Auckland’s Greenhouse Gas Inventory to 2019

Shanju Xie

April 2022

Technical Report 2022/6

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Research and Evaluation Unit RIMU

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Bus at colourful Karangahape Road bus stop, Auckland. Photograph by Bryan Lowe

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Executive summary

Te-Tāruke-ā-Tāwhiri: Auckland's Climate Plan sets the target of limiting temperature rise to 1.5 degrees of warming and net zero emissions by 2050 with an interim emissions reduction target of 50 per cent by 2030 (against a 2016 baseline). Decarbonisation pathways were developed based on the 2016 inventory and provisional emissions for 2017-2019. A timely emissions inventory identifies and quantifies the most recent sources and sinks of greenhouse gas (GHG) emissions and trends. This provides a robust evidence base and an essential tool to evaluate our progress, frame mitigation actions and inform future policy development. In addition, it provides input to the state of Auckland's environment reporting.

Auckland's GHG inventory was first compiled for 2009 and recently for 2018. This inventory reports emissions for 1990, 2009-2019, following the most recently available *New Zealand's Greenhouse Gas Inventory 1990-2019*. In 2019, Auckland gross emissions were 12,709 kilo-tonnes of carbon dioxide equivalent (kt CO_2e) and when carbon sequestration from forestry was included, net emissions were 11,511 kt CO_2e. Transport and stationary energy are the dominant sectors, accounting for 45.2 per cent and 28.1 per cent of gross emissions, respectively (Figure E-1). Carbon dioxide (CO_2) contributed 85.4 per cent, methane (CH_4) 8.0 per cent, nitrous oxide (N_2O) 2.4 per cent and other GHGs 4.3 per cent.

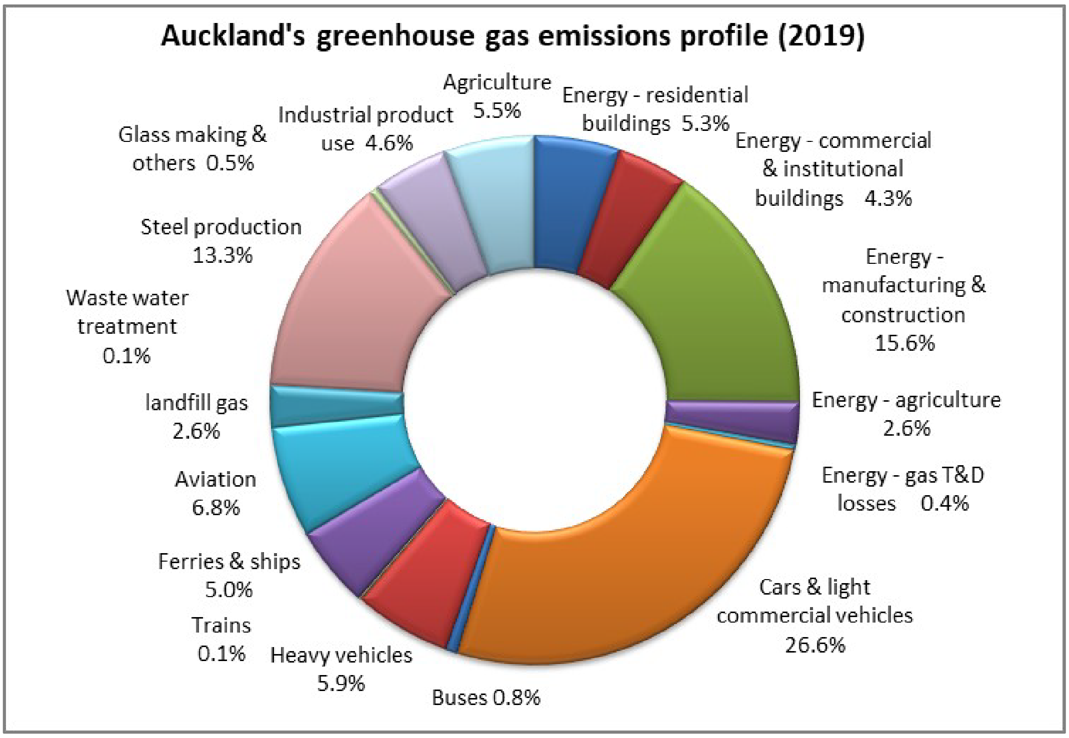

Figure E-1 Auckland's GHG gross emissions profile for 2019

Between 2018 and 2019, gross and net emissions have increased by 353 kt CO_2e (or 2.9 per cent for gross emissions, 3.2 per cent for net emissions) (Figure E-2). Emissions were higher from energy and agriculture sources, but lower from transport, waste, and industrial processes and product use (IPPU) sectors. Between 2016 and 2019, gross and net emissions have increased by 647 kt CO_2e (or 5.4 per cent for gross emissions, 6.0 per cent for net emissions). Emissions were higher from energy, transport and IPPU sectors, but lower from waste and agriculture sources. Changes in carbon sequestration from forestry from 2016 to 2019 were not estimated due to lack of data. To achieve the target of halving 2016 emissions by 2030, a reduction of 6,079 kt CO_2e, or 52.8 per cent of 2019 emissions, is required.

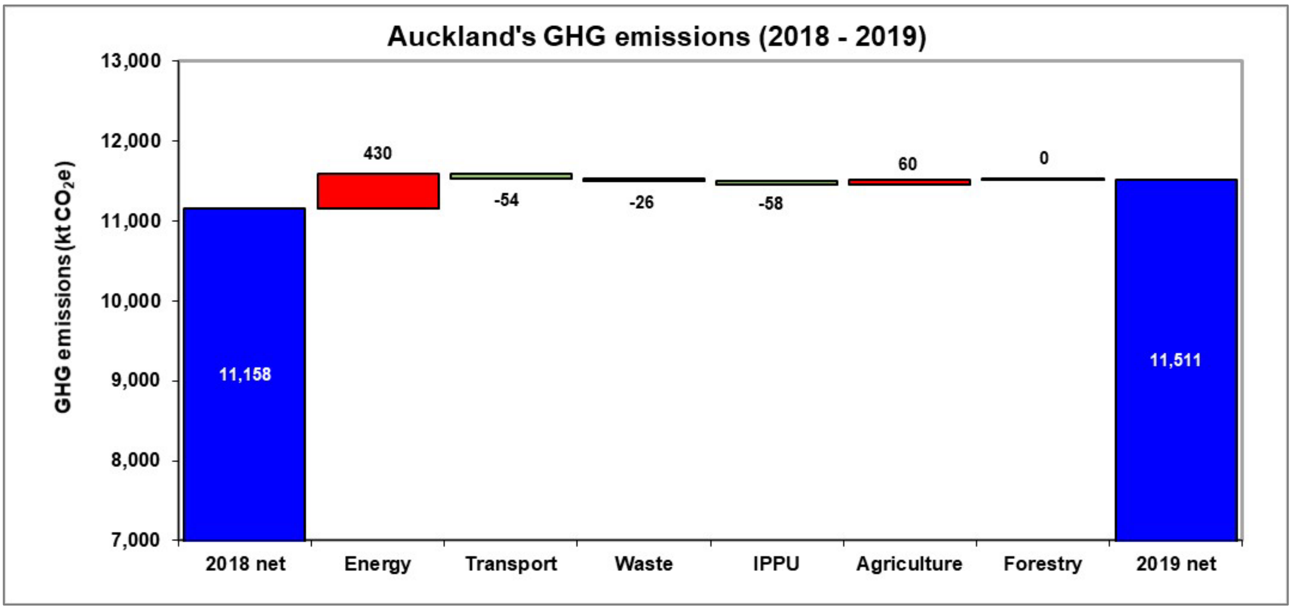

Figure E-2 Auckland's GHG emissions between 2018 and 2019

Higher emissions in 2019 than 2016 require a deeper reduction to meet the 50 per cent reduction target by 2030. This demonstrates the importance of the annual inventory update to track the emissions change, so that effective mitigation strategy, policy and actions can be developed in response to meet the reduction target.

In 2019, net emissions were 6.8 t CO_2e per capita and 101 t CO_2e per million $NZ GDP (2019/2020 prices) while gross emissions were 7.6 t CO_2e per capita and 112 t CO_2e per million $NZ GDP. These values were lower than in 2009, and this shows that emissions have not increased as fast as population and economic growth.

The 2019 inventory reports higher historic emissions than the previous inventory. This is because changes in activity data, emissions factors and ways of measuring emissions have been made in compiling this inventory with new information in line with best practice.

Historic emissions for 1990, 2009 to 2018 have been updated to supersede all published previous inventories.

A large change to gross and net emissions occurs from four sources: aviation, shipping, coal and fuel for off-road transport. Higher emissions for aviation and shipping are due to more emissions accounted to Auckland. Higher emissions for coal and lower emissions for fuel for off-road transport are due to using Stats NZ customised emissions data. Despite changes to the historic estimates, the overall emissions profile and trends across all years has remain unchanged, and transport is still the biggest source of emissions for Auckland.

Overall, this inventory reports higher gross and net emissions than the previous inventory. Future inventories could be improved by a better way of measuring aviation and shipping emissions, and by further aligning with Stats NZ's estimates of regional GHG emissions for comparable sources.

1 Introduction

The climate is changing as temperature rises mainly due to increased greenhouse gas (GHG) levels in the atmosphere caused by human activities. The world must reduce GHG emissions to limit temperature rise and the harmful impacts of associated risks such as accelerated sea level rise and more frequent extreme weather events.

The *Auckland Plan 2050* sets the direction for how Auckland will grow and develop over the next 30 years (Auckland Council, 2018a). It responds to the key challenges we face today – high population growth, sharing prosperity among all Aucklanders, and reducing environmental damage. To address these challenges, the plan identifies six outcomes that will deliver a better Auckland: Belonging and Participation, Māori Identity and Wellbeing, Homes and Places, Transport and Access, Environment and Cultural Heritage, and Opportunity and Prosperity. The *Auckland Plan 2050* is supported by other strategies and action plans that provide detail on how these outcomes can be delivered. The *Auckland Plan 2050* monitoring framework measures progress towards the strategic direction set out in the plan, including reductions of greenhouse gas emissions.

The council approved *Te-Tāruke-ā-Tāwhiri: Auckland's Climate Plan* in July 2020 (Auckland Council, 2020). This sets a direction, underpinned by cross-sector actions, for delivering on Auckland's emissions reduction target and increasing the region's resilience to climate change impacts. The plan sets the target of limiting temperature rise to 1.5 degrees of warming and net zero emissions by 2050 with an interim emissions reduction target of 50 per cent by 2030 (against a 2016 baseline). Emissions modelling has been undertaken to set out the pathways to achieve the target.

A timely emissions inventory identifies and quantifies the most recent sources and sinks of GHGs and trends. This provides a robust evidence base and an essential tool to evaluate our progress, frame mitigation actions and inform future policy development. In addition, it provides input to the state of Auckland's environment reporting.

Auckland's GHG inventories were previously compiled by URS in 2011 for 2009 which was updated by Arup in 2014 (Arup, 2014) and most recently by Auckland Council for emissions to 2018 (Xie, 2020). Auckland's recent GHG inventory has been reviewed by C40 Cities Climate Leadership Group (C40) and was included in the C40 emissions database (C40, 2020a). This document reports Auckland's GHG inventory to 2019, following the most recently available *New Zealand's Greenhouse Gas Inventory 1990-*

2019 (MfE, 2021). As in the inventory to 2018, this inventory was prepared with the most up-to-date information and global best practice in - with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (WRI et al., 2014; 2021). This Protocol provides cities with a clear and robust framework to establish and maintain accurate, credible and comparable emissions accounting and reporting practices. The GPC recommends annual update of inventories, as it provides frequent and timely progress on emissions.

The council joined global cities climate leadership networks to tackle climate change together with leading cities: C40 Cities Climate Leadership Group, Global Covenant of Mayors for Climate & Energy (GCoM), CDP Cities, and ICLEI – Local Governments for Sustainability. GCoM is the largest global alliance for city climate leadership. These networks require their members to update their GHG emissions inventories regularly (every year) (C40, 2020a; GCoM, 2020).

Updates of activity data, emission factors and methodology have been made for this inventory. Previously reported emissions for 1990, 2009 to 2018 (Xie, 2020) have been recalculated in this inventory for consistency.

1.1 Methodology – the GPC

Various methods have been used to develop GHG inventories for cities. The use of different methods makes it difficult for comparisons between cities, raises questions around data quality, and limits the ability to aggregate GHG emissions data. To respond to this challenge and offer a robust and clear framework that builds on existing methodologies, the World Resources Institute (WRI), C40 Cities Climate Leadership Group (C40), and Local Governments for Sustainability (ICLEI) have collaboratively developed the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (the GPC). The GPC offers a robust, transparent and globally accepted framework to consistently identify, calculate and report on city greenhouse gases. This inventory is prepared using the GPC version 1.0 (WRI et al., 2014) and checked for compliance with the recently released version 1.1 (WRI et al., 2021). This provides a robust evidence base to evaluate impacts of mitigation actions and progress to achieve net zero emissions by 2050.

Recently Stats NZ (Stats NZ, 2021) reported Auckland's GHG emissions for 2007-2019 using the United Nations System of Environmental-Economic Accounting (SEEA) framework which is designed primarily to show interactions between the environment and economy in a way consistent with the System of National Accounts. The data is suited to compare emissions between regions, with other regional datasets, such as GDP, labour market statistics or population. It can show how a region contributes to national emissions. It provides complimentary insights into Auckland's emissions, e.g., by households and industries. However, the difference in scope of the GPC and the SEEA framework leads to differences in emissions estimates. For example, the GPC reports grid-supplied electricity use in Auckland's emissions while the SEEA does not.

