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Waikato Region Greenhouse Gas Emissions Inventory 2021-2022

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REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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EnviroStrat
Impact Investment Project Development

Waikato Regional Council

Waikato Region Greenhouse Gas Emissions Inventory

For the period 1 July 2021 to 30 June 2022

Prepared by EnviroStrat Ltd
October 2023

Table of Contents

List of Figures

List of Tables

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Acronyms and Abbreviations

AFOLU	Agriculture, forestry, and other land use
AR5	Fifth Assessment Report of the IPCC
BOD	Biochemical Oxygen Demand
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DOC	Department of Conservation
EECA	Energy Efficiency and Conservation Authority
ETS	Emissions Trading Scheme
FMU	Freshwater Management Unit
FWFP	Freshwater Farm Plan Tool
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIS	Geographical Information Systems
GPC	Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories
GWP	Global warming potential
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Use This
LCDB	Landcover Database
LFG	Landfill gas
LPG	liquefied petroleum gas
LUCAS	Land Use and Carbon Analysis System
LULUCF	Land Use, Land-Use Change and Forestry
MBIE	Ministry of Business, Innovation and Employment
MfE	Ministry for the Environment
MPI	Ministry for Primary Industries
N_2O	Nitrous oxide
NEFD	National Exotic Forest Description
NF_3	Nitrogen trifluoride
NZFGLT	New Zealand Forest Growers Levy Trust
PFCs	Perfluorocarbons
RMA	Resource Management Act
SF_6	Sulphur hexafluoride
TAs	Territorial authorities
WWTP	Wastewater Treatment Plant

Glossary

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 kilometer travelled, etc.).
Scope 1 emissions[1]	GHG emissions from sources located within the Waikato regional boundary.
Scope 2 emissions	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the Waikato regional boundary.
Scope 3 emissions	All other GHG emissions that occur outside the Waikato regional boundary as a result of activities taking place within the boundary.
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+	BASIC+ involves additional data collection and calculation processes to cover IPPU, emissions and removals from AFOLU, and emissions from transboundary transportation.

[1] Scope definitions outlined in the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC).

Executive Summary

This is the third inventory report for Waikato Region's Greenhouse Gas (GHG) Emissions Inventory. The inventory was compiled following the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC)[2], which applies a mixed approach (production and partial consumption-based emissions) within inventory development. GPC is considered best practice for community-based inventories.

Individual emissions inventories have also been prepared for each of 10 territorial authorities in the Waikato Region: Hamilton City, Waikato, Hauraki, Thames Coromandel, Waitomo, Matamata Piako, Otorohanga, Waipā, South Waikato, and Taupō. The inventory period was from 1 July 2021 to 30 June 2022.

1.1 Key points

- Activities within the Waikato regional boundary generated approximately 12,023,719 metric tonnes of carbon dioxide equivalent (tCO_2e) between July 2021 and June 2022.
- The two largest contributors to regional gross emissions are the agriculture sector at 67 %, followed by transport at 16 %.
- Removals generated by the forestry sector are equivalent to 14 % of regional gross emissions.
- Net emissions for the Waikato in 2021/22 are 10,274,006 tCO_2e.
- Gross emissions for Waikato have decreased by 5 % from the previous inventory (2018/19)[3] and have decreased by 3 % from the baseline inventory (2015/16)[4].
- Taupō is the only district where removals exceed emissions due to the high level of sequestration from forestry.

1.2 Data changes since 2018/19 inventory

- For the agriculture sector, animal numbers are based on the 2023 release of agricultural production statistics (final) 2022. This provided agricultural production data by territorial authority.
- Forestry volumes for this inventory were supplied by the NZ Forest Growers Levy Trust. This is high quality data based on levy paid per tonne of wood harvested. Forest harvest volume has significantly increased since the 2018/19 inventory which has an impact on the overall sequestration value of forests in the region. For the previous inventories harvest volumes were sourced from MPI NEFD and Statistics NZ.
- For the transport sector, fuel data for Taupō and aviation data was not available in this inventory due to commercial sensitivities. Past sources of data from FlightAware were sought without success. Taupō fuel use was replicated from 2018/19 inventory. Aviation fuels were calculated based on national reductions of 24-26 % by aviation fuel type with reduced domestic travel post the COVID-19 pandemic reported in the New Zealand GHG Inventory 1990-2021[5].

1.3 Sector contributions

Within the Waikato Region Inventory, the agriculture, forestry, and other land uses (AFOLU) GPC sector remains the largest contributor to the total net emissions (62 %). Emissions and removals from the AFOLU sector are produced through a variety of pathways. These include livestock, land use and land use change (e.g., forested land being harvested and cropland use), aggregate sources and non-CO_2 emission sources on land (e.g., fertiliser and

[2] Greenhouse Gas Protocol 2019. Global protocol for community-scale greenhouse gas inventories.

[3] Waikato Region Greenhouse Gas Emissions Inventory 2018/19 (2020). Waikato Regional Council, EnviroStrat Limited, AECOM.

[4] Waikato Region Greenhouse Gas Emissions Inventory 2015/16 (2017). Waikato Regional Council, EnviroStrat Limited, AECOM.

[5] New Zealand's Greenhouse Gas Inventory 1990-2021 (2023). Ministry for the Environment.

cultivation). These sources are combined to estimate AFOLU (6,388,944 tCO_2e) which is the net total emissions for agriculture and forestry (i.e., agriculture minus forestry removals) in line with GPC. This is followed by transportation (19 %) and stationary energy (15 %). Waste and industrial processes and product use are both lower sources of emissions, making up the remainder of sector contributions (3 % and 1 % respectively). These are seen in *Figure 1*.

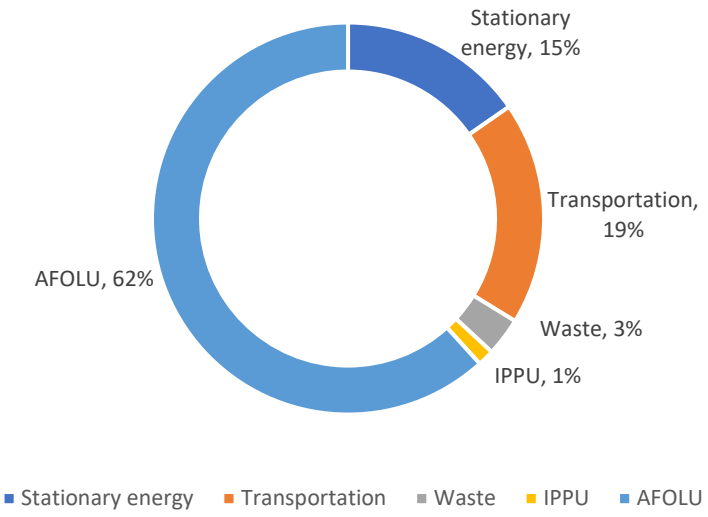

Figure 1. BASIC+ net emissions by source in 2021/22.

Scope 1 emissions (GHG emissions from sources located within the Waikato regional boundary) made up most of the emissions in Waikato region, followed by Scope 2 emissions (GHG emissions occurring as a consequence of using of grid-supplied electricity, heat, steam and/or cooling within the Waikato regional boundary). Scope 3 emissions (GHG emissions that are happening outside the region but are driven by activities within the region) have been estimated for stationary energy and transportation related activities. *Table 1* outlines sector emissions by scope in-line with GPC methodology.

Table 1. Waikato emissions profile by sector and scope

	Scope of emissions				
Sector	**Scope 1 Emissions (tCO_2e)**	**Scope 2 Emissions (tCO_2e)**	**Scope 3 Emissions (tCO_2e)**	**Basic Total Emissions (tCO_2e)**	**% of Total**
Stationary energy	1,004,998	435,381	74,127	1,514,506	15%
Transportation	1,829,783	-	73,798	1,903,581	19%
Waste	326,619	-	-	326,619	3%
IPPU	140,356	-	-	140,356	1%
AFOLU	6,388,944	-	-	6,388,944	62%
Total net emissions	9,690,700	435,381	147,925	10,274,006	

2 Introduction and context

2.1 National context

The New Zealand government ratified the Paris Agreement in April 2017, which is an international commitment to limit global warming to below 2 °C. Today, 196 parties have adopted the agreement which calls for emissions reductions of 60-80 % if global warming is to stay below 2 °C.

To achieve this emissions reduction goal and make a fair contribution to global emissions reductions, New Zealand adopted in 2019 the Climate Change Response (Zero Carbon) Amendment Act[6] to develop and implement clear climate change policies that contribute to the commitments under the 2015 Paris Agreement. The Act sets new mitigation targets committing New Zealand to:

- Reduce annual net emissions of all greenhouse gases (except biogenic methane) to zero by 2050, and
- Reduce annual emissions of biogenic methane to:
    - 10 % below 2017 levels by 2030
    - 24 % to 47 % below 2017 levels by 2050.

Further to this, in May 2022, the Government launched the first climate Emissions Reduction Plan for New Zealand[7], which contains strategies, policies, and actions towards achieving Aotearoa's first emissions budget, as required by the Climate Change Response Act 2002. Components of this plan include:

- Establishing green investment finance systems.
- Ending offshore exploration of fossil fuels.
- Switching fuels to reduce reliance of fossil fuels in the New Zealand transport fleet.
- Amending the Emissions Trading Scheme (ETS) to price agricultural emissions with the aim of reducing emissions.

Central government has started a review of the current ETS, including pricing agricultural emissions and further inclusion of incentives (and consideration of different metrics for forest types) for afforestation planting. These proposed changes in government policy aim to incentivise emissions reduction and are driven by the urgency to reduce global emissions and the importance of New Zealand meeting its Nationally Determined Contribution (NDC).

The latest Climate Change Commission advice notes that councils must "have regard to" National Adaptation Plans[8] and Emissions Reduction Plans in all council decisions. Councils are to enhance adaptive planning and ensure climate adaptation is considered in all decisions regarding the built environment (especially in at-risk areas). Councils have a role in monitoring, engaging, educating, and ensuring development of plans is in alignment with national policies. Councils are to work with territorial authorities and sector organisations (such as agriculture, energy sector, etc.) to engage in strategic planning, deployment of technologies, and enabling sound policies and plans which streamline deployment and implementation of low carbon mitigations where possible. By collecting inventory data and tracking emissions over time, this can assist all councils in monitoring their trajectory towards Government or own emission reduction plans.

When considering agriculture, nitrous oxide and methane emissions from agriculture have been excluded from emissions pricing in the ETS to date. In 2019, the government set up the primary sector Climate Action Partnership — He Waka Eke Noa to consider agricultural emissions. This partnership aims to support farmers with the tools to measure, manage, and reduce on-farm GHG emissions. The government proposed a farm-level, split gas levy

[6] Climate Change Response Act 2002 | Ministry for the Environment for various legislation linked to the original act and subsequent amendment Climate Change Response (Zero Carbon) Amendment Act 2019 No 61, Public Act Contents – New Zealand Legislation.

[7] Aotearoa New Zealand's first emissions reduction plan (2022). Ministry for the Environment.

[8] Aotearoa New Zealand's national adaptation plan (2022). Ministry for the Environment.

(methane and nitrous oxide) for agriculture in 2022. He Waka Eke Noa is also working to provide advice to the Climate Change Commission regarding how to incorporate agricultural emissions into the ETS by 2025. Such policies will be relevant to WRC and regional councils as GHG inventories are required to account for agricultural emissions (BASIC+ GPC methodology). This is especially relevant to Waikato region due to agriculture being the largest source of gross emissions within the inventory.

