# Horizons Region Community Carbon Footprint 2018/19

August 2020

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Client: Horizons Regional Council

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# Executive Summary

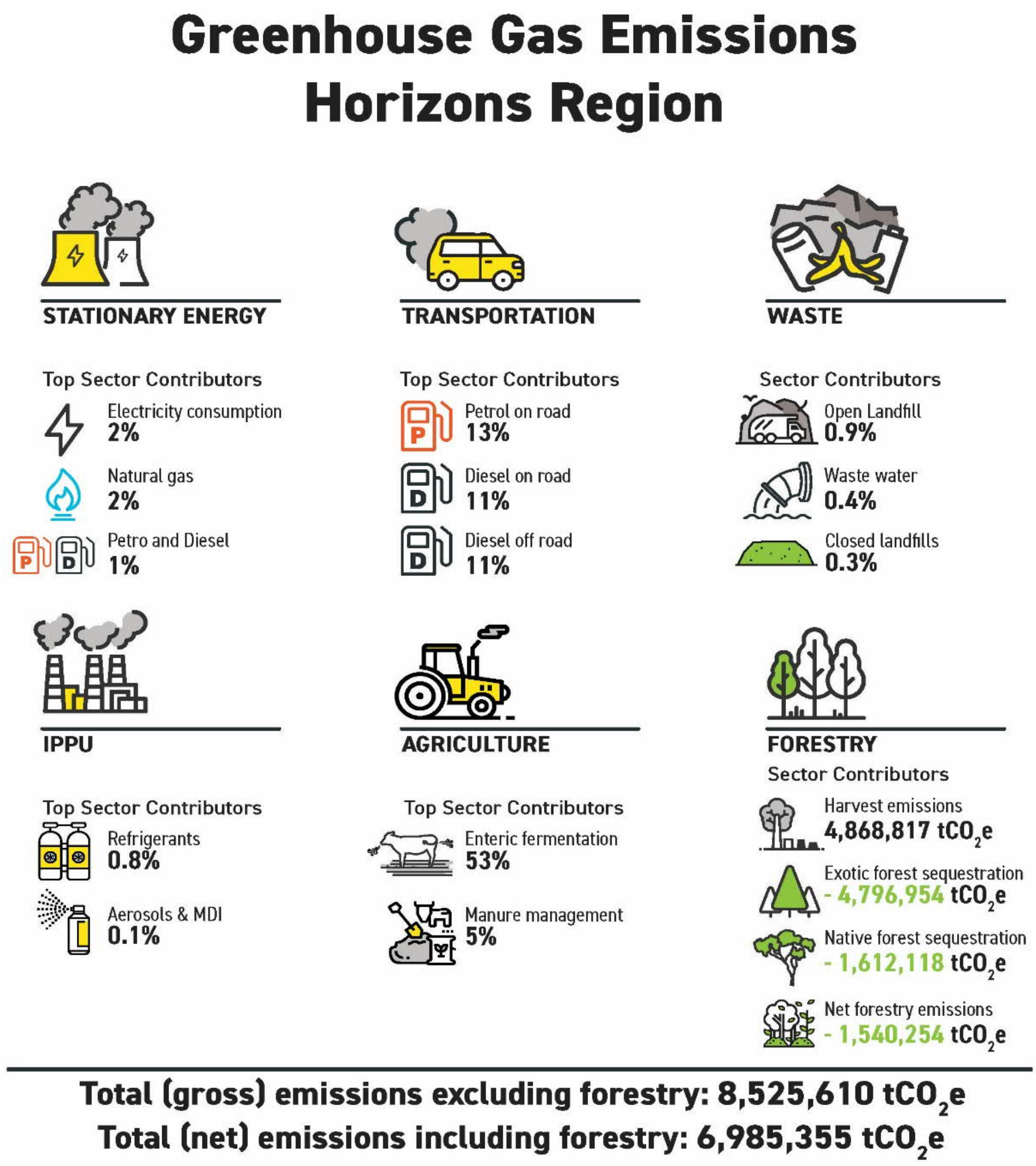
Greenhouse Gas (GHG) emissions for the Horizons Region have been measured using the Global Protocol for Community Scale Greenhouse Gas Emissions Inventory (GPC). The method includes emissions from stationary energy, transportation, waste, industry (IPPU), agriculture and forestry sectors.

This document reports greenhouse gas emissions produced in, or resulting from activity or consumption, within the geographic boundaries of the Horizons Region for the 2018/19 financial reporting year. Referred to hereafter more commonly as 2019 for ease. Greenhouse gas emissions are generally reported in this document in units of Carbon Dioxide Equivalents ($CO_2$e). The results of the community carbon footprint are summarised in Figure 1.

**Major findings from the 2019 Emissions Inventory:**

- In the 2019 reporting year, the Horizons Region emitted **gross 8,529,602 t$CO_2$e**. The biggest emitting territorial authorities in the Region are Tararua, Rangitīkei and Manawatū, with each area emitting 21%, 18% and 17% of the Region's total gross emissions respectively.
- Agriculture (e.g. emissions from livestock and crops) is the largest emitting sector in the Region, representing 66% of total gross emissions, with sheep and cattle accounting for 98% of agricultural emissions. Transport (e.g. road, rail, and air travel) is the second largest source of emissions, accounting for 25% of total gross emissions, with petrol and diesel (on-road, off-road and buses) accounting for 99% of transport emissions. Stationary Energy (e.g. consumption of electricity and natural gas) is the third highest emitting sector in the region, producing 6% of total gross emissions.
- After consideration of carbon sequestration (carbon captured and stored in plants or soil by forests) and emissions from the forestry sector, the Horizons Region emitted **net 6,985,355 t$CO_2$e** emissions. Carbon sequestration from forests totalled 6,409,072 t$CO_2$e in 2019 while emissions produced by harvesting of forestry totalled 4,868,817 t$CO_2$e. The area with the highest levels of carbon sequestration from forestry was the Ruapehu Territorial Authority (38% of the Region's carbon sequestration).

**Figure 1 Summary of change in emissions in the Horizons Region 2018/19 including top contributors to total gross emissions from each sector in 2018/19**



# 1.0 Introduction

AECOM New Zealand Limited (AECOM) has been commissioned by Horizons Regional Council (HRC) to assist in the development of a greenhouse gas footprint for the Region for the 2018/19 (2019) financial year. The study boundary incorporates the jurisdiction of the Horizons Regional Council.

# 2.0 Approach to Analysis

The methodological approach used to calculate emissions follows the Global Protocol for Community Scale Greenhouse Gas Emissions Inventory (GPC) published by the World Resources Institute (WRI) 2015. The GPC includes emissions from stationary energy, transport, waste, industry, agriculture and forestry activities within the Region's boundary. The sector calculations for Agriculture, Forestry, Solid Waste and Wastewater are based on Intergovernmental Panel on Climate Change (IPCC) workbooks and guidance for emissions measurement. The sector calculators also use methods consistent with GHG Protocol guidance published by the WRI for emissions measurement when needed. Data are reported in the GPC sectors and per activity/emission source using the standard format recommended by the standard.

The same methodology has been used for other community scale greenhouse gas (GHG) inventories around New Zealand, (e.g. Wellington, Auckland, Christchurch, Dunedin, Tauranga and Southland) and internationally. The GPC methodology[1] represents international best practice for city and regional level GHG emissions reporting.

This inventory assesses both direct and indirect emissions sources. Direct emissions are production-based and occur within the geographic area (Scope 1 in the GPC reporting framework). Indirect emissions are produced outside the geographic boundary (Scope 2 and 3) but are allocated to the location of consumption. An example of indirect emissions is those associated with the consumption of electricity, which is supplied by the national grid (Scope 2). All other indirect emissions such as cross-boundary travel (e.g. rail and flights), and energy transportation and distribution losses fit into Scope 3.

All assumptions made during data collection and analyses have been detailed within **Appendix B– Assumptions**. The following aspects are worth noting in reviewing the inventory:

- Emissions are expressed on a carbon dioxide-equivalent basis ($CO_2e$) including climate change feedbacks using the 100-year Global Warming Potential (GWP) values[2]. Climate change feedbacks are the climate change impacts from GHGs that are increased or decreased as the climate changes. For example, once the Earth begins to warm, it triggers other processes on the surface and in the atmosphere. Current climate change feedback guidance is important to estimate the long-term impacts of GHG's.
- GPC reporting is production-based (as opposed to consumption-based) but includes indirect emissions from energy consumption. Production-based emissions reporting is generally preferred by policy-makers due to robust established methodologies such as the GPC which enables comparison between different studies. Production-based approaches generally exclude globally produced emissions relating to consumption (e.g. embodied emissions relating to products produced elsewhere but consumed within the geographic area).
- Total emissions are reported as gross emissions (excluding forestry) and net emissions (including forestry)
- Where location specific data was not accessible, information was calculated via a per capita break-down of national or regional level data.
- Emissions for individual main GHG gases are provided in the supplementary spreadsheet information supplied with this report.

[1] http://www.ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
[2] https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf (Table 8.7)

- Transport emissions:
  - Transport emissions associated with air, rail and port activity were calculated using the induced activity method. Fuel consumption data was determined from the number of journeys taken, distance travelled and consumption rates for the appropriate transport mode.

- Solid Waste:
  - Solid waste emissions from landfill are measured using the IPCC First Order Decay method that covers landfill activity between 1950 and the present day. Solid waste emissions were calculated for the currently operating landfill sites at Bonny Glen, Levin and Ruapehu. In the years prior to each landfill site's operation we have allocated the remaining waste volume to 'Closed landfill sites'.
- Wastewater emissions:
  - Emissions have been calculated based on the data provided following IPCC 2006 guidelines. Where data is missing, IPCC and MfE provided figures have been used. Wastewater emissions from individual septic tanks have been calculated.
  - Wastewater emissions include those released directly from wastewater treatment, flaring of captured gas and from discharge onto land/water.
- Industrial emissions
  - Due to data confidentiality, the inventory reports all the known industrial product use emissions as one single value and does not break-down emissions by product type. The availability of emissions associated with industry is also restricted due to confidentiality issues and constraints in communication from relevant stakeholders.
  - Industry and solvent related emissions are estimated based on data provided in the New Zealand Greenhouse Gas Emissions 1990-2017 report (MfE 2019). Emissions are estimated on a per capita basis applying a national average per person.
- Forestry emissions:
  - 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 rather than the Kyoto Protocol). It treats emissions from harvesting and deforestation as instantaneous rather than accounting for the longer-term emission flows associated with harvested wood products.
  - The inventory considers regenerating (growing) forest areas only. Capture of carbon from the atmosphere is negligible for mature forests that have reached a steady state.
  - A further assessment of forest sequestration requested by Council to improve internal knowledge is provided in **Appendix C**.

Overall sector data and results for the GHG inventory have been provided to HRC in calculation table spreadsheets. All assumptions made during data collection and analyses have been detailed within **Appendix B – Assumptions**.

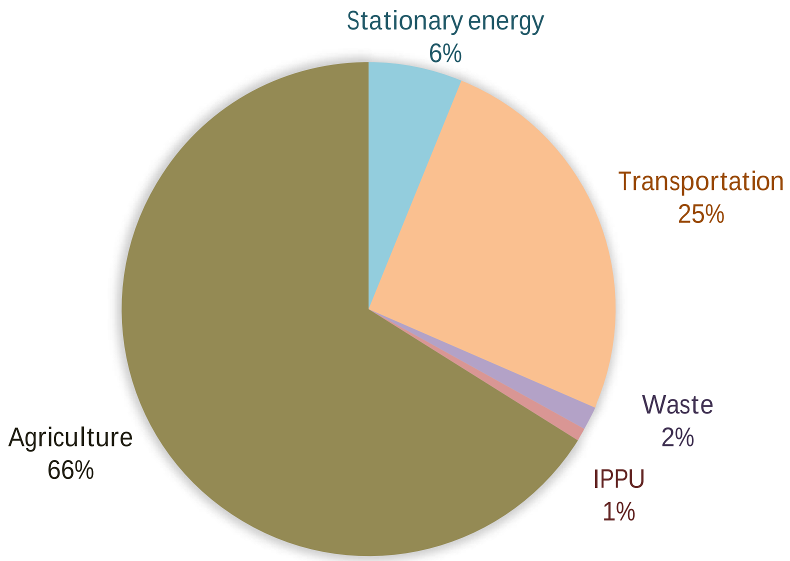
## 3.0 Overall Results

The paragraphs, figures and tables below explain the overall emissions and emissions from each sector. The focus of the information presented are the gross emissions produced in the Region. Reporting of gross emissions informs and enables local action to address emissions.

