Auckland's Greenhouse Gas Inventory to 2021

Shanju Xie

October 2024

Technical Report 2024/7

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Environmental Evaluation and Monitoring Unit (EEMU)

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Executive summary

Te-Tāruke-ā-Tāwhiri: Auckland's Climate Plan sets the target of net zero emissions by 2050 with an interim emissions reduction target of 50 per cent by 2030 (against a 2016 baseline). An emissions inventory provided at a suitable frequency identifies and quantifies the most recent sources and sinks of greenhouse gas (GHG) emissions and trends. This provides a robust evidence base and essential data to evaluate impacts of mitigation actions, progress against the targets, frame further mitigation actions and inform future policy development. In addition, it provides input to the state of Auckland's environment reporting.

This inventory was prepared using the relevant international guidance and best practices, including the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)* which is a globally recognised standard consistent with IPCC guidelines.

Auckland's GHG inventory was first compiled for 2009, and the last release was for 2019. This current inventory reports GHG emissions and carbon removals within the Auckland region for the period 2009-2021. In 2021, Auckland's gross emissions were 10,757 kilo-tonnes of carbon dioxide equivalent (kt CO_2e) and when land and harvested wood products (HWPs) were included, net emissions were 9,559 kt CO_2e. Transport and stationary energy are the dominant sectors, accounting for 49.2 per cent and 22.6 per cent of gross emissions, respectively (Figure E-1). Carbon dioxide (CO_2) contributed 84.9 per cent, methane (CH_4) 8.1 per cent, nitrous oxide (N_2O) 2.9 per cent and other GHGs 4.1 per cent.

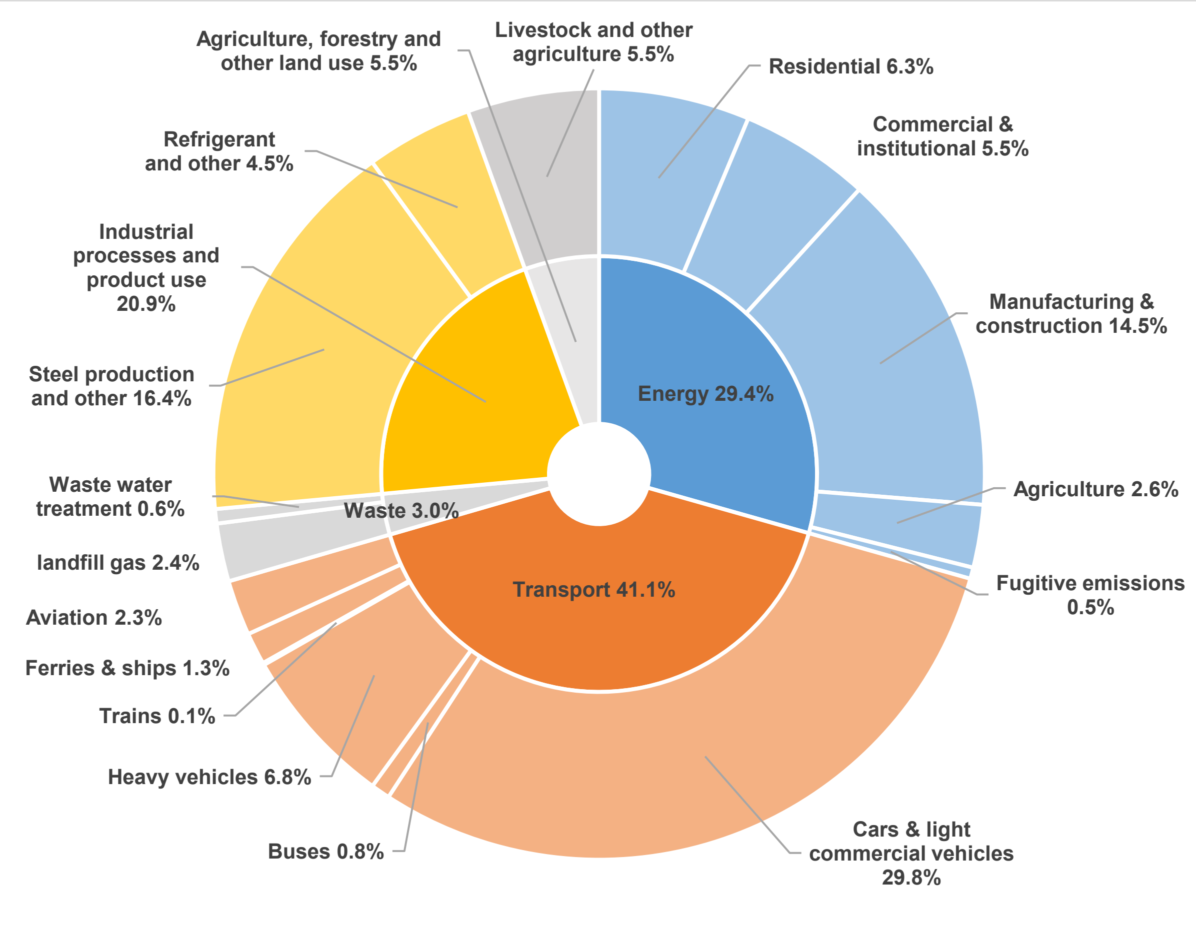

Figure E-1 Gross greenhouse gas emissions percentages in 2021 by sector and source

Gross and net emissions generally increased from 2009 to 2019, showed a marked drop from 2019 to 2020, then rebounded slightly from 2020 to 2021 (Figure E-2). This trend from 2019 to 2021 was largely driven by emissions from transport. COVID-19 restrictions were introduced in 2020 and were still in place in 2021. This reduced transport emissions markedly in 2020 and continued to have an impact in 2021.

Between 2016 and 2021, emissions decreased by 1,259 kt CO_2e (or 10.5 per cent and 11.6 per cent for gross and net emissions) and in 2021, were still well below pre-pandemic levels of 2019 (by 102 kt CO_2e, or 13.7 per cent and 15.2 per cent for gross and net emissions, respectively). The emissions profile shows that levels were lower from transport, waste, and livestock and other agriculture but higher from energy and Industrial processes and product use (IPPU). Emissions from land and HWPs were assumed unchanged between 2016 and 2021 due to lack of recent regional data.

In 2021, gross emissions were 6.3 t CO_2e per capita and 88 t CO_2e per million $NZ GDP (2020/2021 prices) while net emissions were 5.6 t CO_2e per capita and 78 t CO_2e per million $NZ GDP. From 2009 to 2021, there was a downward trend in both per capita emissions and emissions per unit GDP. This shows that emissions have not increased as fast as population and economic growth.

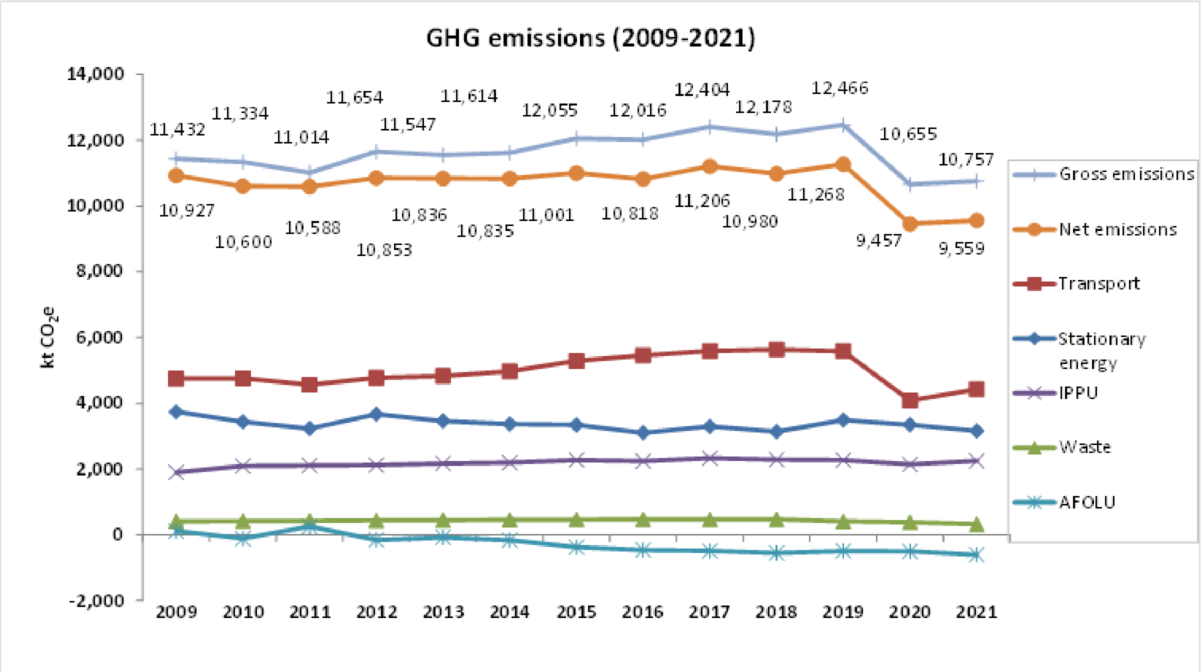

Figure E-2 Auckland's GHG emissions between 2009 and 2021

To achieve the target of halving 2016 emissions by 2030, a reduction of 4,150 kt CO_2e, or 43.4 per cent, of 2021 net emissions is required.

This inventory has been compiled with updated and more accurate activity data, emissions factors, and measurement methodologies and thereby has resulted in a change in historic emissions reported in previous years. Historic emissions from 2009 to 2019 have been updated to supersede all published previous inventories. Updated emissions in 2016 are higher than the previous baseline emissions used for the target setting. This will require additional reductions in emissions to meet the targets. Overall, the inventory update has a similar trend to the previous inventories.

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. In early 2023, the Auckland Anniversary floods and Cyclone Gabrielle caused widespread destruction across Tāmaki Makaurau. Repair and rebuild efforts are underway to recover from these devastating extreme weather events.

The *Auckland Plan 2050* sets the direction for how Auckland will grow and develop over the next 30 years (Auckland Council, 2018). 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 GHG 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 targets and increasing the region's resilience to climate change impacts. The plan sets the target of net zero emissions by 2050 with an interim emissions reduction target of 50 per cent by 2030 (against a 2016 baseline). Both targets are consistent with New Zealand national ambition. They contribute to the global effort, under the Paris Agreement, to limit global average temperature increase to 1.5 degrees Celsius above pre-industrial levels.

An emissions inventory provided at a suitable frequency 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 and *Te-Tāruke-ā-Tāwhiri: Auckland's Climate Plan's* annual progress report.

2 Methodology – the GPC

2.1 Guidance

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 maintain accurate, credible and comparable emissions accounting and reporting practices for cities' GHGs.

The GPC recommends annual update of inventories, as it provides a robust evidence base to evaluate impacts of mitigation actions and progress to achieve net zero emissions by 2050. Auckland's GHG inventories have been published since the year 2009. All annual GHG inventories prepared for Auckland have been reviewed by C40 and were included in the C40 emissions database (C40, 2023a).

This inventory was prepared using the GPC version 1.1 (WRI et al., 2021) for the period from 2009 to 2021, with input from the most recently available *New Zealand's Greenhouse Gas Inventory 1990-2021* (MfE, 2023). Emissions in 1990 were estimated in previous inventories but will not be included in this inventory or future inventories as only emissions trends in recent years are used to monitor and evaluate mitigation policy effectiveness, in addition, input data in 1990 was less accurate.

As in the inventory to 2019 (Xie, 2022), this inventory was prepared with the most up-to-date information and in line with the recommendations of the GPC. Updates of activity data, emission factors and methodology have been made for this inventory. Previously reported emissions from 2009 to 2019 (Xie, 2022) have been recalculated and superseded.

