Auckland's Greenhouse Gas Inventory for 2013

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Auckland's Greenhouse Gas Inventory for 2013

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Executive summary

Auckland's vision is to become the world's most liveable city. The Auckland Plan lays out an aspirational target to achieve a 40 per cent reduction in greenhouse gas (GHG) emissions by 2040 (based on 1990 levels). Auckland Low Carbon Action Plan sets out the pathways and specific actions to achieve the target. Reducing Auckland's GHG emissions is a critical element to achieving this vision. An inventory that identifies and quantifies the sources and sinks of GHGs in Auckland is essential to inform and evaluate our progress.

Auckland's GHG inventory for 2013 and 2009 was prepared with the most up-to-date information and in accordance with the global best practice: the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). In 2013, Auckland's GHG emissions were 11,997 $ktCO_2e$ (kilo-tonnes of carbon dioxide equivalent) (gross emissions) or 10,955 $ktCO_2e$ (net emissions including carbon sequestration from forestry). Of the three GHGs estimated, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) contributed 81.3 per cent, 16.5 per cent and 2.1 per cent of the gross emissions. The transport and stationary energy sectors dominated the emissions, accounting for 69.0 per cent of total gross emissions (Figure E-1).

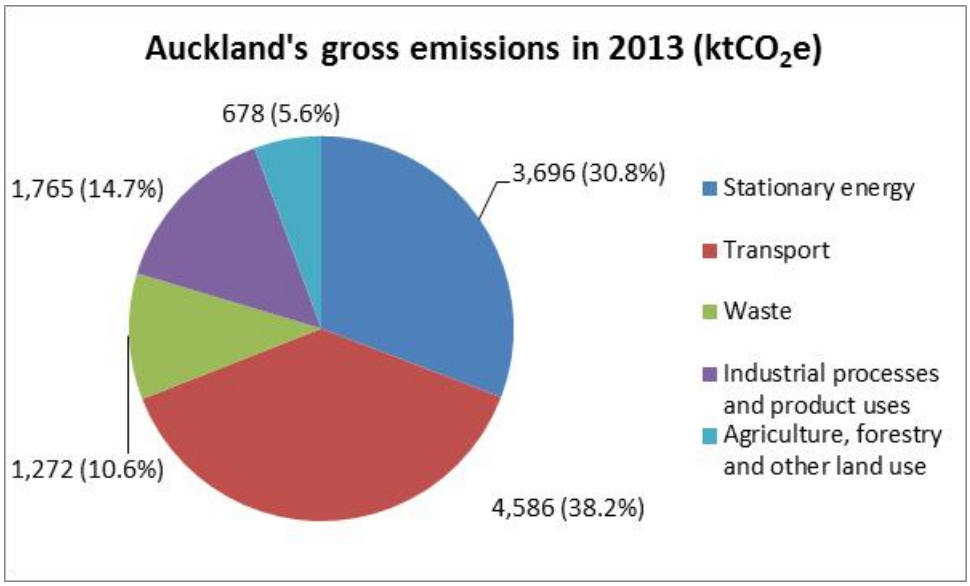

Figure E-1 Auckland's GHG gross emissions profile in 2013

Between 2009 (base year) and 2013, Auckland's GHG emissions have remained relatively stable. There was an increase of 0.6 per cent for gross emissions and 0.9 per cent for net emissions (Figure E-2). The main driver of the increase was the

increased emissions from the industrial processes and product use sector. Over the same timeframe, the population increased by 5.0 per cent and the GDP increased by 8.4 per cent. Subsequently, the emissions intensity by population decreased from 7.6 to 7.3 tCO_2e per capita for net emissions and 8.4 to 8.0 tCO_2e per capita for gross emissions. Similarly the emissions intensity by GDP decreased from 160 to 149 tCO_2e per million $NZ (2009/2010 price) for net emissions and 175 to 163 tCO_2e per million $NZ for gross emissions. Overall, the emissions intensity has reduced and there is evidence that emissions are decoupling from population and economic growth.

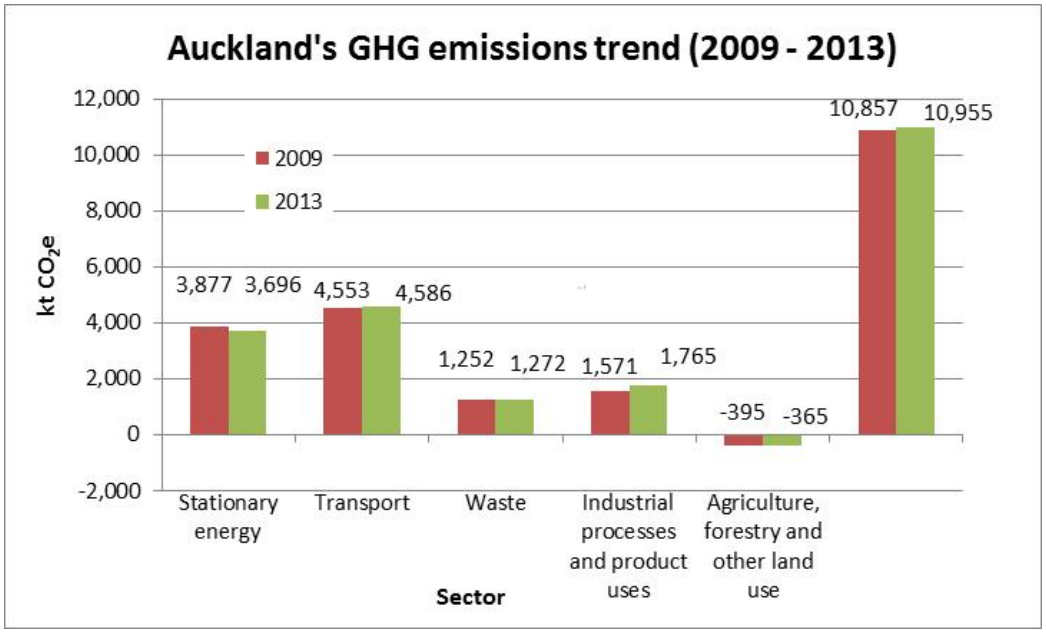

Figure E-2 Auckland's GHG emissions trends between 2009 and 2013

The previous Auckland GHG inventory for 2009 was updated in accordance with the GPC and with improved input data. Further improvements are recommended for future GHG inventories, including:

- Improving data for some activities (i.e., solid waste disposal, shipping, and coal, LPG and biomass consumption) that produce emissions,
- Improving emissions calculation from industrial processes and product use (IPPU) and agriculture, forestry, and other land use (AFOLU) sectors based on New Zealand's Greenhouse Gas Inventory methodologies,
- Reporting emissions for 2010 to 2012 when the activity data is more complete.

1 Introduction

Auckland's vision is to become the world's most liveable city. Reducing our greenhouse gas (GHG) emissions is a critical element to achieving this vision. The Auckland Plan lays out an aspirational target to achieve a 40 per cent reduction in GHGs by 2040 (based on 1990 levels). Auckland Low Carbon Action Plan sets out the pathways and specific actions to achieve the target (Auckland Council, 2014). An emissions inventory that identifies and quantifies the sources and sinks of GHGs in Auckland is essential to inform and evaluate our progress.