Discussion of per capita emissions is limited to when it is useful for comparing emission figures with other geographic areas. Net emissions including results from forestry resources are reported separately.

During the 2019, the Horizons Region emitted **gross 8,525,610 $tCO_2e$** and **net 6,985,355 $tCO_2e$** emissions. The population in 2019 was approximately **247,750** people, resulting in per capita gross emissions of **34.4 $tCO_2e$/person.** Agricultural emissions are the largest contributor to the inventory for the Region, followed by Transport (refer to Figure 2 and Table 1).

**Figure 2 Horizons Region's GHG emissions gross emissions split by sector ($tCO_2e$).**




The Region-level carbon footprint inventory comprises emissions for six different sectors, summarised below:

**Stationary Energy:** Producing 524,955 $tCO_2e$ in 2019, stationary energy was Horizons Region's third highest emitting sector (6.2% of total gross emissions). Electricity consumption was the cause of 38% of stationary energy emissions (199,374 $tCO_2e$, or 2% of the Region's total gross emissions). Natural gas consumption was the cause of 35% of stationary energy emissions (184,902 $tCO_2e$, or 2% of the Region's total gross emissions). Petrol and diesel consumption used for stationary energy was the cause of 20% of stationary energy emissions (104,572 $tCO_2e$, or 1% of the Region's emissions). Stationary uses of LPG, coal and biofuel produced the remaining 7% of stationary energy emissions (36,107 $tCO_2e$)

Stationary energy demand is broken down by fuel type, and also by the sector in which it is consumed. Stationary energy demand is reported for the following sectors: industrial (which includes agriculture, forestry and fishing); commercial; and residential. Additional to agriculture, forestry and fishing, the industrial sector includes mining, food processing, textiles, chemicals, metals, mechanical/electrical equipment and building and construction activities. Emissions from petrol and diesel used for stationary energy are not broken down into these sectors.

- Residential stationary energy consumption accounts for 17% of stationary energy emissions (90,151 $tCO_2e$) and 1% of total gross emissions. Residential stationary energy is energy used in homes (e.g. for heating, lighting and cooking).
- Commercial stationary energy consumption accounts for 16% of stationary energy emissions (82,237 $tCO_2e$) and 1% of total gross emissions. Commercial stationary energy is energy used in all non-residential and non-industrial settings (e.g.in retail, hospitality, education and healthcare).
- Industrial stationary energy consumption accounts for 47% of stationary energy emissions (247,996 $tCO_2e$) and 3% of total gross emissions. Industrial stationary energy is energy used within all industrial settings (e.g. mining, food processing, textiles and building and construction activities), and includes agriculture, forestry and fishing activities.
- The remaining 20% of stationary energy emissions (104,572 $tCO_2e$, 1% of gross emissions) were produced by diesel and petrol, which were not allocated to the above categories. Stationary Energy uses of diesel and petrol include use in stationary generators and motors and for heating.

**Transportation:** The second highest emitting sector, transport, produced 2,162,198 $tCO_2e$ in the reporting year (25.4% of the Region's gross total emissions). Almost all of these emissions can be attributed to Petrol and Diesel used for transport, which produced a total of 2,147,576 $tCO_2e$ (99% of the sector's emissions and 25% of total gross emissions). The rest of the transport emissions are produced by air travel, rail, LPG and port activities totalling 14,622 $tCO_2e$ (0.7% of the sector's total emissions and 0.2% of total gross emissions).

In 2019, Petrol used for transport produced 1,110,566 $tCO_2e$ while Diesel used for transport produced 1,037,010 $tCO_2e$. Bus diesel is included in the total diesel figure. Buses produced 1,349 $tCO_2e$ of Diesel used for transport emissions which represented just 0.1% of total on-road Petrol and Diesel emissions.

**Waste (solid & wastewater):** Waste originating in the region (solid waste and wastewater) produced 131,825 $tCO_2e$ in 2019 which comprises 1.5% of the Region's total gross emissions. Solid waste produced 101,925 $tCO_2e$ in 2019, making up 77% of total waste emissions. Wastewater produced the remaining 23% of waste emissions (29,901 $tCO_2e$).

Solid waste emissions include emissions from open landfills and closed landfills. Both open and closed landfills emit landfill (methane) gas from the breakdown of organic materials disposed of in the landfill. Open landfills contributed 78,670 $tCO_2e$ (1% of the Region's total gross emissions). Closed landfills emitted 23,255 $tCO_2e$ (0.3% of the Region's total gross emissions).

Wastewater produced 29,901 $tCO_2e$ making up 0.3% of total gross emissions. Wastewater tends to be relatively small emission source compared to solid waste as advanced treatment of wastewater produces low emissions. In contrast, solid waste generates methane gas over many years as organic material enters landfill and emissions depend on the efficiency and scale of landfill gas capture.

**Industrial Processes and Product Use (IPPU):** This sector includes emissions associated with the consumption of GHGs for refrigerants, foam blowing, fire extinguishers, aerosols, metered dose inhalers and Sulphur Hexafluoride for electrical insulation and equipment production. IPPU emissions do not include energy use for industrial manufacturing, which is included in the relevant stationary energy sub-category (e.g. coal, electricity and/or petrol and diesel). These emissions are based on nationally reported IPPU emissions due to the difficulty of allocating emissions to particular geographic locations. Addressing IPPU emissions is typically a national policy issue.

IPPU in the Horizons Region produced 74,730 $tCO_2e$ in 2019, contributing 0.9% to the area's total gross emissions. 92% of IPPU emissions (69,070 $tCO_2e$) are the result of refrigerant use.

**Agriculture:** The highest emitting sector, agriculture, emitted 5,631,902 $tCO_2e$ in 2019, 66.1% of the Region's total gross emissions. Agricultural emissions are the result of both crop and livestock farming. Livestock farming emitted 99% of agricultural emissions. Sheep are farmed in the largest numbers across the area, accounting for 82% of farmed livestock (5,041,774 animals) and 44% of agricultural emissions. Cattle make up 17% of farmed livestock (1,027,527 animals) and 54% of agricultural emissions.

Enteric fermentation produced 81% of the Region's agricultural emissions (4,542,492 $tCO_2e$), with dairy cattle, non-dairy cattle and sheep emitting the vast majority of these emissions (29%, 25% and 45% respectively). The second highest source of agricultural emissions were produced from $N_2O$ released by manure from grazing animals on pasture (678,051 $tCO_2e$ or 12% of the sector), with dairy cattle, non-dairy cattle and sheep emitting the vast majority of these emissions (29%, 22% and 48% respectively). A breakdown of agricultural emissions by source is shown in Table 6 in Appendix A.

**Forestry:** The Horizons Region has a regenerative native forested area which includes Manuka, Kanuka and Broadleaved Hardwoods. Regenerating natives occupy 261,179 ha with exotics occupying a further 129,884 ha of land. The Ruapehu District represents 40% and 38% respectively, of native and exotic trees in the region. In total, 6,409,072 $tCO_2e$ were sequestered by forests in the Region in 2019.

Of the total sequestered $CO_2$, native forests sequestered 1,612,118 $tCO_2e$ while exotic forests sequestered 4,796,954 $tCO_2e$ in 2019. Forest harvesting releases carbon stored in forests in the form of carbon dioxide. Harvesting of forestry in 2019 produced 4,868,817 $tCO_2e$.

**Table 1 Summary of gross emissions split by Sector and associated sub-categories**

| Sector | $tCO_2e$ | % Gross | % Sector |
|---|---|---|---|
| **Stationary Energy** | | | |
| Electricity Consumption | 184,245 | 2.2% | 35.1% |
| Electricity T&D Loss | 15,129 | 0.2% | 2.9% |
| Natural Gas | 159,454 | 1.9% | 30.4% |
| Natural Gas T&D Loss | 25,448 | 0.3% | 4.8% |
| LPG | 18,395 | 0.2% | 3.5% |
| Stationary Petrol & Diesel Use | 104,572 | 1.2% | 19.9% |
| Coal | 13,689 | 0.2% | 2.6% |
| Biofuel / Wood | 4,023 | <0.1% | 0.8% |
| **Total:** | 524,955 | 6.2% | 100% |
| **Transportation** | | | |
| Petrol | 1,110,566 | 13.0% | 51.4% |
| Diesel | 1,037,010 | 12.2% | 48.0% |
| Rail Emissions | 7,795 | 0.1% | 0.4% |
| Jet Kerosene | 5,790 | 0.1% | 0.3% |
| Aviation Gas | 589 | <0.1% | <0.1% |
| Marine Diesel | 3 | <0.1% | <0.1% |
| LPG | 445 | <0.1% | <0.1% |
| **Total:** | 2,162,198 | 25.4% | 100% |
| **Waste** | | | |
| Open landfill | 78,670 | 0.9% | 59.7% |
| Closed landfill | 23,255 | 0.3% | 17.6% |
| Wastewater | 29,901 | 0.4% | 22.7% |
| **Total** | 131,825 | 1.5% | 100% |
| **IPPU** | | | |
| Industrial Emissions | 74,730 | 0.9% | 100% |
| **Total** | 74,730 | 0.9% | 100% |
| **Agriculture** | | | |
| Enteric Fermentation | 4,542,492 | 53.3% | 80.7% |
| Manure from Grazing Animals | 678,051 | 8.0% | 12.0% |
| Other Agriculture | 411,359 | 4.8% | 7.3% |
| **Total** | 5,631,902 | 66.1% | 100% |
| **Forestry** | | | |
| Exotic Forest Sequestration | - 4,796,954 | N/A | N/A |
| Native Forest Sequestration | - 1,612,118 | N/A | N/A |
| Harvest Emissions | 4,868,817 | N/A | N/A |
| **Net Forestry Emissions** | - 1,540,254 | N/A | 100% |
| **Total (net) incl. forestry** | **6,985,355** | | |
| **Total (gross) excl. forestry** | **8,525,610** | | |

## 3.1 Biogenic emissions

Biogenic $CO_2$ and methane emissions are stated in Table 2 and Table 3, respectively.

Biogenic $CO_2$ emissions from plants and animals are excluded from gross and net emissions as they are part of the natural carbon cycle. For example, as wood biofuels originate from forestry the Biogenic $CO_2$ from biofuels is excluded from gross emissions.

Biogenic $CH_4$ emissions are included in gross emissions due to their relatively large impact on warming relative to Biogenic $CO_2$. For example, farmed cattle produce Biogenic $CH_4$ emissions, via enteric fermentation, that are included in gross emissions.

The importance of Biogenic $CH_4$ is highlighted in NZ's Climate Change Response (Zero Carbon) Amendment Act. The Act includes targets to reduce Biogenic $CH_4$ by between 24 percent and 47 percent below 2017 levels by 2050, and a 10 percent reduction below 2017 levels by 2030. More information on the Act is available here: https://www.mfe.govt.nz/climate-change/zero-carbon-amendment-act.

**Table 2 Biogenic $CO_2$ (Excluded from gross emissions)**

| **Biogenic $CO_2$ (Excluded from gross emissions)** | | |
|---|---|---|
| Biofuel | 42,360 | t $CO_2$ |
| Biodiesel | - | t $CO_2$ |
| Landfill Gas | 21,215 | t $CO_2$ |
| **Total biogenic $CO_2$** | **63,575** | **t $CO_2$** |

**Table 3 Biogenic Methane (Included in gross emissions)**

| **Biogenic $CH_4$ (Included in gross emissions)** | | |
|---|---|---|
| Biofuel | 106 | t $CH_4$ |
| Biodiesel | - | t $CH_4$ |
| Landfill Gas | 2,385 | t $CH_4$ |
| Wastewater Treatment | 773 | t $CH_4$ |
| Enteric fermentation | 134,719 | t $CH_4$ |
| Manure Management | 26,815 | t $CH_4$ |
| **Total biogenic $CH_4$** | **164,797** | t $CH_4$ |

## 3.2 Net emissions

Net emissions differ from gross emissions because they include emissions related to forestry activity within an area. Emissions from forestry include two main types of activity. Harvesting of forest increases emissions via the use of fuel by equipment and releasing carbon from plants and soils. Planting of native forest e.g. Manuka, Kanuka, and exotic forest e.g. pine, sequesters (captures) carbon from the atmosphere while the trees are growing to maturity. When sequestration by forests exceeds emissions from harvesting the extra quantity of carbon sequestered by forest reduces total gross emissions.

