

Chapter 11:

Where are we currently heading?

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This chapter provides a glimpse of what future emissions in Aotearoa could look like if we keep progressing as we are now – with no policy changes or new regulations. It does this through the Current Policy Reference case, which provides the platform that allows us to test and adjust our thinking to create alternate scenarios which form the basis of our advice.

We dive deep into each sector and explore how the future might play out if policies continue as they are. This chapter also introduces our ENZ modelling tool and discusses the possible impacts of COVID-19 on our future emissions.

11.1 Introduction

This chapter introduces the Current Policy Reference case, which projects how emissions and activities could change in the future assuming no changes to current government policy. It provides a point of reference for comparing our recommended budgets and pathway. The first section of this chapter describes the Current Policy Reference case in more detail and how it was constructed. The second section presents the Current Policy Reference case with charts and tables for key aspects of each sector. The third section considers comparisons between the Current Policy Reference case and other projections of a similar nature. The fourth section provides a discussion of key sources of uncertainty in the Current Policy Reference case, including the impact of COVID-19.

11.2 What is the Current Policy Reference case?

The Current Policy Reference case (also referred to in this chapter as the ‘reference case’) provides a projection of what our emissions could look like out to 2050 if no additional measures are implemented. This reference case is a scenario, and as such the outcomes described are neither what we consider ‘will’ nor ‘should’ occur. Instead, it serves to paint a picture of how emissions and activities might change if we keep to the path we are currently on.

The Current Policy Reference case draws on and aligns closely with sectoral projections by government agencies and the Government’s ‘With Existing Measures’ emissions projections.¹ As such, it incorporates, through assumption, anticipated changes, which are consistent with a future where there are no further developments in government climate legislation and regulation. The reference case assumes market conditions, technology cost reductions and policies continue on current trajectories. The Government projections were updated in October 2020 prior to the 2020 national election. They include policies already in place at that time, but policies proposed or implemented since the October 2020 election are not included. A more detailed discussion of the key recent policy developments included in the reference case is provided in Box 11.1.

The Current Policy Reference case is not designed to necessarily meet 2050 emissions reductions targets (2050 target) or emissions budgets – it is a starting point for our analysis. We use it to calibrate our models with detailed Government projections and to help us understand what additional effort might be required to meet emissions budgets and targets. The reference case also gives a benchmark against which to test the relative impacts of different scenarios and the effectiveness of different interventions in achieving emissions reduction targets.

¹ See (Ministry for the Environment, 2021) for these projections.

The emissions trajectory of 'current' government policies will, of course, change as new climate policies are introduced. Through its role in monitoring the progress of Aotearoa towards budgets and the 2050 targets, we will revise and update the reference case over time. The next advice on emissions budgets, to be delivered in 2024, will be based on a new reference case, which reflects actions taken and external developments between now and then. Government projections and scenarios will also continue to evolve during this time.

Our Current Policy Reference case is, as such, not a fixed scenario against which we will compare repeatedly until 2050. It is a starting reference case for developing the first emissions budgets and the beginning of an iterative modelling and monitoring process which we will continue moving forward. This underpins the dynamic, adaptive approach we are taking towards our policy advice.

11.2.1 How we built the Current Policy Reference case

The Current Policy Reference case was generated using a purpose-built model called ENZ that was originally developed by Concept Consulting. We purchased ENZ and have worked with Concept Consulting to further develop it to meet our needs.

ENZ allows us to investigate, from a whole-of-system point of view, changes to emitting activities and technologies in each sector of the economy. It also allows us to factor in anticipated technological developments. ENZ produces economy-wide emissions estimates along with other data and insights such as energy costs. As well as for the reference case, we use ENZ to generate other scenarios to investigate alternative possible futures in *Chapter 12: Long-term scenarios to meet the 2050 target*. *Appendix 1* of this chapter provides a more detailed description of ENZ and how each sector is represented within it.

The exact design of the Current Policy Reference case varies across sectors. Inputs were derived through a combination of in-house analysis and external engagement. We examined Government projections, including the October 2020 update, expected future reductions in technology costs, research on international trends, and committed policies and industry plans within Aotearoa. We also drew on responses to our call for evidence and engaged widely with industry and sector experts for additional input.

Box 11.1: Key policies shaping the Current Policy Reference case

Freshwater policy

The Essential Freshwater policies and regulations that came into force on 3 September 2020 contained two major components:

- 1) **The National Environmental Standards for Freshwater:** these regulate activities deemed to pose risks to the health of freshwater and freshwater ecosystems. The standards include regulations for winter grazing, restrict agricultural intensification until 2024, and a limit for synthetic nitrogen fertiliser use on pastoral land of 190 kg per hectare per year.
- 2) **National Policy Statement for Freshwater Management:** this provides direction to local authorities on managing freshwater under the Resource Management Act. It sets national objectives for freshwater management, including on wetland protection and restoration, water quality monitoring and tougher national bottom lines for ammonia and nitrate toxicity.

These freshwater policies and regulations are expected to have implications for land sector activities, particularly pastoral agriculture. The effects have been estimated and incorporated by

the Ministry for Primary Industries (MPI) in the October 2020 updated activity projections, which were fed into ENZ. The main impact on the activity data was a reduction in projected livestock numbers, which flows through into lower projected agricultural emissions.

New Zealand Emissions Trading Scheme (NZ ETS)

The NZ ETS is one of the Government's main tools for reducing greenhouse gas (GHG) emissions. It does this by placing a price on emissions by requiring certain sectors of the economy to purchase New Zealand Units (NZUs) equal to their annual emissions. Post-1989 forest owners can also receive NZUs for the emissions removals generated by their forests.

The Current Policy Reference case includes a \$35 carbon price in the NZ ETS in line with the updated all-government assumptions. This is assumed to hold constant in real terms until 2050 and reflects a mid-point between the current upper bound of the cost containment reserve (\$50) and the NZU auction reserve price (\$20).

There is a system of free allocation in the NZ ETS for certain industrial activities determined to be emissions-intensive and trade-exposed. Our analysis assumes changes to industrial allocation do not influence industrial output or incentives to reduce emissions.

Animal agricultural emissions are currently exempt from the emissions price in the NZ ETS, but legislation includes a provision for this sector to lose this exemption in 2025, unless an alternative pricing mechanism is developed. He Waka Eke Noa is working towards this and we will have a role in assessing its progress in 2022. The legislated pricing for agricultural emissions from 2025 would take place at the processor level and with 95% free allocation – this is factored into MPI's activity data that underpin the reference case. Non-animal agricultural emissions such as on-farm fossil fuel use are already subject to emissions pricing.

The amendments to the NZ ETS, passed in June 2020, contained a number of technical changes for forestry in the scheme. These included introducing the use of 'averaging' accounting² for post-1989 forests and creating a new permanent forestry activity. These changes will phase in by 2023, and have given more certainty for forestry in the scheme, with the net effect of increasing projected future afforestation in Aotearoa. This has been incorporated into the MPI October 2020 data update which is used in ENZ to generate the reference case.

Waste is included in the NZ ETS with disposal facilities having obligations to purchase NZUs. However, this only applies to landfills that accept household waste, which only account for approximately one third of waste emissions. Higher NZ ETS prices are unlikely to materially impact waste volumes or waste emissions. This is because most municipal landfills are required to collect greenhouse gas emissions under the National Environmental Standards for Air Quality. These landfills are able to apply for a 'Unique Emissions Factor' (UEF) to reduce their NZ ETS obligations. A UEF can be applied for by landfills if they produce fewer emissions than the 'default emissions factor.' Most household waste goes to landfills that have received a UEF, meaning that they are already at a high rate of capture efficiency.

Waste levy

A waste disposal levy also applies to landfills with the current price for municipal sites set to increase from \$10 to \$60 per tonne and for non-municipal sites from \$0 to between \$10-\$30 by

² For more information on accounting rules see *Chapter 3: How to measure progress*.

2024. As waste volumes are relatively price inelastic³ and the increases to the waste levy are quite low, we have been conservative and assumed that the small increase to the waste levy will not substantially affect the reference case.

No new offshore oil and gas exploration permits

In 2018, the Government announced that there would be no new oil and gas exploration permits offered, except on land in Taranaki. This policy has been included in the Current Policy Reference case. While this has not affected existing exploration permits or companies' ability to extract oil and gas from known reservoirs, we have assumed that our fossil gas reserves do not increase.

Kigali phasedown

In October 2016 Aotearoa adopted the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer. This requires Aotearoa and other signatories to gradually phase down Hydrofluorocarbon (HFC) production and use. Aotearoa, as a developed country, is required to phase down HFC production and use by 85% by 2036. The Amendment was brought into force for Aotearoa on 1 January 2020.

We take historic data for the model from New Zealand's Greenhouse Gas Inventory (the GHG Inventory) and other sources. The most recent official data currently available is from 2019, so we use this as the base year in ENZ. The model then projects data for 2020 onwards.

The land and waste sector reference cases use Government activity projections directly, so they are almost identical to Government 'With Existing Measures' (WEM) scenarios. The reference cases for transport, buildings and industry, however, use modelled activity projections and draw on internally developed assumptions. They are still broadly aligned with Government projections but less closely than for the land and waste sectors. Comparisons between the ENZ reference cases and projections from Government and other organisations are provided later in this chapter.

The following sections describe ENZ and the Current Policy Reference case for each sector. First, overall long-lived greenhouse gas and biogenic methane emissions are presented. This is followed by charts, tables and supporting notes highlighting projected emissions and activity data out to 2050 for transport, energy, industry and building, land and waste.

Detailed assumptions for the Current Policy Reference case and all of our modelled scenarios are available on our website.

11.2.2 Uncertainty and the Current Policy Reference case

There is, inevitably, significant uncertainty within the Current Policy Reference case. We present a single reference case that largely mirrors Government 'with existing measures' scenarios. The reference case depends on a set of assumptions which are detailed in the sections that follow. These assumptions, and the resulting emissions trajectories, are subject to uncertainty. This is based on possible actions within Aotearoa, as well as external developments – many of which are international. A discussion of the uncertainties for each sector in the reference case is provided in the final section of this chapter.

³ (Clough, 2019)

The discussion on uncertainty also includes a section dedicated to the potential effects of COVID-19. As we have a long-term planning focus, the key uncertainty is the duration of impacts caused by the pandemic. For reasons described at the end of this chapter, we assume the impacts of the pandemic will be relatively short term and not fundamentally change any long-term trends.

If these uncertainties cause variations for the reference case, a different level of effort would be required to meet emissions budgets and the 2050 targets.

We recognise and incorporate the major uncertainties which might affect emissions trajectories through modelling multiple future scenarios in addition to the reference case. With the time and resources available to produce this first set of advice, we are unable to model the entire spectrum of possible future scenarios. We have focused on four plausible scenarios which reflect key sources of variation in the drivers of emissions and potential emissions reductions. These are presented in *Chapter 12: Long-term scenarios to meet the 2050 target*. The emissions budgets we propose are ones we believe are achievable under a range of possible futures.

The wellbeing of Iwi/Māori throughout the transition to low emissions is a central part to this. He Ara Waiora⁴ presents a te ao Māori approach to wellbeing, sourced in mātauranga Māori, and provides valuable and appropriate framing to understand and assess impacts of climate policy for Iwi/Māori. It is also a frame that considers broader wellbeing of people and environment for current and future generations. When developing and implementing the emissions reduction plan, the government should consider how those measures impact the four dimensions of wellbeing identified in the framework.

11.3 Overall emissions

We first present total long-lived greenhouse gases and biogenic methane emissions to give a sense of progress towards the 2050 and 2030 targets. Following that, the sectoral data is largely split by gas in order to more clearly highlight the mix of gases being emitted. Note that some of the table totals may not sum exactly due to rounding.

⁴ McMeeking (2019)

11.3.1 Long-lived greenhouse gases

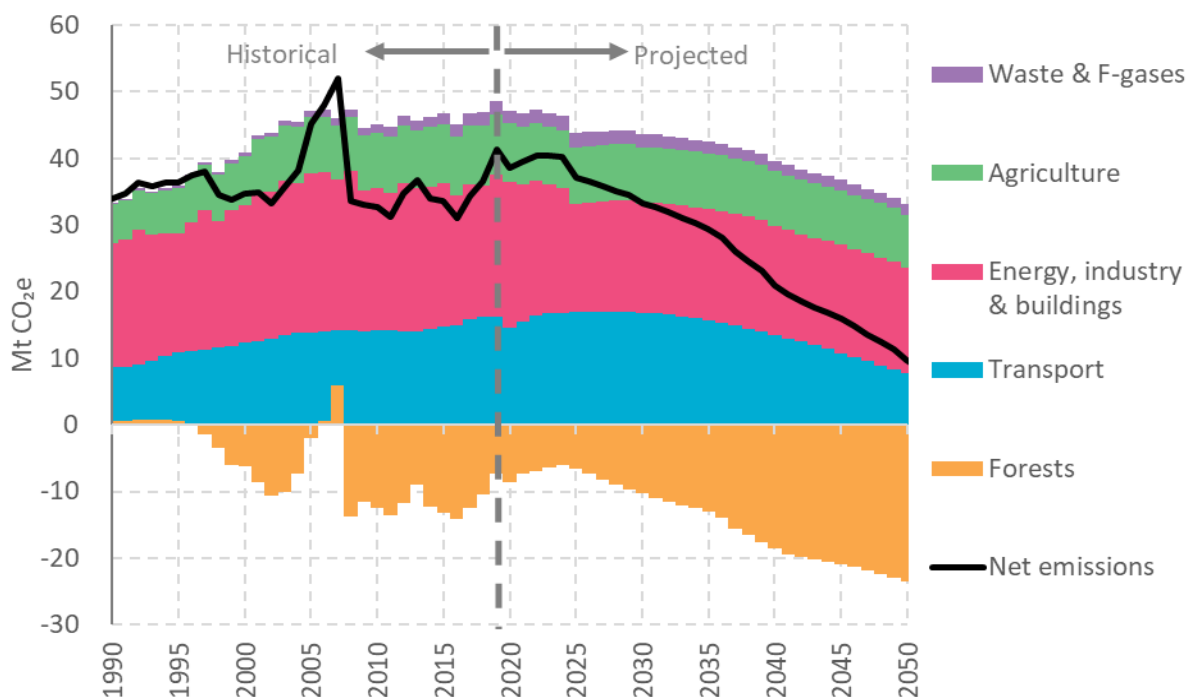


Figure 11.1: Current Policy Reference case total long-lived greenhouse gases emissions and removals by sector

Source: Commission analysis.

Table 11.1: Current Policy Reference case total long-lived greenhouse gases emissions and removals by sector (MtCO_{2e})

	2019	2030	2040	2050
Waste and F-gases	2.0	1.9	1.6	1.6
Agriculture	9.0	8.4	8.3	8.1
Energy, industry and buildings	21.4	16.4	16.3	15.8
Transport	16.2	16.9	13.6	8.1
Forests	-7.4	-10.3	-18.6	-23.4
Net	41.3	33.3	21.2	10.1
Gross	48.6	43.6	39.8	33.6

Notes:

- Long-lived greenhouse gas emissions in Aotearoa come from a range of sources and are comprised of all gases other than biogenic methane. They are largely carbon dioxide (CO₂) and nitrous oxide (N₂O), with some much smaller amounts of F-gases and fossil methane. Figure 11.1 presents these alongside emissions removals by forests, which together account for net emissions of long-lived greenhouse gases.

- Gross long-lived greenhouse gas emissions increased steadily from 33.3 MtCO₂e in 1990 to 47.4 MtCO₂e in 2008, and then largely plateaued to reach 48.6 MtCO₂e in 2019. Note that this trend is distorted due to major underestimation of transport emissions prior to 2001.
- From 2019, gross emissions decline to 43.6 MtCO₂e in 2030 and 33.6 MtCO₂e in 2050. This is driven in large part by projected decreases in transport emissions after 2030, which drop from 16.9 MtCO₂e in 2030 to 8.1 MtCO₂e in 2050. Other sources of emissions also decline steadily from 2019 to 2050.
- The decrease in transport emissions is largely due to the projected electrification of the light vehicle fleet.
- Emissions removals by forests fluctuated between 1990 and 2019. In the Current Policy Reference case, they are expected to increase steadily from 7.4 MtCO₂e in 2019 to 23.4 MtCO₂e in 2050. This results in net emissions of long-lived greenhouse gases declining from 41.3 MtCO₂e in 2019 to 10.2 MtCO₂e in 2050.
- A more detailed discussion of emissions removals by forests in the reference case are discussed in the land subsection.
- The emission sources which are included under each of the categories in Figure 11.2 and Table 11.2 are detailed in the following sections.

11.3.2 Biogenic methane

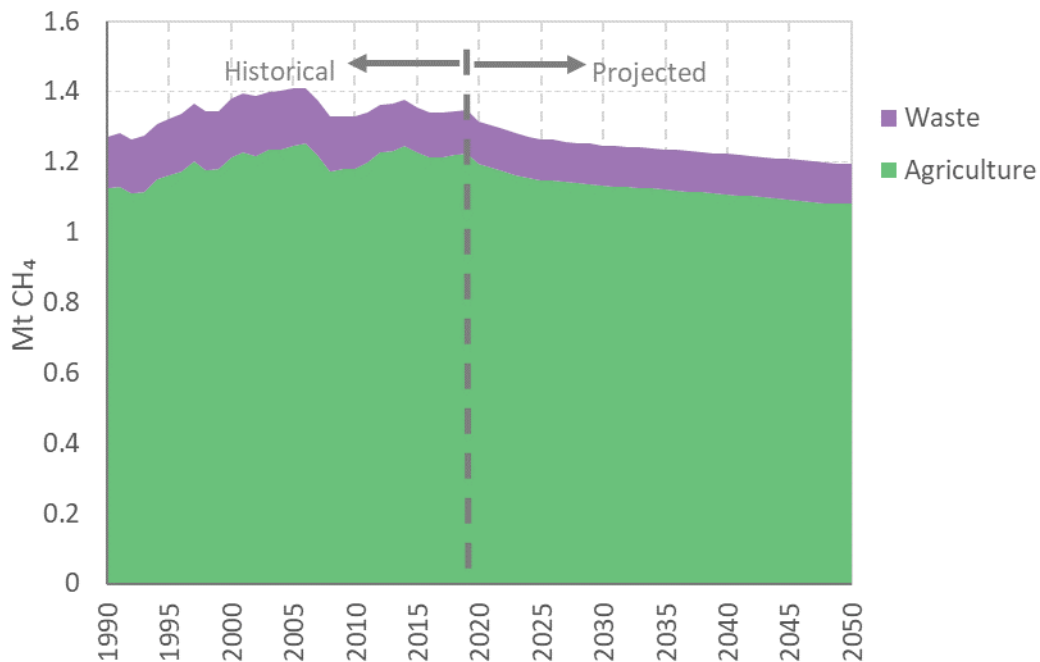


Figure 11.2: Current Policy Reference case total biogenic methane emissions by sector

Source: Commission analysis.

Table 11.2: Current Policy Reference case total biogenic methane emissions by sector (MtCH₄)

	2019	2030	2040	2050
Agriculture	1.22	1.13	1.11	1.08
Waste	0.12	0.12	0.11	0.12
Total	1.35	1.25	1.22	1.20

Notes:

- Biogenic methane emissions largely come from ruminant livestock and organic waste decomposition.
- Agricultural biogenic methane emissions increased steadily from 1.12 MtCH₄ in 1990, peaking at 1.25 MtCH₄ in 2006 before declining to 1.22 MtCH₄ in 2019.
- Waste emissions increased steadily from 0.15 MtCH₄ in 1990, peaking at 0.17 MtCH₄ in 2002 before declining to 0.12 MtCH₄ in 2019.
- In the reference case, agricultural biogenic methane emissions decline to 1.13 MtCH₄ in 2030 and 1.08 MtCH₄ in 2050. Details of these emissions are described in the land section of this chapter.
- In the reference case, waste biogenic methane emissions decline to 0.11 MtCH₄ in 2040 before rising again to 0.12 MtCH₄ in 2050. Details of these emissions are described in the waste section of this chapter.

11.4 Transport

ENZ includes road, rail, shipping and aviation, with the latter two split into domestic and international. It also includes different fuel types: fossil and alternatives. It models the main levers which influence emissions, including the makeup of the vehicle fleet, transport demand and the factors driving them, such as the size of the population. ENZ also takes account of behavioural change, including shifts between travel types, such as more walking or cycling, or reduced demand for travel because of more working from home. In both cases, ENZ responds by reducing the distance travelled by road.

11.4.1 Domestic transport carbon dioxide emissions by travel type

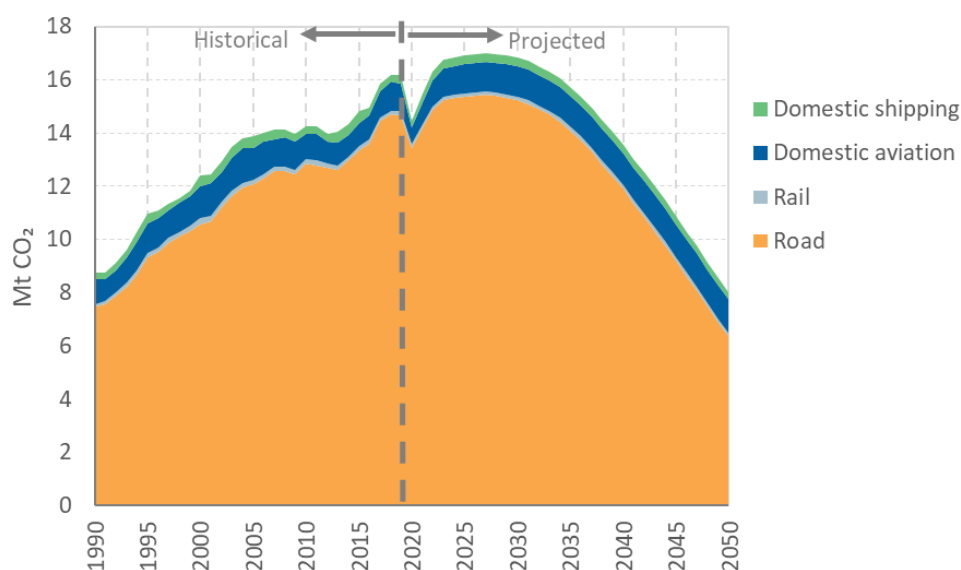


Figure 11.3: Current Policy Reference case domestic transport emissions by travel type

Source: Commission analysis.

Table 11.3: Current Policy Reference case domestic transport emissions by type (MtCO₂)

	2019	2030	2040	2050
Road	14.7	15.2	11.9	6.4
Rail	0.1	0.1	0.1	0.1
Domestic aviation	1.0	1.1	1.2	1.3
Domestic shipping	0.3	0.3	0.3	0.3
Total	16.2	16.9	13.6	8.0

Notes:

- For the Current Policy Reference case, we have assumed that transport emissions return to pre-COVID-19 trends, and that COVID-19 has limited long-term impact on transport emissions. This aligns with the latest projections from the Ministry of Transport (MoT).
- Figure 11.3 shows transport emissions for the major domestic types of travel. In line with the Climate Change Commission (the Commission)'s current policy mandate, we have excluded international aviation and international shipping from this graph, however, we do address international transport in Figure 11.7.
- Between 1990 and 2019, emissions from road vehicles have dominated domestic transport carbon dioxide emissions and have nearly doubled. Emissions from other modes (domestic aviation, railways and domestic shipping) are smaller and have not seen much growth.

- After 2019, emissions from road vehicles are projected to rise slowly to the mid-2020s, then decline steadily due mainly to the expected uptake of electric vehicles (EVs); emissions from other travel types would not change much.
- More than 99% of greenhouse gas emissions in the transport sector were carbon dioxide in 2019.⁵ We have not modelled other greenhouse gas emissions in transport as they are insignificant.
- Between 1990 and 2019, road vehicle emissions have grown with the population and the economy, with little improvement in vehicle efficiency to offset the growth in traffic.
- In domestic aviation, improvements in fuel efficiency and increases in passenger occupancy have helped to offset growth in aviation traffic. The efficiency improvements are expected to continue, but further increases in passenger occupancy may not be feasible.
- Emissions from railways and domestic shipping are small and expected to remain that way.