The land under the jurisdiction of Auckland Council is the geographic boundary of this inventory. For each year of emissions data reported in this inventory, the emissions account for a continuous period of 12 months. This report uses calendar year data wherever possible. 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, 2023). 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) over a time period. Individual GHGs are converted into CO_2e by multiplying the GWP values (over the 100-year time-horizon) in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). This is consistent with the most recent release of *New Zealand's Greenhouse Gas Inventory* (MfE, 2023) when this report was prepared.

Emissions are allocated into three scopes (Figure 2-1). 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 optional by the current GPC version 1.1 (WRI et al., 2021) and is not reported in this inventory due to insufficient data. Five main sectors are sub-divided into sub-sectors (see Table A-1).

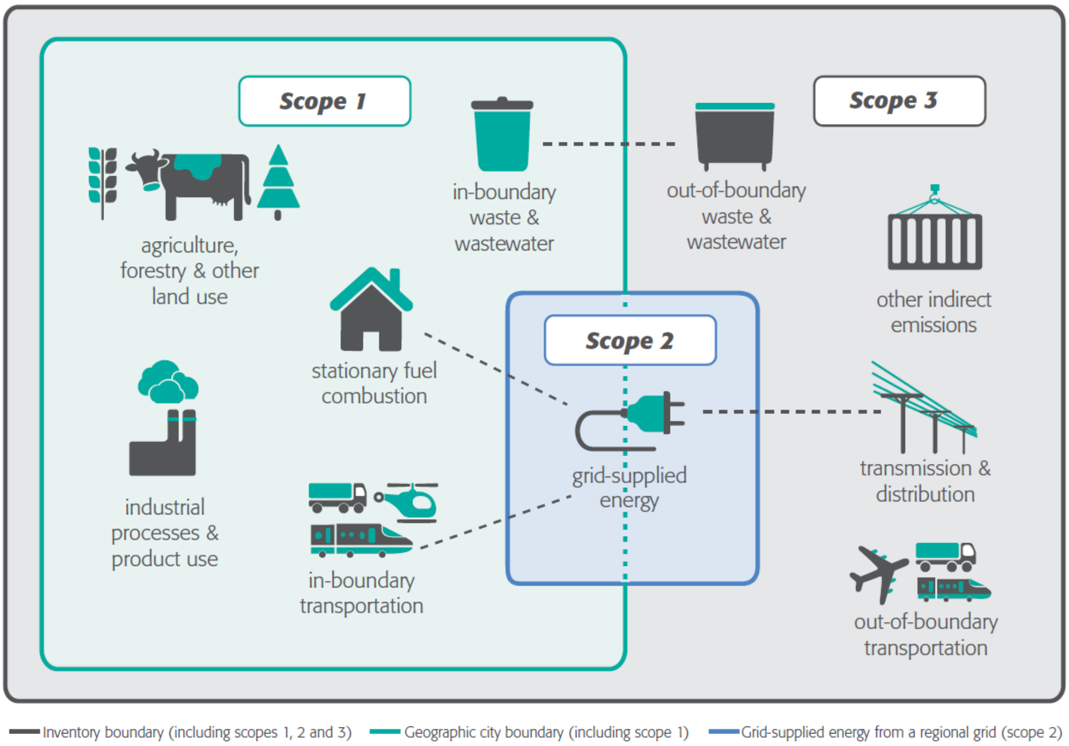

Figure 2-1 Sources and boundaries of city GHG emissions (WRI et al., 2021)

2.2 Information sources and data quality

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 used in the inventory is collected from a variety of sources and varies in quality, format, and completeness. For some sources, emissions data is directly provided by a third party. For others, depending on availability, activity data is either provided by data owners or estimated based on activity-related information. The detail is discussed in Chapter 4 and summarised in Table A-6. Latest available national emission factors are used in this inventory (MfE, 2022a, 2023; MBIE, 2022) when this report was prepared.

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.

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 where city/region-specific emission factors are used. Activity data that is estimated using robust assumptions or where more general emission factors are used (e.g., applied nationally) is rated as Medium (M). Low (L) is referred to highly modelled or uncertain activity data, or where default emission factors are used (e.g., those provided by IPCC guidance (IPCC, 2023)).

Under the GPC, 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 transportation. 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) (v2.5) (C40, 2023b) was used in the compilation of this inventory.

2.3 Updates to historic emissions

This inventory has been improved with updates to activity data, emission factors, and methodology. Historic emissions from 2009 to 2019 have been recalculated to supersede all published previous inventories. Overall, this inventory reports the same trend as the previous inventory (Figure A-1).

Table A-2 shows a comparison of 2016 gross emissions profile between this inventory and the previous 2016 inventory. Reasons of differences in emissions are summarised in Table A-4.

The improvements to data sources and methodology result in lower baseline (2016) emissions from electricity, wood, off-road transport, diesel, ferry, shipping, industrial product use, and livestock; and higher baseline emissions from LPG, coal, petrol, aviation, solid waste disposal, wastewater treatment, and industrial processes. Overall, this inventory reports 6.1% and 6.8% higher gross and net emissions in 2016.

Table A-3 shows a comparison of 2019 gross emissions profile between this inventory and the previous 2019 inventory. Reasons of differences in emissions are summarised in Table A-5. The update results in lower emissions from electricity, coal, off-road transport, aviation and industrial product use; and higher from LPG, ferry, solid waste disposal and wastewater treatment. Overall, this inventory reports 1.9% and 2.0% lower gross and net emissions in 2019.

3 Key findings

3.1 Emissions and sources (2021)

In 2021, Auckland's net GHG emissions were 9,559 kt CO_2e (BASIC+ emissions in Table 3-1). AFOLU contributes a negative value, indicating removal of emissions. Blank cells in Table 3-1 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 3-2 illustrates the GPC reporting requirements. As discussed earlier, reporting on Other Scope 3 is optional and not reported due to insufficient data.

Table 3-1 Emissions summary for 2021

GHG Emission Source (By Sector)		Total GHGs (metric tonnes CO_2-e)					
		Scope 1	Scope 2	Scope 3	BASIC	BASIC+	BASIC+ S3
Stationary Energy	Energy use (all emissions except I.4.4)	1,956,185	1,121,835	82,214	3,078,020	3,160,234	3,160,234
	Energy generation supplied to the grid (I.4.4)	32					
Transportation	(All II emissions)	4,042,696	5,815	376,317	4,048,511	4,424,829	4,424,829
Waste	Waste generated in the city (III.X.1 and IIIX.2)	234,716		82,991	326,707	326,707	326,707
	Waste generated outside city (III.X.3)						
IPPU	(All IV emissions)	2,251,428				2,251,428	2,251,428
AFOLU	(All V emissions)	-603,983				-603,983	-603,983
Other Scope 3	(All VI emissions)						
TOTAL		**7,890,074**	**1,127,651**	**541,222**	**7,453,238**	**9,559,215**	**9,559,215**

Table 3-2 Emission sources covered and reported by the GPC

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

New Zealand's greenhouse gas inventory reports gross emissions by excluding the contribution of the Land Use, Land Use Change and Forestry (LULUCF) sector from total emissions (i.e., net emissions) (MfE, 2023). While this is not a requirement of the GPC, gross and net emissions are presented in this inventory for consistency with the national reporting. LULUCF in the national inventory is reported as part of AFOLU in the GPC, i.e., the land sub-sector and harvested wood products (HWPs). AFOLU comprises three sub-sectors: livestock, land, and aggregate sources and non-CO_2 emission sources on land (i.e., other agriculture and HWPs) (section 4.5). To assist the reporting of gross and net emissions in this inventory, AFOLU is also disaggregated into two subsets: livestock and other agriculture, and land and HWPs.

Therefore, gross emissions are reported as net emissions exclusive of land and HWPs.

In 2021, Auckland gross emissions were 10,757 kt CO_2e. Figure 3-1 shows gross emissions by sector, sub-sector and source. More detailed emissions data is also presented Table A-1. Transport is the dominant contributor of gross emissions (accounting for 41.1 per cent), followed by Stationary Energy (29.4 percent), IPPU (20.9 percent), Waste (3.0 percent), and livestock and other agriculture (5.5 percent).

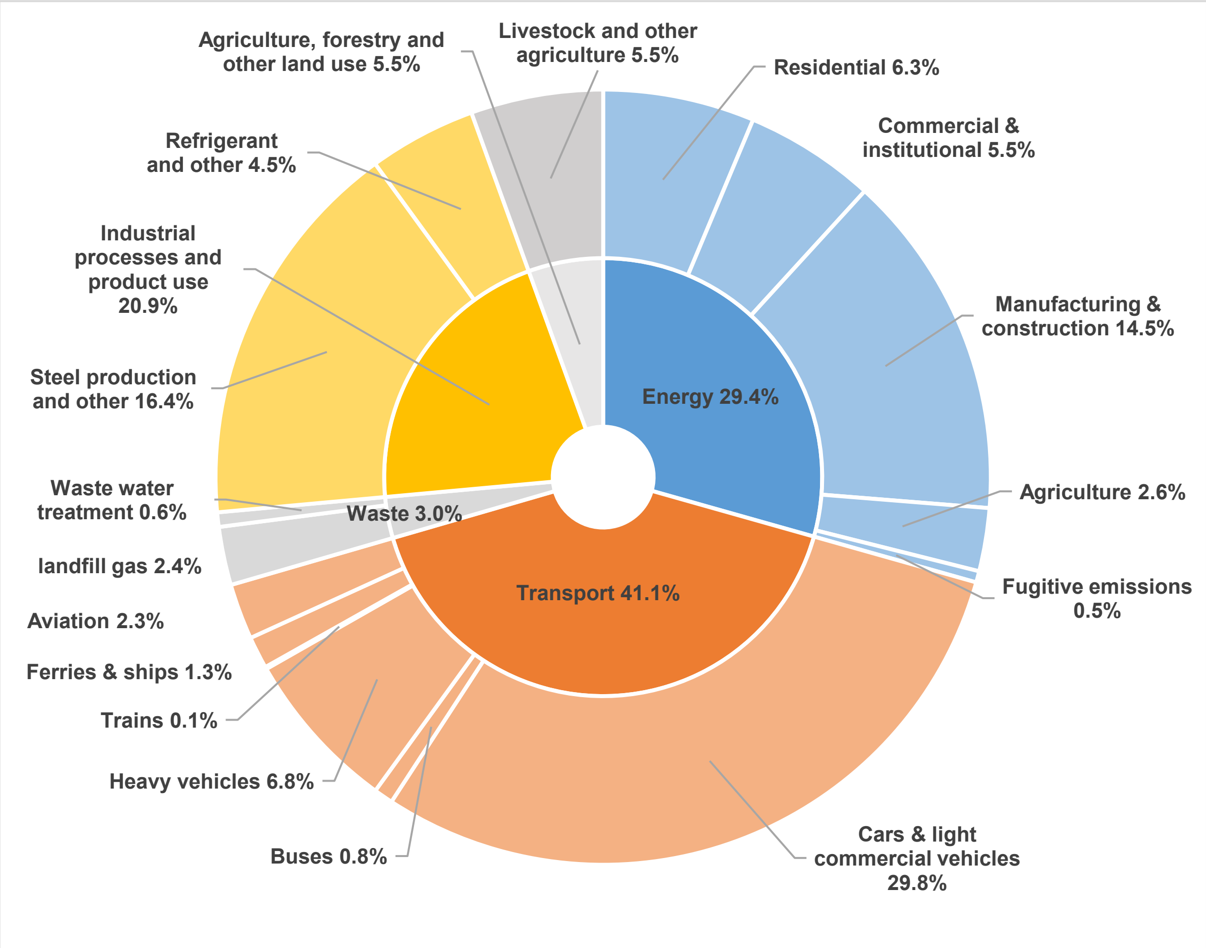

Figure 3-1 Gross greenhouse gas emissions percentages in 2021 by sector and source

Table 3-3 shows the gross emissions by gases. Carbon dioxide is the dominant GHG, making up around 84.9% of the gross emissions, followed by methane at 8.1% and then smaller proportion of other GHGs.