Overall, forestry is a net-negative source of emissions of 1,540,254 $tCO_2e$ due the sequestration of carbon mostly by exotic forest (see Figure 3). The net-negative emissions from forestry reduce gross emissions by 18% to a total of 6,985,355 $tCO_2e$ (total net emissions). Figure 4 shows gross emissions versus net emissions in 2019 and the impact of sequestration by Forestry.

**Figure 3 Horizons Region's forestry harvest emissions, forestry sequestration and net forestry emissions ($tCO_2e$)**

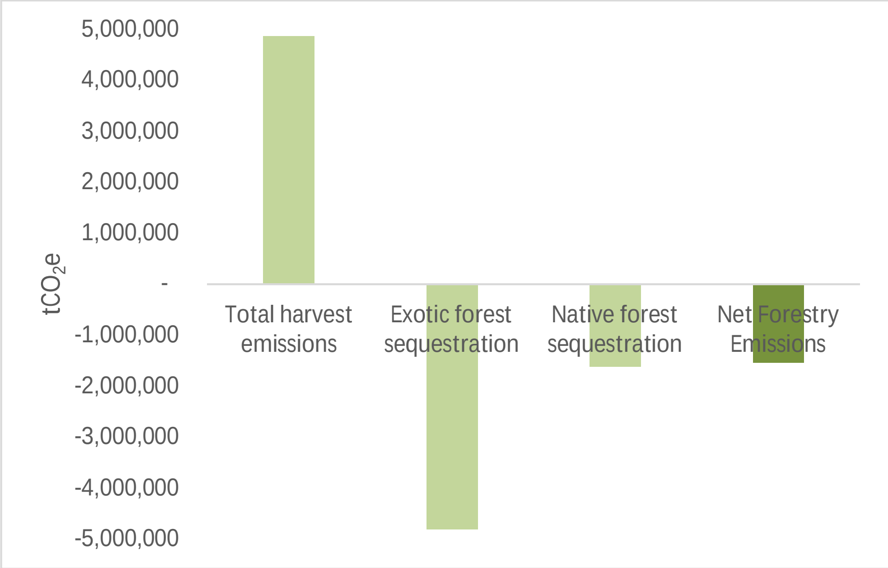
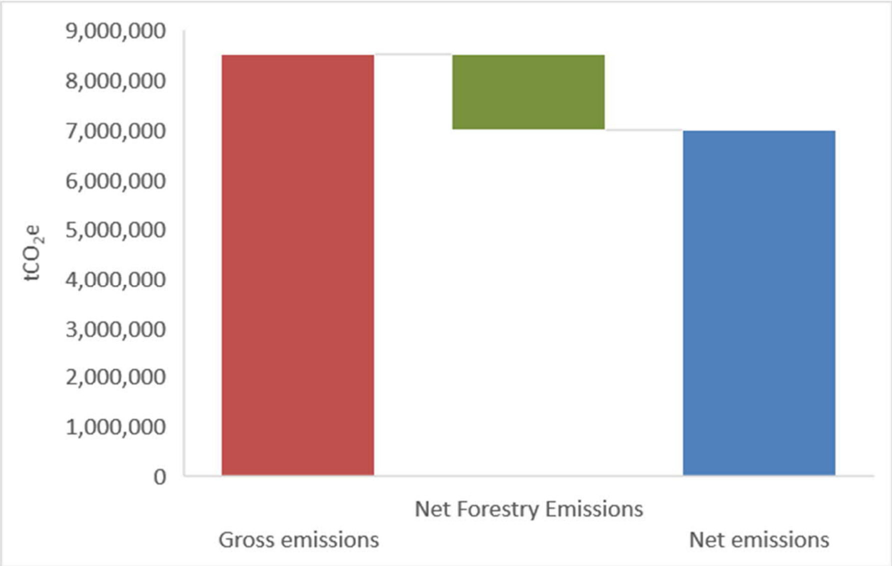



**Figure 4 Horizons Region's Gross and Net emissions including net forestry emissions ($tCO_2e$)**




Carbon sequestered by forestry can be viewed as a liability/risk needing careful consideration. For example, what happens if there is large downturn in exports of exotic pine? If plantations are not replanted or other land use change occurs to exotic forested areas, then emissions will quickly rise. Equally, if native forest is not protected from removal, and removal does happen, then emissions will rise. In summary, when a large of amount of carbon is captured by forests, long-term planning is needed on how best to manage this carbon sink.

## 3.3 Breakdown of emissions between the territorial authorities in the region

Tararua contributes the most to the Horizons Region's total gross emissions. Tararua's high emissions are predominantly due to high agricultural emissions in the area. The Region's gross emissions are dominated by agriculture and it is the areas with the largest agricultural emissions that are the highest gross emitting areas (Tararua, Rangitīkei and Manawatū). When excluding agriculture, Palmerston North has the highest gross emissions in the Region, which is to be expected with the biggest population in the Region.

The areas with the highest per capita emissions are Rangitīkei (97 $tCO_2e$), Ruapehu (95 $tCO_2e$) and Tararua (94 $tCO_2e$) due to large agricultural sectors and small populations in these areas. Palmerston North (10 $tCO_2e$), Whanganui (19 $tCO_2e$) and Horowhenua (24 $tCO_2e$) have the lowest per capita emissions.

**Table 4: Gross emissions in the Horizons Region, by territorial authority ($tCO_2e$)**

| | Horowhenua | Manawatū | Palmerston North | Rangitīkei | Ruapehu | Tararua | Whanganui |
|---|---|---|---|---|---|---|---|
| Total Gross Emissions ($tCO_2e$) | 819,053 | 1,419,704 | 905,802 | 1,519,421 | 1,203,611 | 1,752,405 | 905,613 |
| % of Region Gross Emissions | 10% | 17% | 11% | 18% | 14% | 21% | 11% |
| Total Gross Emissions Per Capita (tCO2e) | 23.6 | 45.2 | 10.3 | 97.2 | 94.8 | 94.3 | 19.3 |

**Figure 5 Breakdown of gross emissions between the cities and districts in the Horizons Region ($tCO_2e$)**

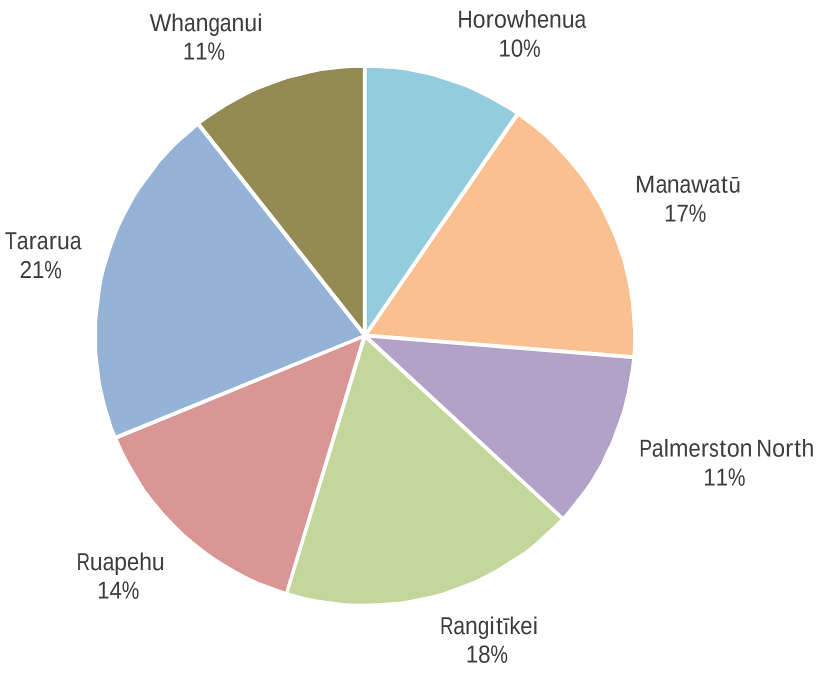


**Figure 6 Total gross emissions in the Horizons Region, by sector ($tCO_2e$)**

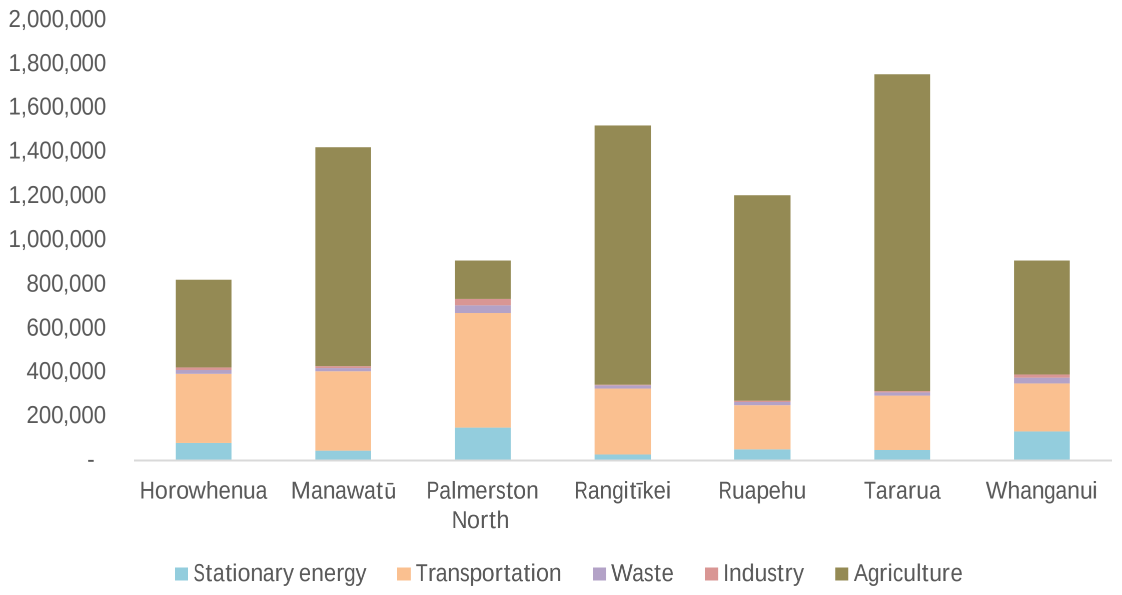



Table 5 shows figures for net emissions including sequestration from forestry. Net emissions can produce a widely different pattern of results across the region than gross emissions.  For example, net emissions for Ruapehu, which has the one of the highest gross emissions, are lower than all other territorial authorities.

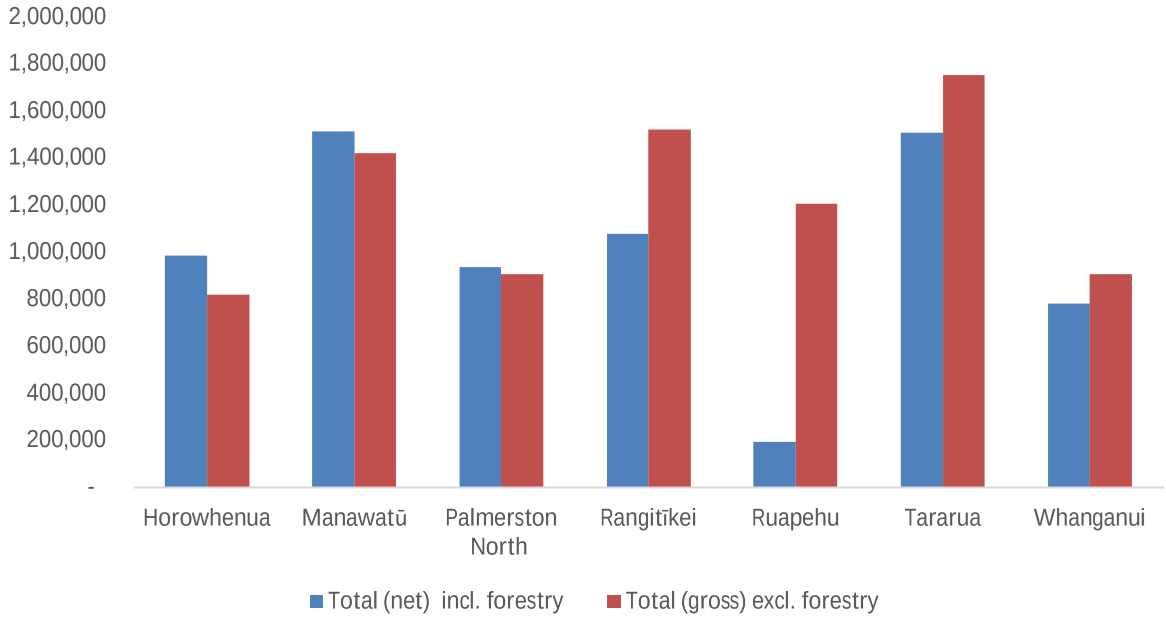
**Table 5 Net emissions (incl. forestry) in the Horizons Region, by territorial authority ($tCO_2e$)**

| | Horowhenua | Manawatū | Palmerston North | Rangitīkei | Ruapehu | Tararua | Whanganui |
|---|---|---|---|---|---|---|---|
| Total Net Emissions ($tCO_2e$) | 983,392 | 1,512,053 | 935,600 | 1,077,394 | 191,684 | 1,505,497 | 779,736 |
| % of Region Net Emissions | 14% | 22% | 13% | 15% | 3% | 22% | 11% |

The influence of forest sequestration of carbon and forestry emissions on gross emissions across the Horizons Region, can be seen clearly in Figure 7.