Auckland's GHG inventories were previously developed by Maunsell AECOM in 2008, URS in 2009 and 2011, and most recently by Arup for 2009 (Arup, 2014). This document reports the Auckland's GHG inventory for 2013, the most recent year when emissions data is available from New Zealand's Greenhouse Gas Inventory (MfE, 2015a). 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. This inventory sourced significant information from New Zealand's Greenhouse Gas Inventory. Auckland Low Carbon Action Plan uses 2009 as the base year for GHG emissions (Auckland Council, 2014). The 2009 emissions were also calculated for consistency and comparison with the 2013 results. The emissions for 2010 to 2012 are not included in this report, but will be reported in the next inventory when the data for some activities (i.e., solid waste disposal, shipping, and coal, LPG and biomass consumption) that produce emissions is more complete.

1.1 Methodology – the GPC

Various methods have been used to develop GHG inventories in cities. This 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, 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 (GPC). The GPC offers a robust, transparent and globally-accepted framework to consistently identify, calculate and report on city greenhouse gases. This report uses the most recent version 1.0 (WRI et al., 2014) in preparing and reporting the GHG emissions in Auckland.

The spatial extent of Auckland Council is the geographic boundary of this inventory. The inventory covers a continuous period of 12 months and accounts for emissions within a

whole year for 2013 and 2009. 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 year data is used.

This report covers three gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Emissions of other gases (i.e., hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen triflouride (NF_3)) are not estimated due to insufficient information. Emissions are reported as metric tonnes of each GHG as well as CO_2 equivalents (CO_2e). CO_2e is a term for describing different GHGs in a common unit. For any quantity and type of GHG, CO_2e signifies the amount of CO_2 which would have the equivalent global warming potential.

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 is not covered in the current version of the GPC and is not included in this inventory. These sectors are sub-divided into sub-sectors and further into sub-categories (see Appendices A and B).

Emissions are allocated into three scopes (Figure 1-1). Scope 1, or "territorial", emissions include those that physically occur within the city and scope 3 emissions refer to those that occur outside the city but are driven by activities taking place within the city's boundaries. 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.

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., kilowatt-hours (kWh) of electricity used in a year). An emission factor is the mass of GHG emissions relative to a unit of activity (e.g., CO_2 emissions in kg from the use of electricity in kWh, $kgCO_2/kWh$).

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.

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. Modelled activity data using robust assumptions or more general emission factors (e.g., applied nationally) rated as Medium (M). Low (L) is referred to highly-modelled or uncertain activity data, or default emission factors (e.g., those provided in IPPC (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 GPC reporting tool (v1.8) (CDP, 2015) 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 between 2009 and 2013 are discussed. 2009 is the base year in the Auckland Low Carbon Action Plan (Auckland Council, 2014). The improvements on the previous inventory and further improvements recommended for the future 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 the emissions, data sources of activity data and emission factors.

Emissions details are presented in Appendices A and B for sectors, sub-sectors and further into sub-categories.

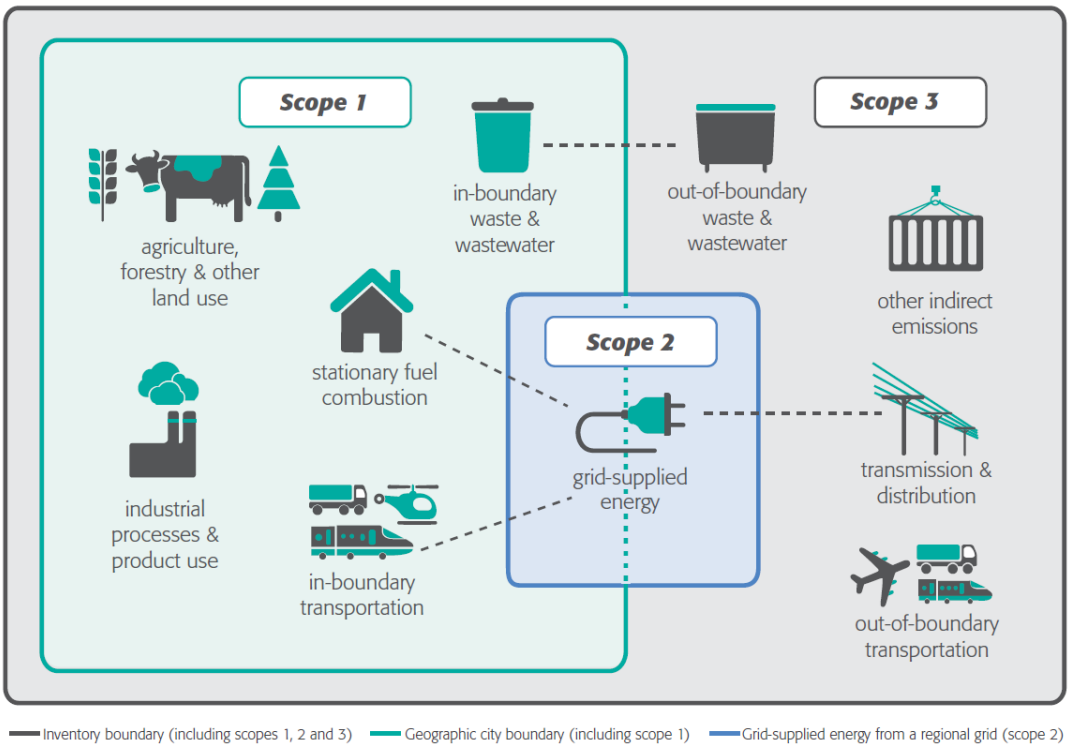

Figure 1-1 Sources and boundaries of city GHG emissions (WRI et al., 2014)

2 Total Emissions and Trends

The total emissions from all sectors were summarised in this Chapter, together with the emissions profiles. The changes in emissions between the base year 2009 and 2013 were discussed. Improvements on the previous inventory and for future inventory were also included in this chapter.

2.1 Total emissions

In 2013, Auckland's net GHG emissions were 10,955 ktCO2e (including carbon sequestration from forestry, see Table 2-1). As discussed earlier, emissions from the "Other Scope 3" (S3) sector were not estimated, therefore "Basic+" and "Basic+S3" reports the same quantity of emissions in Table 2-1. Table 2 2 illustrates the emission sources covered and reported by the GPC.

Table 2-1 GHG emissions summary

GHG Emissions Source (By Sector)		Total GHGs (metric tonnes CO2e)					
		Scope 1	Scope 2	Scope 3	BASIC	BASIC+	BASIC+ S3
STATIONARY ENERGY	Energy use (all emissions except I.4.4)	2,128,584	1,338,632	229,026	3,467,215	3,696,241	3,696,241
	Energy generation supplied to the grid (I.4.4)	750,985					
TRANSPORTATION	(all II emissions)	3,921,142		665,294	3,921,142	4,586,436	4,586,436
WASTE	Waste generated in the city (III.X.1 and III.X.2)	932,043		339,572	1,271,615	1,271,615	1,271,615
	Waste generated outside city (III.X.3)						
IPPU	(all IV emissions)	1,765,352				1,765,352	1,765,352
AFOLU	(all V emissions)	-364,582				-364,582	-364,582
OTHER SCOPE 3	(all VI emissions)						
TOTAL		**9,133,523**	1,338,632	1,233,892	**8,659,972**	**10,955,062**	**10,955,062**

The net emissions from agriculture, forestry and other land use (AFOLU) were a negative value to help clarifying that the value is a removal and not an emission. To exclude the removal and report the emissions only, New Zealand's Greenhouse Gas Inventory reported gross emissions by excluding the Land Use, Land Use Change and Forestry (LULUCF) sector (MfE, 2015a). Similarly, Auckland's gross emissions exclude carbon sequestration from forestry (i.e., from the Land sub-sector (V.2 in Table 2-3)).