To enable the allocation of capital towards activities to reduce emissions and adapt to climate changes, New Zealand also passed legislation that requires around 200 large financial institutions to start making climate-related disclosures from 1 January 2023. This will likely assist with embedding further the practice of emissions accounting and enable better emissions data and monitoring.

2.2 Role of regional and territorial authorities

It is recognised that finding solutions to climate change and transitioning to a low carbon economy cannot be pursued by central government without the involvement and actions of local government. Local Government New Zealand (LGNZ) works with government to develop policies that enable New Zealand communities to be adaptive and resilient and to reduce emissions. In December 2022, it became a legal requirement for local government under the Resource Management Act 1991 (RMA) to "have regard to" the National Adaptation Plan and the Emissions Reduction Plan when preparing or changing regional policy statements, regional plans, and district plans. This requirement is to ensure that planning nationwide is in-line with New Zealand's long-term climate strategies and goals – particularly the National Adaptation Plan and the Emissions Reduction Plan.[9]

Central government and the Ministry for the Environment (MfE) have worked with local government (via Taituarā[10] and local government networks) to accelerate the role of local government in understanding, preparing, and adapting to climate change around New Zealand. There is increasing scientific evidence that climate change has contributed to the multiple "hottest years on record" that have occurred in the last 5 years and to the more intense tropical cyclones that New Zealand has experienced in recent years[11]. Councils are increasing efforts to accelerate adaptive planning around coasts and lowland flood plains.

Alongside a focus on adaptation, territorial and regional authorities around New Zealand are exploring GHG reduction targets as part of their climate mitigation strategies. To develop their carbon reduction strategies, local government agencies need to have a good understanding of their emissions profiles (i.e., the sources of emissions by sectors and gases, and track emissions trends).

2.3 Waikato Region context

The first meeting of the Climate Action Committee of the Waikato Regional Council took place in February 2020. On the recommendation of the Climate Action Committee, all council committee reports post-June 2020 must now include an assessment of climate change implications which can be taken into account when decisions are made by the council. In addition to measuring progress towards emissions reductions through undertaking regular regional GHG inventories, work including the development of a Sustainable Infrastructure Strategy and studies assessing flooding and coastal inundation mean that Waikato Regional Council is well placed to consider and lead planning and implementation in this space.

Since the Climate Action Committee was established, the council, on behalf of the region, has:

- Developed the *Waikato Regional Climate Change Adaptation Guideline* to help council staff and external practitioners plan for climate change adaptation and encourage a consistent approach across the Waikato.
- Made submissions on the National Emissions Reduction and Adaptation Plans, and various other policies, bills, and plans that require a climate change lens, for example the Natural Hazards Insurance Bill.
- Started work with stakeholders to explore ways of reducing greenhouse gases in the Waikato Region.

[9] See the guidance note for more details: National-adaptation-plan-and-emissions-reduction-plan-guidance-note.pdf (environment.govt.nz)

[10] Taituarā – Local Government Professionals Aotearoa is the national membership association for local government professionals.

[11] Aotearoa New Zealand Annual Climate Summary: 2022 (2023). NIWA National Climate Centre.

- Adopted the *Climate Change Investment Strategy* to take climate change considerations into account in relation to its investments and required climate change implications to be taken into account in all council decision-making.
- Developed the *Climate Action Roadmap,* an evidence-based discussion document that identifies nine priority pathways for the region and sets out the council's direction in adaptation and mitigation.
- Led three-yearly GHG inventories to account for greenhouse gas emissions in the Waikato.

The Climate Action Roadmap, released by council in November 2020[12], is based on the results of the 2018/19 GHG inventory. It sets out a roadmap and plans for how to start addressing emissions from some sectors[13]. For the agriculture sector, the Roadmap considers how to bring in more information on soil carbon and peat into inventories.

Consequently, work has been undertaken by Waikato Regional Council in parallel to this inventory to consider how to account for peat losses. While this is early work, and emissions from Organic Soils (peat) are accounted for nationally within the New Zealand GHG Inventory 1990-2021 using the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidance[14], this is the first time a regional council has considered how to account for emissions from peat soils at the regional scale using both the 2006 IPCC Guidance and the 2013 Wetland Supplement[15] methods. This work will sit alongside this inventory as a technical report for reference by council, MfE, and others to consider.

The last piece of work associated with this GHG inventory is to consider emissions for a Freshwater Management Unit (FMU). Waikato Regional Council sought to use this as an opportunity to trial how to spatially apportion the GHG inventory – beyond administrative boundaries (district, region) Sequestration options are also considered within this FMU. The Hauraki FMU (Waihou Piako Catchment boundary) was selected for this work as one of the more challenging FMUs from both a freshwater and GHG perspective.

Current reviews of long-term plans and climate strategies are likely to have an increased focus on these themes, drawing on the evidence-base to direct council funding to areas where risk exists, or mitigation is required (within council's scope of control). This may include further planning of coastal and flood protection infrastructure, and continued work with territorial authorities on transport and waste reduction themes which are longstanding areas of work. Agricultural emissions remain significant so programmes to support transition of the farming sector to lower carbon emissions are important to consider.

2.4 Purpose of the emissions inventory

A GHG emissions inventory is an account of the GHGs emitted to, or removed from, the atmosphere over a given period. The quantification includes both measured and estimated data. This inventory provides the Waikato Regional Council and the territorial authorities of the Waikato Region with an understanding of their emissions generation and removals profile for the 2021/22 (local government) financial year reporting period.

Specifically, the purpose of this report is to:

- Identify where the Waikato Region 2021/22 emissions are coming from and calculate the changes in emissions generation/removal compared to the 2015/16 and 2018/19 GHG inventories.
- Determine the emissions profile of individual districts as basis for developing climate action plans, strategies, setting reduction targets or informing reduction activities in long term plans.
- Provide information and understanding to enable the regional and territorial authorities to engage with key sectors and stakeholders towards reducing GHG emissions.

Over time, the emissions inventory will assist the council to compare emission trends and track progress in emissions reductions across the region. This document summarises the findings and insights from the data collection and calculations, and it also outlines the underlying assumptions and limitations associated with the compilation of the inventory.

[12] Climate Action Roadmap (waikatoregion.govt.nz).

[13] The results from the Waikato Regional Greenhouse Gas (GHG) Inventory 2021/22 have been incorporated into the 2023 update of the Climate Action Roadmap.

[14] Eggleston H, Buendia L, Miwa K, Ngara T, Tanabe K. 2006. 2006 IPCC guidelines for national greenhouse gas inventories.

[15] Hiraishi T, Krug T, Tanabe K, Srivastava N, Baasansuren J, Fukuda M, Troxler T. 2014. 2013 supplement to the 2006 IPCC guidelines for national greenhouse gas inventories: Wetlands. IPCC, Switzerland.

3 Methodology

3.1 The Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories

The GHG emissions inventory for the Waikato Region (and the individual territorial authorities) was compiled following the methodology outlined in the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC)[16], published by the World Resources Institute in 2015[17]. The GPC methodology represents international best practice for city- and community-level GHG emissions reporting. The GPC requires the inventory to include emissions from production and consumption (partially) activities taking place within the regional boundary, including some emissions released outside the city boundary.

This inventory includes emissions from stationary energy, transport, waste, industry, agriculture, and forestry activities within the regional (administrative) boundary of Waikato Region. It covers seven greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

The same GPC methodology was applied for the 2015/16 and 2018/19 Waikato Region GHG emissions inventories and is used by other community-scale GHG inventories undertaken around New Zealand (e.g., by Auckland Council) and internationally. To ensure alignment with past inventories, the development of this inventory has ensured consistency in the emission factors used for quantification of the GHG inventory by using the appropriate IPCC and MfE sources (data enhancements since the previous inventory outlined in section 3.6).

The inventory applies the global warming potential (GWP) metric values of GHGs from the IPCC Fifth Assessment Report (AR5) as a base for calculations. The AR5 GWP100 emission metric values of 1 for CO_2, 34 for CH_4, and 298 for N_2O were applied to emissions calculations. These values are in the upper range of AR5 emission metric values to account for radiative forcing, and importantly have been used across all three GHG inventories for consistency and comparability across inventories.[18] In future inventory development the IPCC Sixth Assessment (AR6) will be applied, and at that point re-calculation of past inventories will be completed alongside any other material improvements in the inventory.

GPC guidelines categorises emissions into scopes; with Scope 1 being largely emissions from sources located within the city or in this case Waikato Region boundary, Scope 2 – emissions occurring due to use of grid supplied electricity, etc. within the regional boundary, and Scope 3 – all other emissions occurring outside the regional boundary as a result of activities taking place within the regional boundary (for example food or construction products imported for consumption in the region or waste sent for treatment outside of the region). The sectors and scopes are shown in diagrammatic form in *Figure 2*. The GPC includes Scope 3 accounting for a limited number of emission sources (like transmission and distribution losses associated with grid-supplied energy) but there is the option to additionally report as "Other Scope 3" sources associated with activity in a city such as the emissions embodied[19] in the products imported into the region.

[16] The protocol is available at: http://www.ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities.

[17] Global protocol for community-scale greenhouse gas inventories: Supplemental guidance for forests and trees (2022). World Resources Institute.

[18] The advice from the Climate Change Commission is for GHG inventories after 2023 to change to new metric values following the recently published AR6. This change will require recalculations of all past inventories for Waikato Region so that the results can be compared, and trends accurately reported.

[19] Ministry for Business Innovation and Employment completed a study in 2022 to develop a whole-of-life embodies carbon assessment technical methodology. This is LCA based and aims to better account for building emissions which goes further than this inventory.

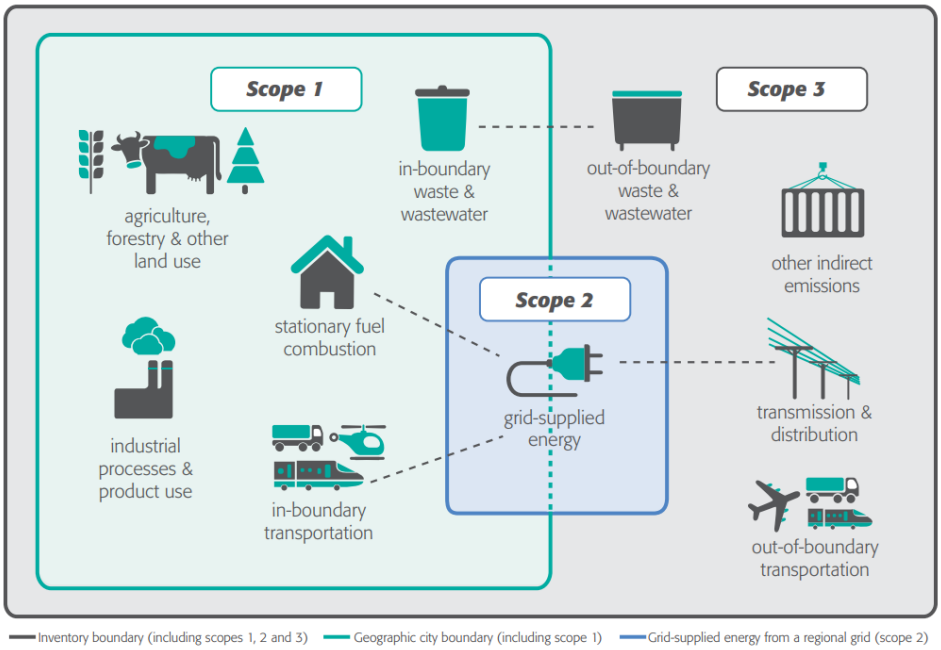

Figure 2. Sources and boundaries of regional GHG emissions. Source: Global Protocol for Community-Scale GHG Inventories (GPC).