In Rangitīkei, Ruapehu, Tararua and Whanganui, forest sequestration of carbon was greater than the carbon released through forest harvesting in 2019, this meant that total net emissions were lower than total gross emissions. In Horowhenua, Manawatū and Palmerston North, carbon emissions from forest harvesting were greater than the carbon sequestered from forests in 2019, therefore total net emissions were higher than total gross emissions.

**Figure 7 Gross emissions and net emissions (incl. forestry) in the Horizons Region ($tCO_2e$)**

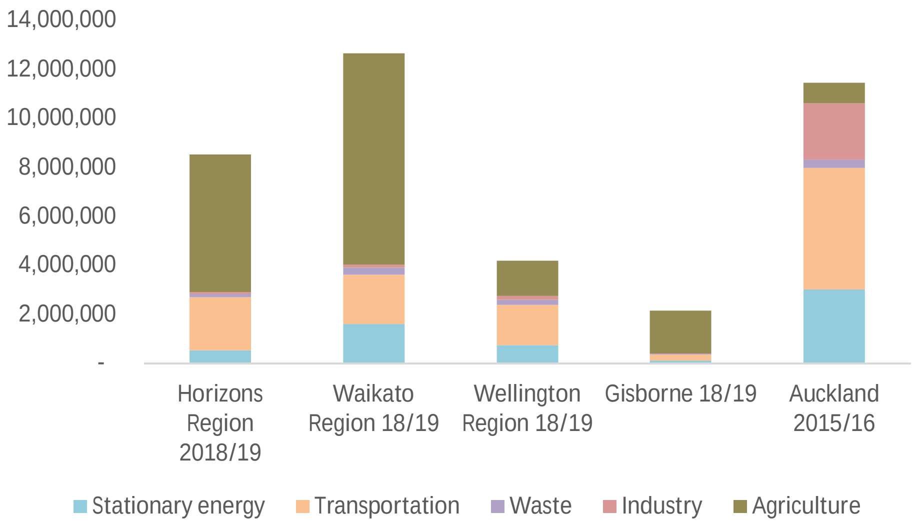


# 4.0 Comparison with other areas in New Zealand

Figure 8 shows a comparison of the gross emissions (excluding forestry) for the Horizons Region with other local authorities in New Zealand split by sector. These studies have been chosen to represent different areas of New Zealand and are all reported using the GPC approach. Note however, that these studies were conducted at differing geographic levels, in differing timeframes, with vastly different population numbers and with slight differences in methodology.

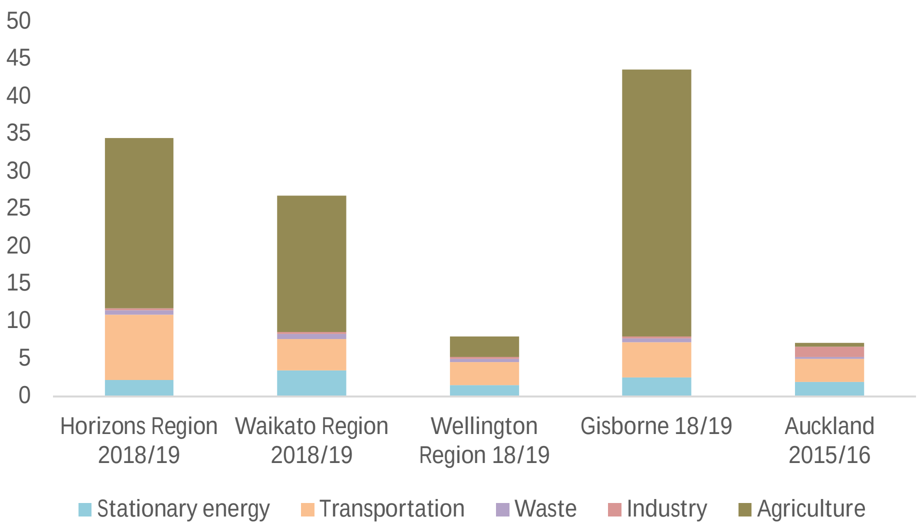
When compared with other GHG Inventory studies, the Horizons Region had higher gross emissions compared to the Greater Wellington Region and Gisborne Territorial Authority (TA), and lower gross emissions than the Waikato and Auckland Regions.

**Figure 8 A comparison of GHG emissions with other regions of New Zealand by gross emissions ($tCO_2e$)**




When comparing different regional carbon footprints, a per capita figure can be useful because it provides a common reference point to understand the difference in emissions. The Horizons Region had higher per capita gross emissions than the Waikato Region, Greater Wellington Region and the Auckland Region partly due to large agricultural and transport emissions within the region. The Horizons Region had lower total per capita gross emissions than the Gisborne Territorial Authority but notably had substantially higher per capita transport emissions than the Gisborne Territorial Authority.

**Figure 9 A comparison of GHG emissions with other regions of New Zealand on a per capita basis ($tCO_2e$)**



# 5.0 Closing Statement

The Horizons Region's GHG inventory provides information for decision-making and action by the Regional Council, their stakeholders and the wider community.

The inventory of greenhouse gas emissions the council has developed covers emissions produced in the stationary energy, transport, waste, industry, agriculture and forestry sectors using the GPC reporting framework. Sector-level data allows councils to target and work with those sectors which contribute the most emissions to the footprint.

The agriculture and transport sectors represent the highest emitting sectors in the Region, 66% and 25% of gross emissions respectively. Within these sectors, enteric fermentation from farmed livestock and on-road transport (petrol and diesel use) are the largest emissions sources, 53% and 23% of gross emissions respectively. Results clearly highlight the need to reduce the impact of greenhouse gas emissions from on-road travel and the agriculture sector to limit the area's contribution to global climate change.

Data quality and availability varies widely between the sectors. Higher quality data for aviation, solid waste and on-road transport would be beneficial in improving accuracy of the results of future inventories.

Understanding of the extensive and long-lasting effects of climate change is improving all the time. It is recommended that this emissions inventory is updated regularly to inform ongoing positive decision making to address climate change issues locally and globally.

# 6.0 Limitations

Where this Report indicates that information has been provided to AECOM by third parties, AECOM has made no independent verification of this information except as expressly stated in the Report. AECOM assumes no liability for any inaccuracies in or omissions to that information. This Report was prepared between **January 2020 and July 2020** and is based on the information reviewed at the time of preparation. AECOM disclaims responsibility for any changes that may have occurred after this time. This Report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This Report does not purport to give legal advice.

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# Appendix A

## Emissions Breakdown

# Appendix A Emissions Breakdown

The pie charts below show a breakdown of the proportion of gross emissions from each sector and source.

*Note: Emission sources lower than 1% of total emissions are not shown but can displayed, if needed.*

**Figure 10 Total gross emissions breakdown, by sector ($tCO_2e$)**

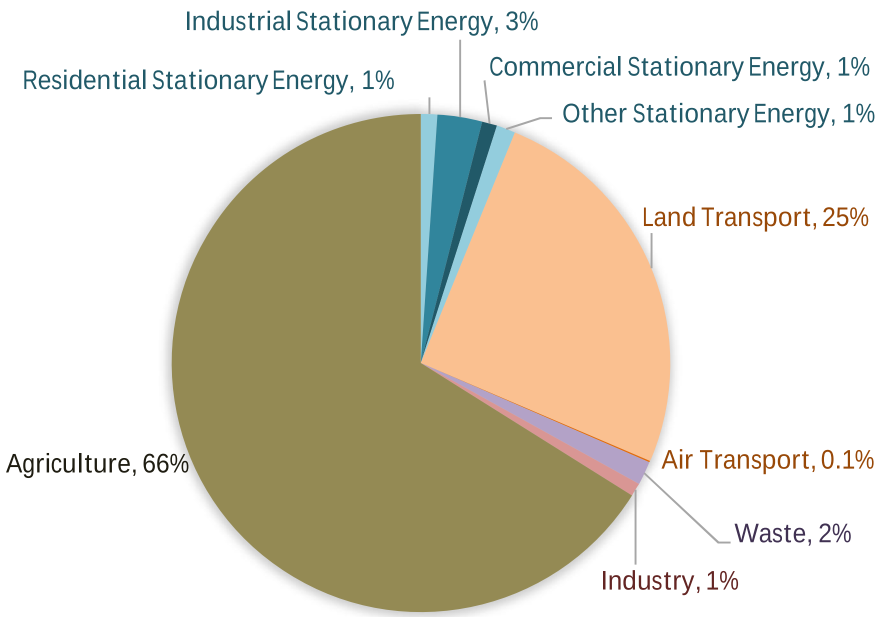


**Figure 11 Total gross emissions breakdown, by source ($tCO_2e$)**

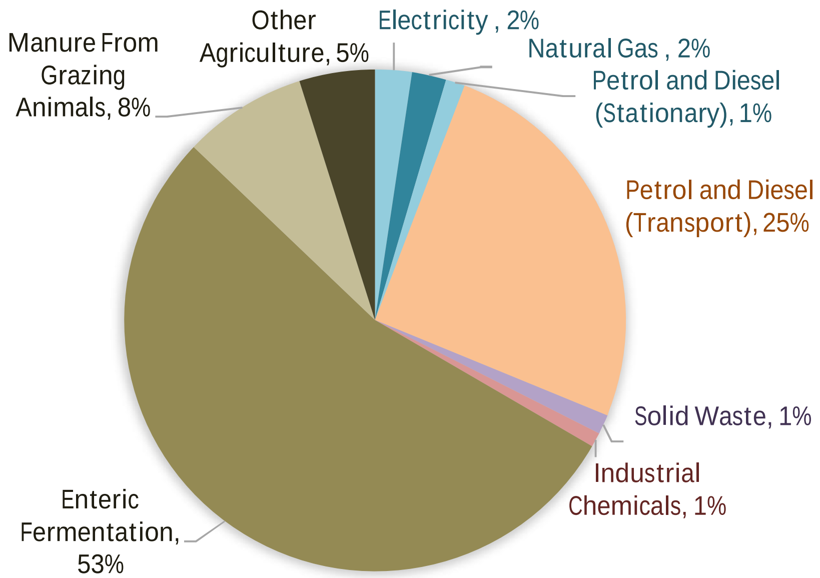

**Figure 12 Total gross emissions breakdown, by fuel type source, highlighting stationary energy emissions ($tCO_2e$)**

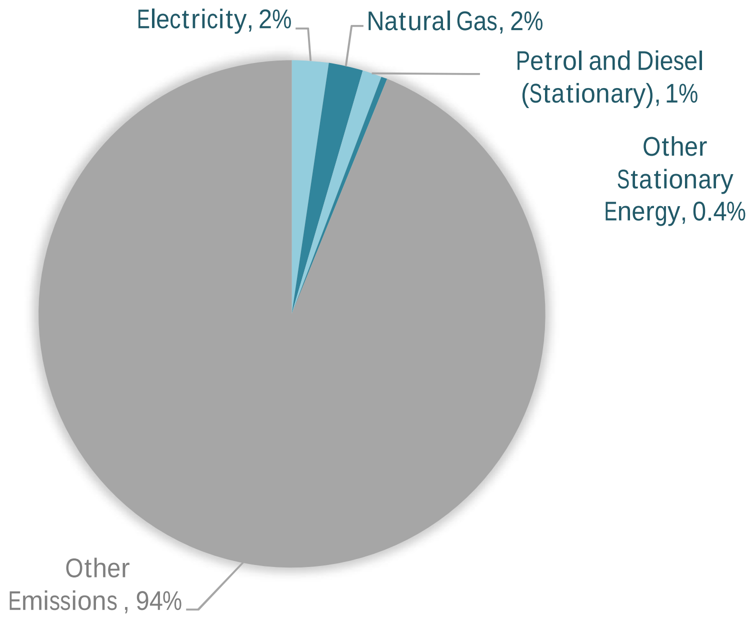


**Figure 13 Total gross emissions breakdown, highlighting stationary energy emissions, showing source of stationary energy emissions ($tCO_2e$)**