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 the total gross emissions, CO_2, CH_4 and N_2O contributed 9,758 kt (81.3 per cent), 1,984 $ktCO_2e$ (16.5 per cent) and 255 $ktCO_2e$ (2.1 per cent), respectively. The contribution from the five sectors was stationary energy 30.8 per cent, transport 38.2 per cent, waste 10.6 per cent, industrial processes and product use 14.7 per cent, and agriculture, forestry and other land use 5.6 per cent. Transport and stationary energy dominated the emissions, accounting for 69.0 per cent of the total emissions (Figure 2-1).

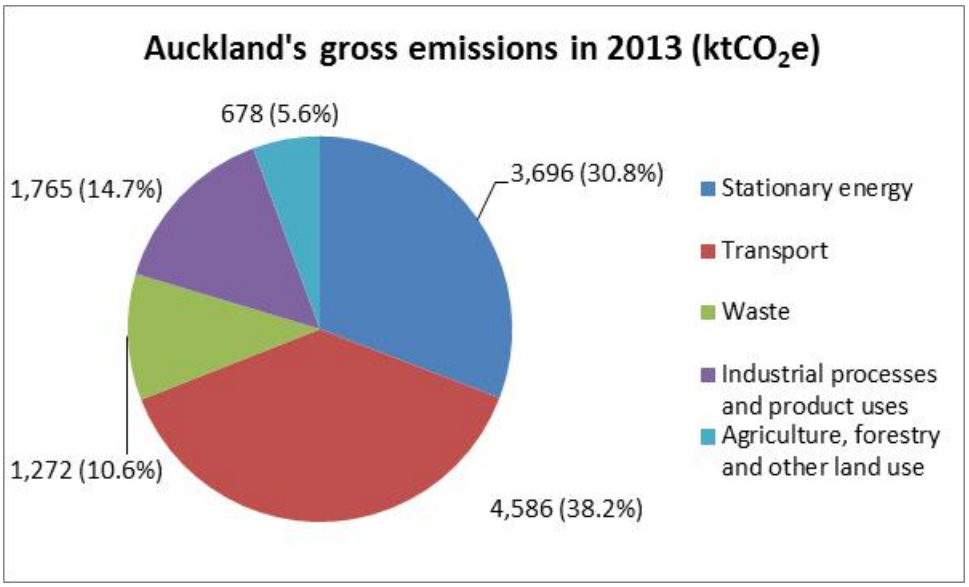

Figure 2-1 Auckland's GHG gross emissions profile in 2013

2.2 Emissions by sector and sub-sector

Table 2-3 and Figure 2-2 summarise the emissions by sector and sub-sector in 2013. For each of the five sectors (stationary energy; transport; waste; industrial processes and product use (IPPU); agriculture, forestry, and other land use (AFOLU)) and their sub-sectors, a description of GHG-relevant activities in Auckland, the GPC approach to calculate the emissions, data sources of activity data and emission factors are discussed in details in Chapters 3 to 7.

Table 2-3 GHG emissions by sector and sub-sector

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	259,149	487,317	56,394	802,860
I.2	Commercial and institutional buildings and facilities	436,378	377,996	54,526	868,900
I.3	Manufacturing industries and construction	1,158,896	356,449	99,270	1,614,615
I.4.1/2/3	Energy industries	IE	IE	IE	
I.4.4	Energy generation supplied to the grid	750,985			
I.5	Agriculture, forestry and fishing activities	274,159	116,871	18,835	409,866
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)	**2,128,584**	**1,338,632**	**229,026**	**3,696,241**
II	TRANSPORTATION				
II.1	On-road transportation	3,841,833	NO	IE	3,841,833
II.2	Railways	61,716	NO	IE	61,716
II.3	Waterborne navigation	17,592	IE	204,914	222,507
II.4	Aviation	IE	IE	460,380	460,380
II.5	Off-road transportation	IE	NO	IE	
SUB-TOTAL	(city induced framework only)	**3,921,142**		**665,294**	**4,586,436**
III	WASTE				
III.1.1/2	Solid waste generated in the city	776,236		339,572	1,115,809
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	155,807		NO	155,807
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)	**932,043**		**339,572**	**1,271,615**
IV	INDUSTRIAL PROCESSES and PRODUCT USES				
IV.1	Emissions from industrial processes occurring in the city boundary	1,747,492			1,747,492
IV.2	Emissions from product use occurring within the city boundary	17,860			17,860
SUB-TOTAL	(city induced framework only)	**1,765,352**			**1,765,352**
V	AGRICULTURE, FORESTRY and OTHER LAND USE				
V.1	Emissions from livestock	539,222			539,222
V.2	Emissions from land	-1,042,270			-1,042,270
V.3	Emissions from aggregate sources and non-CO2 emission sources on land	138,467			138,467
SUB-TOTAL	(city induced framework only)	**-364,582**			**-364,582**
VI	OTHER SCOPE 3				
VI.1	Other Scope 3			NE	
TOTAL	(city induced framework only)	**8,382,538**	**1,338,632**	**1,233,892**	**10,955,062**

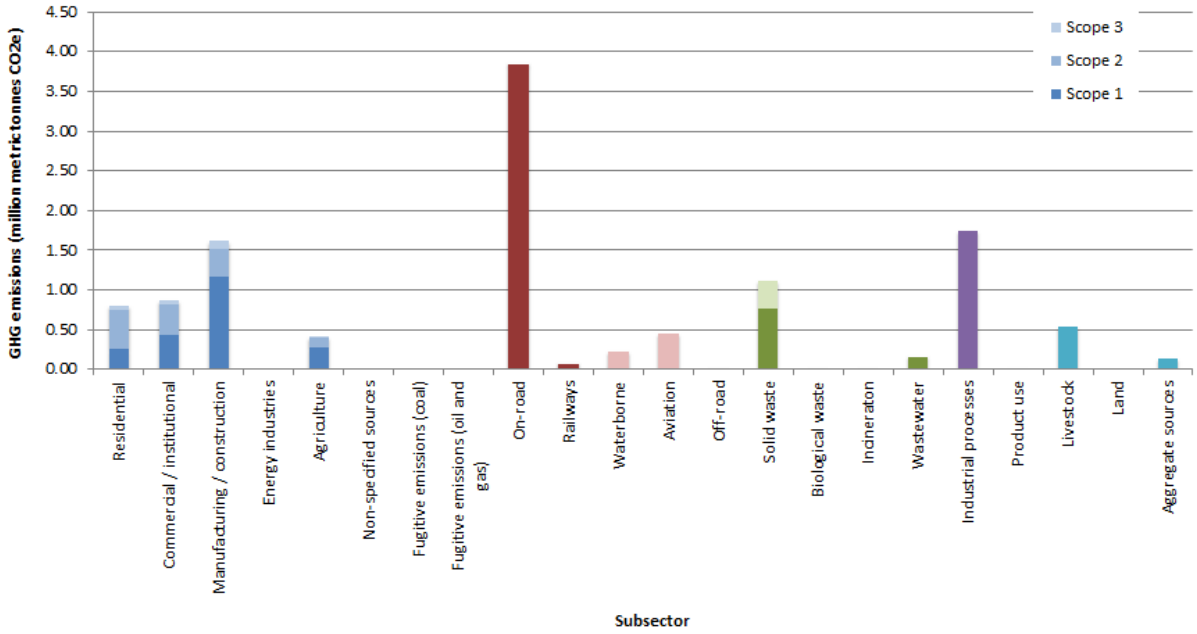

Figure 2-2 Auckland's GHG emissions by sector and sub-sector in 2013

2.3 Trends

Between 2009 (base year) and 2013, Auckland's GHG emissions have remained relatively stable, with an increase of 0.6 per cent for gross emissions and 0.9 per cent for net emissions (Figure 2-3). The main driver of the increase was the increased emissions from the industrial processes and product use sector. There was also an increase in emissions from transport, and waste sectors, but a decrease in the stationary energy sector. The net removals from the AFOLU sector decreased, resulting in a relative increase in emissions.

