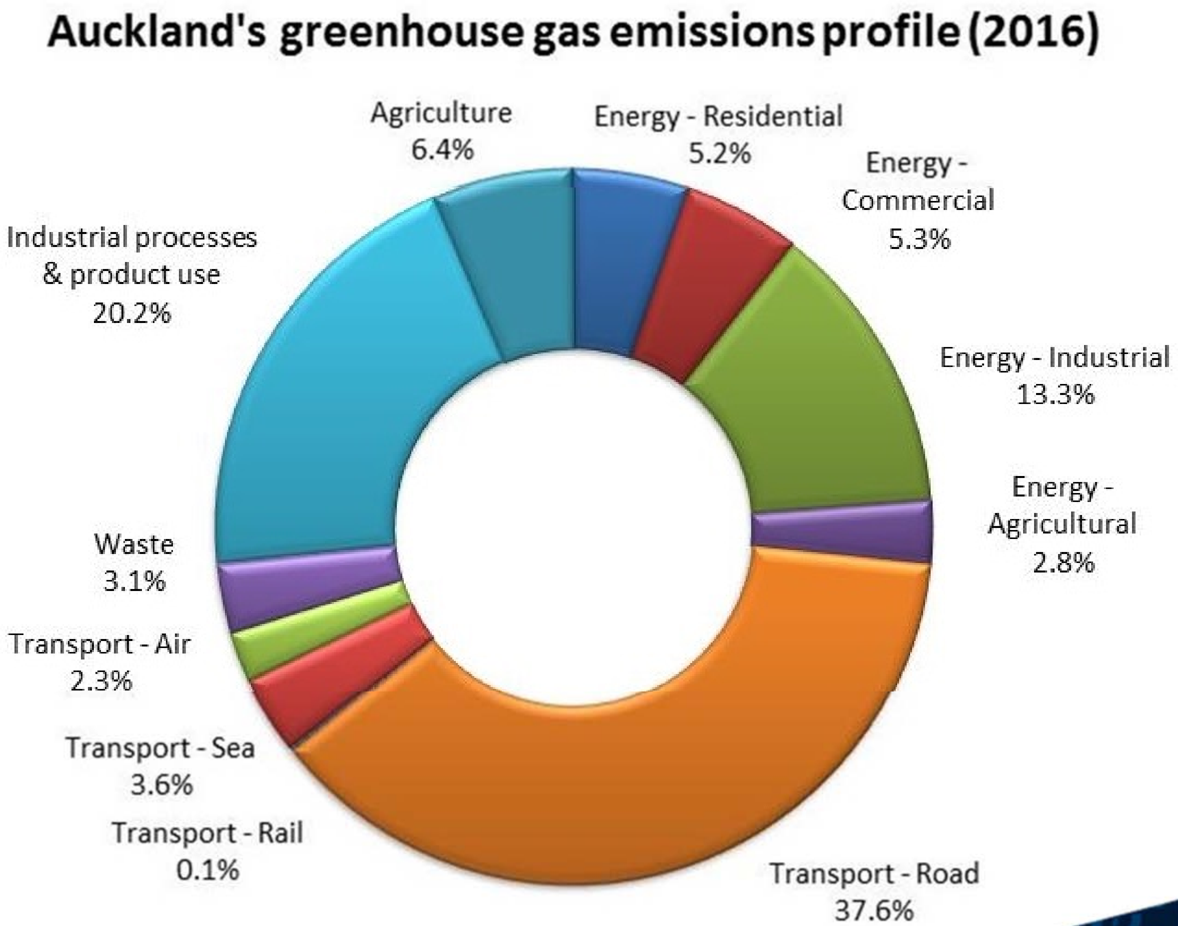
Auckland's Greenhouse Gas Inventory to 2016

Shanju Xie

February 2019 Technical Report 2019/002



RIMU Research and Evaluation Unit

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Cover graphic: Auckland's GHG gross emissions by sector and sub-sector for 2016 (see Figure 2-1, page 6)

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Executive summary

Auckland's current targets are to achieve 10 to 20 per cent reductions in greenhouse gas (GHG) emissions by 2020, 40 per cent by 2040 and 50 per cent by 2050 (based on 1990 levels). The council is in the process of reviewing Low Carbon Auckland and developing an integrated climate action plan for Auckland, addressing both mitigation and adaptation. This requires a robust evidence base to inform development of the integrated plan. An emissions inventory identifies and quantifies sources and sinks of GHGs and trends. This provides an essential tool to evaluate our progress, frame mitigation actions and support target setting.

In 2016, Auckland gross emissions were 11,326 kilo-tonnes of carbon dioxide equivalent (kt CO_2e) and when carbon sequestration from forestry was included, net emissions were 10,128 kt CO_2e. Transport and stationary energy are dominant sectors, accounting for 43.6 per cent and 26.6 per cent of gross emissions, respectively (Figure E-1). Carbon dioxide (CO_2) contributed 83.1 per cent, methane (CH_4) 10.5 per cent, nitrous oxide (N_2O) 1.7 per cent and other GHGs 4.7 per cent.

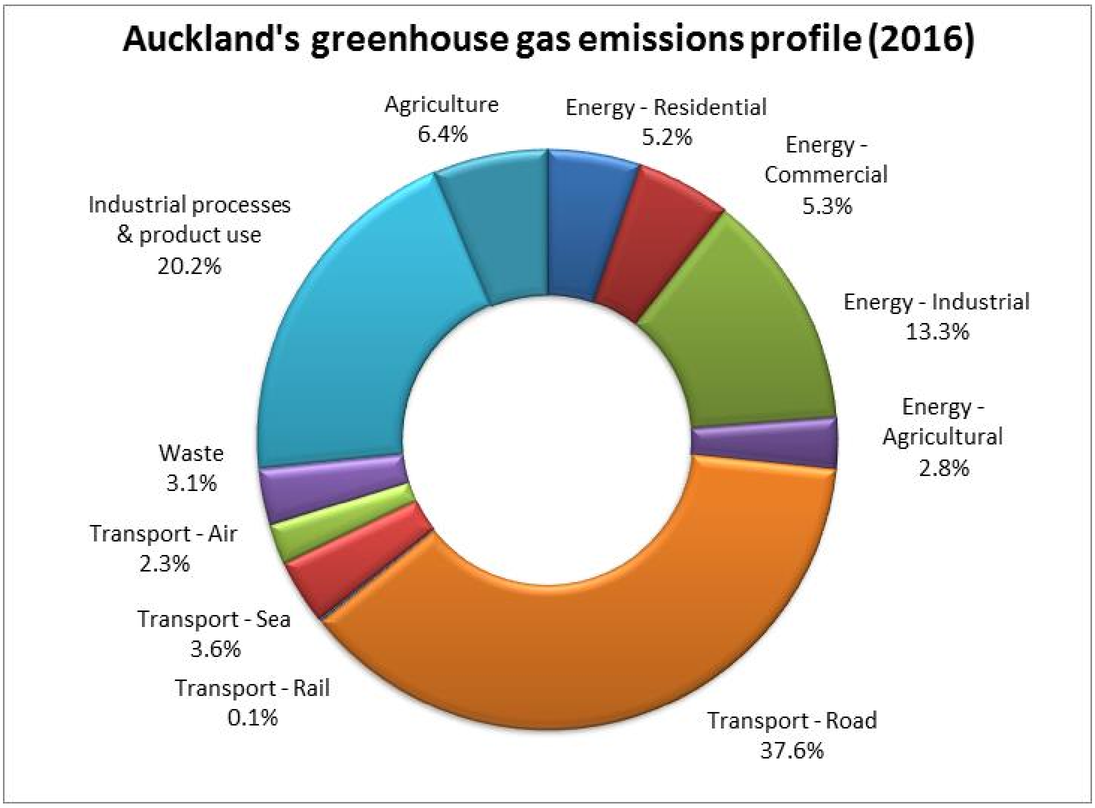

Figure E-1 Auckland's GHG gross emissions profile for 2016

Gross and net emissions in 2016 have dropped from the 2015 levels, driven by decreased emissions from energy, and industrial processes and product use (IPPU) sectors. There was also additional carbon sequestration from forestry. There was a gradual increase in gross emissions from 2009 to 2016 due to increased emissions from transport, waste, IPPU and agriculture sources. Increased carbon sequestration from forestry resulted in lower net emissions in 2016 than in 2009 (Figure E-2).

With respect to current levels, Auckland needs to reduce its net emissions by 24.7 per cent to 33.0 per cent by 2020, 49.8 per cent by 2040 and 58.1 per cent by 2050, to meet its reduction targets. Auckland's Climate Action Plan, currently under development, will set an emission target consistent with the Paris Agreement aspiration of 1.5°C maximum temperature rise and a path to rapidly reduce emissions.