11.4.2 Household transport by transport type

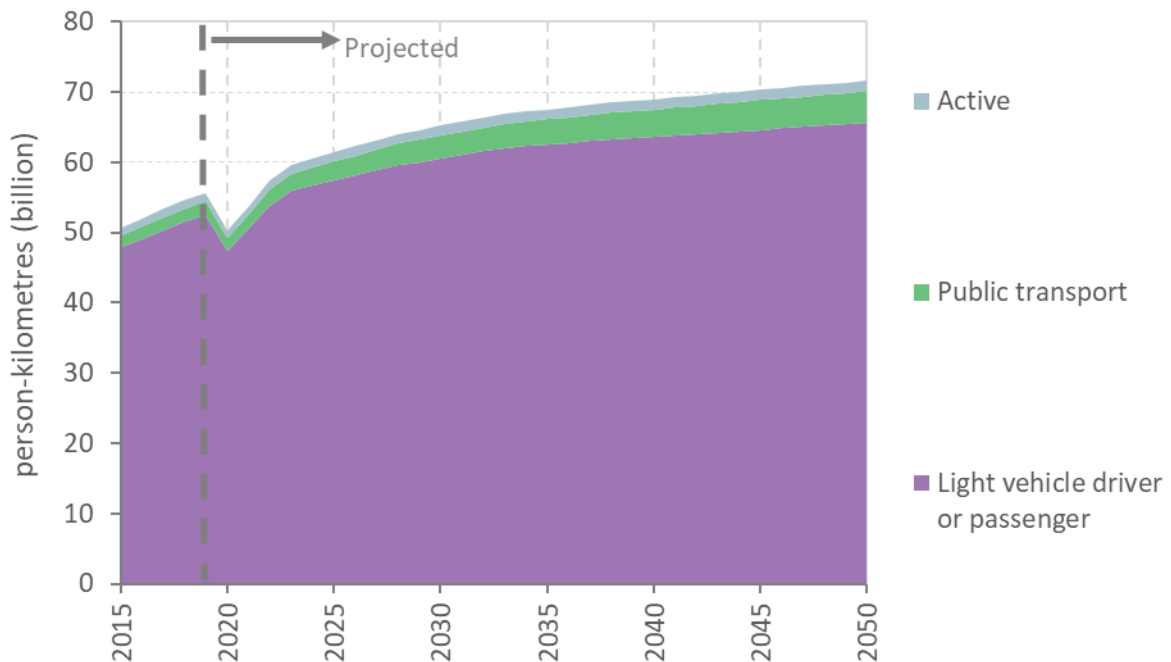


Figure 11.4: Current Policy Reference case household passenger kilometres by travel type

Source: Commission analysis.

⁵ Ministry for the Environment (2020).

Table 11.4: Current Policy Reference case household passenger kilometres by travel type (billions)

	2019	2020	2030	2040	2050
Light vehicle driver or passenger	52.5	47.4	60.6	63.6	65.6
Public transport	2.0	1.9	3.3	3.9	4.5
Active transport	1.2	1.1	1.4	1.5	1.5
Total	55.7	50.4	65.2	69.0	71.6

Notes:

- Figure 11.4 shows household travel, which includes most local travel other than travel for business purposes. It would, for example, exclude tradespeople travelling to job sites or couriers making deliveries.
- Transport modes have been aggregated. Light vehicles include car travel as either a driver or a passenger, using a taxi or vehicle share, and motorcycles. Public transport includes local buses, ferries, and trains. Active transport includes pedestrian travel and cycling.
- Between 1990 and 2018, household travel was dominated by light vehicle drivers and light vehicle passengers, which accounted for about 95% of person-kilometres travelled.
- After 2018, household travel continues to be dominated by light vehicle drivers and light vehicle passengers; there would be significant percentage growth in public transport and active transport due to ongoing improvements in infrastructure and services, but from a small initial base.
- Household travel accounts for about 75% of light vehicle travel and is therefore the major driver of domestic transport emissions; commercial travel accounts for most of the remaining light vehicle travel.
- Cities in Aotearoa generally have a sprawling land-use pattern, which has been difficult to serve with public transport, or walking and cycling. Government transport expenditures have historically focused on roading, accentuating this pattern.
- In the Current Policy Reference case, we do not assume any potential long-term increase in remote working, which would reduce travel demand.

11.4.3 Road transport emissions by vehicle class

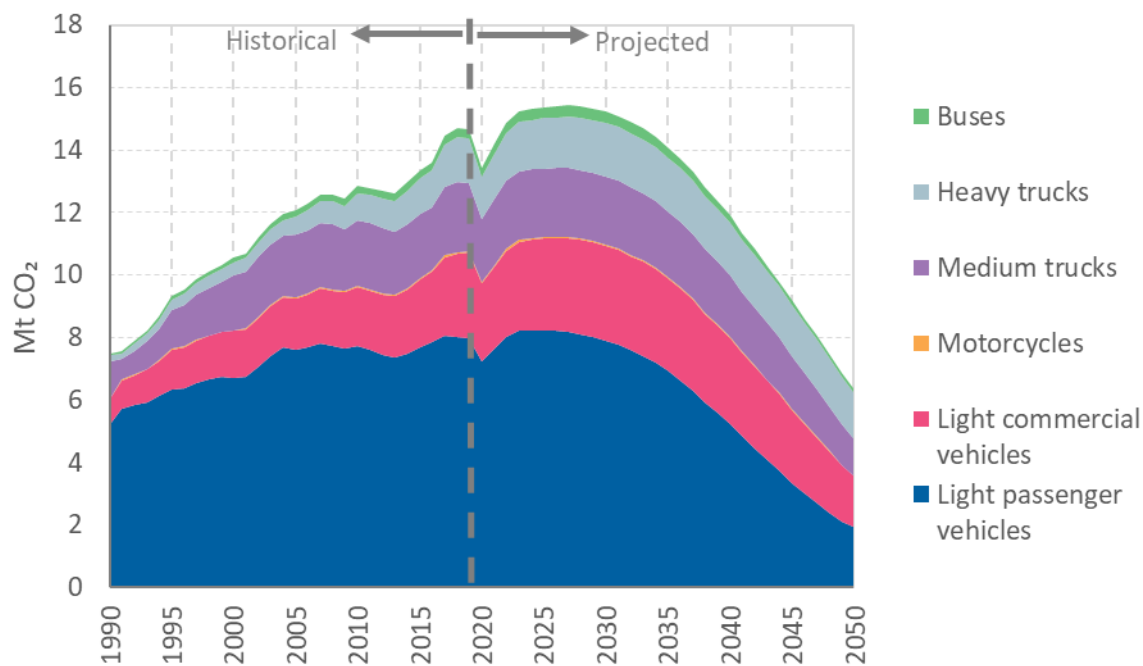


Figure 11.5: Current Policy Reference case emissions by vehicle class⁶

Source: Commission analysis.

Table 11.5: Current Policy Reference case emissions by vehicle class (MtCO₂)

	2019	2030	2040	2050
Light passenger vehicles	8.0	7.9	5.2	1.9
Light commercial vehicles	2.7	3.0	2.7	1.6
Motorcycles	0.0	0.0	0.0	0.0
Medium trucks	2.2	2.2	2.0	1.2
Heavy trucks	1.4	1.7	1.7	1.5
Buses	0.3	0.4	0.2	0.1
Total	14.7	15.2	11.9	6.4

Notes:

- Figure 11.5 shows road transport emissions broken down by the class of vehicle.
- Between 1990 and 2019, emissions grew from all six classes of vehicles. Growth has been especially large for medium and heavy trucks and for light commercial vehicles (vans and utes).

⁶ Note that the data prior to 2001 is based on estimates rather than actual MoT data.

- After 2019, emissions from most vehicle classes are expected to rise until the mid-2020s, then decline as the vehicle fleet becomes increasingly electrified.
- The terms ‘light passenger vehicles’ and ‘light commercial vehicles’ refer to the body type of the vehicle, not the use or ownership of the vehicle. The light passenger vehicle class includes cars and SUVs; the light commercial vehicle class includes vans and utes. Close to 60% of light commercial vehicles are owned by households, not businesses.⁷
- Between 2000 and 2019, light commercial vehicle numbers have gone up about 80% compared to about 54% for light passenger vehicles, reflecting the growing popularity of these large vehicles for both households and businesses.⁸
- Emissions per kilometre for most classes of vehicles have historically gone down very slowly, as efficiency improvements have been offset by growing vehicle size and growing engine size. This pattern is expected to continue for internal combustion engine vehicles.
- While the projected long-term decline in road transport emissions is good news, there are three important caveats to this Current Policy Reference case projection:
 1. As noted, later in this chapter, the continuing decline in battery costs and increasing competitiveness of EVs, which is driving these results, is subject to uncertainty.
 2. Emissions from road transport remain at high levels for at least another ten years, before they begin to decline.
 3. Even in 2050, there would still be around 6.4 MtCO₂ emissions from road vehicles.

Taken together, these caveats imply that the long-term decline in road transport emissions in the reference case would be insufficient to meet our emissions reduction commitments.

11.4.4 Electric vehicle uptake

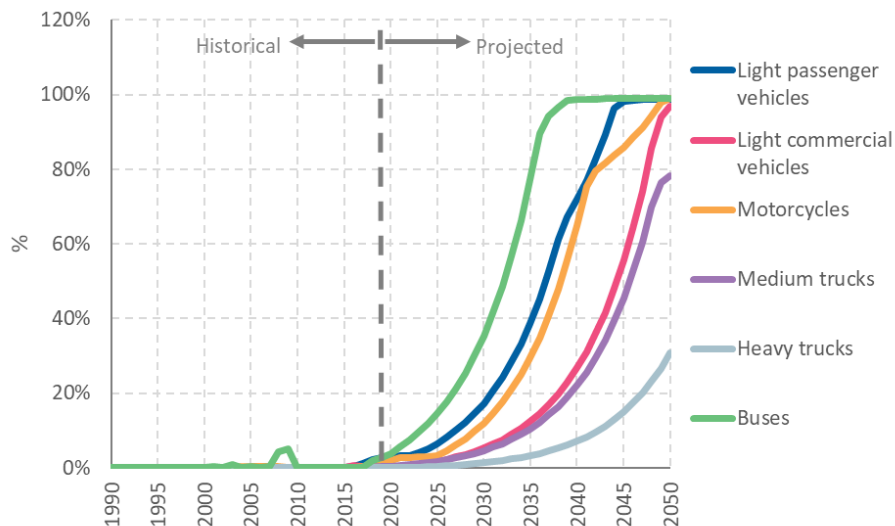


Figure 11.6: Current Policy Reference case percentage of EVs entering the fleet

Source: Commission analysis.

⁷ Ministry of Transport (2019c), see the ‘All Light Vehicles’ sheet.

⁸ Ministry of Transport (2019a), see tab ‘1.1, 1.2’.

Table 11.6: Current Policy Reference case percentage of EVs entering the fleet

	2019	2030	2040	2050
Light passenger vehicles	3%	17%	70%	92%
Light commercial vehicles	0%	5%	27%	96%
Motorcycles	2%	12%	64%	98%
Medium trucks	0%	5%	22%	78%
Heavy trucks	0%	1%	7%	31%
Buses	3%	35%	98%	98%

Notes:

- Figure 11.6 shows the expected uptake of EVs as a percentage of newly registered vehicles (both *new* and *used* imports) entering the fleet each year. These percentages are not to be confused with the percentage of EVs in the fleet each year, which will lag significantly behind the percentage of EVs entering the fleet.
- See *Appendix 1* for more information on how we model EVs.
- Numbers of EVs entering the fleet in 2019 and previous years were very small – less than 10,000.
- Declining battery costs make it likely that EVs will become increasingly competitive with conventional vehicles, implying that EV numbers are likely to grow even in the absence of strong government policies to promote them. As noted in Figure 11.5, the resulting long-term decline in road transport emissions in the reference case would almost certainly be insufficient to meet our emissions reduction commitments.
- Given the many uncertainties, projecting the timing of the growth of EV sales is difficult. The Current Policy Reference case suggests that for light passenger vehicles, the time when more than half the vehicles imported into Aotearoa (both imported new and imported used) would be electric is in the late 2030s, with EVs completely taking over the light passenger vehicle market in the early 2040s.
- Light commercial vehicles switch over to electric at a similar rate to light passenger vehicles. Buses switch over faster; medium and heavy trucks take longer due to the challenges of using battery power for heavy vehicles travelling long distances.
- The bus fleet is split fairly evenly between local public transport buses and buses designed for longer distances, which serve mainly tourists. The public transport portion of the bus fleet is amenable to electrification and almost entirely under government control, so it would likely be an early adopter of electrification.
- Our model is based on battery cost projections from Bloomberg New Energy Finance (BNEF),⁹ a well-regarded source for clean technology trends. The battery cost reductions projected by BNEF result in a rapidly falling cost for EV ownership. However, it is reasonable to expect a lag between the costs of EVs falling and rapid uptake by consumers.

⁹ BloombergNEF (2020)

- Reasons for the potentially lagging uptake of EVs in Aotearoa include the small size of our new vehicle market and the fact that we drive on the left. Both of these factors restrict our access to new vehicle models.
- We are also heavily dependent on used vehicles, imported from Japan. This could limit the uptake of EVs, as the supply of used EVs from Japan depends on what vehicles Japanese consumers choose at least five years prior to entering our market. Japanese consumers have historically favoured conventional hybrid vehicles as a low-emissions option and EV uptake has been slow.
- Our slow fleet-turnover is also a factor for the potentially lagging uptake of EVs. Evidence also suggests that consumer behaviour does not respond only to the relative cost of ownership of EVs versus conventional vehicles – other factors such as range anxiety or new technology hesitancy may also delay uptake.

11.4.5 Emissions from transport including international transport

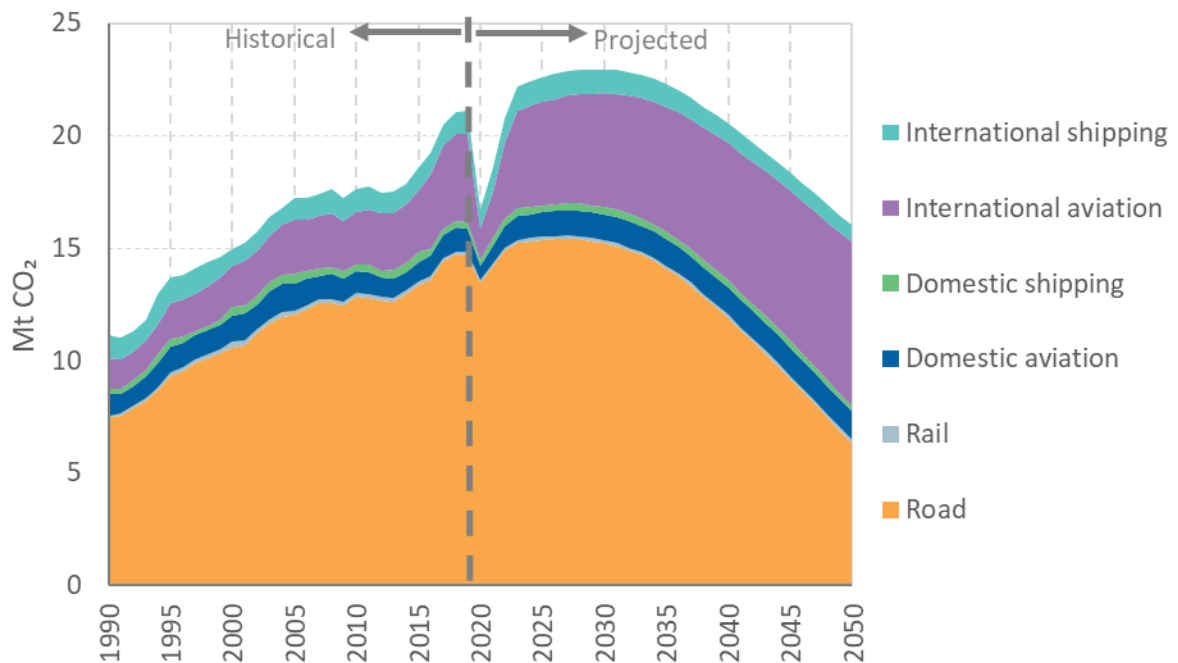


Figure 11.7: Current Policy Reference case emissions from transport including international transport

Source: Commission analysis.

Table 11.7: Current Policy Reference case emissions from transport including international transport (MtCO₂)

	2019	2030	2040	2050
Road	14.7	15.2	11.9	6.4
Rail	0.1	0.1	0.1	0.1
Domestic aviation	1.0	1.1	1.2	1.3
Domestic shipping	0.3	0.3	0.3	0.3
International aviation	3.9	5.1	6.1	7.3
International shipping	1.0	1.1	0.9	0.8
Total	21.1	22.9	20.5	16.0

Notes:

- Figure 11.7 shows emissions by travel type, similar to Figure 11.3, but with the two international modes, international aviation and international shipping, added.
- Between 1990 and 2018, emissions from international transport have been a significant and growing portion of transport emissions in Aotearoa. This is mainly due to growth of international aviation emissions.
- Once the COVID-19 shock has passed, international aviation emissions are likely to resume their growth, driven by increasing numbers of overseas visitors visiting Aotearoa. This is subject to a high degree of uncertainty.
- As noted in *Chapter 3: How to measure progress*, international transport emissions are not within the scope of the first emissions budget, but we may elect to include them in later budgets. International aviation and international shipping are also already subject to specific international agreements to reduce emissions: the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) under the International Civil Aviation Organization and the greenhouse gas reduction provisions of the International Convention for the Prevention of Pollution from Ships (MARPOL) under the International Maritime Organisation.
- There is no internationally agreed approach to measuring a country's contribution to international aviation and shipping emissions. These graphs are based on purchases of bunker fuel in Aotearoa by international carriers.
- Historically, growth in international air traffic has outpaced improvements in aviation fuel efficiency, resulting in growing international aviation emissions. Although subject to significant uncertainty due to the potential long-term impacts of COVID-19, this trend is likely to resume in the future.
- International shipping emissions have not grown significantly as ship efficiency has kept pace with the relatively slow growth in international shipments. International shipping emissions are expected to decline modestly by 2050, as improving ship efficiency outpaces growth in shipments.

11.5 Energy, industry and buildings

Energy, industry and buildings include the energy supply sector and other industrial activities, which use energy and cause emissions. It also includes operational energy use in buildings, namely on-site

combustion of fossil fuels. Within ENZ, it is this module where the supply of energy for transport, buildings and other industrial activities is represented. This includes generating electricity for heating buildings and the refining of oil into petroleum for transport.

ENZ models future industrial activity based on historic trends, assumed growth and known dependencies such as fuel costs, competition for resources and other input drivers. ENZ deploys new emissions reduction technologies when they become technologically ready and economically viable.

Much of our industrial activity which produces emissions is condensed in a small number of plants owned by a small number of firms. Several of these are modelled explicitly, such as the refinery, steel mill and aluminium smelter. Their level of future activity will be a key driver of sector emissions and is also highly uncertain. For example, during 2020, a number of firms undertook strategic reviews and may dramatically change their future operation in Aotearoa.

As it is not possible for ENZ to predict these potential step changes in activity, we conservatively assume most of these activities continue at close to current levels, with existing plants and efficiencies. The exceptions to this are the Tiwai Point aluminium smelter and methanol producing facilities which are assumed to close by 2025 and 2040, respectively. This reflects the signalled exit of the aluminium smelter from Aotearoa by owner Rio Tinto. Methanol production is assumed to stop by 2040. It is assumed Methanex will cease production, as our largest fossil gas fields near the end of their economic life.

Future energy costs and emissions pricing will also be key in determining future emissions within the industrial and energy sectors. Energy and emissions pricing drives most of the modelled dynamics around industry decarbonisation in ENZ. Boiler conversion from coal to lower-emissions fuels occurs in the model when the continuing operating cost of a coal boiler and paying a carbon charge rises above the costs of replacing the boiler and purchasing an alternative fuel. Practical constraints are built into the model around the regional availability of fuels and the rate at which equipment can be replaced and infrastructure can be built. Changes in rates of industrial allocation in the NZ ETS are assumed to have no effect on industrial output, nor on uptake of mitigation options, where decisions are assumed to be made based on marginal costs.

This Current Policy Reference case largely assumes future energy costs and emissions pricing are similar to current levels. Because of this, there is limited switching to lower-emissions fuels.

The commodities produced by our industries and consumed by our society are traded globally. For example, Aotearoa exports infant formula, which has been produced from local milk, to families in China and imports televisions from China. ENZ includes assumptions on the future cost of a small number of commodities which can then influence domestic activity and emissions, but does not model international trade.

In addition to this, ENZ is based on a production-based accounting of greenhouse gas emissions. This means ENZ does not capture emissions embodied in imported materials or the emissions leakage which would occur if domestic industrial activity was displaced with imported material. These are important issues and dynamics and although they are not captured in the model, they will be addressed in commentary throughout the *2021 Supporting Evidence*.

Buildings in ENZ are represented in terms of the energy utilised in their operation. Energy used for space and water heating as well as cooking, lighting and electrical equipment are modelled explicitly within ENZ at an aggregated level for residential, commercial and public buildings.

Greenhouse gas emissions from these uses of energy are accounted for in ENZ. Whether from gas combusted onsite in a gas boiler or from the plants which generate the electricity used in a hot water cylinder. This means that we can see from a whole-energy-system point of view the emissions footprint of operating our homes and workplaces.

As population and GDP increase within the model, the number of buildings and requirements for energy increase. Within the model, buildings are split into existing and future builds with varying energy efficiency opportunities, construction rates and retrofit cycles. Energy uses are disaggregated into space heating, water heating, cooking, lighting and other for each fuel type (electricity, fossil gas, LPG, coal and biomass). In the model, consumer choice of heating technology (fossil fuel or electric) at the time of a new build or retrofit is based on relative costs of equipment and fuel. A fossil fuel phase-out profile overrides this economic based selection – this phase out either reflects societal behavioural changes or a mandated approach.

The energy efficiency of heating in buildings and in appliances are also represented in ENZ. Efficiency measures such as improved insulation or a conversion of lighting to LEDs reduce the operational energy demand for buildings in the model.

11.5.1 Primary metal production

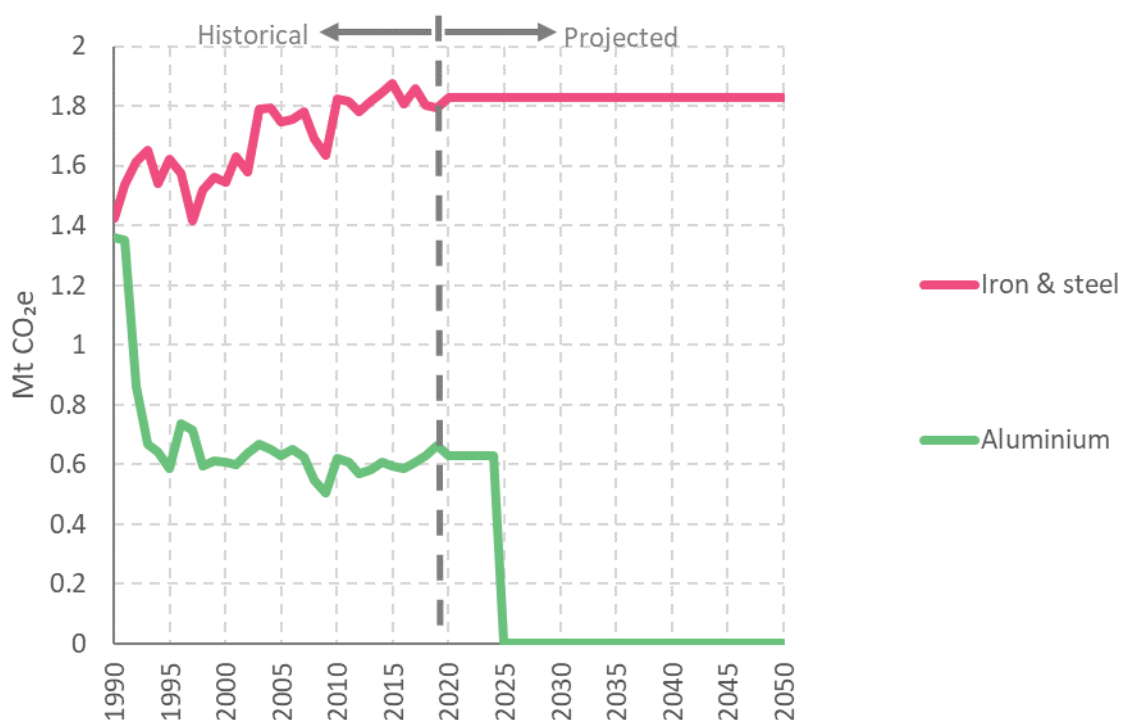


Figure 11.8: Current Policy Reference case emissions from primary metal production

Source: Commission analysis

Table 11.8: Current Policy Reference case emissions from primary metal production (MtCO₂)

	2019	2030	2040	2050
Iron and Steel	1.8	1.8	1.8	1.8
Aluminium	0.7	0.0	0.0	0.0
Total	2.5	1.8	1.8	1.8

Notes:

- Domestic emissions from iron and steel production are mostly from the chemical reaction which occurs between iron sand and coal to produce iron metal. From 1990 to 2019 these emissions have remained largely flat at an average of 1.8 MtCO₂.
- Direct process emissions and fossil fuel use from the production of aluminium have held constant at around 0.7 MtCO₂ since the early 1990s. The operation largely eliminated F-gas emissions at the beginning of the displayed record. Since this time the emissions have been around 90% carbon dioxide and 10% F-gas emissions.
- Aluminium production emissions are projected to reduce from current levels to zero by 2025, where they remain out to 2050.
- This reduction is due to an assumed closure of the Tiwai Point aluminium smelter with production ramping down by 31 December 2024. In January 2021, following negotiations resulting in a new electricity contract, Rio Tinto confirmed continued operation of the smelter through to December 2024.¹⁰
- Projected emissions for iron and steel production remain constant at 1.8 MtCO₂ out to the end of this period. However, there is considerable uncertainty around the future emissions from this activity.
- The steel mill has recently decided to cut 150-200 jobs following a strategic review.¹¹ This restructure has not been assumed to influence emissions in the future. However, Bluescope Steel (owner of NZ Steel) has signalled potential closure of the mill if restructuring and redundancies do not improve profitability.
- It is assumed that the country's only integrated steel mill will not undergo modernisation or transformation during this period.

