitrogen oxides released to the atmosphere (e.g. Atmospheric Deposition)[8].

Enteric Fermentation GHG emissions are produced by CH_4 released from the digestive process of ruminant animals (e.g. cattle and sheep). GHG emissions from Manure from Grazing Animals on Pasture refers to N_2O released from unmanaged manure. Manure Management refers to the GHG emissions (N_2O and CH_4) released in a managed environment (e.g. within cattle sheds) through the capture, storage, treatment, and utilization of animal manure. Decomposition of organic matter occurs when manure or urine is deposited leading to aerobic and anaerobic processes that release N_2O.

Agricultural Soils refers specifically to N_2O emitted from nitrogen leaching/runoff from cultivated soils (e.g. through turning of the earth using ploughs).

Atmospheric Deposition is the process whereby N_2O GHG emissions are produced through volatilisation (the loss of nitrogen into the atmosphere) from nitrogen applied by grazing animals as manure and urine on pasture. Atmospheric Deposition GHG emissions are also produced by volatilisation from synthetic nitrogen fertilisers or organic fertilisers. The application of synthetic or organic fertilisers will greatly increase the amount of direct N_2O emissions through volatilisation because of the greater amounts of nitrogen available.

Indirect GHG emissions from N_2O include leaching of N_2O in the form of water-soluble plant nutrients from the soil, due to rain and irrigation. The application of synthetic or organic fertilisers will also increase the amount of leaching of N_2O by increasing the nitrogen available. For example, the use of organic fertiliser can cause ammonia volatilisation leading to N_2O production. The volatilisation of ammonia is considered an indirect GHG emission source to distinguish this process from direct volatilisation of nitrogen.

GHG emissions from Liming and Dolomite refers to CO_2 emissions from lime applications (calcic lime and dolomite). Liming is used to reduce soil acidity and improve plant growth on agricultural land. Adding lime or dolomite leads to CO_2 emissions as the carbonate in the minerals dissolve and release bicarbonate, which evolves into CO_2 and water.[9]

[8] https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_5_N2O_Agricultural_Soils.pdf
[9] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

Table 10: Christchurch District's Agriculture GHG emissions, by source, for the financial year 2018/19

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Agriculture	Enteric Fermentation (CH_4)	331,625	417,545	79.4%
	Manure from Grazing Animals on Pasture (N_2O)	49,502		11.9%
	Manure Management (CH_4)	17,041		4.1%
	Agricultural Soils (N_2O)	7,020		1.7%
	Atmospheric Deposition (N_2O)	6,332		1.5%
	Leaching (N_2O)	3,672		0.9%
	Liming and Dolomite (CO_2)	2,006		0.5%
	Manure Management (N_2O)	347		0.08%

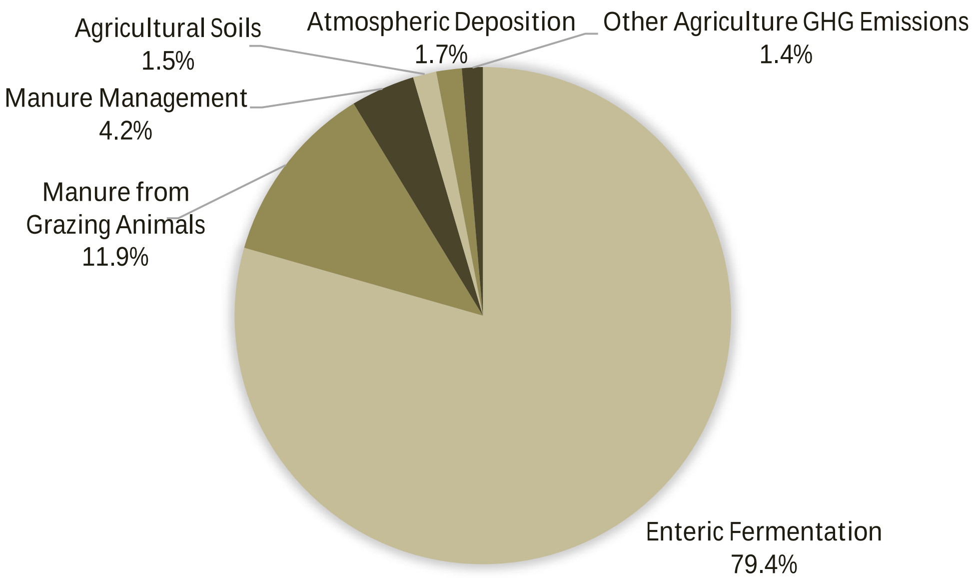

Figure 7 Christchurch District's Agriculture source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2018/19

Table 11 Christchurch District's Agriculture GHG emissions, by source (livestock, crops and fertiliser), for the financial year 2018/19

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Agriculture	Dairy Cattle	189,545	417,545	45.4%
	Sheep	126,770		30.4%
	Non-Dairy Cattle	84,091		20.1%
	Crops and Fertiliser	8,599		2.1%
	Other Livestock	8,541		2.0%

3.4 2018/19 Waste GHG Emissions

The Waste sector (solid waste and wastewater treatment) was Christchurch's fourth highest emitting sector producing 202,854 tCO_2-e in 2018/19 (7.4% of Christchurch's total gross GHG emissions). Solid waste sent to landfill or composting produced 188,171 tCO_2-e (92.8% of the Waste sector's GHG emissions and 6.9% of Christchurch's total gross GHG emissions).

Solid waste GHG emissions include emissions from open landfills and closed landfills. Both open and closed landfills emit landfill gas (methane) from the breakdown of organic materials disposed of in the landfill. Closed landfills produced 143,874 tCO_2-e (70.9% of the Waste sector's GHG emissions and 5.3% of Christchurch's total gross GHG emissions). Open landfills produced 33,542 tCO_2-e (16.5% of the Waste sector's GHG emissions and 1.2% of Christchurch's total gross GHG emissions). GHG emissions from composting are the smallest source of GHG emissions from solid waste producing 10,755 tCO_2-e (5.3% of the Waste sector's GHG emissions and 0.4% of Christchurch's total gross GHG emissions).

Wastewater treatment falls into two broad GHG emission source categories: wastewater treated in centralised treatment plants and wastewater treated in individual treatment systems (i.e. septic tanks). Wastewater treated by individual treatment systems tends to produce higher GHG emissions than if treated in centralised treatment plants. The majority of wastewater in Christchurch is treated by advanced centralised wastewater treatment systems resulting in relatively low GHG emissions.

Wastewater treatment produced 14,683 tCO_2-e (7.2% of the Waste sector's GHG emissions and 0.5% of Christchurch's total gross GHG emissions). Wastewater treated in the Bromley centralised treatment plant produced 12,674 tCO_2-e (6.2% of the Waste sector's GHG emissions and 0.4% of Christchurch's total gross GHG emissions) while individual wastewater treatment systems (i.e. septic tanks) produced 2,009 tCO_2-e (1.0% of the Waste sector's GHG emissions and 0.1% of Christchurch's total gross GHG emissions). Individual wastewater treatment systems service 1.6% of Christchurch's population.

GHG emissions from the combustion of biogas (methane), recovered at the Bromley wastewater treatment plant, Kate Valley landfill and Burwood landfill, and used for energy generation as well as flared, are reported in the Stationary Energy sector.

Table 12 Christchurch District's Waste GHG emissions, by source, for the financial year 2018/19

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Waste	Closed Landfill Sites	143,874	217,776	70.9%
	Open Landfill Sites	33,542		16.5%
	Wastewater Treatment	14,683		7.2%
	Composting	10,755		5.3%

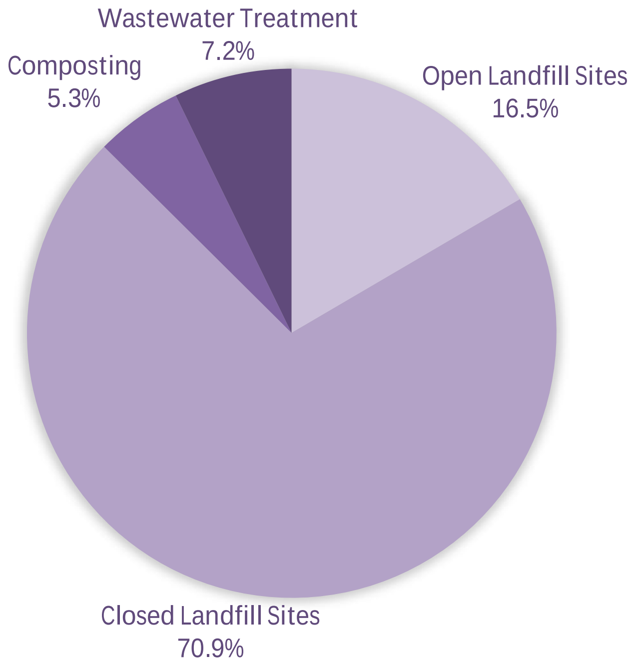

Figure 8 Christchurch District's Waste source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2018/19

3.5 2018/19 Industrial Processes and Product Use (IPPU) GHG Emissions

The IPPU sector was Christchurch's fifth highest emitting sector producing 115,381 tCO_2-e in 2018/19 (4.2% of Christchurch's total gross GHG emissions). The use of refrigerants produced 106,642 tCO_2-e (92.4% of the IPPU sector's GHG emissions and 3.9% of Christchurch's total gross GHG emissions).

The GHG emissions for Industrial Product Use include GHG emissions from (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Nitrogen trifluoride GHG emissions do not occur in New Zealand and are not included in this report. GHG emissions from Industrial Product Use includes GHG emissions associated with the consumption of GHGs for refrigerants, foam blowing, fire extinguishers, aerosols, metered dose inhalers (e.g. used for asthma treatment) and sulphur hexafluoride for electrical insulation and equipment production. The highest GHG emission producing IPPU source, refrigerants, are chemicals used in refrigeration and air conditioning products which are released as greenhouse gases upon disposal.

Industrial Processes which may produce IPPU GHG emissions include the production of cement, lime, glass, ammonia, iron, steel, and aluminium. It is understood that there are no large industrial operations within the Christchurch District's boundary that result in significant Industrial Processes GHG emissions.

IPPU GHG emissions do not include GHG emissions resulting from energy use for industrial manufacturing, which is included in the relevant Stationary Energy source category (e.g. electricity consumed or coal).

Table 13 Christchurch District's IPPU GHG emissions, by source, for the financial year 2018/19

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
IPPU	Refrigerants	106,642	115,381	92.4%
	Aerosols and Metered Dose Inhalers (MDI)	6,943		6.0%
	SF_6	1,198		1.0%
	Foam Blowing	425		0.4%
	Fire Extinguishers	173		0.1%

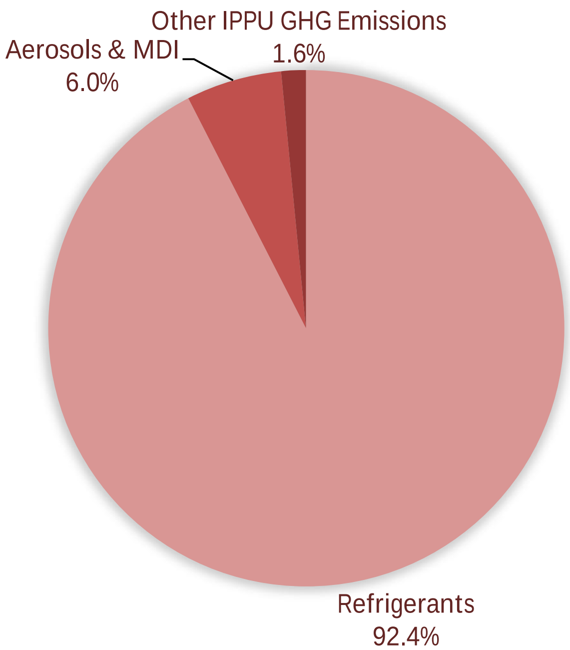

Figure 9 Christchurch District's IPPU source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2018/19

3.6 2018/19 Forest Carbon Sequestration and GHG Emissions

In 2018/19 the Forestry sector produced net negative GHG emissions of 197,773 tCO_2-e due to the sequestration of carbon mostly by exotic forest.

Christchurch has a regenerative native forested area which includes manuka, kanuka, gorse, broom, grey scrub, mixed exotic shrubland as well as broadleaved hardwoods. Regenerating natives occupied 18,790 ha while exotics occupied a further 9,930 ha of land. Native forests sequestered 108,965 tCO_2-e while exotic forests sequestered 373,292 tCO_2-e. In total, 482,257 tCO_2-e were sequestered by forests in Christchurch in 2018/19. GHG emissions from harvesting of forestry produced 284,524 tCO_2-e.

Table 14 Christchurch District's Forestry GHG emissions and sequestration, by source, for the financial year 2018/19

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Forestry	Native Forest Sequestration	-108,965	- 482,257	77.4%
	Exotic Forest Sequestration	-373,292		22.6%
	Forest Harvest GHG Emissions	284,524	284,524	100%
	Net Forestry GHG Emissions	-197,733		-

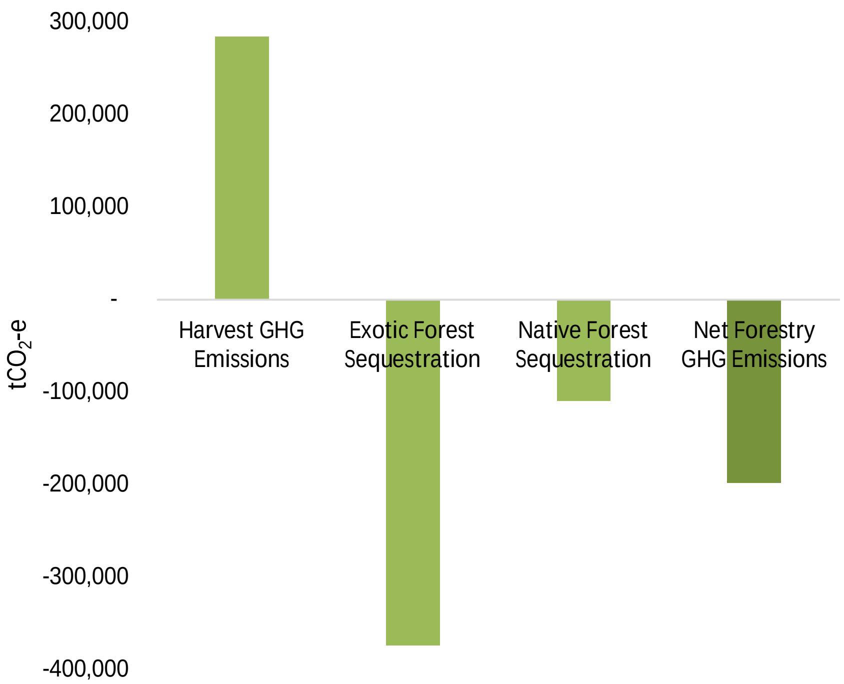

Figure 10 Christchurch District's Forestry harvest GHG emissions, Forestry sequestration and net Forestry GHG emissions for the financial year 2018/19

3.7 2018/19 Biogenic GHG Emissions

Biogenic carbon dioxide (CO_2) and methane (CH_4) GHG emissions are listed in Table 15 and Table 16, respectively (as tonnes of the individual gas, not in CO_2-e).