The land under the jurisdiction of Auckland Council is the geographic boundary of this inventory. For each year of emissions data in this inventory, the emissions account for a continuous period of 12 months. This report uses calendar year data whenever available in alignment with *New Zealand's Greenhouse Gas Inventory* (MfE, 2021). However, if calendar year data is unavailable, other types of annual data are used.

This report considers all seven gases required by the GPC: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). NF_3 emissions are zero since they do not occur in New Zealand (MfE, 2021). Emissions are reported as metric tonnes of each GHG as well as CO_2 equivalents (CO_2e). CO_2e is a term used to compare the emissions from various GHGs based upon their global warming potential (GWP). Individual GHGs are converted into CO_2e by multiplying the global warming potential (GWP) values in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) to be consistent with *New Zealand's Greenhouse Gas Inventory* (MfE, 2021).

Emissions are allocated into three scopes (Figure 1-1). Scope 1, or "territorial", emissions are those that physically occur within the city. Emissions that occur from the use of electricity, steam, and/or heating/cooling supplied by grids which may or may not cross city boundaries, are categorised as scope 2 emissions. Scope 3 emissions refer to those that occur outside the city but are driven by activities taking place within the city's boundaries. The current version of GPC requires reporting of scope 3 emissions from a limited number of sources (transmission and distribution losses associated with grid-supplied energy, and waste disposal and treatment outside the city boundary and transboundary transportation).

Emissions are classified into five main sectors: stationary energy; transport; waste; industrial processes and product use (IPPU); agriculture, forestry, and other land use (AFOLU); and an additional sector for all other emissions occurring outside the geographic boundary as a result of city activities (Other Scope 3). Other Scope 3 includes emissions embodied in fuels, water, food and construction materials. Reporting on Other Scope 3 is not required by the GPC (v1.0 and v1.1) and is therefore not reported in this inventory. Five main sectors are sub-divided into sub-sectors (see Table A-1 and Figure A-1 in Appendix).

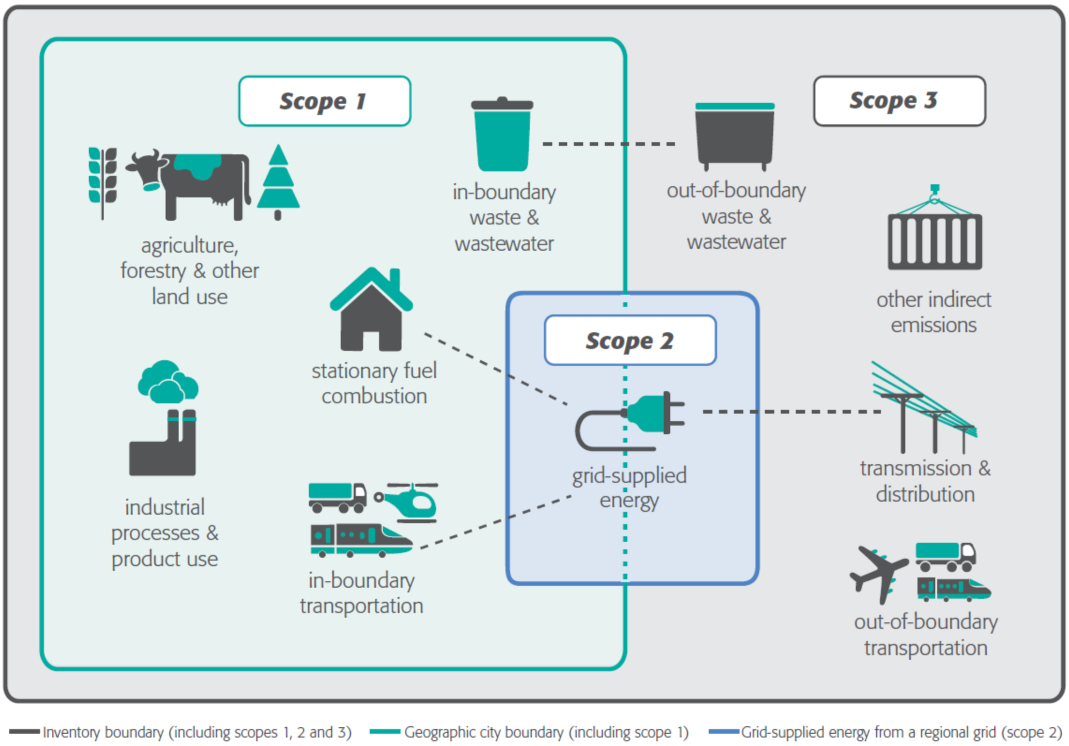

Figure 1-1 Sources and boundaries of city GHG emissions (WRI et al., 2014; 2021)

1.2 Emissions calculation and reporting

Emissions are calculated by multiplying activity data (AD) by an emission factor (EF) associated with the activity. Activity data is a quantity of an activity that results in GHG emissions during a given period (e.g., the number of kilowatt-hours (kWh) of electricity used in a year). An emission factor is a number specific to each activity used to calculate the quantity of GHG emissions produced for each unit of that activity (e.g., CO_2 emissions in kg from the use of electricity in a kWh, kg CO_2/kWh).

Data collected for the inventory comes from a variety of sources and varies in quality, format, and completeness. It is necessary to accommodate limitations in data availability and differences in emission sources between cities. The GPC requires the use of notation keys (IE, NE, NO and C, see below) and an accompanying explanation to justify exclusion or partial accounting of GHG emission source categories, for example, if the activity does not occur or when sufficient AD is unavailable.

IE (Included Elsewhere): GHG emissions for this activity are estimated and presented in another category of the inventory. That category shall be noted in the explanation.

NE (Not Estimated): Emissions occur but have not been estimated or reported; justification for exclusion shall be noted in the explanation.

NO (Not Occurring): An activity or process does not occur or exist within the city.

C (Confidential): GHG emissions which could lead to the disclosure of confidential information and therefore cannot be reported.

The data quality for AD and EFs is assessed with a High-Medium-Low rating. High (H) rating is assigned to detailed activity data or city/region-specific emission factors. Activity data that is modelled using robust assumptions or more general emission factors (e.g., applied nationally) is rated as Medium (M). Low (L) is referred to highly modelled or uncertain activity data, or default emission factors (e.g., those provided by IPCC guidance (IPCC, 2015)).

Total emissions can be reported at the BASIC or BASIC+ levels. The BASIC level covers scope 1 and scope 2 emissions from stationary energy and transport, as well as scope 1 and scope 3 emissions from waste. BASIC+ additionally includes emissions from IPPU and AFOLU and transboundary transport. This inventory reports at the BASIC+ level since emissions were calculated for all the sectors required by BASIC+. The City Inventory Reporting and Information System (CIRIS) (v2.4) (C40, 2020b) was used in the compilation of this inventory.

1.3 Structure of the report

The aggregated emissions of all sectors are presented in Chapter 2. The trends of emissions to 2019 are analysed. Updates of the previous inventory are also discussed.

Chapters 3 to 7 cover emissions from five sectors: stationary energy; transport; waste; industrial processes and product use (IPPU); agriculture, forestry, and other land use (AFOLU). They include a description of GHG-relevant activities in Auckland, the GPC approach to calculate emissions, sources of activity data and emission factors. Findings are summarised in Chapter 8.

2 Emissions and Trends

Total emissions from all sectors together with emissions profiles were presented in this chapter. Trends in emissions to 2019 were discussed. Updates of the previous inventory and future inventory were also included.

2.1 Emissions and sources

In 2019, Auckland's net GHG emissions were 11,511 kt CO_2e (including carbon sequestration from forestry, BASIC+ emissions in Table 2-1). Blank cells in Table 2-1 indicate that emissions occur but have not been estimated or reported, or that an activity or process does not occur or exist within the city. Table 2-2 illustrates the GPC reporting requirements.

Table 2-1 Emissions summary for 2019 in the GPC format (CIRIS)

GHG Emissions Source (By Sector)		Total GHGs (metric tonnes CO2e)					
		Scope 1	Scope 2	Scope 3	BASIC	BASIC+	BASIC+ S3
STATIONARY ENERGY	Energy use (all emissions except I.4.4)	2,326,544	1,163,781	84,109	3,490,325	3,574,434	3,574,434
	Energy generation supplied to the grid (I.4.4)	32					
TRANSPORTATION	(all II emissions)	4,251,632	5,140	1,490,991	4,256,772	5,747,763	5,747,763
WASTE	Waste generated in the city (III.X.1 and III.X.2)	228,580		104,211	332,791	332,791	332,791
	Waste generated outside city (III.X.3)	0					
IPPU	(all IV emissions)	2,350,000				2,350,000	2,350,000
AFOLU	(all V emissions)	-493,772				-493,772	-493,772
OTHER SCOPE 3	(all VI emissions)						0
TOTAL		**8,663,016**	1,168,922	1,679,311	**8,079,889**	**11,511,216**	**11,511,216**

The agriculture, forestry and other land use (AFOLU) sector contributed a negative value, indicating a removal and not an emission. AFOLU is the sum of the agriculture sub-sector and the Land Use, Land Use Change and Forestry (LULUCF) sector.

While this is not a requirement of the GPC, gross emissions are reported in this inventory for comparison with national emissions. To be consistent with *New Zealand's Greenhouse Gas Inventory* (MfE, 2021), Auckland's gross emissions exclude the contribution from the LULUCF sector (i.e., Land and the harvested wood products (HWPs) sub-sectors (see Chapter 7)).

Table 2-2 Emission sources covered and reported by the GPC (WRI et al., 2014; 2021)

Source	Report
	Sources required for BASIC reporting
+	Sources required for BASIC+ reporting
	Additional scope 1 sources required for territorial reporting
	Other scope 3 sources
	Non-applicable emission sources

Of gross emissions in 2019 (12,709 kt CO_2e), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) contributed 85.4 per cent, 8.0 per cent, 2.4 per cent, 4.3 per cent, <0.1 per cent and <0.1 per cent of gross emissions, respectively (Table 2.3).

Table 2-3 Auckland's gross emissions by gas for 2019

GHGs	Carbon dioxide (CO_2)	Methane (CH_4)	Nitrous oxide (N_2O)	Hydrofluoro-carbons (HFCs)	Perfluoro-carbons (PFCs)	Sulphur hexafluoride (SF_6)	Nitrogen trifluoride (NF_3)	Gross emissions
CO_2e (kt)	10,849	1,012	302	542	0	5	NO	12,709
% of gross emissions	85.4%	8.0%	2.4%	4.3%	0.0%	0.0%	NO	100.0%

The contribution from five sectors was stationary energy 28.1 per cent, transport 45.2 per cent, waste 2.6 per cent, IPPU 18.5 per cent, and agriculture 5.5 per cent. Transport and stationary energy are the dominant sectors, accounting for 73.3 per cent of gross emissions (Table 2.4 and Figure 2-1). Emissions by sector, sub-sector and source for 2019 are also summarised in Table A-1 and Figure A-1 (in Appendix).

Table 2.4 shows that this inventory is close to Stats NZ's estimates (Stats NZ, 2021), except for higher emissions from Energy due to including electricity consumption in this inventory, and lower emissions from Waste due to higher-than-NZ-average recovery rate of Auckland landfill gas. This gives confidence that this inventory provides an accurate account of emissions in Auckland.

Based on the SEEA framework, Auckland contributed 13.7 per cent to national gross emissions. Using the results of this inventory and the *New Zealand's Greenhouse Gas Inventory* to calculate the Auckland's contribution to national emissions is problematic due to differences in methodologies for the two inventories.

Table 2-4 Auckland’s gross emissions by sector for 2019

Sector		Stationary energy	Transport	Waste	Industrial processes and product use (IPPU)	Agriculture	Gross emissions
This inventory	CO_2e (kt)	3,574	5,748	333	2,350	704	12,709
	% of gross emissions	28.1%	45.2%	2.6%	18.5%	5.5%	100.0%
Stats NZ (2021)	CO_2e (kt)	7,512		612	2,349	728	11,201
	% of gross emissions	67.1%		5.5%	21.0%	6.5%	100.0%

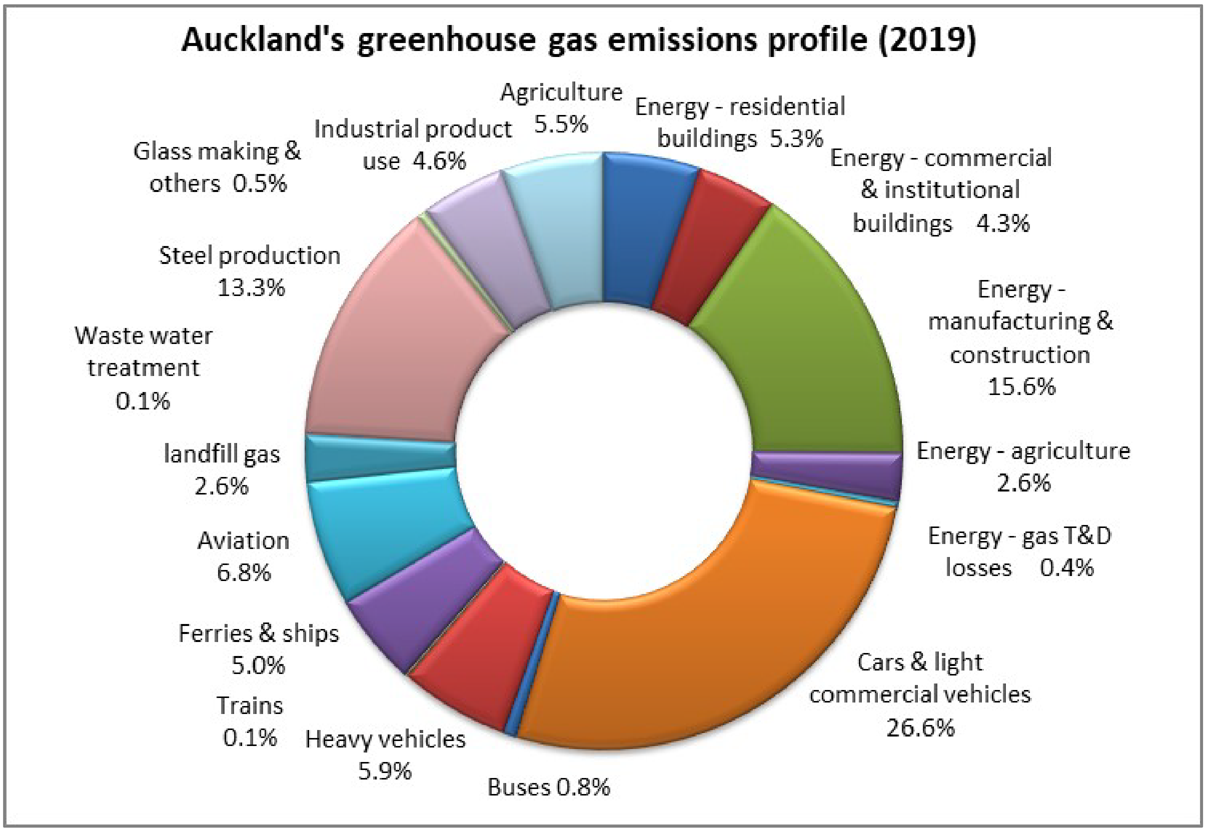

Figure 2-1 Auckland’s GHG gross emissions by sector, sub-sector and source for 2019

New Zealand’s gross emissions were dominated by emissions from agriculture, and transport and energy sectors, contributing 48.1 per cent, 21.9 per cent and 19.7 per cent in 2019, respectively (Figure 2-2) (MfE, 2021). Identifying differences in emissions profiles between Auckland and New Zealand helps develop mitigation actions to address major sources in Auckland.