¹⁰ (Rio Tinto, 2021)

¹¹ Carroll (2020)

11.5.2 Petrochemical production



Figure 11.9: Current Policy Reference case emissions from petrochemical production

Source: Commission analysis

Table 11.9: Current Policy Reference case emissions from petrochemical production (MtCO₂)

	2019	2030	2040	2050
Petrochemical production	2.0	0.7	0.2	0.2

Notes:

- Emissions from chemical production in Aotearoa are mostly from the combustion of fossil gas in steam methane reformers, to produce methanol and urea. These industries were enabled following the discovery and production of fossil gas from onshore and offshore Taranaki fields. Production and emissions from these industries has closely followed the lifecycle of producing fossil gas fields. The Maui field established and sustained the industry until around 2000 and the Pohokura field has ramped up since this time.
- In the reference case, the projected emissions hold at the recent average level of 2.0 MtCO₂ until 2021. Projected emissions then drop to 0.7 MtCO₂ by 2030 and 0.2 MtCO₂ by 2040. They remain at this level until 2050.
- This step change in emissions between 2030 and 2040 reflects the Waitara Valley methanol production train being mothballed in 2021 based on public announcements and the assumed staged closure of the two Motunui methanol production trains. It is possible that production

would cease before or continue after this date, however the current rate of fossil gas consumption for methanol production is incompatible with estimates of permitted fossil gas reserves. Because of this, for this modelling exercise an assumption around closure dates has been required. The residual emissions beyond this date are primarily from the production of urea.

- Because of the uncertainty in the level of future methanol production, there is considerable uncertainty in future emissions in chemical production.
- This projection draws on the analysis of Concept Consulting (2019) in their *Long-term gas supply and demand scenarios* report.

11.5.3 Cement, lime and glass production

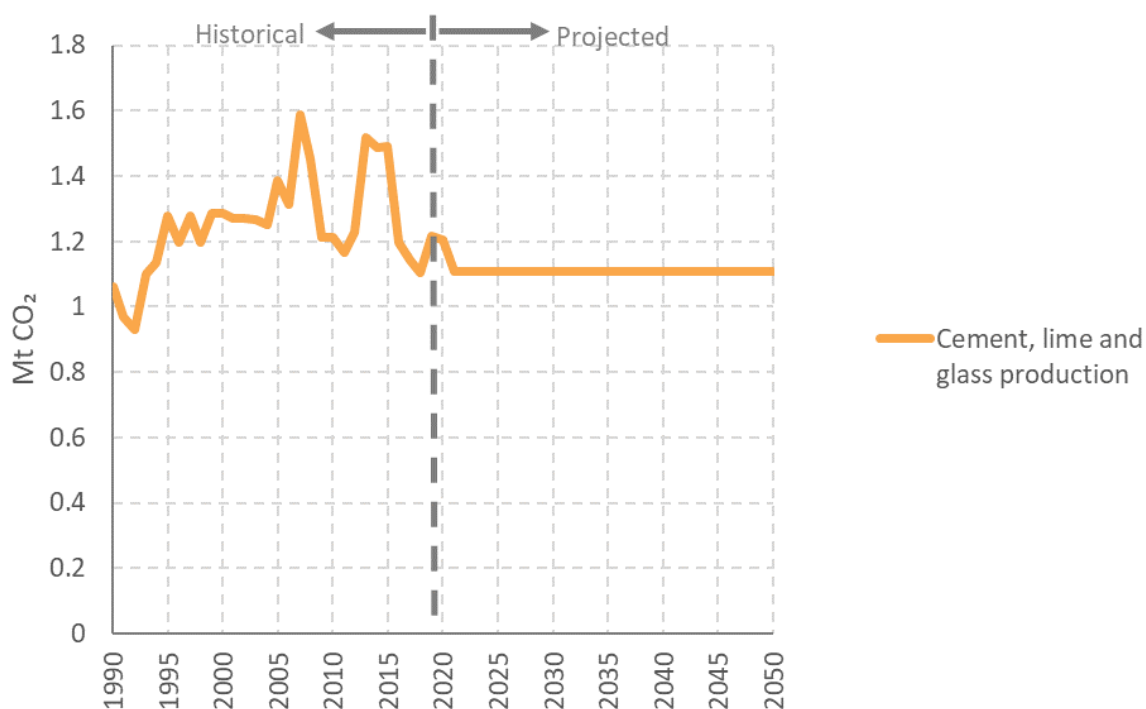


Figure 11.10: Current Policy Reference case emissions from cement, lime and glass production

Source: Commission analysis

Table 11.10: Current Policy Reference case emissions from cement, lime and glass production (MtCO₂)

	2019	2030	2040	2050
Cement, lime and glass production	1.2	1.1	1.1	1.1

Notes:

- Carbon dioxide emissions from cement, lime and glass manufacturing are from fuel combustion for process heat and the calcination reaction which converts limestone into the desired products. Historic emissions have fluctuated slightly due to changes in plants and production but have averaged around 1.3 MtCO₂.

- Figure 11.10 shows that in the reference case, projected emissions would decline slightly from 1.2 MtCO₂ in 2019 to 1.1 MtCO₂ in 2050.
- Under the reference case, small amounts of emissions reduction would be achieved in cement manufacturing through increased use of biofuels and waste materials as an alternative to coal for energy.

11.5.4 Food and wood, pulp and paper processing

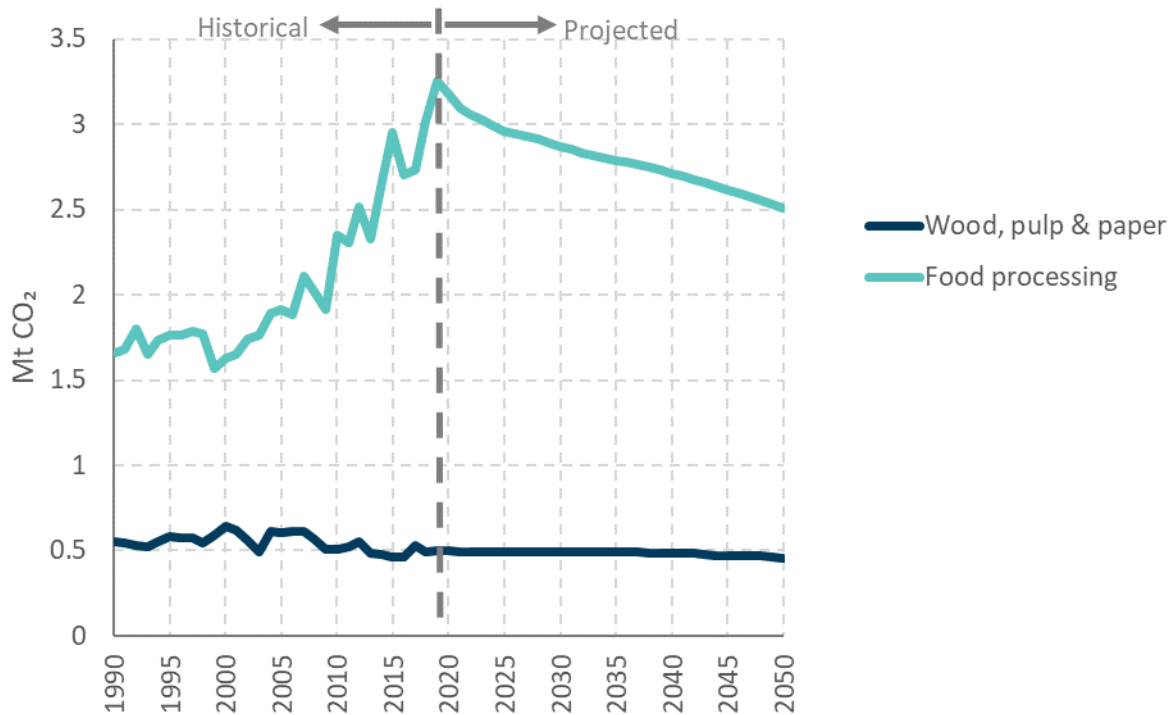


Figure 11.11: Current Policy Reference case emissions from food and wood processing

Source: Commission analysis

Table 11.11: Current Policy Reference case emissions from food and wood processing (MtCO₂)

	2019	2030	2040	2050
Wood, pulp and paper processing	0.5	0.5	0.5	0.5
Food processing	3.3	2.9	2.7	2.5
Total	3.7	3.4	3.2	3.0

Notes:

- Emissions in food processing and wood, pulp and paper manufacturing are largely from the combustion of coal, gas and diesel for process heat. Food processing emissions have historically increased considerably largely due to increases in total dairy production. Wood, pulp and paper processing emissions have remained constant over this period despite increases in production of wood products.

- Figure 11.11 shows that in the reference case, projected emissions in food processing would peak at 3.3 MtCO₂ in 2019 and then would reduce to 2.9 MtCO₂ in 2030 and 2.5 MtCO₂ by 2050.
- This Current Policy Reference projects peak agricultural milk production would occur in 2019 and maximum processing emissions would be concurrent with this. Beyond this, total production would be largely constant, but emissions would reduce at around 0.7% per year due to assumed improvements in energy efficiency and plant modernisation.
- Projected emissions in wood, pulp and paper processing would remain constant at around 0.5 MtCO₂ despite increases in production as increasing energy demand would be offset by greater use of biomass as a fuel.

11.5.5 Electricity generation

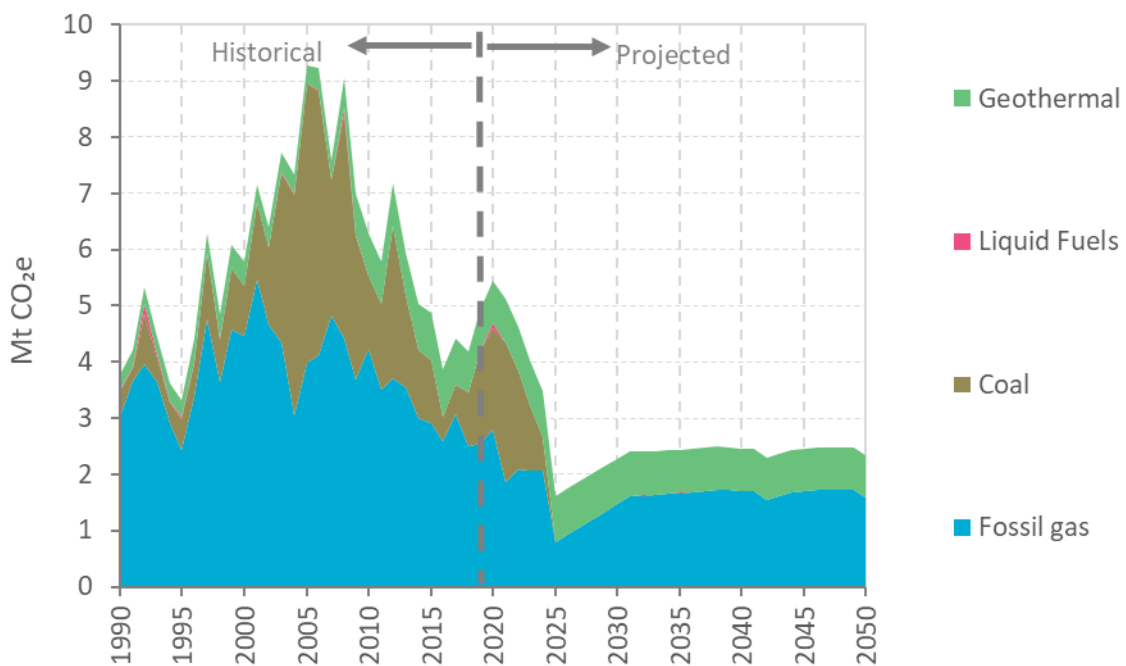


Figure 11.12: Current Policy Reference case emissions from electricity generation by fuel

Source: Commission analysis

Table 11.12: Current Policy Reference case emissions from electricity generation by fuel (MtCO₂)

	2019	2030	2040	2050
Fossil gas	2.5	1.5	1.7	1.6
Coal	1.6	0.0	0.0	0.0
Liquid Fuels	0.0	0.0	0.0	0.0
Geothermal	0.7	0.8	0.8	0.8
Total	4.9	2.3	2.5	2.3

Notes:

- Past emissions from electricity generation have been primarily from the use of coal and fossil gas used in thermal generation plants. The amount of coal and fossil gas used depends on electricity demand and climatic conditions. Electricity demand changes depending on the time of day, with daily peaks in the morning and evening. Demand also varies with the season and is generally higher in winter than in summer. Electricity emissions tend to be higher in years when hydro storage is low, and more fossil fuels are used to meet the shortfall in generation.
- Geothermal electricity generation also contributes to overall electricity emissions, but average emissions per kilowatt-hour are about a quarter that of fossil gas, with substantial variation from field to field.
- Electricity generation emissions peaked at 9.3 MtCO₂ in 2005.
- Figure 11.12 shows that in the reference case, emissions are projected to decrease from 4.9 MtCO₂ in 2019 to 2.2 MtCO₂ in 2030 and 2.3MtCO₂ in 2050, despite a 26% increase in total electricity generation. The system operates at between 89% and 94% renewables from 2025.
- Projected generation emissions would be at a minimum around 2025. This is a consequence of the assumed closure of the aluminium smelter, which would release a surplus of hydroelectricity to the market and temporarily displace some use of fossil gas.
- Geothermal, wind and solar generation would provide increases in electricity supply and would also further displace thermal generation as they would become increasingly affordable to build. Residual emissions beyond 2030 would be from the use of fossil gas for dry year firming and peaking, and from geothermal fields. This is shown in Figure 11.13.
- These emissions and electricity generation totals include cogeneration plants.

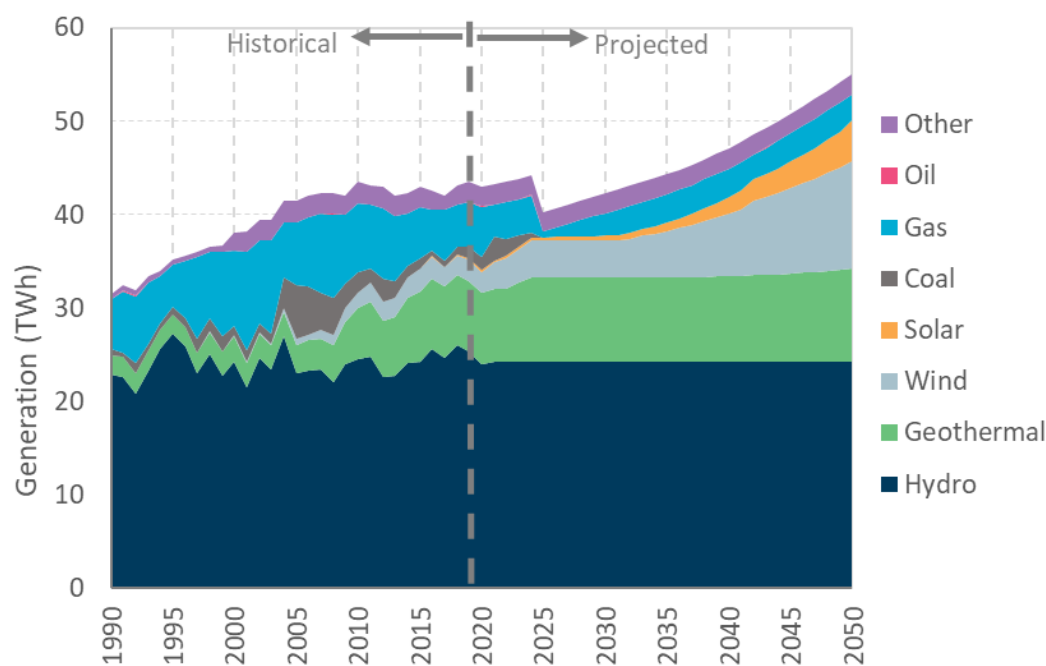


Figure 11.13: Current Policy Reference case electricity generation by fuel type

Source: Commission analysis.

11.5.6 Fossil fuel production



Figure 11.14: Current Policy Reference case emissions from fossil fuel production

Source: Commission analysis

Table 11.13: Current Policy Reference case emissions from fossil fuel production (MtCO₂e)

	2019	2030	2040	2050
Refining	1.0	0.9	0.9	0.9
Other fossil fuel production	1.3	1.0	1.0	0.6
Total	2.4	1.9	1.8	1.5

Notes:

- Emissions from fossil fuel production are mostly from petroleum refining and oil and gas production. Oil and gas production emissions result from operational venting and flaring of carbon dioxide and fugitive emission of methane at wells and in pipelines – these emissions have fluctuated historically. Refining emissions have remained largely constant and have averaged 1 MtCO₂e per year since 1990.
- Figure 11.14 shows that total emissions from these activities are projected to decrease from 2.4 MtCO₂e in 2019 to 1.9 MtCO₂e in 2030 and 1.5 MtCO₂e in 2050.
- The reduction in production emissions out to 2030 is largely due to a 40% downscale in domestic fossil gas production due to reduced demand for electricity generation and the assumed closure of the Waitara Valley methanol production train and one Motunui

methanol production train by 2030. Uncertainty around the level of future of domestic methanol production contributes uncertainty to this projection.

- Refining emissions reduced in 2020 to 17% below 2019 levels, and then hold constant until the end of the projection.
- The refinery has recently announced it will cut back production volumes to 1995 levels and cease bitumen production. This initial emissions reduction represents this restructure. Beyond this, emissions remain constant, despite a reduction in demand for petroleum for transport, because it is assumed that the 40% of current petroleum, which is imported refined, is displaced before domestic processing is reduced. The refinery’s future operation is still uncertain and introduces uncertainty in this projection.

11.5.7 Emissions from fossil fuel use in buildings



Figure 11.15: Current Policy Reference case emissions from onsite fuel use in buildings

Source: Commission analysis

Table 11.14: Current Policy Reference case emissions from onsite fuel use in buildings (MtCO₂)

	2019	2030	2040	2050
Residential buildings	0.7	0.8	0.8	0.8
Commercial and public buildings	1.1	1.2	1.1	1.1
Total	1.8	1.9	1.9	1.9

Notes:

- Direct emissions from fossil fuel use in buildings are primarily from the combustion of fossil gas, coal and liquid fossil fuels for cooking, and space and water heating in residential, commercial and public buildings.
- The annual total of these emissions has held roughly constant during the period from 1990 to 2019 at an average of 1.8 MtCO₂ despite a 40% increase in population and building stock.
- Figure 11.8 shows that total emissions are projected to remain roughly constant relative to 2019 and are 1.9 MtCO₂ at 2030 and 1.9 MtCO₂ at 2050.
- In this reference projection fossil gas and LPG remain affordable fuels for heating in homes and buildings, and the total number of gas connections is assumed to increase as the total building stock increases. However, despite this, combustion emissions hold relatively flat due to efficiency improvements in space and water heating systems and improvements in building performance. Coal use contributed about 10% of the total emissions in 2019 and in this projection is continued to be used as there is no targeted phase out.
- Electricity use in buildings can also contribute to periods of peak demand and the usage of fossil-fuelled thermal plants for electricity generation. These indirect emissions due to thermal generation are accounted for under the classification of electricity generation in this reference case. Similarly, there are emissions from building construction and from the materials used for construction. Construction activity, energy use and emissions are accounted for under industrial activity as are emissions from domestic industries which produce construction material.
- The buildings categorisation is shown as part of Energy, industry and buildings in Figure 11.15. This includes only the direct emissions from the on-site fossil fuel use in residential, commercial and public buildings. This convention is continued in the other sections of this report which present emissions totals across all sectors.

11.5.8 Motive power - mining, construction and agriculture

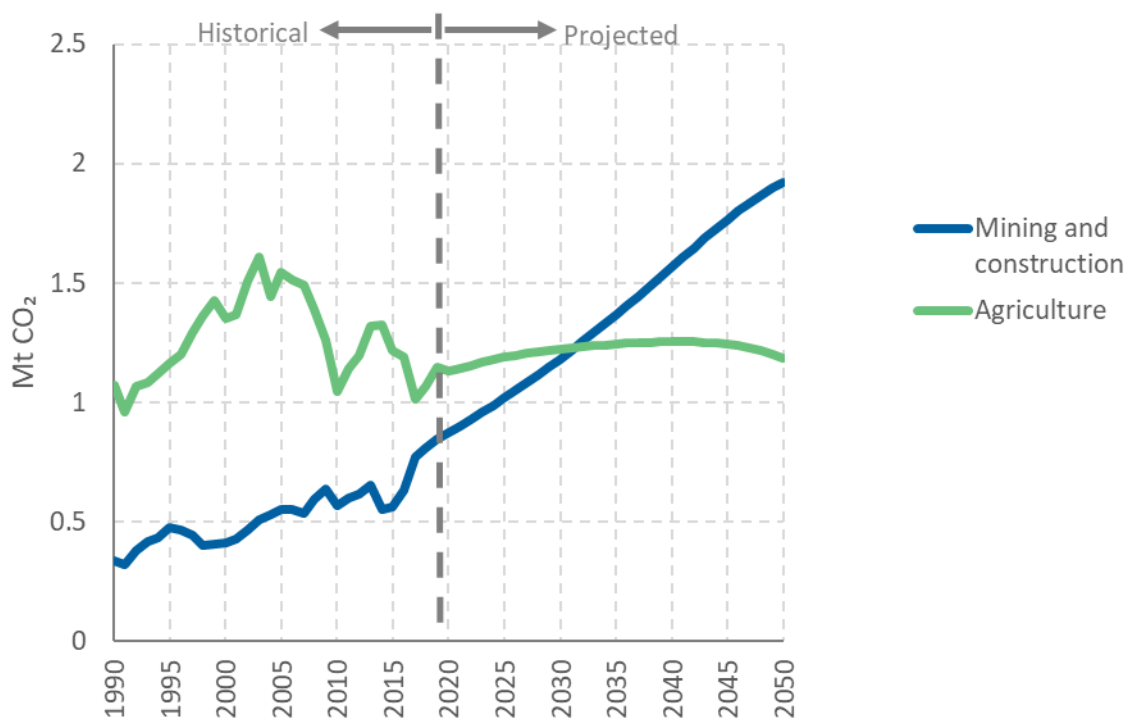


Figure 11.16: Current Policy Reference case motive power emissions

Source: Commission analysis

Table 11.15: Current Policy Reference case motive power emissions (MtCO₂)

	2019	2030	2040	2050
Mining and construction	0.8	1.2	1.6	1.9
Agriculture	1.1	1.2	1.3	1.2
Total	2.0	2.4	2.8	3.1

Notes:

- Motive power emissions are generated by liquid fossil fuel use in the mining, quarrying, construction, agriculture, forestry and fishing sectors. This is primarily diesel for use in machinery and off-road vehicles. There are a diverse set of use cases including mining trucks, farm machinery and fishing vessels. The totals here include the entire share of liquid fuel used in agriculture and the mining and construction sectors.¹²

¹² The Energy Efficiency and Conservation Authority (EECA)'s end use database substantiates that liquid fuel use in these sectors is overwhelmingly for motive power (Energy Efficiency and Conservation Authority, 2020). There is, however, sparse data on non-transport uses of liquid fuel. EECA have identified this as an information gap and is targeting improving the evidence base on these energy uses with a project in 2021.