Biogenic CO_2 GHG emissions from plants and animals are excluded from the total gross GHG emissions as they are part of the natural carbon cycle. For example, because wood biofuels originate from forestry, the Biogenic CO_2 GHG emissions from wood biofuels are excluded from total gross GHG emissions. CO_2 GHG emissions from the combustion of recovered biogas (methane) from the Kate Valley landfill, Bromley landfill and from the Bromley wastewater treatment plant for energy use as well as flaring are also excluded from total gross GHG emissions as they originate from organic material disposed of in the landfill or from the wastewater treatment process.

Biogenic CH_4 GHG emissions are included in total gross GHG emissions due to their relatively large impact on warming relative to Biogenic CO_2 GHG emissions. For example, Biogenic CH_4 GHG emissions produced by farmed cattle, via enteric fermentation and manure, are included in total gross GHG emissions. Landfill biogas (methane) produced from solid waste is included in total gross GHG emissions, unless it is combusted for energy generation or flared (recovered methane). Recovered methane is converted to CO_2 where it is not considered to contribute to global climate change because the carbon was contained in recently living biomass.

The importance of Biogenic CH_4 GHG emissions is highlighted in NZ's Climate Change Response (Zero Carbon) Amendment Act. The Act includes targets to reduce Biogenic CH_4 GHG emissions by between 24 percent and 47 percent below 2017 levels by 2050, and a 10 percent reduction 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 15 Christchurch District's Biogenic carbon dioxide (CO_2) GHG emissions, by source, for the financial year 2018/19. (Excluded from total gross GHG emissions)

Sector/Source		Biogenic Emissions (tCO_2)		% Contribution of the Biogenic CO_2 Emissions
Biogenic CO_2 GHG Emissions	Biofuel (Wood)	74,554	122,322	61.2%
	Landfill Biogas - Methane (Recovered)	30,260		24.7%
	Wastewater Treatment Biogas - Methane (Recovered)	16,609		13.6%
	Biodiesel (Vehicle and Stationary Use)	899		0.7%

Table 16 Christchurch District's Biogenic methane (CH_4) GHG emissions, by source, for the financial year 2018/19. (Included in total gross GHG emissions)

Sector/Source		Biogenic GHG Emissions (tCH_4)		% Contribution of the Biogenic CH_4 GHG Emissions
Biogenic CH_4 GHG Emissions	Enteric Fermentation	9,754	16,076	60.7%
	Landfill Biogas - Methane (Non-Recovered)	5,425		33.7%
	Manure Management	501		3.1%
	Wastewater Treatment Biogas - Methane (Non-Recovered)	228		1.4%
	Biofuel (Wood)	165		1.0%
	Landfill Biogas - Methane (Recovered)	3		0.02%
	Wastewater Treatment Biogas - Methane (Recovered)	0.3		0.002%
	Biodiesel (Vehicle and Stationary Use)	0.04		0.0002%

3.8 2018/19 Net GHG Emissions

Net GHG emissions differ from gross GHG emissions because they include GHG emissions related to forestry activity within an area. GHG emissions from forestry include two main types of activity. Harvesting of forest increases GHG emissions through the releasing of carbon from plants and soils. Planting of native forest (e.g. manuka and kanuka) and exotic forest (e.g. pine), sequesters (captures) carbon from the atmosphere while the trees are growing to maturity. When sequestration by forests exceeds GHG emissions from harvesting, the extra quantity of carbon sequestered by forest reduces total gross GHG emissions.

Overall, Forestry is a net negative source of GHG emissions of 197,733 tCO_2-e due to the sequestration of carbon mostly by exotic forest. The net negative GHG emissions from Forestry reduce total gross GHG emissions by 7.3% to a total net GHG emissions of 2,525,283 tCO_2-e. Figure 11 shows total gross GHG emissions versus total net GHG emissions and the impact of net forestry GHG emissions.

Table 17 Christchurch District's total gross and total net GHG emissions for the financial year 2018/19

Total Emissions	GHG emissions (tCO_2-e)
Gross GHG Emissions	2,723,016
Net GHG Emissions	2,525,283

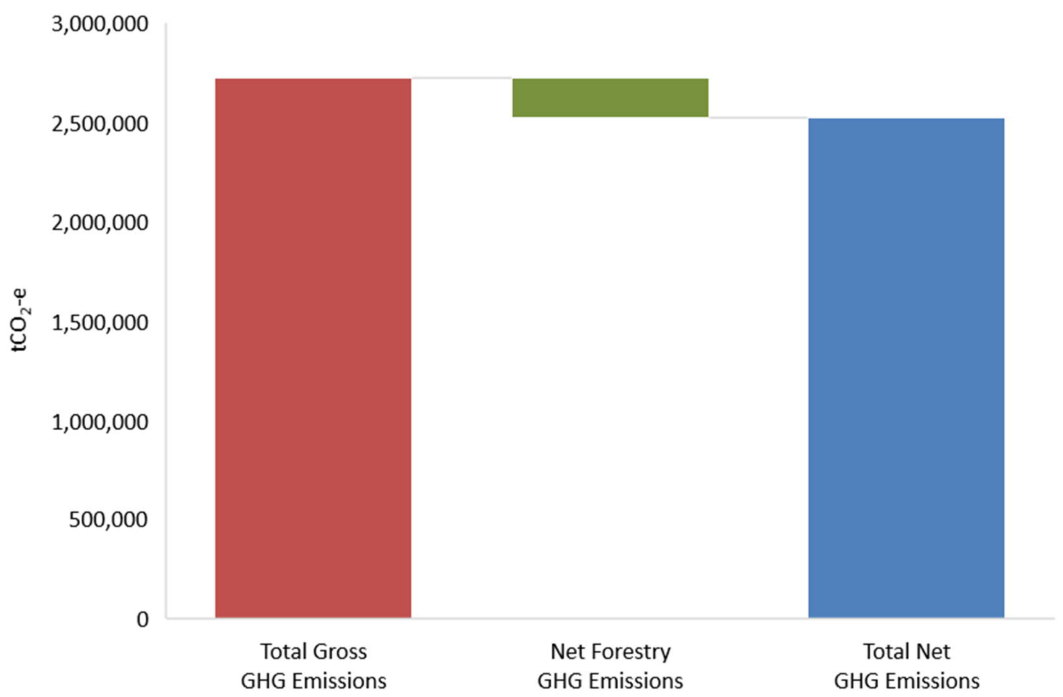

Figure 11 Total Gross GHG Emissions and Total Net GHG Emissions showing the impact of Net Forestry GHG emissions for the financial year 2018/19

Carbon sequestered by forestry can be viewed as a liability/risk needing careful consideration. For example, what happens if there is significant pest damage to harvestable forest, loss of forest due to forest fires or less planting due to a large downturn in the demand for exotic pine? If plantations are not replanted or if other land use change occurs to forested areas, then sequestration of carbon will decrease. Equally, if native forest is removed then sequestration of carbon will decrease. In summary, when a large amount of carbon is captured by forests, long-term planning is needed on how best to manage this carbon sink.

3.9 Comparison of Christchurch District's total gross GHG emissions with other New Zealand Territorial Authorities

Figure 12 shows a comparison of total gross GHG emissions (excluding Forestry) for Christchurch compared with other local authority areas in New Zealand. These studies have been chosen to represent different areas of New Zealand and are all reported using the GPC approach. Note however, that these studies were conducted at differing geographic boundary levels, in differing timeframes, and with slight differences in methodology.

When compared, Christchurch had higher total gross GHG emissions compared to Wellington City[10], New Plymouth[11] and Dunedin City[12] and lower total gross GHG emissions than Auckland[13].

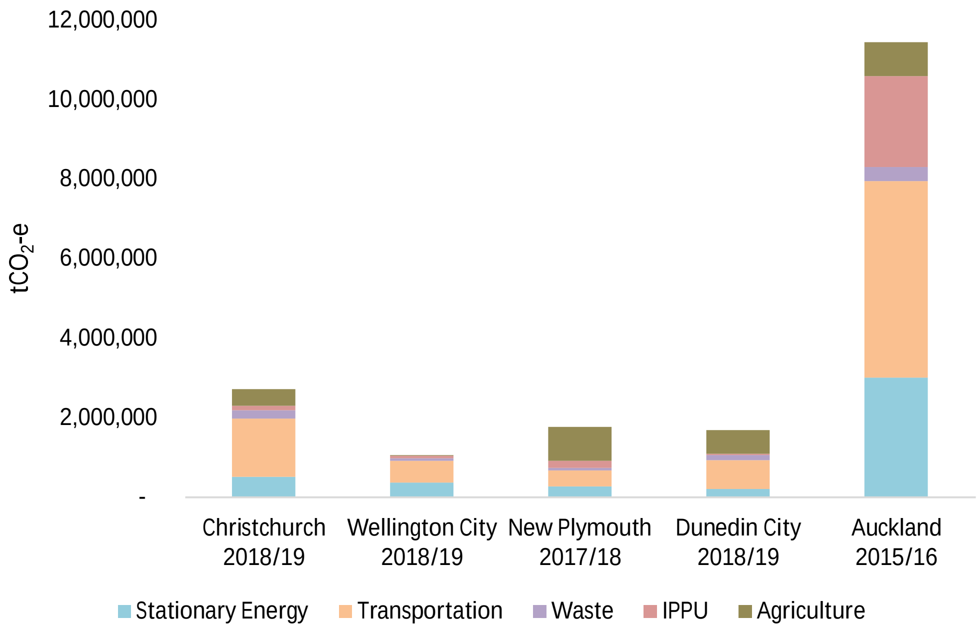

Figure 12 A comparison of Christchurch District's total gross GHG emissions with other New Zealand territorial authorities

When comparing different territorial authority GHG emission inventories, a per capita figure can be useful because it provides a common reference point to understand the difference in GHG emissions (see Figure 13). Christchurch had higher per capita total gross GHG emissions than Wellington City, mostly due to larger per capita Transportation and Agriculture GHG emissions. Per capita total gross GHG emissions in Christchurch were lower than New Plymouth and Dunedin City because Christchurch had substantially less Agriculture sector GHG emissions than both of these territorial authorities. Christchurch's per capita total gross GHG emissions were the same as Auckland.

[10] https://wellington.govt.nz/services/environment-and-waste/environment/climate-change/zero-carbon-capital
[11] Produced by AECOM in 2019. Unpublished at time of writing.
[12] Produced by AECOM in 2020. Unpublished at time of writing.
[13] https://knowledgeauckland.org.nz/publications/aucklands-greenhouse-gas-inventory-to-2016/

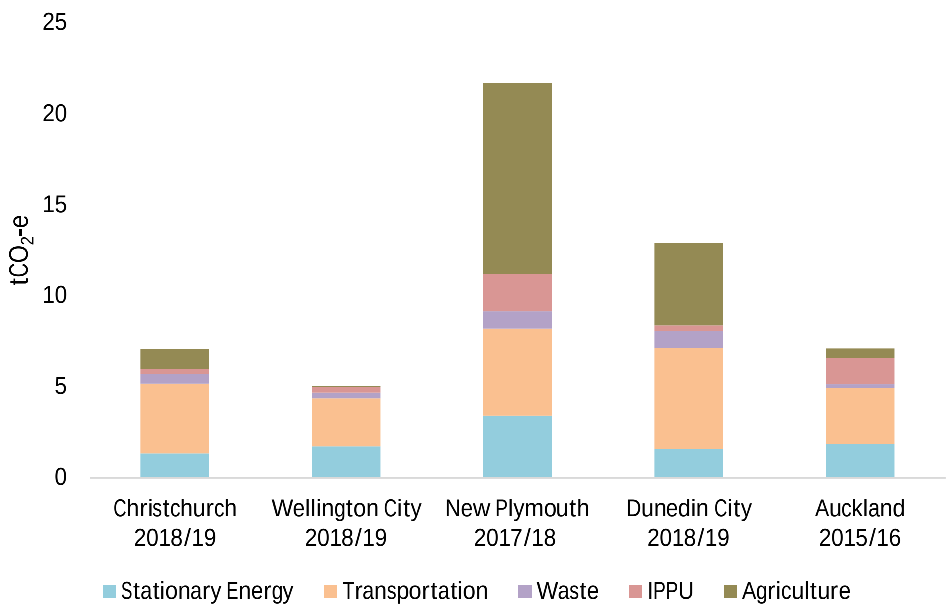

Figure 13: A comparison of Christchurch District's total gross GHG emissions with other New Zealand territorial authorities on a per capita basis

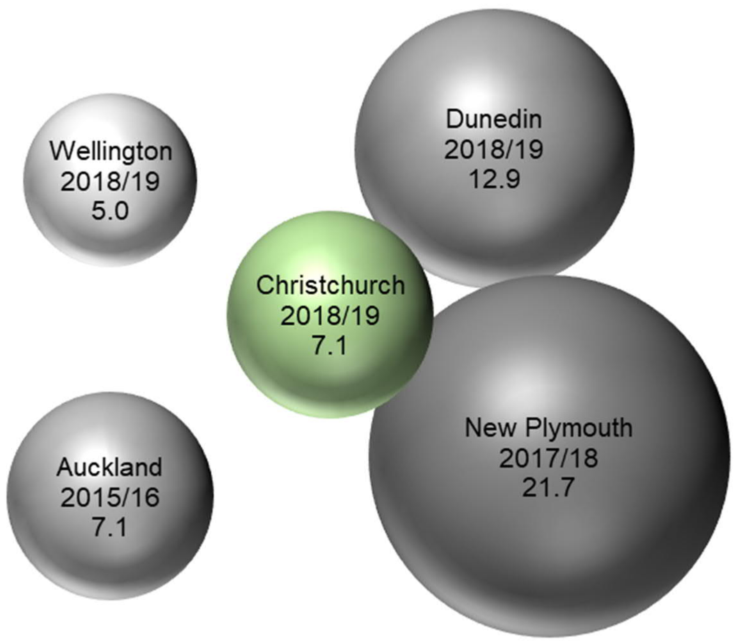

Figure 14 Per capita total gross GHG emissions for selected New Zealand territorial authorities (tCO_2-e/person/year)

2016/17 GHG Emission Inventory Results

4.0 2016/17 GHG Emission Inventory Results

The inventory for the financial year 2016/17 (2016/17) that was reported on in July 2018 by AECOM has been recalculated and updated in this report in line with current best practice methodology and using improved quality of data.