Over the same timeframe, the population of Auckland increased by 5.0 per cent to 1,493,200, and the GDP increased by 8.4 per cent to 73,759 million $NZ (2009/2010 price). Subsequently, average GHG emissions decreased from 7.6 to 7.3 tCO_2e per capita for net emissions and 8.4 to 8.0 tCO_2e per capita for gross emissions (Table 2-4). Similarly the emissions per unit of GDP decreased between 2009 and 2013 from 160 to 149 tCO_2e per million $NZ (2009/2010 price) for net emissions and 175 to 163 tCO_2e per million $NZ for gross emissions (Table 2-4). It is important to note that the emissions intensity has improved. There is evidence that Auckland is decoupling emissions from population and economic growth.

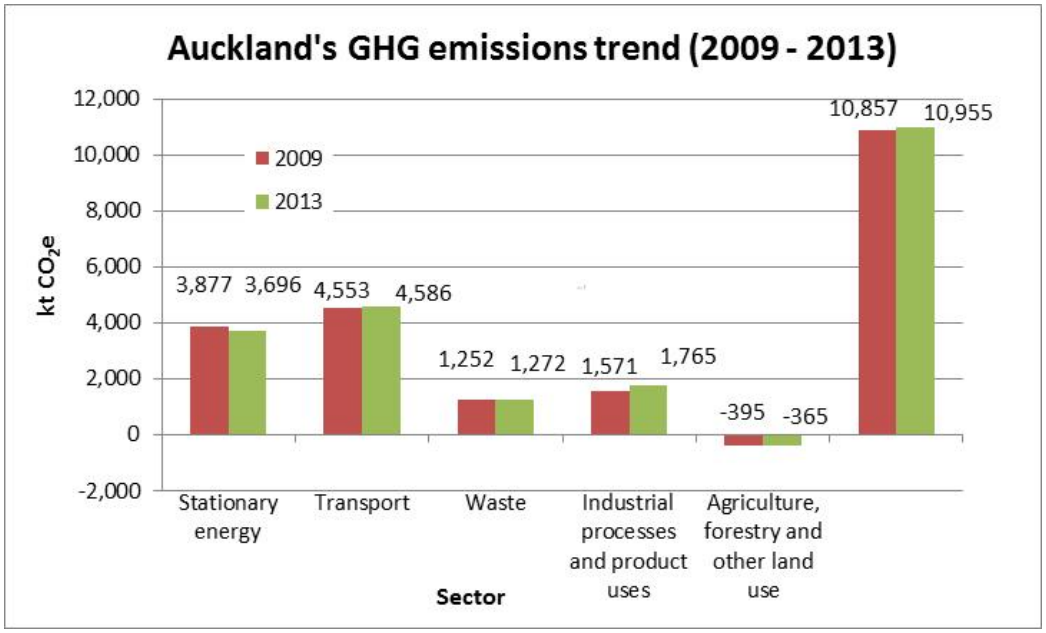

Figure 2-3 Auckland's GHG emissions trends between 2009 and 2013.

Table 2-4 GHG emissions trends between 2009 and 2013

Emissions		2009	2013
Gross emissions	Total emissions ($ktCO_2e$)	11,924	11,997
	Emissions per capital (tCO_2e/person)	8.4	8.0
	Emissions per GDP unit (tCO_2e/GDP unit)	175	163
Net emissions	Total emissions ($ktCO_2e$)	10,857	10,955
	Emissions per capital (tCO_2e/person)	7.6	7.3
	Emissions per GDP unit (tCO_2e/GDP unit)	160	149

2.4 Recalculating emissions for 2009

Although the emissions for 2009 were previously estimated by Arup (2014), it is international good practice (MfE, 2015a) to recalculate the previous estimate to ensure consistency in emission estimates and trends. This means emissions reported in the previous inventory differ from those reported for 2015 in this inventory.

Figure 2-4 shows the emissions for 2009 reported by Arup (2014) and by this inventory. To be comparable with Arup (2014), the carbon sequestration was calculated for exotic forests planted after 1990 only. In comparison, Arup reported lower emissions from stationary energy, transport and waste sectors, higher emissions from the IPPU sector, and higher net removals from the AFOLU sector.

The total gross emissions were 14.1 per cent lower and the net emissions were 16.7 per cent lower than those in this inventory. The differences were due to improvements in activity data, emission factors and methodology, or the identification of additional emission sources in the current inventory.

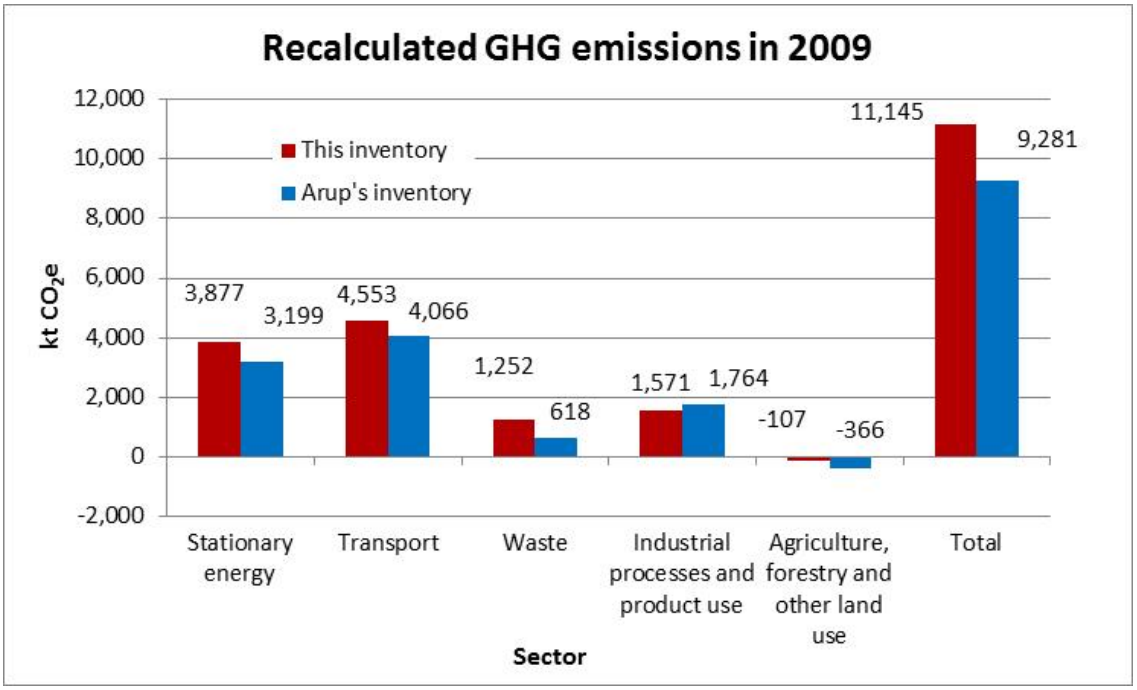

Figure 2-4 Comparison of GHG emissions for 2009 (this inventory vs Arup's inventory)

3 Stationary Energy

The emissions from stationary energy come from energy consumption in buildings 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 categorised 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 include all direct emissions from burning fuel (i.e., oil, gas, LPG, wood and coal) within the Auckland region. Scope 2 emissions include emissions associated with the consumption of grid-supplied electricity which is generated within or outside Auckland. Scope 3 emissions include those due to distribution losses from grid-supplied electricity and gas. The GHG in this sector includes 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. The emissions from other energy consumption were allocated into other four sub-sectors (i.e., residential buildings; commercial and institutional buildings and facilities; manufacturing industries and construction; and agriculture, forestry and fishing activities) based on the EECA energy end use database (EECA, 2015).