- Total emissions have fluctuated historically but with an average of 1.8 MtCO₂ per year.
- Figure 11.16 shows that total emissions are projected to increase from 2.0 MtCO₂ in 2019 to 2.4 MtCO₂ in 2030 and to 3.1 MtCO₂ by 2050.
- The increase in emissions is due to an assumed increase in activity in the mining, quarrying and construction sectors at a rate of 3% per year. This growth is a continuation of the historic trend and consistent with requirements for infrastructure and building projects to support a growing population. Energy demand in the agricultural and forestry sectors is assumed to be constant at current levels. There is a downwards turn in emissions beyond 2040 as EVs and machinery begin to become available and economic for these use cases.

11.5.9 Residual emissions

Table 11.16: Current Policy Reference case residual emissions (MtCO₂)

	2019	2030	2040	2050
Residual	0.8	0.8	0.8	0.7

Notes:

- In addition to the emissions broken out in the transport, buildings and industry sectors, there is a total of emissions which have not been allocated to a specific sector and activity. Most of this is classified as ‘other industry’¹³ in the GHG Inventory classification. For these emissions we note that:
 - Historical emissions have ranged from 0.7 MtCO₂ to 1.8 MtCO₂.
 - Projected emissions largely hold at the 2019 value of 0.8 MtCO₂.
 - For these emissions we coarsely assume that liquid fuel use would decarbonise at the same rate as motive power applications in the mining, construction and agriculture sectors. Solid and gas fuel use would transition fuel use in the same way as the food processing sector.

11.6 Land

ENZ contains the area and emissions associated with the following land uses. While these are not the only land uses that contribute to emissions or emissions removals, they make the biggest contribution towards emissions budgets and targets.¹⁴

The land uses included in ENZ are:

- Sheep, beef and deer farming¹⁵

¹³ May include manufacturing of machinery, textile and leathers, and other industries.

¹⁴ Pre-1990 native forest area is not modelled, as emissions removals from it are not part of emissions accounting for the first set of emissions budgets. Deforestation emissions from these forests are included, however, but do not require a full modelling of the total land area. For a full discussion of forest accounting see *Chapter 3: How to measure progress*.

¹⁵ Area used for production, not whole owned area.

- Dairy farming
- Horticulture
- Arable farming
- Exotic forest (pre-1990 and post-1989)
- New native forest (Post-1989)¹⁶
- Other¹⁷

ENZ models land in Aotearoa at a national level. However, also understanding the uses of Māori collectively-owned land would be a valuable layer in the analysis. Data limitations mean it is not possible to consider specific projections for Māori collectively-owned land out to 2050, but relevant information about Māori collectively-owned land is considered alongside the reference case projections. What is known is that some Māori-collectives own large tracts of land and could face challenges transitioning land use. The Crown needs to work in partnership with Māori-collectives to understand their aspirations for land, particularly forestry, and the barriers to achieving these.

We use ENZ to generate our Current Policy Reference case using land areas and livestock numbers from the MPI October 2020 data update for their ‘With Existing Measures’ scenario. This input data reflects important recent policy developments, such as the National Policy Statement for Freshwater Management and amendments to the NZ ETS, passed by Government in 2020. The key model underlying this activity data is MPI’s Pastoral Supply Response Model, which projects trends in animal populations, primarily in response to export prices, productivity trends and the returns on agricultural land relative to forestry.

Nitrogen fertiliser emissions are attributed to the land use where fertiliser is applied. We estimate fertiliser use per hectare for each land use in 2019 based on data from Stats NZ.¹⁸ Use per hectare is assumed to reduce at 0.15% per year to align with MPI’s ‘With Existing Measures’ scenario. The same split among land uses is also applied to emissions from liming.

A level of ongoing productivity gains is also assumed for land uses in the reference case but there is no adoption of new technologies such as methane inhibitors or vaccines for ruminants. The impact of these technologies is investigated in future policy scenarios presented in *Chapter 12: Long-term scenarios to meet the 2050 target*.

Our Current Policy Reference case emissions projections for forestry and agriculture are similar but not identical to those from MPI models, as shown in the *Section 11.8 Comparisons with other projections*, later in this chapter.

¹⁶ The modelled forestry options (exotic forests and new native forests) are proxies for a range of different forest management practices and species that may suit different farms, catchments and regions. New native forests can be established through reversion and planting. See *Chapter 9: Removing carbon from our atmosphere*.

¹⁷ ‘Other’ land is a broad category that includes other types of farming and areas of land on-farm that are not in pasture, crops, or forest.

¹⁸ (Stats NZ, 2021b)

11.6.1 Agriculture emissions - biogenic methane

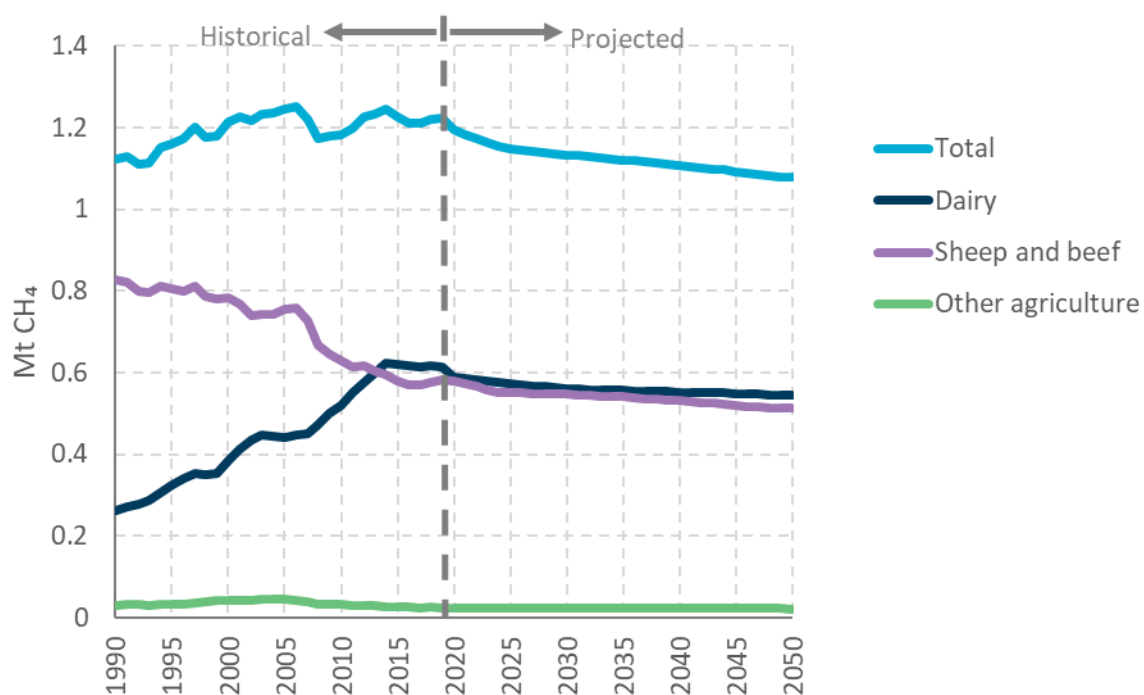


Figure 11.17: Current Policy Reference case biogenic methane emissions from agriculture

Source: Commission analysis.

Table 11.17: Current Policy Reference case biogenic methane emissions from agriculture (MtCH₄)

	2019	2030	2040	2050
Dairy	0.61	0.56	0.55	0.54
Sheep and beef	0.58	0.55	0.53	0.51
Other agriculture	0.02	0.02	0.02	0.02
Total	1.22	1.13	1.11	1.08

Notes:

- Agricultural biogenic methane emissions largely come from dairy and sheep and beef farming.
- Figure 11.17 shows that from 1990 to 2019, biogenic methane emissions from dairy farming increased significantly from 0.26 MtCH₄ to 0.61 MtCH₄. Sheep and beef biogenic methane emissions declined from 0.83 MtCH₄ to 0.58 MtCH₄. Biogenic methane emissions from other types of agriculture stayed constant at approximately 0.02 MtCH₄ in the same period.
- In the reference case, total agricultural biogenic methane emissions decline steadily from 1.22 MtCH₄ in 2019 to 1.08 MtCH₄ in 2050.
- Within this reference case total, dairy biogenic methane emissions decline to 0.56 MtCH₄ in 2030 and 0.54 MtCH₄ in 2050. Sheep and beef biogenic methane emissions decline to 0.55 MtCH₄ in 2030 and 0.51 MtCH₄ in 2050. For other types of agriculture, biogenic methane emissions stayed constant at 0.02 MtCH₄ in 2050. These are mostly from deer farming.

- These reductions are primarily driven by a combination of ongoing emissions intensity improvements and land-use change. Dairy biogenic methane emissions per kilogram of milk solids and sheep and beef biogenic methane emissions per kilogram of meat decline by an average annualised rate of 0.4% and 0.3%, respectively. The rate slowly reduces towards 2050. This is in line with or slightly more conservative than historic trends, which have seen methane emissions efficiency improvements of approximately 1.0% per year across both dairy and meat farming since 1990. These improvements are due to a combination of animal genetics, farm management practices and structural changes in the sector such as less efficient producers exiting the market.
- Land-use change includes slight decreases in dairy land over time and more substantial decreases in sheep and beef land (although at a much slower rate than historic trends). Details of land-use change are provided in *Section 11.6.4: Agricultural and forest land area*.
- These national trends may be different on Māori collectively-owned land, where governance strategic priorities, management practices and owners' aspirations differ from other farms in Aotearoa. For example, there is some evidence that Māori collectively-owned farms have lower animal stocking rates than the national average.¹⁹
- This could mean that emissions reductions linked to stocking rates on Māori collectively-owned land might plateau earlier, as the potential for further reductions are exhausted.

11.6.2 Agricultural emissions - nitrous oxide

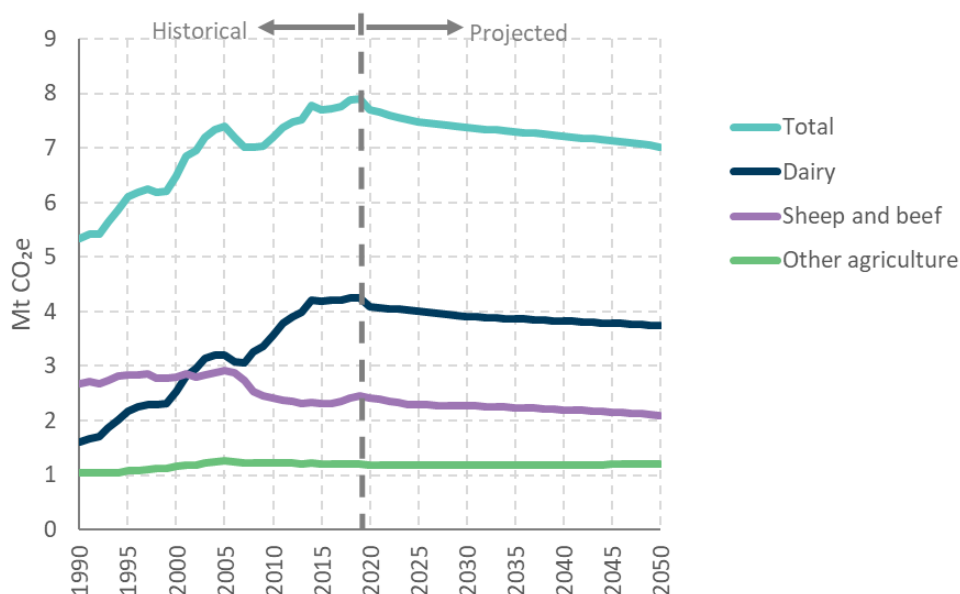


Figure 11.18: Current Policy Reference case nitrous oxide emissions from agriculture

Source: Commission analysis.

¹⁹ Stats NZ (2020)

Table 11.18: Current Policy Reference case nitrous oxide emissions from agriculture (MtCO₂e)

	2019	2030	2040	2050
Dairy	4.2	3.9	3.8	3.7
Sheep and beef	2.4	2.3	2.2	2.1
Other agriculture	1.2	1.2	1.2	1.2
Total	7.9	7.4	7.2	7.0

Notes:

- Agricultural nitrous oxide emissions largely come from animal urine patches and, to a lesser extent, fertiliser use and manure management.
- Figure 11.18 shows that from 1990 to 2019, nitrous oxide emissions from dairy farming increased significantly from 1.6 MtCO₂e to 4.2 MtCO₂e. Sheep and beef nitrous oxide emissions declined from 2.7 MtCO₂e to 2.4 MtCO₂e. Nitrous oxide emissions from other types of agriculture stayed relatively constant at 1.2 MtCO₂e during this period.
- In the Current Policy Reference case, total agricultural nitrous oxide emissions decline from 7.9 MtCO₂e in 2019 to 7.0 MtCO₂e in 2050. Dairy nitrous oxide emissions decline from 2019 levels to 3.9 MtCO₂e in 2030 and 3.7 MtCO₂e in 2050. Sheep and beef nitrous oxide emissions decline to 2.3 MtCO₂e in 2030 and 2.1 MtCO₂e in 2050. Nitrous oxide emissions from other types of agriculture stay roughly constant.
- These reductions are primarily driven by a combination of ongoing efficiency gains and land-use change. Nitrous oxide emissions per kilogram of milk solids and sheep and beef meat decline between 2019-2050 at an annualised average rate of 0.4%. The rate slowly reduces towards 2050 and is slightly slower than historic trends for dairy, and slightly faster for sheep and beef. These improvements are due to a combination of animal genetics, farm management practices and structural changes in the sector such as less efficient producers dropping out of the market. Details of land-use change are provided in *Section 11.7.4: Agricultural and forest land area*.
- The distinct trends on Māori collectively-owned land, in relation to biogenic methane would also apply to nitrous oxide. For example, Māori collectively-owned farms used an average of 0.26 tonnes of fertiliser per hectare of grassland in 2019-2020, compared to 0.29 tonnes for farms in Aotearoa as a whole.²⁰ This suggests fertiliser emissions reductions could be occurring more quickly on Māori collectively-owned land (possibly because of water policies in specific areas) and/or that these reductions could plateau earlier.

²⁰ (Stats NZ, 2021a)

11.6.3 Agriculture emissions - carbon dioxide

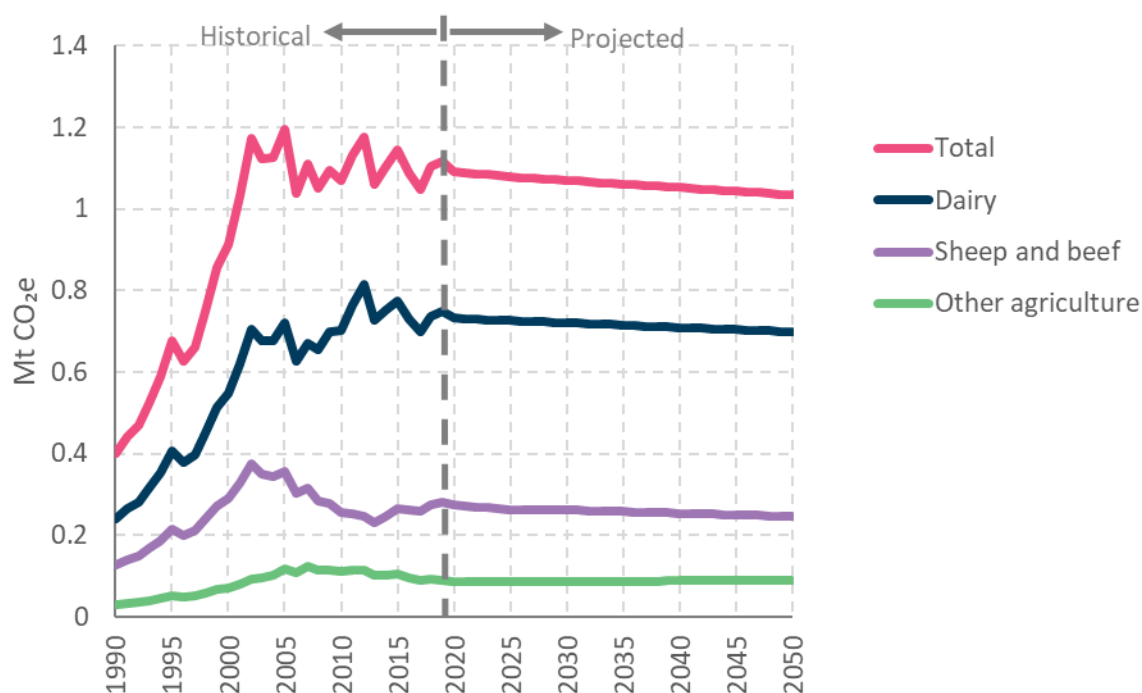


Figure 11.19: Current Policy Reference case carbon dioxide emissions by agriculture

Source: Commission analysis.

Table 11.19: Current Policy Reference case carbon dioxide emissions by agriculture (MtCO₂)

	2019	2030	2040	2050
Dairy	0.75	0.72	0.71	0.70
Sheep and beef	0.28	0.26	0.25	0.25
Other agriculture	0.09	0.09	0.09	0.09
Total	1.12	1.07	1.05	1.03

Notes:

- Agricultural carbon dioxide emissions come from the use of limestone and urea on soils. Emissions from electricity, transport and other energy uses on farms are not included here, but in the relevant non-land sector emissions.
- Figure 11.19 shows that from 1990 to 2019, carbon dioxide emissions from dairy farming increased significantly from 0.24 MtCO₂ to 0.75 MtCO₂. Sheep and beef carbon dioxide emissions increased from 0.13 MtCO₂ in 1990 to 0.28 MtCO₂ in 2019. Carbon dioxide emissions from other agriculture increased from 0.03 MtCO₂ to 0.09 MtCO₂ in the same period.
- In the reference case, dairy carbon dioxide emissions stay relatively stable, increasing to 0.72 MtCO₂ in 2030, before dropping to 0.70 MtCO₂ in 2050. Sheep and beef carbon dioxide emissions decline to 0.26 MtCO₂ in 2030, and 0.25 MtCO₂ in 2050. Carbon dioxide emissions from other agriculture stays stable out to 2050.

- The distinct trends on Māori collectively-owned land in relation to nitrogen fertiliser could also apply to carbon dioxide from lime and urea.

11.6.4 Agricultural and forest land area

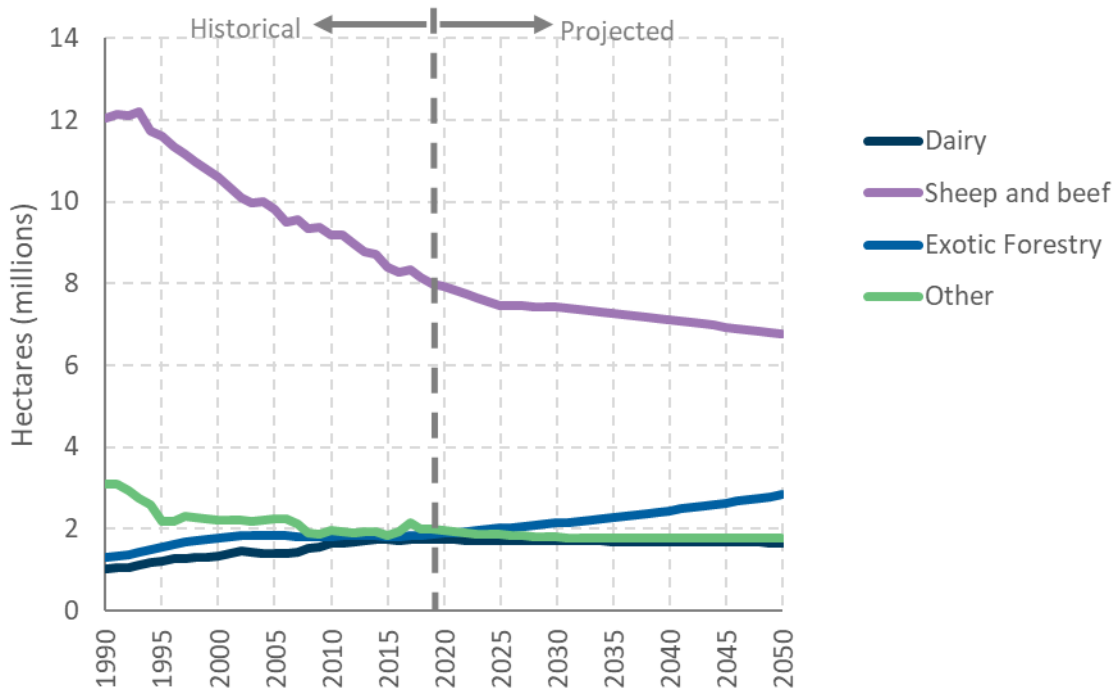


Figure 11.20: Current Policy Reference case agriculture and forest land use (large areas)

Source: Commission analysis

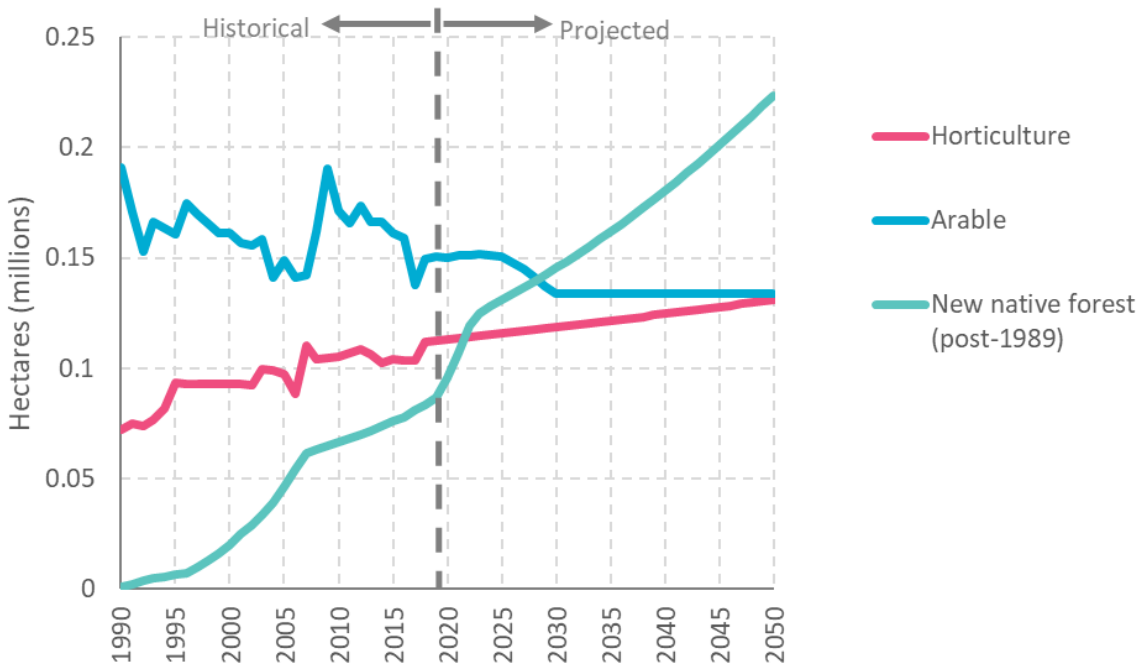


Figure 11.21: Current Policy Reference case agriculture and forest land use (small areas)

Source: Commission analysis.

Table 11.20: Current Policy Reference case agricultural and forest land areas (Mha)

	2019	2030	2040	2050
Dairy	1.74	1.71	1.69	1.66
Sheep, beef and deer	7.99	7.41	7.12	6.75
Exotic forest (pre-1990 and post-1989)	1.87	2.14	2.45	2.84
New native forest (post-1989)	0.09	0.15	0.18	0.22
Horticulture	0.11	0.12	0.12	0.13
Arable	0.15	0.13	0.13	0.13
Other	1.98	1.80	1.77	1.77

Notes:

- Land-use change is a key driver of emissions and removals by agriculture and forests. Different land uses make different contributions, and change between them is driven by a complex set of economic, environmental, cultural and social factors.
- Between 1990 and 2019, the biggest land-use change was the significant decrease in sheep and beef farming area, from 12 million hectares (Mha) to 8 Mha. This was in large part due to the economic restructuring of the late 1980s and early 1990s and the development of more lucrative markets for dairy and forestry. Dairy farming area increased from 1.02 Mha in 1990 to 1.74 Mha in 2019. Exotic forest area increased from 1.32 Mha in 1990 to 1.87 Mha in 2019.
- Areas of horticulture and arable farming, as well as new native forest, did not change significantly between 1990 and 2019.
- In the reference case, sheep and beef farming area decreases to 7.41 Mha in 2030 and 6.75 Mha in 2050. This is a significantly slower rate of decrease than the historic trend. Dairy farm area decreases to 1.71 Ma in 2030 and 1.66 Mha in 2050. Exotic forest area increases to 2.14 Mha in 2030 and 2.84 Mha in 2050. New native forest area increases to 0.15 Mha in 2030 and 0.22 Mha in 2050
- These land-use changes are likely driven by a combination of sheep and beef farms retiring unproductive land, stricter freshwater policies limiting dairy area and a higher emissions price driving more afforestation.
- The total area of exotic forest on Māori collectively-owned land would also likely increase, as Treaty settlements return the remaining Crown forest licensed lands to Iwi. Strategically, if there is alignment with Iwi/Māori aspirations, the Crown could work in partnership with Iwi and other relevant Māori-collectives to increase afforestation in the short to medium term. This approach is particularly relevant given Māori-collectives own reasonably large areas of land with potential for afforestation or optimised afforestation.
- Additionally, there are opportunities associated with forestry that would support Iwi/Māori cultural drivers and Iwi/Māori aspirations, as increased cover of native forestry would support revitalisation and preservation of indigenous biodiversity, mahinga kai species and rongoā.