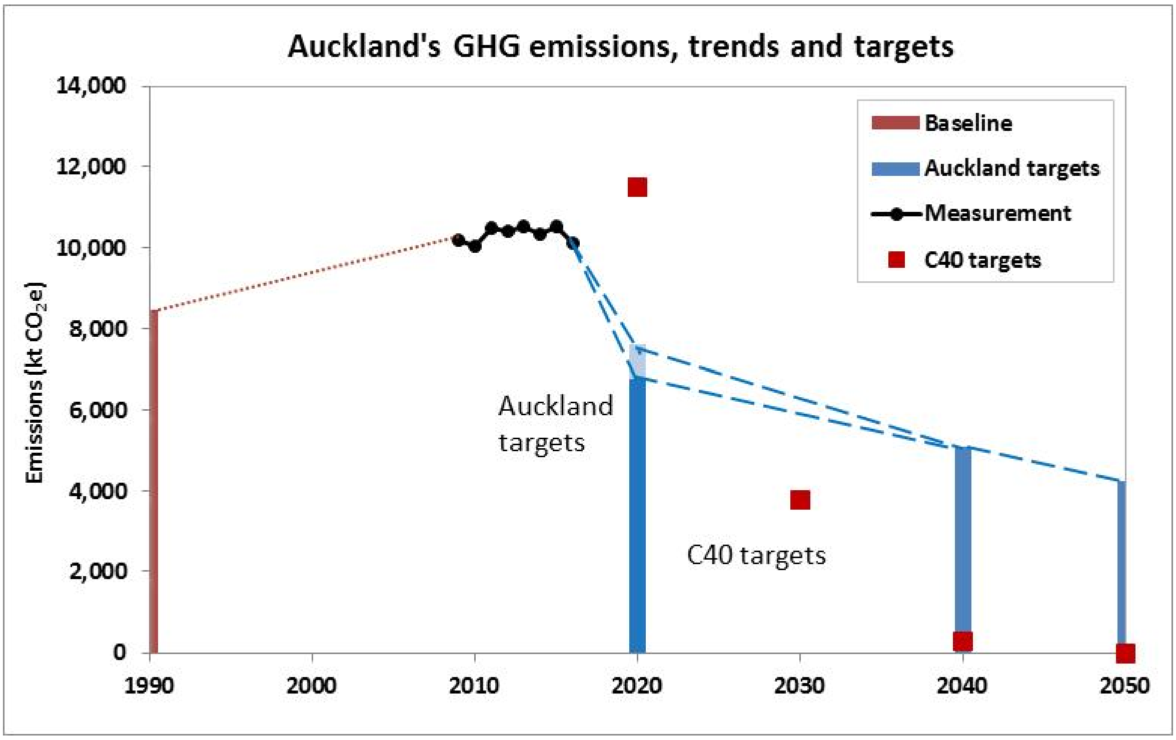

Figure E-2 Auckland's GHG emissions, trends and targets. Auckland targets are a reduction of 10 to 20 per cent, 40 per cent and 50 per cent for 2020, 2040 and 2050, respectively. C40 targets are aspiring to the ambition of the Paris Agreement, developed by C40 Cities Climate Leadership Group and Arup.

In 2016, net emissions were 6.3 t CO_2e per capita and 121 t CO_2e per million $NZ GDP (2009/2010 prices) while gross emissions were 7.0 t CO_2e per capita and 135 t CO_2e per million $NZ GDP. These values were lower than in 2009, and this shows that Auckland decouples emissions from population and economic growth.

Overall, in 2016 gross and net emissions have dropped from the 2015 levels, as a result of lower emissions from energy and IPPU sectors, and more carbon sequestration from forestry. It is not clear if this is the start of a downward trend.

1 Introduction

The climate is changing with rising temperatures 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.

Auckland's current targets are to achieve 10 to 20 per cent reductions in GHG emissions by 2020, 40 per cent by 2040 and 50 per cent by 2050 (based on 1990 levels) (Auckland Council, 2014; 2017). Auckland's Energy Resilience and Low Carbon Action Plan (Low Carbon Auckland) sets out the pathways and specific actions to achieve the targets (Auckland Council, 2014). Since its launch, 71 per cent of actions have been completed or are in progress, with 26 per cent behind schedule or facing challenges and the remaining three per cent either stalled or not able to be delivered (Auckland Council, 2017). Specific targets are set related to the actions. The council is in the process of reviewing Low Carbon Auckland and developing an integrated climate action plan for Auckland, addressing both mitigation and adaptation (Auckland Council, 2018a). This requires a robust evidence base to inform development of the integrated plan. An emissions inventory identifies and quantifies the sources and sinks of GHGs, and trends. This provides an essential tool to evaluate our progress, frame mitigation actions and support target setting.

Auckland's GHG inventories were previously developed by URS in 2011 for 2009 which was updated by Arup in 2014 (Arup, 2014) and most recently by Auckland Council for emissions to 2015 (Xie, 2017). Auckland's recent GHG inventory has been reviewed by C40 Cities Climate Leadership Group (C40) and was included in the C40 emissions database (C40, 2018a). This document reports Auckland's GHG inventory to 2016, following the release of New Zealand's Greenhouse Gas Inventory 1990-2016 (MfE, 2018). As in the inventory to 2015, it was prepared with the most up-to-date information and global best practice in accordance with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (WRI et al., 2014). 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. Improvements in activity data, emission factors and methodology have been made for this inventory. Previously reported emissions for 1990 (gross emissions as the baseline to reduction targets), 2009 (the base year in Low Carbon Auckland) to 2015 (Xie, 2017) have been recalculated in this inventory for consistency.

1.1 Methodology – the GPC: Global Protocol for Community-Scale Greenhouse Gas Emission Inventories

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 report used the most recent version 1.0 (WRI et al., 2014) to prepare and report GHG emissions in Auckland.

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. 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 triflouride (NF_3). NF_3 emissions are zero since they do not occur in New Zealand (MfE, 2018). 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 IPCC Fourth Assessment Report (AR4) to be consistent with New Zealand's Greenhouse Gas Inventory (MfE, 2018).

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 in the current version of the GPC 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).

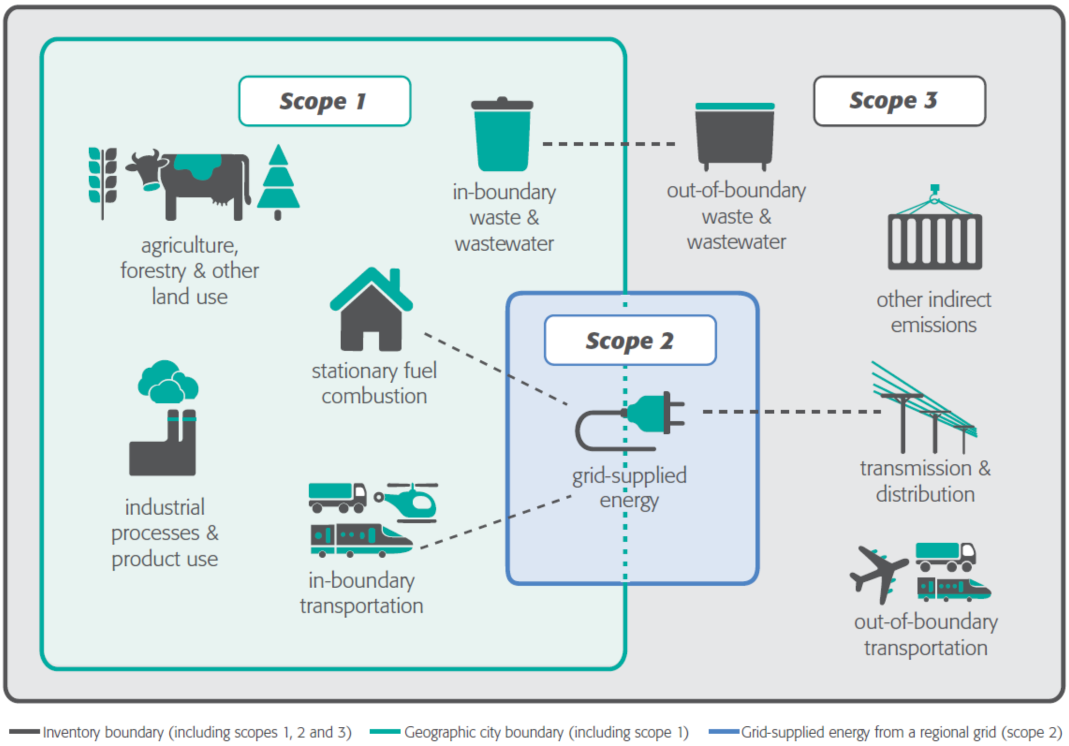

Figure 1-1 Sources and boundaries of city GHG emissions (WRI et al., 2014)

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 of time (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 activity data 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 activity data and emission factors 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) (v2.0) (C40, 2018b) 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 2016 are analysed. Improvements made since 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 2016 were discussed. Improvements on the previous inventory and for future inventory were also included.

2.1 Emissions and sources

In 2016, Auckland's net GHG emissions were 10,128 kt CO_2e (including carbon sequestration from forestry, BASIC+ emissions in Table 2-1). Table 2-2 illustrates the GPC reporting requirements.

Table 2-1 GHG emissions summary for 2016

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)	1,995,682	858,263	163,153	2,853,946	3,017,098	3,017,098
	Energy generation supplied to the grid (I.4.4)	32					
TRANSPORTATION	(all II emissions)	4,341,699	2,959	594,722	4,344,657	4,939,380	4,939,380
WASTE	Waste generated in the city (III.X.1 and III.X.2)	236,093		118,358	354,451	354,451	354,451
	Waste generated outside city (III.X.3)						
IPPU	(all IV emissions)	2,289,487				2,289,487	2,289,487
AFOLU	(all V emissions)	-472,067				-472,067	-472,067
OTHER SCOPE 3	(all VI emissions)						
TOTAL		8,390,926	861,222	876,233	7,553,054	10,128,349	10,128,349

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 since Auckland's reduction targets are set relative to 1990 gross emissions (Arup, 2014). To be consistent with New Zealand's Greenhouse Gas Inventory (MfE, 2018), Auckland's gross emissions exclude the contribution from the LULUCF sector (i.e., Land and the harvested wood products (HWP) sub-sectors (see Chapter 7)).