Improvements in data quality and availability have enabled more accurate reporting of GHG emissions. These data improvements, alongside updates to the methodology have meant that GHG emissions from some sources have changed between the previously 2018 published 2016/17 inventory and this recalculated 2016/17 inventory. For example, specific data for the 2018 published 2016/17 inventory was not previously available for agriculture. This data is now available for 2016/17 and has been used in the recalculation. Another example is the use of updated GHG emission factors, especially for the calculation of GHG emissions from electricity consumed.

Sectors of note where improvements in data and methodology have updated the results significantly are agriculture, aircraft fuel use and electricity consumed. The recalculated total gross GHG emissions for 2016/17 are higher than previously reported in July 2018 predominantly due to higher GHG emissions from aircraft fuel use and from the Agriculture sector.

All reported GHG emissions for 2016/17 are based on the recalculated GHG emissions. During the 2016/17 reporting period Christchurch emitted a total gross 2,665,643 tonnes of carbon dioxide equivalent (tCO_2-e) and a net 2,365,379 tCO_2-e.

The Christchurch District's population in 2016/17 was approximately 374,990 people, resulting in per capita gross GHG emissions of 7.1 tCO_2-e/person in 2016/17. The Transportation sector's GHG emissions were the largest contributor to the inventory for Christchurch, followed by the Stationary Energy sector (refer to Table 18).

Throughout this report a consistent colour scheme has been used to display GHG emissions from each of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) sector categories. The colour scheme follows the recommended GPC reporting framework to ensure consistency of reporting in New Zealand and internationally.

Table 18 Christchurch District's GHG emissions, by sector, for the financial year 2016/17

Sector	GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	1,425,197	53.5%
Stationary Energy	483,079	18.1%
Agriculture	410,970	15.4%
Waste	228,571	8.6%
Industrial Processes and Product Use	117,825	4.4%
Total Gross GHG Emissions (excl. Forestry)	2,665,643	-
Forestry	-300,264	Not included in total gross GHG emissions
Total Net GHG Emissions (incl. Forestry)	2,365,379	-

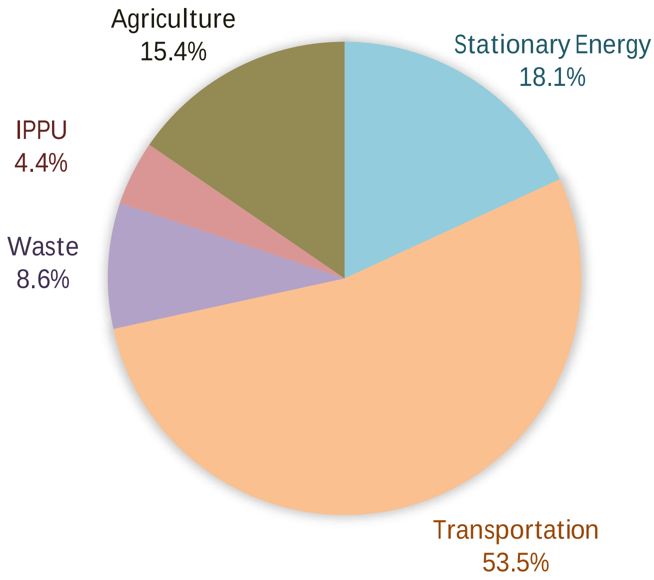

Figure 15 Christchurch District's gross GHG emissions, by sector, for the financial year 2016/17

Table 19 Christchurch District's GHG emissions, by sector and source, for the financial year 2016/17

GHG Emission Sector/Source		GHG Emissions (tCO_2-e)	% of Total Gross GHG Emissions
Transportation	Petrol (On-Road)	530,117	19.9%
	Diesel (On-Road)	428,248	16.1%
	Jet Kerosene (Commercial Flights)	302,609	11.4%
	Diesel (Off-Road)	87,362	3.3%
	Marine Light Fuel Oil (Freight Cargo)	54,298	2.0%
	LPG (Off-Road Mobile Uses	11,850	0.4%
	Petrol (Off-Road)	7,088	0.3%
	Rail (Diesel)	1,817	0.1%
	Aviation Gas (Local Flights)	1,159	0.04%
	Marine Diesel (Tourism Vessels and Local Ferries)	651	0.02%
	Biodiesel (Vehicle Use)	-	-
Stationary Energy	Electricity Consumed	231,039	8.7%
	Petrol & Diesel (Stationary Use)	99,739	3.7%
	LPG (Stationary Use)	79,716	3.0%
	Electricity Transmission and Distribution Losses	18,842	0.7%
	Coal	47,146	1.8%
	Biofuel (Wood)	6,524	0.2%
	Biogas-Methane Recovered (WWTP[14] and Landfill)	74	0.003%
	Biodiesel (Stationary Use)	0.01	0.0000002%
Agriculture – See Section 5.3 for a breakdown of Sources	Agriculture	410,970	15.4%
Waste	Closed Landfill Sites	170,479	6.4%
	Open Landfill Sites	31,035	1.2%
	Wastewater Treatment	14,272	0.54%
	Composting	12,786	0.48%
Industrial Processes and Product Use	Industrial Processes and Product Use	117,825	4.4%
Total Gross GHG Emissions		**2,665,643**	
Forestry	Harvest GHG Emissions	185,825	Not included in total gross GHG emissions
	Native Forest Sequestration	-108,965	
	Exotic Forest Sequestration	- 377,123	
Total Net GHG Emissions		**2,365,379**	

[14] Bromley Wastewater Treatment Plant

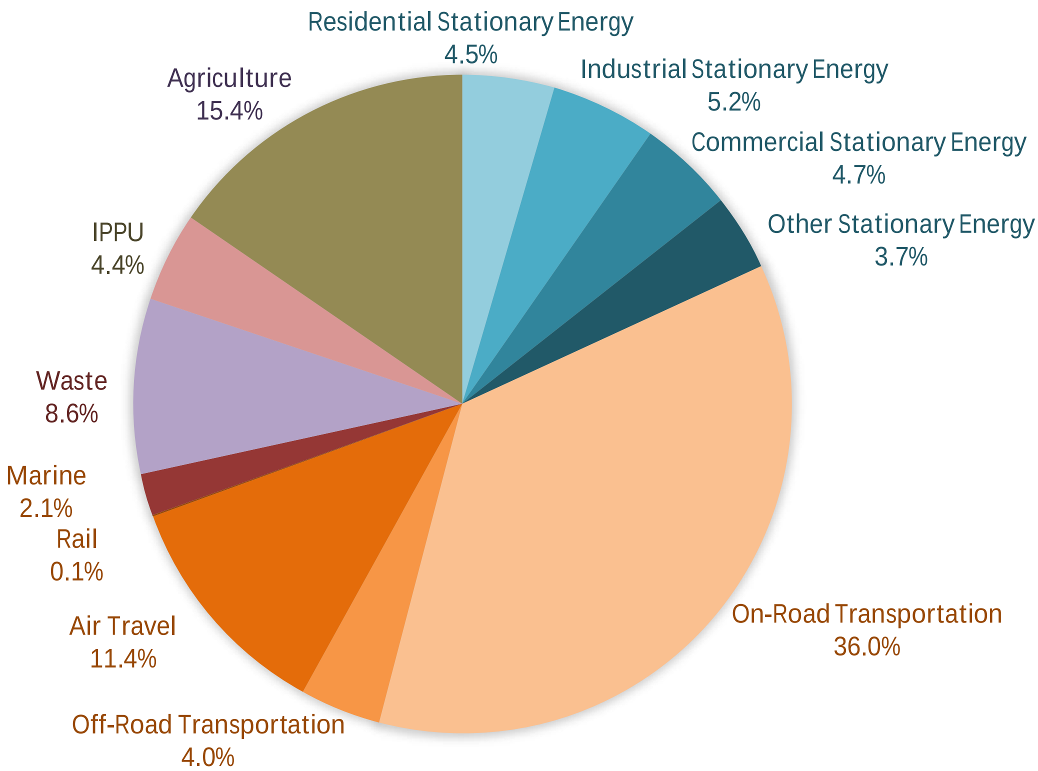

Figure 16 Christchurch District's gross GHG emissions, by source, for the financial year 2016/17

The Christchurch GHG emission inventory for 2016/17 includes GHG emissions for six different category sources which are summarised below.

4.1 2016/17 Transportation GHG Emissions

The Transportation sector was the highest GHG emission emitting sector, producing 1,425,197 tCO_2-e in 2016/17 (53.5% of Christchurch's total gross GHG emissions). The largest contributor to the Transportation sector's GHG emissions was from petrol and diesel, which produced 1,052,814 tCO_2-e (73.9% of the Transportation sector's GHG emissions and 39.5% of Christchurch's total gross GHG emissions). Petrol contributed to 37.7% of the Transportation sector's GHG emissions (537,205 tCO_2-e) while diesel contributed to 36.2% of the Transportation sector's GHG emissions (515,609 tCO_2-e).

Petrol and diesel transportation GHG emissions can be broken down into on-road and off-road usage. On-road transportation consists of all standard transportation vehicles used on roads (e.g. cars, trucks, buses, etc.). Off-road transportation consists of all fuel used for the movement of machinery and vehicles off-roads (e.g. within agriculture, construction and industry).

On-road transportation (petrol and diesel) produced 958,365 tCO_2-e (67.2% of the Transportation sector's GHG emissions and 36.0% of Christchurch's total gross GHG emissions). Off-road transportation (petrol, diesel and LPG) produced 106,299 tCO_2-e (7.5% of the Transportation sector's GHG emissions and 4.0% of Christchurch's total gross GHG emissions).

The second largest source of the Transportation sector's GHG emissions was from air travel (jet kerosene and aviation gas), which produced 303,768 tCO_2-e (21.3% of the Transportation sector's GHG emissions and 11.4% of Christchurch's total gross GHG emissions). Marine transportation produced 54,949 tCO_2-e (3.9% of the Transportation sector's GHG emissions and 2.1% of Christchurch's total gross GHG emissions). Rail diesel produced the remaining 1,817 tCO_2-e (0.1% of the Transportation sector's GHG emissions and 0.1% of Christchurch's total gross GHG emissions). Rail emissions were particularly low in 2016/17 due to the closing of the Christchurch to Picton railway line following the 2016 Kaikoura earthquake. There was no recorded biodiesel used for transportation in 2016/17.

Table 20 Christchurch District's Transportation GHG emissions, by source, for the financial year 2016/17

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Transportation	Petrol (On-Road)	530,117	1,425,197	37.2%
	Diesel (On-Road)	428,248		30.0%
	Air Travel	303,768		21.3%
	Diesel (Off-Road)	87,362		6.1%
	Marine (Freight Cargo, Tourism Vessels and Local Ferries)	54,949		3.9%
	LPG (Off-Road Mobile Uses)	11,850		0.8%
	Petrol (Off-Road)	7,088		0.5%
	Rail (Diesel)	1,817		0.1%
	Biodiesel (Vehicle Use)	0		0.0%

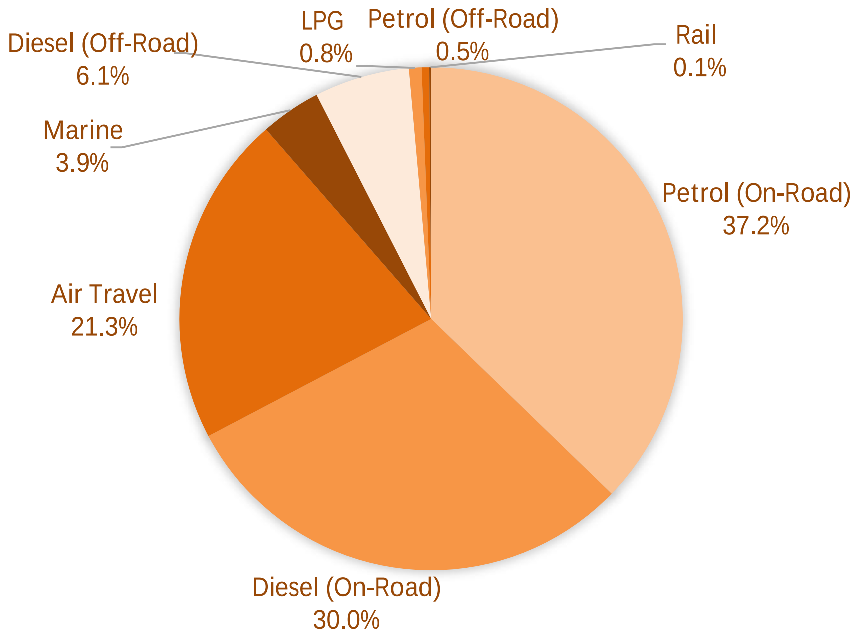

Figure 17 Christchurch District's Transportation source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2016/17

4.2 2016/17 Stationary Energy GHG Emissions

The Stationary Energy sector was Christchurch's second highest emitting sector producing 483,079 tCO_2-e in 2016/17 (18.1% of Christchurch's total gross GHG emissions). The largest contributor to the Stationary Energy sector's GHG emissions was from electricity consumed (including associated electricity transmission and distribution losses), producing 249,881 tCO_2-e (51.7% of the Stationary Energy sector's GHG emissions and 9.4% of Christchurch's total gross GHG emissions).

The second largest source of the Stationary Energy sector's GHG emissions was petrol and diesel use in stationary energy activities which produced 99,739 tCO_2-e (20.6% of the Stationary Energy sector's GHG emissions and 3.7% of Christchurch's total gross GHG emissions).

GHG emissions from bottled LPG use produced 79,716 tCO_2-e (16.5% of the Stationary Energy sector's GHG emissions and 3.0% of Christchurch's total gross GHG emissions).

Coal produced 47,146 tCO_2-e (9.8% of the Stationary Energy sector's GHG emissions and 1.8% of Christchurch's total gross GHG emissions).

Recovered biogas (methane) has been used for energy generation and flaring at Kate Valley landfill, Burwood landfill and Bromley wastewater treatment plant.

GHG emissions from the combustion of recovered biogas (methane), from landfill and wastewater treatment, used for energy generation are included in the Stationary Energy sector (a requirement of the GPC standard).

GHG emissions from flaring of recovered biogas (methane) from landfill and wastewater treatment are generally included in the Waste sector. However, due to difficulties in separating out data for recovered biogas (methane) used for energy generation and recovered biogas (methane) used for flaring, GHG emissions from flaring of recovered biogas (methane) from landfill and wastewater treatment are included in the Stationary Energy sector.

Combustion of biogas (methane) for energy generation and flaring of biogas (methane) results in carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) GHG emissions. Carbon dioxide GHG emissions are biogenic GHG emissions (i.e. generated from organic materials) and have been excluded from the total gross GHG emissions but are reported in the biogenic GHG emissions section of this inventory (section 4.7), following GPC guidance. Methane and nitrous oxide GHG emissions from the combustion of biogas (methane) collected at the Bromley wastewater treatment plant, Kate Valley landfill and Burwood landfill and used for energy generation and flaring, are reported in the Stationary Energy sector. Methane GHG emissions from the combustion of biogas (methane) are also biogenic and so are additionally reported in the biogenic emissions section of this inventory (section 4.7), following GPC guidance.