- Horticulture and arable farming both occupy relatively small land areas and change slightly in the reference case. Arable farming decreases in area from 0.15 Mha in 2019 to 0.13 Mha in 2050. Horticulture area expands slightly from 0.11 Mha in 2018 to 0.13 Mha in 2050.

11.6.5 Afforestation

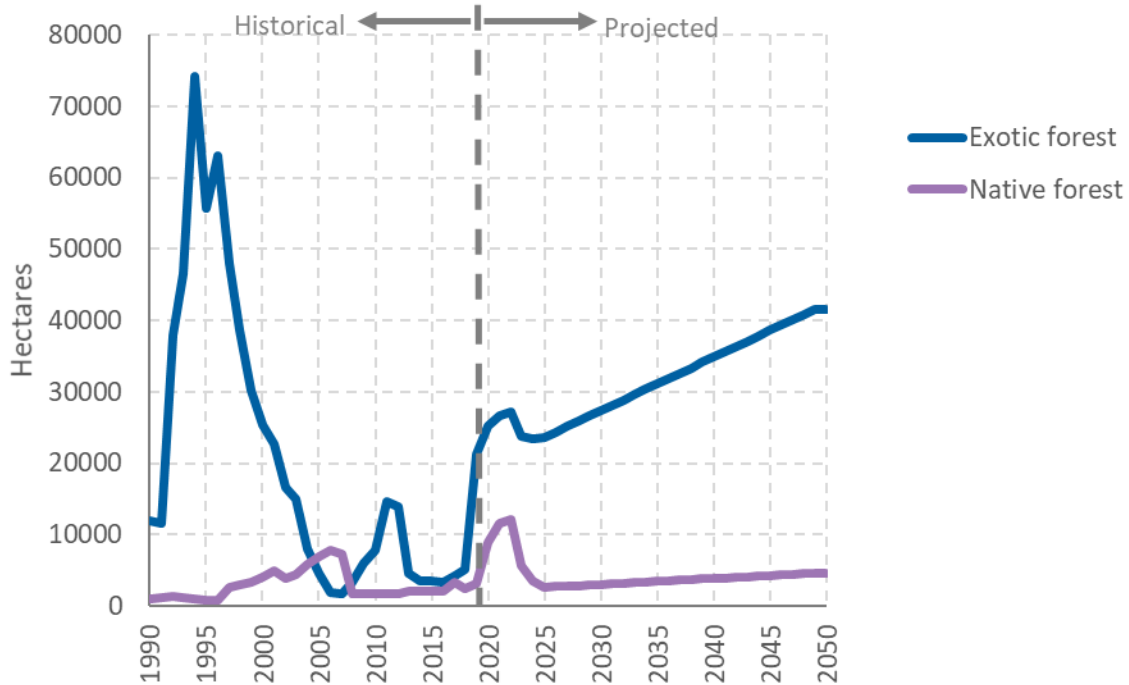


Figure 11.22: Current Policy Reference case gross afforestation

Source: Commission analysis

Table 11.21: Current Policy Reference case gross afforestation (ha/year)

	2019	2030	2040	2050
Exotic forest	21,357	27,381	34,862	41,595
Native forest	3,117	3,042	3,874	4,622
Total	24,474	30,424	38,736	46,216

Notes:

- Gross afforestation represents the increase in post-1989 exotic and native forest.
- Figure 11.22 shows that during the 1990s, there was a large spike in afforestation, reaching over 70,000 ha per year. This was followed by a period of net deforestation and low afforestation until 2018.
- In the reference case, most afforestation is of exotic forests.²¹ Exotic afforestation rates increase from 21,357 ha in 2019 to 27,381 ha in 2030 and 41,595 ha in 2050. Native

²¹ Afforestation areas refer to 'net-stocked' area, meaning the total area of actual forest, excluding roads and other non-forest parts of a forested area.

afforestation rates increase from 3,117 ha in 2019 to 3,042 ha in 2030 and 4,622 ha in 2050. The increase in afforestation between 2018 and 2023 is due to the One Billion Trees afforestation grant scheme.

- The afforestation numbers are taken from MPI, who use an assumption that 90% of afforestation driven by the NZ ETS is exotic and 10% native. The data also includes an assumption that 6.1% of the exotic forests are permanent and not harvested.
- Total gross exotic afforestation in the reference case between 2019-2050 is 1.0 Mha.
- Māori collectively-owned land use is likely to follow a slightly different trajectory than these national numbers. Cultural and spiritual ties with the whenua and indigenous biodiversity mean some Māori-collectives have stronger preferences for native forests over exotic forests. This means that the percentage of afforestation on Māori collectively-owned land, that is native forests in the reference case, is likely to be higher than the 10% assumed nationwide number.

11.6.6 Deforestation

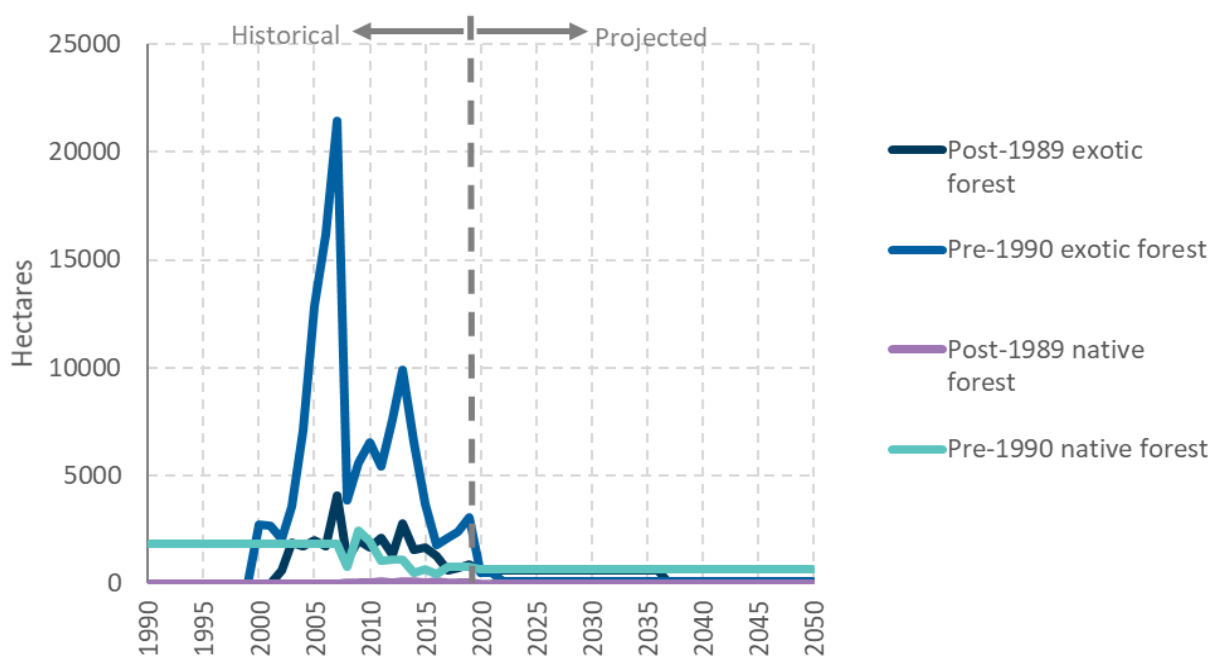


Figure 11.23: Current Policy Reference case deforestation

Source: Commission analysis

Table 11.22: Current Policy Reference case deforestation (ha)

	2019	2030	2040	2050
Post-1989 exotic	885	620	0	0
Pre-1990 exotic	3,052	73	73	73
Post-1989 native	59	0	0	0
Pre-1990 native	750	664	664	664
Total exotic deforestation	3,936	693	73	73
Total native deforestation	809	664	664	664

Notes:

- Deforestation is when forests are removed and converted to another land use. It is not a temporary forest loss (e.g., harvesting activity occurring as part of ongoing forestry land use).
- Figure 11.23 shows that between 2005-2007 there were spikes in exotic deforestation in anticipation of the introduction and reforms to the NZ ETS.
- In 2019 there were 885 ha and 3,052 ha of post-1989 and pre-1990 exotic deforestation, respectively. There were 59 ha and 750 ha of post-1989 and pre-1990 native deforestation, respectively.
- In the Current Policy Reference case there are low levels of ongoing deforestation. Post-1989 exotic deforestation decreases to 620 ha in 2030 and then 0 ha from 2037 onwards. Pre-1990 exotic deforestation is stable at 73 ha per year from 2022. From 2020 onwards there is no projected post-1989 native deforestation and pre-1990 native deforestation rates are constant at 664 ha per year.

11.6.7 Net forest emissions

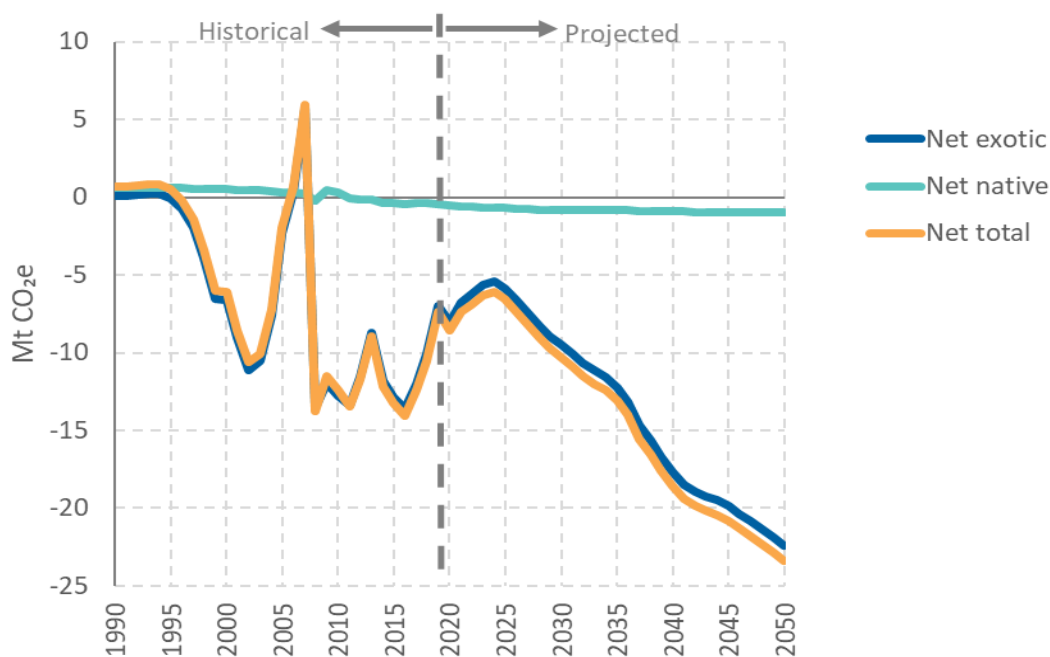


Figure 11.24: Current Policy Reference case net forest emissions

Source: Commission analysis

Table 11.23: Current Policy Reference case net forest emissions (MtCO₂)

	2019	2030	2040	2050
Exotic forest emissions removals	-10.58	-10.02	-17.75	-22.51
Native forest emissions removals	-0.77	-1.16	-1.25	-1.34

Exotic forest deforestation emissions	3.60	0.53	0.05	0.07
Native forest deforestation emissions	0.35	0.34	0.36	0.36
Exotic forest net emissions	-6.97	-9.48	-17.70	-22.44
Native forest net emissions	-0.42	-0.81	-0.89	-0.97
Total net forest emissions	-7.39	-10.29	-18.60	-23.41

Notes:

- Net forest emissions represent the carbon sequestered by forests minus emissions associated with deforestation and land-use change. Greater emissions removals result in negative net forest emissions when they exceed deforestation emissions. Net forest emissions therefore align closely with afforestation and deforestation rates.
- Figure 11.24 shows that In the reference case, net emissions removals by forests decline from 7.4 MtCO₂ in 2019 to 6.1 Mt CO₂ in 2024, before steadily increasing to reach 10.3 MtCO₂ by 2030 and 23.4 MtCO₂ by 2050. Most of these emissions removals are from exotic forests.
- Within net forest emissions, exotic deforestation emissions decline from 3.6 MtCO₂ in 2019 to 0.5 MtCO₂ in 2030 and to 0.07 MtCO₂ from 2050 onwards. Native deforestation emissions stay constant at about 0.35 MtCO₂ from 2030 onwards.

11.6.8 Forestry output

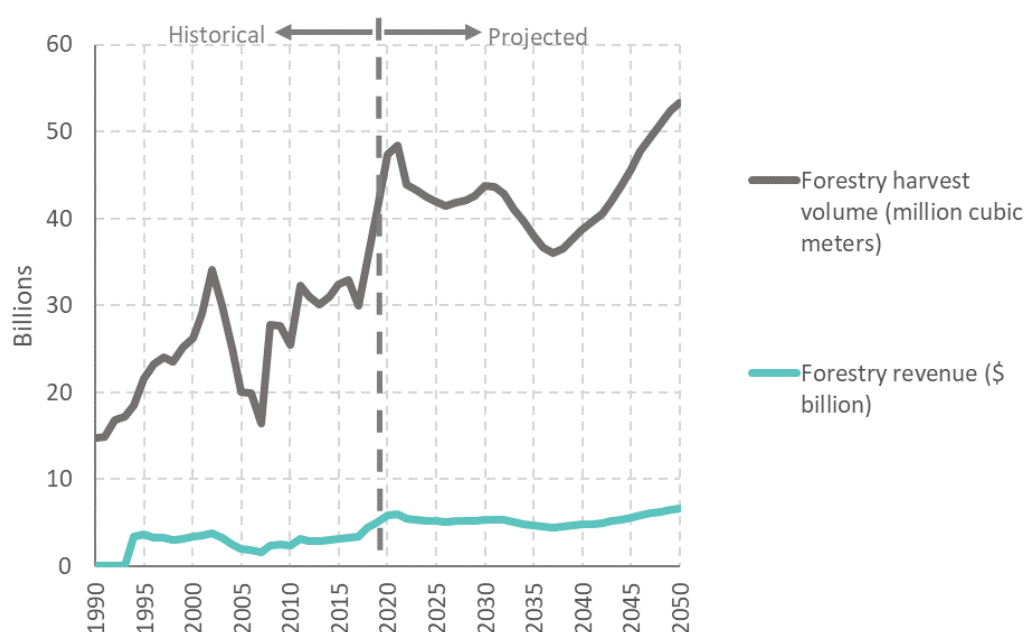


Figure 11.25: Current Policy Reference case forestry harvested volumes and revenue

Source: Commission analysis

Table 11.24: Current Policy Reference case forestry harvested volumes and revenue

	2019	2030	2040	2050
Forestry harvest volume (million cubic metres)	41.21	43.71	38.72	53.30
Forestry revenue (\$ billions)	5.08	5.39	4.77	6.57

Notes:

- Our production forests are mostly radiata pine and produce significant volumes of harvested wood for both export and domestic use.
- Between 1990 and 2019, harvested volumes increased from 14.8 to 41.21 million cubic metres. The growth is staggered in large part because of the mixed age class of production forests. Forestry revenue increased from \$3.4 billion in 1994²² to \$5.08 billion in 2019.
- In the reference case, harvested volumes increase to 43.71 million cubic metres in 2030 and 53.30 million cubic metres in 2050. Forestry revenue increases to \$5.39 billion in 2030 and \$6.57 billion in 2050. The growth in forestry outputs after 2030 is linked to the large projected increases in exotic production forests shown in Figure 11.25.

11.6.9 Sheep and beef production

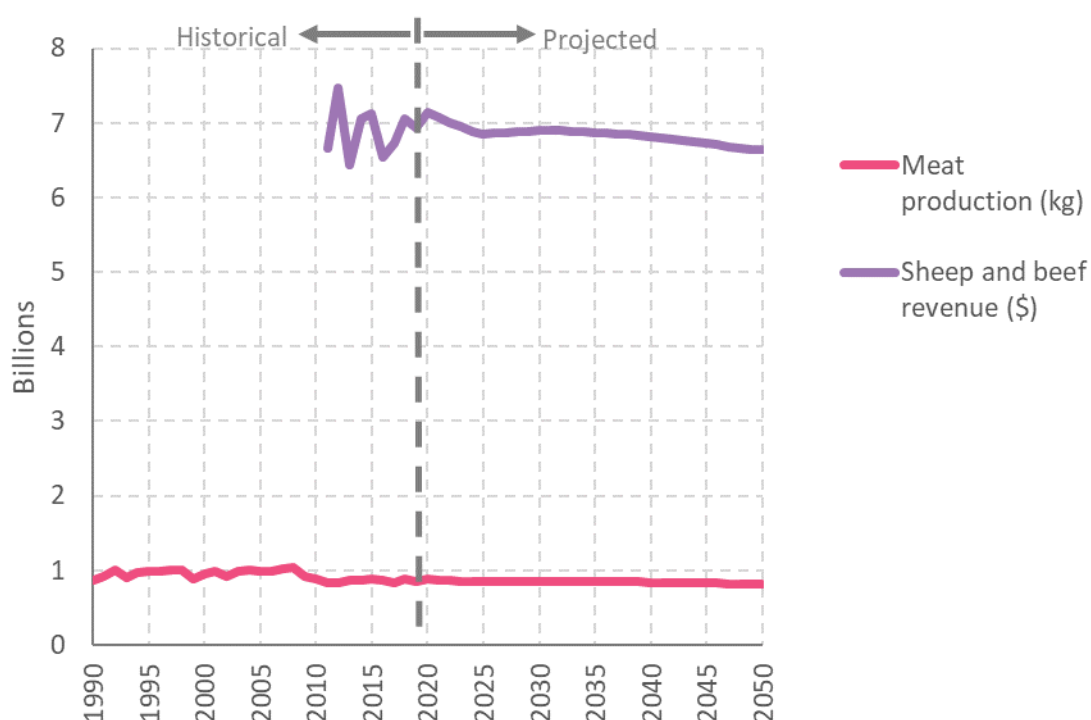


Figure 11.26: Current policy reference case sheep and beef production

Source: Commission analysis.

²² Forestry revenue data was only available from 1994.

Table 11.25: Current policy reference case sheep and beef production

	2019	2030	2040	2050
Meat production (billion kg)	0.86	0.85	0.84	0.82
Sheep and beef farming revenue (\$ billions)	6.94	6.90	6.82	6.64

Notes:

- Our meat exports are primarily based on sheep and beef meat.
- Between 1990 and 2019 meat production fluctuated between 0.86 and 0.87 billion kg per year.
- In the reference case, meat production decreases from 0.86 billion kg in 2019 to 0.82 billion kg by 2050.
- This is due to improving animal performance, with an annualised, averaged productivity gain in meat production per stock unit between 2019-2050 of 0.4% in the reference case. The historical rate from 1990-2019 was 2.1%. However, these gains are partially offset by the decline in sheep and beef land area shown in *Section 11.6.4 Agriculture and forest land area*.
- In turn, sheep and beef revenue²³ is expected to be \$6.9 billion in 2019 and in 2030 then decrease to \$6.64 billion in 2050.
- Revenue reflects production and the export price assumptions that can be found in our detailed assumptions spreadsheets available online.

²³ Sheep and beef revenue data was only available from 2010.

11.6.10 Sheep and beef stock numbers

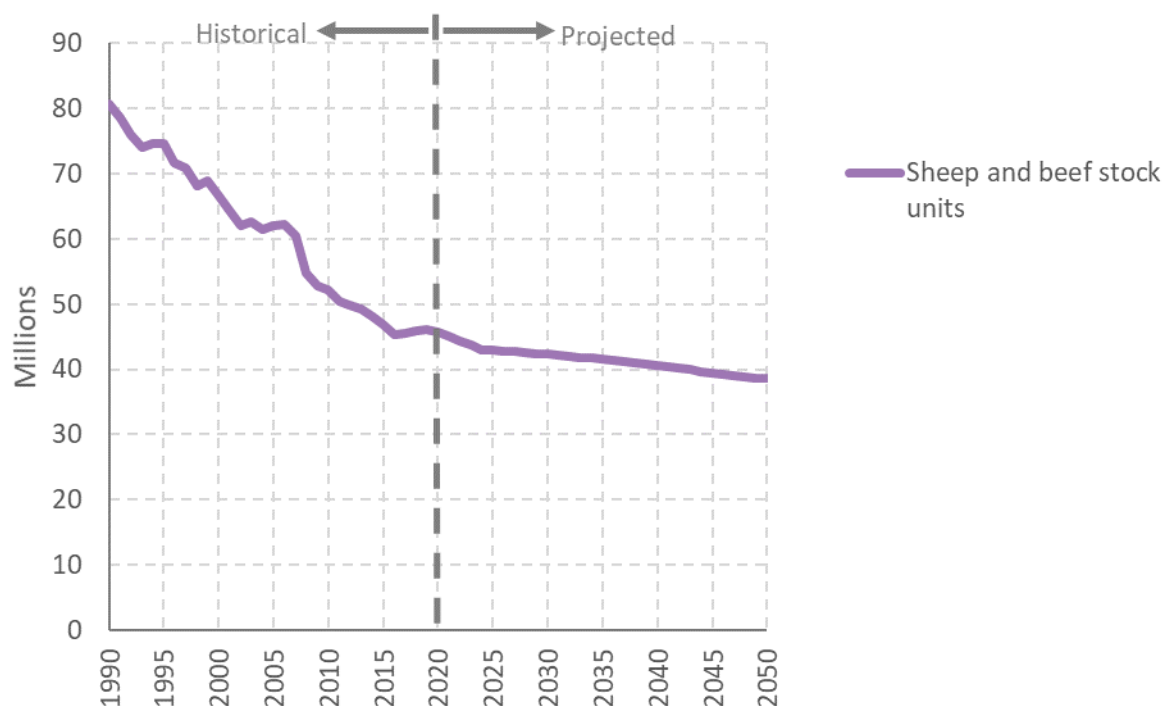


Figure 11.27: Current Policy Reference case sheep and beef stock units

Source: Commission analysis.

Table 11.26: Current Policy Reference case sheep and beef stock units (millions)

	2019	2030	2040	2050
Sheep and beef stock units	80.8	46.2	42.3	40.5

Notes:

- Stock units is a measurement to standardise sheep and beef herds across animal type and size. Different types of sheep convert to between 0.7-1.0 stock units, while cattle convert to between 4.0 and 6.0.²⁴
- Figure 11.27 shows that between 1990 and 2019, sheep and beef stock units decreased steadily from 80.8 million to 46.2 million. This was driven by the significant decrease in sheep and beef land area shown in Figure 11.27.
- In the reference case, sheep and beef stock units are expected to decline more slowly than the historical trend, in line with sheep and beef farm area. Stocking units reach 42.4 million in 2030 and 38.7 million in 2050.

²⁴ Beef + Lamb NZ (2017, p. 21) and BakerAg (2018). Animal numbers were provided by MPI and converted into stock units in ENZ using a ratio of one beef cattle animal to five sheep.