3.1 Emissions from stationary energy

The emissions from stationary energy and their scope categorisation are summarised in Table 2-3 and Figure 2-2. The total emissions were 3,696 ktCO_2e, with the majority from the consumption of electricity (38.7 per cent) and natural gas (31.7 per cent), and the remainder from the use of diesel, petrol and fuel oil (14.0 per cent), coal and wood (12.8 per cent), and LPG (2.8 per cent).

3.2 Scope 1: emissions from fuel combustion

Scope 1 includes direct emissions from the combustion of fuels within the Auckland region. The 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 the natural gas consumption in Auckland was sourced from Energy in New Zealand (MBIE, 2015a). Data about the quantity of gas consumed at Otahuhu and Southdown power plants was provided by the two stations. The national emission factors (MBIE, 2015b) were used.

The non-transport consumption of liquefied petroleum gas (LPG) in Auckland was sourced from the EECA's database (EECA, 2015) for 2012. The activity data for other years was estimated by the national data and the ratio of the Auckland consumption to the national

consumption in 2012. The national average emission factors (MBIE, 2015b) were used.

Consumption figures of coal and wood in 2012 were sourced from the EECA database (EECA, 2015) and used for 2009 and 2013 due to insufficient information for these two years. The national emission factors (MBIE, 2015b) were used. The CO_2 emissions from wood burning were reported as biogenic.

Fuel oil consumption for the non-transport use in 2012 was sourced from EECA (2015). The consumption for 2009 and 2013 was calculated from the national data and the 2012 ratio of the Auckland use to the national data. National emission factors were applied (MfE, 2015b). As discussed in Section 3.6, the Scope 1 emissions from petrol and diesel use for off-road transport were reported under Stationary Energy.

The emissions from combustion of gas from landfills and waste treatment plants were small (MfE, 2015a) and were not included in this inventory. CH_4 from landfill and waste treatment plants not captured or combusted was estimated in the Waste sector (Chapter 4).

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

The GPC includes emissions from the 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.

The total amount of electricity consumed was sourced from Vector Ltd (2015), Counties Power Ltd (2015) and the New Zealand Electricity Authority (NZEA, 2015). The national average emission factors provided by MBIE (2015b) were used.

3.4 Scope 3: distribution losses from grid-supplied electricity and gas

Scope 3 emissions include transmission and distribution losses from the use of grid-supplied electricity and gas. The grid loss factor for the calculation was sourced from national data (MBIE, 2015a; MfE, 2015).

4 Transport

The emissions from transport come from directly combusting fuel or indirectly consuming grid-delivered electricity to transport vehicles and mobile equipment or machinery. For transport occurring within the Auckland region, emissions from combustion of fuels are reported in scope 1 and emissions from grid-supplied electricity are included in scope 2. Scope 3 includes 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

The emissions from transport and their scope categorisation are summarised in Table 2-3 and Figure 2-2. On-road transport accounted for 83.7 per cent of the total 4,586 ktCO_2e. The contributions from other sources were 16.3 per cent (aviation 10.0 per cent, shipping 4.5 per cent, and train and ferry 1.8 per cent).

4.2 On-road transport

The data of petrol and diesel sales for land transport were collected and provided by Auckland Transport. The data was used to calculate emissions from on-road transport. The national emission factors (MfE, 2015a; MBIE, 2015b) were applied. The results were included in Scope 1 emissions.

4.3 Railways

Diesel use for rail was estimated for passenger and freight trains. Auckland Transport (2015) provided the CO_2 emissions from diesel use by passenger trains for 2010/2011 to 2012/2013, from which the diesel use was calculated. The 2010/2011 data was used for year 2009. Total diesel use for rail in Auckland in 2012 was provided by EECA (2015). Diesel use by freight trains was calculated as the difference between total diesel use and diesel use for passenger trains, and the absolute amount was assumed unchanged in years 2009, 2012 and 2013. Total diesel use for rail in 2009 and 2013 was calculated as total consumption by passenger trains and freight trains. The national emission factors (MfE, 2015a; MBIE, 2015b) were applied. The results were included in Scope 1 emissions.

4.4 Water transport

The fuel oil used by ferries in 2010 was sourced from Peeters (2011) (Scope 1). The data was used for 2009 and 2013.

The emissions from shipping at sea ports in Auckland were categorised as Scope 3 emissions. The data for fuel consumption in 2008 was sourced from Forbes (2009). For other years, the consumption was calculated from the national totals (MBIE, 2015a) and the proportion of Auckland to the national consumption in 2008. The national emission factors were applied (MBIE, 2015a; 2015b). It was assumed that half of the emissions were attributable to Auckland. It is the same assumption as in the previous inventory (Arup, 2014).

4.5 Aviation

Aviation activities in Auckland are dominated by domestic and international flights at the Auckland Airport. Others include local helicopter, light aircraft, sightseeing and training flights. Scope 1 includes emissions from the jet fuel use for aviation activities occurring within the city boundary. It is considered that the Scope 1 emissions in Auckland were small, therefore not included. Emissions from grid-supplied energy consumed by aircraft charging at airports were included in Scope 2 of Stationary Energy (Chapter 2). Scope 3 includes emissions from departing flights at airports that serve the city (WRI et al., 2014).

The aviation fuel (Jet A1) delivered to Auckland was provided by MBIE (2015a) for 2010-2014. The consumption at the Auckland Airport was provided by the Joint User Hydrant Installation (JUHI) Depot at Auckland Airport for 2009 – 2014. The non-Auckland-Airport use for 2010-2014 was calculated as the difference between the MBIE data (total) and the JUHI data (at the Auckland Airport). The average of the differences for 2010 - 2014 was used for 2009 in calculating the total aviation fuel consumption in 2009. The national emission factors were applied (MBIE, 2015a; 2015b).

The proportion of emissions from the aviation fuel use at the Auckland Airport attributable to Auckland was calculated based on the proportion of departure passengers who were Auckland residents. For international departure, the proportion of NZ residents was obtained from StatsNZ (2015). For domestic departure, the total passengers were obtained from the Auckland Airport (2015). It was assumed that domestic departure passengers include half the visitors of international arrivals which were sourced from StatsNZ (2015). For both international and domestic departure, the proportion of Auckland residents to NZ residents was estimated by the ratio of population of Auckland to NZ. It was assumed that 10 per cent of the non-Auckland-Airport emissions were attributed to Auckland.

4.6 Off-road transport

The petrol and diesel delivered to Auckland from 2010 - 2014 were sourced from MBIE (2015a). The data was used as the total consumption in Auckland. The off-road

consumption was calculated as the difference between the total delivered and the use for on-road transport and railways. The averaged off-road use for 2010-2014 was use for 2009 in calculating the total fuel consumption in 2009. National emission factors were used (MBIE, 2015a; 2015b). These Scope 1 emissions were reported under Stationary Energy (Chapter 2) allocated to the four sectors based on the EECA database (EECA, 2015).