The Stationary Energy sector's GHG emissions are also broken down by sub-sector. Stationary Energy GHG emissions are reported for the following sub-sectors within the Stationary Energy sector: industrial; commercial; and residential. GHG emissions from petrol and diesel used for stationary energy and from the recovery and combustion of biogas (methane) for stationary energy use are not broken down into these sub-sectors.

- The Industrial Stationary Energy sub-sector produced 137,499 tCO_2-e (28.5% of the Stationary Energy sector's GHG emissions and 5.2% of Christchurch's total gross GHG emissions). Industrial stationary energy is energy used within all industrial settings (e.g. mining, food processing, textiles, chemicals, metals, mechanical/electrical equipment and building and construction activities), and includes agriculture, forestry and fishing activities.
- The Commercial Stationary Energy sub-sector produced 125,996 tCO_2-e (26.1% of the Stationary Energy sector's GHG emissions and 4.7% of Christchurch's total gross GHG emissions). Commercial stationary energy is energy used in all non-residential and non-industrial settings (e.g. in retail, hospitality, education and healthcare).
- The Residential Stationary Energy sub-sector produced 119,772 tCO_2-e (24.8% of the Stationary Energy sector's GHG emissions and 4.5% of Christchurch's total gross GHG emissions). Residential stationary energy is energy used in homes (e.g. for heating, lighting and cooking).
- The remaining Stationary Energy sector's GHG emissions from diesel, petrol and combustion of biogas (methane) produced 99,812 tCO_2-e (20.7% of the Stationary Energy sector's GHG emissions and 3.7% of Christchurch's total gross GHG emissions) and were not allocated to the above Stationary Energy sub-sector categories.

Table 21 Christchurch District's Stationary Energy GHG emissions, by source, for the financial year 2016/17

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Stationary Energy	Electricity Consumed	231,039	483,079	47.8%
	Petrol & Diesel (Stationary Use)	99,739		20.6%
	LPG (Stationary Use)	79,716		16.5%
	Coal	47,146		9.8%
	Electricity Transmission and Distribution Losses	18,842		3.9%
	Biofuel (Wood)	6,524		1.4%
	Biogas-Methane Recovered (WWTP[15] and Landfill)	74		0.02%
	Biodiesel (Stationary Use)	0.01		0.000001%

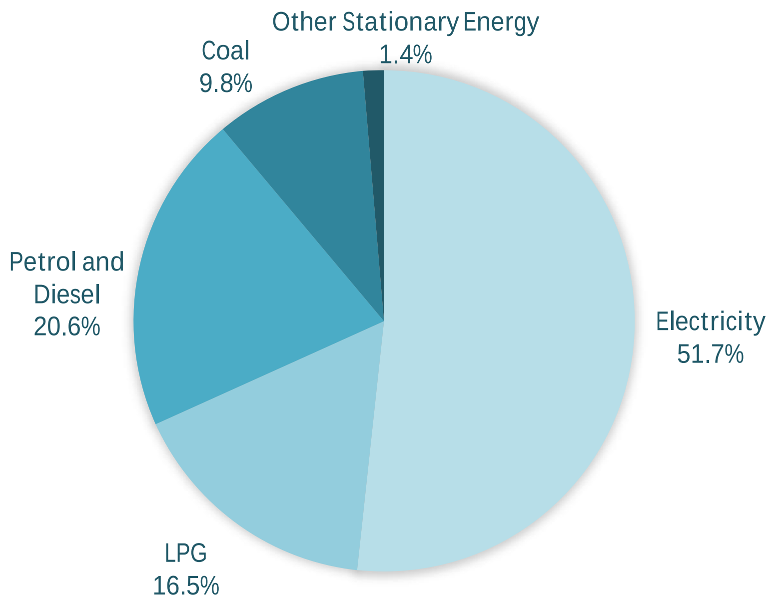

Figure 18 Christchurch District's Stationary Energy source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2016/17

[15] Bromley Wastewater Treatment Plant

Table 22 Christchurch District's Stationary Energy GHG emissions, by sub-sector, for the financial year 2016/17

Sector/Sub-Sector		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Stationary Energy	Industrial	137,499	483,079	28.5%
	Commercial	125,996		26.1%
	Residential	119,772		24.8%
	Other Stationary Energy	99,812		20.7%

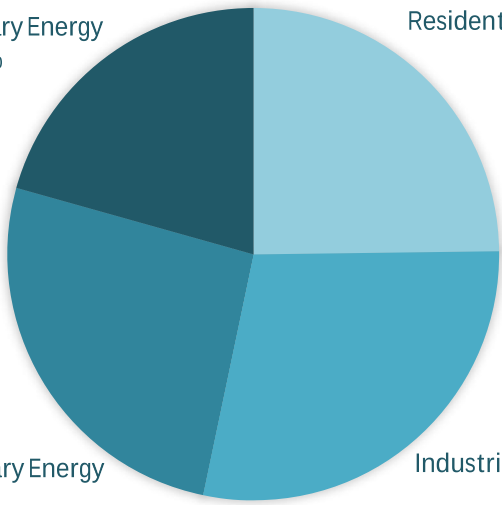

Figure 19 Christchurch District's Stationary Energy sub-sector GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2016/17

4.3 2016/17 Agriculture GHG Emissions

The Agriculture sector was Christchurch's third highest emitting sector producing 410,970 tCO_2-e in 2016/17 (15.4% of Christchurch's total gross GHG emissions). Livestock produced the majority of the Agriculture sector's GHG emissions, tCO_2-e (97.8% of the Agriculture sector's GHG emissions and 15.1% of Christchurch's total gross GHG emissions). Sheep are farmed in the largest numbers across Christchurch, accounting for 71.3% of farmed livestock (253,331 animals). Dairy cattle make up 14.4% of farmed livestock (51,273 animals). Non-dairy cattle make up 10.2% of farmed livestock (36,307 animals) while small numbers of other livestock make up the remaining 4.0% (e.g. pigs, goats, deer and horses).

Enteric fermentation from livestock produced 326,160 tCO_2-e (79.4% of the Agriculture sector's GHG emissions and 12.2% of Christchurch's total gross GHG emissions). The second largest source of the Agriculture sector's GHG emissions was from methane (CH_4) being released by manure from grazing animals on pasture producing 48,589 tCO_2-e (11.8% of the Agriculture sector's GHG emissions and 1.8% of Christchurch's total gross GHG emissions). The remaining Agriculture sector's GHG emissions are in Table 23.

Agriculture sector GHG emissions can also be broken down into livestock type and crops and fertiliser, see Table 24. Dairy cattle produced 185,241 tCO2-e (45.1% of the Agriculture sector's GHG emissions and 6.9% of Christchurch's total gross GHG emissions), sheep produced 123,625 tCO2-e (30.1% of the Agriculture sector's GHG emissions and 4.6% of Christchurch's total gross GHG emissions), and non-dairy cattle produced 84,950 tCO2-e (20.7% of the Agriculture sector's GHG emissions and 3.2% of Christchurch's total gross GHG emissions). Crops and fertiliser produced 8,599 tCO2-e (2.1% of the Agriculture sector's GHG emissions and 0.3% of Christchurch's total gross GHG emissions). Small numbers of other livestock (e.g. pigs, goats, deer and horses) make up the remaining 8,556 tCO2-e (2.1% of the Agriculture sector's GHG emissions and 0.3% of Christchurch's total gross GHG emissions).

The measurement of GHG emissions in the agriculture sector considers both direct and indirect GHG emissions from N_2O. Direct sources include those where N_2O is emitted directly to the atmosphere from cultivated soils and fertiliser applied and/or grazed grassland systems (e.g. Enteric Fermentation). Indirect GHG emissions sources result from either the movement of nitrogen from agricultural systems into ground water or surface water through drainage and surface runoff (e.g. Leaching), or ammonia or nitrogen oxides released to the atmosphere (e.g. Atmospheric Deposition)[16].

Enteric Fermentation GHG emissions are produced by CH_4 released from the digestive process of ruminant animals (e.g. cattle and sheep). GHG emissions from Manure from Grazing Animals on Pasture refers to N_2O released from unmanaged manure. Manure Management refers to the GHG emissions (N_2O and CH_4) released in a managed environment (e.g. within cattle sheds) through the capture, storage, treatment, and utilization of animal manure. Decomposition of organic matter occurs when manure or urine is deposited leading to aerobic and anaerobic processes that release N_2O.

Agricultural Soils refers specifically to N_2O emitted from nitrogen leaching/runoff from cultivated soils (e.g. through turning of the earth using ploughs).

Atmospheric Deposition is the process whereby N_2O GHG emissions are produced through volatilisation (the loss of nitrogen into the atmosphere) from nitrogen applied by grazing animals as manure and urine on pasture. Atmospheric Deposition GHG emissions are also produced by volatilisation from synthetic nitrogen fertilisers or organic fertilisers. The application of synthetic or organic fertilisers will greatly increase the amount of direct N_2O emissions through volatilisation because of the greater amounts of nitrogen available.

Indirect GHG emissions from N_2O include leaching of N_2O in the form of water-soluble plant nutrients from the soil, due to rain and irrigation. The application of synthetic or organic fertilisers will also increase the amount of leaching of N_2O by increasing the nitrogen available. For example, the use of organic fertiliser can cause ammonia volatilisation leading to N_2O production. The volatilisation of ammonia is considered an indirect GHG emission source to distinguish this process from direct volatilisation of nitrogen.

GHG emissions from Liming and Dolomite refers to CO_2 emissions from lime applications (calcic lime and dolomite). Liming is used to reduce soil acidity and improve plant growth on agricultural land. Adding lime or dolomite leads to CO_2 emissions as the carbonate in the minerals dissolve and release bicarbonate, which evolves into CO_2 and water.[17]

[16] https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_5_N2O_Agricultural_Soils.pdf
[17] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

Table 23 Christchurch District's Agriculture GHG emissions, by source, for the financial year 2016/17

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Agriculture	Enteric Fermentation (CH_4)	326,160	410,970	79.4%
	Manure from Grazing Animals on Pasture (CH_4)	48,589		11.8%
	Manure Management (CH_4)	17,041		4.1%
	Atmospheric Deposition (N_2O)	6,902		1.7%
	Agricultural Soils (N_2O)	6,318		1.5%
	Leaching (N_2O)	3,610		0.9%
	Liming and Dolomite (CO_2)	2,006		0.5%
	Manure Management (N_2O)	344		0.1%

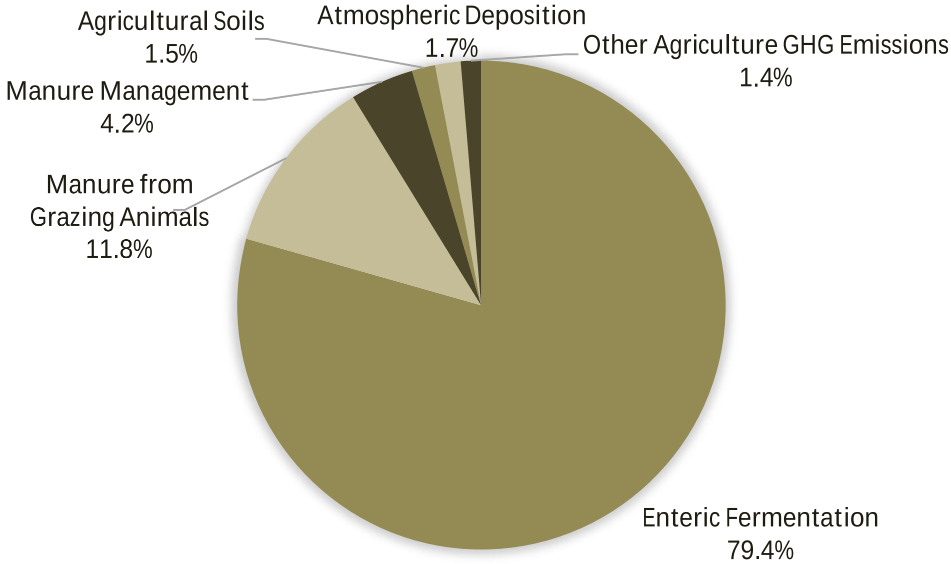

Figure 20 Christchurch District's Agriculture source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2016/17

Table 24 Christchurch District's Agriculture GHG emissions, by source (livestock, crops and fertiliser), for the financial year 2016/17

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
	Dairy Cattle	185,241		45.1%
	Sheep	123,625		30.1%
Agriculture	Non-Dairy Cattle	84,950	410,970	20.7%
	Crops and Fertiliser	8,599		2.1%
	Other Livestock	8,556		2.1%

4.4 2016/17 Waste GHG Emissions

The Waste sector (solid waste and wastewater treatment) was Christchurch's fourth highest emitting sector producing 228,571 tCO_2-e in 2016/17 (8.6% of Christchurch's total gross GHG emissions). Solid waste sent to landfill or composting produced 214,300 tCO_2-e (93.8% of the Waste sector's GHG emissions and 8.0% of Christchurch's total gross GHG emissions).

Solid waste GHG emissions include emissions from open landfills and closed landfills. Both open and closed landfills emit landfill gas (methane) from the breakdown of organic materials disposed of in the landfill. Closed landfills produced 170,479 tCO_2-e (74.6% of the Waste sector's GHG emissions and 6.4% of Christchurch's total gross GHG emissions). Open landfills produced 31,035 tCO_2-e (13.6% of the Waste sector's GHG emissions and 1.2% of Christchurch's total gross GHG emissions). GHG emissions from composting are the smallest source of GHG emissions from solid waste producing 12,786 tCO_2-e (5.6% of the Waste sector's GHG emissions and 0.5% of Christchurch's total gross GHG emissions).

Wastewater treatment falls into two broad GHG emission source categories: wastewater treated in centralised treatment plants and wastewater treated in individual treatment systems (i.e. septic tanks). Wastewater treated by individual treatment systems tends to produce higher GHG emissions than if treated in centralised treatment plants. The majority of wastewater in Christchurch is treated by advanced centralised wastewater treatment systems resulting in relatively low GHG emissions.

Wastewater treatment produced 14,272 tCO_2-e (6.2% of the Waste sector's GHG emissions and 0.5% of Christchurch's total gross GHG emissions). Wastewater treated in the Bromley centralised treatment plant produced 12,158 tCO_2-e (5.3% of the Waste sector's GHG emissions and 0.4% of Christchurch's total gross GHG emissions) while individual wastewater treatment systems (i.e. septic tanks) produced 2,113 tCO_2-e (0.9% of the Waste sector's GHG emissions and 0.1% of Christchurch's total gross GHG emissions). Individual wastewater treatment systems service 1.8% of Christchurch's population.