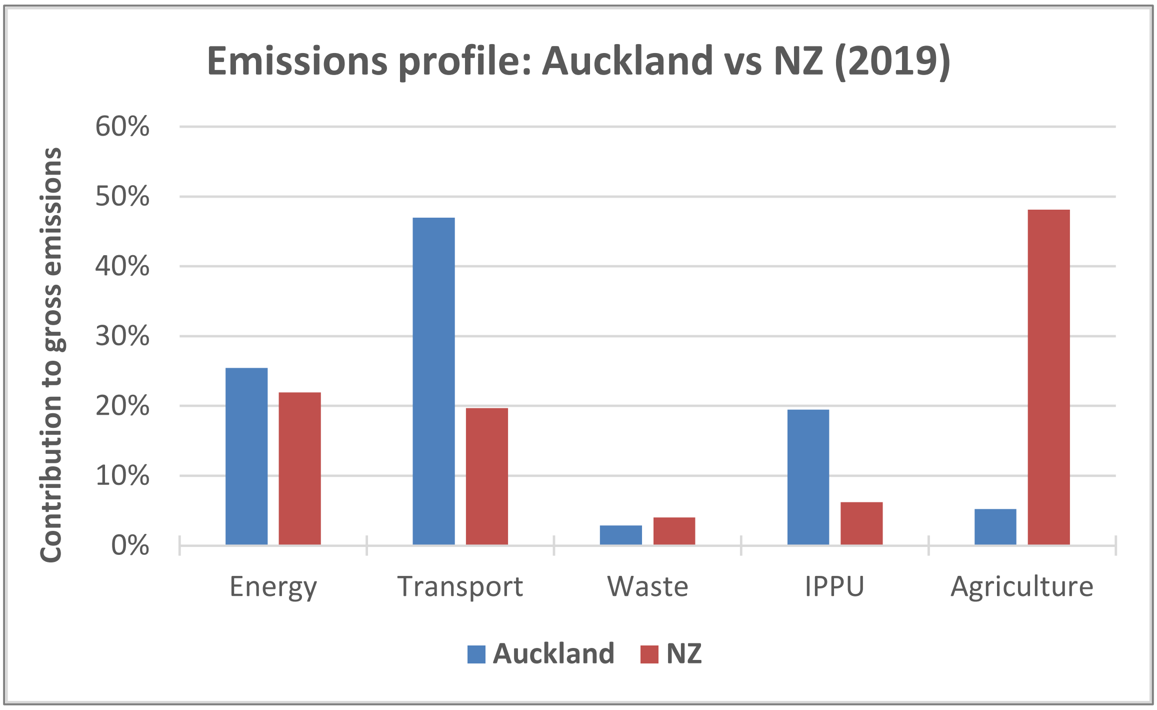

Figure 2-2 A comparison of emissions profiles between Auckland and New Zealand

2.2 Trends

Between 2018 and 2019

Between 2018 and 2019, Auckland's GHG emissions have increased by 353 kt CO_2e (or 2.9 per cent for gross emissions, 3.2 per cent for net emissions) (Figure 2-3). Emissions were higher from energy and agriculture sources, but lower from transport, waste and IPPU sectors. Changes in emissions from the LULUCF sector were not estimated due to lack of data (see Chapter 7).

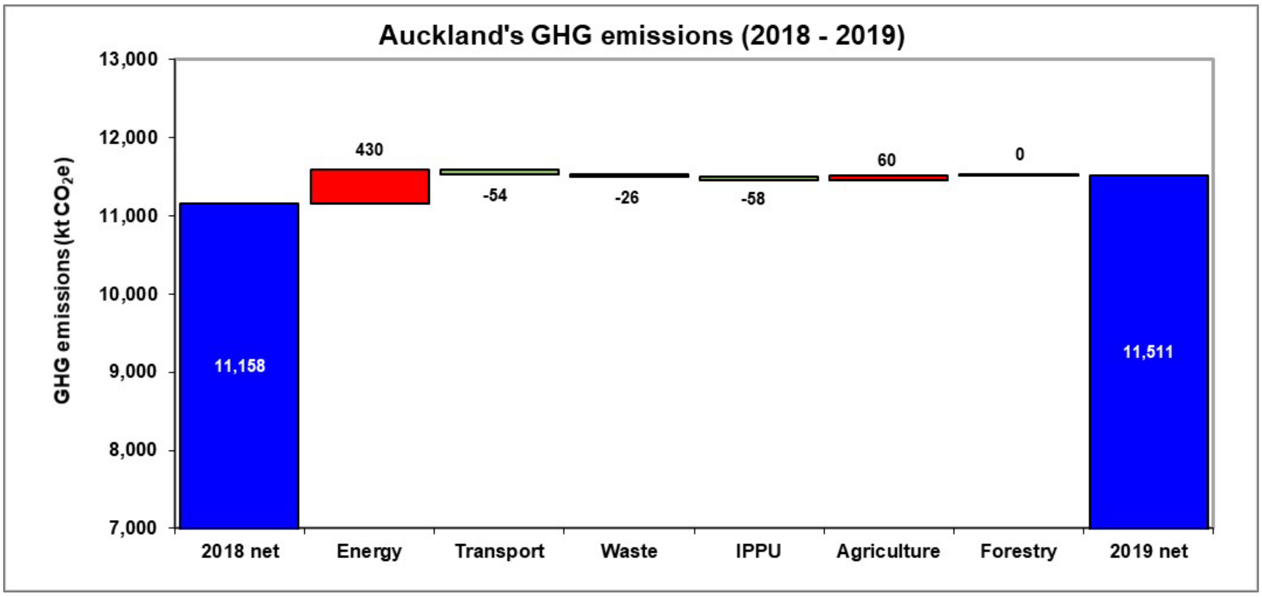

Figure 2-3 Auckland's GHG emissions between 2018 and 2019

Between 2016 and 2019

Between 2016 and 2019, Auckland's GHG emissions have increased by 647 kt CO_2e (or 5.4 per cent for gross emissions, 6.0 per cent for net emissions) (Figure 2-4). Emissions were higher from energy, transport and IPPU sectors, but lower from waste and agriculture sources. Changes in emissions from the LULUCF sector were not estimated due to lack of data (see Chapter 7).

To achieve the target of halving 2016 emissions by 2030, a reduction of 6,079 kt CO_2e, or 52.8 per cent of 2019 emissions, is required.

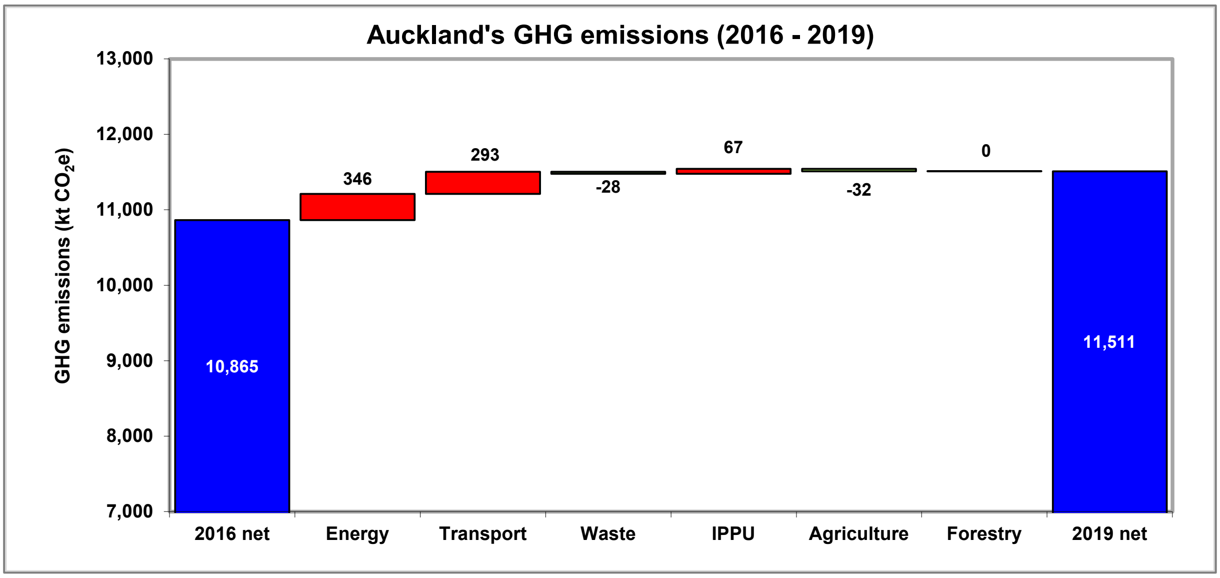

Figure 2-4 Auckland's GHG emissions between 2016 and 2019

Between 2009 and 2019, 1990 and 2019

As emissions for 1990 and 2009-2015 were reported in previous inventories, this inventory updates historic emissions and provides further information about emissions trends.

Between 2009 and 2019, gross and net emissions have increased by 1,424 kt CO_2e or 12.6 per cent, and 732 kt CO_2e or 6.8 per cent, respectively (Figure 2-5). Emissions were higher from transport, waste, IPPU and agriculture sources, but lower from energy and LULUCF sectors. Changes in emissions from the LULUCF sector between 2016 and 2019 were not estimated due to lack of data (see Chapter 7).

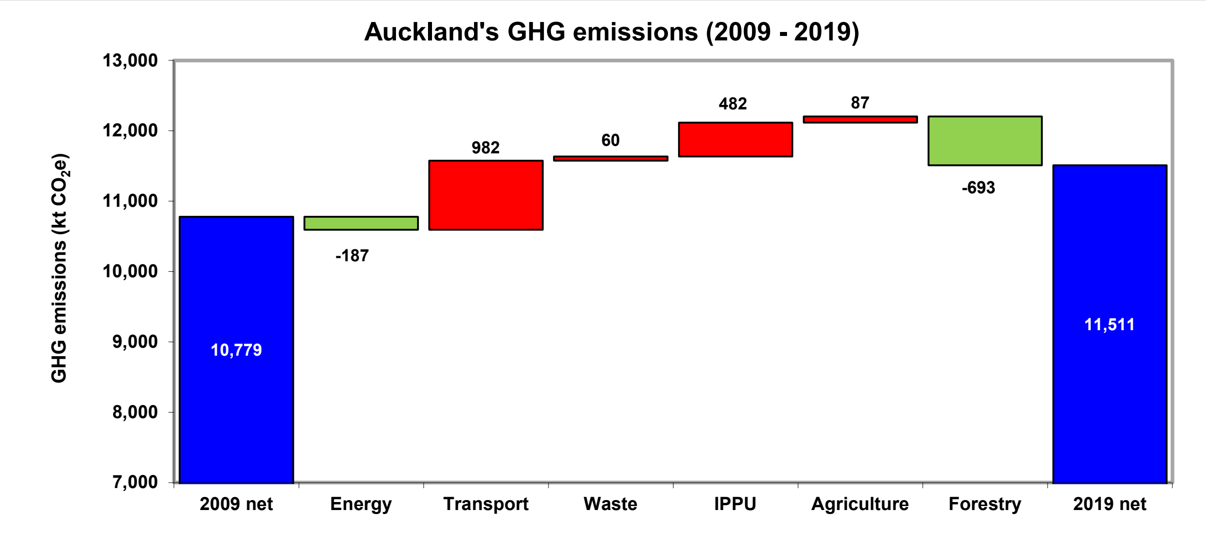

Figure 2-5 Auckland's GHG emissions between 2009 and 2019

Between 1990 and 2019, gross and net emissions have increased by 3,586 kt CO_2e or 39.3 per cent, and 3,748 kt CO_2e or 48.3 per cent, respectively (Figure 2-6). Emissions were higher from energy, transport, IPPU and LULUCF sectors, but lower from waste and agriculture sources. Changes in emissions from the LULUCF sector between 2016 and 2019 were not estimated due to lack of data (see Chapter 7).