5 Waste

The waste sector includes emissions generated from the processing and disposal of solid waste and wastewater treatment. The emissions from activities in this sector include predominantly methane (CH_4), with some nitrous oxide (N_2O) and little carbon dioxide (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 the use of grid-supplied electricity in waste treatment facilities within Auckland are included in Scope 2 in Stationary Energy (Chapter 3).

5.1 Emissions from waste

The emissions from waste and their scope categorisation are summarised in Table 2-3 and Figure 2-2. The waste sector emitted 1,272 ktCO_2e, 87.7 per cent from solid waste sources and 12.3 per cent from waste water treatment.

5.2 Solid waste

The total amount of solid waste generated within Auckland sent to landfills was sourced from the previous inventory (Arup, 2014) for 2009 and from the Auckland waste assessment report (Auckland Council, 2011) for 2010. The total solid waste generated in Auckland in 2013 was estimated by scaling the national total (MfE, 2015a) based on the ratio of Auckland waste to the national total in 2010. The proportion of the total waste sent to landfills in Auckland was also reported in the Auckland waste assessment report (Auckland Council, 2011) for 2010 which was used for 2009 and 2013. The national emission factors (MfE, 2015a) were applied. The emissions from this proportion of waste were reported in Scope 1. The emissions from waste generated in Auckland but treated outside Auckland were included in Scope 3.

5.3 Wastewater treatment

Emissions from wastewater generated and treated in Auckland were estimated by scaling the national emissions in the category of “Wastewater treatment and discharge” (MfE, 2015a) by the ratio of Auckland population to the national total. These were categorised as Scope 1 emissions.

6 Industrial Processes and Product Use (IPPU)

Emissions from non-energy related industrial activities and product use are assessed and reported under IPPU. The emissions for Auckland are estimated by allocation of emissions from New Zealand's Greenhouse Gas Inventory, an approach adopted in the previous inventory (Arup, 2014).

6.1 Emissions from IPPU

The emissions from industrial processes and product use (IPPU) and their scope categorisation are summarised in Table 5-1. Almost all the emissions came from industrial processes (1,747 ktCO_2e, 99.0 per cent). Product Use sources contributed 18 ktCO_2e (1.0 per cent).

6.2 Industrial processes

Emissions from industrial processes included those from the iron and steel production reported in New Zealand's Greenhouse Gas Inventory (MfE, 2015a) since the sources of emissions were all allocated in Auckland. This approach was used in the previous inventory (Arup, 2014). The emissions (CO_2) were included in Scope 1.

6.3 Product use

The national emissions in the category of "Other product manufacture and use" (MfE, 2015a) were allocated to Auckland on a population basis. The emissions (N_2O) were included in Scope 1.

7 Agriculture, Forestry and Other Land Use (AFOLU)

Agriculture, forestry and other land use (AFOLU) activities are divided into three categories: livestock, land, and aggregate sources and non-CO_2 emissions sources on land. GHG from AFOLU consists of CH_4, N_2O and CO_2, all reported in Scope 1 emissions.

7.1 Emissions from AFOLU

The emissions from agriculture, forestry and other land use (AFOLU) and their scope categorisation are summarised in Table 2-3 and Figure 2-2. Emissions from livestock were 539 $ktCO_2e$. Aggregate sources and non-CO_2 emission sources on land contributed 138 $ktCO_2e$. Carbon removals from forest sequestration were -1,042 $ktCO_2e$. The net emissions were -365 $ktCO_2e$. The removal is expressed as a negative value to help clarifying that the value is a removal and not an emission.

To exclude the removal and report the emissions only, New Zealand's Greenhouse Gas Inventory reported gross emissions by excluding the Land Use, Land Use Change and Forestry (LULUCF) sector (MfE, 2015a). Similarly, Auckland's gross emissions exclude carbon sequestration from forestry (i.e., from the Land sub-sector).

7.2 Livestock

CH_4 is produced in the digestive processes (enteric fermentation) of livestock and through management of their manure. The number of livestock (dairy cattle, non-dairy cattle, sheep and deer) in Auckland was sourced from StatsNZ (2015). The national emission factors (MfE, 2015a) were applied. The emissions were categorised in Scope 1. The amount of N_2O emissions from the manure management was small (MfE, 2015a) and was not included in this inventory.

7.3 Land

Land use is divided into six categories: forest land, cropland, grassland, wetlands, settlements and other. CO_2 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 use. Due to insufficient data for a comprehensive estimate, only the changes of carbon stocks in exotic forests are calculated. This is the approach applied in the previous inventory (Arup 2014).

The species and planted areas of exotic forests were reported in the National Exotic Forest Description published by Ministry for Primary Industries (MPI, 2015). Carbon sequestration rates for exotic forest were sourced from Paul et al. (2008).

7.4 Aggregate sources and non-CO_2 emission sources on land

Aggregate sources and non-CO_2 emission sources on land include fertilizer use, liming, urea application. The emissions (CO_2 and N_2O) from liming, urea application and agricultural soils (Scope 1) were estimated based on national emissions (MfE, 2015a) allocated to Auckland by the proportion of the land areas of cropland and grassland compared to the national total. The land use data was sources from the Land Use Carbon Analysis System (LUCAS) New Zealand Land Use Map (https://data.mfe.govt.nz) which is also used for New Zealand's Greenhouse Gas Inventory.

Emissions from wood burning as energy were reported in Stationary Energy (Chapter 3) with non-CO_2 emissions under Scope 1 and CO_2 emissions as biogenic CO_2. For crop residue burning, the amount of emissions was small (MfE, 2015a) and was not included in this inventory.

8 Conclusions

In 2013, Auckland's GHG emissions were 11,997 ktCO_2e (gross emissions) or 10,955 ktCO_2e (net emissions including carbon sequestration from forestry). CO_2, CH_4 and N_2O contributed 9,758 kt (81.3 per cent), 1,984 ktCO_2e (16.5 per cent) and 255 ktCO_2e (2.1 per cent) to the gross emissions. The contribution from other GHGs (i.e., HFCs, PFCs, SF_6 and NF_3) was not estimated.

The contributions of the five sectors to the gross emissions were 30.8 per cent from stationary energy, 38.2 per cent from transport, 10.6 per cent from waste, 14.7 per cent from industrial processes and product use (IPPU), and 5.6 per cent from agriculture, forestry, and other land use (AFOLU). The transport and stationary energy sectors dominated the emissions, accounting for 69.0 per cent of the total gross emissions.

The emissions intensity has improved. There is evidence that Auckland is decoupling emissions from population and economic growth. Between 2009 (base year) and 2013, Auckland's GHG emissions increased by 0.6 per cent for gross emissions and 0.9 per cent for net emissions. Over the same timeframe, the population increased by 5.0 per cent and the GDP increased by 8.4 per cent. Subsequently, average GHG emissions decreased from 7.6 to 7.3 tCO_2e per capita for net emissions and 8.4 to 8.0 tCO_2e per capita for gross emissions. The emissions per unit of GDP decreased from 160 to 149 tCO_2e per million $NZ (2009/2010 price) for net emissions and from 175 to 163 tCO_2e per million $NZ for gross emissions.

There were improvements in activity data, emission factors and methodology, or the identification of additional emission sources in the current inventory. As a result, the previous inventory (Arup, 2014) reported lower 2009 emissions than this inventory: 14.1 per cent lower for gross emissions and 16.7 per cent lower for net emissions.