Table 3-3 Auckland's gross emissions by gas for 2021

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)	9,133	868	312	439	0	5	NO	10,757
% of gross emissions	84.9%	8.1%	2.9%	4.1%	0.0%	0.0%	NO	100.0%

3.2 Trends

This section discusses trends in emissions from various sectors between 2009 (first inventory year) and 2021 (current inventory), impacts of COVID-19 restrictions on recent emissions, as well as trends between 2016 (baseline year) and 2021. In all the comparisons, emissions from land use between 2016 and 2021 were assumed to be unchanged due to lack of regional data.

Between 2009 and 2021

Gross and net emissions generally increased from 2009 to 2019, showed a marked drop from 2019 to 2020, then rebounded slightly from 2020 to 2021 (Figure 3-2). Both emissions in 2020 and 2021 are lower than in 2009.

This trend in recent years (2020 and 2021) was largely driven by reduced emissions from transport during COVID-19 restrictions (discussed later in this section).

In 2012 and 2019, emissions from stationary energy are slightly higher. This is due to lower-than-normal rainfall leading to lower hydro generation and an increase in gas and coal generation (MBIE, 2021).

Between 2009 and 2016, emissions from IPPU gradually increase, due to higher emissions from the iron and steel production, and industrial product use, while emissions from waste sector are mostly steady. Between 2011 and 2016, increased carbon sequestration from forestry results in increased removals from AFOLU.

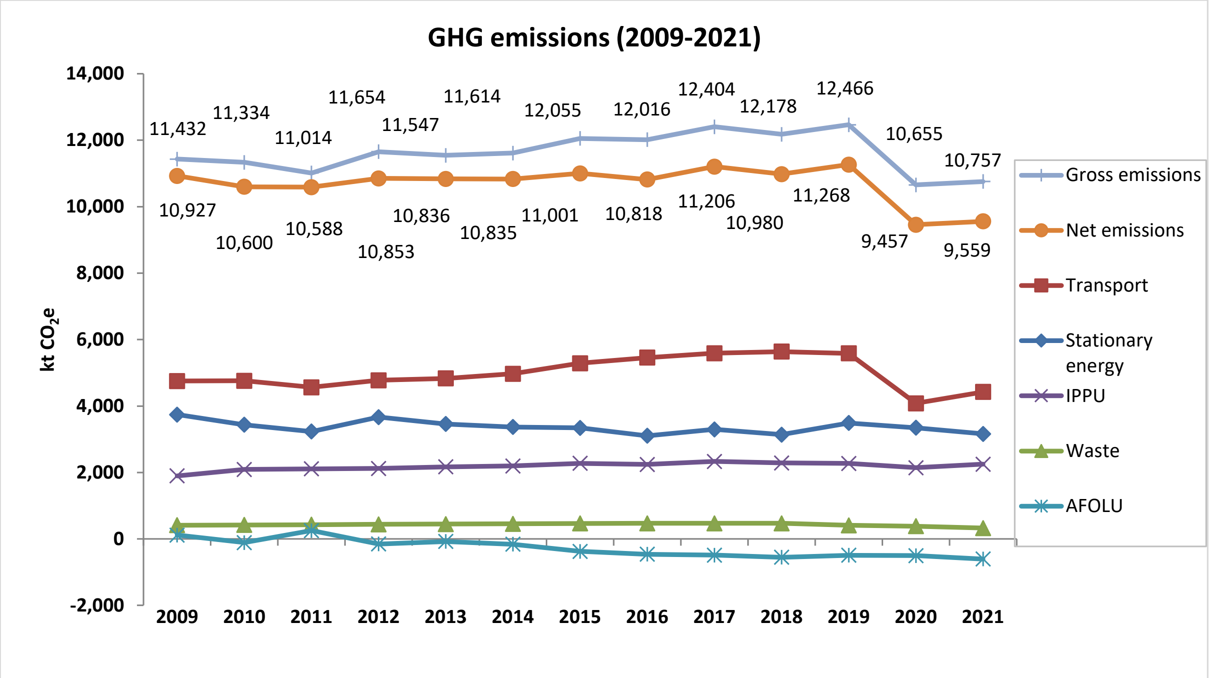

Figure 3-2 Auckland's GHG emissions from 2009 to 2021

Reduced emissions during COVID-19 restrictions

From pre-pandemic levels in 2019, emissions in 2020 decreased by 1,811 kt CO_2e (or 14.5 per cent and 16.1 per cent for gross and net emissions, respectively), largely driven by reduced emissions from transport during COVID-19 restrictions (Figure 3-3). Emissions were lower from energy, transport, waste, IPPU, and livestock and other agriculture, except land and HWPs.

Compared to 2020, emissions in 2021 slightly increased by 102 kt CO_2e (or 1.0 per cent and 1.1 per cent for gross and net emissions, respectively) (Figure 3-3). Emissions were higher from transport and IPPU sectors, and slightly lower from energy, waste and agriculture sources. The rebound in emissions reflect an increase in on-road traffic volumes and industrial activities.

Overall, COVID-19 restrictions reduced emissions markedly in 2020 and continued to have an impact in 2021. Emissions in 2021 were still well below 2019 levels (by 102 kt CO_2e, or 13.7 per cent and 15.2 per cent for gross and net emissions, respectively).

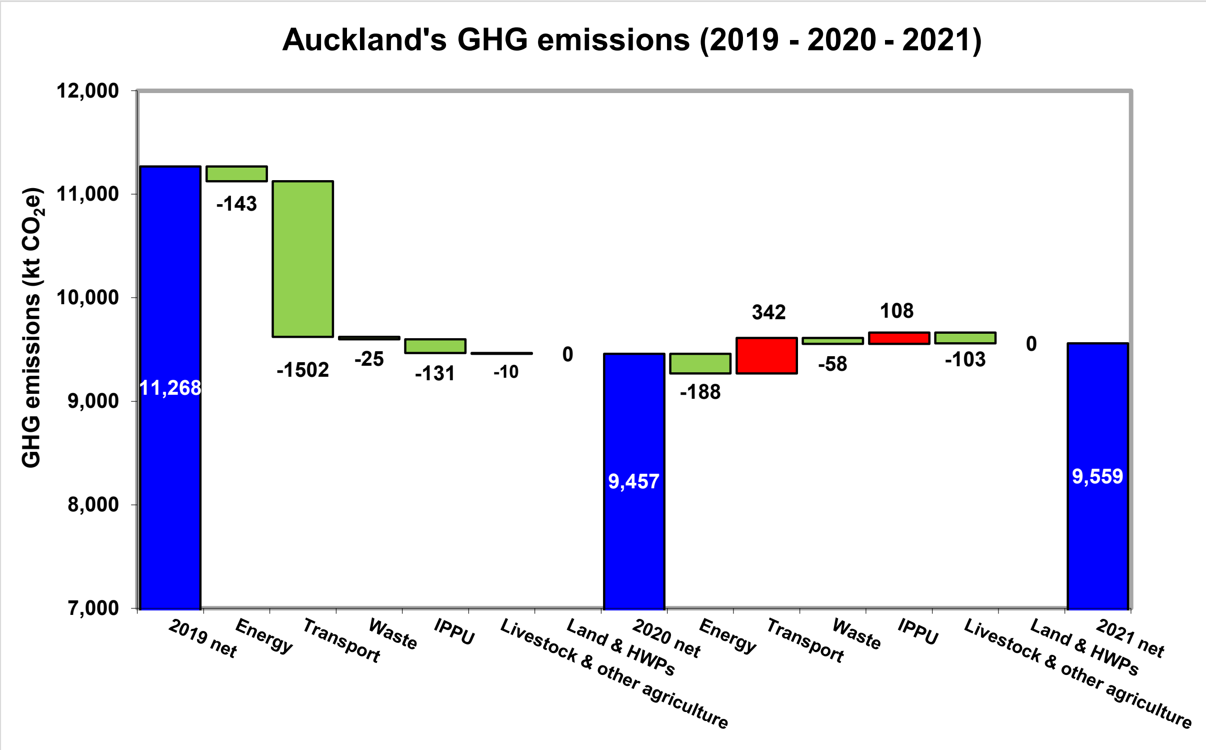

Figure 3-3 Auckland's GHG emissions between 2019 and 2020, 2020 and 2021

Between 2016 and 2021

Between 2016 and 2021, emissions decreased by 1,259 kt CO_2e (or 10.5 per cent and 11.6 per cent for gross and net emissions) (Figure 3-4). As discussed earlier, the drop in emissions was due to COVID-19 restrictions. Emissions were lower from transport, waste, and agriculture and higher from energy and IPPU. To achieve the target of halving 2016 emissions by 2030, a reduction of 4,150 kt CO_2e, or 43.4 per cent, of 2021 net emissions is required.

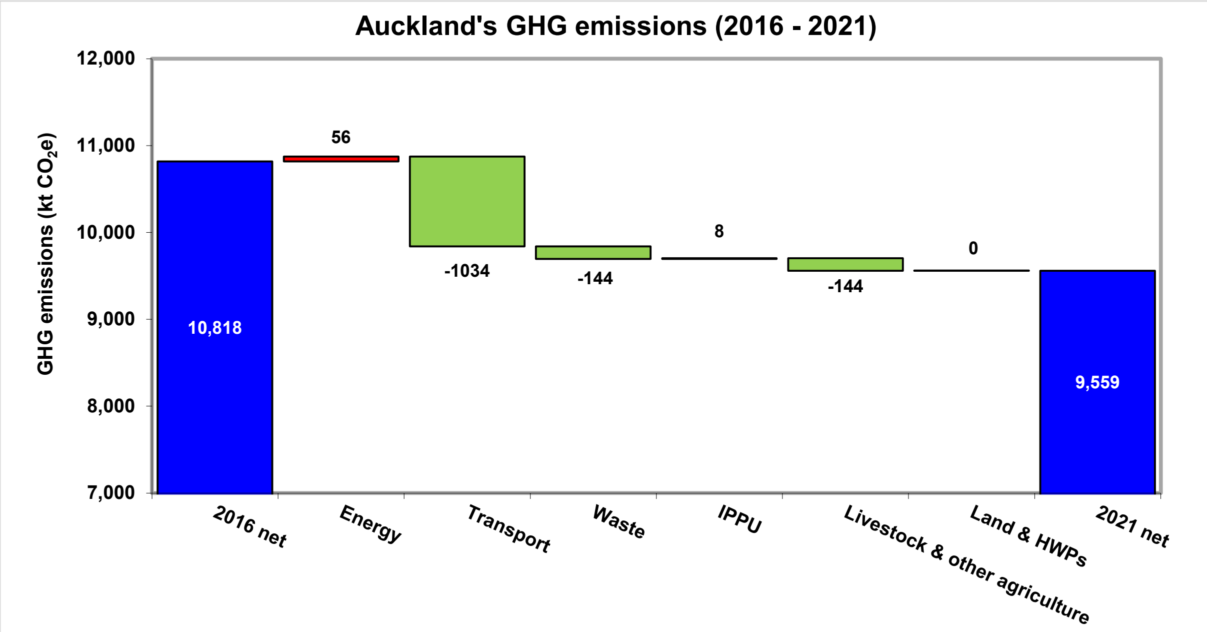

Figure 3-4 Auckland's GHG emissions between 2016 and 2021

4 Sectoral analysis

4.1 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 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.