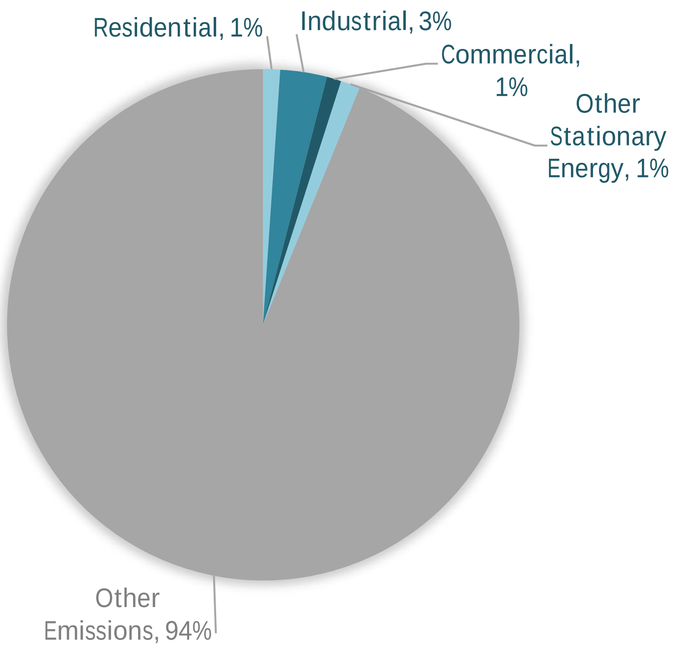

**Figure 14 Total gross emissions breakdown, by source, highlighting transport emissions ($tCO_2e$)**

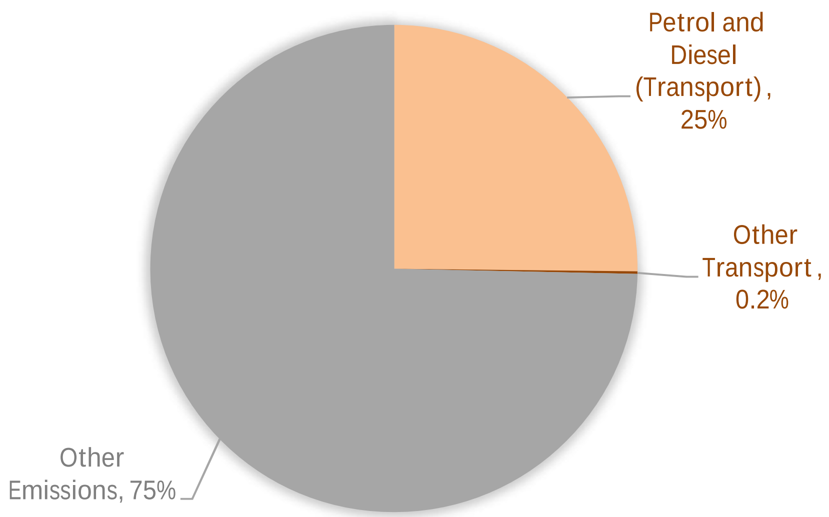


**Figure 15 Total gross emissions breakdown, by source, highlighting agriculture emissions ($tCO_2e$)**

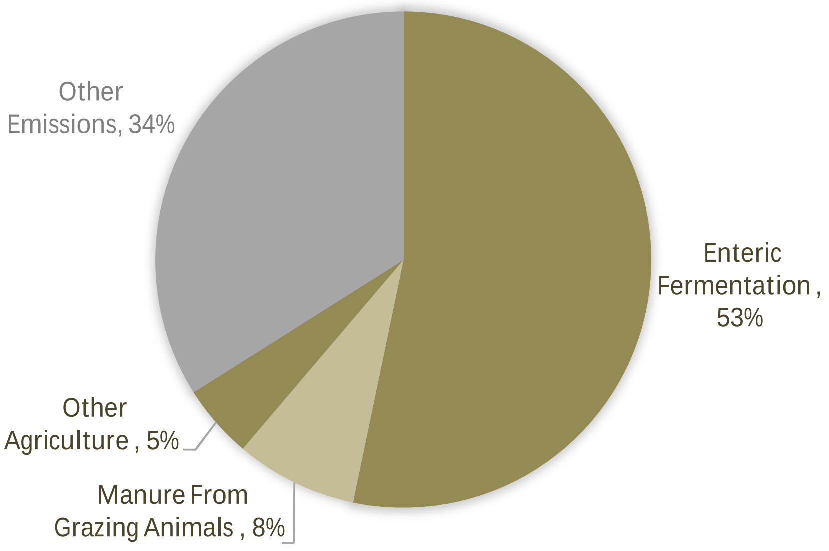

**Table 6 Horizons Region agricultural emissions, by source ($tCO_2e$)**

| Emission Source | tCO2e | % Sector |
|---|---|---|
| Dairy Cattle | 1,671,667 | 30% |
| Non-Dairy Cattle | 1,321,560 | 23% |
| Sheep | 2,460,378 | 44% |
| Other Livestock | 64,258 | 1% |
| Crops | 45,439 | 1% |
| Other Agricultural Emissions | 68,597 | 1% |

**Figure 16 Horizons Region agricultural emissions, by source ($tCO_2e$)**

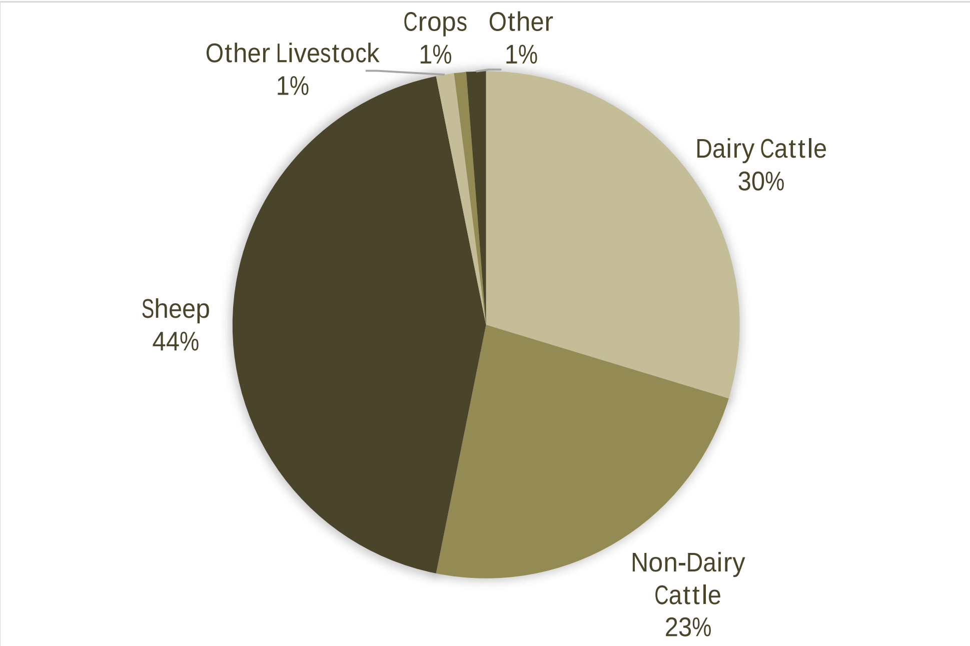


**Table 7 Gross emissions, net emissions, per capita emissions and emissions per hectare for all districts within the Horizons Region ($tCO_2e$)**

| | Horowhenua | Manawatū | Palmerston North | Rangitīkei | Ruapehu | Tararua | Whanganui |
|---|---|---|---|---|---|---|---|
| Total Gross Emissions | 819,053 | 1,419,704 | 905,802 | 1,519,421 | 1,203,611 | 1,752,405 | 905,613 |
| Total Net Emissions | 983,392 | 1,512,053 | 935,600 | 1,077,394 | 191,684 | 1,505,497 | 779,736 |
| Total Gross Emissions per Capita | 23.6 | 45.2 | 10.3 | 97.2 | 94.8 | 94.3 | 19.3 |
| Total Gross Emissions per hectare | 7.7 | 5.5 | 22.9 | 3.4 | 1.8 | 4.0 | 3.8 |

### Basic and Basic+ emissions reporting (Global Covenant of Mayors)

BASIC and BASIC+ emissions reporting are standardised reporting methods used by the Global Covenant of Mayors for Climate and Energy for comparison of emissions with other cities around the world and to demonstrate the importance of regional-level climate action at a local and global scale. BASIC and BASIC+ emissions are reported as outlined in the Global Protocol for Community Scale Greenhouse Gas Emissions Inventory (GPC).

BASIC emissions reporting excludes emissions from Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use and greenhouse gas emissions occurring outside the regional boundary as a result of activities taking place within the regional boundary. BASIC+ emissions reporting includes those emissions excluded from BASIC emissions reporting (which is equal to the total gross emissions reported in this study).

**Table 8 BASIC and BASIC+ emissions**

| | **Emissions $tCO_2e$** |
|---|---|
| **BASIC** | 2,778,401 |
| BASIC per capita | 11.2 |
| **BASIC+** | 8,525,610 |
| BASIC+ per capita | 34.4 |

# Appendix B

## Assumptions

| Nova Sector / Category | Assumption and Exclusions |
|---|---|
| General | |
| Geographical Boundary | LGNZ local council mapping boundaries have been applied |
| Transport Emissions | |
| Petrol and Diesel: | Petrol and diesel consumption have been divided by likely end use. The division into transport and stationary energy end use (and within transport, on-road and off-road) was calculated using fuel end use data provided by the Energy Efficiency and Conservation Authority (EECA) in April 2020.<br><br>On-road transport is defined as all standard transportation vehicles used on roads e.g. cars, bikes, buses.<br><br>Off-road transport is defined as machinery for agriculture, construction and other industry used off-roads.<br><br>Stationary energy petrol and diesel use is defined as fuel not used for transport either on or off roads. Petrol and diesel used for stationary energy has been reported in the Stationary Energy sector.<br><br>Data provided for Palmerston North, Whanganui, Horowhenua and Manawatu Territorial Authorities. Data for the Region has been estimated based on litres per Vehicle Kilometres Travelled (VKT) from these districts combined and extrapolated using the total VKT in the Region. |
| Rail Diesel | Consumption was calculated by Kiwi Rail using the Induced Activity method for system boundaries. The following assumptions were made:<br><br>- Net Weight is product weight only and excludes container tare (the weight of an empty container)<br>- The Net Tonne-Kilometres (NTK) measurement has been used. NTK is the sum of the tonnes carries multiplied by the distance travelled.<br>- National fuel consumption rates have been used to derive litres of fuel for distance.<br>- Type of locomotive engine used, and jurisdiction topography, have not been incorporated in the calculations.<br><br>Using the induced activity method, the trans-boundary routes were determined, and the number of stops taken along the way derived. The total amount of litres of diesel consumed per route was then split between the departure territorial authority, arrival territorial authority and any territorial authority the freight stopped at along the way. If the freight travelled through but did not stop within a territorial authority, no emissions were allocated.<br><br>All rail emissions have been classified as Scope 3. |
| Jet Kerosene | Calculated using the Induced Activity method as per rail diesel.<br><br>Palmerston North Airport has been treated as a regional airport serving a wider area than just Palmerston North City. Emissions from aircraft fuel connected to Palmerston North |