GHG emissions from the combustion of biogas (methane), recovered at the Bromley wastewater treatment plant, Kate Valley landfill and Burwood landfill, and used for energy generation as well as flared, are reported in the Stationary Energy sector.

Table 25 Christchurch District's Waste GHG emissions, by source, for the financial year 2016/17

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Waste	Closed Landfill Sites	170,479	242,466	74.6%
	Open Landfill Sites	31,035		13.6%
	Wastewater Treatment	14,272		6.2%
	Composting	12,786		5.6%

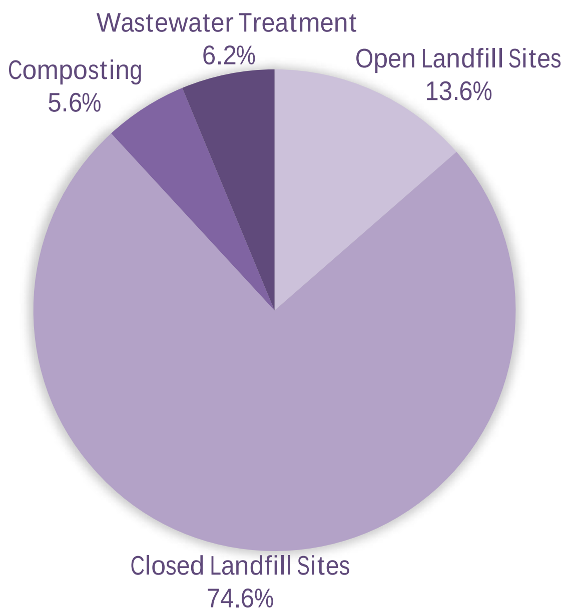

Figure 21 Christchurch District's Waste source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2016/17

4.5 2016/17 Industrial Processes and Product Use (IPPU) GHG Emissions

The IPPU sector was Christchurch's fifth highest emitting sector producing 117,825 tCO_2-e in 2016/17 (4.4% of Christchurch's total gross GHG emissions). The use of refrigerants produced 108,693 tCO_2-e (92.2% of the IPPU sector's GHG emissions and 0.04% of Christchurch's total gross GHG emissions).

The GHG emissions for Industrial Product Use include GHG emissions from (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Nitrogen trifluoride GHG emissions do not occur in New Zealand and are not included in this report. GHG emissions from Industrial Product Use includes GHG emissions associated with the consumption of GHGs for refrigerants, foam blowing, fire extinguishers, aerosols, metered dose inhalers (e.g. used for asthma treatment) and sulphur hexafluoride for electrical insulation and equipment production. The highest GHG emission producing IPPU source, refrigerants, are chemicals used in refrigeration and air conditioning products which are released as greenhouse gases upon disposal.

Industrial Processes which may produce IPPU GHG emissions include the production of cement, lime, glass, ammonia, iron, steel, and aluminium. It is understood that there are no large industrial operations within the Christchurch District's boundary that result in significant Industrial Processes GHG emissions.

IPPU GHG emissions do not include GHG emissions resulting from energy use for industrial manufacturing, which is included in the relevant Stationary Energy source category (e.g. electricity consumed or coal).

Table 26 Christchurch District's IPPU GHG emissions, by source, for the financial year 2016/17

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
IPPU	Refrigerants	108,693	117,825	92.2%
	Aerosols & Metered Dose Inhalers (MDI)	7,077		6.0%
	SF6	1,446		1.2%
	Foam Blowing	433		0.4%
	Fire Extinguishers	176		0.1%

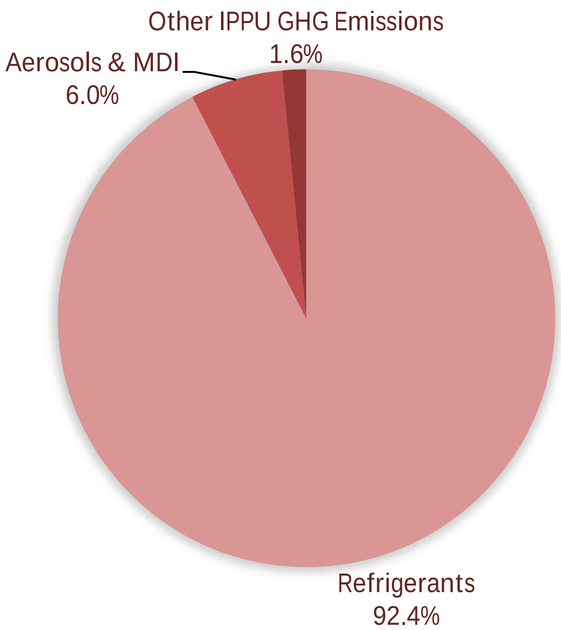

Figure 22 Christchurch District's IPPU source GHG emissions, by % contribution of the sector's GHG emissions, for the financial year 2016/17

4.6 2016/17 Forest Carbon Sequestration and GHG Emissions

In 2016/17 the Forestry sector produced net negative GHG emissions of 300,264 tCO_2-e due to the sequestration of carbon mostly by exotic forest.

Christchurch has a regenerative native forested area which includes manuka, kanuka, gorse, broom, grey scrub, mixed exotic shrubland as well as broadleaved hardwoods. Regenerating natives occupied 18,790 ha while exotics occupied a further 9,970 ha of land. Native forests sequestered 108,965 tCO_2-e while exotic forests sequestered 377,123 tCO_2-e. In total, 486,088 tCO_2-e were sequestered by forests in Christchurch in 2016/17. GHG emissions produced from harvesting of forestry produced 185,825 tCO_2-e.

Table 27 Christchurch District's Forestry GHG emissions and sequestration, by source, for the financial year 2016/17

Sector/Source		GHG Emissions (tCO_2-e)		% Contribution of the Sector GHG Emissions
Forestry	Native Forest Sequestration	-377,123	- 486,088	77.6%
	Exotic Forest Sequestration	-108,965		22.4%
	Forest Harvest GHG Emissions	185,825	185,825	100%
	Net Forestry GHG Emissions	-300, 264		N/A

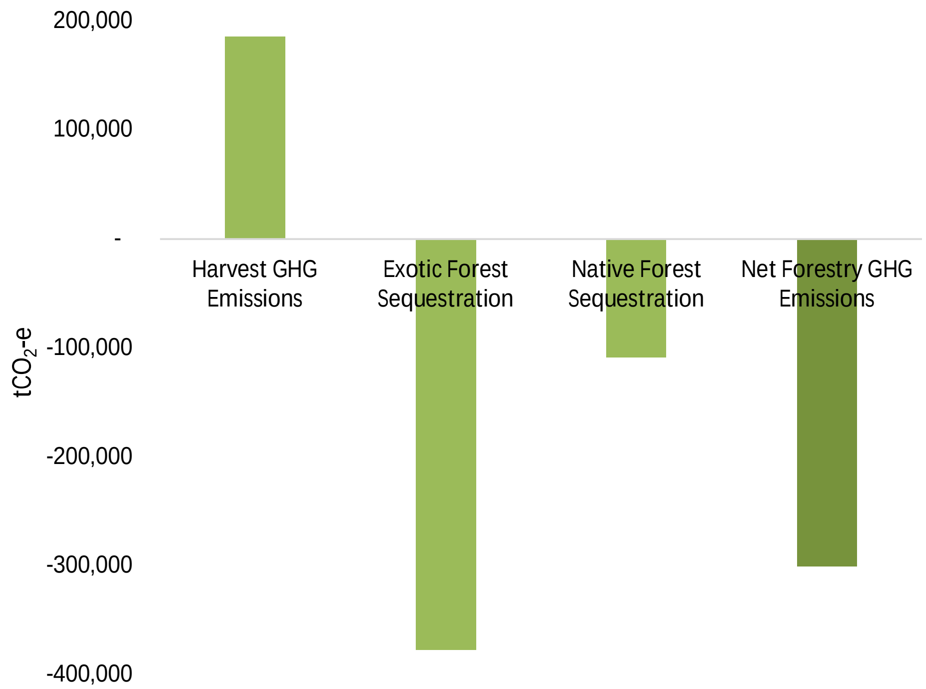

Figure 23 Christchurch District's Forestry harvest GHG emissions, Forestry sequestration and net Forestry GHG emissions for the financial year 2016/17

4.7 2016/17 Biogenic GHG Emissions

Biogenic carbon dioxide (CO_2) and methane (CH_4) GHG emissions are listed in Table 28 and Table 29, respectively (as tonnes of the individual gas, not in CO_2-e).

Biogenic CO_2 GHG emissions from plants and animals are excluded from the total gross GHG emissions as they are part of the natural carbon cycle. For example, because wood biofuels originate from forestry, the Biogenic CO_2 GHG emissions from wood biofuels are excluded from total gross GHG emissions. CO_2 GHG emissions from the combustion of recovered biogas (methane) from the Kate Valley landfill, Bromley landfill and from the Bromley wastewater treatment plant for energy use and flaring are also excluded from total gross GHG emissions as they originate from organic material disposed of in the landfill or from the wastewater treatment process.

Biogenic CH_4 GHG emissions are included in total gross GHG emissions due to their relatively large impact on warming relative to Biogenic CO_2 GHG emissions. For example, Biogenic CH_4 GHG emissions produced by farmed cattle, via enteric fermentation and manure, is included in total gross

GHG emissions. Landfill biogas (methane) produced from solid waste is included in total gross GHG emissions, unless it is combusted for energy generation or flared (recovered methane). Recovered methane is converted to CO_2 where it is not considered to contribute to global climate change because the carbon was contained in recently living biomass.

The importance of Biogenic CH_4 GHG emissions is highlighted in NZ's Climate Change Response (Zero Carbon) Amendment Act. The Act includes targets to reduce Biogenic CH_4 GHG emissions by between 24 percent and 47 percent below 2017 levels by 2050, and a 10 percent reduction 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 28 Christchurch District's Biogenic carbon dioxide (CO_2) GHG emissions, by source, for the financial year 2016/17. (Excluded from total gross GHG emissions)

Sector/Source		Biogenic GHG Emissions (tCO_2)		% Contribution of the Biogenic CO_2 GHG Emissions
Biogenic CO_2 GHG Emissions	Biofuel (Wood)	71,902	102,051	70.5%
	Landfill Biogas - Methane (Recovered)	15,511		15.2%
	Wastewater Treatment Biogas - Methane (Recovered)	14,561		14.3%
	Biodiesel (Stationary Use)	77		0.1%

Table 29 Christchurch District's Biogenic methane (CH_4) GHG emissions, by source, for the financial year 2016/17. (Included in total gross GHG emissions)

Sector/Source		Biogenic GHG Emissions (tCH_4)		% Contribution of the Biogenic CH_4 GHG Emissions
Biogenic CH_4 GHG Emissions	Enteric Fermentation	9,593	16,690	57.5%
	Landfill Biogas - Methane (Non-Recovered)	6,173		37.0%
	Manure Management	501		3.0%
	Wastewater Treatment Biogas-Methane (Non-Recovered)	253		1.5%
	Biofuel (Wood)	168		1.0%
	Landfill Biogas - Methane (Recovered)	1		0.01%
	Wastewater Treatment Biogas - Methane (Recovered)	0.3		0.002%
	Biodiesel (Stationary Use)	0.0001		0.000001%

4.8 2016/17 Net GHG Emissions

Net GHG emissions differ from gross GHG emissions because they include GHG emissions related to forestry activity within an area. GHG emissions from forestry include two main types of activity. Harvesting of forest increases GHG emissions through the releasing of carbon from plants and soils. Planting of native forest (e.g. manuka and kanuka) and exotic forest (e.g. pine), sequesters (captures) carbon from the atmosphere while the trees are growing to maturity. When sequestration by forests exceeds GHG emissions from harvesting, the extra quantity of carbon sequestered by forest reduces total gross GHG emissions.

Overall, Forestry is a net negative source of GHG emissions of 300,264 tCO2-e due to the sequestration of carbon mostly by exotic forest. The net negative GHG emissions from Forestry reduce total gross GHG emissions by 11.2% to a total net GHG emissions of 2,365,379 tCO2-e. Figure 24 shows total gross GHG emissions versus total net GHG emissions and the impact of net forestry GHG emissions.

Table 30 Christchurch District's total gross and total net GHG emissions for the financial year 2016/17

Total Emissions	GHG emissions (tCO_2-e)
Gross GHG Emissions	2,665,643
Net GHG Emissions	2,365,379

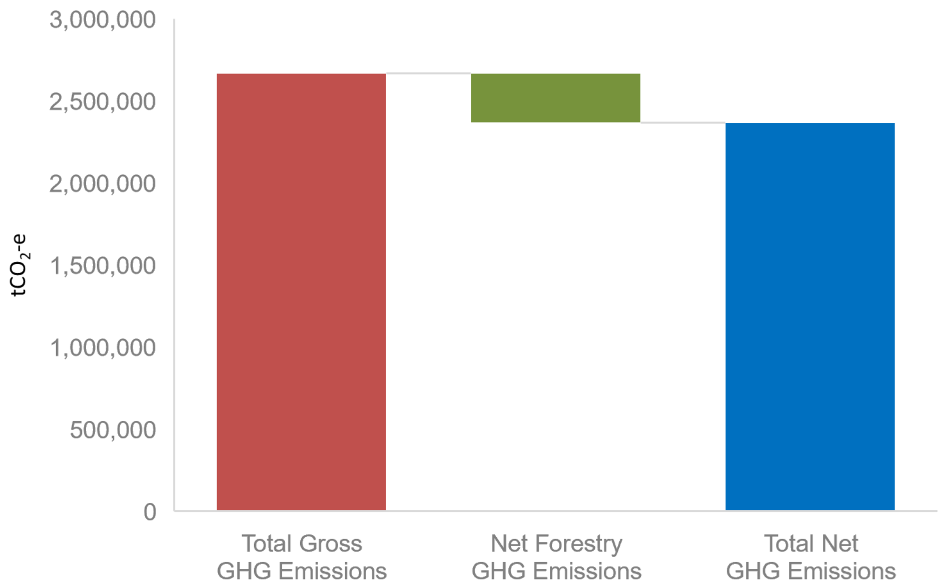

Figure 24 Total Gross GHG Emissions and Total Net GHG Emissions showing the impact of Net Forestry GHG emissions for the financial year 2016/17

Carbon sequestered by forestry can be viewed as a liability/risk needing careful consideration. For example, what happens if there is significant pest damage to harvestable forest, loss of forest due to forest fires or less planting due to a large downturn in the demand for exotic pine? If plantations are not replanted or if other land use change occurs to forested areas, then sequestration of carbon will decrease. Equally, if native forest is removed then sequestration of carbon will decrease. In summary, when a large amount of carbon is captured by forests, long-term planning is needed on how best to manage this carbon sink.