3.2 Inventory boundary

The boundary of the 2021/22 emissions inventory is the Waikato Region. There are 11 territorial authorities within this Waikato Region; however, as with the past two inventories, Rotorua Lakes district was excluded given the small land area within the regional boundary. Noting the exclusion of Rotorua, the geographical scope of the inventory covers 2,466,665 ha and 507,465 residents (population averaged for 2021/22 years). This population is an increase of 33,985 since the last inventory in 2018/19, most growth occurred within Hamilton City and Waikato districts.

The Waikato Region has a predominantly agricultural economy, it is a transportation corridor and distribution hub, and has significant electricity generation assets and users (e.g., Waikato hydro lakes generation, geothermal assets in southern parts of the region, and Huntly gas/coal fired power station). Hamilton and Taupō airports are located within the regional boundary.

3.3 Emissions calculations and reporting

This inventory assesses both direct (production-based) emission sources within the geographic area (Scope 1) and indirect (consumption-based) emission sources associated with goods and services imported into the geographic area. Examples of indirect emission sources include electricity from the national grid (Scope 2), transport into the area that originates or terminates outside the area (e.g., aviation (Scope 3)). The inventory does not currently apply life cycle assessment (embodied emissions) for calculations of emissions.

Emissions are reported for the period from 1 July 2021 to 30 June 2022. Wherever possible, primary data has been sought within each sector of the inventory. New Zealand specific emission factors from the New Zealand GHG Inventory 1990-2021, which are country-specific based on local conditions (Tier 2), were used wherever available (e.g., major livestock categories for agriculture have New Zealand specific emission factors). Where Tier 2 factors were not available, IPCC default emission factors (Tier 1) were applied.

The inventory includes emissions from stationary energy, transport, waste, industry, agriculture, and forestry as follows:

- Stationary energy includes emissions from electricity consumed by residential, commercial, and industry users, electricity generated from non-renewable sources (i.e., landfill gas combustion), as well as consumption of coal, natural gas, biodiesel, and wood.
- Transport includes emissions from on- and off-road petrol and diesel (including biodiesel) sold within the region, rail diesel, jet kerosene and aviation gas, and LPG used for road transport.
- Waste includes emissions from the treatment of wastewater and the disposal of solid waste.
- Industrial processes and product use (IPPU) cover GHG emissions from industrial chemical or physical processes, as well as emissions associated with the consumption (i.e., product use) of GHGs for refrigerants, foam blowing, fire extinguishers, aerosols, metered dose inhalers (MDI), and sulphur hexafluoride (SF_6) for electrical insulation and equipment production.
- Agriculture includes emissions from livestock, crops, and fertiliser use.
- The forestry sector includes emissions from harvested trees and carbon sequestered by commercial exotic forests and other native forest cover (excluding Department of Conservation (DOC) estate which is accounted for nationally). Carbon stored in mature forests is not included in the inventory.[20]

Other aspects to note when reviewing the inventory:

- Emissions are expressed as carbon dioxide-equivalents (CO_2e) including climate change feedback using the 100-year Global Warming Potential (GWP) values and climate-carbon feedback from the IPCC AR5[21].
- Total emissions are reported as gross emissions (excluding forestry) and net emissions (including forestry).
- Emissions are calculated by multiplying activity data by an emission factor associated with the activity.
- In-line with the GPC, activity data for the various emission sources includes data from bottom-up sources (locally provided measures or estimates) and top-down sources (based on national-level information), depending on data availability.
- GPC requires that total emissions are reported at the BASIC or BASIC+ levels. This inventory reports at the BASIC+ level. This includes Scope 1 and Scope 2 emissions from stationary energy and transport, Scope 1 from waste, and Scope 1 emissions from IPPU and AFOLU and Scope 3 from transboundary transport and stationary energy.

3.4 Inclusion of biogenic emissions

The GPC framework requires biogenic CO_2 emissions (e.g., CO_2 released from combustion of wood) to be reported outside the total emissions. Biogenic emission sources in the Waikato footprint include biofuel use from wood, biodiesel, and landfill gas. The reasoning behind this is that the CO_2 emissions for biological sources are already accounted for in agriculture and forestry sectors within this inventory (i.e., the natural carbon cycle), so further accounting risks double counting given emissions are assumed at point of harvest.

Biogenic methane emissions are included in the total emissions reported, as they have an impact on climate change due to an increase in GWP of methane compared to CO_2 (34 times GWP of CO_2). Sources of biogenic methane include biofuel, biodiesel, landfill gas, wastewater treatment, enteric fermentation, and manure management from agriculture.

[20] Maturing forests (age 26-40 years for exotic species) sequester carbon in trees and wood products. When trees are harvested, the carbon is released back to the atmosphere through decay or combustion. Assuming that the total area used for forestry activities remains similar (i.e., all forests harvested are being replanted) the overall carbon balance is expected to be neutral. Increasing the forest area will lead to net sequestration, while reducing the forest area will result in net emissions to the atmosphere.

[21] Emissions are expressed on a carbon dioxide-equivalent basis (CO_2e) including climate change feedback using the 100-year Global Warming Potential (GWP) values: 34 for methane and 298 for nitrous oxide.

3.5 Assumptions, limitations, and uncertainties

Emissions inventories involve a range of assumptions, limitations, and uncertainties. Examples of data limitations include:

- Emissions from industrial product use by scaling national emissions from industrial product use on a population basis; this inventory estimates solid waste emissions from both open and closed landfills based on both the national inventory figures and a more recent Waikato-Bay of Plenty waste and recycling stock take, then allocated on a population basis.
- This inventory estimates emissions from wastewater treatment using top-down methods of scaling national emissions from the New Zealand GHG Inventory 1990-2021 and applies this to territorial authorities within the Waikato Region on a population basis.
- Emissions from agriculture are based on data collected by Statistics NZ as part of their Agricultural Production Statistics 2022 (final). This provides agricultural data at district level, which is important for calculations of emissions at TA level. When assessing findings across TAs, it is noted that for Hamilton City which is a largely urban council with rural boundaries, uncertainty regarding animal numbers exists when statistics are downscaled to an urban council. For this reason, agriculture results for Hamilton should be viewed as indicative. Further work to improve data quality in this District may occur post inventory.

In addition to activity-related assumptions and uncertainties, the GPC methodology also includes assumptions in terms of calculations of sector emissions:

- Forestry: this inventory accounts for forest carbon stock changes from afforestation, reforestation, deforestation, and forest management (i.e., it applies land use accounting conventions under the UN Framework Convention on Climate Change. It treats emissions from harvesting and deforestation as instantaneous rather than accounting for the longer-term emission flows associated with harvested wood products. The increase in forest harvest volume since last inventory has resulted in significant emissions changes for many TAs, and thus, it is recommended this data be enhanced with a forestry study at regional and district scale ahead of next GHG inventory development.
- When compiling land use and native forest data, the inventory relies on the Landcover Database (LCDB) version 5 (2018/19)[22] and references shrub species not in mature native forest. Therefore, some native forest species vegetation may be underestimated when considering sequestration. Native forests managed by the Department of Conservation are accounted for within national accounting and have not been accounted for in this inventory.

Uncertainties also exist where data is missing or has been estimated based on limited information (i.e., aviation data).

A full listing of assumptions and limitations are included in Appendix A. Data sources and identified data gaps are listed in Appendix B. Specific information on assumptions, limitations, and uncertainties are included together with the sector results.

3.6 Data enhancements since the last inventory

Since the 2018/19 inventory, the methodology has remained largely unchanged. However, some more robust data has been sourced to enhance the current inventory. Most sections report on the same data sources for simplicity and ability to compare across inventory years. The significant updates or improvements in the data are listed below. The aim of updating data sources is either to upgrade to high data accuracy, replace data no longer collected (e.g., forestry harvest), or to better align with GPC methods.

[22] Manaaki Whenua - Landcare Research 2021. LCDB v5.0 – Land cover database version 5.0, Mainland, New Zealand.

Upgrades include:

- For agriculture, updated animal populations and activity data have been applied across the inventory using the 2022 Agricultural Production Statistics[23]. This census-level data provides farm data by territorial authority. The last Agricultural Production Census in New Zealand was undertaken in 2017, so this offers a significant update and robust data insights by territorial authority.
- Emission factors have been updated to include the 2023 release of the New Zealand GHG Inventory 1990-2021. Agriculture emission factors are recalculated on a yearly basis to reflect changes in seasonal production variables. This is explained in sections 5.2 and 5.3 of the New Zealand GHG Inventory 1990-2021. Emission factors show variable change depending on livestock type and gas.
- An update of data source for forest harvest volume from the Statistics NZ Agricultural Production Census, to levy data supplied by the NZ Forest Owners Association and the NZ Forest Growers Levy Trust (NZFGLT)[24]. The NZFGLT publishes information about the levy collected when forests are harvested (by region). This was then apportioned using mature forest ages found within the National Exotic Forest Description reports 2022[25], published by the Ministry for Primary Industries (MPI).

4 Emissions results and analysis

This section provides the inventory results presented as emissions sectors and sub-sectors detailed to illustrate how emissions estimates are generated, and the changes in the six-year period since the 2015/16 baseline inventory.

4.1 Main sources of emissions

Activities within the Waikato Region boundary generated approximately 12,023,719 tCO_2e of gross emissions between July 2021 and June 2022. When the removals from forestry are included, the total net emissions for the region were 10,274,006 tCO_2e.

Agriculture continues to be the largest contributor to the total gross emissions for Waikato (67 %), followed by transportation (16 %), and stationary energy (13 %) (*Figure 3*). Forestry removed -1,749,712 tCO_2e (equivalent to 14 %) of total gross emissions. Forestry removals have decreased 44 % from the 2018/19 inventory largely due to a significant increase in harvest volume in this inventory period (*Table 2*).

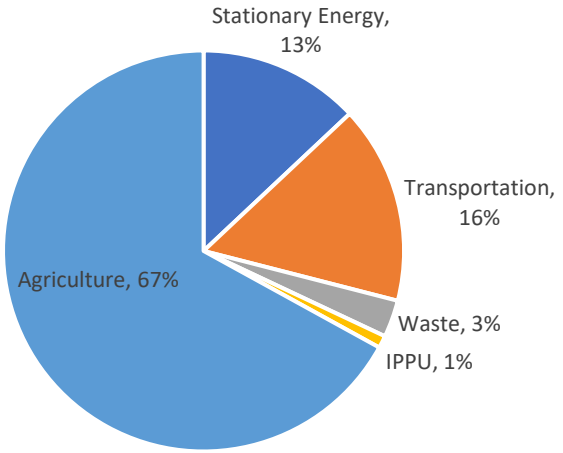

Figure 3. Percentage of gross emissions by source (excl. forestry) for the Waikato Region, 2021/22

[23] Statistics New Zealand, 2023. Agricultural production statistics: Year to June 2022 (provisional).

[24] Forest Growers Levy Trust 2023. Levy analysis.