| | |
|---|---|
| | airport have been distributed between all territorial authorities in the region on a per capita basis.<br><br>An estimate of fuel use was calculated for flights departing and arriving from Palmerston North Airport:<br>- Previously obtained fuel use data for FY1617 has been updated and used for this study due to difficulty in obtaining more recent data. An additional scheduled route has been added to Napier since 2017 so this additional fuel use has been calculated and added to the 2016/17 figure.<br>- Departures and arrivals information, and aircraft models, were used to calculate flight numbers, flight distances and fuel use.<br>- All flight-path distances between Palmerston North and the destination / origin airport were calculated.<br>- A density for kerosene of 0.81g/cm³ was applied to all trips.<br>- Fuel Burn (kg$CO_2$e/km) for each model of aircraft was sourced where accessible. Where not available, the national inventory average figures were applied.<br>- As per the induced activity method, only 50% of emissions calculated per one-way arrival and departure were allocated to Palmerston North Airport. The remaining 50% of each leg was allocated to the originating or destination airport.<br><br>An estimate of fuel use for Whanganui Airport has also been calculated using the above methodology. Whanganui Airport is a small, local airport and so emissions have been allocated to the Whanganui Territorial Authority only.<br><br>All aircraft fuel emissions have been classified as Scope 3. Scope 2 electricity use by airport / planes are incorporated within the general electricity consumption data for the territorial authority. |
| Aviation Gas | Aviation gas is mostly used by small aircraft for relatively short flights. Aviation Gas consumption of 250,000 liters per airport was estimated based on community carbon footprints developed for other regions in New Zealand, using advice from industry experts. Included in this fuel use is fuel consumed by the flight school located at Palmerston North Airport.<br><br>All aircraft fuel emissions have been classified as Scope 3. |
| Marine Diesel | Freight and commercial:<br>- This has not been calculated due to difficulty of obtaining reliable data<br>Private use:<br>- This is assumed to be an insignificant contributor to emissions.<br>- Most small private boats use fuel purchased at vehicle gas stations so this consumption will be included in transport petrol and diesel emissions.<br>Port Operations:<br>- All port operations fuel use is allocated to Whanganui District as these vessels do not cross territorial authority boundaries. |
| LPG | Total North Island consumption data was used and then split on a per capita basis to determine the territorial authority's consumption. National LPG end use data has been used to breakdown consumption into stationary energy and transport usage, these are then reported separately in their respective categories. |
| Bitumen | Not calculated |
| Lubricants | Not calculated |
| Stationary Energy Emissions | |

| | |
|---|---|
| Consumer Energy End Use | Stationary energy demand (e.g. electricity use, natural gas, etc.) is broken down by the sector in which they are consumed. We report stationary energy demand in the following categories: industrial (which includes agriculture, forestry and fishing); commercial; and residential. These sectors follow the Australia New Zealand Standard Industrial Classification 2006 definitions.<br>Additional to agriculture, forestry and fishing, the industrial sector includes mining, food processing, textiles, chemicals, metals, mechanical/electrical equipment and building and construction activities.<br>Emissions from petrol and diesel used for stationary energy are not broken down into these sectors.<br>Energy demand used for transport is reported in the transport sector. |
| Electricity Consumption | Electricity consumption for the territorial authority has been calculated using grid demand trends from the EMI website (www.emi.ea.govt.nz) to obtain raw grid exit point data.<br>The breakdown into sectors is based on NZ average consumption per sector (residential, commercial and industrial). |
| Electricity Generation | There is electricity generation in the Horizons Region, however, emissions produced in electricity generation are not required to be reported for the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) standard. |
| Public Transport Electricity | Any electricity used in the public transport system is included in stationary energy electricity consumption figures. |
| Coal production | Not Calculated: There are no active coal mines within the region. (NZP&M 2019) |
| Coal Consumption | Coal consumption calculated using national per capita coal consumption. The breakdown into sectors is based on NZ average consumption per sector (residential, commercial and industrial). |
| Biofuel and Wood Consumption | Consumption has been calculated based on national per capita Commercial and Residential emissions for biofuel use (provided New Zealand Greenhouse Gas Emissions 1990 -2017 (MfE 2019). |
| LPG Consumption | LPG consumption has been calculated using total North Island per capita LPG consumption data. National LPG end use data has been used to breakdown consumption into stationary energy and transport usage, these are then reported separately in their respective categories. |
| Petrol and Diesel (stationary energy end-use) | Total Petrol and diesel fuel use was divided by likely end use. The division into transport and stationary energy end use (and within transport, on-road and off-road) was calculated using fuel end use data provided by the Energy Efficiency and Conservation Authority (EECA) in April 2020. Stationary energy petrol and diesel use is defined as fuel not used for transport either on or off roads.<br>Petrol and diesel used for transport has been reported in the Transport sector (see above). |
| Natural Gas Consumption | Data has been directly provided by suppliers in the region.<br>The breakdown into sectors is based on NZ average consumption per sector (residential, commercial and industrial).<br>There is no natural gas connection in the Ruapehu Territorial Area. |
| Coal Fugitive Emissions | Not Calculated: There are no active coal mines within the region. (NZP&M 2019) |
| Oil and Gas Fugitive Emissions | Not Calculated: There are no gas or oil processing plants within the region. |
| Biogenic Emissions | Some Carbon Dioxide ($CO_2$) emissions are considered to be biogenic. These are $CO_2$ emissions where the carbon has been recently derived from $CO_2$ present in the |

| | |
|---|---|
| | atmosphere (for example, some agricultural and waste emissions). These emissions are not included in calculating total $CO_2e$. |
| Agricultural Emissions | |
| General | No assumptions were made during the collection of agricultural data as it was sourced from territorial authority-specific data provided by Statistics NZ and the Ministry for the Environment National Inventory. |
| Solid Waste Emissions | |
| Landfills | Solid waste emissions from landfill are measured using the IPCC First Order Decay method that covers landfill activity between 1950 and the present day. Solid waste emissions were calculated for the currently operating landfill sites at Bonny Glen, Levin and Ruapehu. Bonny Glen and Levin do process waste from outside the Region but the data we have only concerns waste produced in the Region. Waste from Ruapehu is treated exclusively at Ruapehu landfill and the site does not accept waste from outside Ruapehu.<br><br>Where waste volume data was not available, we have used the national per capita waste volume to estimate waste volume for each territorial area and distributed between the landfill sites based on their proportion of the Region's waste volume.<br><br>In the years prior to each landfill site's operation we have allocated the remaining national average waste volume per person to 'Closed landfill sites'. Unless new data is provided, we assume that there is no landfill gas recovery on closed landfill sites. |
| Landfill Gas Recovery | LFG efficiency has been estimated based on LFG generation from waste deposited and reported LFG extraction volumes. |
| Wastewater Emissions | |
| Wastewater Volume | Wastewater treatment plant data provided at territorial authority level. Emissions have been calculated based on the data provided following IPCC 2006 guidelines. Where data is missing, IPCC and MfE provided figures have been used, e.g. for biochemical oxygen demand (BOD). Calculation of emissions includes emissions released directly from wastewater treatment, flaring of captured gas and from discharge onto land/water. Calculations for wastewater emissions from individual septic tanks are also included. Populations not connected to known wastewater treatment plants are assumed to be using septic tanks.<br><br>We have not calculated emissions from combustion within sludge digestion. We have also not accounted for overflows, fugitive emissions or sludge removal. |
| Biochemical Oxygen Demand (BOD) | The biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in water. It is used as a surrogate to measure the degree of organic pollution in water.<br><br>BOD has been assumed using influent composite samples and inlet flow meters. |
| Population Connected to WWTP or Septic Tanks | Population connected to wastewater treatment plants have been provided at the territorial authority level. |
| Industrial Emissions | |
| Industry & Solvent Emissions | Calculated from MfE National Inventory data, as this the latest, most recently available data on the required solvents. Emissions are estimated on a per capita basis. |
| Industrial Activity | No information could be obtained from Industry representatives within the territorial authority. National level data has been used and split on a per capita basis to determine the territorial authority's consumption. |

| Forestry Emissions | |
|---|---|
| Exotic Wood Harvested | Territorial authority figures were calculated using the assumed percentage share of territorial authority forest area of harvest age (>26 years old) in the region, in the reporting year. |
| Roundwood Removal | It has been assumed that only 70% of the tree is removed as roundwood and that the above ground tree makes up approximately 74% of the total carbon stored. |
| **Emission Factors** | |
| General | All emission factors have detailed source information in the calculation tables within which they are used. Where possible, the most up to date, NZ specific emission factors have been applied. |

# Appendix C

## Forest Sequestration Assessment

## Executive Summary

AECOM has examined carbon sequestration options for HRC based on afforestation in the region. In total nine scenarios involving the growth of exotic and native species were included in the assessment.

HRC has requested the development of carbon sequestration scenarios with the aim of providing some context of scale of their regional emissions. These scenarios do not represent HRC's policy position. The total area included in this assessment is 328,373 hectares across the region. The land is classed as highly erodible, erodible or top priority land. It is important to note HRC does not control the 328,373 hectares and has no policy to afforest this land. The purpose of this memo is to build internal knowledge around potential sequestration options.

The assessment examines sequestration using nine scenarios agreed by the Council. The scenarios that sequester the most carbon are listed below.

1. Exotic scenarios
    a. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land (that has not yet been afforested) with exotic forestry across 15 years?
    b. The same scenario as (1a) above but with exotic forestry harvested at 27 years with no replanting.
5. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land planted in a mix of mānuka/kānuka and exotics across 1-2 years, with harvesting of exotics occurring at 27 years with no replanting

The full list of scenarios in the assessment are listed in Section 1 of the main report.

As Table C1 illustrates, Scenario 1a and 1b would sequester the most carbon by 2050. Scenario 1a would sequester 116,361,491 $tCO_2e$ by 2050 and Scenario 1b would sequester 129,011,292 $tCO_2e$). Over the long-term Scenario 5 would sequester the highest amount of carbon at both 2120 and 2250. In Scenario 5 native forest would sequester 217,339,504 $tCO_2e$ by 2120 and 498,475,181 $tCO_2e$ by 2250. To provide a reliable method for native plantings, native forestry is modelled as a succession forest. Carbon stored in a succession forest would ultimately sequester the most carbon and enhance biodiversity. To achieve the sequestration rates modelled, native forestry plantations would have to be actively managed, ensuring that when the lifespan of mānuka is reached (approximately 70 years), larger native trees are planted.

AECOM was also asked to examine the amount of land area in hectares needed to sequester 50% of the 2018/19 net community carbon footprint for the region. The net community carbon footprint does not include forestry already planted within the region that is sequestering carbon. 50% of the net emissions for HRC region is 4,262,805 $tCO_2e$. Assuming a mixture of native and exotic species being planted over a staggered, 30-year period to the year 2050, approximately 98,482 hectares (ha) is needed to sequester 50% of net emissions. Across a 15-year period, approximately 153,193 ha is needed to sequester 50% of net emissions.

However, if planting occurred immediately, across 1 to 2 years, then approximately 328, 273 ha of land would be needed to sequester 50% of the net community carbon footprint. Planting land immediately requires more land. The reason more land is needed is because sequestration rates for forestry vary depending on their age. When trees are younger (e.g. between 1-5 years old) they sequester less carbon than they do between 6-25 years old. As trees mature, they increase in biomass and sequester more carbon, until they reach a steady state. If all trees are planted in a short-time frame (e.g. 1-2 years) these trees would all be within the lower range age class with lower sequestration rates, and more land would be needed to sequester carbon faster.

## Introduction

Horizons Regional Council (HRC) has requested AECOM to provide advice on potential forestry sequestration scenarios that could reduce their regional council community carbon footprint. This is particularly pertinent given the *Climate Change Response (Zero Carbon) Amendment Act 2019* which aims for New Zealand to be carbon neutral by 2050.

We received and agreed multiple scenarios from HRC. However, it is important to understand these scenarios do not represent HRC's policy position, but are to be used internally to improve understanding of the potential for sequestration within the region. We have also expanded these scenarios, adding in scenarios that we believe provide a complete picture, which includes Scenarios 1(b), 2(b), (5) and (6). We have added in two additional scenarios which demonstrate the effect on carbon sequestration if exotics are harvested at 28 years. Based on client comments in the draft review, we have also added in an additional scenario (Scenario 9) which outlines how much land would be required to store the carbon equivalent of a 50% reduction in HRC emissions if planting occurred across 30 years (i.e. by 2050).