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

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 2016 (11,326 kt CO_2e), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) contributed 83.1 per cent, 10.5 per cent , 1.7 per cent , 4.2 per cent , <0.1 per cent and 0.1 per cent of gross emissions, respectively. The contribution from five sectors was stationary energy 26.6 per cent, transport 43.6 per cent, waste 3.1 per cent, IPPU 20.2 per cent, and AFOLU (agriculture) 6.4 per cent. Transport and stationary energy are the dominant sectors, accounting for 70.2 per cent of gross emissions (Figure 2-1). Emissions by sector and sub-sector for 2016 are also summarised in Table A-1 and Figure A-1 (in Appendix).

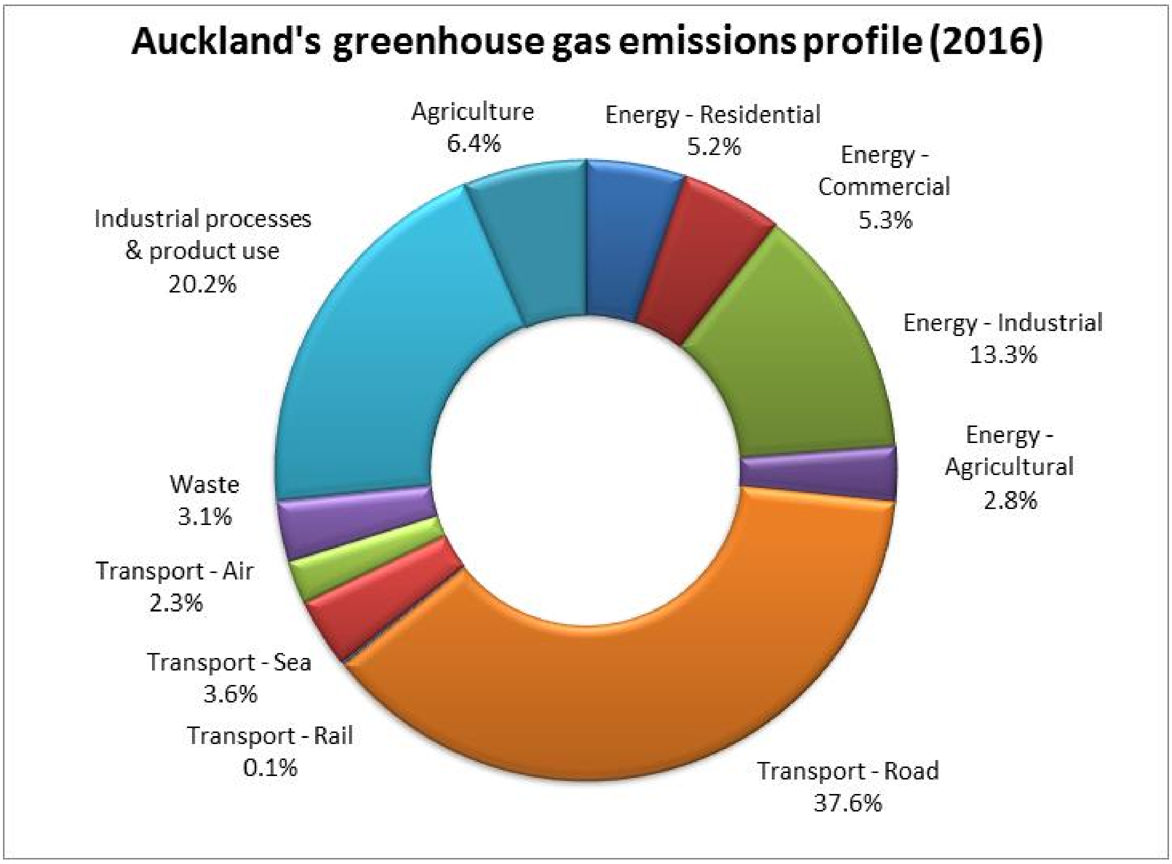

Figure 2-1 Auckland’s GHG gross emissions by sector and sub-sector for 2016

2.2 Trends

Between 2015 and 2016

Between 2015 and 2016, Auckland's GHG emissions have decreased by 266 kt CO_2e or 2.3 per cent for gross emissions and by 410 kt CO_2e or 3.9 per cent for net emissions (Figure 2-2). Emissions were lower from energy and IPPU sectors; but higher from transport, waste and agriculture sources in 2016 than in 2015. There were additional 144 kt CO_2e sequestered from the LULUCF sector (mainly forestry) in 2016 than in 2015.

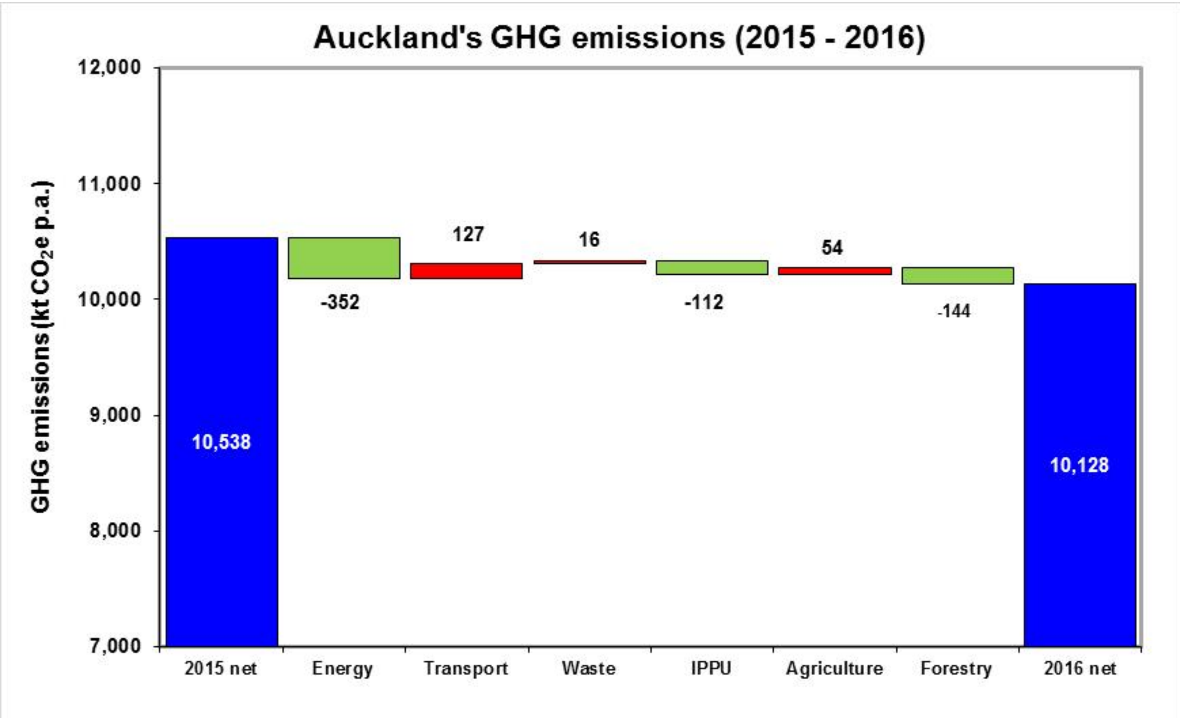

Figure 2-2 Auckland's GHG emissions between 2015 and 2016

Between 2009 and 2016

Between 2009 and 2016, gross emissions have increased by 599 kt CO_2e or 5.6 per cent, but net emissions have decreased by 94 kt CO_2e or 0.9 per cent due to more carbon sequestration from forestry (Figure 2-3). Emissions have decreased from the energy sector, but increased from other sources (transport, waste, IPPU and agriculture).