11.6.11 Dairy production

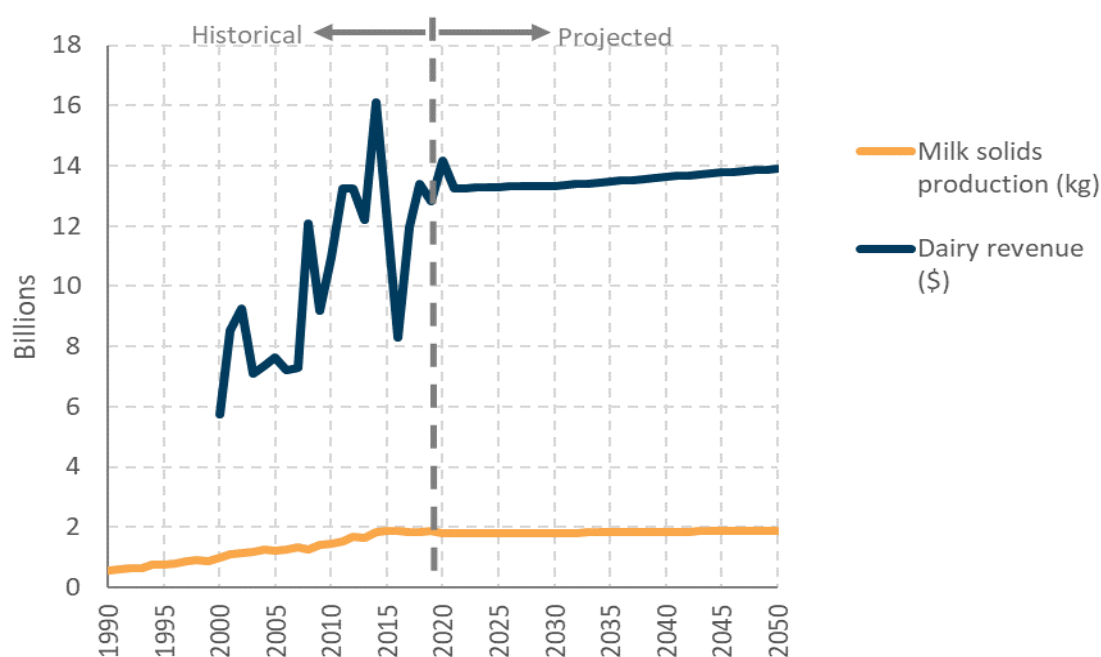


Figure 11.28: Current Policy Reference case dairy production

Source: Commission analysis

Table 11.27: Current Policy Reference case dairy production

	2019	2030	2040	2050
Milk solids (billion kg)	1.88	1.80	1.85	1.88
Dairy farming revenue (\$ billions)	12.8	13.3	13.6	13.9

Notes:

- Dairy products are some of our leading exports and production typically measured in terms of kilograms of milk solids.
- Figure 11.28 shows that between 1990 and 2019, milk solids production increased steadily, from 570 million kg milk solids to 1.88 billion.
- This is driven by both productivity gains and a growing area of land dedicated to dairy farming. The average annualised growth of milk solids production per dairy cattle between 2019-2050 is 0.5% in the reference case. This compares to 2.2% for the period 1990-2019.²⁵
- Dairy revenue follows a similar trend to production.²⁶ It increases steadily from 1990 to 2019, varying due to changes in export prices and reaching \$12.8 billion in 2019.

²⁵ Dairy cattle numbers refer to all dairy cattle, not just milking cows.

²⁶ Dairy revenue data was only available from 2000.

- In the Current Policy Reference case, milk solids production decreases to 1.8 billion kg in 2030 but increases to 1.88 billion kg in 2050. Dairy revenue follows a similar trend, reaching \$13.9 billion in 2050.

11.6.12 Dairy cattle

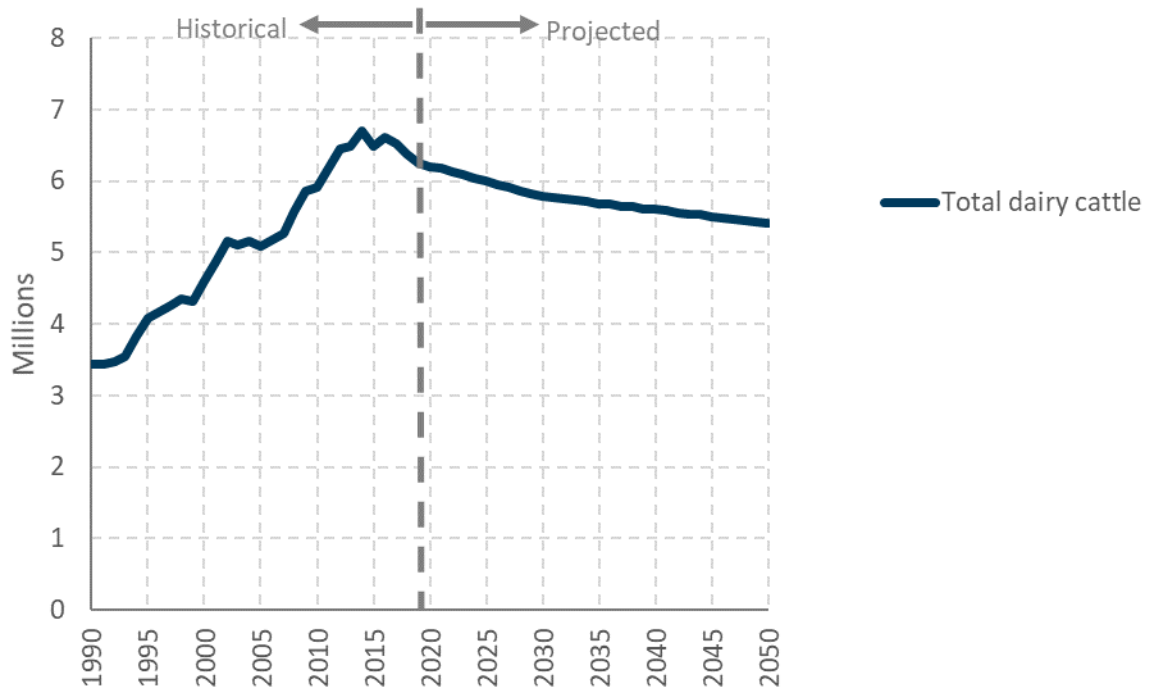


Figure 11.29: Current Policy Reference case dairy cattle numbers

Source: Commission analysis.

Table 11.28: Current Policy Reference case dairy milking cows (millions)

	2019	2030	2040	2050
Dairy cattle	6.26	5.78	5.60	5.40

Notes:

- Dairy stock numbers are measured in terms of total dairy cattle. This includes the entire dairy herd, including support animals, not just milking cows.
- Figure 11.29 shows that between 1990 and 2019 the number of dairy cattle increased substantially in line with the increasing land area used for dairy farming. Dairy cattle increased from 3.4 million in 1990 to 6.26 million in 2019.
- In the reference case, dairy cattle numbers are expected to decrease to 5.78 million in 2030 and 5.4 million in 2050.
- This decrease is due to a combination of declines in dairy farming land area, shown in *Section 11.6.4 Agricultural and forest land use*, and some decreases in animal stocking rates.

11.7 Waste

For the waste sector, ENZ draws on the Ministry for the Environment (MfE)'s 'with existing measures' scenario, modelling and assumptions for both future volumes and destinations of waste, and the current use of different emissions reduction technologies. These Government projections estimate what might occur in the waste sector, if existing policies and measures are maintained.

It models the main parameters which affect waste generation and waste emissions: how much waste ends up in landfill sites, how much waste can be recovered from landfill and how widespread and efficient gas capture systems are at disposal sites.

ENZ includes the broad categories of disposal sites: municipal with landfill gas (LFG) capture, municipal with no LFG capture, non-municipal landfills and farm fills. It also includes other waste disposal end points, including biological treatment (composting), recycling/reusing, anaerobic digestion and open burning/incineration.

The Current Policy Reference case assumes that in the absence of further support and direction from Government, that waste reduction and waste recovery rates remain low and that there are no expansion of LFG capture sites or increases in the average gas recovery rate.

11.7.1 Waste Emissions by Category

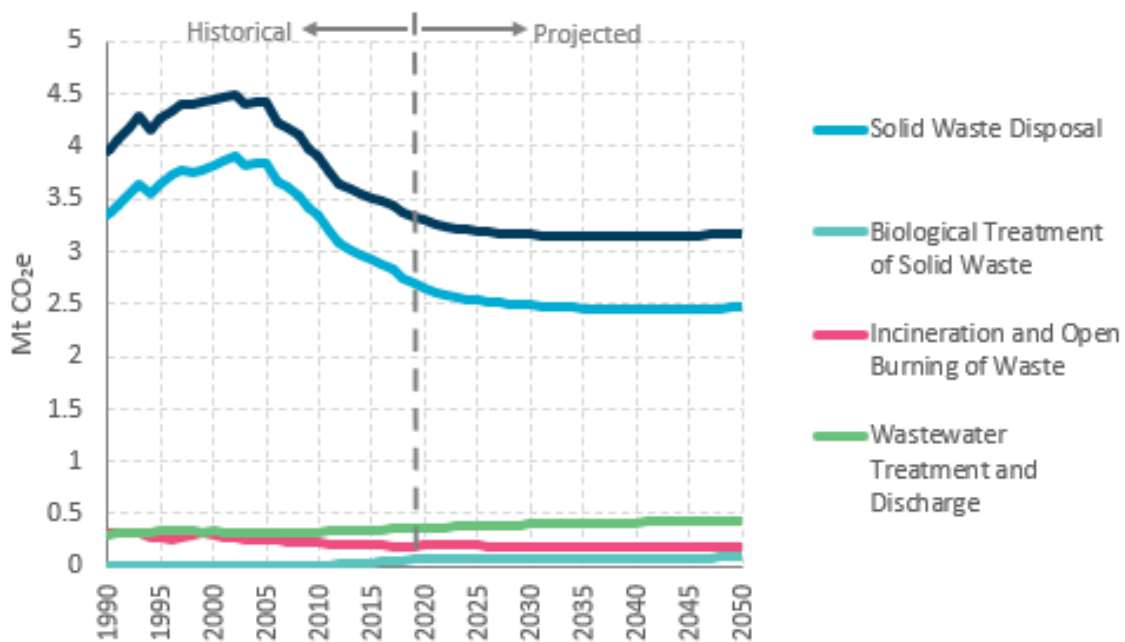


Figure 11.30: Current Policy Reference case waste emissions per category

Source: Commission analysis

Table 11.29: Current Policy Reference case waste emissions per category (MtCO_{2e})

	2019	2030	2040	2050
Solid Waste Disposal	2.6929	2.4831	2.4480	2.4650
Biological Treatment of Solid Waste	0.0652	0.0782	0.0822	0.0864
Incineration and Open Burning of Waste	0.1863	0.1941	0.1875	0.1823
Wastewater Treatment and Discharge	0.3725	0.4016	0.4206	0.4344
Total waste	3.3169	3.1570	3.1383	3.1683

Notes:

- Waste emissions in Aotearoa are mostly from organic waste decomposing at landfill, which produces biogenic methane emissions (81%), with the second largest source from wastewater treatment (11%), and the rest coming from open burning/incineration (6%) and composting (2%).
- Despite the large increase in waste volumes of nearly 62% from 1990 to 2018, this has been counteracted by the increased adaptation of LFG capture technology due to the requirements imposed by the National Environment Standards for Air Quality (Air Quality NES). The Air Quality NES require landfills that meet a particular threshold of organic content and waste volumes to have LFG capture systems. This has driven a consolidation of municipal landfills from 300 municipal landfills in 1990 to 39 landfills by 2019.
- Figure 11.30 shows that in the reference case, waste emissions are set to have a slight decrease due to the continued shift of organic waste from landfills without LFG capture to sites with gas capture.

11.7.2 Waste emissions by gas

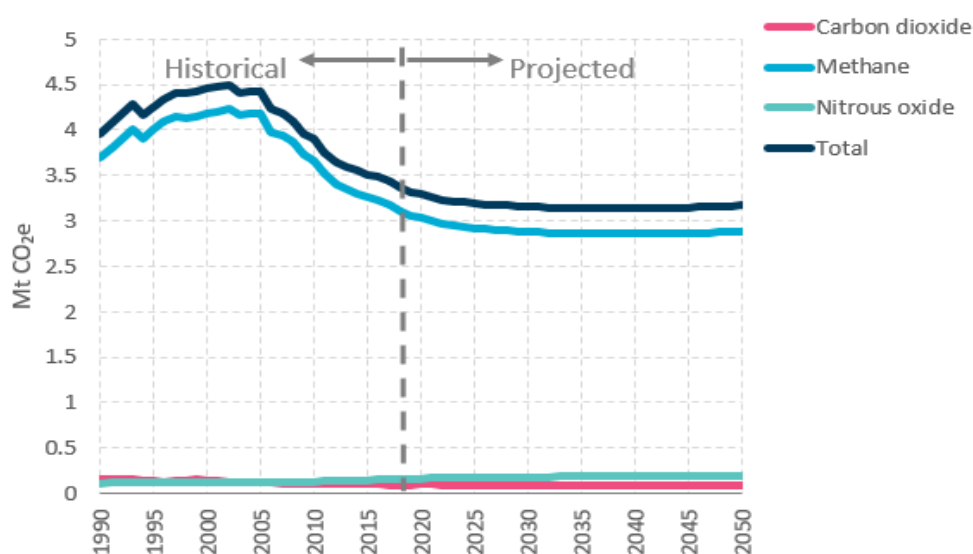


Figure 11.31: Waste emissions by gas Mt CO_{2e}

Source: Commission analysis

Table 11.30: Waste emissions by gas MtCO₂e (actual methane in Mt and nitrous oxide amounts in kt within the brackets)

	2019	2030	2040	2050
Carbon dioxide	0.0902	0.0939	0.0907	0.0883
Methane	3.0623 (0.122)	2.8810 (0.115)	2.8568 (0.114)	2.8824 (0.115)
Nitrous oxide	0.1644 (0.552)	0.1820 (0.611)	0.1908 (0.64)	0.1977 (0.663)
Total	3.3169	3.1570	3.1383	3.1683

Notes:

- Waste emissions are mostly biogenic methane emissions (92%) with a smaller portion coming from nitrous oxide emissions (5%) and carbon dioxide (3%).
- Biogenic methane emissions are mostly from waste decomposing from landfill, with some coming from wastewater treatment plants and another smaller portions from burning and composting. Figure 11.31 shows a slight decrease to 2050 is projected due to the shift of organic waste to landfills with LFG capture.
- Nitrous oxide emissions are mostly from wastewater treatment plants and are expected to increase through to 2050, driven largely by an increase in population.
- Carbon dioxide emissions are from the open burning of waste in rural areas and incineration of mostly medical waste. They are projected to decline through to 2050 due to the decrease in farm activity.

11.7.3 Waste biogenic methane emissions

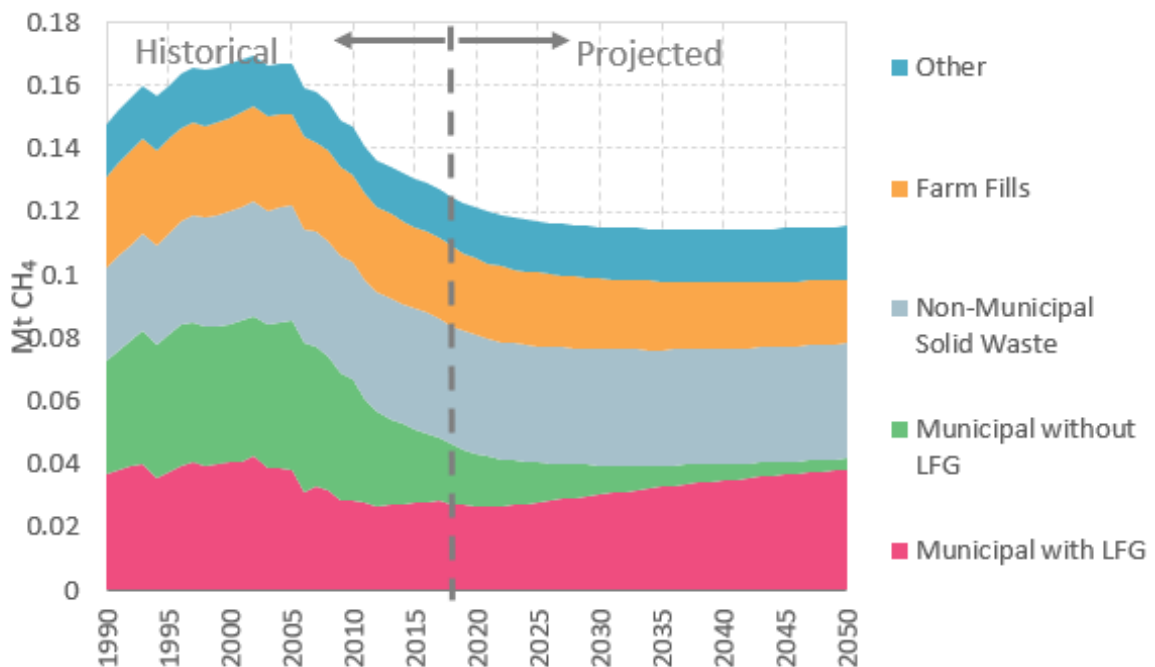


Figure 11.32: Current Policy Reference case biogenic waste emissions

Source: Commission analysis

Table 11.31: Current Policy Reference case waste biogenic methane emissions (MtCH₄)

	2019	2030	2040	2050
Municipal with LFG	0.0271	0.0303	0.0347	0.0382
Municipal without LFG	0.0174	0.0093	0.0052	0.0035
Non-Municipal Solid Waste				
	0.0375	0.0368	0.0365	0.0364
Farm Fills	0.0247	0.0224	0.0212	0.0203
Other	0.0158	0.0165	0.0167	0.0169
Total	0.1224	0.1152	0.1143	0.1153

Notes:

- Solid waste decaying at landfills is the largest source of biogenic methane in waste spread out across municipal with LFG capture, municipal without LFG capture, non-municipal and farm fill sites.
- The ‘other’ category makes up the remainder, with wastewater treatment, composting, open burning/incineration and uncategorised sites.
- Figure 11.32 shows that between 1990 and 2019, emissions from municipal landfills without LFG capture and farm fill emissions fell, while emissions from municipal landfill with LFG capture and non-municipal landfills rose.
- The shift in municipal landfill emissions is due to closure of many municipal landfills without LFG capture. This is caused by the requirement to capture LFG emissions, which led to the shift of waste volumes towards sites with LFG capture. The change in non-municipal and farm fill emissions can be attributed to changing waste volumes from farms and increased industrial, construction and commercial activity.

11.7.4 Waste Volumes at Disposal Sites

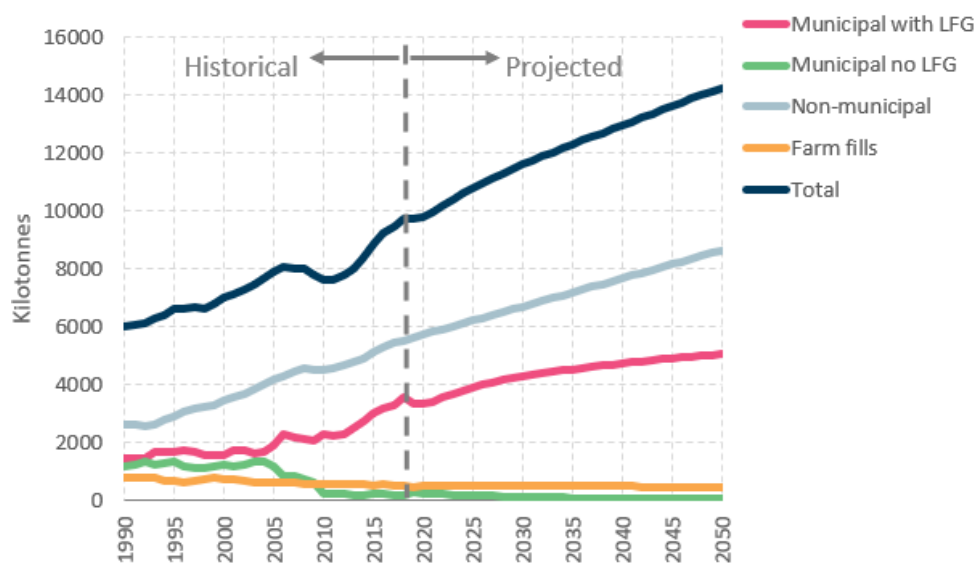


Figure 11.33: Current Policy Reference case waste emissions per category

Source: Commission analysis.

Table 11.32: Current Policy Reference case waste volumes at end disposal sites (kt)

	2019	2030	2040	2050
Municipal with LFG capture	3,350	4,285	4,727	5,057
Municipal without LFG capture	279	120	79	87
Non-Municipal	5,622	6,683	7,655	8,626
Farm sites	479	499	482	469
Total	9,730	11,587	12,942	14,238

Notes:

- Waste volumes are a key driver of waste emissions as organic waste decomposes at landfill and produces emissions.
- As previously mentioned, the shift in waste volumes between 1990 and 2018 from municipal landfills without LFG capture and municipal sites with LFG capture has been driven by the Air Quality NES.
- In the reference case, waste volumes are projected to grow at municipal and non-municipal landfills, while slightly decreasing at farm fills. This has been driven primarily by population growth.

11.7.5 Hydrofluorocarbon gases (HFCs)

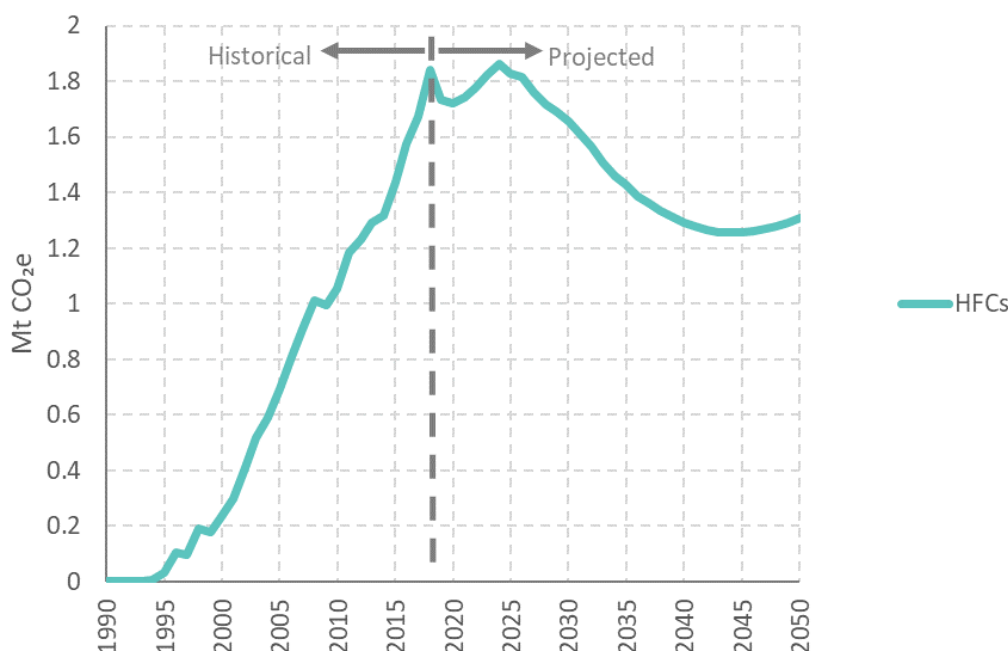


Figure 11.34: Current Policy Reference case HFC emissions

Source: Commission analysis

Table 11.33: Current Policy Reference case F-gases emissions (MtCO₂e)

	2019	2030	2040	2050
HFCs	1.7	1.7	1.3	1.3

Notes:

- These emissions are primarily from leakage and improper disposal of HFCs used in refrigeration and air conditioning equipment. Over the period from 1990 to 2018 these emissions increased significantly due to the growing use of HFCs as a replacement for chlorofluorocarbons (CFCs). CFCs were recognised as being destructive to the ozone layer and the Montreal Protocol, an international treaty, successfully phased out their use.
- Figure 11.33 shows that projected emissions from HFCs peak at around 2.0 MtCO₂e in 2024 and reduce to 1.7 MtCO₂e in 2030 and 1.3 MtCO₂e by 2050.
- The reduction in emissions is a result of the Kigali Amendment to the Montreal Protocol which restricts the bulk imports of HFCs in new equipment from 2019 and the uptake of alternative low global warming potential refrigerants. Despite the regulation, emissions reductions are limited due to continued use of HFCs in existing equipment.

11.8 Comparisons with other projections

As part of the country's obligation to the United Nations Framework Convention on Climate Change, the Government publishes biennial reports, which track historic emissions and project future trends. The most recent version of this is the *Fourth Biennial Report* produced by MfE in December 2019 drawing on contributions by multiple Ministries.²⁷

These Government projections were updated in October 2020²⁸ in order to reflect new policy developments and the ongoing disruption the COVID-19 pandemic has had across the economy. This section shows comparisons between our Current Policy Reference case and the updated Government projections. The Government projections explore multiple emissions scenarios, however the comparisons shown here are for the 'with existing measures' projection, which, in exploring a future without additional policy intervention to target emissions reductions, is similar in logic to the reference case. The comparisons here are made at an aggregated level with emissions largely classified in terms of the GHG Inventory conventions. Emissions are split between transport, non-transport energy, industrial process and product use (IPPU), land use and waste.

