Technical Annex

Modelling and analysis to support the draft advice on Aotearoa New Zealand's fourth emissions budget

April 2024

Contents

Introduction

He Pou a Rangi Climate Change Commission (the Commission) is publishing this technical annex to provide further information on the modelling, data, and analysis that underpins three separate but related consultation documents:

- our *Draft advice on Aotearoa New Zealand's fourth emissions budget*
- a discussion document on our *Review of the 2050 emissions reduction target*
- a discussion document on our *Review on whether emissions from international shipping and aviation should be included in the 2050 target, and if so how.*

We are consulting with the public on these three documents from 8 April – 31 May 2024. This technical annex should be read alongside the consultation documents and supporting material published on our website, which includes:

- assumptions logs and results workbooks
- updated methodologies and user manuals for our models
- external analysis commissioned as part of this work.

This supporting material can be found here: https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/preparing-advice-on-emissions-budgets/advice-on-the-fourth-emissions-budget/modelling-and-data-for-our-draft-advice-on-the-fourth-emissions-budget-20362040/

About our consultation documents

He Pou a Rangi Climate Change Commission is an independent Crown entity established by the Climate Change Response Act 2002 (the Act) to provide expert, evidence-based advice and monitoring to successive governments on how to reduce emissions and adapt to the effects of climate change.

Under the Act, the Commission must provide the Government with advice on setting Aotearoa New Zealand's fourth emissions budget by the end of 2024. As part of this work, we will also advise on the rules that apply to emissions budgets and whether revisions are needed to the first, second, and third emissions budgets. The Minister of Climate Change will set the fourth emissions budget by 31 December 2025. In preparation for delivering this advice, we have prepared our *Draft advice on Aotearoa New Zealand's fourth emissions budget*, and are now seeking feedback from the public.

The Act also requires us to review the 2050 target every five years, beginning in 2024. By the end of this year, we will advise the Government on the outcome of our first review, including whether any changes should be made to the target's timeframe, level, structure or rules. In preparation for delivering this advice, we have prepared a discussion document on our *Review of the 2050 emissions reduction target,* and are now seeking feedback from the public.

We are also required under the Act to advise the Government by the end of 2024 on whether to include international shipping and aviation emissions in the 2050 target, and if so, how. In preparation for delivering this advice, we have prepared a discussion document on our *Review on whether emissions from international shipping and aviation should be included in the 2050 target, and if so how,* and are now seeking feedback from the public.

This technical annex and the separate assumptions logs are relevant to all three consultation documents. Chapter references throughout this annex refer to our draft advice on the fourth emissions budget, unless otherwise stated.

About this document

This document provides further technical information for readers who want to learn more about the modelling underpinning our consultation documents.

It includes detail on these aspects of our analysis and proposals:

- our approach to modelling levels of greenhouse gas emissions and the economic impacts of actions to reduce them
- the data underpinning our draft advice
- how we have defined the reference scenario for each sector
- macroeconomic modelling of scenarios
- emissions from international bunker fuels
- temperature response modelling
- our approach for advising on revisions to budgets.

The Commission's approach for modelling emissions and economic impacts

Why we use models

The Commission uses a range of modelling to support our advice. Models are tools to help analyse and assess the choices that Aotearoa New Zealand has on how it can reduce emissions. They allow us to use assumptions to understand what these could mean for emissions and economic activity. However, on their own they don't tell the whole story, which is why they are inputs to our broader analysis.

The models we have used can provide useful insights about the dynamics of the economy and the flow on effects that can occur when one sector makes changes. Our modelling also includes some estimates of costs and savings from taking particular actions. These allow us to understand some of the implications of the different modelled outcomes, and therefore what the impacts could be for businesses, households and the overall economy. The results of the modelling have been used to support the Commission's draft advice on our proposed level of the fourth emissions budget, and the discussion documents on the review of the 2050 emissions target, and whether emissions from international shipping and aviation should be included in the targets.