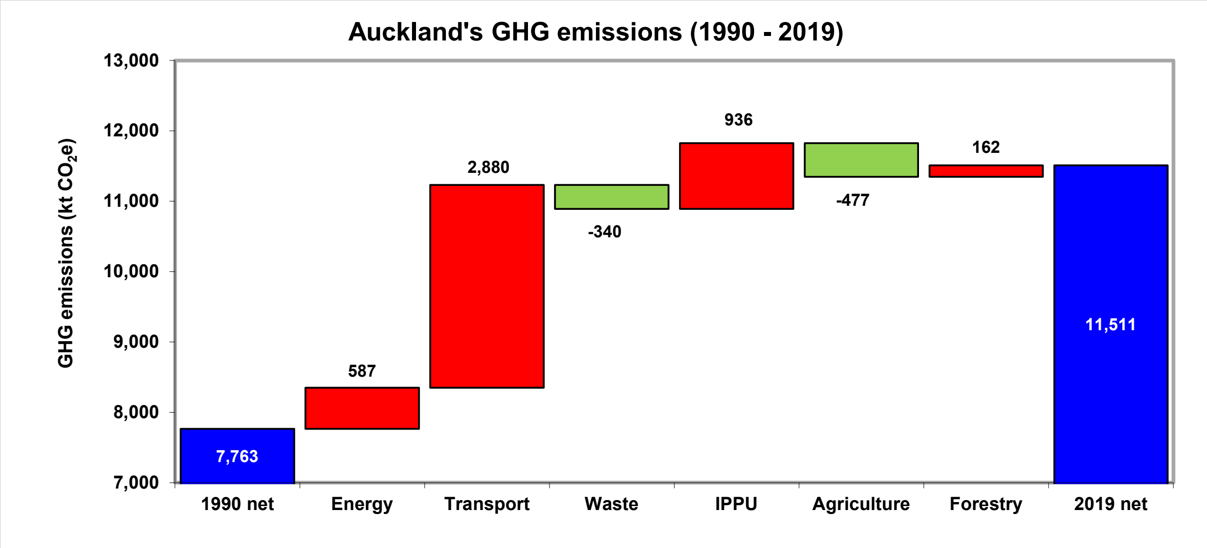

Figure 2-6 Auckland's GHG emissions between 1990 and 2019

Overall, gross and net emissions in 2019 have increased from the 2018 and 2016 levels. This continues a gradually upward trend since 2009. Changes in carbon sequestration from forestry (the LULUCF sector, Figure 2-7) from 2016 to 2019 were not estimated due to lack of data. In 2012 and 2019, there was lower than normal rainfall which led to lower hydro generation and an increase in gas and coal generation (MBIE, 2021a). This caused a spike in emissions from electricity consumption, therefore the stationary energy sector (Figure 2-8). Auckland's gross emissions largely tracked a similar trend to national emissions for 2009-2019 (MfE, 2021) (Figure 2-9). Faster growth in gross emissions for Auckland is driven by transport and IPPU sectors. Work is ongoing to further understand Auckland's emissions trends and driving factors for evaluating progress of Auckland's climate plan.

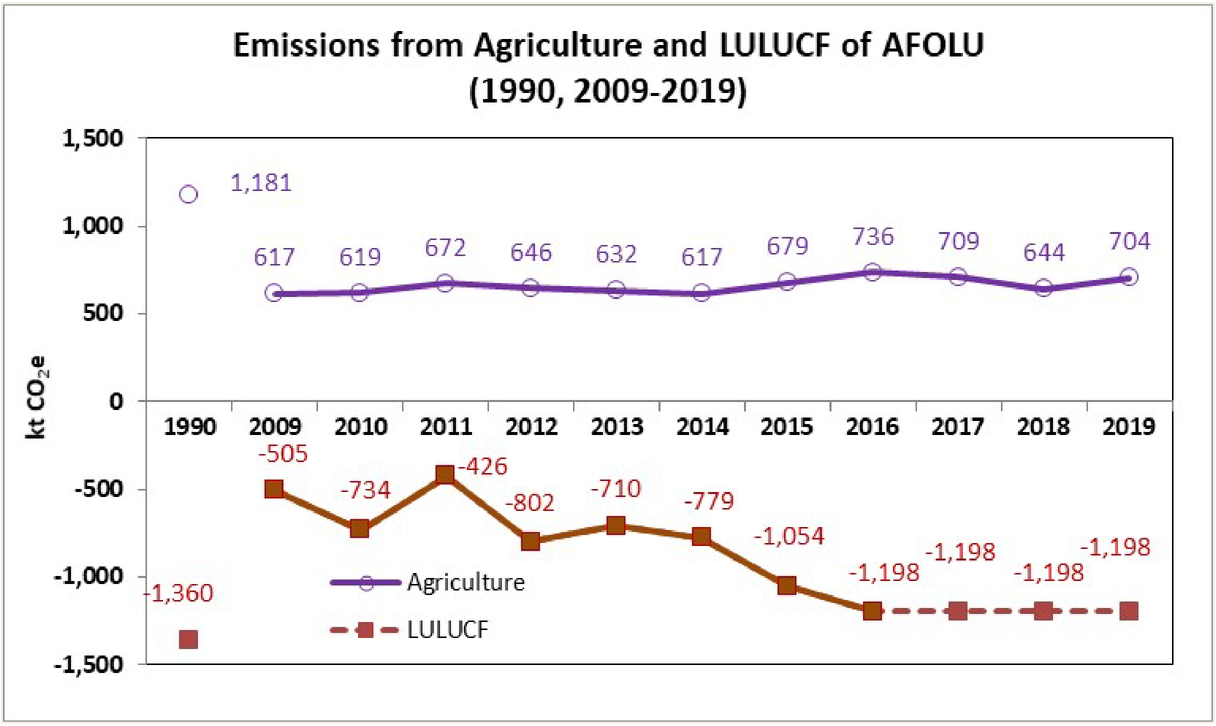

Figure 2-7 Emissions from agriculture and LULUCF sources for 1990, 2009 to 2019

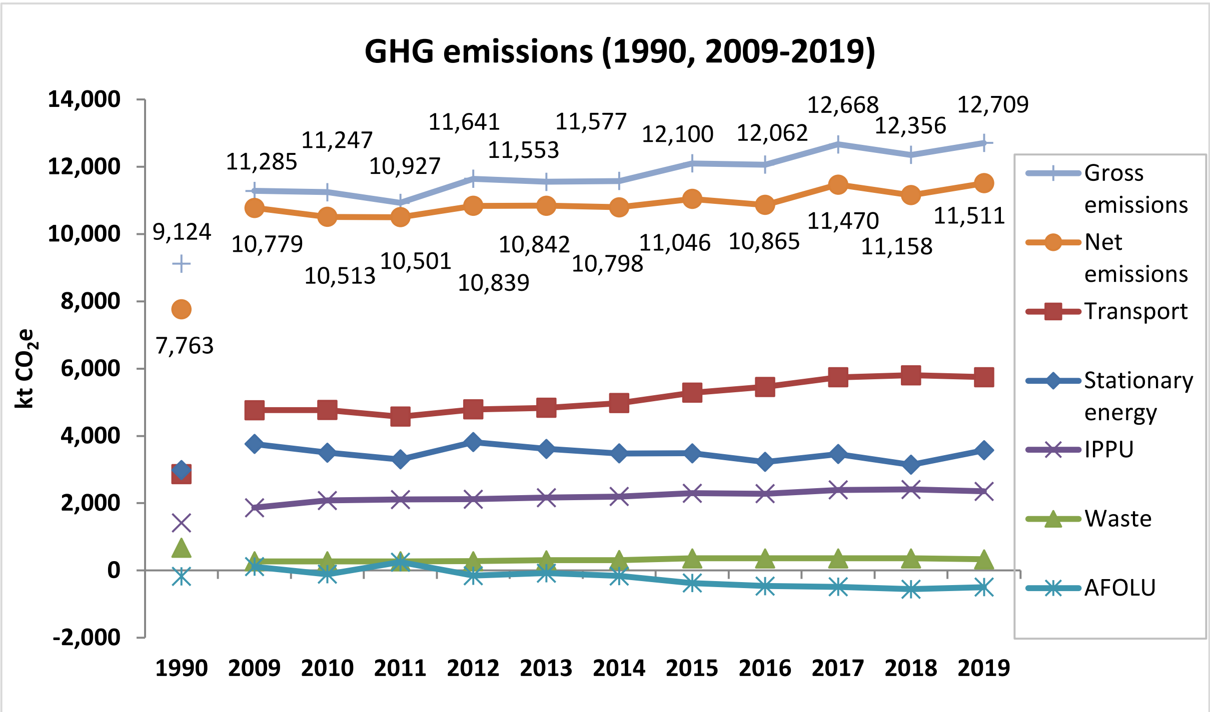

Figure 2-8 Auckland's GHG emissions for 1990, 2009 to 2019

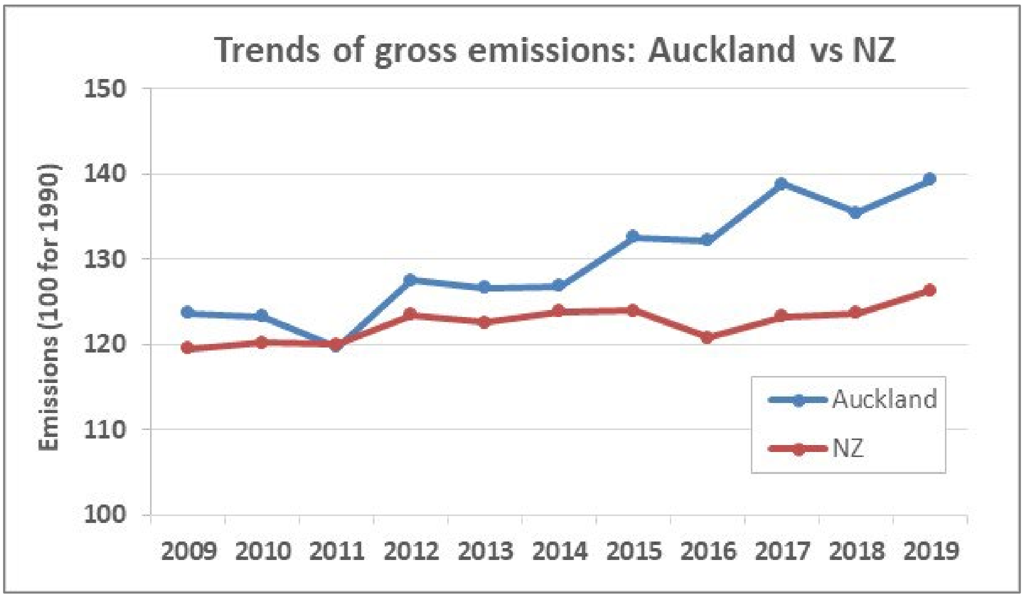

Figure 2-9 Trends of gross emissions: Auckland vs New Zealand (2009-2019)

2.3 Comparison between this inventory and emissions data for decarbonisation pathway development

Decarbonisation pathways have been developed to achieve a 50 per cent reduction of emissions by 2030 (against a 2016 baseline) and reach net zero emissions by 2050 (Auckland Council, 2020). These were based on *Auckland's greenhouse gas inventory to 2016* (Xie, 2019) with provisional emissions for 2017-2019 (Figure 2.10). Figure 2.10 also shows the business as usual (BAU) projection, the decarbonisation pathway from 2016 baseline and potentially steeper pathway from 2020 (provisional data).

Emissions from this inventory are higher than those for the pathway development. Higher gross emissions for 2017-2019 than 2016 requires a deeper reduction to meet the 50 per cent reduction target by 2030. This demonstrates the importance of the annual inventory update to track the emissions change, therefore effective mitigation strategy, policy and actions can be developed in response to the recent emissions trend to meet the reduction target. The comparison between this inventory and the data for the pathway development is to inform future update of decarbonisation pathways.

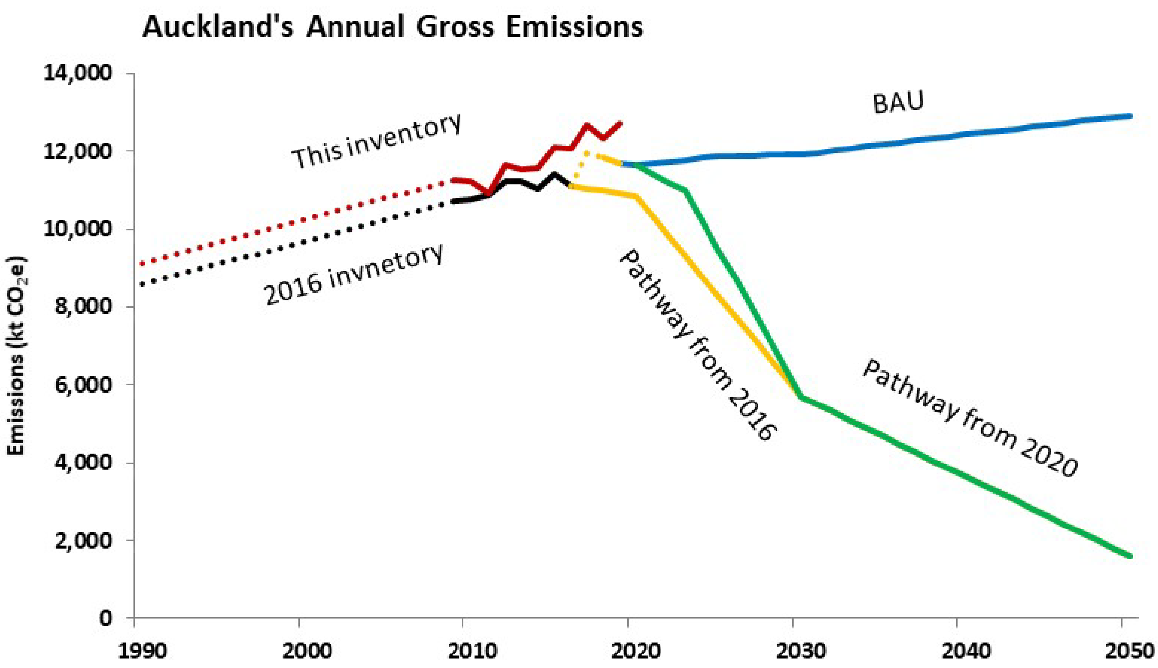

Figure 2-10 Comparison between this inventory (red dot and line) and emissions data for decarbonisation pathway development (black dot and line, and yellow dot)

2.4 Emissions per capita and per unit GDP

Increased population and economic activities generally result in increased emissions. Trends of emissions per capita or per unit GDP are also useful indicators for tracking progress of climate actions. From 2009 to 2019, Auckland's population increased from 1.4 million to 1.6 million and GDP increased from $NZ 81.9 billion to $NZ 110.1 billon (2019/2020 prices). Population, GDP and GHG emissions are compared in Figure 2-11. Figure 2-12 shows the emission intensity by population and GDP. In 2019, net emissions were 6.8 t CO_2e per capita and 101 t CO_2e per million $NZ GDP while gross emissions were 7.6 t CO_2e per capita and 112 t CO_2e per million $NZ GDP. These values have generally decreased since 2009, suggesting Auckland's emissions intensity has decoupled from population and economic growth. Gross and net emissions per capita for 1990 were higher than those for 2009. For 1990, the GDP data is not available, therefore, emissions per unit GDP is not calculated.