[25] The Ministry for Primary Industries 2023. National exotic forest description as at 1 April 2022.

Table 2. GPC BASIC+ Community Greenhouse Gas Emissions Inventory by Sector and Sub-Sector, Waikato Region (2021/22)

	Scope 1 Emissions (tCO_2e)	Scope 2 Emissions (tCO_2e)	Scope 3 Emissions (tCO_2e)	Basic Total Emissions (tCO_2e)	% of total net (including forestry)	% of total gross (excluding forestry)
Stationary Energy	1,004,998*	435,381	74,127	**1,514,506**	**15**	**13**
Residential Buildings	67,860	137,913	14,517	220,290	2	2
Commercial & Institutional buildings and facilities	87,865	105,040	12,733	205,638	2	2
Manufacturing Industries and Construction	597,642	192,429	46,876	836,947	8	7
Other sources (fugitive emissions from mining)	251,630	-	-	251,630	2	2
Transportation	1,829,783	-	73,798	**1,903,581**	**19**	**16**
On road transportation	1,645,826	-	-	1,645,826	16	14
Railways	-	-	37,751	37,751	0	0
Aviation		-	27,249	27,249	0	0
Off-road transportation	192,755	-	-	192,755	2	2
Waste	326,619	-	-	**326,619**	**3**	**3**
Solid waste disposal	289,197	-	-	289,197	3	2
Wastewater treatment and discharge	37,422	-	-	37,422	0	0
IPPU	140,356	-	-	**140,356**	**1**	**1**
AFOLU	6,388,944	-	-	**6,388,944**	**62**	
Agriculture	8,138,656			8,138,656		**67**
Forestry	-1,749,712	-	-	-1,749,712		
Total Net (Including Forestry)	9,690,700	435,381	147,925	**10,274,006**		
Total Gross (Excluding Forestry)	11,440,412	435,381	147,925	**12,023,719**		

*This value has been rounded up by 1 tCO_2e.

4.1.1 Stationary energy

Stationary energy use in the region is responsible for 1,514,506 tCO_2e in 2021/22, representing 13 % of the gross emissions (*Table 3*).

The main source of emissions from stationary energy is natural gas consumption, contributing 4 % of the gross regional emissions, with natural gas transmission and distribution losses contributing (T&D losses) an additional 0.3 % (*Table 3*). Electricity consumption (Scope 2) contributes approximately 4 % of the gross regional emissions. Fugitive emissions (Scope 1) from coal mining contributes 2 % of this sector's emissions.

Table 3. Summary of Waikato Region stationary energy emissions by source, 2021/22

Sector/Category Source		Emissions (tCO_2e)		Sector Percentage Contribution (%)
Stationary Energy	Electricity	435,381	Σ 1,514,506	29
	Electricity T&D Loss	35,751		2
	Natural Gas	474,725		31
	Natural Gas T&D Loss	38,376		3
	LPG	37,245		2
	Diesel	202,827		13
	Petrol	5,561		0
	Coal	26,135		2
	Biofuel[26]	6,875		0
	Fugitive Emissions (Coal)	251,630		17

4.1.2 Transportation

Transportation sources emitted 1,903,581 tCO_2e for the period 2021/22, representing 16 % of the Waikato Region's total gross emissions and about 19 % of net emissions (*Table 4*). Transportation was the second highest contributor to regional net and gross emissions after agriculture although it represents less than a quarter of the magnitude of agricultural emissions.

On-road transport (predominantly Scope 1 emissions from diesel and petrol), contributed approximately 86 % of the transportation emissions during the reporting period. A breakdown of the transportation emission sources is provided in the table below.

Table 4. Summary of Waikato Region transportation emissions by source, 2021/22

Sector/Category		Emissions (tCO_2e)		Sector Percentage Contribution (%)
Transportation	On-road petrol and diesel	1,640,194	Σ 1,903,581	86
	Rail emissions	37,751		2
	LPG	700		0
	Aviation gas	1,825		0
	Jet kerosene	25,425		1
	Off-road petrol and diesel	192,755		10
	Biodiesel	0		0
	Bus	4,931		0

4.1.3 Waste

The waste sector generated 326,619 tCO_2e of emissions in 2021/22, accounting for 2.7 % of the region's gross emissions. The majority of waste sector emissions result from landfilling solid waste disposal (89 %). Process emissions from wastewater treatment contributed 11 % of the sector total (*Table 5*).

Combustion of landfill gas (LFG) and sludge incineration was estimated to generate emissions of approximately 17,832 tCO_2e (biogenic[27]) which is 18.9% of the total biogenic emissions reported separately.

[26] Only the methane emissions are accounted for under GPC, see section on biogenic emissions for more details.

[27] The GPC Standard recommends reporting biogenic emissions separately to the total greenhouse gas emissions.

Table 5. Summary of Waikato Region waste emissions by source 2021/22

Sector/Category Source		Emissions (tCO_2e)		Sector Contribution (%)
Waste	Solid Waste Disposal	289,197	Σ 326,619	89
	Wastewater	37,422		11

Solid waste emissions were estimated using a first-order decay model that requires waste volume estimates for the last 50 years. Historical waste volumes sent to landfill were estimated using the average waste generated per person per year, as reported by the MfE, and historical national population figures as reported by Statistics NZ. For 2020 onwards, waste volumes and landfill destination of waste per territorial authority were updated using the Waikato-Bay of Plenty regional waste and recycling 2021 data.[28]

Solid waste emissions (289,197 tCO_2e) account for 2 % of total gross emissions for the Waikato Region. Overall, waste emissions increased by 12 % from 2018/19 due to population increase.

While not the case historically, a significant proportion of municipal solid waste generated within the Waikato Region is now disposed of at the Hampton Downs (66 %) and Tirohia landfills (16 %), while the remaining solid waste is deposited at several smaller landfills (16 %). Waste from outside of the region (namely from Auckland and Bay of Plenty) that is sent to landfills in Waikato is not accounted for in the emissions inventory and represents an area of enhancement for the future.

Wastewater treatment generated emissions of 37,422 tCO_2e or approximately 0.35 % of the total gross emissions for the region. The New Zealand GHG Inventory 1990-2021 was used to calculate the per capita wastewater treatment and disposal emissions. These emissions were then extrapolated to estimate the total wastewater emissions for the Waikato region based on population numbers. This top-down approach is regarded as sufficient to provide an estimate of the likely order of magnitude of emissions. There are efforts by some of the district councils and WaterNZ to enhance emissions calculations for wastewater, and this can be used to improve emissions calculations in future inventories and move away from the current top-down approach.

4.1.4 Industrial processes and product use (IPPU)

In 2021/22 industrial GHG emissions contributed 140,356 tCO_2e (1 %) towards regional gross emissions. The emissions for industrial product use include emissions from hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Scope 1). Emissions from industrial product use (*Table 6*) were estimated based on common reporting format output tables data provided in the New Zealand Greenhouse Gas Emissions 1990-2021 report[29].

Table 6. Summary of industrial product use emissions for Waikato Region

Sector/Category		Emissions (tCO_2e)		Sector Percentage Contribution (%)
IPPU	Refrigerants	130,849	Σ 140,356	93
	Foam Blowing	574		0
	Fire extinguishers	226		0
	Aerosols & MDI	7,285		5
	SF_6	1,421		1

[28] Waikato Regional Council 2021. Waikato and Bay of Plenty waste and recycling stocktake. Waikato Regional Council Technical Report Current 2022/11.

[29] Ministry for the Environment (2023). New Zealand Greenhouse Gas Emissions 1990-2021.

4.1.5 Agriculture

Agriculture generated an estimated 8,138,656 tCO_2e, representing 67 % of regional gross emissions and 89 % of biogenic methane emissions. Agriculture is the most significant sector nationally making up 49 % of national emissions, 74 % of biogenic methane and 36 % of New Zealand's gross emissions in the New Zealand GHG Inventory 1990-2021.

With multiple years of the Waikato GHG emissions inventory now available, this offers the opportunity to track changes in emissions at territorial authority and regional scale as changes in farming occur. While mitigations may occur in future, the most significant reductions that have occurred over the past two inventory periods are associated with reductions in animal numbers, especially the regional dairy herd over the past 5 years.

Animal numbers have changed since the 2018/19 inventory. Reductions in animal numbers in the major livestock classes include dairy (down 8 %) and sheep (down 12 %). These decreases are partially countered by an increase in beef cattle numbers (up 18 %). For minor livestock classes, most are down by around 25 %, apart from pig numbers which increased (by 41 %). Animal numbers are based on the 2023 release of Agricultural Production Statistics 2022 (final). This offers census level data for agriculture by territorial authority. Alongside reduced animal numbers in Waikato, fertiliser reductions also contributed to overall reductions in agricultural emissions in this inventory. Similar reductions in emissions from the major livestock classes and fertiliser use were noted in the national GHG inventory.

The combined impact of reductions in animal numbers and variable changes in emission factors led to a reduction in emissions for the Waikato Region of around 449,000 tCO_2e or 5 % of the agriculture sector emissions. Results of this inventory are seen in *Table 7*.

Table 7. Summary of Waikato Region agricultural emissions by source and gases 2021/22

Sector/Category		Emissions (tCO_2e)		Sector Percentage Contribution (%)
Agriculture	**Emissions from Livestock**	**6,680,923**	Σ 8,138,656	**82**
	Enteric fermentation (CH_4)	6,169,188		76
	Manure Management (CH_4)	509,811		6
	Manure Management (N_2O)	1,924		0
	Emissions from Aggregate sources	**1,457,733**		**18**
	Liming and Dolomite	112,309		1
	Agricultural soils	153,645		2
	Manure from grazing animals	1,026,267		13
	Agricultural leaching	74,158		1
	Agricultural atmospheric deposition	91,353		1

There is a significant amount of biogenic methane produced within the agricultural sector. He Waka Eke Noa is currently reviewing ways to bring in pricing mechanisms and incentivise deployment of science-based mitigations in this space (along with other nitrous oxide mitigations).

4.1.6 Forestry carbon sequestration and emissions

Forestry activities in the Waikato Region in 2021/22 led to a net sequestration of -1,749,712 tCO_2e (equivalent to 14 % of gross emissions). The forestry sector emissions include carbon sequestered through growing trees, and carbon lost through harvesting. The GPC methodology assumes that all carbon stored in trees is released in the year the trees are harvested. However, GPC does account for wood discarded during forest harvest operations (slash) and

around 30% buried within roots and dead material. For the Waikato Region, exotic forest accounted for 91 % of sequestration, whereas native forest accounted for 9 % (*Table 8*).

Table 8. Summary of forest emissions/removals by source 2021/22

Sector/Category Source		Emissions (tCO_2e)		Sector Contribution (%)
Forestry	Exotic forest sequestration	-11,328,634	Σ -1,749,712	91
	Native forest sequestration	-1,142,511		9
	Total harvest emissions*	10,721,433		

* Includes wood remaining on site, below ground, dead wood, and litter

In this inventory, an updated source for forest harvest volume (cubic metres) was required as Statistics NZ no longer collects forest harvest volumes. For this reason, advice was sought, and data was sourced from the NZ Forest Owners Association (NZFOA). This data was supplied for the 2021/22 year from the NZ Forest Growers Levy Trust (NSFGLT – associated with NZFOA). The NZFGLT publishes yearly figures on levies collected[30] when forests are harvested. This data showed that the Central North Island wood region (includes Waikato and Bay of Plenty) contributed 30 % of New Zealand's exotic, and 48 % of domestic harvest in the 2021/22 year, showing the significance of forest harvest to emissions inventories within the Waikato and surrounding regions. Given the change in forest harvest volume and emissions has been materially different since last inventory, a recommendation has been made to seek further primary data in this section of the inventory ahead of next GHG inventory development.