In April 2021 the Government also published a new GHG Inventory. We have updated our Current Policy Reference case based on this, which leads to some differences with the government projections. This is because publicly available government projections do not yet incorporate all the changes based on the new GHG Inventory. It is anticipated that updated government projections will have a much closer alignment than the comparisons shown here.

²⁷ Ministry for the Environment (2019). The Ministry of Business, Innovation and Employment (MBIE) contributes energy use emissions, MfE contributes IPPU and waste emission projections and MPI contributes forestry and agriculture emissions projections.

²⁸ The projections are available at (Ministry for the Environment, 2021).

As mentioned earlier in this chapter, a major strength of the ENZ modelling tool, which has been used to create our reference case, is that it can represent ways of reducing emissions for all sectors of the economy in detail. It also represents many of the key interactions that can happen between sectors; for example, changes to dairy production would impact the energy requirement in the food processing sector. In comparison, government projections are produced by separate agencies and focus on particular parts of the economy, often in isolation. Because of this additional detail, our reference case may present a more consistent vision of our future emissions across the economy than the individual Government projections.

The following subsections present comparisons of the reference case with publicly available Government projections. We have also continued working with Government agencies to better align the reference case.

11.8.1 Net emissions

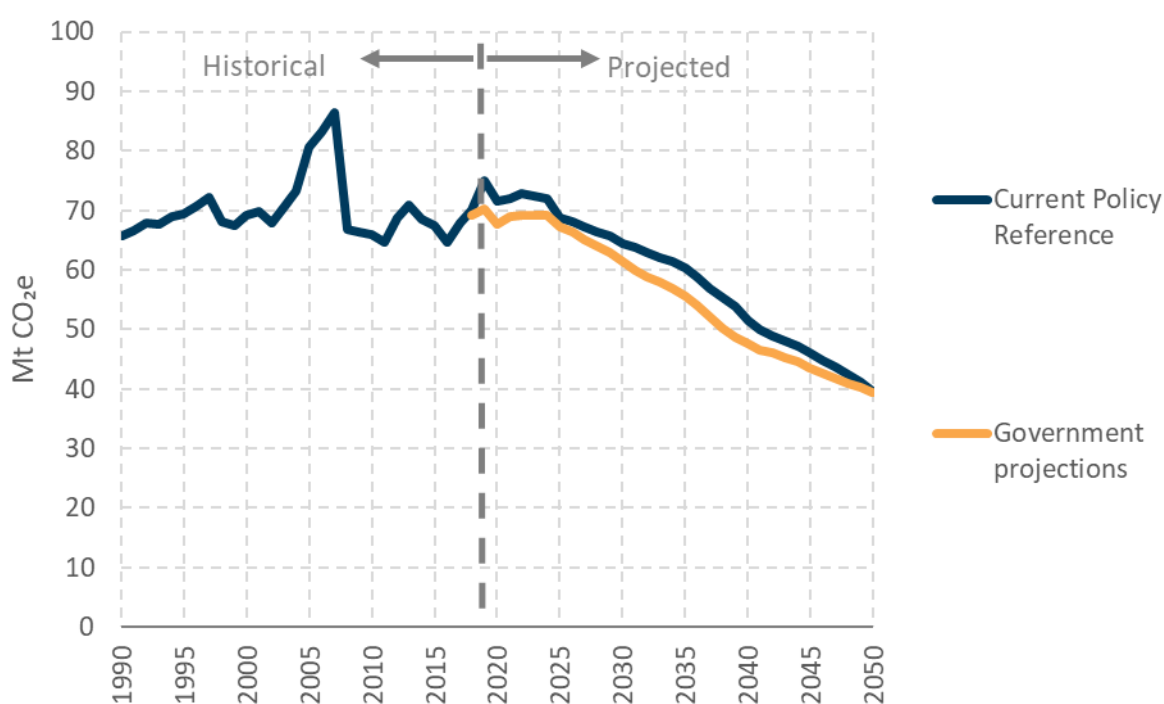


Figure 11.35: Comparison of Current Policy Reference case and Government projected emissions

Table 11.34: Comparison of Current Policy Reference case and Government projected emissions

	2019	2030	2040	2050
Current Policy Reference	74.9	64.5	51.6	39.6
Government projections	70.3	61.3	47.6	39.4

Notes:

- Both projections demonstrate the same general trend of reducing gross emissions.
- The Government projections have not been updated to include the 2021 GHG Inventory – this is the reason for some of the discrepancies between the projections.

- The following sections explore the differences for each sector in detail.

11.8.2 Non-transport energy emissions

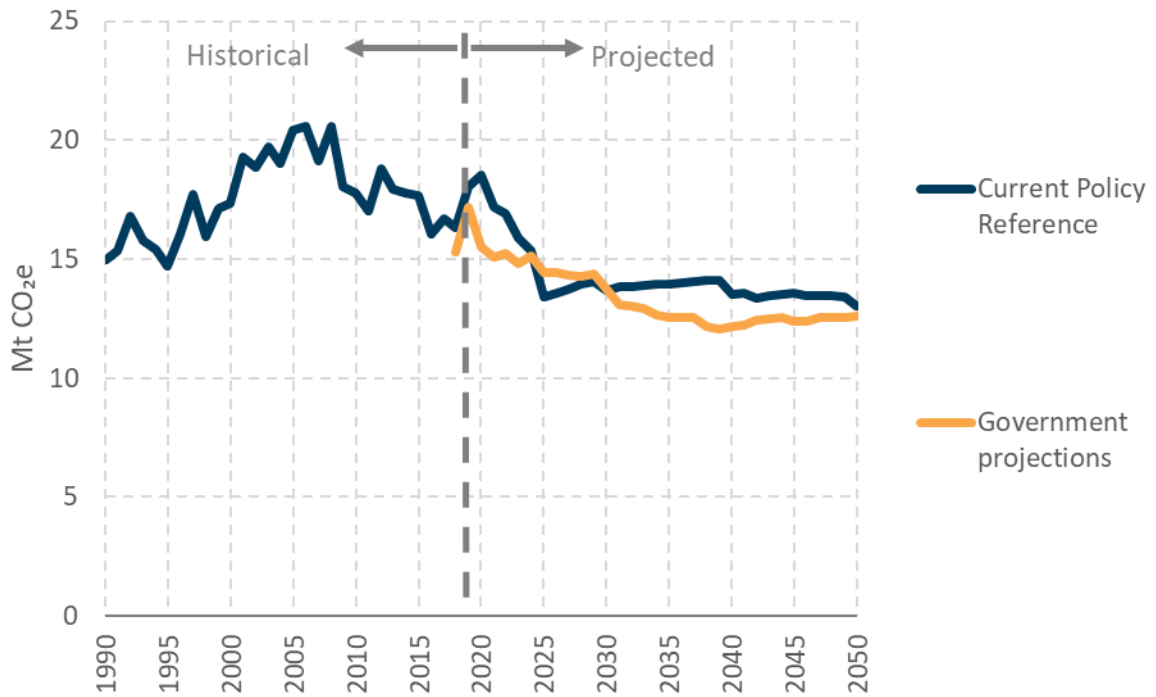


Figure 11.36: Comparison of Current Policy Reference case and Government projected non-transport energy emissions

Source: Commission analysis.

Table 11.35: Comparison of Current Policy Reference case non-transport energy emissions with Government projections (MtCO₂e)

	2019	2030	2040	2050
Current Policy Reference	18.1	13.7	13.5	13.0
Government projections	17.2	13.8	12.2	12.6

Notes:

- Non-transport energy includes emissions from fossil fuel use in industry, buildings and in electricity generation as well as fugitive emissions.
- The Government projections have not been updated to include the 2021 GHG Inventory – this is the reason for some of the discrepancies between the projections.
- In addition to this, we have recently worked with Government agencies to align key assumptions and modelling methodologies. Because of this, it is anticipated that when the Government agencies publish updated projections, there will be much better alignment than what is shown here.

- Emissions reductions shown in Figure 11.36 for both projections are due largely to a reduction in emissions from electricity generation and from closures of heavy industry (aluminium smelting and methanol production).

11.8.3 Transport emissions

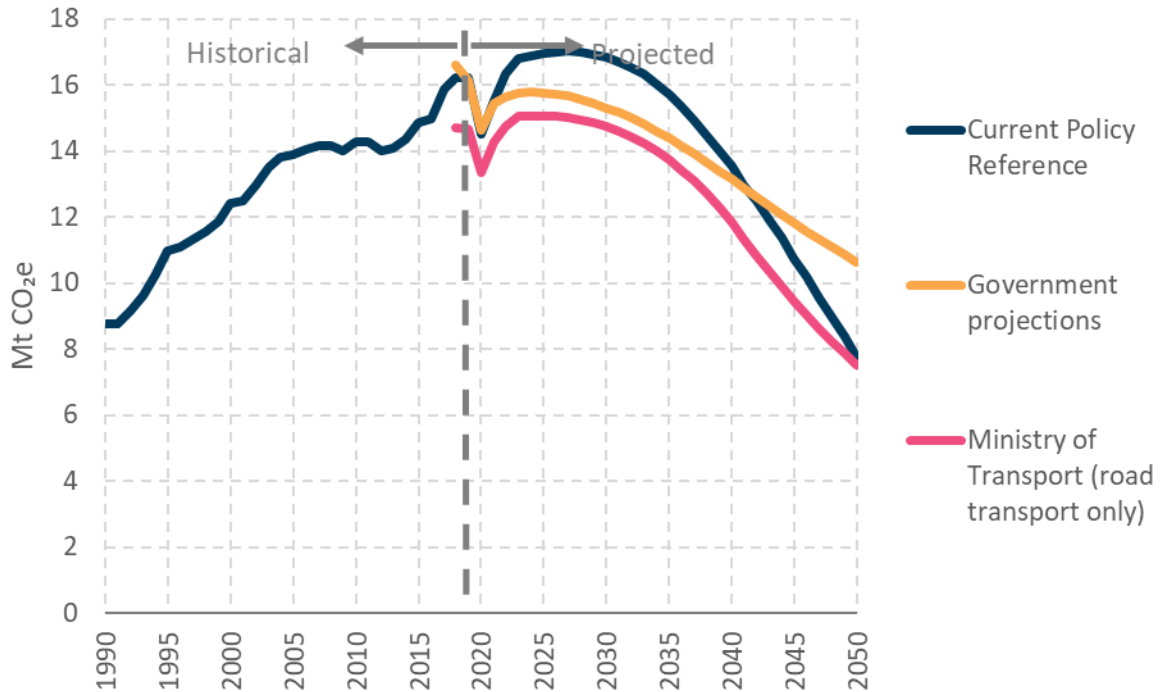


Figure 11.37: Comparison of Current Policy Reference case transport emissions with other government projections

Source: Commission analysis.

Table 11.36: Comparison of Current Policy Reference case transport emissions with Government projections (MtCO₂)

	2019	2030	2040	2050
Current Policy Reference	16.2	16.8	13.5	7.8
Government Projections	16.1	15.3	13.1	10.6
Ministry of Transport²⁹	14.7	14.7	11.8	7.5

Notes:

- The Government projections shown here have not been updated to include the 2021 GHG Inventory, and an updated outlook on the impact of COVID-19. This could be the reason for some of the discrepancies between the projections.

²⁹ MoT projections are provisional ones provided to the Commission in 2021 and include road emissions only.

- We have assumed that transport emissions return to pre-COVID-19 trends, and that COVID-19 has limited long-term impact on transport emissions. This is based on new work from MoT.
- The MoT Vehicle Fleet Emission Model³⁰ projections are very similar to our reference case, although they have a slower decline in the later years. Their projection only includes road transport emissions and excludes emissions from domestic aviation, shipping and rail. This explains most of the gap between our reference case and MoT’s projections.
- This reference case projection has been revised from that in the *2021 Draft Advice for Consultation*. The new projection is about 0.6 MtCO₂ higher by 2030 and brings us into alignment with MoT projections of future transport activity and emissions.
- Government projections of transport emissions show a strong shock in 2020 due to the COVID-19 pandemic, followed by a partial recovery and the start of a long-term decline, which is not as rapid as our reference case.
- All of the projections shown in Figure 11.37 show a long-term decline in transport emissions, driven by the uptake of EVs. As the speed of this uptake is quite uncertain, it is not surprising that the shape of the curves differ.

11.8.4 Industrial process and product use emissions

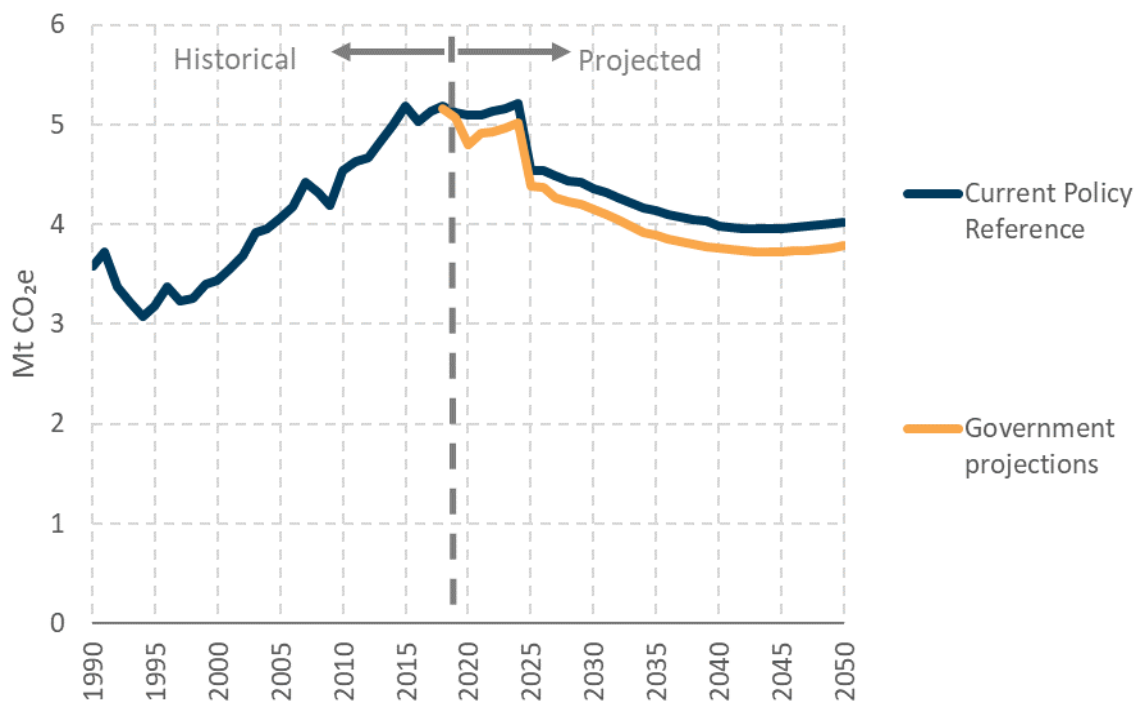


Figure 11.38: Comparison of Current Policy Reference case and Government projected IPPU emissions

Source: Commission analysis.

³⁰ Ministry of Transport (2019b)

*Table 11.37: Comparison of Current Policy Reference case IPPU emissions with Government projections
(MtCO_{2e} per year)*

	2019	2030	2040	2050
Current Policy Reference	5.1	4.4	4.0	4.0
Government projections	5.1	4.2	3.8	3.8

Notes:

- IPPU emissions includes non-energy emissions from steelmaking, cement production and other industrial activities. It also includes emissions from HFCs and other F-gases.
- The government projections have not been updated to include the 2021 GHG Inventory – this is the main reason for the discrepancies shown in Figure 11.38 .
- Both projections demonstrate the same general trend in emissions. The stepped reduction in the level of emissions at the end of 2024 is due to the assumed closure of the aluminium smelter at Tiwai Point. There is minor reduction in IPPU emissions beyond this.

11.8.5 Agriculture emissions³¹

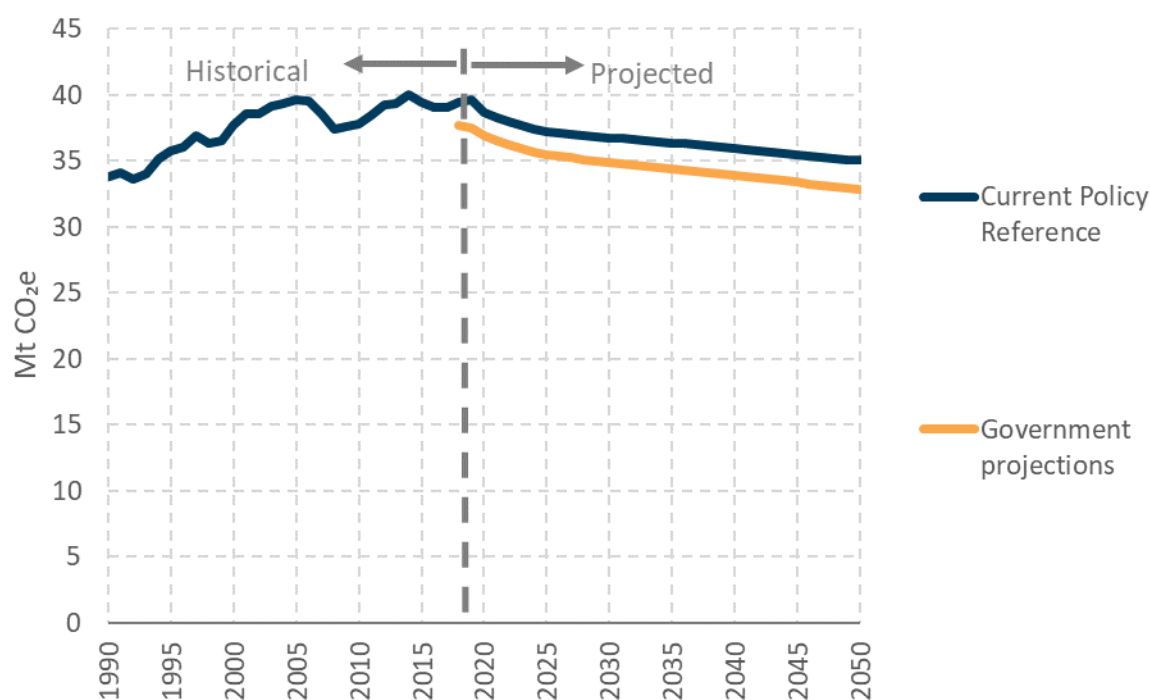


Figure 11.39: Current Policy Reference case agricultural emissions compared to Government projections (MtCO₂e)

Source: Commission analysis.

Table 11.38: Current Policy Reference case agriculture emissions compared to Government projections (Mt CO₂e)

	2019	2030	2040	2050
Current Policy Reference case	39.6	36.7	36.0	35.1
Government WEM baseline projections	37.5	34.9	33.9	32.9

³¹ Other organisations have modelled the dynamics of future developments in the land sector using sector specific models. Motu's Land Use in Rural New Zealand (LURNZ) model simulates land-use change in response to changes in economic returns for different land uses. Manaaki Whenua – Landcare Research's New Zealand Forestry and Agricultural Regional Model (NZFARM) is another model which projects agricultural production and land use. It optimises these for maximum profits based on costs, prices and environmental constraints. Motu used LURNZ and NZFARM to project a land sector base case for the Biological Emissions Reference Group in 2018 and reports by the Productivity Commission and the Parliamentary Commissioner for the Environment have used LURNZ to project avenues towards future emissions reductions targets. However, these projections are not directly comparable with the reference case. Significant policy developments since they were published mean that key assumptions used in those modelling efforts differ considerably from those in our reference case. The emissions reductions targets used in these reports are also different from the 2050 and 2030 targets now under legislation.

Notes:

- Agricultural emissions are primarily biogenic methane from ruminant livestock and nitrous oxide from animal urine and fertiliser. Smaller amounts of carbon dioxide come from limestone and urea.
- In our analyses we use a split-gas approach, as per the charts presenting the reference case for agricultural emissions earlier in this chapter.
- For the purposes of overall comparison with government projections, however, we here present them in an all-gas format. Figure 11.39 shows the reference case for agriculture aggregated as MtCO₂e, compared against government projections.
- The projections align well in terms of trend, with the constant absolute difference being due to government projections that have not been updated to include the 2019 GHG Inventory.³²

11.8.6 Net forest emissions



Figure 11.40: Current Policy Reference case net forest emissions compared to government WEM baseline projections

Source: Commission analysis

³² See (Ministry for the Environment, 2021) for details on the changes that occurred in the updated 2019 GHG Inventory.

Table 11.39: Current Policy Reference case net forest emissions compared to Government projections (MtCO_{2e})

	2019	2030	2040	2050
Current Policy Reference case	-7.4	-10.3	-18.6	-23.4
Government WEM baseline projections	-9.1	-10.1	-18.8	-24.0

Notes:

- Net forest emissions include emissions removals by forests, balanced against emissions from deforestation.
- Figure 11.40 shows that net forest emissions in the reference case align very closely with government projections. This aligns with us having used MPI’s ‘With Existing Measures’ forest activity projections in our reference case.

11.8.7 Waste emissions

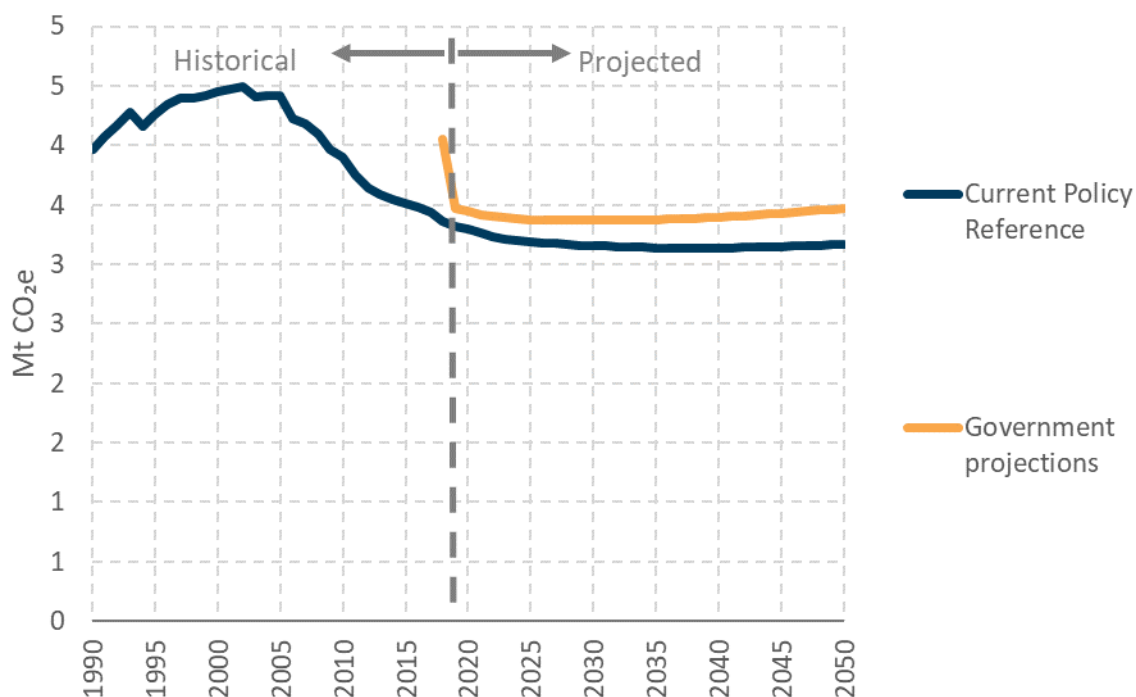


Figure 11.41: Current Policy Reference case waste emissions compared to Government projections

Source: Commission analysis

Table 11.40: Current Policy Reference case waste emissions compared to Government projections

	2019	2030	2040	2050
Current Policy Reference case	3.3	3.2	3.1	3.2
Government WEM baseline projections	3.5	3.4	3.4	3.5

Notes:

- Figure 11.41 compares ENZ model projections of waste emissions compared to most recent projections produced by the MfE.
- The ENZ waste module was derived from MfE's waste models which is why the emissions projections between the two are very similar – the slight difference is attributable to the difference in treatment of non-municipal landfills.
- MfE projects the emissions from non-municipal landfills through extrapolating the historical emissions trend.³³
- ENZ projects emissions from non-municipal waste through modelling waste volumes and decay at non-municipal landfills. Waste volumes were kept at the base year rate as extrapolation of waste trends would have led to some waste streams reaching zero in 10-20 years. In the absence of good quality data for non-municipal fills, we felt a cautious approach was warranted.
- The linear projection of the historical emissions trend overestimates emissions from non-municipal landfills whereas ENZ could provide a more accurate picture from modelling waste volumes.