4.1.1 Emissions from stationary energy

Emissions from stationary energy are summarised in Figure 4-1. In 2021, total emissions were 3,160 kt CO_2e, with majority (66.7 %) of emissions from consumption of electricity and natural gas, followed by coal (18.3 per cent), LPG (11.8 per cent), fuel for off-road transport (2.6 per cent), and wood (0.7 per cent) (Figure 4-1). Emissions from electricity, mainly from burning coal and natural gas to generate electricity, are all occurred outside Auckland.

Looking at sub-sector distribution, nearly half (49.3 per cent) of all emissions came from manufacturing industries and construction, 21.5 per cent from residential buildings; 18.6 per cent from commercial and institutional buildings and facilities; 9.0 per cent from agriculture, forestry, and fishing activities; and 1.6 per cent from natural gas transport and distribution (T&D) losses (i.e., fugitive emissions).

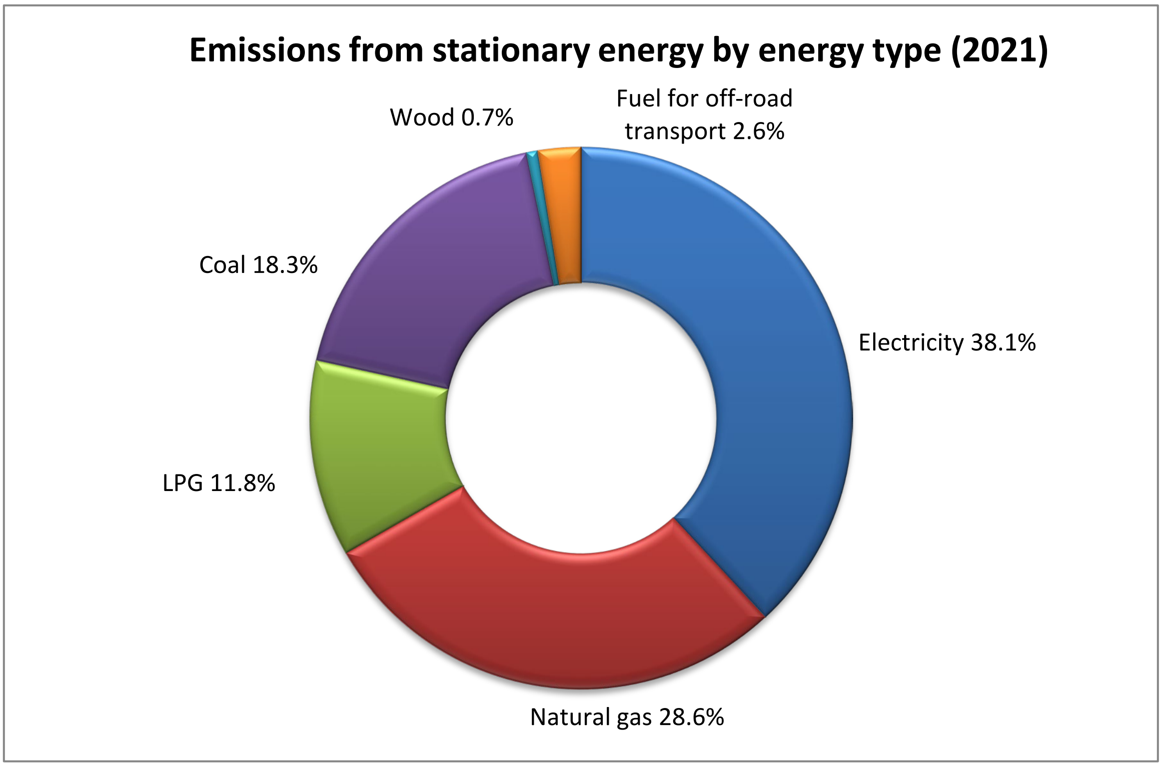

Figure 4-1 Emissions from stationary energy by energy type for 2021

4.1.2 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, LPG, coal, wood, petrol, diesel and fuel oil).

The total amount of natural gas consumption in Auckland was estimated from various sources (MBIE, 2022; Vector Ltd, 2022; MfE, 2023). Its allocation to sub-sectors was calculated based on two datasets: Stats NZ's emissions data for Auckland (Stats NZ, 2022a) and industrial emissions data (Atkins, 2018). 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.

The two datasets (Stats NZ, 2022a and Atkins 2018) were also used to estimate emissions (total and sub-sectors) from LPG, coal, diesel, petrol and fuel oil for stationary and off-road transport sources.

Emissions from wood were estimated from the Auckland air emissions inventory (Metcalfe, et. al., 2018) and industrial emissions data (Atkins, 2018). CO_2 emissions from wood burning were reported as biogenic, which were not included in total emissions. CH_4 and N_2O emissions from wood burning were included in total emissions.

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 from landfill gas flaring were reported in the Waste sector (section 4.3).

4.1.3 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. There is no grid supply of heating or cooling from outside Auckland and therefore only emissions associated with grid-supplied electricity are reported.

Electricity consumption was sourced from various organisations (Vector Ltd, 2022; Counties Power Ltd, 2022; NZEA, 2022). Allocation of electricity consumption into sub-sectors was based on Vector Ltd data (Vector Ltd, 2022). 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 (section 4.2).

4.1.4 Scope 3: distribution losses from grid-supplied energy

Scope 3 emissions include transmission and distribution losses from the use of grid-supplied electricity.

4.2 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 used for transporting vehicles (e.g. trains) 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.

4.2.1 Emissions from transport

Emissions from transport are summarised in Figure 4-2. In 2021, on-road transport accounted for 90.3 per cent of total 4,425 kt CO_2e emissions from transport (Figure 4-2). Contributions from other sources were 5.6 per cent from aviation, 3.3 per cent from ferries and ships, and 0.2 per cent from trains.

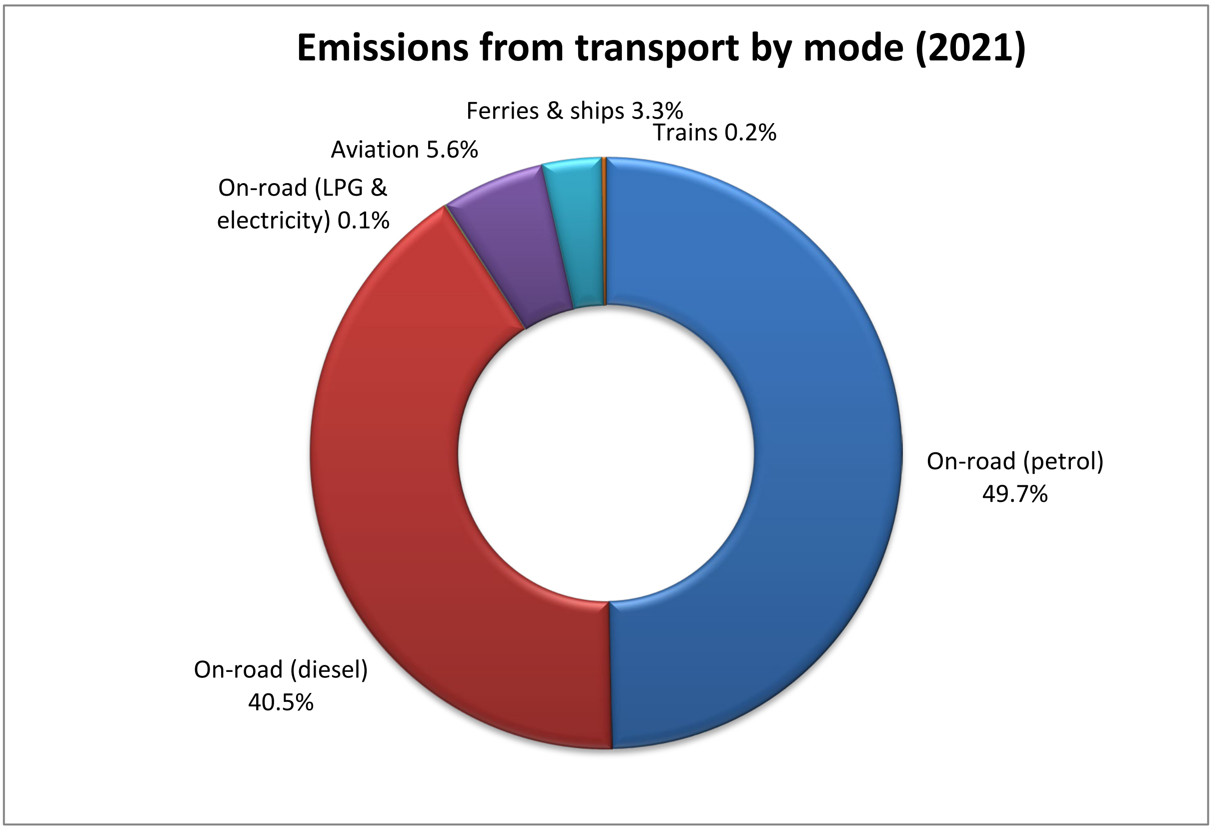

Figure 4-2 Emissions from stationary energy by energy type for 2021

4.2.2 On-road transport

Petrol and diesel sales within Auckland region are provided by Auckland Transport and based on the local authority fuel tax reports (Auckland Transport, 2022). The data was used to calculate emissions from on-road transport. The results were included in Scope 1 emissions.

LPG and electricity use was sourced from Ministry of Transport (MoT, 2022a). Diesel and electricity consumption by buses was provided by Auckland Transport (2022). The split of on-road emissions into heavy vehicles, buses, and cars and light commercial vehicles (Figure 3-1) were based on the 2016 emissions report (Auckland Council, 2020).

4.2.3 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). Diesel and electricity consumption for passenger trains was provided by Auckland Transport (2022). Diesel use by freight trains from 2012 to 2021 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, 2022b). The fuel burn rate was converted from the emissions rate (in gCO_2e/t-km) provided by KiwiRail (KiwiRail, 2021). Diesel use by rail freight for previous years (2009 to 2011) was estimated by scaling national consumption. Emissions from diesel and electricity were reported in Scopes 1 and 2, respectively.

4.2.4 Water transport

Emissions from diesel consumption on ferries were provided by Auckland Transport (2022) and reported in Scope 1.

Auckland Transport provided the total amount of fuel oil used to refuel ships at seaports from 2012 to 2021. Average ratio of fuel oil consumption in Auckland to the national total over the period of 2012 to 2021 was used to estimate consumption for other years (2009-2011).

Emissions from shipping were reported in Scope 3. Export data at NZ shipping ports in tonnage was extracted from the Freight Information Gathering System (FIGS) (MoT, 2022b). This data was used to portion goods of total export at ports of Auckland, to estimate shipping emissions attributable to Auckland.

4.2.5 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 (Section 4.1.3). 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 (2022b) and Auckland Airport (2022). The Joint User Hydrant Installation (JUHI) Depot provided aviation fuel consumption at Auckland Airport.

4.2.6 Off-road transport

Emissions from fuels for off-road transport were estimated and reported under Stationary Energy (section 4.1).

4.3 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.

4.3.1 Emissions from waste

Emissions from waste are summarised in Table A-1. The waste sector emitted 327 kt CO_2e, with 80.1 per cent from solid waste sources and 19.9 per cent from wastewater treatment.

4.3.2 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, 2022a) are derived from the IPCC 2006 "tier 1" methodology (IPCC, 2023) 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)).

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. Emissions from farm fills and rural waste were provided by Stats NZ (2022a).

4.3.3 Wastewater treatment and discharge

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 plants. Emissions from wastewater treatment and discharge in Auckland were sourced from Watercare's carbon footprint reporting (Watercare Services Ltd, 2022).

4.4 Industrial Processes and Product Use (IPPU)

Emissions from non-energy related industrial processes 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.