4.1.7 Biogenic emissions

Below are the regional tables for the Biogenic CO_2 (*Table 9*) and Biogenic methane (*Table 10*) for the past three GHG inventories. Biogenic emissions are produced when biomass materials such as trees, crops, or animal fats, are burned and release CO_2, even though they originally stored or sequestered CO_2. Biogenic CO_2 emissions are reported separately, considering that these emissions from biomass usage are linked to corresponding land use change or carbon stock change, and are effectively reported for in other sectors (i.e., stationary energy, transportation, agriculture, and waste)[31].

Table 9. Regional table for Biogenic CO_2 for 2015/16, 2018/19 and 2021/22

Biogenic CO_2 (Excluded from gross emissions)		2015/16 (tCO_2)	2018/19 (tCO_2)	2021/22 (tCO_2)
	Biofuel	80,015	71,711	73,119
	Biodiesel	-	728	3,245
	LFG – SWTP	4,916	7,986	17,832
	Total biogenic CO_2	**84,932**	**80,425**	**94,196**

[30] For an example of data from NZFLGT see Combined_December_Report.pdf (fglt.org.nz) Export and domestic harvest were considered for Central north Island wood region.

[31] See GPC Protocol report for more detail on biogenic emissions.

Table 10. Regional table for Biogenic CH_4 for 2015/16, 2018/19 and 2021/22

Biogenic Methane (Included in gross emissions)		2015/16 (tCH_4)	2018/19 (tCH_4)	2021/22 (tCH_4)
	Enteric fermentation (CH_4)	200	203	181
	Manure Management (CH_4)	-	3	0.01
	Landfill Gas	7,215	673	3,937
	Wastewater Treatment	35,687	1,289	1,101
	Enteric fermentation	205,405	196,741	181,447
	Manure Management	15,112	27,121	14,994
	Total biogenic CH_4	**263,618**	**226,030**	**201,660**

4.2 Emissions estimates for Waikato Region and breakdown by territorial authorities

Calculation of emissions for individual territorial authorities (TA) was based on activity data at local / TA level or by applying national averages. Activity data was available as follows:

- Stationary energy: primarily TA level data with limited national level data used for estimates at TA level; emissions distributed based on population and land area.
- Transport: based on fuel tax data collected by TA, Hamilton Bus fuel provided and rail diesel by commercial providers.
- Waste: primarily national level data with specific TA data linked to landfill gas; emissions distributed by population.
- IPPU: national level data, emissions distributed by TA population.
- Agriculture: TA level data from Agricultural Production Statistics 2022 (final).
- Forestry: Exotic plantation data from National Exotic Forest Distribution, Forest harvest volumes from NZ Forest Growers Levy Trust (apportioned from Central North Island to Waikato TAs based on mature age exotic forests).

The breakdown below is not intended as a benchmark between TAs but simply as an indicative framework of reference to understand the differences between emissions profiles and the potential areas of interest to work together (*Table 11*).

Table 11. Overall emission estimates for Waikato Region and breakdown by territorial authorities (2021/22), tCO_2e

Emissions (tCO_2e)	Waikato Region 2021/22	Hamilton City 2021/22	Hauraki 2021/22	Matamata-Piako 2021/22	Otorohanga 2021/22	South Waikato 2021/22	Taupō 2021/22	Thames-Coromandel 2021/22	Waikato District 2021/22	Waitomo 2021/22	Waipā 2021/22
Stationary energy	1,514,506	280,747	34,371	142,784	16,428	349,186	74,956	44,570	392,019	41,332	138,114
Transportation	1,903,581	675,802	80,577	138,106	40,601	96,240	160,957	122,108	328,152	36,336	224,703
Waste	326,619	49,089	17,581	29,394	22,108	37,406	84,142	26,649	24,011	19,790	16,450
Industry	140,356	49,647	6,112	10,220	2,994	7,122	11,395	9,266	24,284	2,680	16,636
Agriculture	8,138,656	71,295*	617,324	1,347,153	783,964	705,615	1,037,853	204,493	1,550,479	843,484	976,999
Forestry	-1,749,712	512*	149,516	45,005	186,467	-740,165	-1,960,210	-350,978	393,600	983,671	-457,130
Total net (incl. forestry)	10,274,006	1,127,092	905,481	1,712,662	1,052,562	455,404	-590,907	56,108	2,712,545	1,927,293	915,772
Total gross (excl. forestry)	12,023,719	1,126,579	755,965	1,667,657	866,094	1,195,569	1,369,303	407,086	2,318,945	943,621	1,372,902
Population (2021-22 average)	507,465	179,500	22,100	36,950	10,825	25,750	41,200	33,500	87,800	9,690	60,150
Per capita net emission (incl. Forestry)	20	6	41	47	97	18	-14	2	31	199	15
Per capita gross emission (excl. Forestry)	24	6	34	45	80	46	33	12	26	97	23

* Note: Hamilton City agriculture and forestry results carry some uncertainty due to downscaled inventory data and differences between urban and rural settlements. It is recommended that these numbers be viewed as indicative and further work on this may be undertaken in the future.

For further perspective, the emissions intensity was also calculated per unit of Gross Domestic Product (GDP) which is used as a measure of economic activity within physical boundaries. Emission estimates by territorial authority per million dollars GDP are seen in *Table 12*.

Table 12. Emission estimates for Waikato Region and individual territorial authorities

	Total net emissions (incl. Forestry) (tCO_2e)	Total gross emissions (excl. Forestry) (tCO_2e)	GDP 2021r[32] ($m)	Net emissions intensity (tCO_2e/$m GDP)	Gross emissions intensity (tCO_2e/$m GDP)
Hamilton	1,127,092	1,126,579	12,658	89	89
Hauraki	905,481	755,965	761	1,190	993
Matamata-Piako	1,712,662	1,667,657	2,263	757	737
Otorohanga	1,052,562	866,094	496	2,122	1,746
South Waikato	455,404	1,195,569	1,321	345	905
Taupō	-590,907	1,369,303	2,530	-234	541
Thames-Coromandel	56,108	407,086	1,021	55	399
Waikato District	2,712,545	2,318,945	2,782	975	834
Waipā	915,772	1,372,902	2,551	359	538
Waitomo	1,927,293	943,621	696	2,769	1,356
Waikato Region	10,274,006	12,023,719	27,884	368	431

4.3 Comparison to New Zealand per capita average emissions

To provide a perspective into the Waikato Region's emissions profile, a summary overview is presented below in comparison to New Zealand's most recent GHG inventory (2023), both in terms of total emissions and on a per capita basis (*Table 13*).

On a per capita basis, Waikato Region's gross emissions are significantly higher than national per capita average emissions (23.7 vs 15.0 tCO_2e / cap). Agricultural emissions are high (16.0 vs 7.4 tCO_2e) showing the dominance of agricultural emissions in the Waikato. Forestry sequesters slightly less compared to the national average (-3.4 vs -4.1 tCO_2e), waste emissions are very similar given use of national-level calculations, whereas stationary energy and IPPU emissions are below the national averages.

[32] 2021 MBIE release of modelled Regional GDP 2021 release | Ministry of Business, Innovation & Employment (mbie.govt.nz).

Table 13. Overview of Waikato Region's emissions against New Zealand average emissions (tCO_2e/capita)

	Waikato GHG inventory 2021/22		New Zealand GHG inventory 2023 (1990-2021)	
Population no		507,465		5,111,300
	Emissions (tCO_2e)	**Per capita emissions (tCO_2e/cap)**	**Emissions (tCO_2e)**	**Per capita emissions (tCO_2e/cap)**
Stationary energy	1,514,506	3.0	18,555,200	3.6
Transportation	1,903,581	3.8	12,654,900	2.5
Waste	326,619	0.6	3,214,900	0.6
IPPU	140,356	0.3	4,609,600	0.9
Agriculture	8,138,656	16.0	37,786,100	7.4
Forestry	-1,749,712	-3.4	-21,078,200	-4.1
Total (net) incl. forestry	10,274,006	20.2	55,746,400	10.9
Total (gross) excl. forestry	12,023,719	23.7	76,824,600	15.0

4.4 Trends and changes over time

Trends over the three inventories undertaken to date have been similar, with modest changes seen within each sector year to year (Figure 4). The three sectors with greatest changes are transport with an increasing but fluctuating trend between years, agriculture with a downward trend based largely on animal number reductions (particularly dairy and sheep), and forestry with increased harvest volumes. Forestry produced the largest change in the 2021/22 inventory, compared with previous inventories, from increased harvest volumes (noting the change in data source). Increased harvest volumes significantly reduce the overall sequestration potential of the forestry sector to overall gross Waikato emissions.

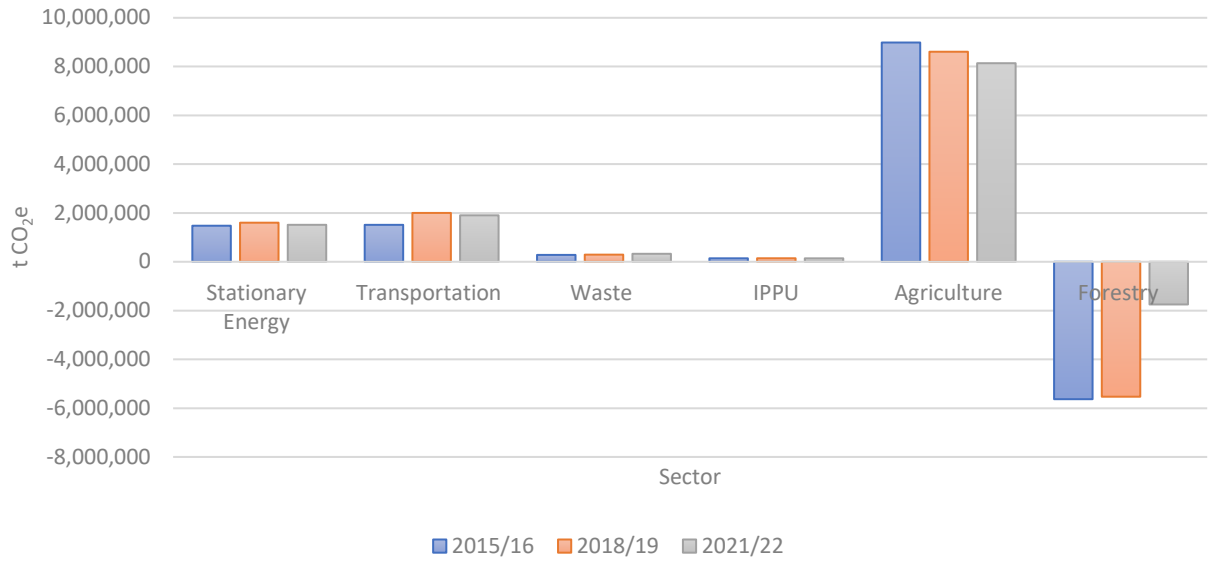

Figure 4: Trends and changes in inventory emissions by sector – 2015/16 to 2021/22.