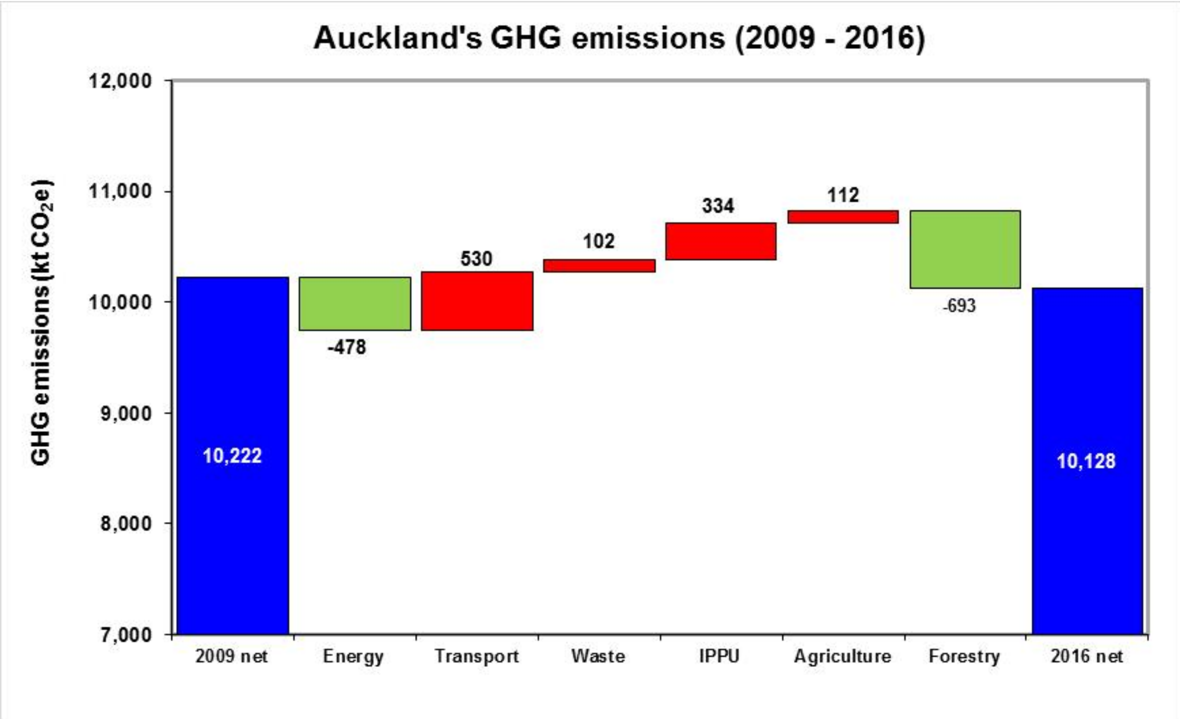

Figure 2-3 Auckland’s GHG emissions between 2009 and 2016

Between 1990 and 2016

Between 1990 and 2016, gross emissions have increased by 2848 kt CO_2e or 33.6 per cent (Figure 2-4). Since 1990 gross emissions were used as the baseline of the reduction targets (Arup, 2014), the emissions change was analysed relative to gross emissions in 1990. The transport sector contributed the most increase in gross emissions, followed by IPPU and energy sources. There was a reduction in emissions from waste and agriculture sources. There was also a considerable amount of carbon sequestration from forestry in 2016.

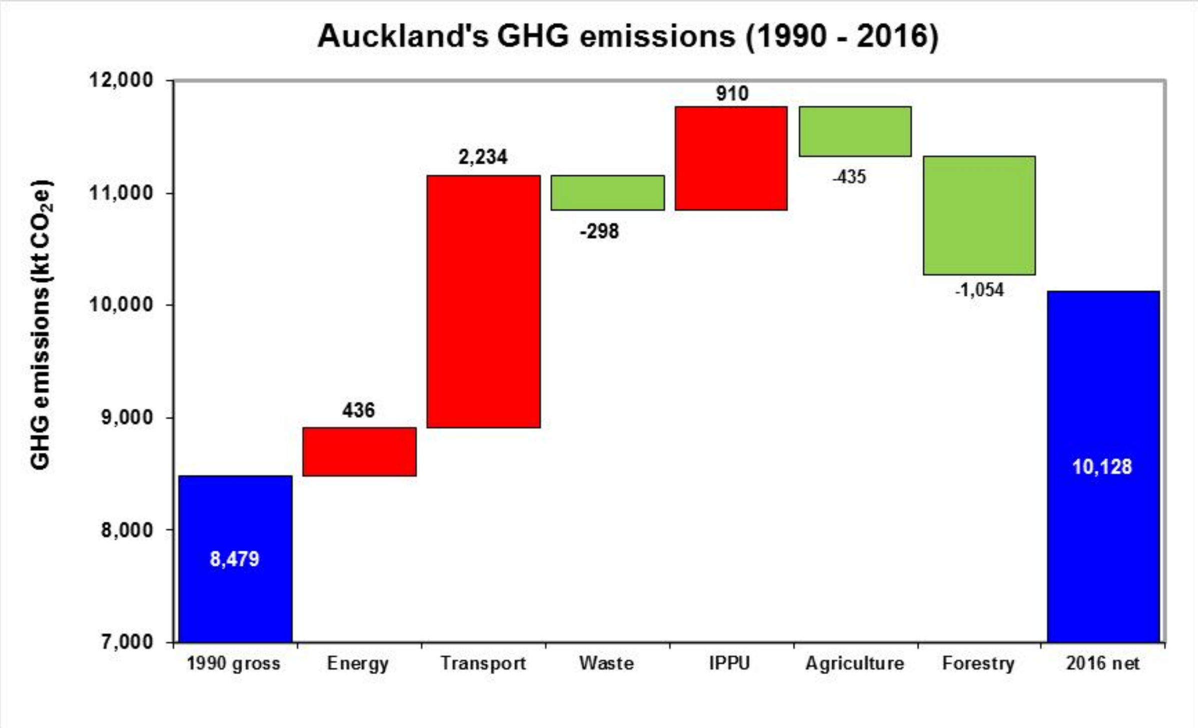

Figure 2-4 Auckland’s GHG emissions between 1990 and 2016

Overall, gross and net emissions in 2016 have dropped from the 2015 levels. It is not clear if this is the start of a downward trend. From 2009 to 2016, there was a gradual increase in gross emissions, but increased carbon sequestration from forestry resulted in a decrease in net emissions (Figures 2-5 and 2-6). In 2012, there was lower than normal rainfall which led to lower hydro generation and an increase in gas and coal generation (MBIE, 2018a). This caused a spike in emissions from electricity consumption, therefore the stationary energy sector (Figure 2-5). Work is needed to further understand emissions trends and driving factors.