Modelling also allows us to explore the uncertainty around the assumptions in a structured way. We do not use models to forecast what will happen. Instead, they are used to understand what could happen under various sets of assumptions we have made. Any projections made are inherently uncertain, especially when projecting decades into the future. Changes in how people live their lives are not always easy to predict, and new technologies are continually developing. We have therefore used our models to better understand uncertainty and try to give the best answers possible given the things we know we don't know – through modelling a range of scenarios and pathways and conducting sensitivity analyses.

Our modelling builds on the approach taken in *Ināia tonu nei* which was externally reviewed and scrutinised. Since then, we have made improvements to the models to enable us to better reflect mitigation technologies that could be available in the future, as well as understand some of the cost impacts and implications in greater detail. All changes to the models have been externally reviewed.

We will further refine our modelling and analysis using feedback from consultation as we finalise our advice.

Why more than one model is useful

We have used two main models to support our draft advice. All models have constraints, we specify the constraints of our models in the below sections. These models need to be supplemented by other forms of analysis to form a complete picture. All models are necessarily a simplification of a more complex system and are not intended to represent all aspects of that system in detail. Therefore, it is not possible or appropriate to rely solely on a single model to guide our work. Using a combination of models is helpful because they can provide different insights. By understanding the strengths and limitations of our different models we have been able to ensure we draw the appropriate conclusions. In some cases, our models can provide different perspectives on the same parts of the system (for example, the speed at which electric vehicles (EVs) are adopted). Where this is the case, interpreting the different results is helpful to draw conclusions.

Our approach to modelling emissions in ENZ

Overview of ENZ

We produce our emissions scenarios using a purpose-built model called Energy and Emissions in New Zealand (ENZ) that was developed by Concept Consulting. The Commission purchased ENZ and have worked with Concept Consulting to further develop it to meet our needs.

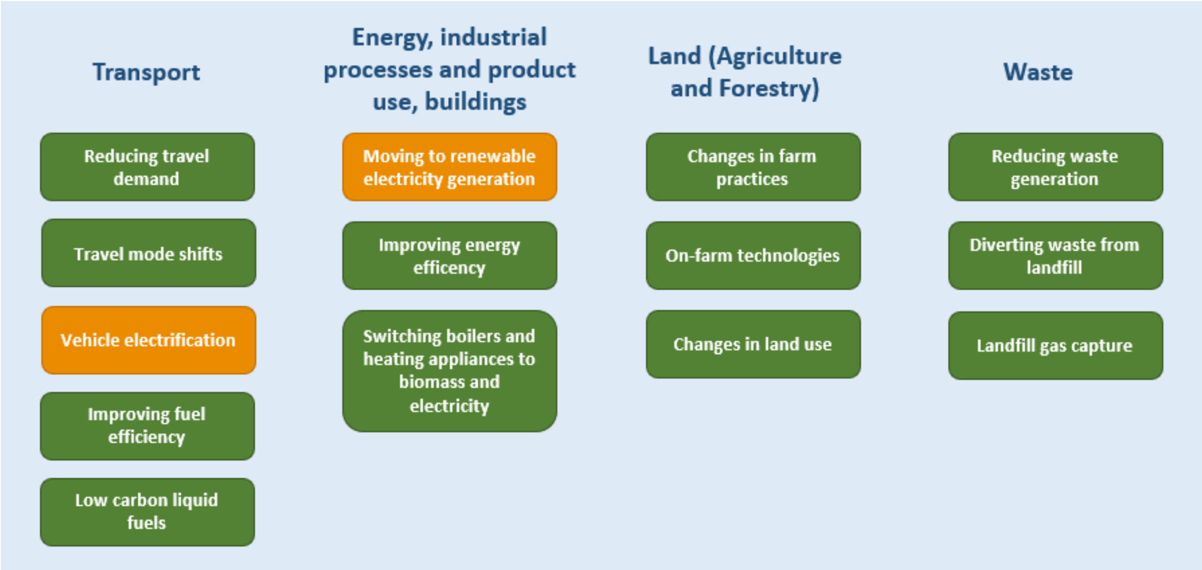
ENZ is a bottom-up, technology-rich model. It allows us to investigate, from a whole-of-system point of view, changes to emitting activities and technologies in each sector of the economy. It allows us to factor in anticipated technological developments or changes in behaviour or practice. ENZ produces economy-wide emissions estimates along with other data and insights such as energy costs.