Table 14 below shows that most sectors have reduced emissions since the 2018/19 inventory. Sectors with reductions since the first inventory include agriculture and IPPU. The sequestration value of forestry has also significantly reduced with increased forest harvest volume increasing significantly since the baseline inventory. For some sectors such as stationary energy and transport, emissions have increased from baseline year to last inventory, followed by a slight reduction since 2018/19. Waste emissions have continued to increase, largely as a result of increasing population. However, more detailed inventory studies using enhanced data at district level have indicated that waste diversion methods are now having an effect and lower emissions (both solid and wastewater sectors). As these district level studies and methods become more widespread, national inventory methods are likely to change, enabling the region to better reflect positive change in these sectors. Even with reductions in the value of forest sequestration, reductions in animal numbers in agriculture has meant the overall gross emissions for the region are lower in 2021/22 than they were in the baseline year of 2015/16.

Table 14. Emissions overview & changes since 2015/16 baseline

Emissions sources	Waikato Region 2015/16 emissions (tCO_2e)	Waikato Region 2018/19 emissions (tCO_2e)	Waikato Region 2021/22 emissions (tCO_2e)	% difference (from 2015/16 baseline)
Stationary Energy	1,477,156	1,601,427	1,514,506	3
Transportation	1,513,258	2,001,658	1,903,581	26
Waste	281,003	291,708	326,619	16
IPPU	141,492	143,213	140,356	-1
Agriculture	8,986,635	8,608,976	8,138,656	-9
Forestry	-5,632,761	-5,530,909	-1,749,712	69
Total (net) incl. forestry	6,766,782	7,116,073	10,274,006	52
Total (gross) excl. forestry	12,399,543	12,646,982	12,023,719	-3

Forestry emissions trends

With a reinvigorated focus on forests for sequestration, re-planting and new planting rates are up slightly for native replanting but there is a significant increase in replanting of exotic forests from 7,000 ha in 2018 to 34,000 ha of new planting nationally in 2021. While this is the case nationally, with larger harvest volumes in some territorial authority areas within the region, many districts have gone from net sinks to net emitters of forest emissions given harvest rates[33].

Forest harvest volume is cyclical, and it is likely that in the next few years more replanting than harvesting is likely to occur. This will re-balance forest sequestration within the Waikato Region. National Exotic Forest Description (NEFD) roundwood removals (harvests) have shown a steady increase since 2009 with slight plateauing in 2019, and some restocking planting had dropped since 2020. These trends nationally may explain the increase in wood harvest, but at regional scale, given the significant area of the Central North Island wood region within Waikato, this harvest to restocking ratio may be more significant than national trends. A regional forestry study is suggested in the recommendations given the significance of this sector.

Transportation emissions trends

The transportation sector has seen a slight decrease in overall emissions since the 2018/19 inventory. This can largely be attributed to the impacts of the COVID-19 pandemic and the increase in people working from home, which has subsequently decreased travel requirements. The largest decrease came from on-road petrol and diesel usage,

[33] NZ Forest Owners Association Facts & figures 2021/22. available at FGT_4234_Facts_and_Figures_2021_22_Internals_FA_web_updated_1feb2023.pdf (nzfoa.org.nz).

which corroborates this. A notable decrease was also seen in air travel, which can be attributed to more online working reducing needs for domestic travel alongside increased cost and health challenges of flying. This is in line with observations within the last two National GHG Inventories which have commentary on COVID-19 impacts at a national level.

Agricultural emissions

Overall emissions from agriculture have reduced by 847,979 tCO_2e since the first baseline inventory in 2015/16. This is largely driven by reductions in animal numbers (*Table 15*).

Emission factors have changed since the first inventory, enteric methane increasing slightly year on year as production intensity and animal intakes increase within each sector. While this is the case, minor changes in emission factors produced a less significant increase than gross reduction in livestock numbers.

The agricultural sector has been focused on on-farm production efficiency and for some time has been considering animal numbers to manage nutrient loss, profitability, and more recently, to reduce GHG emissions. As part of sector campaigns, over 80 % of farms now have on-farm GHG emission numbers through the "know your numbers" campaign, the first step in industry sector reduction plans.

With the government focused on emission reduction plans, and given agriculture makes up about 50 % of the national emissions inventory, a large amount of investment is being directed to on-farm mitigations for methane and nitrous oxide. Once technologies are proven and approved for use, these mitigations should further reduce agriculture emissions in coming years.

Table 15. Emission summaries since baseline GHG inventory from 2015/16 to 2021/22

Agriculture GHG Emissions Summary (tCO_2e)			
	2015/16 (recalculated)	**2018/19**	**2021/22**
Emissions from livestock within the region	**7,498,961**	**7,138,863**	**6,679,000**
Enteric fermentation	6,983,757	6,649,325	6,169,188
Manure Management (CH_4)	513,793	488,171	509,811
Manure Management (N_2O) (excluding organic fertilisers and pasture)	1,411	1,366	1,924
Emissions from aggregate sources and non-CO_2 emission sources on land within the city boundary	**1,487,674**	**1,470,113**	**1,481,945**
Liming & Dolomite	n.a.	75,901	74,158
Agricultural Soils (synthetic and organic fertilisers + crop residue)	199,542	174,601	216,009
Manure from grazing animals on pasture	1,040,787	990,496	1,026,267
Agricultural leaching	85,093	78,821	74,158
Agricultural atmospheric deposition	162,252	150,292	91,353
Total Agriculture emissions	**8,986,635**	**8,608,976**	**8,138,656**

5 Conclusions and recommendations

This GHG inventory for the Waikato Region 2021/22 provides consistent information for the region and territorial authorities to understand the emissions profile and trends since the baseline inventory in 2015/16. Emissions estimates and the breakdown at territorial authority and sector-level enable councils to engage, set informed reduction targets, effectively monitor the progress towards those targets, and the contribution different sectors make. The inventory is an effective framework for communicating with stakeholders and for informing decisions that impact climate mitigation.

Observing and understanding trends using emissions inventory data is important for informing policy and setting reduction targets throughout New Zealand. New Zealand's climate commitments and central government's focus on the emissions budgets provide a framework for exploring mitigation options informed by a detailed regional emissions inventory.

With an emissions profile dominated by agriculture, the Waikato Region will need to focus its reduction efforts on this sector as well as consider options for maintaining or increasing forest carbon sequestration potential if looking to reduce net emissions. At a territorial authority level, the emissions profiles vary with a clear difference between urban and rural. Urban councils are more heavily dominated by transport and stationary energy emissions, whereas rural councils are heavily dominated by agricultural emissions, followed by transport emissions.

The Waikato Regional Council is committed to taking action to mitigate, adapt, and lessen the impacts due to climate change. This emissions inventory is a useful tool for supporting the Climate Action Roadmap and for continuously updating the actions that the council can take to mitigate and adapt to climate change.

A range of recommendations are provided below in relation to how the inventory can be enhanced and acted on.

Inventory preparation and data collection

Access to data continues to pose challenges in inventory preparation – both in terms of primary activity data as well as the ability to estimate emissions at TA level. Overall, significant emission sources (e.g., agriculture) have been estimated using bottom-up data. However, some emissions are estimated using top-down approaches (i.e., applying national average emissions for wastewater, etc.). Attempts to access some primary data have been restricted by claims of commercial confidentiality.

Recommendation 1: Enhancing access to primary activity data: sector and territorial authorities level

All GHG inventories are built on gathering sound data across GHG sectors and districts. The preparation of this year's inventory has highlighted that there is a need and opportunity to enhance data for specific sectors, by leveraging the procurement power of Waikato Regional Council and TAs who are part owners/shareholder or have various contractors of services, data may be enhanced for the sectors listed below:

- **Stationary energy** – further consider and seek additional data sources to quantify the significant fossil fuel users within the region, particularly for energy production or process heat. Better data about solid biofuel use is necessary as this is currently a challenge to access. Biofuel is also becoming more important as a fuel source in the energy generation (and process heat) as climate change policy shifts away from fossil-fuel based generation of energy and process heat.
- **Transportation** – ensure fuel tax data is collected in a standardised manner by territorial authorities throughout the region. For territorial authorities with airports, work with those airports to consider how access to fuel data or flight data may be gained for the next GHG inventory. Hamilton and Taupō Airports either work directly with fuel companies as service providers to provide data (retaining commercial sensitivities across supplier companies), or capture data on flight destinations/arrivals and aircraft type to calculate emissions. Such work is underway at present but will not be completed for this inventory. Hamilton Airport was proactive in looking to improve this data collection.
- Better data for public transport use/uptake – as public transport has become a significant focus in major urban centres, better data would be useful. With current data it is difficult to quantify a shift from private vehicle use to public transport. In Hamilton, data was available on bus fleet and passenger train (Te Huia)

However, other data for the region on public transport was highly variable and not easily sourced from providers.

- **Solid waste** – out of region waste that is disposed of in Waikato, (i.e., from Auckland City and Bay of Plenty) needs to be tracked and emissions reported separately. To further enhance waste activity data, procurement contracts with waste providers across the region could be updated to include the requirement for waste management data (or emissions calculations) to be provided to TAs. Commercial confidentiality is not a justifiable reason not to share such information with the territorial authorities as clients – given the pressing need to reduce emissions and the obligations of the private sector to reduce emissions.
- **Wastewater (connected to above)** – while wastewater is not a significant source of emissions, it is an area of interest for TAs and the public more broadly. There are ongoing efforts by WaterNZ to standardise emissions calculations that can be used to generate a more accurate inventory (away from the top-down approach currently used). At present, Hamilton, Waikato, and Waipā districts are engaged in undertaking pilot studies to further differentiate waste streams and better account for GHG emissions for wastewater treatment as part of a national project. Alongside this, WaterNZ is developing an inventory of wastewater treatment plants systems throughout New Zealand. For the next Waikato GHG inventory, it is likely that this primary data will be available and better estimated using actual data. However, for the purposes of this inventory, methods from the last inventory were replicated so results could be compared.
- **Agriculture** – emissions calculations for agriculture at district level are highly dependent on the data made available from the NZ Agricultural Production Census – which takes place every five years. The relatively small, and urban dominated, district area of Hamilton City means that downscaled district data does not reflect expected animal numbers. This issue has become clear in the development of this inventory and given the importance of agriculture within the Waikato Inventory, further consideration of how to enhance this data around town boundaries is worthy of further consideration/study.
- Agricultural emissions are a significant focus by government and industry to accelerate reductions in agricultural emissions. Farmers will need to have a written plan in place to manage their GHG emissions by December 2024. While policy details are not yet agreed, there are already efforts in the primary sector to collect relevant data and estimate emissions at farm level. Such data could be used for generating more timely and accurate emissions calculations at regional and TA level which may build on increasing on-farm data captured in Freshwater Farm Plan Tools (FWFPs). Alongside this, if mitigations are deployed on farm, then some database system to quantify and account for mitigations deployed at scale, will be required to quantify mitigation benefits at farm to catchment to regional scale. Such data challenges require planning and management, especially when considering the interaction of downscaled farm data, upscaled for wider accounting purposes. This is complex and will require sound data agreements to ensure confidentiality of on-farm data while enabling accounting for GHG emissions.
- **Scope 3 inclusions -** In addition to data enhancements outlined above, a greater focus on Scope 3 (cross boundary) emissions is also recommended given increasing focus and developments in this space. Examples of this are inclusion of embodied emissions in fuel, construction, or food products.