4.4.1 Emissions from IPPU

Emissions from IPPU are summarised in Table A-1. The majority of the emissions came from Industrial Processes (1,768 kt CO_2e, 78.5 percent) and followed by Industrial Product Use (483 kt CO_2e, 21.5 per cent).

4.4.2 Industrial processes

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, 2023). Production of steel and iron results in CO_2 emissions. Other industrial processes include the glass production from Visy Glass Operations (NZ) Limited.

Total emissions from industrial processes were provided by Stats NZ (2022a) for 2009-2020. Emissions for 2021 were estimated as the sum from the iron and steel production and from the glass production. They were sourced from *New Zealand's Greenhouse Gas Inventory* (MfE, 2023).

4.4.3 Industrial product use

GHGs are emitted from lubricants and paraffin waxes used in non-energy products, fluorinated gases used in electronics production, and fluorinated gases used as substitutes for ozone depleting substances. Total CO_2e emissions from industrial product use were provided by Stats NZ (2022a) for 2009-2021. The reported proportion of CO_2, N_2O, HFCs, PFCs and SF_6 was the same as in *New Zealand's Greenhouse Gas Inventory* (MfE, 2023).

4.5 Agriculture, Forestry and Other Land Use (AFOLU)

AFOLU activities are divided into three categories: livestock, land, and aggregate sources and non-CO_2 emission sources on land. GHGs consist of CH_4, N_2O and CO_2, and are reported as Scope 1 emissions. As discussed in section 3.1, to assist the reporting of gross and net emissions, AFOLU is also disaggregated into two subsets: livestock and other agriculture, and land and HWPs.

4.5.1 Emissions from AFOLU

Emissions from the AFOLU sector in 2021, are summarised in Table A-1. Emissions from livestock and other agriculture were estimated to be 594 kt CO_2e. Emissions from land and HWPs was –1,198 kt CO_2e, resulting in AFOLU emissions of –604 kt CO_2e. The removal is expressed as a negative value to clarify that the value is a removal and not an emission.

4.5.2 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 (i.e., direct N_2O emissions from manure management). The number of livestock (dairy cattle, non-dairy cattle, sheep, deer, pig, goat and horse) in Auckland was sourced from Statistics New Zealand (Stats NZ, 2022b).

4.5.3 Land

Land use is divided into six broad 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 of net stocked forest area was provided by the Ministry for Primary Industries. The results for 1990-2016 were reported in the previous inventory (Xie, 2022). Due to lack of forest harvesting statistics for Auckland, modelling for 2017-2021 was not undertaken. Therefore, emissions and removals were assumed unchanged from 2016 to 2021.

4.5.4 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 and indirect N_2O from managed soils, and indirect N_2O from manure management) and HWPs.

Other agriculture

CO_2 and N_2O emissions from liming, urea application, direct and indirect N_2O from managed soils were estimated based on national emissions (MfE, 2023) allocated to Auckland based on the proportion of cropland and grassland to the national total. The land use data (cropland and grassland) was sourced from the Land Use Carbon Analysis System (LUCAS) New Zealand Land Use Map (MfE, 2022b). 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 minor and not included in this inventory.

Harvested wood products (HWPs)

As for the land sub-sector, changes of carbon stocks in the HWPs pool were provided by Ministry for the Environment for 2009-2016. This was calculated by using a simplified version of the national methodologies with some Auckland-specific activity data. Changes of carbon stocks were assumed unchanged from 2016 to 2021.

Overall, emissions from the AFOLU sector are shown from 2009 to 2021 in Figure 4-3.

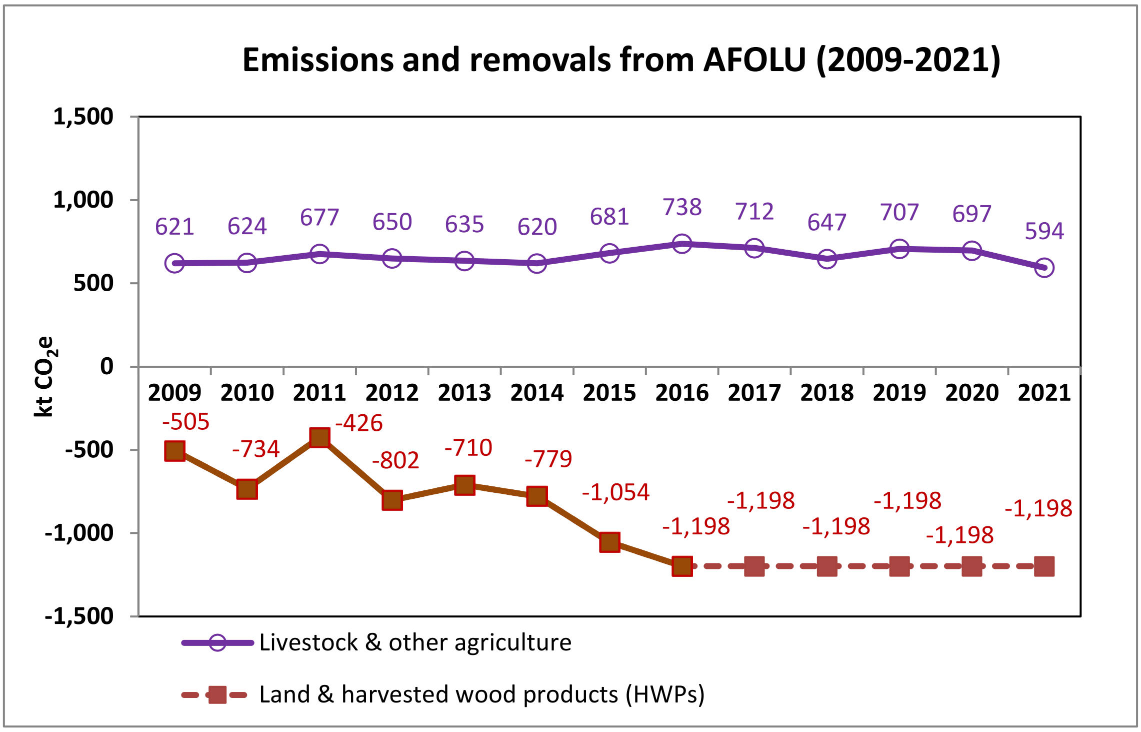

Figure 4-3 Emissions and removals from livestock and other agriculture, and land and HWPs from 2009 to 2021

5 Discussion

5.1 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 useful indicators for tracking progress on climate actions. From 2009 to 2021, Auckland's population increased from 1.4 million to 1.7 million (Stats NZ, 2022b) and GDP increased from $NZ 87.9 billion to $NZ 122.5 billon (2020/2021 prices) (Infometrics, 2022). Population, GDP and emissions are compared in Figure 5-1. In 2021, gross emissions were 6.3 t CO_2e per capita and 88 t CO_2e per million $NZ GDP while net emissions were 5.6 t CO_2e per capita and 78 t CO_2e per million $NZ GDP.

Figure 5-2 shows the emission intensity by population and GDP. The emission intensity generally decreased since 2009, suggesting Auckland's emissions have not increased as fast as population and economic growth. The marked drop in emissions per capita and per unit GDP in 2020 and 2021 as compared to 2019 is due to COVID-19 restrictions.

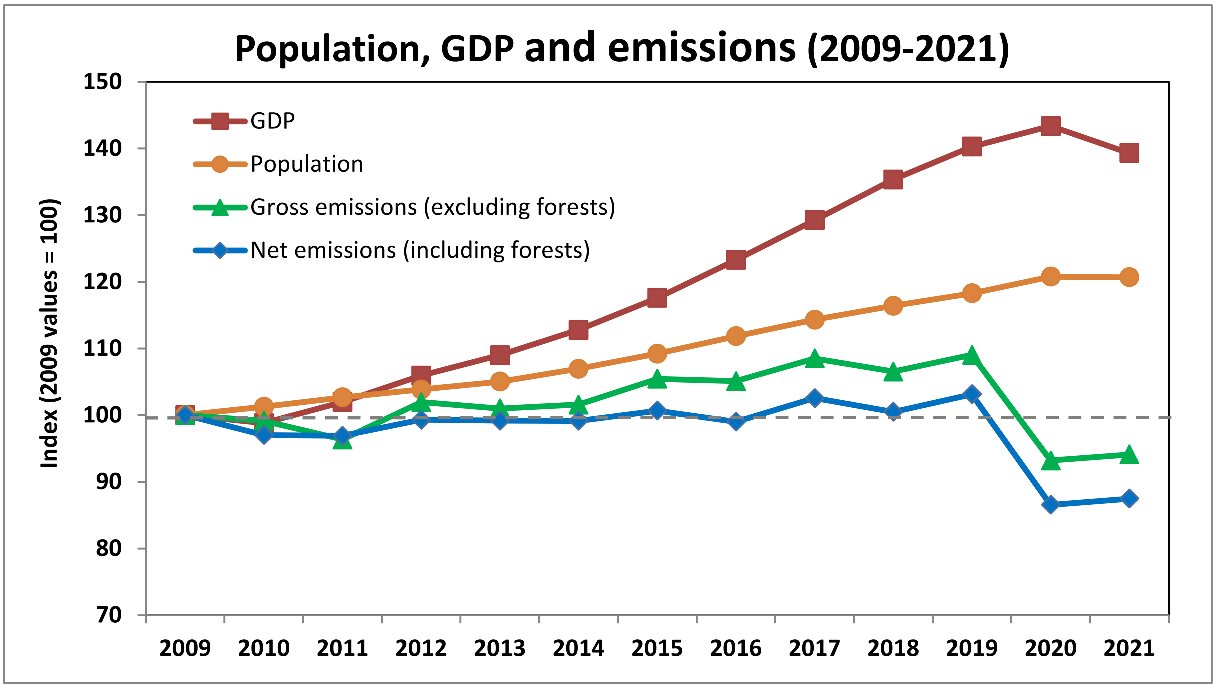

Figure 5-1 Auckland's population, GDP and GHG emissions from 2009 to 2021

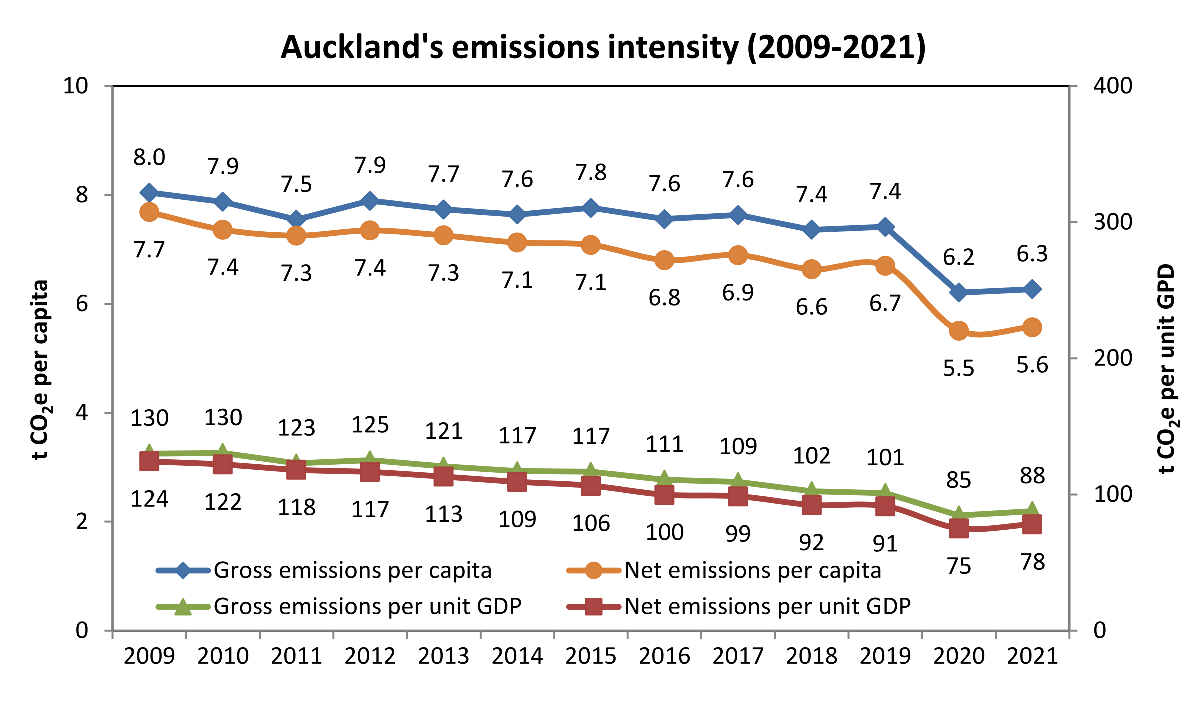

Figure 5-2 Auckland's emissions intensity from 2009 to 2021

5.2 Impact of 2016 baseline update on achieving the emission target

The target of net zero emissions by 2050 with an interim emissions reduction target of 50 per cent by 2030 was set against a 2016 baseline which was reported in *Auckland's greenhouse gas inventory to 2016* (Xie, 2019). Emissions in 2016 in this inventory are higher than those reported in the previous 2016 inventory, by 690 kt CO_2e or 6.8 per cent. This requires an additional 345 kt CO_2e to be reduced to meet the interim 2030 target. This demonstrates the importance of maintaining an annual inventory update which reflect the latest information available. This informs the timely development and update of effective mitigation strategies, policy and actions which are necessary for Auckland to meet its targets.