Comparison of GHG Emission Inventories Between 2016/2017 and 2018/2019

4.9 Comparison of GHG Emission Inventories Between 2016/2017 and 2018/2019

This section outlines the notable changes in GHG emissions between 2016/17 and 2018/19 for each sector and source.

The two GHG emission inventories (2016/17 and 2018/19) have been created with the aim of direct comparison of results. Where possible the same datasets, quality of data and methodology have been used for the 2016/17 and 2018/19 inventories. One exception was for rail GHG emissions, where the data used for the 2018/19 inventory was not available for recalculating the 2016/17 inventory so using the same dataset for both inventories was not possible, therefore comparison of these results may be less accurate.

Total gross GHG emissions increased by 2.2%, from 2,665,643 tCO_2-e in 2016/17 to 2,723,016 tCO_2-e in 2018/19. As Christchurch's population has risen, per capita gross GHG emissions have remained steady (7.1 tCO_2-e/person/year for both financial years). Total net GHG emissions increased by 6.8%, from 2,365,379 tCO_2-e in 2016/17 to 2,525,283 tCO_2-e in 2018/19. This is a larger increase than the increase in total gross GHG emissions due to an increase in forest harvesting GHG emissions while forest sequestration remained steady. Table 31 shows the change in gross GHG emissions for each sector between 2016/17 and 2018/19. The increase in GHG emissions from the Transportation and Stationary Energy sectors was predominantly responsible for the increase in Christchurch's total gross GHG emissions.

Table 31 A comparison of Christchurch District's GHG emissions, by sector, between financial years 2016/17 and 2018/19

Sector	2016/17 GHG Emissions (tCO_2-e)	2018/19 GHG Emissions (tCO_2-e)	Change Between 2016/17 and 2018/19 (tCO_2-e)	% Change Between 2016/17 and 2018/19
Transportation	1,425,197	1,470,159	44,962	3.2%
Stationary Energy	483,079	517,077	33,998	7.0%
Agriculture	410,970	417,545	6,575	1.6%
Waste	228,571	202,854	-25,718	-11.3%
Industrial Processes and Product Use	117,825	115,381	-2,444	-2.1%
Total Gross GHG Emissions (excl. Forestry)	**2,665,643**	**2,723,016**	57,373	2.2%
Forestry	-300,264	-197,733	102,531	-34.1%
Total Net GHG Emissions (incl. Forestry)	**2,365,379**	**2,525,283**	159,904	6.8%

Table 32 A comparison of Christchurch District's GHG emissions, by sector and source, between financial years 2016/17 and 2018/19

GHG Emission Sector/Source		2016/17 GHG Emissions (tCO_2-e)	2018/19 GHG Emissions (tCO_2-e)	Change Between 2016/17 and 2018/19 (tCO_2-e)	% Change Between 2016/17 and 2018/19
Transportation	Petrol (On-Road)	530,117	522,258	-7,859	-1.5%
	Diesel (On-Road)	428,248	457,784	29,536	6.9%
	Jet Kerosene (Commercial Flights)	302,609	315,769	13,160	4.3%
	Diesel (Off-Road)	87,362	93,668	6,306	7.2%
	Marine Light Fuel Oil (Freight Cargo)	54,298	55,523	1,225	2.3%
	LPG (Off-Road Mobile Uses)	11,850	2,411	-9,439	-79.7%
	Petrol (Off-Road)	7,088	6,109	-979	-13.8%
	Rail (Diesel)	1,817	14,783	12,966	713.6%
	Aviation Gas (Local Flights)	1,159	1,159	-	0.0%
	Marine Diesel (Tourism Vessels and Local Ferries)	651	692	41	6.3%
	Biodiesel (Vehicle Use)	0	3	3	N/A
Stationary Energy	Electricity Consumed	231,039	284,524	53,484	23.1%
	Petrol & Diesel (Stationary Use)	99,739	54,978	-44,760	-44.9%
	LPG (Stationary Use)	79,716	97,979	18,263	22.9%
	Coal	47,146	49,623	2,477	5.3%
	Electricity Transmission and Distribution Losses	18,842	23,363	4,521	24.0%
	Biofuel (Wood)	6,524	6,480	- 44	-0.7%
	Biogas-Methane Recovered (WWTP[18] and Landfill)	74	130	56	75.8%
	Biodiesel (Stationary Use)	0.01	0.18	0.2	3,510.8%
Agriculture	Agriculture	410,970	417,545	6,575	1.6%
Waste	Closed Landfill Sites	170,479	143,874	-26,604	-15.6%
	Open Landfill Sites	31,035	33,542	2,507	8.1%
	Wastewater Treatment	14,272	14,683	411	2.9%
	Composting	12,786	10,755	-2,031	-15.9%

[18] Bromley Wastewater Treatment Plant

GHG Emission Sector/Source		2016/17 GHG Emissions (tCO_2-e)	2018/19 GHG Emissions (tCO_2-e)	Change Between 2016/17 and 2018/19 (tCO_2-e)	% Change Between 2016/17 and 2018/19
Industrial Processes and Product Use	Industrial Processes and Product Use	117,825	115,381	-2,444	-2.1%
Total Gross GHG Emissions		**2,665,643**	**2,723,016**	57,373	2.2%
Forestry	Harvest GHG Emissions	185,825	284,524	98,699	53.1%
	Native Forest Sequestration	-108,965	-108,965	-	0.0%
	Exotic Forest Sequestration	-377,123	- 373,292	3,831	1.0%
Total Net GHG Emissions		**2,365,379**	**2,525,283**	159,904	6.8%

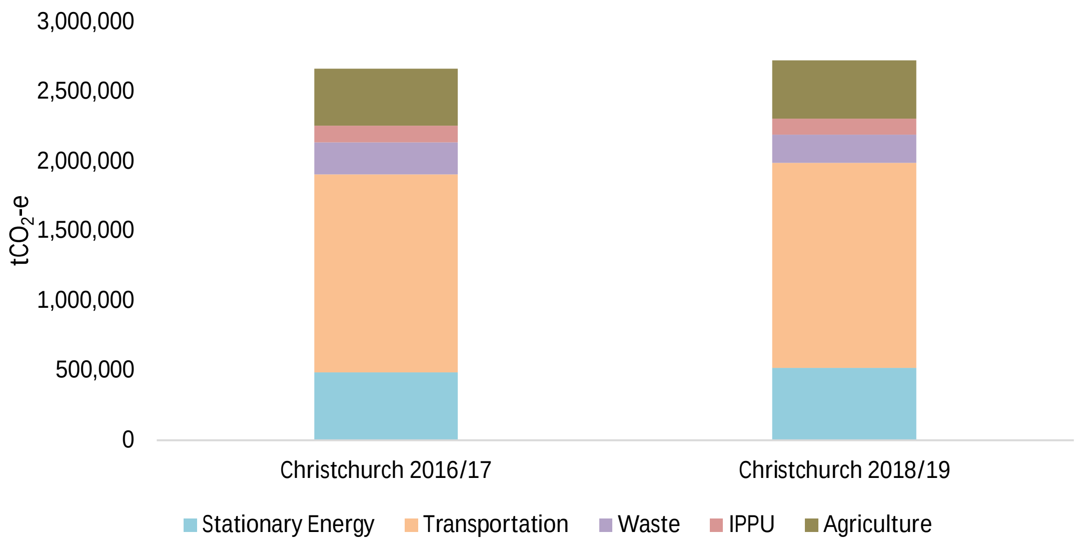

Figure 25 A comparison of Christchurch District's gross GHG emissions between financial years 2016/17 and 2018/19

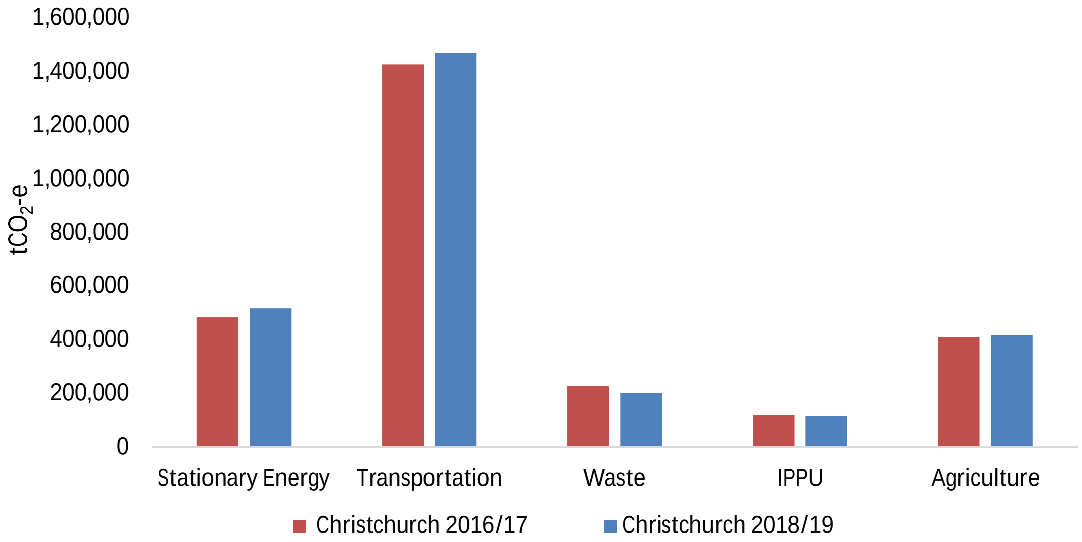

Figure 26 A comparison of Christchurch District's gross GHG emissions, by sector, between financial years 2016/17 and 2018/19

The rest of this section summarises major changes in the sector's GHG emissions between 2016/17 and 2018/19:

Change in Transportation GHG Emissions between 2016/17 and 2018/19

The Transportation sector's contribution to Christchurch's total gross GHG emissions increased between 2016/17 and 2018/19 by 3.2%.

Total gross GHG emissions from the Transportation sector increased between 2016/17 and 2018/19 from 1,425,197 tCO_2-e (53.5% of Christchurch's total gross GHG emissions) to 1,470,159 tCO_2-e (54.0% of Christchurch's total gross GHG emissions), an increase of 3.2% (44,962 tCO_2-e). This increase in the Transportation sector's GHG emissions is the largest increase in Christchurch's total gross GHG emissions.

GHG emissions from all sources of the Transportation sector increased, with on-road, air, and rail transportation increasing by the largest amounts within the Transportation sector's GHG emissions.

On-road transport is the highest emitting source within the Transportation sector and increased between 2016/17 and 2018/19 from 958,365 tCO_2-e (36.0% of Christchurch's total gross GHG Emissions) to 980,041 tCO_2-e (36.0% of Christchurch's total gross GHG Emissions), an increase of 2.3% (21,676 tCO_2-e).

Air travel GHG emissions increased between 2016/17 and 2018/19 from 303,768 tCO_2-e (11.4% of Christchurch's total gross GHG emissions) to 316,928 tCO_2-e (11.6% of Christchurch's total gross GHG emissions), an increase of 4.3% (13,160 tCO_2-e).

Rail transportation was heavily impacted by the Kaikoura earthquake in 2016 which helps to explain the relatively small amount of GHG emissions in 2016/17 and the large increase between 2016/17 and 2018/19.

Change in Stationary Energy GHG Emissions between 2016/17 and 2018/19

The Stationary Energy sector's contribution to Christchurch's total gross GHG emissions increased between 2016/17 and 2018/19 by 7.0%. Electricity consumed (including associated electricity transmission and distribution losses) was the largest contributor to the increase in the Stationary Energy sector's GHG emissions.

Total gross GHG emissions from the Stationary Energy sector increased between 2016/17 and 2018/19 from 483,079 tCO_2-e (18.1% of Christchurch's total gross GHG emissions) to 517,077 tCO_2-e (19.0% of Christchurch's total gross GHG emissions), an increase of 7.0% (33,998 tCO_2-e). GHG emissions from Industrial, Residential and Commercial Stationary Energy sub-sectors all increased between 2016/17 and 2018/19.

The Industrial Stationary Energy sub-sector GHG emissions increased between 2016/17 and 2018/19 from 137,499 tCO_2-e (5.2% of Christchurch's total gross GHG emissions) to 189,081 tCO_2-e (6.9% of Christchurch's total gross GHG emissions), an increase of 37.5% (51,582 tCO_2-e).

The Residential Stationary Energy sub-sector GHG emissions increased between 2016/17 and 2018/19 from 119,772 tCO_2-e (4.5% of Christchurch's total gross GHG emissions) to 143,967 tCO_2-e (5.3% of Christchurch's total gross GHG emissions), an increase of 20.2% (24,195 tCO_2-e).

The Commercial Stationary Energy sub-sector GHG emissions increased between 2016/17 and 2018/19 from 125,996 tCO_2-e (4.7% of Christchurch's total gross GHG emissions) to 128,922 tCO_2-e (4.7% of Christchurch's total gross GHG emissions), an increase of 2.3% (2,925 tCO_2-e).

The other remaining Stationary Energy GHG emissions decreased between 2016/17 and 2018/19 from 99,812 tCO_2-e (3.7% of Christchurch's total gross GHG emissions) to 55,108 tCO_2-e (2.0% of Christchurch's total gross GHG emissions), a decrease of 44.8% (44,704 tCO_2-e).

The increase in the Stationary Energy sector's GHG emissions is predominantly due to the increase in GHG emissions from electricity consumed. Changes in the methods of electricity generation in New Zealand impact the CO_2-e intensity of the electricity supply (e.g. through greater or lesser use of fossil fuels) which impacts the amount of GHG emissions per unit of electricity consumed (as calculated in these inventories). The CO_2-e intensity of the electricity supply increased between 2016/17 and 2018/19 due to an increase in the use of fossil fuels to generate electricity as electricity demand grew faster than the increase in the supply of renewable electricity generation. The associated increase in GHG emissions per unit of electricity consumed caused GHG emissions from electricity consumed to increase by 23.2% between 2016/17 and 2018/19, (249,881 tCO_2-e to 307,887 tCO_2-e) even as the quantity of electricity consumed decreased between 2016/17 and 2018/19 by 0.6%. As the use of fossil fuels for electricity generation is replaced by renewable sources over time, the CO_2-e intensity of electricity consumed should fall, reducing GHG emissions from electricity being consumed.

The only source of stationary energy GHG emissions where GHG emissions reduced is stationary energy petrol and diesel use. Stationary energy petrol and diesel use decreased between 2016/17 and 2018/19 from 99,739 tCO_2-e (3.7% of Christchurch's total gross GHG emissions) to 54,978 tCO_2-e (2.0% of Christchurch's total gross GHG emissions), a decrease of 44.9% (44,760 tCO_2-e). The allocation of petrol and diesel use was based on fuel end-use data from the Energy End Use Database published by the Energy Efficiency and Conservation Authority (EECA) for 2016 and 2018. This is the best available data covering the end use of petrol and diesel in New Zealand. The decrease in stationary energy petrol and diesel GHG emissions between 2016/17 and 2018/19 was mainly due to a methodological shift in how total petrol and diesel consumption was allocated between the Stationary Energy and Transportation sectors. The decrease in stationary energy petrol and diesel GHG emissions in 2018/19 is mirrored by a rise in transportation petrol and diesel GHG emissions.