Recommendation 2: Forestry, harvest versus planting, and sequestration

Given the significant role of forests in sequestration or removal of carbon dioxide from the atmosphere and given the significant increase in harvest volumes (resulting in increased emissions) highlighted in this inventory, a regional study of Waikato forestry is recommended. Such a study can add local district information on where forestry is grown to enhance the NEFD and seek local forestry expert advice on forest harvest projections. This recommendation comes as forest harvest data shows an increase in harvest in the forestry cycle, but, when harvest volumes are apportioned to districts on mature age trees solely, this is likely to under/overestimate where harvest has occurred. In this inventory and issuing of district reports, some districts such as Hamilton City have had very negligible (or no) harvest of small plantations of exotic trees. Whereas districts such as Taupō or South Waikato where forestry is prevalent, harvests may have been more significant. Gaining better data on this is important to balance consumption/production calculations of emissions and strengthening to reflect district level forestry

circumstances. Alignment to the forestry supplement[34] under the GPC methodology may also be considered while also aligning to the outcomes of Government's reviews of forestry under the ETS[35] (currently under consultation).

Recommendation 3: Continue automation of emissions calculations and data management

GHG inventories aggregate data over time across activities, sectors, and fuel type, and have significant potential to be used as a spatial management and collaboration tool by local government. As the number of inventories grows with time, data management becomes increasingly complex and resource intensive. To make the inventory process more efficient, enhanced quality control will enable the Waikato Region to use the data more easily. For the purposes of this GHG inventory, data has been calculated with data compiled into PowerBI from 2018/19 and this 2021/22 inventory. PowerBI is an interactive data visualization software for compiling and comparing data, it enables interaction across Microsoft products such as excel, and offers the ability to enhance graphing and visual insights. Further development is needed to bring in the 2015/16 dataset, then refine the data design in PowerBI and further develop useful dashboards and visual aids and infometrics to communicate results. Once this PowerBI database compilation is completed, past inventories will be able to be viewed, and new datasets will be more easily loaded to enable comparison across inventories.

Recommendation 4: Review of the data gathering and inventory development timelines

A three-year reporting interval has been applied to date for inventory preparation. Different reporting intervals are used by local government entities across New Zealand. It is recommended that Waikato Regional Council and the TAs discuss whether the current interval is sufficient or more frequent disclosure is necessary – recognising the role of regional councils to give regard to climate mitigation under the RMA. This, however, needs to consider the resources required for emissions reporting and obligations under the new resource management system. Any review of timeline should also consider the timelines for upgrades to data at national and district level, i.e., if relying on census level data, this is on a 5 yearly basis.

Recommendation 5: Data supply agreements to address significant data gaps

To improve the data collection process and address key data gaps, data agreements may be explored by regional and territorial authorities with concerned parties. Examples of data gaps relating to territorial authorities include access and provision of aviation data and waste management data from contractors to council who often co-own or contract services.

When seeking data for this year's inventory for aviation, fuel suppliers noted commercial sensitivity and did not provide data. At present Hamilton Airport is upgrading their data systems and inventory processes with a current push to more disclosures and data is likely to be available for the next inventory. Likewise, for solid waste, district councils supplied data, but this was highly variable and needed further work before it could be included in the inventory. For this reason, calculations were undertaken in line with IPCC top-down methods with use of national and regional waste studies. Again, some TAs such as Hamilton, Waikato, and Waipā are involved in more detailed studies in waste with a push to more detail nationally. Once methods are embedded into good practice for waste sectors and included in upgrades at national level, these new data variables and complexity can be included in future inventories.

Given the role of agriculture, it is worth considering whether any refinement of downscaled farm data from Statistics NZ is possible under a data agreement. This may suffice to ease cross boundary perturbations that affect TAs with small rural populations. Such agreements would need to retain confidentiality by ensuring farm production data is not released (e.g., animal numbers, etc.) as part of inventory reporting.

Recommendation 6: Transition emissions calculations to the latest IPCC GWP figures

The IPCC Sixth Assessment Report (AR6) was released in March 2023. The Climate Change Commission has recommended that from 2023 onwards, inventories apply AR6 GWP figures. As this inventory report covers the years 2021/22, and the AR6 was only released in March 2023, the AR5 has been used for the preparation of this inventory. It is recommended that Waikato Regional Council consider updating to AR6 in the next inventory development and re-calculate prior inventories to enable comparison.

[34] Described in detail at: https://ghgprotocol.org/sites/default/files/2022-12/global-protocol-community-scale-ghg-inventories-guidance.pdf

[35] NZ ETS review: Consultation now open (2023). Ministry for the Environment.

In a supplementary report to this inventory, Waikato Regional Council quantified emissions from Organic Soils using the 2013 IPCC Wetland Supplement and local data where applicable[36]. The New Zealand GHG Inventory is going to adopt this methodology for calculating emissions in future inventories. To align with the national inventory, Waikato Regional Council will include Organic Soils in the next inventory. As outlined above for use of new IPCC GWP figures, inclusion of Organic Soils into the next inventory will also require a re-calculation of prior inventories.

[36] Intergovernmental Panel on Climate Change 2013. 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.

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Appendices

A. Assumptions and limitations

Table 16. Waikato region GHG Inventory data assumptions, limitations, and exclusions – 2021/22

Sector/Category	Assumptions and Exclusions
Stationary Energy Emissions	
Residential, commercial, and industrial stationary energy emissions	• Coal and biomass related emissions have been estimated using a top-down approach, applying the national average consumption for commercial and residential coal use, estimated based on population figures. • Consumption of natural gas and electricity data are based on total energy distributed to grid exit points within the region. The energy provided to these grid exit points has then been allocated to the entire region. This may in some instances mean that energy used outside the region may be counted as part of the region's footprint, depending on the distribution network for gas and electricity, which may not fully match the region's boundaries in all cases. • Emission per user group (i.e., residential, commercial, and industrial) was estimated based on national average energy use split between these groups as reported by the Ministry of Business, Innovation and Employment (MBIE, 2023)). • Coal and natural gas consumption for the Huntly Power Station have been excluded from the regional emissions estimates, as this is already reflected in the national emissions factor for electricity generation.
Electricity Generation	• The national emission factor for electricity generation was estimated based on data published by MBIE in their quarterly electricity and liquid fuel emissions table (MBIE 2020). • The emissions from stationary energy generation (e.g., from the Huntly Power Station) occurring within the region have not been included in the Waikato Region carbon footprint, as these are part of the national emissions calculations for electricity generation. Waikato's share of the emissions from stationary energy generation is already accounted for as part of the emissions estimated for the region's electricity consumption.
Electricity Consumption	• Consumption of electricity data is based on total energy distributed to grid exit points within the Transpower Network. The methodology for electricity consumption matches the 2018/19 methodology based on grid exit points. • The electricity consumption figure used for the Waikato Region is likely to be conservative, as the total energy distributed to the exit-grid points does not follow regional boundaries. However, it is likely that the affected population/area is relatively small and therefore the impact to the energy consumption to the Waikato Region is not likely to be significant.
LPG	• LPG consumption in the Waikato region is based on the total amount of LPG supplied to the North Island and calculated on a per capita basis using 2021/22 population estimates. • LPG stationary energy estimates are based on the national share of 9 kg and 45 kg gas bottles, and bulk sales provided by the LPG Association of New Zealand.

Natural Gas	• Natural gas consumption is based on total gas distributed to exit grid points within the Waikato region as supplied by First Gas (excludes sites that have direct connections to the transmission network). • Natural gas used by Huntly Power station and the Te Rapa cogeneration plant has not been included as these are already reflected in the national emissions factor for electricity generation. • The natural gas distribution network does not follow regional boundaries and may include some of the surrounding rural areas. However, it is assumed that the population in these areas is relatively small and therefore the impact to the regional natural gas consumption is not likely to be significant. • Emissions of 6.34 kg CO_2e/GJ during distribution was applied, based on the national average reported for distribution loss of reticulated natural gas.
Industrial Stationary Energy Emissions	• No specific data was available for industrial stationary energy consumption with the exception of natural gas use for co-generation plants at the Fonterra Te Rapa & Lichfield Dairy plants and fugitive emissions from mining. • Industrial stationary petrol and diesel use have been estimated based on total fuel sold within the region and the Energy Efficiency and Conservation Authority (EECA) Energy End use Database.
Fugitive Emissions	• Not included in the Inventory as there is no production of oil or gas within the Waikato region. • Fugitive emissions from coal have been included in industrial stationary energy emissions.
Coal	• Emissions relating to the use of coal from residential, commercial, as well as from agriculture, forestry, and fishery activities have been included for the Waikato region. • Coal consumption for heavy industry was not included (e.g., dairy processing) as these are not relevant for the region (no heavy industry) or use natural gas as fuel source. • Fugitive emissions from coal mining have been included under stationary energy (industrial emissions), based on the national average emissions factor for fugitive emissions from sub-bituminous coal mining reported by MfE.
Transportation Emissions	
Road	• Total volume of fuel sold within the Waikato region and the breakdown by region in FY2021/22 was provided by nine of the ten territorial authorities. The data for Taupō district was taken from the last inventory. • Fuel consumption figures (petrol and diesel) also include fuel used for off-road transport and recreational water transport, as these are sold through the same network. Due to lack of data these could not be reported separately. • Bus diesel was included in the total diesel figures. It only includes Hamilton City Bus consumption FY2021/22 and contributes only to the regional and Hamilton City Council calculations.
Rail	• Emissions from rail transport are estimated based on length of rail network and average fuel consumption per km. Freight volume as provided by Kiwi Rail for the 2021/22 financial year. • The rail network in Waikato is electric and diesel.

	• The total volume of rail diesel accounts for fuel used to shift freight via the Waikato region rail network. • It was assumed that diesel sold for rail transport is not included in the Waikato fuel sales data for road transport.
Aviation	• Attempts were made to seek primary data on fuel from fuel companies and Hamilton airport was in the process of gathering such data, but this was not completed within the time of preparation of this inventory. • The 2018/19 aviation emissions, from jet kerosene, were estimated using the average number of plane movements understood to take place via the flightaware.com website. The number of flights estimated was likely to be conservative as movements of large jet planes and some smaller planes. Planes departing and arriving at the same airport (e.g., tourist flights) were not included. • Actual flight data was sought through Hamilton Airport and FlightAware or was not available for the 2021/22 inventory. Estimations were applied to 2018/19 aviation fuel data and fuel use was apportioned based on reductions seen in the New Zealand GHG Inventory (1990-2021) between 2018 and 2021 for jet kerosene and aviation fuel; (26.2 % and 24.4 % respectively) based on percentage reductions of aviation emissions (for both types of aviation fuels) referenced in the New Zealand GHG Inventory 1990-2021.
Liquefied Petroleum Gas (LPG)	• LPG consumption in the Waikato region is based on the total amount of LPG supplied to the North Island and calculated on a per capita basis using 2021/22 population estimates. • LPG transportation energy estimates are based on the national share of automotive and forklift sales as provided by the LPG Association of New Zealand. • LPG consumption estimate does not take into account automotive and forklift sales in the region that may then be taken out of the region or individual territorial authority boundaries.
Biodiesel	• Assumed that 5.4% of total diesel is biodiesel in line with the New Zealand GHG Inventory 1990-2021. Since the last inventory, refining in New Zealand has stopped. All biodiesel is now imported and dispersed across suppliers. For that reason, we have applied the New Zealand GHG Inventory 1990-2021 assumption rather than collecting primary data which was not easily sourced. • The New Zealand GHG Inventory 1990-2021 denotes a change in feedstock and calculation method, and with feedstock being assumed as fossil origin, part of the CO_2 emissions previously reported as biomass memo items is now included in the national total emissions.
Off-Road	• Estimated based on EECA – End-Use Energy Database applying a national average split to the total amount of petrol and diesel sold within the region.
Waste Emissions	
Solid Waste Disposal	• Solid waste emissions were estimated using a 1st-order decay model (which requires waste volume estimates for the last 50 years). • Reliable historic population figures, provided by Statistics NZ, only go back to 1986 therefore 30 years of data has been estimated for the Waikato region solid municipal waste emissions. • Due to limited specific current and/or historic data for the region, waste volumes sent to landfill for the Waikato region have been estimated by applying the New Zealand national average waste generation per capita (reported by MfE in the New