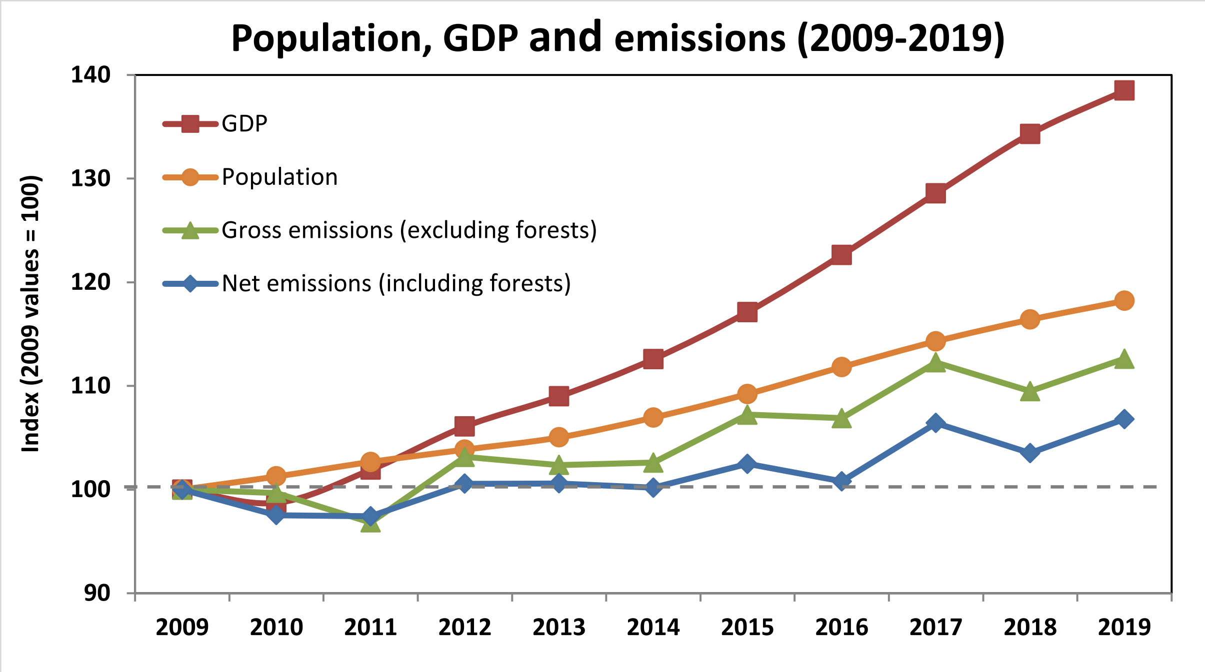

Figure 2-11 Auckland's population, GDP and GHG emissions from 2009 to 2019

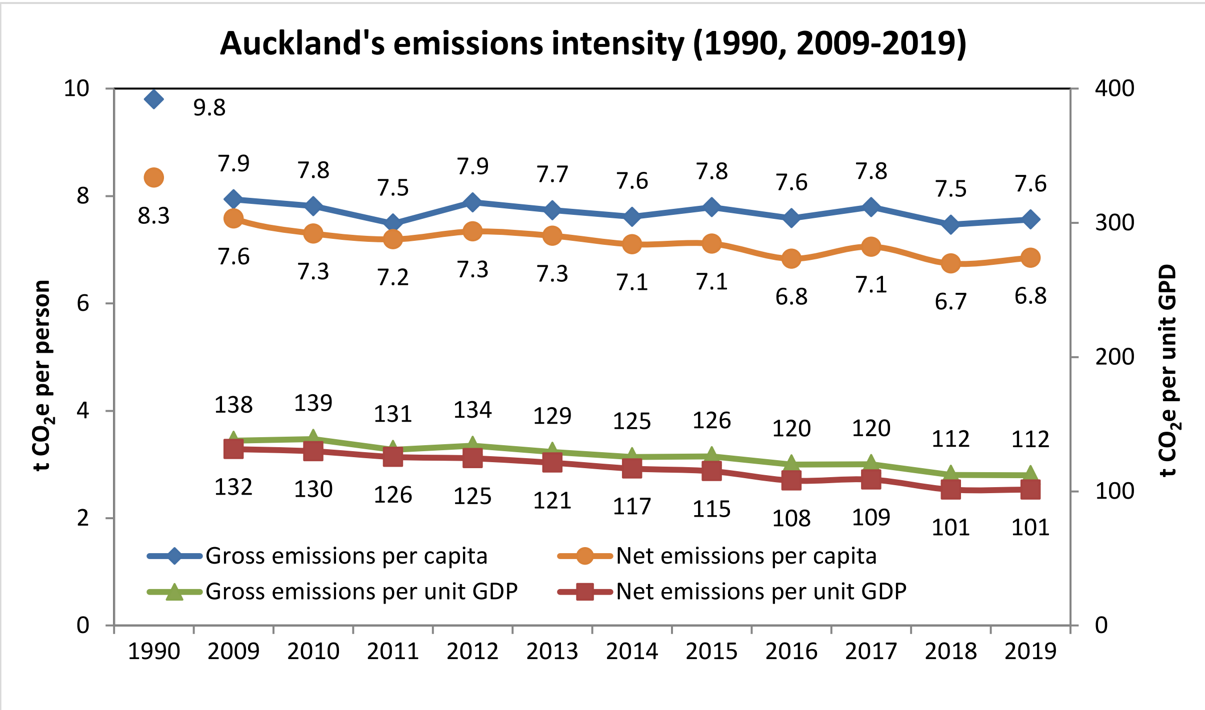

Figure 2-12 Auckland's emissions intensity for 1990, 2009 to 2019

2.5 Comparison of emissions with previous inventory

The 2019 inventory reports higher historic emissions than the previous inventory. This is because changes in activity data, emissions factors and ways of measuring emissions have been made in compiling this inventory with new information in line with best practice. Historic emissions for 1990, 2009 to 2018 have been updated to supersede all published previous inventories (Xie, 2020) (Figure 2-13). Table A-2 (in Appendix) compares emissions in 2018 between this inventory and the previous inventory for all emissions sources. A large change to gross and net emissions in 2018 occurs from four sources: aviation, shipping, coal and fuel for off-road transport. Higher emissions for aviation and shipping are due to a higher proportion of emissions attributable to Auckland. This is the first time Stats NZ provides customised emissions data for input into Auckland's GHG inventory (Stats NZ, 2021). Stats NZ estimates higher emissions for coal and lower emissions for fuel for off-road transport. A change in the emissions profile is also reported, notably a higher contribution from aviation and shipping (Figure A-2 in Appendix). Overall, this inventory reports higher gross and net emissions than the previous inventory (Figure 2-13).

From 2009 to 2019, the previous inventory demonstrates an upward trend for gross emissions and a flat trend for net emissions. This inventory shows an upward trend for both gross and net emissions. The upward trend for net emissions is due to faster growth in gross emissions in this inventory than the previous inventory. Future inventories could be improved by a better way of measuring aviation and shipping emissions, and by further aligning with Stats NZ's estimates of regional GHG emissions for comparable sources.

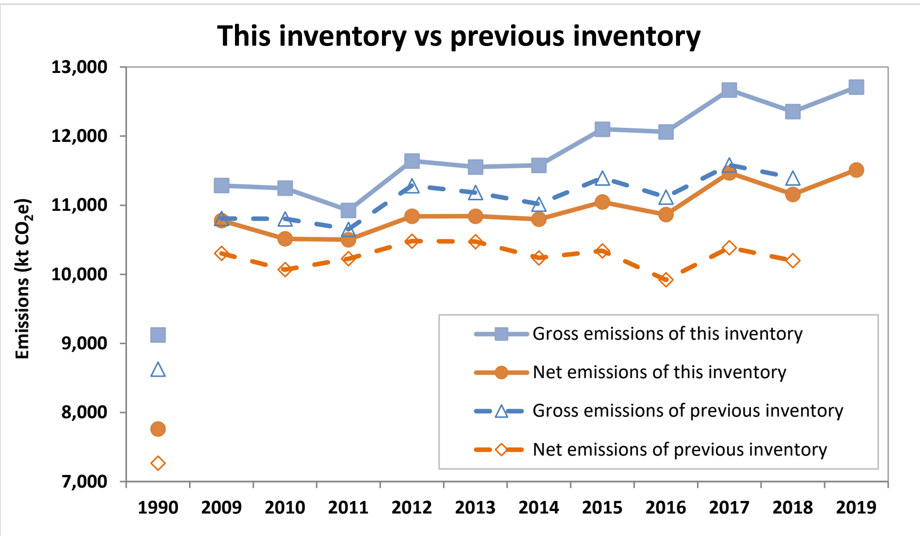

Figure 2-13 Comparison of GHG emissions: 2019 inventory vs 2018 inventory

3 Stationary Energy

Emissions from stationary energy come from energy consumption in buildings (e.g., natural gas for cooking at homes, electricity for heating at offices) and from non-mobile equipment and machinery, as well as fugitive emissions released in the process of generating, delivering, and consuming useful forms of energy (such as electricity or gas). These emissions are split into the following sub-sectors: residential buildings; commercial and institutional buildings and facilities; manufacturing industries and construction; and agriculture, forestry and fishing activities.

Scope 1 emissions are all direct emissions from burning fuel (oil, gas, liquefied petroleum gas (LPG), wood and coal) and fugitive emissions from delivering and distributing natural gas. Scope 2 emissions are those associated with consumption of grid-supplied electricity which is generated within or outside Auckland. Scope 3 emissions are from distribution losses from grid-supplied electricity. GHGs in this sector are CO_2, CH_4 and N_2O.

3.1 Emissions from stationary energy

Emissions from stationary energy are summarised in Tables 2-1 and A-1, and Figure 2-1. Total emissions were 3,574 kt CO_2e, with 55.4 per cent from manufacturing industries and construction, 18.7 per cent from residential buildings; 15.3 per cent from commercial and institutional buildings and facilities; 9.0 per cent from agriculture, forestry and fishing activities; and 1.5 per cent from natural gas transport and distribution (T&D) losses. They came from electricity (34.9 per cent), natural gas (27.4 per cent), fuel for off-road transport (1.8 per cent), LPG (8.6 per cent), coal (26.8 per cent) and wood (0.6 per cent) (Figure 3.1).

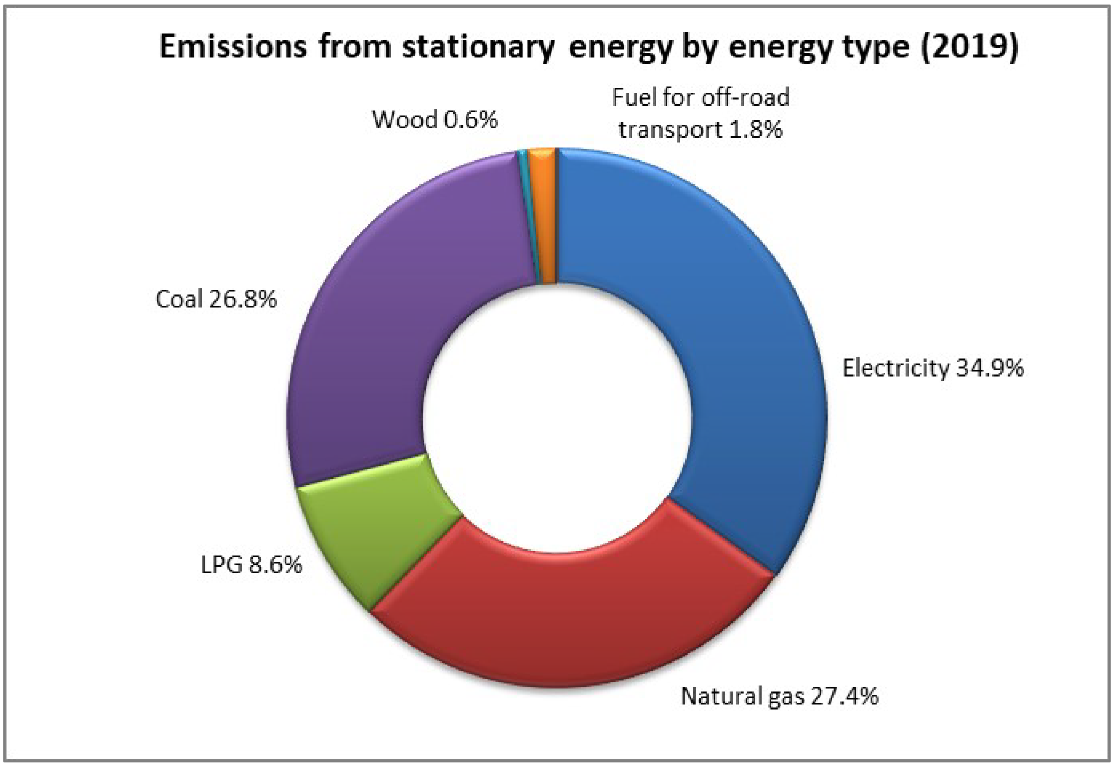

Figure 3-1 Emissions from stationary energy by energy type for 2019

3.2 Scope 1: emissions from fuel combustion

Scope 1 emissions are calculated based on consumption data for each of the fuel types used in Auckland (natural gas, coal, petrol, diesel, fuel oil and wood).