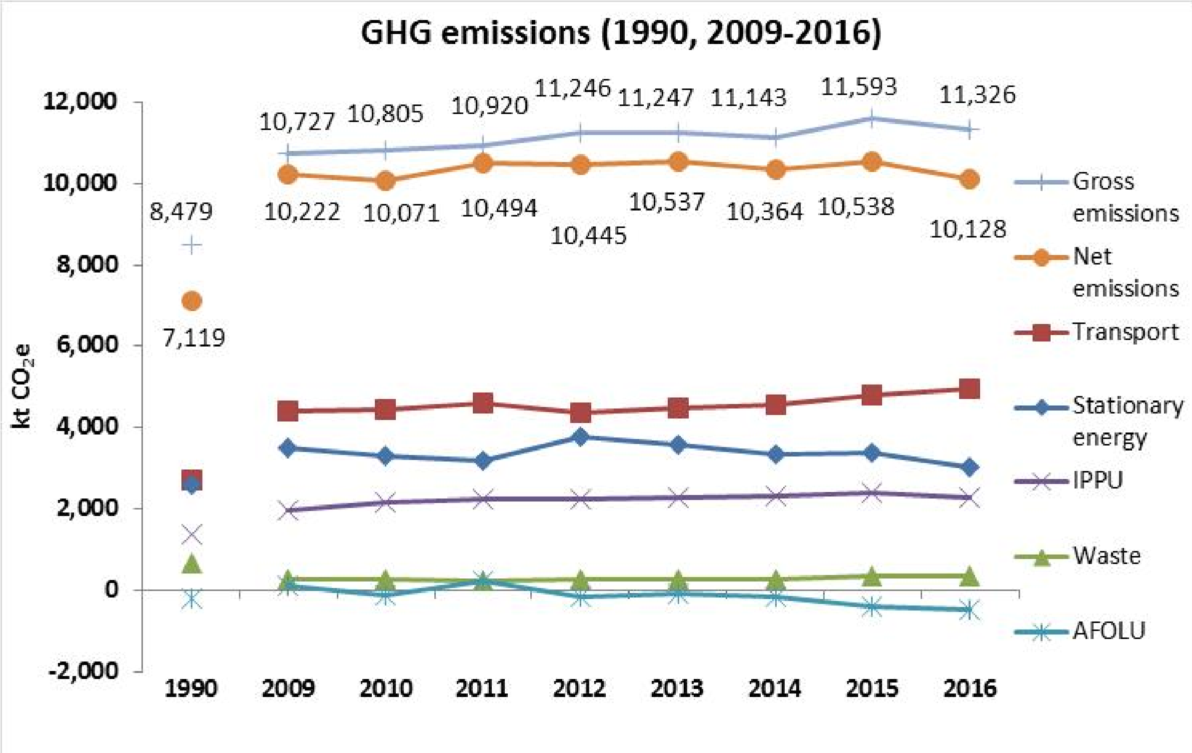

Figure 2-5 Auckland's GHG emissions for 1990, 2009 to 2016

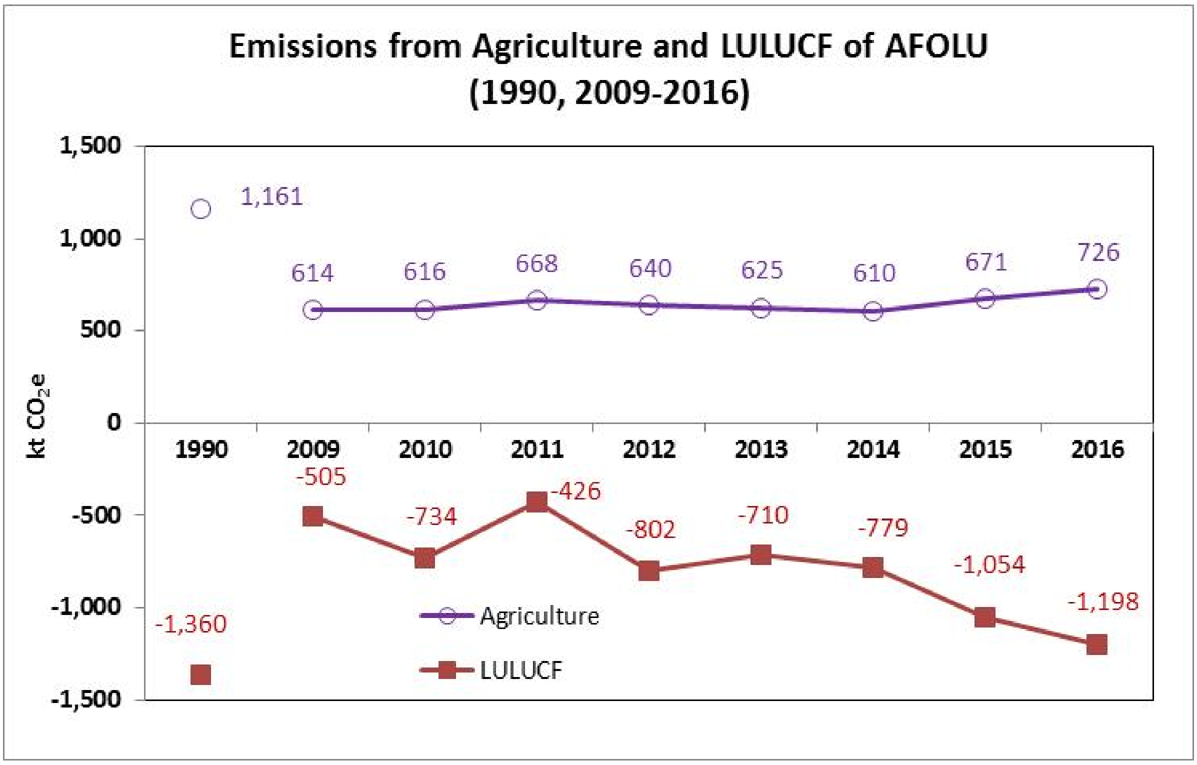

Figure 2-6 Emissions from agriculture and LULUCF sources

2.3 Emissions reductions for meeting targets

As mentioned earlier, Auckland's current targets are to achieve 10 to 20 per cent reductions in emissions by 2020, 40 per cent by 2040 and 50 per cent by 2050 relative to 1990 levels (Auckland Council, 2014; 2017). To support cities aspiring to the ambition of the Paris Agreement, C40 and Arup (2017) developed targets for each C40 city to help play their part in limiting global temperature rise to 1.5°C. Auckland's emissions would need to sharply decline over the next 5-10 years, and reach net zero emissions by 2050.

Compared to 2016 levels, Auckland needs to reduce its net emissions by 24.7 per cent to 33.0 per cent (2498 kt CO_2e to 3345 kt CO_2e) by 2020, 49.8 per cent (5041 kt CO_2e) by 2040 and 58.1 per cent (5889 kt CO_2e) by 2050 to meet its targets (Figure 2-7). C40 targets require a reduction of 62.5 per cent (6328 kt CO_2e) by 2030, 97.0 per cent (9828 kt CO_2e) by 2040 and 100.0 per cent (10,128 kt CO_2e) by 2050 (Figure 2-7). 2016 emissions are lower than the C40 target for 2020. Auckland must transform from a fossil fuel-dependent, high energy-using, high-waste society to a mobile, quality, compact city – a city typified by sustainable resource use and a prosperous eco-economy, and powered by efficient, affordable clean energy (Auckland Council, 2014; 2017; 2018a).

Auckland's Climate Action Plan, currently under development, will set an emission target consistent with the Paris Agreement aspiration of 1.5°C maximum temperature rise and a path to rapidly reduce emissions (Auckland Council, 2018a; 2018d). Work is under way to model emissions to 2050. The projection provides better information regarding the amount of emissions required to reduce for a specific time frame (e.g., by 2020, 2030, 2040 and 2050) in order to meet targets, therefore helps develop further mitigation actions.

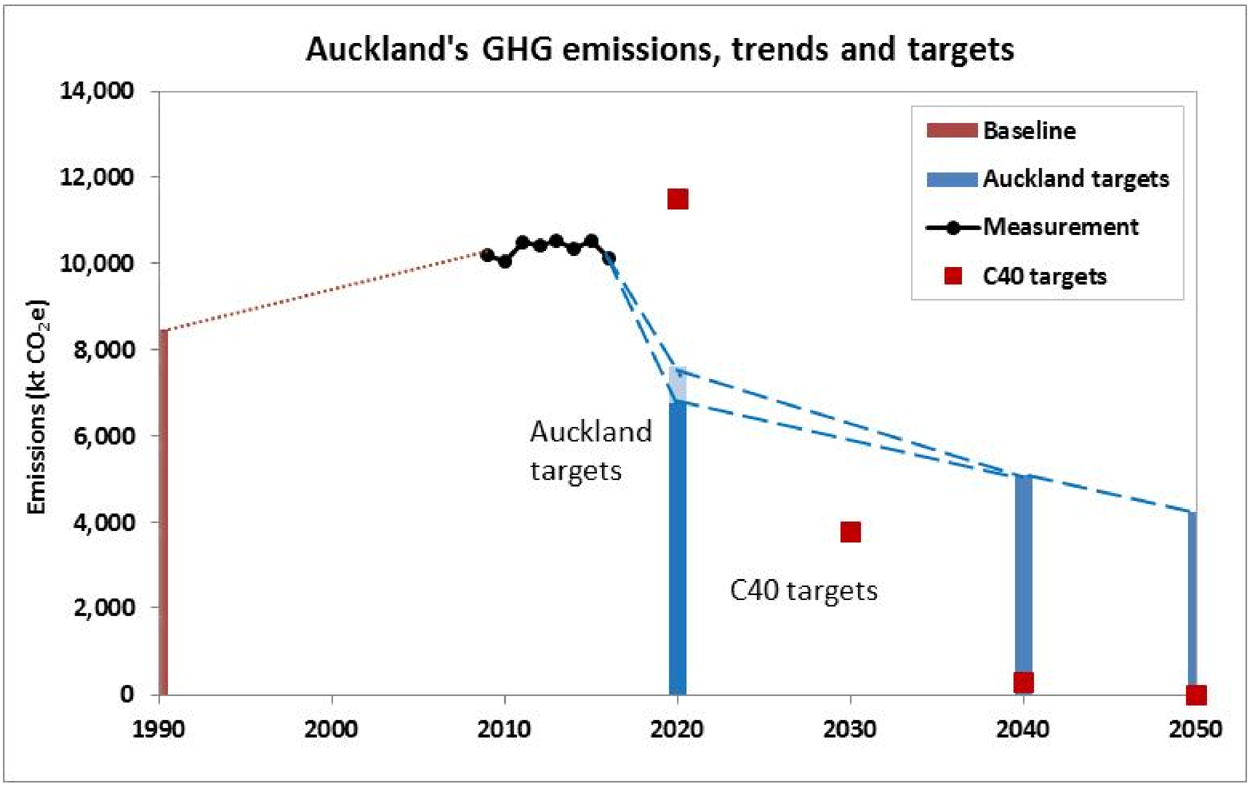

Figure 2-7 Auckland's GHG emissions, trends and targets. Auckland targets are a reduction of 10 to 20 per cent, 40 per cent and 50 per cent of 1990 gross emissions for 2020, 2040 and 2050, respectively. C40 targets are aspiring to the ambition of the Paris Agreement.

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 2016, Auckland's population increased from 1.4 million to 1.6 million and GDP increased from $NZ 69.8 billion to $NZ 83.8 billon (2009/2010 prices). Population, GDP and GHG emissions are compared in Figure 2-8. Figure 2-9 shows the emission intensity by population and GDP. In 2016, net emissions were 6.3 t CO_2e per capita and 121 t CO_2e per million $NZ GDP while gross emissions were 7.0 t CO_2e per capita and 135 t CO_2e per million $NZ GDP. These values have generally decreased since 2012, and this shows that Auckland decouples emissions 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.

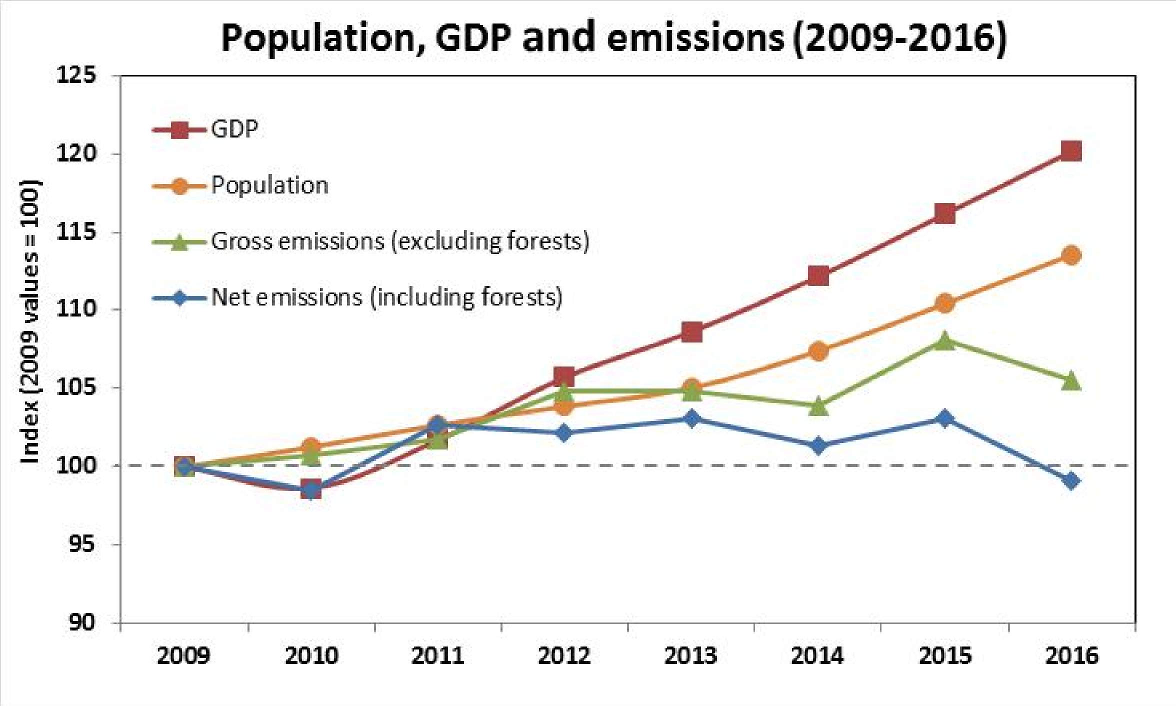

Figure 2-8 Auckland's population, GDP and GHG emissions from 2009 to 2016.