Change in Agriculture GHG Emissions between 2016/17 and 2018/19

The Agriculture sector's contribution to Christchurch's total gross GHG emissions increased between 2016/17 and 2018/19 by 1.6%.

The Agriculture sector's GHG emissions increased between 2016/17 and 2018/19 from 410,970 tCO_2-e (15.4% of Christchurch's total gross GHG emissions) to 417,545 tCO_2-e (15.3% of Christchurch's total gross GHG emissions), an increase of 1.6% (6,575 tCO_2-e).

Change in Waste GHG Emissions between 2016/17 and 2018/19

The Waste sector's contribution to Christchurch's total gross GHG emissions reduced between 2016/17 and 2018/19 by 11.3%.

The Waste sector's GHG emissions decreased between 2016/17 and 2018/19 from 228,571 tCO_2-e (8.6% of Christchurch's total gross GHG emissions) to 202,854 tCO_2-e (7.4% of Christchurch's total gross GHG emissions), a decrease of 11.3% (25,718tCO_2-e). Increased use and efficiency of landfill gas recovery has driven down the Waste sector's GHG emissions. Landfill gas recovery reduces the warming effect of GHG emissions from landfill by either using the methane recovered for electricity generation or breaking methane down by flaring.

The waste GHG emissions from closed landfill sites decreased between 2016/17 and 2018/19 from 170,479 tCO_2-e (6.4% of Christchurch's total gross GHG emissions) to 143,874 tCO_2-e (5.3% of Christchurch's total gross GHG emissions), a decrease of 15.6% (26,604 tCO_2-e). In 2016/17 solid waste from closed landfill sites made up 74.6% of the Waste sector's GHG emissions and in 2018/19 GHG emissions from closed landfill sites had decreased but still accounted for 70.9% of the Waste sector's GHG emissions.

Solid waste GHG emissions from the only currently open landfill site (Kate Valley) increased between 2016/17 and 2018/19 from 31,035 tCO_2-e (1.2% of Christchurch's total gross GHG emissions) to 33,542 tCO_2-e (1.2% of Christchurch's total gross GHG emissions), an increase of 8.1% (2,507 tCO_2-e). This increase in GHG emissions is due to the production of GHG emissions from solid waste already in the open landfill site.

Wastewater Treatment GHG emissions increased between 2016/17 and 2018/19 from 14,272 tCO_2-e (0.5% of Christchurch's total gross GHG emissions) to 14,683 tCO_2-e (0.4% of Christchurch's total gross GHG emissions), an increase of 2.9% (411 tCO_2-e).

Composting GHG emissions decreased between 2016/17 and 2018/19 from 12,786 tCO_2-e (0.5% of Christchurch's total gross GHG emissions) to 10,755 tCO_2-e (0.4% of Christchurch's total gross GHG emissions), a decrease of 15.9% (2,031 tCO_2-e).

Change in Industrial Processes and Product Use (IPPU) GHG Emissions between 2016/17 and 2018/19

The Industrial Processes and Product Use (IPPU) sector's contribution to Christchurch's total gross GHG emissions reduced between 2016/17 and 2018/19 by 2.1%. A nationwide reduction in IPPU GHG emissions have driven the reduction in IPPU GHG emissions in Christchurch.

The IPPU sector's GHG emissions decreased between 2016/17 and 2018/19 from 117,825 tCO_2-e (15.4% of Christchurch's total gross GHG emissions) to 115,381 tCO_2-e (15.3% of Christchurch's total gross GHG emissions), a decrease of 2.1% (2,444 tCO_2-e).

Change in Forestry GHG Emissions between 2016/17 and 2018/19

The Forestry sector's sequestration of carbon by native and exotic forests between 2016/17 and 2018/19 decreased from 486,088 tCO_2-e to 482,257 tCO_2-e, a decrease of 1.0% (3,831 tCO_2-e). Between 2016/17 and 2018/19 forestry harvesting GHG emissions increased from 185,825 tCO_2-e to 284,524 tCO_2-e, an increase of 53.1% (98,699 tCO_2-e).

The Forestry sector's GHG emissions remained net negative between 2016/17 and 2018/19, however between 2016/17 and 2018/19, net negative GHG emissions from forestry decreased from -300,264 tCO_2-e to -197,733 tCO_2-e, a decrease of 34.1% (102,531 tCO_2-e).

5.0 Basic and Basic+ GHG Emissions Reporting (Global Covenant of Mayors for Climate and Energy)

BASIC and BASIC+ GHG emission reporting are standardised reporting methods used by the Global Covenant of Mayors for Climate and Energy for comparison of GHG emissions with other cities around the world and to demonstrate the importance of climate action at a local and global scale. BASIC and BASIC+ GHG emissions are reported as outlined in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC).

The BASIC level covers scope 1 and scope 2 GHG emissions from Stationary Energy and Transportation, as well as scope 1 and scope 3 GHG emissions from Waste. BASIC+ involves more challenging data collection and calculation processes and includes all GHG emissions reported in the total gross GHG emissions in this inventory. The GHG emission sources covered in BASIC+ also align with sources required for national reporting in IPCC guidelines. BASIC level reporting enables comparison with areas where technical capacity and data availability are not sufficient for BASIC+ reporting.

We have calculated GHG emissions using the BASIC and BASIC+ framework.

Table 33 Christchurch District BASIC and BASIC+ GHG emissions for the financial year 2016/17

	GHG Emissions (tCO_2-e)
BASIC	2,118,006
BASIC per capita (per person/year)	5.6
BASIC+	2,665,643
BASIC+ per capita (per person/year)	7.1

Table 34 Christchurch District BASIC and BASIC+ GHG emissions for the financial year 2018/19

	GHG Emissions (tCO_2-e)
BASIC	2,166,727
BASIC per capita (per person/year)	5.6
BASIC+	2,723,016
BASIC+ per capita (per person/year)	7.1

6.0 Closing Statement

The Christchurch 2016/17 and 2018/19 GHG emission inventories provide information for decision-making and action by the Christchurch City Council (Council), their stakeholders and the wider community.

The Christchurch GHG emission inventories include GHG emissions produced in the Stationary Energy, Transportation, Waste, IPPU, Agriculture and Forestry sectors using the GPC reporting framework. Sector and source-level data allows the Council to target the key GHG emission sources, and work with the sectors, which contribute the most to Christchurch's GHG emissions.

The results highlight the importance of different sectors to Christchurch's total gross GHG emissions, especially from aviation, on-road transportation and stationary energy activities. Data quality and availability varies widely between the sectors examined. Availability of higher quality data for non-commercial flights and LPG would be beneficial in improving accuracy of the results of future inventories.

Understanding of the extensive and long-lasting effects of climate change is improving all the time. It is recommended that a Community-Scale GHG Emission Inventory for Christchurch is completed every few years to help inform how Christchurch's GHG emissions are tracking against Christchurch's GHG emission reduction targets.

7.0 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 February 2020 and September 2020 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.

Legal advice can only be given by qualified legal practitioners. Except as required by law, no other party should rely on this document without the prior written consent of AECOM. Where such agreement is provided, AECOM will provide a letter of reliance to the agreed third party in the form required by AECOM. To the extent permitted by law, AECOM expressly disclaims and excludes liability for any loss, damage, cost or expenses suffered by any third party relating to or resulting from the use of, or reliance on, any information contained in this Report. AECOM does not admit that any action, liability or claim may exist or be available to any third party. It is the responsibility of third parties to independently make inquiries or seek advice in relation to their requirements and proposed use of the information.

Appendix A

Assumptions and Exclusions

<table>
<tr><th>Sector / Source</th><th>Assumptions and Exclusions</th></tr>
<tr><td colspan="2">General</td></tr>
<tr><td>Geographical Boundary</td><td>Local Government NZ (LGNZ) local council mapping boundaries have been applied.</td></tr>
<tr><td colspan="2">Transportation Sector GHG Emissions</td></tr>
<tr><td>Petrol and Diesel (On-Road and Off-Road)</td><td>The total volume of petrol and diesel purchased in Christchurch was provided by Christchurch City Council. This data has been used to calculate GHG emissions from petrol and diesel consumed in Christchurch. This method follows the Ministry for the Environment (MfE) and Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) guidance.

Total Christchurch petrol and diesel consumption was split by likely end-use into the Transportation and Stationary Energy sectors (and also into on-road transportation and off-road transportation). This was calculated using fuel end-use data from the Energy End Use Database published by the Energy Efficiency and Conservation Authority (EECA) for 2016 (published in 2018) and 2018 (published in 2020). For the 2020 Energy End Use Database publication, EECA revised and improved data for a number of sectors in the database, including residential, and a range of industrial sectors. This has meant that the breakdown of end-use changed significantly between these years. Without significant further data collection, this is the best data available to determine likely use of petrol and diesel for Christchurch.

On-road transportation is defined as all standard transportation vehicles used on roads (e.g. cars, trucks, buses). Off-road transportation is defined as machinery and vehicles used off roads (e.g. in agriculture, construction and other industries). Petrol and diesel used in private marine vessels was included in off-road transportation.

Stationary energy petrol and diesel use is defined as fuel not used for transportation either on-road or off-road Petrol and diesel used for stationary energy has been reported in the Stationary Energy sector.</td></tr>
<tr><td>Rail (Diesel)</td><td>Rail diesel consumption was calculated by Kiwi Rail.
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 quantity of fuel used per distance travelled.
- Type of locomotive engine used, and jurisdiction topography, have not been incorporated in the calculations.

The total amount of diesel consumed per route was 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 GHG emissions were allocated.

All rail GHG emissions have been classified as Scope 3.</td></tr>
</table>

Sector / Source	Assumptions and Exclusions
Jet Kerosene (Commercial Flights)	An estimate was calculated for flights departing from, and arriving at, Christchurch Airport. - Departures and arrivals information, and aircraft models, were used to calculate flight numbers, flight distances and fuel use. - All flight-path distances between Christchurch and the destination / origin airport were calculated. - A density for kerosene of 0.81g/cm³ was applied to all trips. - Fuel Burn (kgCO_2-e/km) for each model of aircraft was sourced where accessible. Where not available, the average of available fuel burn figures was applied. - GHG emissions from jet kerosene consumed by domestic commercial flight journeys departing from, and arriving at, Christchurch Airport have been allocated equally between Christchurch and the territorial authority containing the origin/destination airport of the journey. The same approach has been used for international flights (i.e. Christchurch is allocated 50% of all GHG emissions from jet kerosene consumed by arriving and departing flights at Christchurch Airport). - GHG emissions from Christchurch Airport have been split between all districts in Canterbury on a per capita basis. The Christchurch share of Canterbury aviation GHG emissions is assumed based on Christchurch's population as a proportion of Canterbury's population. All aircraft fuel GHG emissions have been classified as Scope 3. Scope 2 electricity consumed by the Christchurch Airport and aircraft are incorporated within the Stationary Energy sector data for Christchurch. Electricity transmission and distribution losses associated with the electricity consumed by the Christchurch Airport and aircraft have been classified as Scope 3 and are incorporated within the Stationary Energy sector data for Christchurch.
Aviation Gas (Local Flights)	Aviation gas is mostly used by small aircraft for relatively short flights. Aviation Gas consumption of 500,000 litres for Christchurch airport, for 2016/17 and for 2018/19, was estimated by AECOM using advice from industry aviation experts. All aircraft fuel GHG emissions have been classified as Scope 3. Scope 2 electricity consumed by the Christchurch Airport and aircraft are incorporated within the Stationary Energy sector data for Christchurch. Electricity transmission and distribution losses associated with the electricity consumed by the Christchurch Airport and aircraft have been classified as Scope 3 and are incorporated within the Stationary Energy sector data for Christchurch.
Marine Diesel (Tourism Vessels and Local Ferries)	Marine diesel covers the local ferry service that operates in Lyttelton Harbour and tourism operators. The data was collected from two Christchurch commercial marine vessel operators. Most private marine vessels use fuel purchased at vehicle fuel stations. Petrol and diesel used in private marine vessels was included in off-road transportation.

Sector / Source	Assumptions and Exclusions
Marine Light Fuel Oil	Marine light fuel oil covers GHG emissions from cargo shipping activities. GHG emissions from marine light fuel oil consumed during in-coming and out-going cargo shipping vessel journeys have been allocated equally between the origin and destination port of the journey. The same approach has been used for international cargo shipping vessel journeys (i.e. Lyttelton Port is allocated 50% of all GHG emissions from marine light fuel oil consumed during in-coming and out-going cargo shipping vessel journeys to and from Lyttelton Port). GHG emissions calculated for marine light fuel oil at Lyttelton Port are broken down between territorial authorities based on the destination or origin of port cargo tonnage. Port cargo tonnage data has been taken from the Lyttelton Port Company Annual Reports for both the 2016/17 and 2018/19 financial years. AECOM has estimated that 47% of marine light fuel GHG emissions in the financial year 2016/17 and 54% of marine light fuel GHG emissions in the financial year 2018/19 are allocated to Christchurch based on the following assumptions: - GHG emissions relating to the import and export of containers, cars and dry bulk imports was split between all territorial authorities in Canterbury based on each territorial authority's population share of the total population of Canterbury. - GHG emissions relating to import of bulk fuel (petrol and diesel) was split between all territorial authorities in Canterbury based on each territorial authority's total vehicle kilometres travelled as a proportion of total vehicle kilometres travelled in Canterbury. - GHG emissions relating to the export of logs has been split between all territorial authorities in Canterbury based on each territorial authority's harvestable forest area as a proportion of total harvestable forest area in Canterbury. - GHG emissions relating to the export of coal was all assumed to originate outside of Christchurch so no GHG emissions relating to coal exports have been included in Christchurch's GHG emission inventories report.
Cruise Ships	Data for cruise ship fuel use or associated GHG emissions is unavailable so cruise ship GHG emissions are not included in this GHG emission inventories report.
LPG (Off-Road Mobile Uses)	Total South Island LPG consumption data provided by the LPG Association for both financial years was used and then split on a per capita basis to determine Christchurch's LPG consumption. Total Christchurch LPG consumption was split by likely end-use into the Transportation and Stationary Energy sectors. This was calculated using fuel end-use data from the Energy End Use Database published by the Energy Efficiency and Conservation Authority (EECA) for 2016 and 2018. This consumption data is then reported separately in their respective Stationary Energy sector and Transportation sector source categories.
Biodiesel (Vehicle Use)	Biodiesel GHG emissions data has been provided directly by the supplier for both 2016/17 and 2018/19 financial years. For 2016/17 biodiesel fuel use was provided in litres. The supplier estimated that for 2016/17 100% of biodiesel usage was for the Stationary Energy sector. No biodiesel fuel was used for transport in 2016/17. For 2018/19 biodiesel fuel use was provided in carbon dioxide equivalents (CO_2-e) using the latest GHG emission factor (MfE 2019). The supplier estimated that for 2018/19 95% of biodiesel usage was for the Transportation sector and 5% was for the Stationary Energy sector. Due to the change of ownership of the biodiesel supplier, the methods used for calculating historical GHG emissions data for 2016/17 and for 2018/19 differ. For the purposes of this report the methods are assumed to be equivalent.
Bitumen	No data was available. Not calculated.