The total amount of natural gas consumption in Auckland for 1990, 2009-2019 was estimated from various sources (MBIE, 2021a; Vector Ltd, 2021; MfE, 2021). Gas use by sub-sectors was calculated from Stats NZ's data for Auckland (Stats NZ, 2021) and industrial emissions (Atkins, 2018). Fugitive emissions were losses from transport and distribution of natural gas. National emission factors were used (MfE, 2020). Emissions from gas use at Otahuhu and Southdown power stations were not included in total emissions since generated electricity was supplied to national electric grids. The two stations ceased operation from 2016.

Non-transport consumption of LPG (total and sub-sectors) was estimated from Stats NZ's data for Auckland (Stats NZ, 2021) and industrial emissions (Atkins, 2018). National emission factors were used (MBIE, 2021b; MfE, 2020).

Emissions from coal (total and sub-sectors) were estimated from Stats NZ's data for Auckland (Stats NZ, 2021) and industrial emissions (Atkins, 2018). Emissions from wood were estimated from the Auckland air emissions inventory (Metcalfe, et. al., 2018) and industrial emissions (Atkins, 2018). CO_2 emissions from wood burning were reported as biogenic, which were not included in total emissions. CH4 and N_2O emissions from wood burning were included in total emissions. National emission factors for coal and wood were used (MBIE, 2021b; MfE, 2020).

Emissions from consumption of diesel, petrol and fuel oil for stationary and off-road transport sources (total and sub-sectors) were estimated from Stats NZ's data for Auckland (Stats NZ, 2021) and industrial emissions (Atkins, 2018). National emission factors were used (MBIE, 2021b; MfE, 2020). As discussed in Section 4.6, these emissions were reported under Stationary Energy.

CO_2 (biogenic), CH_4 and N_2O emissions from landfill gas combustion for electricity or heat in 2016 were sourced from the air emissions inventory (Crimmins, 2018). The amount of waste to landfills relative to 2016 was used to estimate emissions for other years. Emissions for 1990 were zero since landfill gas was not used to generate electricity. Emissions from landfill gas flaring were reported in the Waste sector (Chapter 5).

3.3 Scope 2: emissions from consumption of grid-supplied electricity

The GPC covers emissions from consumption of grid-supplied electricity, steam, heating and cooling in the city under Scope 2. As there is no grid supply of heat or cooling from outside Auckland, only emissions associated with grid-supplied electricity are reported.

Electricity consumption for 2009-2019 was sourced from various organisations (Vector Ltd, 2021; Counties Power Ltd, 2021; NZEA, 2021; Auckland Transport, 2021). The data for 1990 was estimated by scaling national consumption based on the historical ratio (2009-2016). Allocation of electricity consumption into sub-sectors was based on Vector Ltd data (Vector Ltd, 2021). National average emission factors were used (MBIE, 2021b; MfE, 2020). Electric passenger trains went into service from 2014 and will gradually replace all diesel trains. Emissions from electricity consumption by trains and vehicles were reported in the Transport sector.

3.4 Scope 3: distribution losses from grid-supplied energy

Scope 3 emissions include transmission and distribution losses from the use of grid-supplied electricity. The grid loss factor was sourced from the national data (MBIE, 2021a; MfE, 2020).

4 Transport

Emissions from transport come from directly combusting fuel or indirectly consuming grid-delivered electricity to transport vehicles and mobile equipment or machinery. For transport occurring within the Auckland region, emissions from combustion of fuels are reported in scope 1 and emissions from grid-supplied electricity are included in scope 2. Scope 3 reports the emissions from a portion of transboundary journeys occurring outside the Auckland region, and transmission and distribution losses from grid-supplied electricity. The emissions are calculated for on-road vehicles, railways, water transport, aviation and off-road transport, respectively. The gases reported in this sector are CO_2, CH_4 and N_2O.

4.1 Emissions from transport

Emissions from transport are summarised in Tables 2-1 and A-1, and Figure 2-1. On-road transport accounted for 80.0 per cent of total 5,748 kt CO_2e emissions from transport (Figure 3.2). Contributions from other sources were 15.0 per cent from aviation, 11.1 per cent from ferries and ships, and 0.2 per cent from trains.

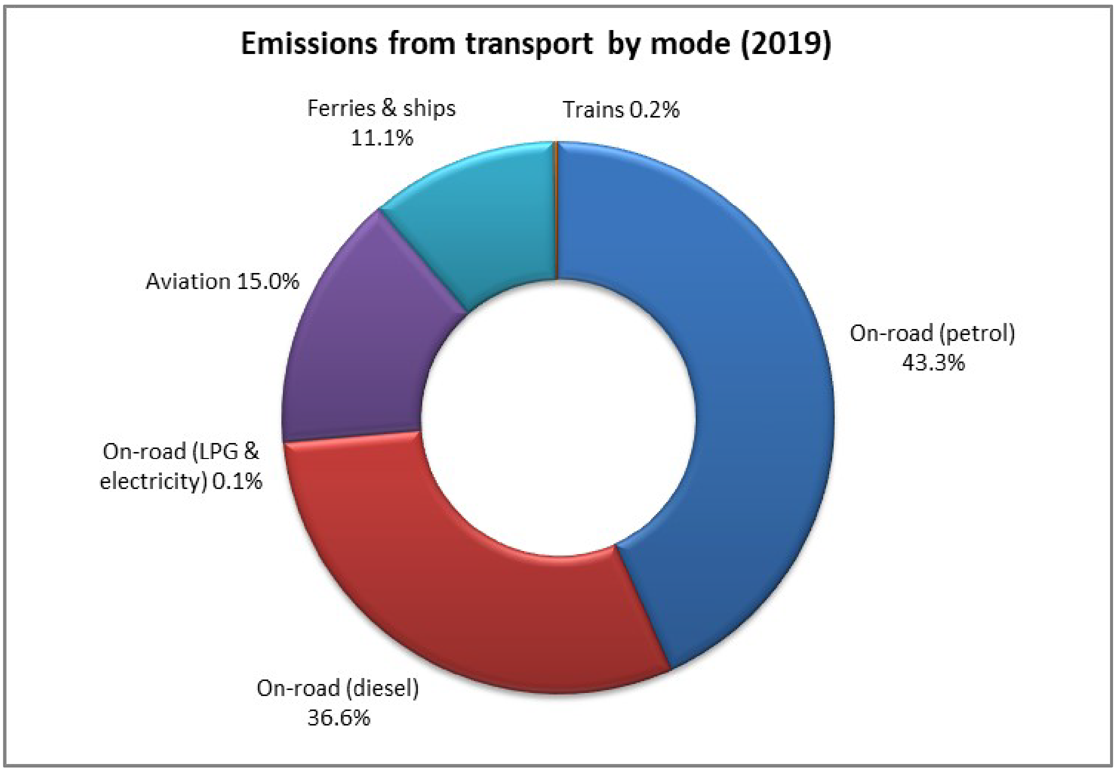

Figure 3-2 Emissions from transport by mode for 2019

4.2 On-road transport

Petrol and diesel sales for land transport were provided by Auckland Transport. The data was used to calculate emissions from on-road transport. National emission factors were applied (MBIE, 2021b; MfE, 2020). The results were included in Scope 1 emissions.

Emissions from LPG and electricity use were sourced from Ministry of Transport (MoT, 2021a). Emissions from buses were provided by Auckland Transport (2021). The split of on-road emissions into heavy vehicles, buses, and cars and light commercial vehicles (Figure 2-1) were based on the 2016 emissions report (Auckland Council, 2020).

4.3 Railways

Rail is for the mass transit of commuters within the region (managed by Auckland Transport) or for moving freight within or to and from Auckland (managed by KiwiRail). Emissions of diesel and electricity consumption for passenger trains were provided by Auckland Transport (2021). Diesel use by freight trains from 2012 to 2019 was calculated by freight carried (in tonnes-km) multiplied by fuel burn rate (in litres per t-km). Rail freight was estimated based on rail tonnage data from the Freight Information Gathering System (FIGS) (MoT, 2021b). The fuel burn rate was converted from the emissions rate (in gCO_2e/t-km) (KiwiRail, 2021). Diesel use for rail freight for previous years was estimated by scaling national consumption. Emissions from diesel and electricity were reported in Scopes 1 and 2, respectively.

4.4 Water transport

Auckland Transport provided the total amount of fuel oil used to refuel ships at seaports from 2012 to 2019. The ratio of Auckland consumption to the national total averaged over this period was used to estimate consumption for other years (1990, 2009-2011).

Emissions of diesel from ferries were provided by Auckland Transport (2021) and reported in Scope 1. Emissions from shipping were reported in Scope 3. The national emission factors were applied (MBIE, 2021b; MfE, 2020). Export data at NZ shipping ports in tonnage was extracted from the Freight Information Gathering System (FIGS)

(MoT, 2021b). This data was used to portion goods from Auckland of total export at ports of Auckland, therefore, to portion shipping emissions attributable to Auckland.

4.5 Aviation

Aviation activities in Auckland are dominated by domestic and international flights at Auckland Airport. Other activities include local helicopter, light aircraft, sightseeing and training flights at three other airports in Auckland (Ardmore Airport, North Shore Aerodrome and the military airbase at Whenuapai). Emissions from the jet fuel use at the three airports were small and not reported. Emissions from grid-supplied energy consumed by aircraft charging at airports were included in Scope 2 of Stationary Energy. Emissions from departing flights at Auckland Airport were reported in Scope 3. The proportion of Scope 3 emissions attributable to Auckland was calculated based on the proportion of departure passengers who were Auckland residents. International and domestic departures were estimated from data from Stats NZ (2020) and Auckland Airport (2021). The Joint User Hydrant Installation (JUHI) Depot provided aviation fuel consumption at Auckland Airport for 2009-2019. 1990 data was estimated by scaling national aviation fuel consumption. National emission factors were applied (MBIE, 2021b; MfE, 2020).

4.6 Off-road transport

Emissions from diesel and petrol for off-road transport were estimated and reported under Stationary Energy in Section 3.2.

5 Waste

Emissions are generated from the processing and disposal of solid waste and wastewater treatment, predominantly CH_4 with smaller contributions from N_2O and CO_2. Emissions from waste treated inside Auckland are reported in Scope 1 and emissions from waste generated in Auckland but treated outside Auckland are included in Scope 3. Emissions from grid-supplied electricity in waste treatment facilities are reported in Scope 2 in Stationary Energy.

5.1 Emissions from waste

Emissions from waste are summarised in Tables 2-1 and A-1, and Figure 2-1. The waste sector emitted 333 kt CO_2e, with 98.0 per cent from solid waste sources and 2.0 per cent from wastewater treatment.

5.2 Solid waste

The total amount of solid waste and its composition generated within Auckland sent to landfills were sourced the council's waste team. Equations to estimate emissions from landfills (MfE, 2020) are derived from the IPCC 2006 "tier 1" methodology (IPCC, 2015) and allow all the potential emissions to be accounted for in the year of disposal. Of five landfills receiving Auckland's waste, the methane recovery rate was estimated as zero for Claris (without a landfill gas collection system) and 75 per cent for Puwera, Redvale, Whitford and Hampton (well equipped with gas capture facilities (DEFRA, 2014)). Emissions from waste sent to landfills in Auckland were reported in Scope 1. Emissions from waste generated in Auckland but treated outside Auckland were reported in Scope 3.

A small amount of CO_2 (biogenic), CH_4 and N_2O are emitted from landfill gas flaring. Emissions for 2016 were sourced from the air emissions inventory (Crimmins, 2018). Emissions for other years were estimated based on the amount of waste to landfills relative to 2016, except for 1990. Emissions from landfill gas flaring in 1990 were zero since landfill gas was not well managed at that time.

Emissions from farm fills and rural waste were provided by Stats NZ (2021) for 2007-2019. Emissions for 1990 were estimated as the average between 2007 and 2011.

5.3 Wastewater treatment

Watercare Services Ltd is the water and wastewater service provider for Auckland. Auckland's wastewater is transported through a public wastewater network to wastewater treatment plants. The majority of Auckland's wastewater is treated at the Mangere or Rosedale treatment plant. Emissions from wastewater generated and treated in Auckland were sourced from Watercare Services Ltd (2017).

6 Industrial Processes and Product Use (IPPU)

Emissions from non-energy related industrial activities and product use are assessed and reported in the IPPU sector. Emissions (CO_2, N_2O, HFCs, PFCs and SF_6) are reported in Scope 1.