Further improvements are recommended for future GHG inventories, including:

- Improving activity data for solid waste disposal, shipping, and coal, LPG and biomass consumption,
- Improving emissions calculation from industrial processes and product use (IPPU) and agriculture, forestry, and other land use (AFOLU) sectors based on New Zealand's Greenhouse Gas Inventory methodologies,
- Reporting emissions for 2010 to 2012 when the activity data is more complete.

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10 References

Arup (2014). *Assessing the carbon abatement reduction potential in Auckland's energy resilience and low carbon action plan*. Prepared by Arup for Auckland Council. Auckland Council technical report, TR2014/005

Auckland Airport (2015). *Monthly traffic updates and Annual reports*, retrieved on 22 July 2015 from https://www.aucklandairport.co.nz

Auckland Council (2011). *Auckland Council waste assessment*, retrieved on 16 June 2015 from http://www.aucklandcouncil.govt.nz

Auckland Council (2014). *Auckland's Energy Resilience and Low Carbon Action Plan*, retrieved on 16 June 2015 from http://www.aucklandcouncil.govt.nz

Auckland Regional Council (2010). *State of the Auckland region 2009*, retrieved on 16 June 2015 from http://www.aucklandcouncil.govt.nz

Auckland Transport (2015). *Annual report 2014*, retrieved on 16 June 2015 from https://at.govt.nz

CDP (2015). *GPC reporting tool v1.8*, retrieved on 20 November 2015 from https://www.cdp.net/en-US/Pages/guidance-cities.aspx

Counties Power Ltd (2015). *Disclosure Information*, retrieved on 16 June 2015 from http://www.countiespower.com/disclosures.htm

EECA (2015). *Energy Efficiency and Conservation Authority energy end use database*, retrieved on 15 September 2015 from http://enduse.eeca.govt.nz/

Forbes B. (2009). *Industry Snapshot for the Auckland Region: the Energy Sector*, Auckland Regional Council.

IPCC (2015). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, retrieved on 20 November 2015 from http://www.ipcc-nggip.iges.or.jp/public/2006gl/

MBIE (2014). *Energy in New Zealand*, retrieved on 16 June 2015 from http://www.med.govt.nz/sectors-industries/energy

MBIE (2015a). *Energy data* from Ministry for Business, Innovation and Employment, retrieved on 16 June 2015 from http://www.med.govt.nz/sectors-industries/energy, or personal communications.

MBIE (2015b). *Energy GHG emissions data* (i.e., energy greenhouse gas emission web tables) from Ministry for Business, Innovation and Employment, retrieved on 16 June 2015 from http://www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-greenhouse-gas-emissions

MfE (2015a). *New Zealand's Greenhouse Gas Inventory 1990-2013*, retrieved on 16 June 2015 from https://www.mfe.govt.nz/climate-change/reporting-greenhouse-gas-emissions/nzs-greenhouse-gas-inventory

MfE (2015b). *Guidance for Voluntary Corporate Greenhouse Gas Reporting*, retrieved on 16 June 2015 from https://www.mfe.govt.nz/climate-change/reporting-greenhouse-gas-emissions/nzs-greenhouse-gas-inventory

MPI (2015). *National exotic forest description*, retrieved on 16 June 2015 from http://www.mpi.govt.nz

NZEA (2015). *Electricity market information (EMI).* retrieved on 16 June 2015 from http://www.emi.ea.govt.nz

Paul, T., Kimberley, M and Beets, P (2008). *Indicative forest sequestration tables*. Report prepared by Scion for Ministry of Agriculture and Forestry.

Peeters, S (2011). *Port-Related Air Emissions for the Auckland Region 2006 and 2010*. Report prepared by M&P Consulting Limited for Auckland Regional Council.

StatsNZ (2015). *Infoshare database*, retrieved on 16 June 2015 from http://www.stats.govt.nz/infoshare

Vector Ltd (2015). *Annual reports*, retrieved on 16 June 2015 from http://vector.co.nz.

WRI (World Resources Institute) et al. (2014). *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*, retrieved on 16 June 2015 from http://www.ghgprotocol.org/about-ghgp

11 Abbreviations

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

AFOLU	Agriculture, forestry and other land use
C40	Cities Climate Leadership Group
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
HFCs	Hydrofluorocarbons
ICLEI	ICLEI - Local Governments for Sustainability
IPPU	Industrial processes and product use
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 fossilized or from fossil sources.

City: Used throughout the GPC to refer to geographically discernable 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 A: GHG Emissions Report 2013

GPC ref No.	Scope	GHG Emissions Source (By Sector and Sub-sector)	Notation keys	GHGs (metric tonnes CO_2e)								
				CO_2	CH_4	N_2O	PFC	HFC	SF_6	NF_3	Total tCO_2e	CO_2(b)
I		STATIONARY ENERGY										
I.1		Residential buildings										
I.1.1	1	Emissions from fuel combustion within the city boundary		235,141	21,150	2,858					259,149	259,233
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary		471,794	14,702	821					487,317	
I.1.3	3	Transmission and distribution losses from grid-supplied energy		33,026	23,311	57					56,394	
I.2		Commercial and institutional buildings and facilities										
I.2.1	1	Emissions from fuel combustion within the city boundary		431,283	660	4,435					436,378	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary		365,955	11,404	637					377,996	
I.2.3	3	Transmission and distribution losses from grid-supplied energy		25,673	28,809	44					54,526	
I.3		Manufacturing industries and construction										
I.3.1	1	Emissions from fuel combustion within the city boundary		1,143,652	3,707	11,537					1,158,896	735,727
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary		345,095	10,753	601					356,449	
I.3.3	3	Transmission and distribution losses from grid-supplied energy		24,458	74,770	42					99,270	
I.4		Energy industries										
I.4.1	1	Emissions from energy production used in power plant auxiliary operations within the city	IE									
I.4.2	2	Emissions from grid-supplied energy consumed by energy industries	IE									
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy used in power plant auxiliary operations	IE									
I.4.4	1	Emissions from energy generation supplied to the grid		748,524	2,126	335					750,985	
I.5		Agriculture, forestry and fishing activities										
I.5.1	1	Emissions from fuel combustion within the city boundary		271,762	568	1,829					274,159	
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary		113,148	3,526	197					116,871	
I.5.3	3	Transmission and distribution losses from grid-supplied energy consumption		7,948	10,874	14					18,835	
I.6		Non-specified sources										
I.6.1	1	Emissions from fuel combustion within the city boundary	NO									
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	NO									
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NO									
I.7		Fugitive emissions from mining, processing, storage, and transportation of coal										
I.7.1	1	Fugitive emissions from mining, processing, storage, and transportation of coal within the city boundary	NO									
I.8		Fugitive emissions from oil and natural gas systems										
I.8.1	1	Fugitive emissions from oil and natural gas systems within the city boundary	NO									
II		TRANSPORTATION										
II.1		On-road transportation										
II.1.1	1	Emissions from fuel combustion on-road transportation occurring in the city		3,787,324	21,039	33,471					3,841,833	
II.1.2	2	Emissions from grid-supplied energy consumed in the city for on-road transportation	NO									
II.1.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	IE									
II.2		Railways										
II.2.1	1	Emissions from fuel combustion for railway transportation occurring in the city		60,758	94	864					61,716	
II.2.2	2	Emissions from grid-supplied energy consumed in the city for railways	NO									
II.2.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	IE									
II.3		Waterborne navigation										
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring in the city		17,427	45	121					17,592	
II.3.2	2	Emissions from grid-supplied energy consumed in the city for waterborne navigation	IE									
II.3.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use		202,895	499	1,520					204,914	
II.4		Aviation										
II.4.1	1	Emissions from fuel combustion for aviation occurring in the city	IE									
II.4.2	2	Emissions from grid-supplied energy consumed in the city for aviation	IE									
II.4.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use		456,926	89	3,364					460,380	
II.5		Off-road transportation										
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring in the city	IE									
II.5.2	2	Emissions from grid-supplied energy consumed in the city for off-road transportation	NO									
II.5.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	IE									