5.3 Comparison with national Inventory

Identifying differences in emissions profiles between Auckland and New Zealand helps develop mitigation actions to address major sources in Auckland. Figure 5-3 shows that the emission distribution within various sectors for New Zealand is different to Auckland profile. In 2021, New Zealand's gross emissions were dominated by agriculture (49.2%), transport (18.0%) and energy (22.6%) sectors (MfE, 2023). Comparatively, in Auckland, transport and energy were the dominant sectors in 2021, together accounting for 70.5 per cent of gross emissions, following by IPPU at 20.9%.

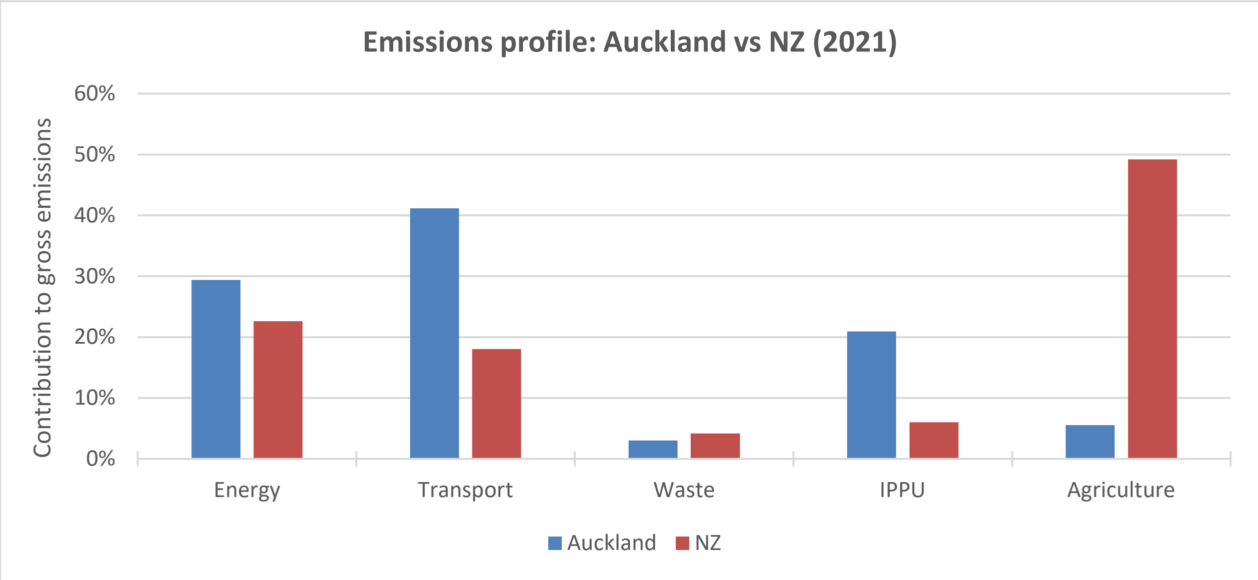

Figure 5-3 A comparison of emissions profiles between Auckland and NZ. For Auckland, Agriculture includes livestock and other agriculture.

Although different sectoral profiles, Auckland's gross emissions largely tracked a similar trend to national emissions for 2009-2021 (MfE, 2023) (Figure 5-4, emissions were indexed back to 2009). In Auckland, the increase in gross emissions between 2009 and 2019 was relatively faster and mainly driven by transport and IPPU sectors. A bigger drop between 2019 and 2020 and a small rebound between 2020 and 2021 are due to the dominance of the transport sector for Auckland emissions profile. Work is ongoing to further understand Auckland's emissions trends and driving factors for evaluating progress of Auckland's climate plan.

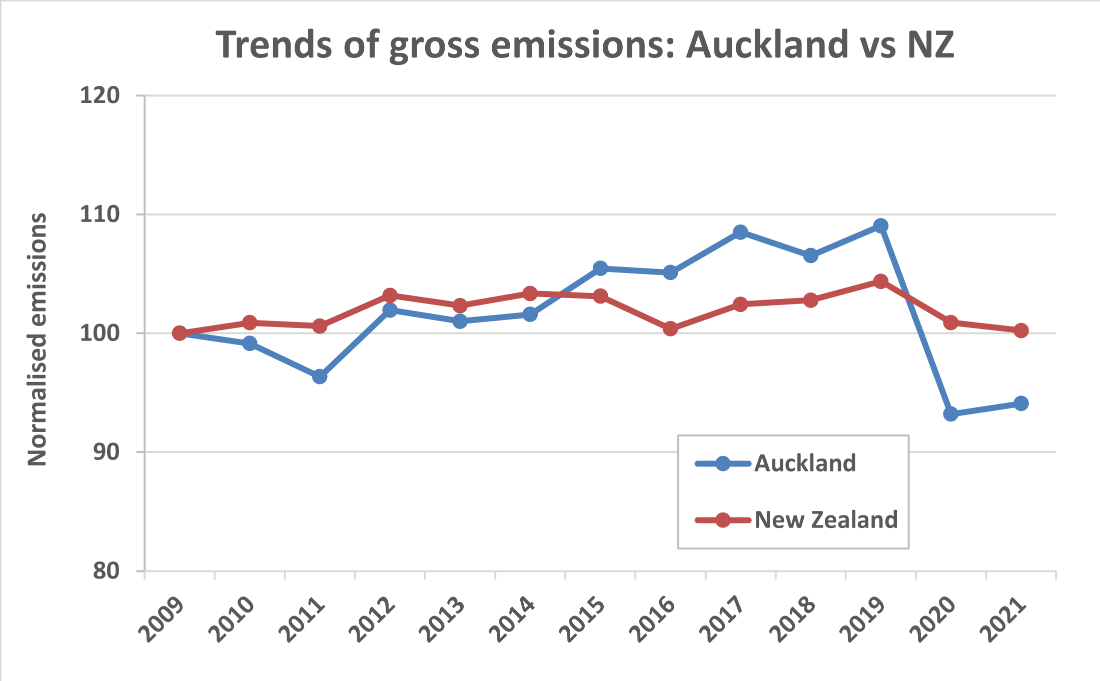

Figure 5-4 Trends of gross emissions: Auckland vs New Zealand (2009-2021)

5.4 Comparison with Stats NZ regional emissions

Stats NZ (2022a) reported Auckland's GHG emissions for 2007-2021 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. Nevertheless, it is still useful to compare the two datasets to ensure that the differences can be justified by the difference in methodology.

Table 5-1 presents a comparison of this inventory with Stats NZ emissions data in 2020. Both datasets show a similar emissions profile. This inventory reports higher emissions from Energy (Stationary energy and Transport) as consumption of grid-electricity is included and lower emissions from Waste as the recovery rate of landfill gas is higher in Auckland than national average (used in Stats NZ estimates). This gives confidence that this inventory provides an accurate account of emissions in

Auckland. Based on the SEEA framework, Auckland contributed 12.4 per cent to national gross emissions in 2021 (Stats NZ, 2022a).

Table 5-1 Auckland's gross emissions by sector for 2020 vs Stats NZ data

Sector		Stationary energy	Transport	Waste	Industrial processes and product use (IPPU)	Agriculture	Gross emissions
This inventory (2020)	CO_2e (kt)	3,348	4,082	384	2,143	697	10,655
	% of gross emissions	31.4%	38.3%	3.6%	20.1%	6.5%	100.0%
Stats NZ (2020)*	CO_2e (kt)	6,305		627	2,142	723	9,797
	% of gross emissions	64.4%		6.4%	21.9%	7.4%	100.0%

* 2020 is the most recent year with emissions disaggregated in these sectors by Stats NZ (2022a)

6 Limitations

The input data of this inventory came from various organisations. Emissions data and activity data were collected where available. Activity data of some emissions sources were calculated based on activity-related information. Work is in progress to fill in existing gaps where possible. These include:

- Emissions and removals of land and HWPs are assumed unchanged from 2016 to 2021 due to lack of recent regional data.
- There is a need to gather more updated information as well as improve data quality of some estimated activity data, for example, coal consumption, energy use by off-road transport, allocation of energy consumption into sub-sector (residential, commercial, industrial and agriculture).
- The apportionment of on-road emissions by vehicle class (heavy, light, bus) is based on a 2016 emissions report.

7 Conclusions

Concluding findings of the inventory are as follows:

- In 2021, Auckland's gross and net emissions were 10,757 kt CO_2e and 9,559 kt CO_2e, respectively. Carbon dioxide (CO_2) contributed 84.9 per cent of gross emissions. Transport and stationary energy dominated emissions, accounting for 49.2 per cent and 22.6 per cent of gross emissions, respectively.

- Between 2009 and 2021, gross and net emissions generally increased from 2009 to 2019, markedly dropped from 2019 to 2020, then slightly recovered from 2020 to 2021. This trend was largely driven by emissions from transport.

- Emissions in 2021 were well below pre-pandemic levels in 2019 (by 102 kt CO_2e, or 13.7 per cent and 15.2 per cent for gross and net emissions, respectively). Between the baseline year 2016 and 2021, emissions have decreased by 1,259 kt CO_2e (or 10.5 per cent and 11.6 per cent for gross and net emissions). In 2020 and 2021, emissions have been lowest since 2009. This drop in 2020 and 2021 was due to COVID-19 restrictions.

- Compared to baseline year 2016, emissions in 2021 were lower from transport, waste, and livestock and other agriculture but higher from energy and IPPU. Land and HWPs were assumed unchanged between 2016 and 2021 due to lack of regional data.

- In 2021, gross emissions were 6.3 t CO_2e per capita and 88 t CO_2e per million $NZ GDP (2020/2021 prices) while net emissions were 5.6 t CO_2e per capita and 78 t CO_2e per million $NZ GDP. Emissions per capita or per unit GDP broadly decreased from 2009. This shows that emissions have not increased as fast as population and economic growth.

- To achieve the target of halving 2016 emissions by 2030, a reduction of 4,150 kt CO_2e, or 43.4 per cent, of 2021 net emissions is required.