	Zealand GHG Inventory 1990-2017) and using historic population figures reported by Statistics NZ. • Landfill gas emissions were estimated for landfills with and without landfill gas capturing systems. The majority of solid waste emissions (54 %) were released from landfills without landfill gas collection. These are predominantly from closed landfills that have been used in the past but are still emitting landfill gas. • Data on specific waste composition was not available therefore this data has been modelled based on the national average waste composition reported by MfE 2019. • For 2021/22 fate of waste for Waikato was based on the Waikato and Bay of Plenty region waste and recycling stock take (WAIBoP stocktake) 2021. This denotes Waikato, Hamilton and Waipā districts send all their waste to landfill at Hampton Downs. Hauraki district, Thames-Coromandel, Matamata-Piako and some South Waikato district waste is sent to landfill at Tirohia. Otorohanga and Waitomo and some South Waikato waste is sent to Waitomo landfill site. Taupō district sends all their waste to Broadlands Road landfill site. See Figure 2 of the WAIBoP stocktake report for landfill locations and waste flows for further detail. • Hampton Downs has been collecting landfill gas since 2006 and Tirohia has been collecting landfill gas since 2001. All other landfill sites in the Waikato region do not collect landfill gas. • From the Waikato and Bay of Plenty region waste and recycling stocktake 2021 this also denotes waste inclusions from Auckland, Bay of Plenty and Gisborne District Council to Hampton Downs and Tirohia landfills. As accurate historical data is not available this has not been included in this inventory but may be useful to capture further data on for the next inventory. • In the development of this inventory when seeking data, it became clear that there are significant solid waste transfers to landfill coming into the Waikato region from both Auckland, and Bay of Plenty. The 2021 Waikato Bay of Plenty documents the contemporary Bay of Plenty (and Gisborne) inclusions, and some data was sought from EnviroNZ who manage Auckland waste streams. While some data was gained, without a long-term history of waste inclusions it was not possible to back calculate waste emissions using IPCC/GPC methodologies. Looking forward, it will be important to seek further historical data and calculate emissions for inclusions ahead of the next GHG inventory.
Incineration	• No emissions from industrial processes have been included due to the lack of specific activity data. It is understood there are very few large industrial operations resulting in emissions from chemical or physical processes taking place within the Waikato Region.
Wastewater Treatment	• No data for the specific type of wastewater treatment methods or number of individuals in the region using different wastewater treatment methods was available for the Waikato region at the time of deriving the wastewater emissions. • National wastewater emissions from New Zealand GHG Inventory 1990-2021 and population data from 2021/22 were used to calculate the per capita wastewater treatment and disposal emissions, and the total wastewater emissions from the Waikato region. 2023 data was the most up to date information available from the New Zealand GHG Inventory 1990-2021.
Industrial Emissions	
Industrial Processes	• No emissions from industrial processes have been included due to the lack of specific activity data. It is understood there are very few large industrial operations resulting

	in emissions from chemical or physical processes taking place within the Waikato region.
Product Use including: HFC, PCFs and SF_6	• Emissions for refrigerants, fire extinguishers, foam blowing, aerosols and metered dose inhalers, as well as SF6 in electrical equipment are estimated based on New Zealand average per capita emissions (Table 1.A(a)s4) data provided in the New Zealand GHG Inventory 1990-2021.
Agricultural Emissions	
Agriculture	• Agricultural emissions are based on agricultural production statistics (2022 FINAL) data available online from Statistics NZ. This data provides census level data of animal and cropping farm system variables at territorial authority scale. Given this is census level verified data, for most Districts this data is high quality (and aligns to New Zealand GHG Inventory development). However, when applied to urban councils (namely Hamilton City) this data has some limitations due to perturbations applied by Statistics NZ to protect the data of small number of rural landowners. For future inventories enhancements may be needed to gain more accurate data for Hamilton City to enable re-apportioning of some animal numbers with neighbouring Districts. • Emission Factors (for most sources) were sourced from the New Zealand GHG Inventory 1990-2021. This has a mix of New Zealand specific emission factors and application of IPCC 2006 where New Zealand based science has not been undertaken for minor livestock categories. Most significant animal and farming losses (dairy, non-dairy cattle, sheep, and deer) have New Zealand based studies and specific emission factors. • Emissions for field burning of agricultural residues have not been included in the calculations above, due to lack of data and methodological guidance by the IPCC 2006 Guidelines. These emissions are assumed to be insignificant within the Waikato context.
Forestry Emissions	
Forestry	• Exotic forest volumes are based on data provided in the National Exotic Forest Description (NEFD) published by MPI (MPI 2022). The data is provided at a territorial authority level. • Carbon sequestration for exotic forests include above ground, below ground, dead wood, and litter. • Carbon sequestration rates for exotic forests are based on yield tables provided by Me, assuming a 50/50 split between pre 1990 and post 1989 forests within the Waikato region. • Harvest data has been calculated from NZ Forest Growers Levy Trust (NZFGLT) data from actual levy collected per ton harvested. This provides levy data for Central north island wood supply region, and data was then apportioned using mature age forests found within the NEFD 2022. • Once data on export and domestic harvest was extracted from NZFGLT for Central North Island wood region was then apportioned to the Waikato and associated territorial authorities (excluding Bay of Plenty and other region districts) using mature age forests (26-40 years) found within the NEFD. • Due to insufficient data for land use changes, no emissions from land use change of cropland, wetlands, settlements, and other land have been estimated.

	• Maturing native forests (i.e., Mānuka and Kānuka), as well as grassland with woody biomass have been included as native forests. Data for native forests is based on LCDB vol. 5 data (2018). • Sequestration rates for indigenous forests were based on advice from MfE regarding yearly carbon sequestration on per hectare basis for selected indigenous forest categories (2017). • Emissions from forest harvesting activities are included in the Inventory as part of the Land Use, Land-Use Change and Forestry (LULUCF) emissions. • For the purpose of this report, it was assumed that all carbon stored in tree biomass (above and below ground as well as in dead wood and litter) become an emission in the year of the tree harvest. • For Hamilton City Council who have very small stands of exotic forest, and significant planting of natives since the last survey for the New Zealand Land Cover Database (LCDB), this TA is considering further study to enhance GHG inventory calculations with verified GIS data within the City Boundary. This study is being considered.
Emission Factors	
Emission Factors – Mobile and Stationary Energy	• Emissions factors are based on published New Zealand specific emission factors where possible. Sources include the New Zealand GHG Inventory 1990-2021 and Guidance for Voluntary GHG Reporting for Organisations (MfE, 2022) and the IPCC AR5 report. A detailed list of emission factors is provided in the individual emissions calculations table in the Excel tables prepared as part of this project. • Advice received by MfE (for a previous report) supported the use of the most recently published emissions factors for all reporting years and emissions calculations. • The Global Warming Potential used to convert CH_4 and N_2O to CO_2e is based on the IPCC AR5 for 100-year GWP including climate-carbon feedbacks. These conversion factors are 34, 298, and 1 respectively.

B. Data Sources and Data Gaps

Data for the community carbon footprint was collected from a number of data sources. Key data sources are detailed below:

Table 17. Waikato region GHG Inventory Data Sources – 2021/22

Emissions Category		Data Source
Stationary Energy		• First Gas Limited • Transpower • Electricity Authority • Genesis Energy (Huntly Power Station coal and gas use) • LPG Association NZ • MBIE (2023) Energy in NZ • MBIE (2023) Data Tables for Coal • MfE (2023) New Zealand's Greenhouse Gas Inventory 1990-2021
Transportation		• Hamilton City Council for Fuel tax data (6 districts) • Otorohanga (2 districts) • KiwiRail • LPG Association NZ • MfE (2023) New Zealand's Greenhouse Gas Inventory 1990-2021
Waste	Solid Waste	• Waikato Bay of plenty waste and recycling stock take 2021 • Waste Management • Envirowaste • Individual territorial authorities
	Wastewater	• MfE (2023) New Zealand's Greenhouse Gas Inventory 1990-2021
Industrial		• MfE (2023) New Zealand's Greenhouse Gas Inventory 1990-2021
Agriculture		• Statistics New Zealand Agricultural production statistics 2022 (FINAL) – provides territorial authority reporting of farm production variables. This covers most production variables within pastoral farm systems. • MfE (2023) New Zealand's Greenhouse Gas Inventory 1990-2021
Forestry		• National Exotic Forest Description 2022 – provides data on standing volume, ag distribution, and planting of exotic (and some native planning) at territorial authority. • NZ Forest Growers Levy Trust – tables on Export and domestic forest harvest tonnages (converted to cubic metres) for harvest volume. • Harvest volume was apportioned to territorial authority by calculating mature age (26-40 years) forests from NEFD.

A data gap analysis was undertaken during the data collection stage of the project. The following data gaps and alternative data sources were identified:

Table 18. Waikato region GHG Inventory Data Gaps – 2021/22

Emissions Category		Data Gap	Alternative Data Source
Stationary Energy		• Specific biofuel use/consumption • City residential consumption	• No alternative data source (assumed in line with national Inventory 2023) • National average (on per capita basis)
Transportation		• Aviation fuel use • Taupō Fuel use • Specific Biodiesel use	• Estimated based on MfE (2023) New Zealand's Greenhouse Gas Inventory 1990-2021. Re-used 2018/19 Taupō fuel data in this instance. • Applied national Biodiesel mandate (5.4%)
Waste	**Solid Waste**	• Diversion of waste statistics per landfill site	• Assume all waste landfilled
	Wastewater	• Further detailed data on influent/effluent and biochemical oxygen demand (BOD) to enable use of WaterNZ methods	• WaterNZ growing inventory of WWTP sites, and working directly with TA's.
Industrial		• Significant industrial (physical & chemical) process activity resulting in GHG emissions. • Industrial product use (e.g., asthma inhaler, aerosols, etc.)	• No sources identified – assumed not to be relevant or significant. • Emissions were estimated based on national emissions data on a per capita basis
Agriculture		• Refinement of Hamilton City Council animal numbers and production statistics • Cropping on organic soils	• With HCC, survey rural landowners and work with rural consultants/ agriculture sector organisations to collect primary data and enable re-apportioning of agricultural data within HCC boundary. • Work with Waikato Regional Council to consider LUCAS GIS datasets and assess organic soil losses
Forestry		• Waikato specific studies on forest plantings and harvest	• Some coverage with MPI Wood availability forecast but not Waikato Specific • Applied apportioning calculations from NEFD mature age forests. • Carry out Waikato Region and District study of forest planting and harvest to enhance inventory data statistics.