These scenarios are as follows:

1. Exotic scenarios – 15 years
    a. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land (that has not yet been afforested) with exotic forestry across 15 years?
    b. The same scenario as (1a) above but with exotic forestry harvested at 27 years with no replanting.
2. Exotic scenarios – planted across 1-2 years (as soon as possible)
    a. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land (that has not yet been afforested) with exotic forestry across 1-2 years?
    b. The same scenario as (2a) above but with exotic forestry harvested at 27 years with no replanting.
3. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land planted in a mix of mānuka/kānuka and exotics across 15 years, with harvesting of exotics occurring at 27 years with no replanting.
4. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land planted in a mix of mānuka/kānuka and exotics across 1-2 years, with harvesting of exotics occurring at 27 years with no replanting.

5. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land planted in a mix of mānuka/kānuka across 1-2 years.
6. How much carbon would be stored if HRC afforested all top priority, highly erodible and erodible land planted in a mix of mānuka/kānuka across 15 years.
7. How much land would be required to store the carbon equivalent of a 50% reduction in the region's net emissions in forestry planted across 15 years?
8. How much land would be required to store the carbon equivalent of a 50% reduction in the region's emissions, if planting occurred in a 1-2 year timeframe?
9. How much land would be required to store the carbon equivalent of a 50% reduction in the region's emissions, if planting occurred across 30 years?

Table C1 summarises the tonnes of carbon sequestered ($tCO_2e$) over five different timeframes for Scenarios 1-6. The reasons for the variations will be explained in further detail in the Analysis section. Table C1 does not include longer-term carbon sequestration rates for exotic forestry (s1a and 1b). There is limited data available on exotic forestry sequestration rates post-50 years, and we have assumed that exotic forestry reaches maturation at 50 years and sequestration is minimal.  For Scenarios 7-9, Table C1 provides an estimate of the land required to lower the Horizon Region's total emissions. In all scenarios that include native plantings (Scenarios 3, 4, 5 and 6) we have assumed there would be no harvesting of natives.

*Table C1: Summary of sequestration scenarios.*

| Scenario | $tCO_2e$ accumulated in 2035 | $tCO_2e$ accumulated in 2050 | $tCO_2e$ accumulated in 2070 | $tCO_2e$ accumulated in 2120 | $tCO_2e$ accumulated in 2250 |
|---|---|---|---|---|---|
| **S1a** | 39,381,713 | 116,361,491 | n/a | n/a | n/a |
| **S1b** | 67,821,204 | 129,011,292 | n/a | n/a | n/a |
| **S2a** | 29,422,454 | 85,329,900 | 113,564,921 | 167,629,475 | 308,197,313 |
| **S2b** | 50,670,612 | 97,485,022 | 111,902,236 | 147,945,272 | 241,657,164 |
| **S3** | 29,422,454 | 85,329,900 | 113,564,921 | 167,629,475 | 308,197,313 |
| **S4** | 50,670,612 | 97,485,022 | 111,902,236 | 147,945,272 | 241,657,164 |
| **S5** | 33,520,023 | 65,958,755 | 109,210,398 | 217,339,504 | 498,475,181 |
| **S6** | 19,463,239 | 51,901,971 | 95,153,614 | 203,282,720 | 484,418,397 |
| **Scenario** | Total land required to 50% offset (ha) | | | | |
| **S7** | 153,193 – based on scenario 3 (staggered planting occurs across 15 years until 2035) | | | | |
| **S8** | 328, 273 – based on scenario 4 (the land is planted across 1-2 years) | | | | |
| **S9** | 98,482 – based on a new scenario, where staggered planting occurs across 30 years (until 2050) | | | | |

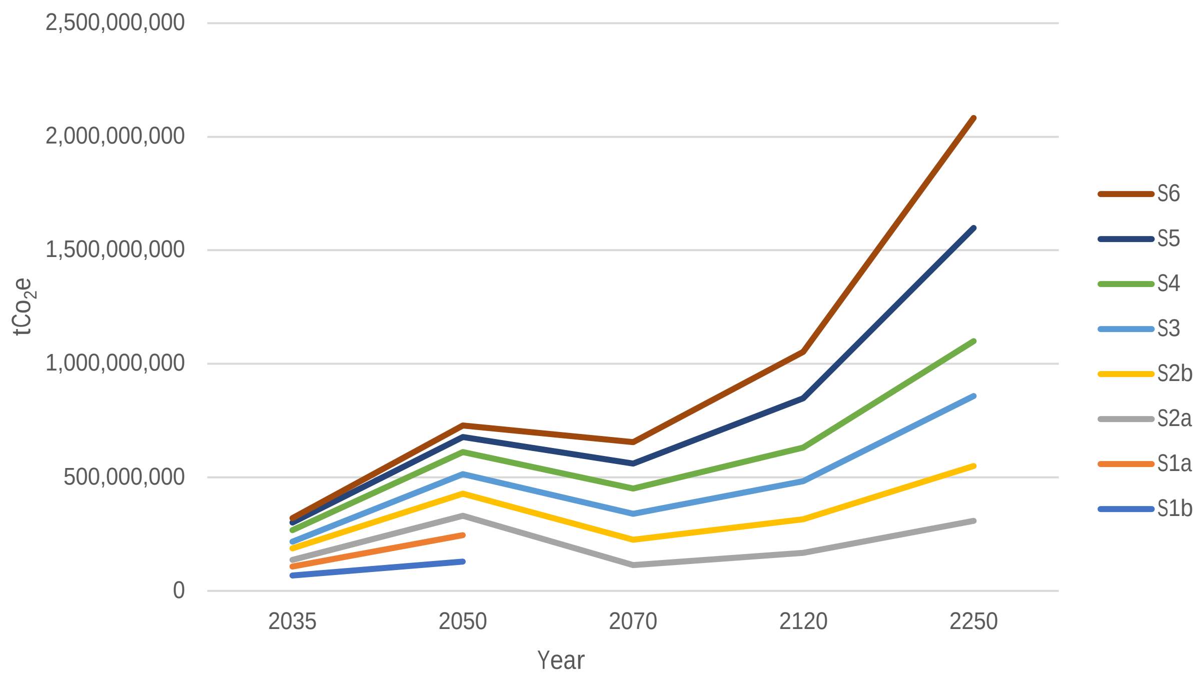


*Figure C1: Tonnes of carbon sequestered across time for various forestry scenarios.*

## Methodology

A literature review was undertaken to source carbon stock data for both native and non-native forestry and evaluate the quality and accuracy of various carbon stock data. The most authoritative source from this review was the carbon stock data sourced from the *Climate*

*Change (Forestry Sector) Regulations 2001* and subsequent updates.[1] This source provided carbon stock data for both exotic softwoods[2] and indigenous shrublands[3], that represent the first stage of a managed succession forest.[4] From this carbon stock data, carbon sequestration rates were then calculated and graphed to illustrate the relationship between both native and non-native sequestration rates.

A model was then developed, tailored to the scenarios outlined in 1-6, using the sourced carbon stock data from the 2001 Regulations. The amount of land area that HRC classifies as 'highly erodible and erodible land' has been provided by HRC and inputted into the model – the total amount of land being 328,273 hectares (see Table C2). At this stage, we have undertaken the calculations by amalgamating the different land classes provided by HRC into one 'highly erodible and erodible land' category. The outcomes of this model are discussed in the Analysis section below.

## Analysis

### Literature review

Indigenous and exotic forests provide multiple environmental benefits, including reduced soil erosion and soil nutrient risks and maintenance of topsoil.[5] Both indigenous and exotic forests have enhanced environmental benefits where they replace agricultural and marginal land.[6] These benefits provide flow-on effects in terms of improving freshwater quality by reducing sediment loss in upper catchments.[7]

While both types of forests provide a habitat for organisms, indigenous forests support more native species than exotic forests.[8] Anecdotal evidence also suggests that indigenous forests also tend to have higher benefits in terms of tourism and recreation.

While an exotic forest plantation would provide a significant economic benefit from timber production, they can have a detrimental impact on soil leading to erosion and sedimentation, water quality and biodiversity as needles often form an acidic surface cover reducing native plant growth. If exotic forest plantations are replanted this may reduce biodiversity due to intensive use of pesticides following the harvest and new planting. Uncontrolled exotic forestry often results in wilding issues where seeds blown from exotic plantations invade new areas and reduce native plant growth. This effect is more pronounced in New Zealand than in Europe due to the speed at which exotic forestry (such as pinus radiata) matures here. In Europe there is 50

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[1] Climate Change (Forestry Sector) Regulations 2001, Schedule 6, Table 2.

[2] Note that the sequestration rate of exotic softwoods rather than pinus radiata was used, as both the native carbon stock data and exotic softwood carbon stock data was sourced from the same table as we assumed data contained in the same table was obtained using similar methodologies.

[3] Note that there was no data for mānuka available, hence sequestration rates for both mānuka/kānuka were used, referred to in the Climate Change (Forestry Sector) Regulations 2001 as indigenous shrublands.

[4] Ministry for Primary Industries. (2017). Carbon Look-up Tables for Forestry in the Emissions Trading Scheme. Retrieved from https://www.mpi.govt.nz/dmsdocument/4762-a-guide-to-look-up-tables-for-forestry-in-the-emissions-trading-scheme

[5] Parliamentary Commissioner for the Environment. (2008). Seeding the carbon storage opportunity in indigenous forests. Retrieved from https://www.pce.parliament.nz/media/1360/cstorage_in_indigenous_forests__26_06_2008.pdf.

[6] Parliamentary Commissioner for the Environment, above n 2.

[7] Parliamentary Commissioner for the Environment, above n 2.

[8] Parliamentary Commissioner for the Environment, above n 2.

-100 years between the harvests and chemical application, while in New Zealand it is between 25 and 30 years. Exotic forest species such as pinus radiata also have the potential to spread onto land that is of high biodiversity value, impacting upon native ecosystems ecologically as well as visually.[9]

Forestry is highly valuable to climate change mitigation. Trees act as a carbon sink, removing carbon from the atmosphere as the forests grow. Forests, in comparison to other ecological matter, have a larger mass of material, and therefore have an enhanced ability to store carbon.[10]

The sequestration rate of trees is generally greatest before the trees reach full growth (before maximum biomass is achieved).[11] To maximise carbon sequestration, it is best to plant species either with high wood density, fast growth, or large stature.[12] From a short-term sequestration perspective, non-native trees are generally more attractive as they offer higher short-term gains due to their higher initial growth rates coupled with their high initial stocking rates.[13] However, native trees have the ability to sequester carbon for much longer timeframes than non-native forests.[14] Although there is limited data available for exotic forestry sequestration rates post 50 years (as most exotic forests are typically harvested at 28 years) we assume that exotic forestry reaches maturation at 50 years and there is no growth in carbon captured. However, as native forestry is not harvested (and typically reaches a steady state around 150-200 years[15], carbon can be stored for over a thousand years in long-living species appropriate to the region. There is limited data available for native sequestration rates post 50 years, which makes it difficult to assess the longer-term benefits of planting native forestry.

Despite the data limitations, we have attempted to illustrate both shorter and longer-term sequestration rates for exotic and native forestry using two Figures. Figure C2 below illustrates the carbon sequestration rates of both native and exotic forestry between 1-50 years from the same source; the *Climate Change (Forestry Sector) Regulations 2001*.[16] It indicates that exotic softwoods[17] have much higher sequestration rates than indigenous forests over the first 50 years. The data for the indigenous sequestration rate in Figure C2 below has been modeled on naturally regenerating shrubland, which is comprised of 70% mānuka/kānuka.[18] This type of shrubland has a shorter-lifespan (approximately 80 years),[19] and limited biomass compared to

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[9] Parliamentary Commissioner for the Environment, above n 2.
[10] Parliamentary Commissioner for the Environment, above n 2.
[11] Carswell, F. E., Burrows, L. E., Hall, G. M., Mason, N. W., & Allen, R. B. (2012). Carbon and plant diversity gain during 200 years of woody succession in lowland New Zealand. New Zealand Journal of Ecology, 191-202.
[12] Ibid.
[13] Trees That Count. (n.d). Carbon Sequestration. Retrieved from https://www.treesthatcount.co.nz/media/17712/ttc_rs_carbon-sequestration_v6.pdf.
[14] Carswell, F. E., Burrows, L. E., Hall, G. M., Mason, N. W., & Allen, R. B. (2012). Carbon and plant diversity gain during 200 years of woody succession in lowland New Zealand. New Zealand Journal of Ecology, 191-202.
[15] Carswell, F. E., Burrows, L. E., Hall, G. M., Mason, N. W., & Allen, R. B. (2012). Carbon and plant diversity gain during 200 years of woody succession in lowland New Zealand. New Zealand Journal of Ecology, 191-202.
[16] Climate Change (Forestry Sector) Regulations 2001, Schedule 6, Table 2.
[17] Exotic softwoods are defined in the Climate Change (Forestry Sector) Regulations 2001 as exotic forest species in the class Coniferopsida (gymnosperms), other than Pinus radiata or Douglas fir (see section 4 – Interpretation).
[18] Ministry for Primary Industries. (2017). A Guide to Carbon Look-up Tables for Forestry in the Emissions Trading Scheme. Retrieved from https://www.mpi.govt.nz/dmsdocument/31695/send.
[19] Personal communication with Dr Larry Burrows.

larger forests. These two factors explain the relatively short carbon sequestration rates illustrated below for native forestry. Figure C2 is limited in that it does not provide carbon stock data on a succession forest, i.e. what would occur once the mānuka/kānuka die out and are replaced by larger native trees in the forest canopy that increase sequestration.