8 Acknowledgements

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New Zealand Steel: Alan Eyes

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, Glenn Conley

9 References

Atkins, M. (2018). Process heat emissions & energy use in the Auckland Region. Report prepared by Energy Research Group, University of Waikato for Auckland Council.

Auckland Airport (2022). Monthly traffic updates and Annual Reports, retrieved on 15 December 2022 from https://www.aucklandairport.co.nz

Auckland Council (2018). Auckland Plan 2050, retrieved on 25 August 2023 from https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/auckland-plan/Pages/default.aspx

Auckland Council (2020). Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan, retrieved on 25 August 2023 from https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/aucklands-climate-plan/Documents/auckland-climate-plan.pdf

Auckland Transport (2022). Annual reports and other information, retrieved on 20 August 20220 from https://at.govt.nz and personal communications

C40 (C40 Cities Climate Leadership Group) (2023a). Auckland's GHG emissions, retrieved on 21 August 2023 from https://www.c40knowledgehub.org/s/article/C40-cities-greenhouse-gas-emissions-interactive-dashboard?language=en_US

C40 (C40 Cities Climate Leadership Group) (2023b). City Inventory Reporting and Information System (CIRIS) (v2.5), retrieved on 7 May 2023 from https://resourcecentre.c40.org

Counties Power Ltd (2022). Annual reports and Disclosure Information, retrieved on 26 August 2022 from http://www.countiespower.com

Crimmins, P (2018). Auckland Air Emissions Inventory 2016 – Industry. Auckland Council technical report, TR2018/019

DEFRA (2014). Energy recovery for residual waste – A carbon based modelling approach, retrieved on 1 August 2017 from http://randd.defra.gov.uk

Infometrics (2022). Auckland GDP data, retrieved on 20 September 2022 https://www.infometrics.co.nz/

IPCC (2023). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, retrieved on 22 August 2023 from https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

KiwiRail (2021). KiwiRail integrated report 2020, retrieved on 1 July 2021 from https://www.kiwirail.co.nz/media/annual-reports

MBIE (2022). Energy GHG emissions data (energy greenhouse gas emission web tables) from Ministry for Business, Innovation and Employment, retrieved on 20 August 2022 from https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/new-zealand-energy-sector-greenhouse-gas-emissions

MfE (2022a). Measuring Emissions: Detailed Guide 2022, retrieved on 20 September 2022 from https://environment.govt.nz/publications/measuring-emissions-a-guide-for-organisations-2022-detailed-guide/

MfE (2022b). New Zealand land use map, latest access on 7 March 2022 from

https://environment.govt.nz/facts-and-science/science-and-data/new-zealand-land-use-map

MfE (2023). New Zealand's Greenhouse Gas Inventory 1990-2021, retrieved on 7 May 2023 from https://environment.govt.nz/publications/new-zealands-greenhouse-gas-inventory-1990-2021

Metcalfe, J., Wickham, L. and Sridhar, S. (2018). Auckland air emissions inventory 2016 – home heating. Prepared by Emission Impossible Ltd for Auckland Council. Auckland Council technical report, TR2018/018

MoT (2022a). Transport Outlook, with update data, retrieved on 25 July 2022 from https://www.transport.govt.nz/statistics-and-insights/transport-outlook/sheet/updated-future-state-model-results

MoT (2022b). Freight Information Gathering System (FIGS), retrieved on 7 December 2022 from https://www.transport.govt.nz/statistics-and-insights/freight-and-logistics/trade-trends

NZEA (New Zealand Electricity Authority) (2022). Electricity market information (EMI), retrieved on 10 May 2022 from http://www.emi.ea.govt.nz

Stats NZ (2022a). Regional greenhouse gas emissions by industry and households: year ended 2021, retrieved on 18 October 2022 from https://protect-au.mimecast.com/s/3uIZCRONEjivGD7AFNELf8?domain=stats.govt.nz/ and customised report and licensed by Stats NZ for re-use under the Creative Commons Attribution 4.0 International licence

Stats NZ (2022b). Infoshare database, retrieved on 12 December 2022 from http://www.stats.govt.nz/infoshare

Vector Ltd (2022). Annual reports, regulatory disclosure documents, retrieved on 21 September 2022 from http://vector.co.nz

Watercare Services Ltd (2022). Annual Reports 2022 and of previous years, retrieved on 17 November 2022 from https://www.watercare.co.nz/About-us/Reports-and-publications, and personal communications

WRI (World Resources Institute) et al., (2021). Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (version 1.1), retrieved on 25 August 2023 from https://ghgprotocol.org/ghg-protocol-cities

Xie, S (2019). Auckland's greenhouse gas inventory to 2016. Auckland Council technical report, TR2019/002

Xie, S (2022). Auckland's greenhouse gas inventory to 2019. Auckland Council technical report, TR2022/6

10 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

11 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.

12 Appendix: Emissions tables, update of historic emissions, data sources

Table A-1 GHG emissions by sector and sub-sector for 2021 in the GPC format*

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 ENERG				
I.1	Residential buildings	196,407	450,523	33,017	679,947
I.2	Commercial and institutional buildings and facilities	462,976	116,488	8,537	588,000
I.3	Manufacturing industries and construction	1,085,100	441,064	32,323	1,558,487
I.4.1/2/3	Energy industries	NO	NO	NO	
I.4.4	Energy generation supplied to the grid	32			
I.5	Agriculture, forestry and fishing activities	160,984	113,761	8,337	283,082
I.6	Non-specified sources	NO	NO	NO	
I.7	Fugitive emissions from mining, processing, storage, and transportation of coa	NO			
I.8	Fugitive emissions from oil and natural gas systems	50,718			50,718
SUB-TOTAL	(city induced framework only)	1,956,185	1,121,835	82,214	3,160,234
II	TRANSPORTATION				
II.1	On-road transportation	4,018,564	2,186	160	4,020,910
II.2	Railways	5,673	3,629	266	9,568
II.3	Waterborne navigation	18,459	IE	125,941	144,400
II.4	Aviation	NO	IE	249,950	249,950
II.5	Off-road transportation	IE	NO	NO	
SUB-TOTAL	(city induced framework only)	4,042,696	5,815	376,317	4,424,829
III	WASTE				
III.1.1/2	Solid waste generated in the city	178,730		82,991	261,721
III.2.1/2	Biological waste generated in the city	NO		NO	
III.3.1/2	Incinerated and burned waste generated in the city	NO		NO	
III.4.1/2	Wastewater generated in the city	64,986		NO	64,986
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)	243,716		82,991	326,707
IV	INDUSTRIAL PROCESSES and PRODUCT USES				
IV.1	Emissions from industrial processes occurring in the city boundary	1,768,428			1,768,428
IV.2	Emissions from product use occurring within the city boundary	483,000			483,000
SUB-TOTAL	(city induced framework only)	2,251,428			2,251,428
V	AGRICULTURE, FORESTRY and OTHER LAND USE				
V.1	Emissions from livestock	458,485			458,485
V.2	Emissions from land	-1,313,386			-1,313,386
V.3	Emissions from aggregate sources and non-CO2 emission sources on land	250,918			250,918
SUB-TOTAL	(city induced framework only)	-603,983			-603,983
VI	OTHER SCOPE 3				
VI.1	Other Scope 3			NE	
TOTAL	(city induced framework only)	7,890,042	1,127,651	541,522	9,559,215

* See Table 3-2 for the meaning of cell colours

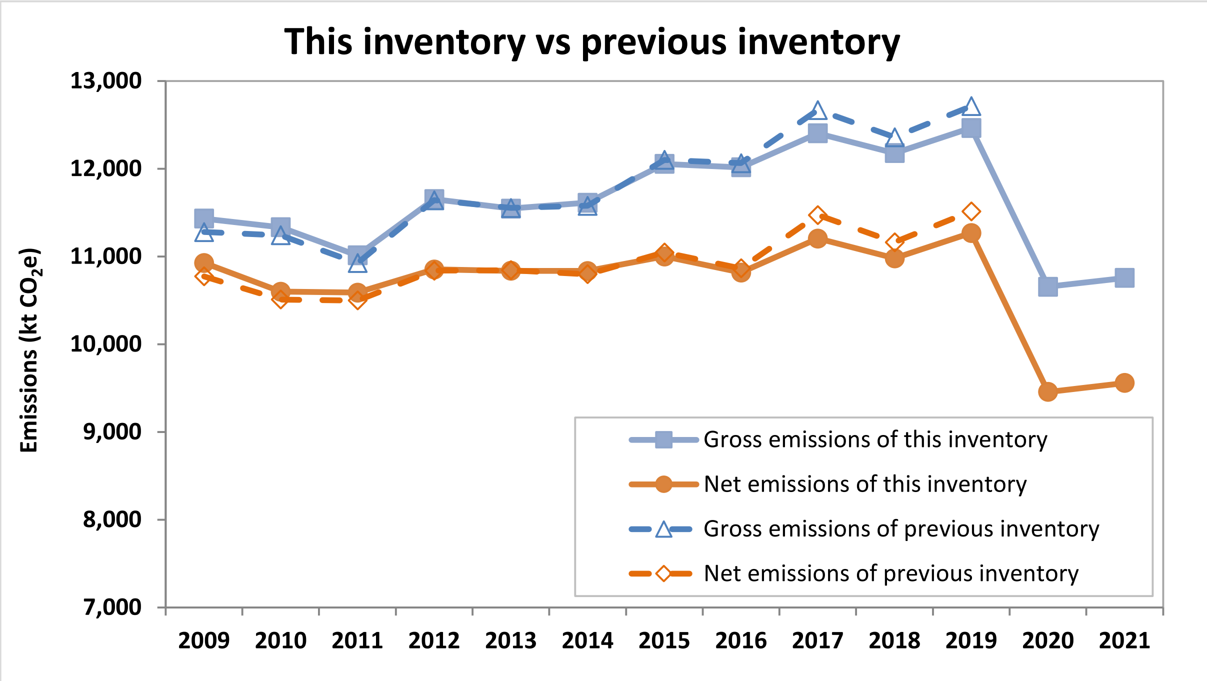

Figure A-1 Comparison of GHG emissions: this inventory vs previous 2019 inventory

Table A-2 2016 gross emissions profile in this inventory vs previous 2016 inventory

Sources	2016 inventory*		This inventory		Change	
	$ktCO_2e$	% of gross emissions	$ktCO_2e$	% of gross emissions	$ktCO_2e$	% of gross emissions
Energy - Residential	590	5.2%	520	4.3%	-70	-0.9%
Energy - Commercial	601	5.3%	462	3.8%	-139	-1.5%
Energy - Industrial	1,504	13.3%	1,807	15.0%	302	1.8%
Energy - Agricultural	321	2.8%	215	1.8%	-107	-1.1%
Fugitive from natural gas**			101	0.8%		
Transport - Road	4,259	37.6%	4,349	36.2%	90	-1.4%
Transport - Rail	12	0.1%	10	0.1%	-2	0.0%
Transport - Sea	412	3.6%	390	3.2%	-23	-0.4%
Transport - Air	257	2.3%	711	5.9%	454	3.6%
Waste	354	3.1%	471	3.9%	117	0.8%
Industrial processes & product use	2,289	20.2%	2,243	18.7%	-46	-1.5%
Agriculture	726	6.4%	738	6.1%	13	-0.3%
Gross emissions	**11,326**	**100.0%**	**12,016**	**100.0%**	**690**	**6.1%**

* *Auckland's greenhouse gas inventory to 2016* (Xie, 2019).