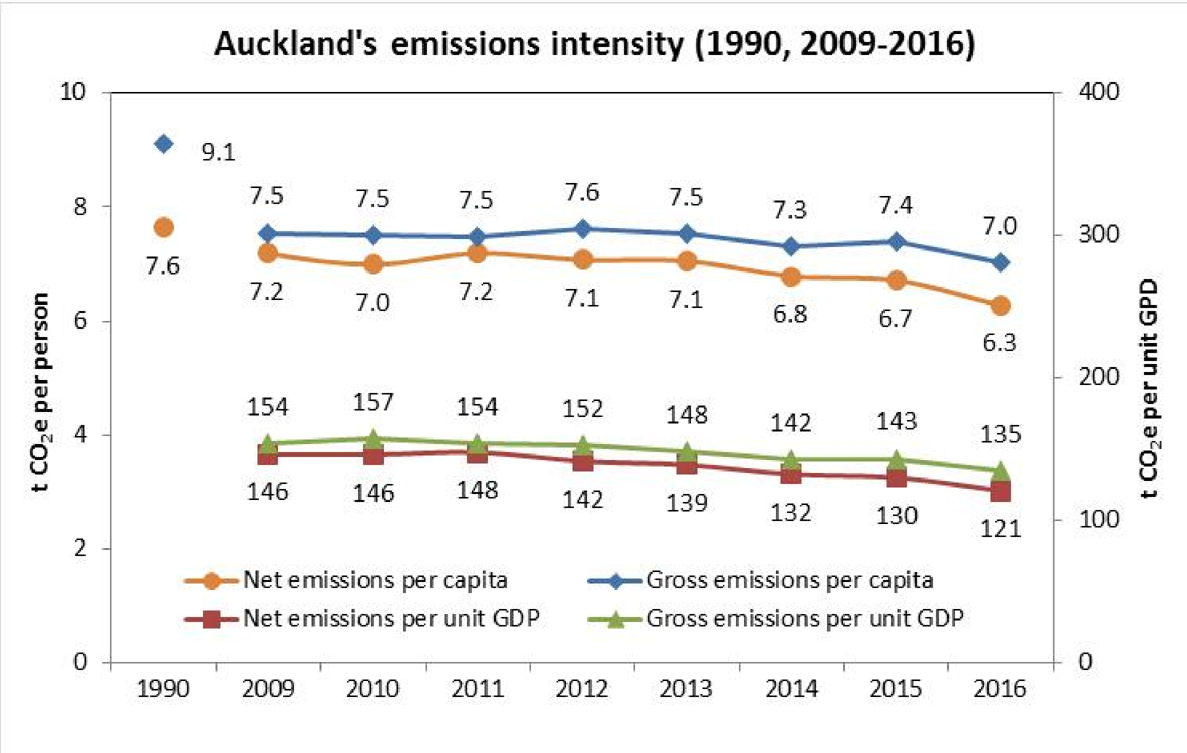

Figure 2-9 Auckland's emissions intensity for 1990, 2009 to 2016

2.5 Comparison of emissions with previous inventory

It is international good practice to recalculate previous estimates to ensure consistency in emissions estimates and trends (MfE, 2018). This means emissions in this inventory differ from those for a given year in the previous inventory (Figure 2-10). Although this inventory reports higher gross and net emissions, both inventories show a very similar trend. Changes have been made in this inventory:

- The global warming potential (GWP) values in the IPCC Fourth Assessment Report (AR4) were used to be consistent with New Zealand's Greenhouse Gas Inventory (MfE, 2018). GWP values in the Fifth Assessment Report (AR5) were used in the previous inventory (Xie, 2017).
- Activity data and emission factors were updated from the latest national data where applicable (MBIE, 2018a; 2018b; MfE, 2017; 2018).
- Information was sourced from recent air emissions inventories (Sridhar and Metcalfe, 2018; Peeters, 2018; Crimmins, 2018).

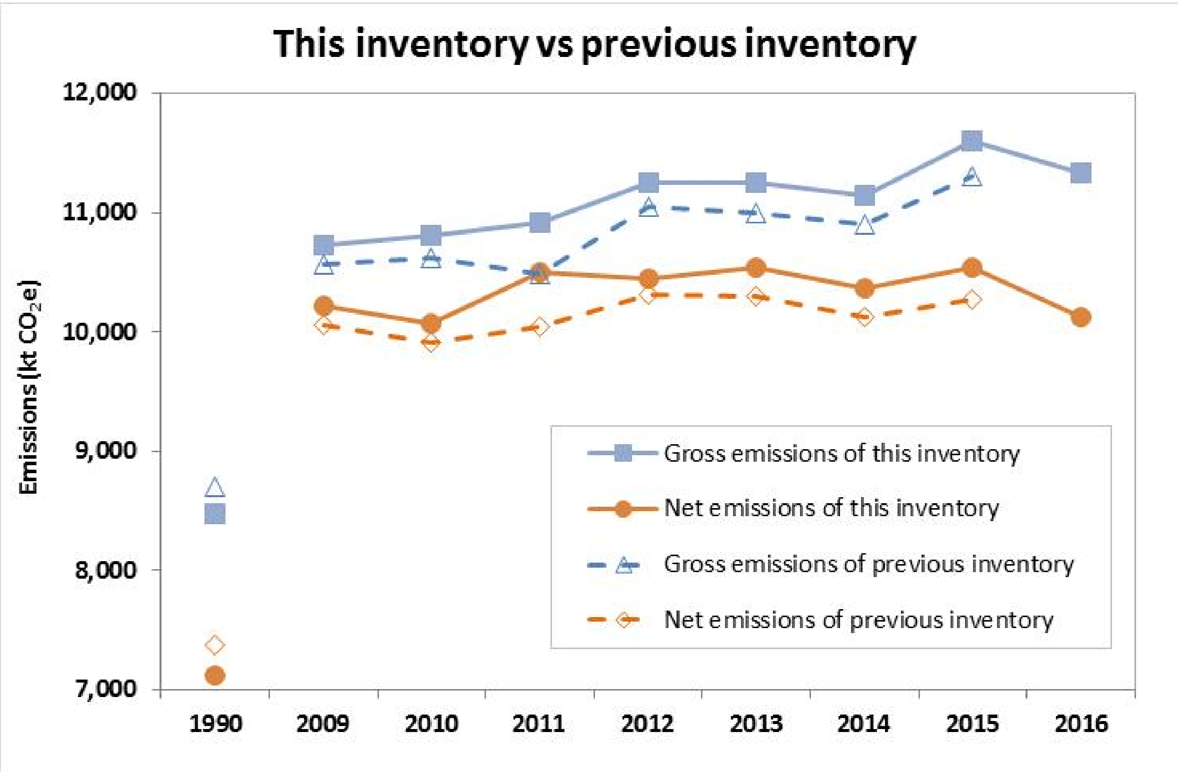

Figure 2-10 Comparison of GHG emissions: this inventory vs the previous inventory

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) within the Auckland region. 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 and gas. GHGs in this sector are CO_2, CH_4 and N_2O.

Emissions from gas use at Otahuhu and Southdown power stations were allocated into the energy industries sub-sector since generated electricity was supplied to national electric grids. Allocation of electricity consumption into sub-sectors (residential buildings; commercial and institutional buildings and facilities; manufacturing industries and construction; and agriculture, forestry and fishing activities) was based on Vector Ltd data (Vector Ltd, 2018). Emissions from other energy consumption were allocated into sub-sectors based on the EECA energy end use database (EECA, 2018).

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 3017 kt CO_2e, with 49.9 per cent from manufacturing industries and construction, 19.6 per cent from residential buildings; 19.9 per cent from commercial and institutional buildings and facilities; and 10.7 per cent from agriculture, forestry and fishing activities. They came from consumption of electricity (30.5 per cent); natural gas (32.0 per cent); the use of diesel, petrol and fuel oil (27.5 per cent); LPG (4.4 per cent) and coal and wood (5.7 per cent) (Figure 3.1).