6.1 Emissions from IPPU

Emissions from IPPU are summarised in Tables 2-1 and A-1, and Figure 2-1. Emissions came from Industrial Processes (1,762 kt CO_2e, 75.0 per cent) and Industrial Product Use (588 kt CO_2e, 25.0 per cent).

6.2 Industrial processes

CO_2 is mostly emitted from the production of steel from iron sand and from scrap steel. In New Zealand, all the iron and steel production (from New Zealand Steel Ltd and Pacific Steel Ltd until its close in 2015) is in Auckland. *New Zealand's Greenhouse Gas Inventory* reports its emissions in the categories of "2.C.1 Iron and Steel Production" (MfE, 2021). Emissions from glass production were aggregated with small emissions from other sources to preserve confidentiality. Other sources from industrial processes include the use of soda ash and limestone in glass making (O-I New Zealand Ltd).

Total emissions from industrial processes were provided by Stats NZ (2021) for 2007-2019. Emissions for 1990 were estimated as the sum from the iron and steel production and from other sources. The former was sourced from *New Zealand's Greenhouse Gas Inventory* (MfE, 2021). The latter was estimated as the average between 2007 and 2011.

6.3 Industrial product use

GHGs are emitted from non-energy products from fuels and solvent use (CO_2), product uses as substitutes for ozone depleting substances (HFCs), and other product manufacture and use (N_2O, PFCs and SF_6). Total emissions from industrial product use were provided by Stats NZ (2021) for 2007-2011. Emissions for 1990 were estimated from NZ emissions allocated to Auckland on a population basis. Emissions of CO_2, N_2O, HFCs, PFCs and SF_6 were reported with the same proportion as NZ emissions.

7 Agriculture, Forestry and Other Land Use (AFOLU)

AFOLU activities are divided into three categories: livestock, land, and aggregate sources and non-CO_2 emissions sources on land. GHGs consist of CH_4, N_2O and CO_2, and are reported as Scope 1 emissions.

For comparison with *New Zealand's Greenhouse Gas Inventory* (MfE, 2021), the emissions are also disaggregated into two categories: the LULUCF sector and agriculture sources. The former is the Land sub-sector (section 7.3) and the harvested wood products (HWPs) (reported in Section 7.4). The latter are the remainder of the AFOLU emissions (Sections 7.2 and 7.4, exclusive of HWPs)). In this inventory, the LULUCF sector is dominated by carbon sequestration from forestry, therefore the LULUCF sector is also termed as carbon sequestration from forestry, or forestry in Figures 2-3 to 2-6.

7.1 Emissions from AFOLU

Emissions from the AFOLU sector are summarised in Tables 2-1 and A-1, and Figure 2-1. Emissions from agriculture sources were 704 kt CO_2e. Carbon sequestered from forestry was –1,198 kt CO_2e, resulting in AFOLU emissions of –494 kt CO_2e. The removal is expressed as a negative value to clarify that the value is a removal and not an emission.

To exclude the removals and report the emissions only, *New Zealand's Greenhouse Gas Inventory* reported gross emissions by excluding the LULUCF sector (MfE, 2021). Accordingly, Auckland's gross emissions exclude the LULUCF sector.

7.2 Livestock

CH_4 is produced in digestive processes of livestock (enteric fermentation) and through management of their manure. N_2O is also emitted from the manure management system. The number of livestock (dairy cattle, non-dairy cattle, sheep, deer, pig and goat) in Auckland was sourced from Statistics New Zealand (Stats NZ, 2020). National emission factors per animal were estimated from *New Zealand's Greenhouse Gas Inventory* (MfE, 2021).

7.3 Land

Land use is divided into six categories: forest land, cropland, grassland, wetlands, settlements and other. Emissions and removals are calculated from the changes in ecosystem carbon stocks for both land remaining in a land use category and land converted to another land use category. The calculation was undertaken by Ministry for the Environment by applying *New Zealand's Greenhouse Gas Inventory* methodologies for the LULUCF sector for Auckland with some Auckland-specific activity data and parameters where available. The Auckland specific age class distribution was provided by the Ministry for Primary Industries. The results for 1990-2016 were reported in the previous inventory (Xie, 2020). Due to lack of forest harvesting statistics for Auckland, modelling for 2017-2019 was not undertaken. Therefore, emissions were assumed unchanged from 2016 to 2019.

7.4 Aggregate sources and non-CO_2 emission sources on land

Aggregate sources and non-CO_2 emission sources on land are other agriculture (fertilizer use; liming, urea application; direct N_2O from managed soils, indirect N_2O from managed soils, and indirect N_2O from manure management) and harvested wood products (HWPs).

Other agriculture

Emissions (CO_2 and N_2O) from liming, urea application, direct N_2O from managed soils, and indirect N_2O from managed soils were estimated based on national emissions (MfE, 2021) allocated to Auckland by the proportion of the cropland and grassland land to the national total. The land use data was sourced from the Land Use Carbon Analysis System New Zealand Land Use Map (MfE, 2022). Emissions from the decay of crop residues are reported in the Waste sector, as part of farm fills and rural waste. Emissions from crop residue burning are likely minor and not included in this inventory.

Harvested wood products (HWPs)

As for the land sub-sector, changes of carbon stocks in the harvested wood products pool were provided by Ministry for the Environment and were modelled using a simplified version of the national methodologies with some Auckland-specific activity data. The results for 1990-2016 were reported in the previous inventory (Xie, 2020). Emissions were assumed unchanged from 2016 to 2019 due to lack of Auckland forest harvesting data.

8 Conclusions

Concluding findings of the inventory are as follows:

- In 2019, Auckland's gross and net emissions were 12,709 kt CO_2e and 11,511 kt CO_2e, respectively. Carbon dioxide (CO_2) contributed 85.4 per cent of gross emissions. Transport and stationary energy dominated emissions, accounting for 45.2 per cent and 28.1 per cent of gross emissions, respectively.
- From 2018 to 2019, gross and net emissions have increased by 353 kt CO_2e (or 2.9 per cent for gross emissions, 3.2 per cent for net emissions). Emissions were higher from energy and agriculture sources, but lower from transport, waste and IPPU sectors.
- From 2016 to 2019, gross and net emissions have increased by 647 kt CO_2e (or 5.4 per cent for gross emissions, 6.0 per cent for net emissions). Emissions were higher from energy, transport and IPPU sectors, but lower from waste and agriculture sources. Changes in carbon sequestration from forestry (i.e., the LULUCF sector) from 2016 to 2019 were not estimated due to lack of data. To achieve the target of halving 2016 emissions by 2030, a reduction of 6,079 kt CO_2e, or 52.8 per cent of 2019 emissions, is required.
- Higher gross emissions in 2019 than 2016 requires a deeper reduction to meet the halving reduction target by 2030. This demonstrates the importance of the annual inventory update to track the emissions change, so that effective mitigation strategy, policy and actions can be developed in response to meet the reduction target.
- In 2019, net emissions were 6.8 t CO_2e per capita and 101 t CO_2e per million $NZ GDP (2019/2020 prices) while gross emissions were 7.6 t CO_2e per capita and 112 t CO_2e per million $NZ GDP. These values were lower than in 2009, suggesting Auckland's emission intensity has decoupled from population and economic growth.
- Despite changes to the historic estimates, the overall emissions profile and trends across all years has remain unchanged, and transport is still the biggest source of emissions for Auckland.

9 Acknowledgements

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Stats NZ: Adam Tipper for providing customised Stats NZ's data which are licensed by Stats NZ for re-use under the Creative Commons Attribution 4.0 International licence

Vector Limited: Ross Malcolm

Watercare Services Limited: Roseline Klein, Chris Thurston

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11 Abbreviations

This chapter is based on WRI et al., (2014, 2021)

AFOLU	Agriculture, forestry and other land use
AR4	IPCC Fourth Assessment Report
AR5	IPCC Fifth Assessment Report
C40	C40 Cities Climate Leadership Group
CDP	Formerly the Carbon Disclosure Project, a global disclosure system
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EF	Emission factor
GDP	Gross domestic product
GHG	Greenhouse gas
GPC	Global Protocol for Community-scale Greenhouse Gas Emission Inventories
GWP	Global warming potential
HFCs	Hydrofluorocarbons
HWPs	Harvested wood products
ICLEI	ICLEI – Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial processes and product use
LULUCF	Land use, land use change and forestry
MSW	Municipal solid waste

N_2O	Nitrous oxide
NF_3	Nitrogen trifluoride
PFCs	Perfluorocarbons
SF_6	Sulphur hexafluoride
WRI	World Resources Institute
WWTP	Wastewater treatment plant

12 Glossary

This chapter is based on WRI et al., (2014).

Activity data: A quantitative measure of a level of activity that results in GHG emissions. Activity data is multiplied by an emission factor to derive the GHG emissions associated with a process or an operation. Examples of activity data include kilowatt-hours of electricity used, quantity of fuel used, output of a process, hours equipment is operated, distance travelled, and floor area of a building.

Allocation: The process of partitioning GHG emissions among various outputs.

Base year: A historical datum (e.g., year) against which a city's emissions are tracked over time.

BASIC: An inventory reporting level that includes all scope 1 sources except from energy generation, imported waste, *IPPU*, and *AFOLU*, as well as all scope 2 sources.

BASIC+: An inventory reporting level that covers all BASIC sources, plus scope 1 *AFOLU* and *IPPU*, and scope 3 in the *Stationary Energy* and *Transportation* sectors.

Biogenic emissions (CO_2(b)): Emissions produced by living organisms or biological processes, but not fossilised or from fossil sources.

City: Used throughout the GPC to refer to geographically discernible subnational entities, such as communities, townships, cities, and neighbourhoods.

City boundary: See geographic boundary.

CO_2 equivalent: The universal unit of measurement to indicate the global warming potential (GWP) of each GHG, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate the climate impact of releasing (or avoiding releasing) different greenhouse gases on a common basis.

Emission: The release of GHGs into the atmosphere.

Emission factor(s): A factor that converts activity data into GHG emissions data (e.g., kg CO_2e emitted per litre of fuel consumed, kg CO_2e emitted per kilometre travelled, etc.).

Geographic boundary: A geographic boundary that identifies the spatial dimensions of the inventory's assessment boundary. This geographic boundary defines the physical perimeter separating in-boundary emissions from out-of-boundary and transboundary emissions.

Global warming potential: A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2.

Greenhouse gas inventory: A quantified list of a city's GHG emissions and sources.

Greenhouse gases (GHG): For the purposes of the GPC, GHGs are the seven gases covered by the UNFCCC: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulphur hexafluoride (SF_6); and nitrogen trifluoride (NF_3).

In-boundary: Occurring within the established geographic boundary.

Inventory boundary: The inventory boundary of a GHG inventory identifies the gases, emission sources, geographic area, and time span covered by the GHG inventory.

Out-of-boundary: Occurring outside of the established geographic boundary.

Reporting: Presenting data to internal and external users such as regulators, the general public or specific stakeholder groups.

Reporting year: The year for which emissions are reported.

Scope 1 emissions: GHG emissions from sources located within the city boundary.

Scope 2 emissions: GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary.

Scope 3 emissions: All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

Transboundary emissions: Emissions from sources that cross the geographic boundary.

13 Appendix: Emissions by Sector and Sub-sector, and Comparison to Previous Inventory

Table A-1 GHG emissions by sector and sub-sector for 2019 in the GPC format (CIRIS)*

GPC ref No.	GHG Emissions Source (By Sector and Sub-sector)	Total GHGs (metric tonnes CO_2e)			
		Scope 1	Scope 2	Scope 3	Total
I	STATIONARY ENERGY				
I.1	Residential buildings	196,603	439,856	31,789	668,249
I.2	Commercial and institutional buildings and facilities	411,312	126,818	9,165	547,295
I.3	Manufacturing industries and construction	1,471,768	473,258	34,203	1,979,229
I.4.1/2/3	Energy industries	IE	IE	IE	0
I.4.4	Energy generation supplied to the grid	32			
I.5	Agriculture, forestry and fishing activities	191,978	123,849	8,951	324,779
I.6	Non-specified sources	NO	NO	NO	0
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal	NO			0
I.8	Fugitive emissions from oil and natural gas systems	54,883			54,883
SUB-TOTAL	(city induced framework only)	2,326,544	1,163,781	84,109	3,574,434
II	TRANSPORTATION				
II.1	On-road transportation	4,231,388	1,344	97	4,232,830
II.2	Railways	9,533	3,796	274	13,603
II.3	Waterborne navigation	10,711	IE	626,250	636,961
II.4	Aviation	0	IE	864,370	864,370
II.5	Off-road transportation	IE	NO	IE	0
SUB-TOTAL	(city induced framework only)	4,251,632	5,140	1,490,991	5,747,763
III	WASTE				
III.1.1/2	Solid waste generated in the city	221,940		104,211	326,151
III.2.1/2	Biological waste generated in the city	NO		NO	0
III.3.1/2	Incinerated and burned waste generated in the city	NO		NO	0
III.4.1/2	Wastewater generated in the city	6,640		NO	6,640
III.1.3	Solid waste generated outside the city	NO			
III.2.3	Biological waste generated outside the city	NO			
III.3.3	Incinerated and burned waste generated outside city	NO			
III.4.3	Wastewater generated outside the city	NO			
SUB-TOTAL	(city induced framework only)	228,580		104,211	332,791
IV	INDUSTRIAL PROCESSES and PRODUCT USES				
IV.1	Emissions from industrial processes occurring in the city boundary	1,762,000			1,762,000
IV.2	Emissions from product use occurring within the city boundary	588,000			588,000
SUB-TOTAL	(city induced framework only)	2,350,000			2,350,000
V	AGRICULTURE, FORESTRY and OTHER LAND USE				
V.1	Emissions from livestock	558,770			558,770
V.2	Emissions from land	-1,313,386			-1,313,386
V.3	Emissions from aggregate sources and non-CO2 emission sources on land	260,844			260,844
SUB-TOTAL	(city induced framework only)	-493,772			-493,772
VI	OTHER SCOPE 3				
VI.1	Other Scope 3			NE	0
TOTAL	(city induced framework only)	8,662,984	1,168,922	1,679,311	11,511,216

* See Table 2-2 for the meaning of the colours of cells.