** Emissions from "fugitive from natural gas" in 2016 inventory were reported in "Energy" sources.

Table A-3 2019 gross emissions profile in this inventory vs previous 2019 inventory

Sources	2019 inventory*		This inventory		Change	
	$ktCO_2e$	% of gross emissions	$ktCO_2e$	% of gross emissions	$ktCO_2e$	% of gross emissions
Energy - residential buildings	668	5.3%	634	5.1%	-34	-0.2%
Energy - commercial & institutional buildings	547	4.3%	604	4.8%	56	0.5%
Energy - manufacturing & construction	1,979	15.6%	1,889	15.2%	-90	-0.4%
Energy - agriculture	325	2.6%	309	2.5%	-15	-0.1%
Energy - gas T&D losses	55	0.4%	55	0.4%	0	0.0%
Cars & light commercial vehicles	3,418	26.9%	3,376	27.1%	-42	0.2%
Buses	100	0.8%	100	0.8%	0	0.0%
Heavy vehicles	715	5.6%	756	6.1%	40	0.4%
Trains	14	0.1%	11	0.1%	-3	0.0%
Ferries & ships	637	5.0%	651	5.2%	14	0.2%
Aviation	864	6.8%	690	5.5%	-174	-1.3%
landfill gas	326	2.6%	347	2.8%	21	0.2%
Waste water treatment	7	0.1%	62	0.5%	56	0.4%
Steel production	1,694	13.3%	1,694	13.6%	0	0.3%
Glass making & others	68	0.5%	68	0.5%	0	0.0%
Industrial product use	588	4.6%	512	4.1%	-76	-0.5%
Agriculture	704	5.5%	707	5.7%	3	0.1%
Gross emissions	**12,709**	**100.0%**	**12,466**	**100.0%**	**-243**	**-2.0%**

* *Auckland's greenhouse gas inventory to 2019* (Xie, 2022)

Table A-4 Analysis of changes in 2016 emissions from previous 2016 inventory

Source	Emissions in 2016 ($ktCO_2e$)		Change		% Change to 2016 inventory's		Reasons of change
	2016 inventory*	This inventory	$ktCO_2e$	%	Gross emissions	Net emissions	
STATIONARY ENERGY							
Electricity	920	903	-17	-1.8%	-0.1%	-0.2%	Update of emissions factors
Natural gas	965	965	0	0.0%	0.0%	0.0%	No changes
LPG	131	262	130	99.1%	1.1%	1.3%	Update of LPG use
Wood	32	21	-10	-32.3%	-0.1%	-0.1%	Update of wood use
Coal	140	905	765	547.9%	6.8%	7.6%	Update of coal use
Fuel for off-road transport	829	49	-780	-94.1%	-6.9%	-7.7%	Update of fuel use
TRANSPORT							
Petrol (vehicles)	2,583	2,688	105	4.1%	0.9%	1.0%	Update of emissions factors
Diesel (vehicles)	1,671	1,659	-11	-0.7%	-0.1%	-0.1%	Update of emissions factors
LPG (vehicles)	5	2	-3	-64.2%	0.0%	0.0%	Update of LPG use
Electricity (trains and vehicles)	3	4	1	41.4%	0.0%	0.0%	Update of emissions factors
Train (diesel)	8	6	-3	-32.4%	0.0%	0.0%	Update of emissions data from Auckland Transport
Ferry	33	27	-6	-17.1%	0.0%	-0.1%	Update of emissions data from Auckland Transport
Aviation	257	711	454	176.6%	4.0%	4.5%	Update of emissions allocated to Auckland
Shipping	379	362	-17	-4.5%	-0.1%	-0.2%	Update of emissions factors
WASTE							
Solid waste disposal	348	411	63	18.1%	0.6%	0.6%	Update of emissions factors
Waste water treatment	7	60	54	808.7%	0.5%	0.5%	Update of Watercare GHG inventory
INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)							
Industrial processes	1,770	1,778	8	0.4%	0.1%	0.1%	Update with Stats NZ customised emissions data
Product use	519	465	-54	-10.5%	-0.5%	-0.5%	Update with Stats NZ customised emissions data
AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)							

Livestock	569	579	10	1.8%	0.1%	0.1%	Update of livestock numbers and emissions factors
Land	-1,313	-1,313	0	0.0%	0.0%	0.0%	No changes
Aggregate sources and non-CO2 emission sources on land	272	275	2	0.9%	0.0%	0.0%	Update of livestock numbers
Gross emissions	11,326	12,016	690	6.1%	6.1%	6.8%	
Net emissions	10,128	10,818	690	6.8%	6.1%	6.8%	

* *Auckland's greenhouse gas inventory to 2016* (Xie, 2019)

Table A-5 Analysis of changes in 2019 emissions from previous 2019 inventory

Source	Emissions in 2019 ($ktCO_2e$)		Change		% Change to 2019 inventory's		Reasons of change
	2019 inventory*	This inventory	$ktCO_2e$	%	Gross emissions	Net emissions	
STATIONARY ENERGY							
Electricity	1,248	1,160	-88	-7.0%	-0.7%	-0.8%	Update of emissions factors
Natural gas	978	978	0	0.0%	0.0%	0.0%	No changes
LPG	308	372	65	21.0%	0.5%	0.6%	Update of LPG use
Wood	21	21	0	0.0%	0.0%	0.0%	No changes
Coal	956	902	-54	-5.6%	-0.4%	-0.5%	Update of coal use
Fuel for off-road transport	63	57	-6	-9.5%	0.0%	-0.1%	Update of fuel use
TRANSPORT							
Petrol (vehicles)	2,490	2,490	0	0.0%	0.0%	0.0%	No changes
Diesel (vehicles)	1,739	1,739	0	0.0%	0.0%	0.0%	No changes
LPG (vehicles)	2	1	-1	-41.6%	0.0%	0.0%	Update of LPG use
Electricity (trains and vehicles)	6	6	0	0.1%	0.0%	0.0%	No changes
Train (diesel)	10	6	-3	-32.0%	0.0%	0.0%	Update of emissions data from Auckland Transport
Ferry	11	28	18	164.8%	0.1%	0.2%	Update of emissions data from Auckland Transport
Aviation	864	690	-174	-20.1%	-1.4%	-1.5%	Update of emissions allocated to Auckland
Shipping	626	623	-3	-0.5%	0.0%	0.0%	Update of emissions factors
WASTE							
Solid waste disposal	326	347	21	6.3%	0.2%	0.2%	Update of emissions factors
Waste water treatment	7	62	56	837.9%	0.4%	0.5%	Update of Watercare GHG inventory
INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)							
Industrial processes	1,762	1,762	0	0.0%	0.0%	0.0%	No changes
Product use	588	512	-76	-12.9%	-0.6%	-0.7%	Update of Stats NZ customised emissions data
AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)							
Livestock	559	561	2	0.4%	0.0%	0.0%	Update of livestock numbers and emissions factors

Land	-1,313	-1,313	0	-1,313	0.0%	0.0%	No changes
Aggregate sources and non-CO2 emission sources on land	261	262	1	261	0.0%	0.0%	Update of livestock numbers
Gross emissions	12,709	12,466	-243	-1.9%	-1.9%	-2.1%	
Net emissions	11,511	11,268	-243	-2.1%	-1.9%	-2.1%	

* *Auckland's greenhouse gas inventory to 2019* (Xie, 2022)

Table A-6 Information sources and data quality

	Activity data or emissions data	Data quality*
STATIONARY ENERGY		
Electricity	Total consumption was sourced from various organisations (Vector Ltd, 2022; Counties Power Ltd, 2022; NZEA, 2022). Allocation of total consumption into sub-sectors was based on Vector Ltd data (Vector Ltd, 2022).	H for total consumption as data was robust. M for sub-sector consumption due to uncertainty in breakdown of total consumption into sub-sectors.
Natural gas	Total consumption was collected from various sources (MBIE, 2022; Vector Ltd, 2022; MfE, 2023). Its allocation to sub-sectors was calculated based on two datasets: Stats NZ's data for Auckland (Stats NZ, 2022a) and industrial emissions data (Atkins, 2018).	H for total consumption as data was robust. M for sub-sector consumption due to uncertainty in breakdown of total consumption into sub-sectors.
LPG	These two datasets (see the cell above) were also used to estimate emissions (total and sub-sectors) from LPG, coal, diesel, petrol and fuel oil for stationary and off-road transport sources.	M for total and sub-sector consumption due to uncertainty in calculations.
Wood	Emissions from wood were estimated from the Auckland air emissions inventory (Metcalfe, et. al., 2018) and industrial emissions data (Atkins, 2018).	The same as LPG.
Coal	The same as LPG.	The same as LPG.
Fuel for off-road transport	The same as LPG.	L due to high uncertainty in calculations.
TRANSPORT		
Petrol (vehicles)	Petrol sales were provided by Auckland Transport and based on the local authority fuel tax reports.	H as data was robust.
Diesel (vehicles)	Diesel sales were provided by Auckland Transport and based on the local authority fuel tax reports.	H as data was robust.
LPG (vehicles)	LPG use was sourced from Ministry of Transport (MoT, 2022a).	M as recent data was based on modelling.
Electricity (trains and vehicles)	Electricity consumption was sourced from Ministry of Transport (for vehicles) (MoT, 2022a) and Auckland Transport (for trains).	M as recent data for vehicles was based on modelling.
Train (diesel)	Diesel consumption for passenger trains was provided by Auckland Transport. Diesel use by freight trains was calculated based on rail tonnage data from the Freight Information Gathering System (FIGS) (MoT, 2022b).	M as data for freight trains was calculated based on activity-related information.
Ferry	Diesel use was provided by Auckland Transport.	H as data was robust.
Aviation	The Joint User Hydrant Installation (JUHI) Depot provided aviation fuel consumption at Auckland Airport. The proportion attributable to Auckland was calculated based on passenger information (Stats NZ, 2022; Auckland Airport, 2022).	M due to uncertainty in estimating the portion attributed to Auckland.
Shipping	Total amount of fuel oil used to refuel ships at seaports was provided by Auckland Transport. The proportion attributable to Auckland was calculated based on export data at NZ shipping ports in tonnage from the Freight Information Gathering System (FIGS) (MoT, 2022b).	M due to uncertainty in estimating the portion attributed to Auckland.
WASTE		
Solid waste disposal	Emissions data was provided by the waste team at Auckland Council, which was based on total amount of solid waste and its composition.	M due to uncertainty in estimating total amount of solid waste and its composition.
Waste water treatment	Emissions data was provided by Watercare Services Ltd (2022).	Not assessed.

INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)		
Industrial processes	Emissions data was sourced from Stats NZ (2022) and New Zealand's Greenhouse Gas Inventory (MfE, 2023)	Not assessed.
Product use	Total CO2e emissions from industrial product use were provided by Stats NZ (2022a). The reported proportion of CO_2, N_2O, HFCs, PFCs and SF_6 was the same as in New Zealand's Greenhouse Gas Inventory (MfE, 2023)	Not assessed.
AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)		
Livestock	The number of livestock (dairy cattle, non-dairy cattle, sheep, deer, pig, goat and horse) was sourced from Statistics New Zealand (Stats NZ, 2022b).	H as data was robust.
Land	Emissions and removals data was provided by Ministry for the Environment for 2009 – 2016, but was assumed unchanged from 2016 to 2021.	Not assessed.
Aggregate sources and non-CO2 emission sources on land	CO_2 and N_2O emissions from liming, urea application, direct and indirect N_2O from managed soils were estimated based on national emissions (MfE, 2023) allocated to Auckland based on the proportion of cropland and grassland to the national total. As for the land sub-sector, changes of carbon stocks in the harvested wood products (HWPs) pool were provided by Ministry for the Environment for 2009 – 2016, but was assumed unchanged from 2016 to 2021.	Not assessed.

* The quality of activity data was assessed with a High (H)-Medium (M)-Low (L) rating where possible, see section 2.2 for details.

Find out more:

research@aucklandcouncil.govt.nz

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