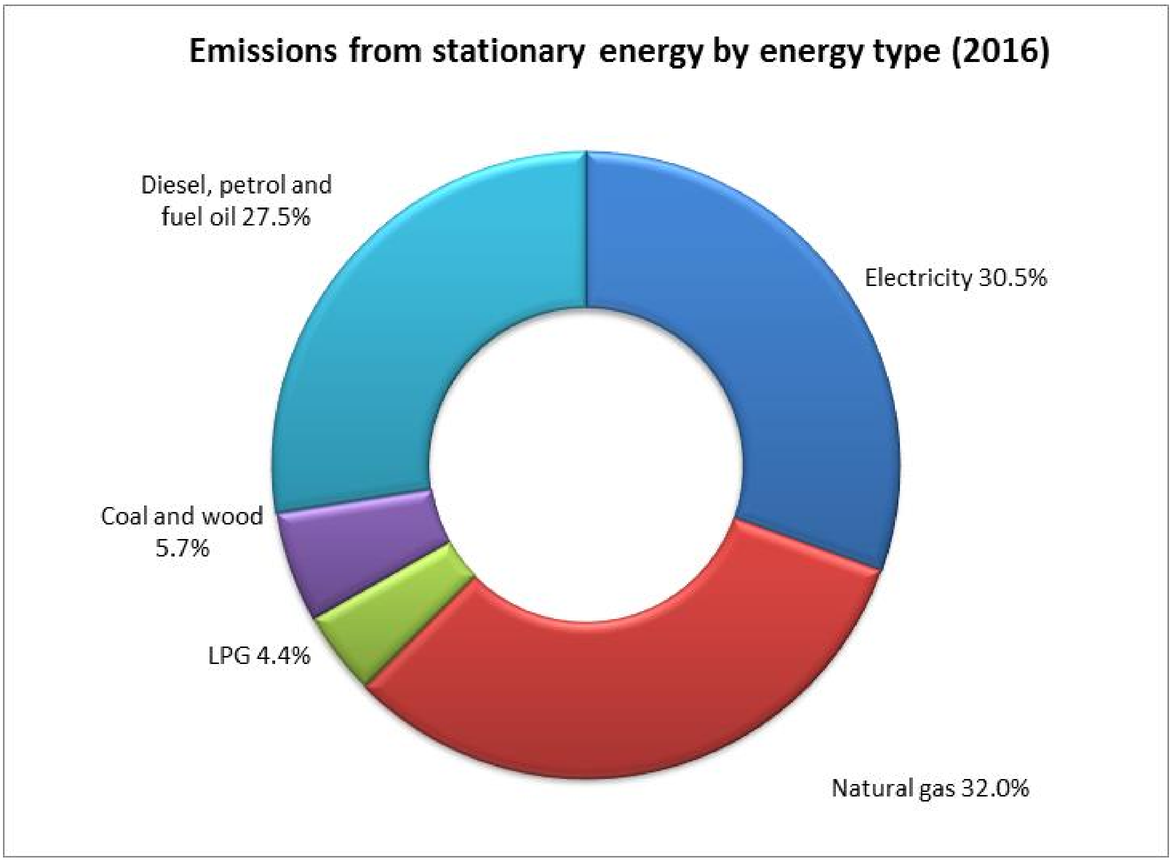

Figure 3-1 Emissions from stationary energy by energy type for 2016

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 2009-2016 was sourced from MBIE (2018a). The amount of natural gas for electricity generation by the power plants was subtracted from the total, as generated electricity was supplied to national electric grids. The natural gas use in 1990 was calculated by scaling national consumption based on the historical ratio (2009-2016). Fugitive emissions were those from the distribution of natural gas. National emission factors were used (MBIE, 2018b).

Non-transport consumption of LPG in Auckland in 2012 was sourced from the EECA's database (EECA, 2018). The activity data for other years was estimated by scaling the national data using the ratio in 2012. National emission factors were used (MBIE, 2018b).

Consumption of coal in 2009 was sourced from a previous inventory (Arup, 2014). The ratio of Auckland use to national total in 2009 was used to calculate consumption for other years. Consumption of wood in 2012 was sourced from the EECA database (EECA, 2018) and was assumed unchanged for other years since emissions were small. CO_2 emissions from wood burning were reported as biogenic, which were not included in total emissions. National emission factors for coal and wood were used (MBIE, 2018b).

Fuel oil consumption for non-transport use in 2012 was sourced from EECA (2018). The data for other years was calculated from scaling the national data using the ratio in 2012. National emission factors were applied (MfE, 2018b). As discussed in Section 4.6, emissions from petrol and diesel use for off-road transport 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 assumed zero since landfill gas was not well managed at that time. 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 2009-2016 was sourced from various organisations (Vector Ltd, 2018; Counties Power Ltd, 2018; NZEA, 2018; Auckland Transport, 2018). The data for 1990 was estimated by scaling national consumption based on the historical ratio (2009-2016). National average emission factors were used (MBIE, 2018b). Electric passenger trains went into service from 2014 and will replace all diesel trains by 2019. Emissions from electricity consumption were reported under Transport.

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 or natural gas. The grid loss factor (electricity) or loss emission factors (natural gas) were sourced from the national data (MBIE, 2018a; 2018b; MfE, 2017).

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. Emissions from electricity for non-transport consumption are reported under Stationary Energy. 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 86.1 per cent of total 4939 kt CO_2e emissions from transport. Contributions from other sources were 5.2 per cent from aviation, 7.7 per cent from shipping, and 1.0 per cent from train, ferry and LPG.

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 (MfE, 2017; 2018). The results were included in Scope 1 emissions.

EECA (2018) reported the LPG use data for transport in Auckland in 2012. The data for other years was calculated as a proportion of the national total using the ratio in 2012. National emission factors were applied (MBIE, 2018b).

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). Diesel use for rail was estimated for passenger and freight trains. Diesel consumption for passenger trains was sourced from Auckland Transport for 2006 to 2016 and reported in the Air Emissions Inventory (Sridhar and Metcalfe, 2018). It also reported diesel use by freight trains for 2006, 2011 and 2016, calculated based on total gross tonne kilometres (GTKs) over the Auckland corridor (provided by KiwiRail) multiplied by a New Zealand-averaged fuel burn rate (in litres per GTK). Total diesel use in 1990 was estimated by scaling national consumption. The data for other years was linearly interpolated.

Emissions from diesel were reported in Scope 1. As discussed in Section 3.3, electric passenger trains went into service from 2014 and will replace all diesel trains by 2019. Electricity consumption was provided by Auckland Transport and its emissions were reported in Scope 2.

4.4 Water transport

The total amount of fuel oil refuelling to ships at sea ports and ferries was provided by Auckland Transport from 2012 to 2016. The ratio of Auckland consumption to the national total averaged over this period was used to estimate consumption for other years (1990, 2009-2011).

CO_2 emissions from ferries were estimated for 2006 and 2010 (Peeters, 2011), and 2016 (Peeters, 2018). The data were used to calculate ferry fuel consumption. Consumption for other years was linearly interpolated. Emissions from ferries were reported in Scope 1. Fuel consumption by shipping at sea ports was calculated as the difference between the total and ferry consumption. Emissions from shipping were reported in Scope 3. The national emission factors were applied (MBIE, 2018a; 2018b). The proportion of export values from Auckland to New Zealand (Infometrics Ltd, 2018) was used to portion emissions attributable to Auckland.

4.5 Aviation

Aviation activities in Auckland are dominated by domestic and international flights at Auckland Airport. Others 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). Scope 1 emissions are those from the jet fuel use at the three airports. Emissions from grid-supplied energy consumed by aircraft charging at airports were included in Scope 2 of Stationary Energy (Chapter 3). Scope 3 emissions are those from departing flights at Auckland Airport. The proportion of Scope 3 emissions attributable to Auckland was calculated based on the proportion of departure passengers who were Auckland residents. Data of international and domestic departures were obtained from StatsNZ (2018) and Auckland Airport (2018).

MBIE (2018a) provided total aviation fuel supplied to Auckland from 2010 to 2016. The data of other years was estimated by scaling the national total. The Joint User Hydrant Installation (JUHI) Depot provided aviation fuel consumption at Auckland Airport for 2009-2016. Consumption for other years was estimated by scaling the Auckland total. The use of aviation fuel at three other airports was calculated as the difference between total use in Auckland and consumption at Auckland Airport. National emission factors were applied (MBIE, 2018a; 2018b).

4.6 Off-road transport

Petrol and diesel delivered to Auckland from 2010 to 2016 were sourced from MBIE (2018a). The data was used as total consumption in Auckland. Total consumption of other years was calculated by scaling the fuel sales data. Off-road consumption of diesel and petrol was calculated as the difference between total consumption and the use for on-road transport and railways. National emission factors were used (MBIE, 2018a; 2018b). These Scope 1 emissions are reported under Stationary Energy (Chapter 3) allocated to four sub-sectors (residential buildings; commercial and institutional buildings and facilities; manufacturing industries and construction; and agriculture, forestry and fishing activities) based on the EECA database (EECA, 2018).

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 (Chapter 3).

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 354 kt CO_2e, with 98.1 per cent from solid waste sources and 1.9 per cent from waste water treatment.

5.2 Solid waste

Due to lack of data, only emissions from landfilled waste were reported. The total amount of solid waste and its composition generated within Auckland sent to landfills were sourced from various reports (Auckland Regional Council, 2010; Auckland Council, 2011; 2018b; 2018c; Arup, 2014). Equations to estimate emissions from landfills (MfE, 2017) 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.