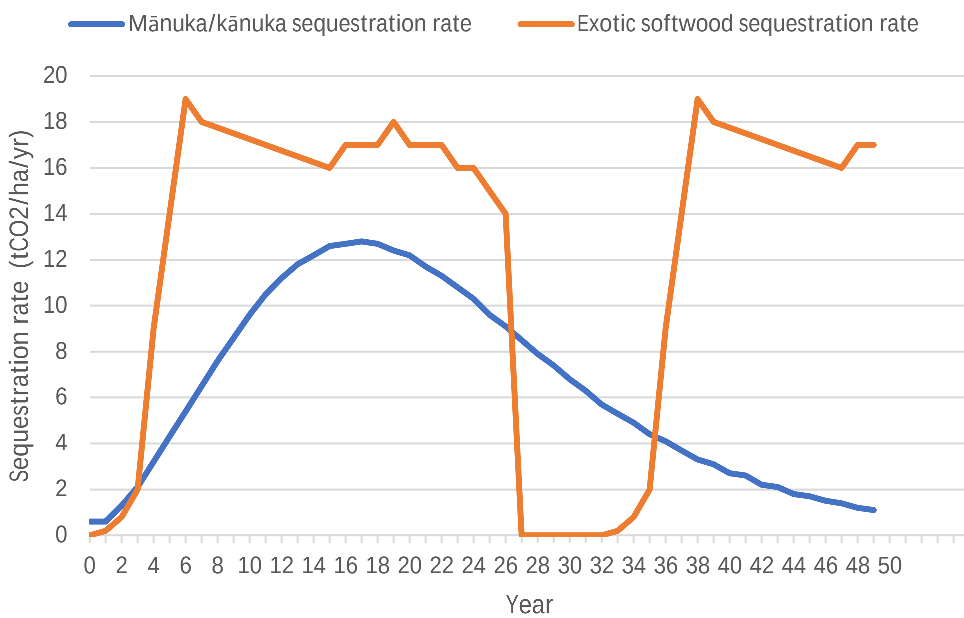


*Figure C2: Comparison of native and non-native sequestration rates from the Climate Change Regulations 2001.*

Due to the *Climate Change (Forestry Sector) Regulations 2001's* short-term (0-50 year timeframe), the sequestration rates for indigenous and exotic forestry plantations prima facie incentivise exotic plantations, as they illustrate that indigenous forestry generally has a slower initial growth rate than exotic forestry species.[20] Another important consideration is harvesting. If exotic forestry is harvested (at approximately 27 years) most of the carbon is released into the atmosphere post-harvesting. Over the medium-term (30-40 years), the amount of carbon stored in native forestry can surpass that stored in an exotic forestry plantation where harvesting takes place.[21] Figure C2 above depicts the impacts of harvesting on the exotic sequestration rate. The exotic softwood sequestration rate declines at year 28 (which depicts harvesting) and then increases when replanting occurs five years later.

[20] Parliamentary Commissioner for the Environment, above n 2.
[21] Parliamentary Commissioner for the Environment, above n 2.

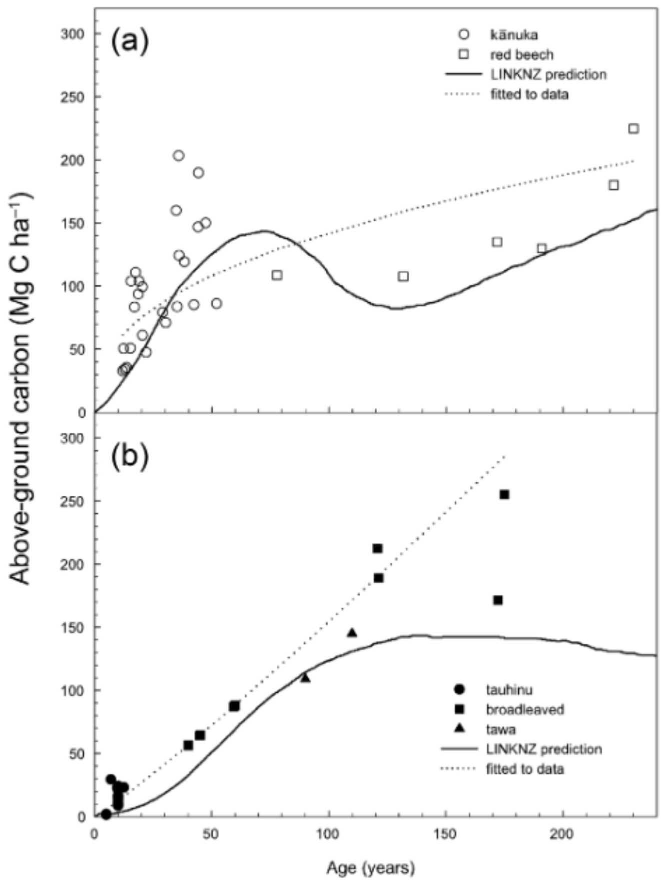


*Figure C3: Above-ground carbon stocks (Mg C ha–1) predicted by the LINKNZ ecosystem process model during the first 240 years of (a) kānuka–red beech succession and (b) coastal broadleaved succession. Stocks estimated from field measurement are shown as points.  Symbols change to represent the dominant canopy species at each stage. Also shown are the relationships fitted by regression to field measurement (Carswell et al, 2012).*

To account for the limitations in Figure C2, we have reproduced a graph from Carswell et al 2012, which illustrates the carbon stock data for native forestry based on a 200 year succession forest. This study quantified carbon accumulation in two lowland forests; forest (a) being a kānuka-red beech succession forest, and forest (b) being a coastal broadleaved forest. This forestry data was taken from a secondary succession forest and is not a newly planted native forest. This carbon stock data was then measured against an ecosystem process model (known as LINKNZ) to compare accuracy. Figure C3 is valuable in that it indicates the long-term contribution of carbon stock data in a naturally regenerating forest across a 250-year time period. Both kānuka–red beech and coastal redwood succession forests would continue to store new carbon for over 200 years.

In summary, while it appears that exotic forestry absorbs atmospheric carbon at higher rate than a mānuka/kānuka forest, this initial benefit stops when exotic trees are harvested between 25 and 30 years after being planted. Indigenous forests, especially if they are encouraged to follow succession from mānuka/kānuka to large native tree species continue to increase the carbon storage for at least 200 years. Carbon in the unharvested indigenous forests is stored indefinitely, while carbon measurements typically account for the carbon in the harvested trees as released in the year they are cut.

### Model development

A model was developed that provides both exotic and native sequestration rates based on whether land is afforested in one year or over multiple years. We sourced both carbon sequestration rates from Table 2 of the *Climate Change (Forestry Sector) Regulations* 2001. Note that the sequestration rate of exotic softwoods rather than pinus radiata was used, as both the native carbon stock data and exotic softwood carbon stock data was sourced from the same table as we assumed data contained in the same table was obtained using similar methodologies. We used an average linear sequestration rate for native forestry sequestration, given the variability of native sequestration rates. This linear sequestration rate was the average sequestration rate for mānuka/kānuka over a 50 -year time period, as sourced from the 2001 Regulations, with forest succession added.

In the development of HRC's Sustainable Land Use Initiative (SLUI), farmed land was categorised by how prone the land is to erode and have sediment enter waterways, therefore where HRC would target work with landowners for land erosion treatment. These categories are top priority, highly erodible, erodible and not erodible. Through the SLUI programme, HRC works with landowners to assess erosion issues on their property and support planting work through a grant scheme. The areas defined for top priority, highly erodible and erodible land have been used to develop scenarios for this report as a proxy for the types of landscapes that afforestation is most likely occur on. Using this total land area is not suggesting that this land should be afforested in its entirety, but rather is used to illustrate some of the different scenarios that could occur as a result of afforestation, the scale of land that would be required to offset emissions and highlight some of the limitations.

*Table C2: Breakdown of erodible land available for planting as provided by Horizons Regional Council.*

| Land class | Land (ha) |
|---|---|
| Top priority land | 25,294 |
| Highly erodible land | 93,928 |
| Erodible land | 209,051 |
| **Total land** | **328,273** |

*Table C3: Summary of model results.*

| **Scenario** | **Total sequestration by 2035 ($tCO_2e$)** | **Total sequestration by 2050 ($tCO_2e$)** |
|---|---|---|
| 1a – 328,273 ha exotic forestry planted across 15 years - **Trees not harvested** | 39,267,912 | 111,218,569 |
| 1b – 328,273 ha exotic forestry planted across 15 years – **Trees harvested after 27 years with no replanting** | 39,381,713 | 110,723,971 |
| 2a – 328,273 ha exotic forestry planted as soon as possible - (50% in year 1 and 50% in year 2) - **Trees not harvested** | 67,821,202 | 124,513,951 |
| 2b – 328,273 ha exotic forestry planted as soon as possible - (50% in year 1 and 50% in year 2) - **Trees harvested after 27 years with no replanting** | 67,821,204 | 121,657,976 |
| 3 – 328,273 ha forestry planted across 15 years but planted in a mix of mānuka/kānuka and exotics – **exotic trees harvested after 27 years with no replanting** | 29,422,454 | 82,252,901 |
| 4 – 328,273 ha forestry planted as soon as possible - (50% in year 1 and 50% in year 2) - **exotic trees harvested after 27 years with no replanting** | 50,670,612 | 93,808,364 |
| 5 – 328,273 ha mānuka/kānuka forest planted as soon as possible (50% in year 1 and 50% in year 2) | 33,520,023 | 65,958,755 |
| 6 – 328,273 ha indigenous forest per year across 15 years | 19,463,239 | 51,901,971 |
| **Scenario 7 and 8** | Total land required to offset (ha) | |
| 7 – How much land would be required to store the carbon equivalent of a 50% reduction in HRC emissions in forestry planted across 15 years? | 153,193 | |
| 8 – How much land would be required to store the carbon equivalent of a 50% reduction in HRC emissions, if planting occurred in a 1-year timeframe? | 328, 273 | |
| 9 – How much land would be required to store the carbon equivalent of a 50% reduction in HRC emissions, if planting occurred in a 30 year timeframe? | 98,482 | |

## Findings

As Table C3 illustrates, the findings from the model show that in the short-term, more carbon would be sequestered if trees are planted as early as possible and if exotic forestry is planted. However, as we have discussed above, over the longer-term native forestry also sequesters significantly more carbon than exotic forestry.

Scenario 5 has the maximum amount of carbon sequestered over the long term. If increasing native cover were encouraged, Scenario 3 sequesters more carbon both in the short-term and longer-term. If HRC was most interested in maximizing sequestration by 2050, Scenario 1(a) would achieve this aim. However, any strategy to reduce net emissions that includes planting exotic species carries the risk of a producing important negative impacts on soil health and biodiversity.

## Limitations

Our limitations are as follows:

- There is limited data for long-term forest sequestration rates in New Zealand, particularly regarding long-term sequestration rates, which limits the accuracy of carbon sequestration projections.
- We could find no authoritative source of long-term native sequestration rates in a naturally regenerating forest. A lack of data makes it very difficult to accurately predict the longer-term carbon sequestration projections. We could however find estimates which we have included in our analysis.
- There is limited data available on exotic forestry sequestration rates post-50 years, and we have assumed that exotic forestry reaches maturation at 50 years and sequestration is negligible. Data in this area is scarce as most exotics are harvested after 27 years. The results in this study should be treated as indicative due to high uncertainties about sequestration rates.
- Across all our scenarios, we are only looking at new plantings and we have not included land that has already been afforested within the Horizons region.

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