III		WASTE											
III.1		Solid waste disposal											
III.1.1	1	Emissions from solid waste generated in the city and disposed in landfills or open dumps within the city			776,236						776,236		
III.1.2	3	Emissions from solid waste generated in the city but disposed in landfills or open dumps outside the city			339,572						339,572		
III.1.3	1	Emissions from waste generated outside the city and disposed in landfills or open dumps within the city	NO										
III.2		Biological treatment of waste											
III.2.1	1	Emissions from solid waste generated in the city that is treated biologically in the city	NO										
III.2.2	3	Emissions from solid waste generated in the city but treated biologically outside of the city	NO										
III.2.3	1	Emissions from waste generated outside the city boundary but treated in the city	NO										
III.3		Incineration and open burning											
III.3.1	1	Emissions from waste generated and treated within the city	NO										
III.3.2	3	Emissions from waste generated within but treated outside of the city	NO										
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city	NO										
III.4		Wastewater treatment and discharge											
III.4.1	1	Emissions from wastewater generated and treated within the city			102,555	53,252					155,807		
III.4.2	3	Emissions from wastewater generated within but treated outside of the city	NO										
III.4.3	1	Emissions from wastewater generated outside the city boundary but treated within the city	NO										
IV		INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)											
IV.1	1	Emissions from industrial processes occurring in the city boundary		1,747,492							1,747,492		
IV.2	1	Emissions from product use occurring within the city boundary				17,860					17,860		
V		AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)											
V.1	1	Emissions from livestock			539,222						539,222		
V.2	1	Emissions from land		-1,042,270							-1,042,270		
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land		16,687		121,779					138,467		
VI		OTHER SCOPE 3											
VI.1	3	Other Scope 3	NE										

14 Appendix B: GHG Emissions Report 2009

GPC ref No.	Scope	GHG Emissions Source (By Sector and Sub-sector)	Notation keys	GHGs (metric tonnes CO_2e)								
				CO_2	CH_4	N_2O	PFC	HFC	SF_6	NF_3	Total tCO_2e	CO_2(b)
I		STATIONARY ENERGY										
I.1		Residential buildings										
I.1.1	1	Emissions from fuel combustion within the city boundary		206,036	21,137	2,877					230,050	259,233
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary		572,381	13,144	1,161					586,686	
I.1.3	3	Transmission and distribution losses from grid-supplied energy		40,804	18,076	83					58,962	
I.2		Commercial and institutional buildings and facilities										
I.2.1	1	Emissions from fuel combustion within the city boundary		434,012	859	4,424					439,295	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary		443,977	10,196	900					455,073	
I.2.3	3	Transmission and distribution losses from grid-supplied energy		31,695	22,272	64					54,031	
I.3		Manufacturing industries and construction										
I.3.1	1	Emissions from fuel combustion within the city boundary		1,063,805	3,739	12,070					1,079,613	735,727
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary		418,669	9,614	849					429,133	
I.3.3	3	Transmission and distribution losses from grid-supplied energy		30,086	57,617	60					87,764	
I.4		Energy industries										
I.4.1	1	Emissions from energy production used in power plant auxiliary operations within the city	IE									
I.4.2	2	Emissions from grid-supplied energy consumed by energy industries	IE									
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy used in power plant auxiliary operations	IE									
I.4.4	1	Emissions from energy generation supplied to the grid		915,495	2,603	411					918,509	
I.5		Agriculture, forestry and fishing activities										
I.5.1	1	Emissions from fuel combustion within the city boundary		294,429	747	2,216					297,392	
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary		137,272	3,152	278					140,702	
I.5.3	3	Transmission and distribution losses from grid-supplied energy consumption		9,808	8,399	20					18,226	
I.6		Non-specified sources										
I.6.1	1	Emissions from fuel combustion within the city boundary	NO									
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	NO									
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NO									
I.7		Fugitive emissions from mining, processing, storage, and transportation of coal										
I.7.1	1	Fugitive emissions from mining, processing, storage, and transportation of coal within the city boundary	NO									
I.8		Fugitive emissions from oil and natural gas systems										
I.8.1	1	Fugitive emissions from oil and natural gas systems within the city boundary	NO									
II		TRANSPORTATION										
II.1		On-road transportation										
II.1.1	1	Emissions from fuel combustion on-road transportation occurring in the city		3,769,086	21,577	32,474					3,823,138	
II.1.2	2	Emissions from grid-supplied energy consumed in the city for on-road transportation	NO									
II.1.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	IE									
II.2		Railways										
II.2.1	1	Emissions from fuel combustion for railway transportation occurring in the city		57,858	89	823					58,770	
II.2.2	2	Emissions from grid-supplied energy consumed in the city for railways	NO									
II.2.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	IE									
II.3		Waterborne navigation										
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring in the city		16,812	43	116					16,972	
II.3.2	2	Emissions from grid-supplied energy consumed in the city for waterborne navigation	IE									
II.3.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use		199,133	490	1,458					201,080	
II.4		Aviation										
II.4.1	1	Emissions from fuel combustion for aviation occurring in the city	IE									
II.4.2	2	Emissions from grid-supplied energy consumed in the city for aviation	IE									
II.4.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use		449,160	87	3,297					452,545	
II.5		Off-road transportation										
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring in the city	IE									
II.5.2	2	Emissions from grid-supplied energy consumed in the city for off-road transportation	NO									
II.5.3	3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	IE									

III		WASTE										
III.1		Solid waste disposal										
III.1.1	1	Emissions from solid waste generated in the city and disposed in landfills or open dumps within the city			716,902						716,902	
III.1.2	3	Emissions from solid waste generated in the city but disposed in landfills or open dumps outside the city			386,024						386,024	
III.1.3	1	Emissions from waste generated outside the city and disposed in landfills or open dumps within the city	NO									
III.2		Biological treatment of waste										
III.2.1	1	Emissions from solid waste generated in the city that is treated biologically in the city	NO									
III.2.2	3	Emissions from solid waste generated in the city but treated biologically outside of the city	NO									
III.2.3	1	Emissions from waste generated outside the city boundary but treated in the city	NO									
III.3		Incineration and open burning										
III.3.1	1	Emissions from waste generated and treated within the city	NO									
III.3.2	3	Emissions from waste generated within but treated outside of the city	NO									
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city	NO									
III.4		Wastewater treatment and discharge										
III.4.1	1	Emissions from wastewater generated and treated within the city			98,349	50,424					148,773	
III.4.2	3	Emissions from wastewater generated within but treated outside of the city	NO									
III.4.3	1	Emissions from wastewater generated outside the city boundary but treated within the city	NO									
IV		INDUSTRIAL PROCESSES and PRODUCT USES (IPPU)										
IV.1	1	Emissions from industrial processes occurring in the city boundary		1,563,070							1,563,070	
IV.2	1	Emissions from product use occurring within the city boundary				7,881					7,881	
V		AGRICULTURE, FORESTRY and OTHER LAND USE (AFOLU)										
V.1	1	Emissions from livestock			539,792						539,792	
V.2	1	Emissions from land		-1,066,704							-1,066,704	
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land		17,716		114,566					132,283	
VI		OTHER SCOPE 3										
VI.1	3	Other Scope 3	NE									