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 for 1990 were zero since landfill gas was not well managed at that time.

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 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. Auckland's sources are identified among those in New Zealand's Greenhouse Gas Inventory and their emissions are estimated. 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 mainly came from Industrial Processes (1770 kt CO_2e, 77.3 per cent). Industrial Product Use contributed 519 kt CO_2e (22.7 per cent).

6.2 Industrial processes

CO_2 is emitted from two distinct industrial processes in Auckland. They are production of steel from iron sand and from scrap steel, and use of soda ash and limestone in glass making. In New Zealand, all the iron and steel production and most of the glass production are located in Auckland. Their emissions were sourced from New Zealand's Greenhouse Gas Inventory (MfE, 2018) which reported emissions from glass production in the category of "Other process uses of carbonates" to aggregate the data with other sources and preserve confidentiality. This inventory reported all the emissions from the iron and steel production. 90% of the emissions from "Other process uses of carbonates" were allocated to Auckland (MfE, 2018).

6.3 Industrial product use

GHGs are emitted from non-energy products from fuels and solvent use (CO_2), product uses as substitutes for ODS (ozone depleting substances) (HFCs), and other product manufacture and use (N_2O, PFCs and SF_6). Emissions in the categories of "Non-energy products from fuels and solvent use", "Product uses as substitutes for ODS (ozone depleting substances)" and "Other product manufacture and use" from New Zealand's Greenhouse Gas Inventory (MfE, 2018) were allocated to Auckland on a population basis. Emissions of CO_2, N_2O, HFCs, PFCs and SF_6 were reported.

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.

7.1 Emissions from AFOLU

Emissions from the AFOLU sector are summarised in Tables 2-1 and A-1, and Figure 2-1. For comparison with New Zealand's Greenhouse Gas Inventory, they are also reported as carbon sequestration from forestry and agriculture sources. The former is emissions from the Land Use, Land Use Change and Forestry (LULUCF) sector (MfE, 2018) (i.e., the Land sub-sector and the harvested wood products (HWP) sources in the GPC). The latter is AFOLU emissions excluding carbon sequestration from forestry.

Emissions from agriculture sources were 726 kt CO_2e. Carbon sequestered from land was −1198 kt CO_2e, resulting in AFOLU emissions of −472 kt CO_2e. The removal is expressed as a negative value to help clarifying 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, 2018). Similarly, Auckland's gross emissions exclude carbon sequestration from forestry.

7.2 Livestock

CH_4 is produced in digestive processes of livestock (enteric fermentation) and through management of their manure. N_2O is emitted from the manure management system. The number of livestock (dairy cattle, non-dairy cattle, sheep and deer) in Auckland was sourced from Statistics New Zealand (StatsNZ, 2018). National emission factors were applied (MfE, 2018).

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 (MfE, 2018) 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.

7.4 Aggregate sources and non-CO_2 emission sources on land

Aggregate sources and non-CO_2 emission sources on land are fertilizer use, liming, urea application, agricultural soils and harvested wood products (HWPs). Emissions (CO_2 and N_2O) from liming, urea application and agricultural soils were estimated based on national emissions (MfE, 2018) 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. Emissions from crop residue burning are minor and not included in this inventory.

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 (MfE, 2018) with some Auckland-specific activity data.

8 Conclusions

Concluding findings of the inventory are as follows:

- In 2016, Auckland's gross and net emissions were 11,326 kt CO_2e and 10,128 kt CO_2e, respectively. Carbon dioxide (CO_2) contributed 83.1 per cent of gross emissions. Transport and stationary energy dominated emissions, accounting for 43.6 per cent and 26.6 per cent of gross emissions, respectively.
- Gross and net emissions in 2016 have dropped from the 2015 levels, driven by decreased emissions from energy, and industrial processes and product use (IPPU) sectors. There was also more carbon sequestration from forestry. It is not clear if this is the start of a downward trend. There was a gradual increase in gross emissions from 2009 to 2016 due to increased emissions from transport, waste, IPPU and agriculture sources. Increased carbon sequestration from forestry resulted in lower net emissions in 2016 than in 2009. Work is needed to further understand emissions trends and driving factors.
- With respect to current levels, Auckland needs to reduce its net emissions by 24.7 per cent to 33.0 per cent by 2020, 49.8 per cent by 2040 and 58.1 per cent by 2050, to meet its reduction targets of 10 to 20 per cent by 2020, 40 per cent by 2040 and 50 per cent by 2050 (based on 1990 emissions). The council is developing an integrated climate action plan which will set an emission target consistent with the Paris Agreement aspiration of 1.5°C maximum temperature rise and a path to rapidly reduce emissions.
- In 2016, net emissions were 6.3 t CO_2e per capita and 121 t CO_2e per million $NZ GDP (2009/2010 prices) while gross emissions were 7.0 t CO_2e per capita and 135 t CO_2e per million $NZ GDP. These values were lower than in 2009, and this shows that Auckland decouples emissions from population and economic growth.
- Improvements in activity data, emission factors and methodology have been made for this inventory. The emissions trend was not affected by the change in estimates between inventories.

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11 Abbreviations

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

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
HWP	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 triflouride
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

Table A-1 GHG emissions by sector and sub-sector for 2016*

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	233,971	316,488	39,437	589,895
I.2	Commercial and institutional buildings and facilities	478,090	94,946	28,361	601,397
I.3	Manufacturing industries and construction	1,065,942	354,106	84,344	1,504,393
I.4.1/2/3	Energy industries	IE	IE	IE	
I.4.4	Energy generation supplied to the grid	32			
I.5	Agriculture, forestry and fishing activities	217,680	92,723	11,011	321,414
I.6	Non-specified sources	NO	NO	NO	
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal	NO			
I.8	Fugitive emissions from oil and natural gas systems	NO			
SUB-TOTAL	(city induced framework only)	1,995,682	858,263	163,153	3,017,098
II	TRANSPORTATION				
II.1	On-road transportation	4,258,592	IE	IE	4,258,592
II.2	Railways	8,370	2,959	212	11,541
II.3	Waterborne navigation	32,996	IE	379,339	412,335
II.4	Aviation	41,741	IE	215,171	256,912
II.5	Off-road transportation	IE	NO	IE	
SUB-TOTAL	(city induced framework only)	4,341,699	2,959	594,722	4,939,380
III	WASTE				
III.1.1/2	Solid waste generated in the city	229,453		118,358	347,811
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	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)	236,093		118,358	354,451
IV	INDUSTRIAL PROCESSES and PRODUCT USES				
IV.1	Emissions from industrial processes occurring in the city boundary	1,770,079			1,770,079
IV.2	Emissions from product use occurring within the city boundary	519,408			519,408
SUB-TOTAL	(city induced framework only)	2,289,487			2,289,487
V	AGRICULTURE, FORESTRY and OTHER LAND USE				
V.1	Emissions from livestock	568,911			568,911
V.2	Emissions from land	-1,313,386			-1,313,386
V.3	Emissions from aggregate sources and non-CO2 emission sources on land	272,408			272,408
SUB-TOTAL	(city induced framework only)	-472,067			-472,067
VI	OTHER SCOPE 3				
VI.1	Other Scope 3			NE	
TOTAL	(city induced framework only)	8,390,894	861,222	876,233	10,128,349

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

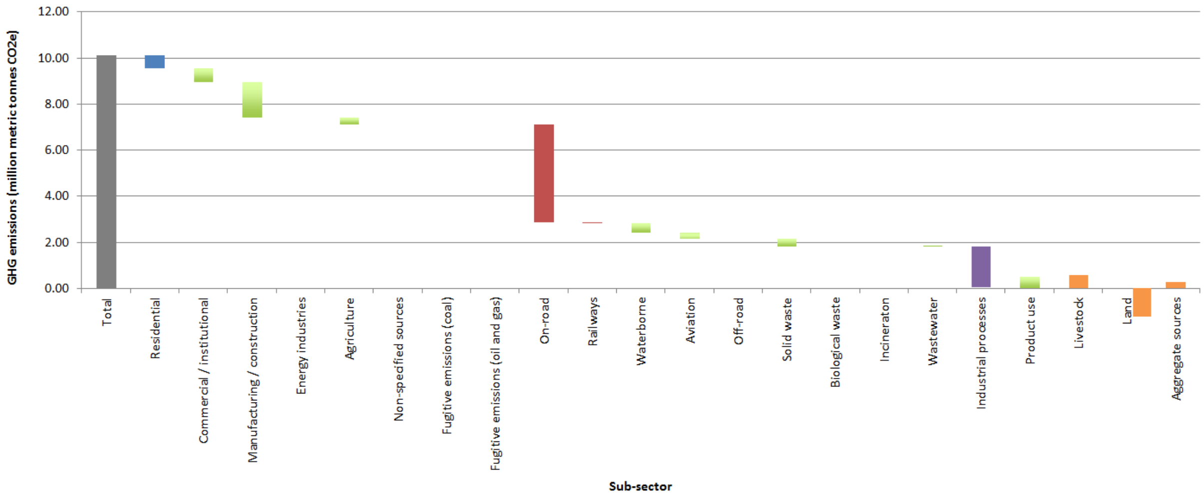

Figure A-1 Auckland's GHG emissions by sector and sub-sector for 2016

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rimu@aucklandcouncil.govt.nz or visit
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