Sector / Source	Assumptions and Exclusions
Lubricants used in Transportation	No data was available. Not calculated.
Stationary Energy Sector GHG Emissions	
Stationary Energy Sub-Sectors	The Stationary Energy sector GHG emissions are also broken down by stationary energy fuel source, and also by the sub-sector in which it is consumed. Stationary Energy GHG emissions are reported for the following sub-sectors within the Stationary Energy sector: industrial (which includes agriculture, forestry, fishing, mining, food processing, textiles, chemicals, metals, mechanical/electrical equipment and building and construction activities); commercial; and residential. These sub-sectors follow the Australia New Zealand Standard Industrial Classification 2006 definitions. Stationary energy petrol and diesel GHG emissions and stationary energy biogas (methane) GHG emissions are not broken down into the Stationary Energy sub-sectors Industrial, Commercial and Residential.
Electricity Consumed	Electricity consumed was provided by Orion in MWh from Transpower's grid. This includes electricity consumed from embedded generation. Embedded generation is electricity generation which is connected to a local distribution network rather than to the National Grid. Embedded generation encompasses a range of technologies and scales, including small-scale systems such as solar photovoltaic modules, small wind turbines and micro-hydro schemes. This embedded generation may be used, for example, as electricity sources for businesses, homes or farms. The breakdown into Stationary Energy sub-sectors is based on New Zealand average electricity consumed per sub-sector (Industrial, Commercial and Residential) by Ministry of Business, Innovation and Employment (MBIE) 2019.
Electricity Generation	GHG emissions produced from electricity generation are not required to be reported for the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). Electricity consumed from embedded generation is included in the Electricity Consumed GHG emissions source. Embedded generation is electricity generation which is connected to a local distribution network rather than to the National Grid. Embedded generation encompasses a range of technologies and scales, including small-scale systems such as solar photovoltaic modules, small wind turbines and micro-hydro schemes.
Electricity Transmission and Distribution Losses	Electricity utility companies often purchase electricity from independent power generators or the grid and resell it to end-consumers through a transmission and distribution (T&D) system. A proportion of the electricity purchased by a utility company is lost (T&D losses) during its transmission and distribution to end-consumers. GHG emissions resulting from transmission and distribution losses in the network are allocated based on electricity consumed. Financial year specific GHG emission factors are calculated for transmission and distribution losses per unit of electricity consumed from data from the Ministry of Business, Innovation and Employment Energy Statistics databases. This method follows the Ministry for the Environment and Global Protocol for Community-Scale Greenhouse Gas Emission Inventories guidance.
Public Transport Electricity	There are electrified public transport systems in Christchurch. The GHG emissions from this electricity use is included in the electricity consumed source and the electricity transmission and distribution losses source in the Stationary Energy sector.
Coal production	Not calculated: There are no active coal mines within Christchurch (New Zealand Petroleum and Minerals 2019).

Sector / Source	Assumptions and Exclusions
Coal Consumption	Coal consumption data for commercial and industrial use was collected by contacting individual organisations and companies from the air discharge consent contact list provided by Environment Canterbury. The coal consumption data reported on was based on supplied data from individual organisations and companies that responded to the request for the data. Data was not estimated when there was no response from individual organisations and companies. Residential coal consumption is not permitted in Christchurch.
Biofuel (Wood)	Residential biofuel GHG emissions estimates are based on national residential GHG emissions for wood fuel consumption, provided in the New Zealand Greenhouse Gas Emissions Inventory 1990-2015, published by the Ministry for the Environment in 2019. National wood fuel GHG emissions have been split on a per capita basis to determine Christchurch's wood fuel GHG emissions. Wood fuel consumption data for commercial and industrial use was collected by contacting individual organisations and companies from the air discharge consent contact list provided by Environment Canterbury. The wood fuel consumption data reported on was based on supplied data from individual organisations and companies that responded to the request for the data. Data was not estimated when there was no response from individual organisations and companies.
LPG (Stationary Use)	Total South Island LPG consumption data provided by the LPG Association for both financial years was used and then split on a per capita basis to determine Christchurch's LPG consumption. Total Christchurch LPG consumption was split by likely end-use into the Transportation and Stationary Energy sectors. This was calculated using fuel end-use data from the Energy End Use Database published by the Energy Efficiency and Conservation Authority (EECA) for 2016 (published in 2018) and 2018 (published in 2020). This consumption data is then reported separately in their respective Stationary Energy sector and Transportation sector source categories.
Natural Gas	Not calculated: There is no natural gas connection in Christchurch.
Coal Fugitive Emissions	Not calculated: There are no active coal mines in Christchurch. (New Zealand Petroleum and Minerals 2019).
Oil and Gas Fugitive Emissions	Not calculated: There are no gas or oil processing plants in Christchurch.
Petrol and Diesel (Stationary Use)	The total volume of petrol and diesel purchased in Christchurch was provided by Christchurch City Council. This data has been used to calculate GHG emissions from petrol and diesel consumed in Christchurch. This method follows the Ministry for the Environment (MfE) and Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) guidance. Total Christchurch petrol and diesel consumption was split by likely end-use into the Transportation and Stationary Energy sectors. This was calculated using fuel end-use data from the Energy End Use Database published by the Energy Efficiency and Conservation Authority (EECA) for 2016 (published in 2018) and 2018 (published in 2020). Stationary energy petrol and diesel use is defined as fuel not used for transportation, either on-road or off-road. Petrol and diesel used for stationary energy uses has been reported in the Stationary Energy sector while petrol and diesel used for transportation has been reported in the Transportation sector.

Sector / Source	Assumptions and Exclusions
Biogas (Methane recovered from Landfill and from the Wastewater Treatment Plant)	Recovered biogas (methane) has been used for energy generation and flaring at Kate Valley landfill, Burwood landfill and Bromley wastewater treatment plant. GHG emissions from the combustion of recovered biogas (methane), from landfill and wastewater treatment, used for energy generation are included in the Stationary Energy GHG emissions (a requirement of the GPC standard). GHG emissions from flaring of recovered biogas from landfill and wastewater treatment are generally included in the Waste sector. However, due to difficulties in separating out data for recovered biogas used for energy generation and recovered biogas used for flaring, GHG emissions from flaring of recovered biogas from landfill and from the Bromley wastewater treatment plant are also included in the Stationary Energy GHG emissions. For future Christchurch Greenhouse Gas Emission Inventories, it is recommended to separately report on recovered flared methane and recovered biogas (methane) combusted for energy use as GHG emission sources in their respective Stationary Energy and Waste sector categories. Combustion of biogas (methane) for energy generation and through flaring results in CO_2, CH_4 and N_2O GHG emissions. CH_4 and N_2O GHG emissions from the combustion of biogas (methane), collected at the Bromley wastewater treatment plant, Kate Valley landfill and Burwood landfill and used to produce energy as well as flaring, are reported in the Stationary Energy sector. CO_2 GHG emissions from the combustion of biogas (methane) are biogenic GHG emissions and have been excluded from the total gross GHG emissions. CH_4 GHG emissions from the combustion of biogas (methane) are biogenic and are additionally reported in the Biogenic Emissions section of the inventory. The GHG emissions associated with the Bromley wastewater treatment plant, including biogas (methane) combustion GHG emissions (CH_4 and N_2O) have been calculated by Council using the nitrous oxide GHG emission factor produced by Beca Consultants. Biogenic tCO_2 resulting from combustion of biogas has been calculated by AECOM following the same method used by Council for the calculation of CH_4 and N_2O.
Agriculture Sector GHG Emissions	
General	Data on livestock numbers, crop production and fertiliser use in Christchurch was taken from the Agricultural Production Statistics: June 2017 (final) publication provided by Statistics New Zealand in 2018. This dataset has been used for both the 2016/17 and 2018/19 financial years. GHG emission factors for the Agriculture sector for the 2016/17 and 2018/19 financial years have been used from the New Zealand Greenhouse Gas Inventory 1990-2017 (Ministry for the Environment, 2019) to calculate GHG emissions. GHG emissions from the use of fuel for stationary energy purposes in the agriculture industry are not included in the Agriculture GHG emissions sector. All stationary energy uses of fuel in the agriculture industry are included in the Stationary Energy sector in the relevant source (e.g. electricity, coal, etc.) and in the Industrial Stationary Energy sub-sector.

Sector / Source	Assumptions and Exclusions
Waste Sector GHG Emissions	
Open and Closed Landfill Sites	Solid waste GHG emissions from landfill are measured using the Intergovernmental Panel on Climate Change (IPCC) First Order Decay (FOD) method that covers landfill activity between 1950 and the present day. Solid waste GHG emissions were calculated for the currently operating landfill at Kate Valley, and three closed landfill sites; Burwood, Bexley and Sawyers Arms. The efficiency of Landfill Gas (LFG) recovery at the Kate Valley landfill site has been estimated by Canterbury Waste Services, a division of Waste Management NZ, at a minimum of 90% efficiency. To be conservative, the 90% minimum efficiency Landfill Gas (LFG) recovery rate has been used. Therefore, the estimated 10% non-recovery of LFG figure was used to calculate the amount of methane (CH_4) released into the environment from the Kate Valley landfill and included in the Waste sector GHG emissions total. Recovered LFG (biogas - methane) at Kate Valley landfill was combusted to produce energy. Any surplus recovered gas was destroyed (flared) at high temperature. GHG emissions from flaring of recovered biogas (methane) from landfill generally are included in the Waste sector. However, due to difficulties in separating out data for recovered biogas used for energy generation and recovered biogas used for flaring, GHG emissions from flaring of recovered biogas from landfill are also included in the Stationary Energy sector GHG emissions. Waste from Canterbury (and elsewhere) also goes to Kate Valley landfill. The waste volume produced in Christchurch and sent to Kate Valley was provided by Christchurch City Council and used in IPPC FOD model for the Kate Valley landfill GHG emissions calculation. The amount of biogas (methane) recovered from the Burwood landfill site was provided by Christchurch City Council. Recovered methane at Burwood landfill was combusted for energy generation and through flaring and the related GHG emissions were recorded in the Stationary Energy sector GHG emissions. There was no methane recovery at the Bexley landfill site or the Sawyers Arms landfill site. The IPCC FOD model has been used for the calculation of Bexley landfill site and the Sawyers Arms landfill site based on waste volume sent to these two sites provided by Christchurch City Council.
Composting	Composting quantity (wet weight) for both 2016/17 and 2018/19 financial years has been provided by Christchurch City Council. GHG emission factors from the New Zealand Greenhouse Gas Inventory (Ministry for the Environment, 2019) were used to calculate GHG emissions.

Sector / Source	Assumptions and Exclusions
Wastewater Treatment	The majority of wastewater in Christchurch is treated at the Bromley wastewater treatment plant. There are also a number of smaller sites, including sites at Lyttleton, Diamond Harbour and Akaroa, for which GHG emissions have been excluded from this GHG emission inventories report. Beca was commissioned by Christchurch City Council to determine a nitrous oxide GHG emission factor to use for the Bromley wastewater treatment plant GHG emission calculations. Council staff, using this nitrous oxide GHG emission factor, provided the data and calculations for the GHG emissions produced from the Bromley wastewater treatment plant to AECOM. AECOM has adjusted the GHG emission results provided by Council using global warming potentials from AR4 to AR5 with climate-carbon feedbacks in line with IPCC (2013) guidance[1] to ensure that a consistent approach has been used throughout the GHG inventories. GHG emissions from flaring of recovered biogas (methane) from the Bromley wastewater treatment plant should be included in the Waste sector. However, due to difficulties in separating out data for recovered biogas used for energy generation and recovered biogas used for flaring, GHG emissions from flaring of recovered biogas from the Bromley wastewater treatment plant are also included in the Stationary Energy sector GHG emissions. Biogenic tCO_2 resulting from the combustion of biogas (methane) has been calculated by AECOM following the same method used by Council for the calculation of CH_4 and N_2O. Calculations for wastewater treatment GHG emissions from individual septic tanks are also included. Septic tank calculations were undertaken by AECOM using calculations developed by AECOM and based on Intergovernmental Panel on Climate Change (IPCC) 2006 workbooks and guidance. The population connected to septic tank systems has been provided at the district level by Christchurch City Council.
Industrial Processes and Product Use (IPPU) Sector GHG Emissions	
Industrial Product Use (IPPU)	The GHG emissions for industrial product use include GHG emissions from (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Nitrogen trifluoride GHG emissions do not occur in New Zealand and are not included in this report. The industrial product use sector includes GHG emissions associated with the consumption of GHGs for refrigerants, foam blowing, fire extinguishers, aerosols, metered dose inhalers (e.g. used for asthma treatment) and sulphur hexafluoride for electrical insulation and equipment production. Industrial Product Use GHG emissions were calculated from data provided by the Ministry for the Environment in the New Zealand Greenhouse Gas Inventory (2019). Christchurch GHG emissions from industrial product use are estimated on a per capita basis.
Industrial Processes (IPPU)	Not calculated: No GHG emissions from industrial processes have been included in the reported IPPU sector's GHG emissions. Following discussion with industry representatives within Christchurch, it is understood that there are no large industrial operations in Christchurch that result in significant industrial processes GHG emissions.

[1] IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Sector / Source	Assumptions and Exclusions
Forestry Sector GHG Emissions	
Harvest GHG Emissions	Christchurch's total harvested forest data (m^3) was calculated as a proportion of the Canterbury region's total. Canterbury's total harvested forest data was split between territorial authorities based on each territorial authority's proportion of Canterbury's total forest area of harvestable age (>26 years old). An AECOM-developed methodology based on IPPC 2013 guidance has been used which assumes that only 70% of each tree is removed from the site, with the remaining 30% of each tree remaining on site (e.g. roots and offcuts), and that the above ground tree makes up approximately 74% of the total carbon stored in each tree.
GHG Emission Factors	
General	All GHG emission factors have detailed source information in the calculation tables within which they are used. New Zealand specific GHG emission factors from the New Zealand Greenhouse Gas Inventory (Ministry for the Environment, 2019) have been applied where available. GHG emission factors from the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for National Greenhouse Gas Inventories (2019 Refinement) publication have been used where New Zealand specific GHG emission factors were not available.