11.9 Dealing with uncertainty

As discussed at the beginning of this chapter, there is uncertainty surrounding the single reference case presented here. The broader issue of potentially significantly different futures is addressed largely through our consideration of multiple future scenarios in *Chapter 12: Long-term scenarios to meet the 2050 target*. Smaller uncertainties, related to potential variation in key variables and assumptions, however, can also be very important. We have considered these in sensitivity analyses for our demonstration path in our advice, *Ināia Tonu Nei*.

The key uncertainties for each sector that could affect all our ENZ outputs are discussed below.

11.9.1 Transport

Probably the largest source of uncertainty in our reference case for transport is the cost and performance of batteries for EVs. We believe our assumptions are in line with both the expectations of industry experts and ongoing trends. If battery costs decline as we have assumed, EVs would become increasingly competitive with conventional fossil-fuelled vehicles. There are, however, no guarantees that this will happen, or about the speed at which this would happen.

Other key sources of uncertainty in our reference case for transport include:

- Oil prices, which affect both the competitiveness of fossil-fuelled vehicles compared to EVs, and the attractiveness of owning larger and less energy efficient conventional vehicles.
- Population and economic growth rates, which underlie the demand for transport.
- Changing work practices and advancing information technology, which could facilitate more remote working.

³³ (Ministry for the Environment, 2019)

- Changing tastes and markets for housing, including potential shifts to more multi-family housing and more urban living.
- Changing tastes in transport choices, including potential shifts to more walking, cycling and public transport.
- Self-driving vehicle technologies, which could change the amount of travel and the way vehicles are used, in ways that are still unclear.
- For international aviation especially, the long-term impacts of COVID-19 are another significant source of uncertainty, which are discussed in a separate section.

11.9.2 Energy, industry and buildings

As discussed throughout the sector discussion, much of the emissions across these sectors results from the production activity of individual industries. Changes in the level or production of these industries would have a significant impact on the emissions totals over the budget periods. This makes industry activity a key uncertainty. Emissions-intensive industrial activity in Aotearoa is concentrated at a small number of sites operated by a small number of companies.

The signalled closure of the aluminium smelter at Tiwai Point demonstrates the significant impact on the emissions trajectory, and expected totals for any given budget period, that even a single major change can have. For this reference case, we assume that heavy industry largely continues to operate at close to current production levels. The exceptions to this are the aluminium smelter and the petrochemical industry. We look at the sensitivity of our demonstration path in our advice, *Ināia Tonu Nei*, to different industrial closure plans.

11.9.3 Land

There are multiple sources of uncertainty for the land sector relevant to the reference case.

Market factors

External market factors can cause uncertainty for the land sector. For example, the price of milk or logs changing significantly from what is in the reference case. Changes in export prices can influence land-use decisions, which can, in turn, impact emissions from the land sector.

For agriculture, export prices are influenced by global demand for meat and dairy products. An increase in demand could be driven by a growing global middle class demanding more of these products. A decrease in demand could be driven by the development of plant-based and synthetic protein products that may undercut demand for traditional meat and dairy.

Higher meat export prices may mean land that might have otherwise been unprofitable to farm becomes productive again. Lower prices may contribute to a decline in sheep, beef and deer land area. This could alter the trend of land retirement. This trend is strong historically but essentially stops in the reference case after 2025. As exotic afforestation is assumed to occur on sheep, beef and deer land, varied carbon and log prices may also lead to a change in sheep, beef and deer land area.

For forestry, a change in global log demand is the key driver of harvesting activity in Aotearoa. Changes in the average harvest age of planted forests due to processing constraints and market forces could cause fluctuations in estimates of emissions removals compared to our reference case. Commercial afforestation is driven by log demand and the NZ ETS carbon price. Deviations in the

carbon price from the constant \$35 in real terms used in the reference case would likely see variation in afforestation and thereby net forest emissions.

Physical climate change effects

The physical effects of climate change and people's responses could affect the land sector. These climate response dynamics are not included in the reference case. Yet, the risk of extreme weather events will increase and weather and temperature patterns will change. This could be fundamentally challenging to the agriculture and forestry sectors by 2050. Challenges may include large areas of land becoming unsuitable for their current land use and the need for rapid adoption of different technologies and practices, such as irrigation, in order to adapt. Research is underway in Aotearoa to quantify these potential impacts, but data is not yet available to include in our modelling.

11.9.4 Waste

The unreliability of activity data for waste in non-municipal sites and farm fills means that any projections must be considered with a high degree of caution. The efficacy of LFG capture efficiency, particularly for old landfills, and uncertainties around LFG capture also contribute to the uncertainty.

Another potential variable is the potential impact of the waste levy increases, depending on the level of actual sensitivity of waste volumes to the levy increases, this may result in higher or lower increases than forecast.

There is also large uncertainty around the refrigerants space, such as the impacts of the carbon price on the consumption of F-gases, potential for continued imports of recycled HFCs and the potential leakage rates. Because of these uncertainties, there is potential for the reference case to be under or overstating the emissions reductions from the Kigali Amendment.

11.9.5 Impact of COVID-19

Any discussion of the uncertainties in future emissions must address the current COVID-19 public health crisis. At the time of this writing, international aviation to and from Aotearoa is operating at token levels, the tourism and tertiary education sectors in Aotearoa are taking a large hit, export and import supply chains for many products have been disrupted, seasonal workers and many skilled workers are unable to enter the country and unemployment is well above levels of the past few years. Yet the Commission's planning horizon remains a long-term one, to 2050 and beyond. Our first budget period does not even begin until 2022. The key uncertainty around COVID-19 for the Commission is therefore the long-term impacts.

The ENZ model results presented in this section have been adjusted to reflect our best estimate of the short and long-run impacts of COVID-19. In the short-term, defined to be 2020 and 2021, our transport and industrial projections have been scaled down to match the demand impacts on each type of transport and industry, as shown in the most recent update to the Government projections of emissions. These generally show a sharp drop in 2020, compared to 2019, with an assumed recovery in 2021. The recovery is, however, not a complete one, in that it will only bring demand back to roughly where it was in 2019, rather than showing growth relative to 2019, as would have been expected pre-COVID-19. After 2021, we assume growth continues at a rate similar to what would have been expected pre-COVID-19, but starting from this new, slightly lower level.

Complicating the situation is that there appears to have been a downgrading of economic growth expectations over the last few years even without COVID-19. Figure 11.42 shows a comparison of GDP projections underlying three of the emissions projections discussed under in *Section 11.8: Comparisons with other projections*. The one from 2016 underlies MoT emissions projections; the

one from 2019 underlies the *Fourth Biennial Report*, while the one from 2020 underlies the latest Government projections. The Figure shows that the GDP projections have trended lower over time, even in the 2016 to 2019 period preceding COVID-19.

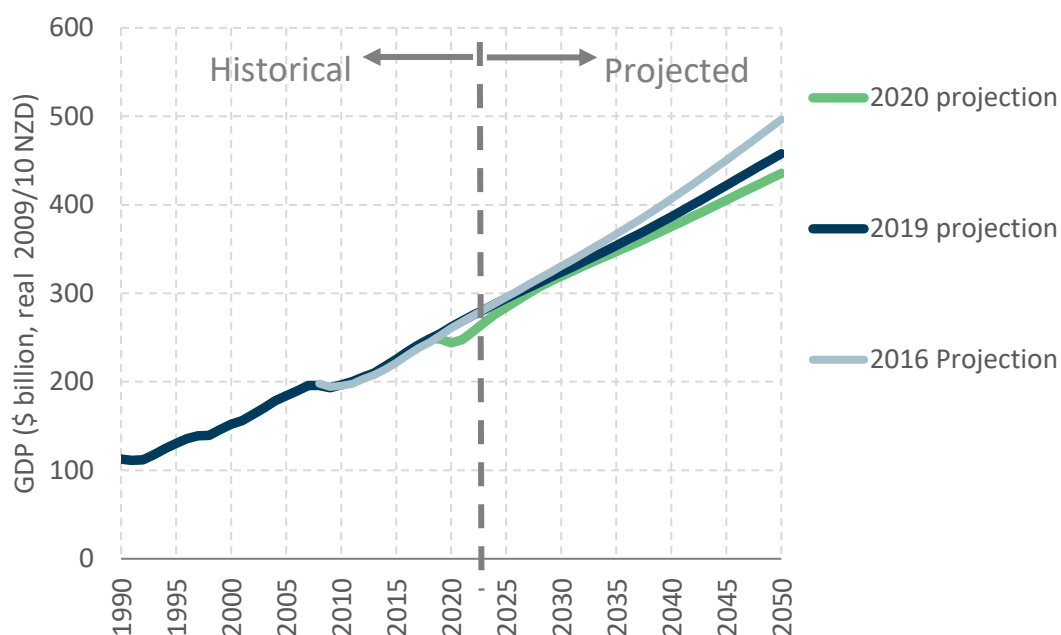


Figure 11.42: Comparison of GDP Projections Underlying Recent Emissions Projections

Source: Commission analysis

Table 11.41: Comparison of GDP Projections Underlying Recent Emissions Projections (\$ billion, real 2009/10 NZD)

	2018	2020	2030	2040	2050
2020 projection	249	244	319	375	435
2019 projection	248	262	324	387	458
2016 Projection	244	261	331	407	496

Although we have adjusted our long-term projections to reflect the impacts of COVID-19, and implicitly other changes to the economic outlook since 2019, these impacts are relatively small. This view is consistent with the fact that, as of May 2021, COVID-19 vaccines are being administered in Aotearoa and around the world. The vaccine rollout is expected to bring the health crisis to a close within the next year or so.

We recognise that there is a wide divergence of opinion as to what the long-term impacts of COVID-19 will be on emissions and the economy. Our message here is not intended to be dismissive. COVID-19 poses very serious challenges to the future of the world economy and severe long-term outcomes are within the realm of possibility. The Commission will need to closely monitor the situation and adjust its projections to reflect any new developments. For the moment, however, we are taking the view that the crisis will resolve in a relatively short time and that economic growth will return to something like its previous path. This is also a conservative assumption. COVID-19 cannot, and should not, be counted upon to provide Aotearoa with much help in reaching net zero emissions by 2050.

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Appendix 1: ENZ: Our scenarios model

We produce our emissions scenarios, including the Current Policy Reference case (reference case), using a purpose-built model called ENZ that was originally developed by Concept Consulting. We purchased ENZ and have worked with Concept Consulting to further develop it to meet our needs.

ENZ is a partial equilibrium, linked sector model built in Microsoft Excel. It allows us to investigate, from a whole-of-system point of view, changes to emitting activities and technologies in each sector of the economy. It allows us to factor in anticipated technological developments. ENZ produces economy-wide emissions estimates along with other data and insights such as energy costs. As well as the reference case, we use ENZ to generate other scenarios to investigate alternative possible futures in *Chapter 12: Long-term scenarios to meet the 2050 target*.

ENZ models all the emitting sectors of the Aotearoa economy – energy, industry, transport, agriculture, forestry, product use and waste. It gives a detailed sense of feasible emissions reductions in each of these sectors by factoring in specific technologies and emissions reductions opportunities.

The model accounts for key supply chain links between sectors, and resource constraints. For example, if ENZ projects the number of electric vehicles (EVs) to rise, it also calculates the increase in electricity demand and increases electricity generation accordingly. If ENZ projects a conversion of coal boilers to using biomass, it also calculates the forestry residues required to supply this.

The main sectors are included in ENZ as follows:

Transport

ENZ includes road transport, rail, shipping and aviation, with the latter two split into domestic and international. Road vehicles are divided into light passenger vehicles (cars and SUVs), light commercial vehicles (vans and utes), motorcycles, buses, medium trucks (defined as less than 30 tonnes gross vehicle mass (GVM)) and heavy trucks (over 30 tonnes GVM). ENZ models the dynamics of the transport fleet, such as vehicle scrappage and the pattern of usage over a vehicle's life, based on fleet statistics published by the Ministry of Transport. The model also includes different fuel types: fossil fuels, electricity, hydrogen, and biofuels or other synthetic fuels.

ENZ models the main levers which influence emissions, including transport demand and the size and makeup of the vehicle fleet, based on factors driving them, such as population. It also accounts for projected improvements in vehicle efficiencies.

ENZ takes account of behavioural change, including mode shift for passenger and freight transport and reduced demand for travel. These behavioural changes are input as scenario assumptions; ENZ does not model changes in travel behaviour in response to factors such as changes in fuel prices. ENZ draws on underlying regional travel data and projections from the Ministry of Transport and aggregates these into five broad regions: Auckland, Waikato, Wellington, Canterbury, and the rest of Aotearoa.

Electric vehicles

One of the most significant aspects of the transport modelling in ENZ is the uptake of EVs. EVs may be either pure battery EVs or plug-in hybrids.

ENZ assumes that consumers choose between conventional vehicles and EVs based on the total cost of ownership of each type of vehicle over an assumed five-year ownership period.

The major driver of EV uptake is the assumed decline in battery costs. These are based on projections by Bloomberg New Energy Finance Limited's *Electric Vehicle Outlook 2020*.¹ These figures suggest, for example, that the cost of batteries for a typical light passenger vehicle will decline from about NZD 13,500 in 2018 to NZD 6,100 in 2030 even while the battery size increases from 53 kWh to 66 kWh (with a corresponding increase in vehicle range). It also implies that, based on cost alone (excluding penalties), the purchase price of a light EV will drop below the purchase price of a conventional vehicle sometime between now and 2030.

There are also non-price barriers to EV uptake, such as consumer range anxiety and lack of vehicle charging infrastructure. These barriers are discussed in more detail in *Chapter 6: Reducing emissions from transport, buildings and urban form*. To represent these, ENZ includes three classes of penalties to slow the uptake of electric vehicles in Aotearoa compared to what costs alone would indicate:

- Global early tech capital cost penalties, reflecting the global barriers to electric vehicle production.
- Aotearoa-specific capital cost penalties, reflecting barriers to EV uptake specific to this country.
- Productivity penalties, which apply mainly to trucks, reflecting how batteries could reduce vehicle payload or range, thereby increasing operating costs per unit of payload.

In addition, there is a bias against EVs built into the consumer choice function. This causes conventional vehicles to take a larger share of the market than EVs, even when the total operating costs of EVs (including penalties) and conventional vehicles are the same. This bias reduces as EVs gain in market share. There are also limits in the model on the speed at which the EV shares of newly registered vehicles can increase.

Assumptions are also made for the number of vehicle kilometres travelled by each class of vehicle in the reference case to reflect assumed travel type shifts for both travellers and freight.

Energy, industry and buildings

There are a diverse range of energy use types and industrial processes represented within ENZ. Generally, the activities which produce the largest share of emissions are represented in the most detail. A number of high-emitting, single site industries are also modelled explicitly. For example, the refinery, steel mill, aluminium smelter and cement plant.

How industries operate and function within the model is based on detailed in-house analysis as well as analysis of published literature. It is also informed by engagement with technical experts, industry specialists and takes into account industry forecasts. This means where there are physical constraints on how a plant operates, for example, this is reflected.

ENZ models future industrial activity and demand for energy based on historic trends, assumed growth and known dependencies such as fuel costs, competition for resources and other input drivers. ENZ deploys new emissions reduction technologies when they become technologically ready and economically viable.

Electricity generation

ENZ includes a basic representation of the electricity sector and runs and builds generation to meet the demand set by industries, households and other user groups. Demand is coarsely classified in

terms of baseload demand and flexible demand – flexible demand sets the requirement for flexible generation which fossil fuelled ‘thermal’ power plants help to meet in the system.

Most thermal generation plants are represented explicitly in the model, whereas renewable resources are aggregated by type. There is a short ‘generation stack’ of committed projects which add to this renewable resource and beyond this a representative cost and supply curve of new geothermal, wind and solar projects.

Thermal generation runs in the model up to the threshold where it would be at an equivalent cost to build a renewable resource, which is only generating some of the time and spilling energy for the rest. As the cost of thermal generation increases with fuel and carbon price, and the cost of renewable generation is projected to fall, thermal generation plays a decreasing share in each of these scenarios.

Other points to note:

- As wind and solar generation penetrate further into the system they become less valuable in the electricity market as they can be always generating, or not generating at the same time – this effect is represented by cost penalties in the model, which dynamically increase the cost of these resources.
- The operation of fossil gas and coal generation is one cause of electricity generation emissions that the model reports. The model also reports aggregate emissions from geothermal generation.
- The model does not represent varying hydro flows or manages hydro reservoir resources. Hydro generation is for an average year, but the dry year risk sets the capacity of thermal generation still in the system.
- This is not a market model with offers and bidders. The wholesale electricity price for the year is set by the long run marginal cost of the next renewable project to be built.
- This price becomes the input for other users in the model and is a factor on their decision to fuel switch to electricity.

Process heat

ENZ includes a regional representation of process heat users in Aotearoa which links in with the forestry and agricultural modules. The food processing sector is represented in the most detail with dairy, meat and other food processing activity broken down to the regions of Northland, Central North Island, East Coast, Hawke’s Bay, Southern North Island, Nelson and Marlborough, West Coast, Canterbury, Otago and Southland.

Within the model the regional agricultural activity sets the demand for energy for the meat and dairy processing sectors. Along with deploying efficiency measures, these industries undertake fuel switching to biomass or electricity as fossil fuel costs increase. The local forestry harvest sets the availability of biomass as forestry residue or pulp logs, which users generally take up to the extent they are available. The model ensures that the biomass resource is not utilised multiple times.

The cost of fuel switching from coal, fossil gas and diesel to biomass or electricity is based on new boiler cost estimates, connection costs and fuel prices. These factors are encapsulated within a ‘marginal abatement cost’ calculation and industries begin to convert their boilers as the carbon price approaches this.

Buildings

Buildings in ENZ are represented in terms of the energy utilised in their operation. Energy used for space and water heating as well as cooking, lighting and electrical equipment are modelled explicitly within ENZ at an aggregated level for residential, commercial and public buildings. As population and GDP increase within the model, the number of buildings and requirements for energy increase.

Greenhouse gas emissions from these uses of energy are accounted for in ENZ, whether they are from fossil gas combusted onsite in a gas boiler or from plants which generate the electricity used in a hot water cylinder. This means that we can see from a whole-energy-system point of view the emissions footprint of operating our homes and workplaces.

Within the model, buildings are split into existing and future builds with varying energy efficiency opportunities, construction rates and retrofit cycles. Energy uses are disaggregated into space heating, water heating, cooking, lighting and other for each fuel type (electricity, fossil gas, LPG, coal, biomass). In the model, consumer choice of heating technology (fossil fuel or electric) at the time of a new build or retrofit is based on relative costs of equipment and fuel.

A fossil fuel phaseout profile overrides this economic based selection – this phaseout either reflects societal behavioural changes or a mandated approach. Improvements in energy efficiency of appliances and in buildings are also represented within ENZ.

Land (agriculture and forestry)

ENZ contains the land uses which are the main sources of emissions and removals from the land sector. It includes the area and emissions associated with each land use.

The land uses included in ENZ are:

- Sheep, beef and deer farming³⁴
- Dairy farming
- Horticulture
- Arable farming
- Exotic forest (pre-1990 and post-1989)
- New native forest (Post-1989)
- Other

ENZ also accounts for deforestation of pre-1990 native forest.

ENZ models land in Aotearoa at a national level. However, also understanding the trends in Māori collectively-owned land is a critical layer in the analysis. Data limitations mean it is not possible to consider specific projections for Māori collectively-owned land out to 2050 but relevant information about Māori collectively-owned land is considered alongside the reference case projections.

A crude attempt at estimating a Māori emissions profile by Iwi takiwā could be achieved through Crown agencies including Te Puni Kōkiri, Ministry for the Environment (MfE), Ministry for Primary Industries (MPI), Manaaki Whenua, Te Tumu Paeroa and other Crown Research Institutes, giving

³⁴ Area used for production, not whole owned area.

³⁵ This land is mostly land on farms not used for production.

effect to kotahitanga and working collaboratively to build on existing data. Addressing this gap, and the associated information and capability enablement required, is consistent with giving effect to rangatiratanga and supporting more equitable outcomes for Iwi/Māori. However, it is imperative that the enabling platform/mechanism ensures Māori-collectives maintain mana motuhake (control and autonomy) over their data and information.

For the land sector, ENZ draws on land areas and livestock numbers from the MPI October 2020 data update and uses these to model emissions and output. ENZ is calibrated to historic data and produces similar but not identical outcomes to government models. The key model underlying the activity data is MPI's Pastoral Supply Response Model, which projects trends in animal populations, primarily in response to export prices, productivity trends and the returns on agricultural land relative to forestry.

Greenhouse gas emissions are calculated as a function of land area, stocking rates, animal productivity and the application of emissions reduction technologies:

- Land areas for the different farm types are input assumptions.
- Average stocking rates are specified for dairy and sheep and beef. In the reference case these are based on projected livestock populations from MPI.
- Production per animal is projected based on two factors: (1) a baseline rate of improvement based on MPI's projections, (2) an equation relating changes in stocking rate to changes in production. The latter assumes production per animal can increase up a curve towards a maximum value as stocking rate is reduced. The curve parameters are varied by scenario.
- Baseline emissions per animal are projected based on the observed relationship to production per animal, with parameters fitted to historic data.
- The impact of emissions reduction technologies, such as low-methane breeding, is superimposed on this baseline trend. These technologies are assumed to have no impact on production.

Forestry carbon dioxide emissions and removals are calculated in the ENZ model using methodologies and assumptions consistent with MPI's forestry emissions projections model. We apply the accounting approach described in *Chapter 3: How to measure progress*, with post-1989 exotic production forests credited up to their estimated long-term average carbon stock.

Exotic forestry yields and economics are modelled based on assumptions provided by Scion. Harvest yields are assumed to increase over successive forestry vintages due to genetic improvements. However, carbon sequestration lookup tables are assumed to remain constant over time, in line with current accounting conventions. Volumes of forest harvest residues, pulp logs and saw logs are calculated to provide estimates of available biomass supply for bioenergy and forestry sector revenue.

The small proportion of emissions from other livestock is taken as a fixed projection from MPI. Emissions from horticulture and cropping, which arise from fertiliser and lime application, are assumed to scale with land area.

Nitrogen fertiliser emissions are attributed to the land use where fertiliser is applied. We estimate historic fertiliser use per hectare based on data collected by Stats NZ.³⁶ For the reference case, we scale the future use per hectare to align with MPI's 'With Existing Measures' scenario. The same split among land uses is also applied to emissions from liming.

In mitigation scenarios where stocking rates and productivity are changing relative to the reference case, ENZ models reductions in the use of nitrogen fertiliser on dairy farms based on estimated changes in dry matter consumed per hectare. This requires assumptions to be made about relative contributions to the total reduction in dry matter intake from imported supplement, fertiliser use, and grazing off (when dairy cattle are grazed on sheep and beef farms). Our assumptions are based on the current average feed mix reported in *DairyNZ's Economic Survey*³⁷ and analysis of a number of studies assessing changes in nitrogen fertiliser use in conjunction with changes in stocking rates.

ENZ does not currently model mitigation-driven changes in fertiliser use for other land uses, including sheep and beef farming. Dairy farming accounts for roughly two thirds of current use of nitrogen fertiliser.

Waste

For the waste sector, ENZ is built to replicate MfE's models which are used to estimate waste emissions in New Zealand's Greenhouse Gas Inventory. This includes a First Order Decay model for landfills, with all parameters and assumptions (such as degradable organic carbon content and decay constants for different waste types) matching those used in the inventory.

ENZ models the main parameters which affect landfill and waste emissions: how much waste ends up in landfill sites, how much waste can be recovered from landfill and how widespread and efficient gas capture systems are at disposal sites.

The recovery measures modelled in the waste module are: recycling (which includes reuse), composting, anaerobic digestion and use for boiler fuel. The baseline for all the recovery measures has been set at zero, as any changes to waste volumes will reduce the waste to landfill baseline.

ENZ includes the broad categories of disposal sites: municipal with landfill gas (LFG) capture, municipal with no LFG capture, non-municipal landfills and farm fills. It also includes other waste disposal end points including biological treatment (composting), anaerobic digestion and open burning/incineration.

³⁶ (Stats NZ, 2021b)

³⁷ (DairyNZ, 2020)