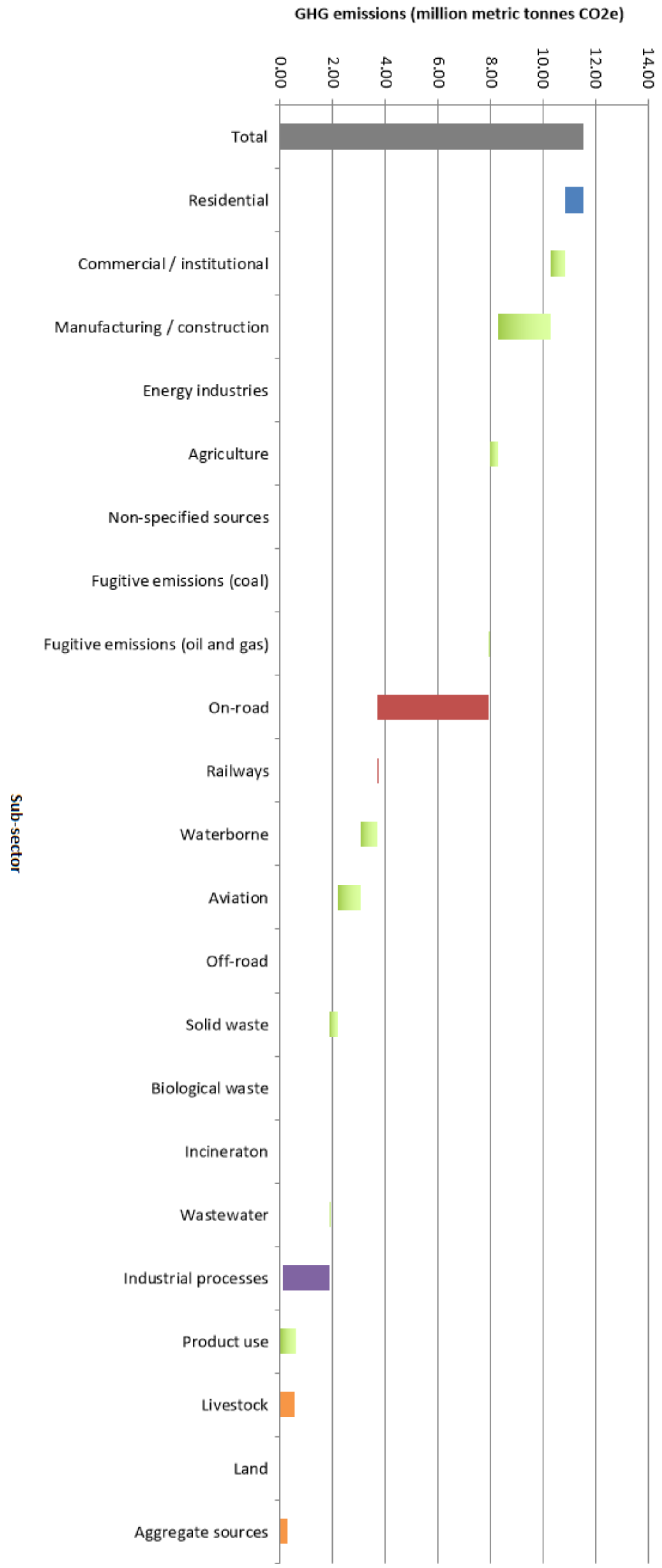


Figure A-1 Auckland's GHG emissions by sector and sub-sector for 2019

Table A-2 Comparison of emissions in 2018 between this inventory and previous inventory

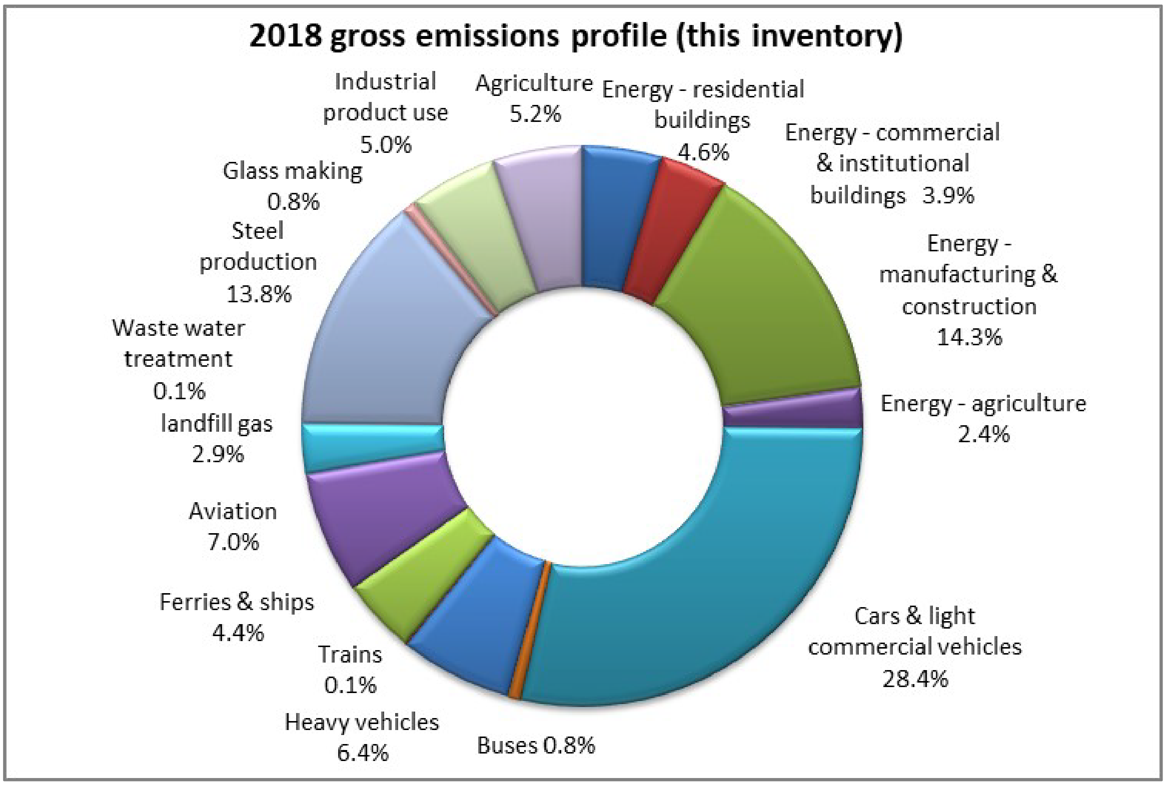
Emissions source	Emissions in 2018 ($ktCO_2e$)				% Change to previous inventory's		Reasons of emissions change
	Previous inventory (1)	This inventory	Change ($ktCO_2e$)	Change (%)	Gross emissions	Net emissions	
STATIONARY ENERGY							
Electricity	1,049.0	1,002.5	-46.5	-4.4%	-0.4%	-0.5%	Update of electricity use and emissions factors
Natural gas	1,015.2	944.5	-70.6	-7.0%	-0.6%	-0.7%	Update of gas use
LPG	142.3	265.4	123.1	86.5%	1.1%	1.2%	Use of Stats NZ customised data
Wood	21.5	21.5	0.0	0.0%	0.0%	0.0%	No change
Coal	148.5	849.3	700.8	471.8%	6.1%	6.9%	Use of Stats NZ customised data
Fuel for off-road transport	669.5	60.9	-608.5	-90.9%	-5.3%	-6.0%	Use of Stats NZ customised data
TRANSPORT							
Petrol (vehicles)	2,575.3	2,575.3	0.0	0.0%	0.0%	0.0%	No change
Diesel (vehicles)	1,807.4	1,807.4	0.0	0.0%	0.0%	0.0%	No change
LPG (vehicles)	2.3	2.3	0.0	0.0%	0.0%	0.0%	No change
Electricity (trains and vehicles)	4.6	5.5	0.9	19.2%	0.0%	0.0%	Add electricity vehicles (EVs)
Train (diesel)	8.5	9.2	0.8	8.9%	0.0%	0.0%	Update of diesel use
Ferry	35.1	10.4	-24.7	-70.3%	-0.2%	-0.2%	Use of Auckland Transport data
Aviation	350.8	860.6	509.8	145.3%	4.5%	5.0%	See note (2)
Shipping	160.3	530.7	370.5	231.2%	3.3%	3.6%	See note (3)
WASTE							
Solid waste disposal	329.5	351.9	22.4	6.8%	0.2%	0.2%	Add farm waste
Waste water treatment	6.6	6.6	0.0	0.0%	0.0%	0.0%	No change
INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)							
Industrial processes	1,773.2	1,789.0	15.8	0.9%	0.1%	0.2%	Use of Stats NZ customised data
Product use	655.7	619.0	-36.7	-5.6%	-0.3%	-0.4%	Use of Stats NZ customised data
AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)							
Livestock	509.0	510.5	1.5	0.3%	0.0%	0.0%	Add pigs and goats
Land	-1,313.4	-1,313.4	0.0	0.0%	0.0%	0.0%	No change

Aggregate sources and non-CO2 emission sources on land	247.3	248.7	1.5	0.6%	0.0%	0.0%	Move indirect N_2O from manure management here from "Livestock"
Gross emissions	11,395.7	12,355.6	959.9	8.4%	8.4%	9.4%	
Net emissions	10,197.9	11,157.8	959.9	9.4%	8.4%	9.4%	

(1) Previous inventory: *Auckland's greenhouse gas inventory to 2018* (Xie, 2020).

(2) Aviation emissions increase due to updating the proportion of emissions attributable to Auckland which was calculated based on the proportion of departure passengers who were Auckland residents. International and domestic departures were estimated from data from Stats NZ and Auckland Airport. This proportion was 17.4% for 2018 in the 2019 inventory, as compared to 7.1% in the 2018 inventory.

(3) Shipping emissions increase due to improving estimates of the proportion of emissions attributable to Auckland. In this inventory, export data at NZ shipping ports in tonnage was extracted from the Freight Information Gathering System (FIGS). This data was used to portion goods from Auckland of total export at ports of Auckland, therefore, to portion shipping emissions attributable to Auckland. This resulted in a proportion of 82.7% for 2018 in the 2019 inventory, as compared to 25.0% in the 2018 inventory where the proportion of export by values from Auckland to New Zealand was used to portion emissions attributable to Auckland.



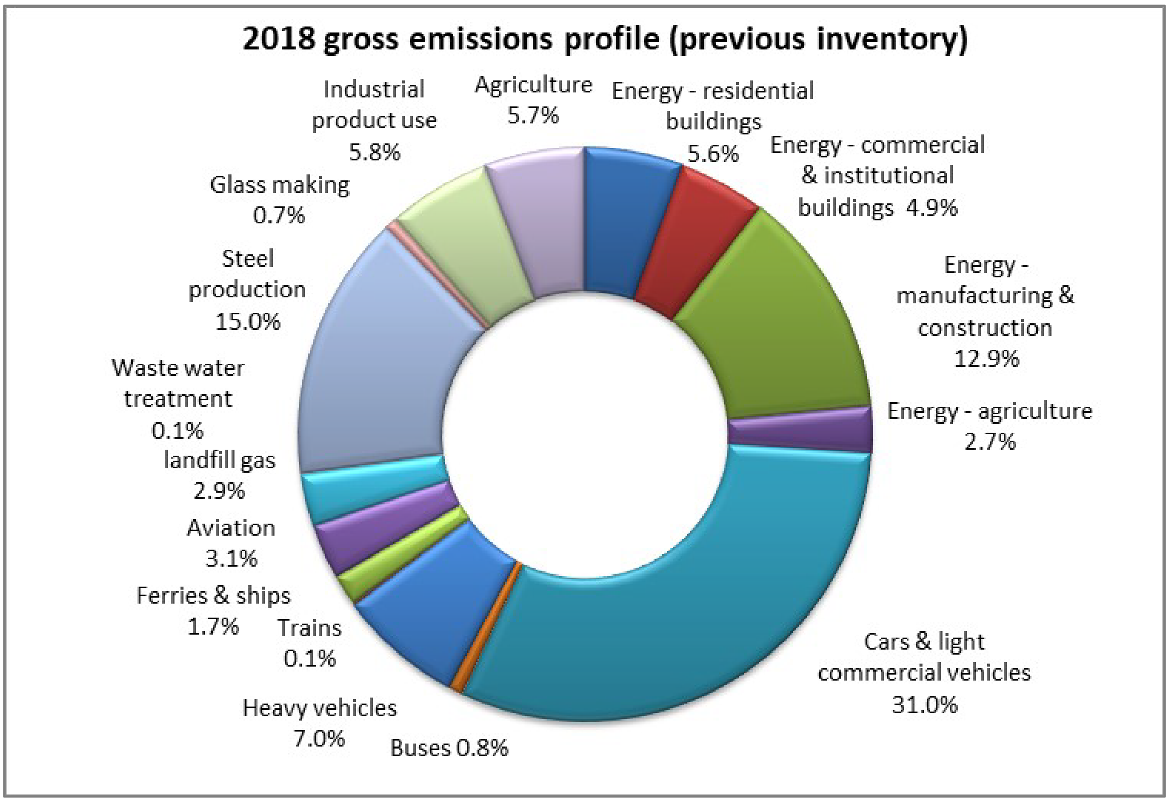


Figure A-2 Comparison of 2018 gross emissions profile between this inventory (top) and the previous inventory (bottom)

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