ENZ models all the relevant sectors of the Aotearoa New Zealand 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 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.

ENZ deploys emissions reduction technology when it becomes economic to do so, considering various costs. The user can also specify when technology uptake occurs and the extent to which it is deployed to over-ride this economic selection. **Figure 1** below indicates which of these methods was used for each of the key emissions reduction options in the model (information on data sources can be found on pg. 13).

Figure 1: *Key emissions reductions options represented in the ENZ model. Orange boxes mean that the model simulates their uptake in each year based on costs, available resources and other factors. Green boxes mean that we specify their uptake as an input assumption in each scenario we run.*



Source: Commission analysis

Emissions values in ENZ

One of the inputs into the ENZ model is the government's estimated emissions values to 2050.[i] We have used these to determine the speed of adoption for only some mitigations – the selection of electricity generation technologies and electric vehicle uptake. All other actions are selected based on scenario specific assumptions to determine uptake of actions.

We have opted to limit the use of the emissions values to predict the speed of adoption for most measures because:

- In some sectors, for example in process heat, there are constraints beyond the cost of decarbonisation such as supply chain issues and workforce constraints. As these are not modelled explicitly in ENZ we have specified decarbonisation pathways for these sectors externally to the model.
- For some mitigations we believe non-economic factors could drive the adoption of these actions.
- Some mitigations provide wider co-benefits, which are not considered by the individual decision maker, provide benefits for wider society.

We have held the emissions values constant across the scenarios and pathways modelled. This simplifies the comparisons between the reference scenario and other scenarios.

The emissions values used as an input in the scenarios should not be directly interpreted as emissions prices which would be observed in the New Zealand Emissions Trading Scheme (NZ ETS). In addition to not being a modelled price path, the actions selected under the scenarios could be encouraged through a mix of pricing and other policies, which could mean that the market price in the NZ ETS would not necessarily equal the emissions values needed to meet the 2050 target.

[i] The Emissions values follow the mid-point of ETS settings (cost containment reserve trigger price and reserve trigger price) published by the Ministry for Environment in the 2023 ETS limits and price control settings for units' consultation document. These values are consistent with the values used in the government's agency projections.

Limitations of ENZ

We have selected a modelling approach that balances the level of complexity with the required outputs and insights. As with any modelling, our approach has some limitations.

ENZ models emissions levels across all key emitting sectors of the economy, based on a set of input assumptions. This involves modelling a broad range of production activities and mitigations. Sectors are modelled in varying levels of detail depending on the level of information available, the complexity of the sector and the materiality of the sector's emissions. However, ENZ is not an optimisation model.

In practice, the uptake of mitigation measures or technologies can be influenced by a number of non-cost factors which ENZ does not have information on.

Further limitations are detailed in **Table 1** below.

Table 1: *Limitations in the ENZ model*

Limitation	Mitigation
The road transport stock module assumes an even distribution of retirement across the fleet. This means, that in instances where road travel demand growth is low or negative, EV uptake is constrained, and the EV share is lower than in higher-demand growth scenarios.	To mitigate this effect, we added a dynamic stock turnover feature into ENZ.
ENZ is not a dedicated electricity market model, and as such only models the electricity system at a high level.	We have procured detailed electricity market modelling to complement the results from ENZ (pg. 9). This provides some validation that the higher-level electricity modelling performed in ENZ is not unrealistic.
ENZ does not have functionality to project emissions from F-gases itself and requires assumed projections to be built in.	We rely on projections of F-gas emissions provided by the Ministry for the Environment (MfE) which are built into ENZ.

Further detail on our ENZ modelling is in the *ENZ model technical manual,* and can be found here: https://www.climatecommission.govt.nz/public/Uploads/EB4/supporting-docs/EB4-05-ENZ-technical-manual-for-draft-EB4-advice.pdf

Our approach to understanding economic impacts through C-PLAN

Overview of C-PLAN

C-PLAN is a Computable General Equilibrium (CGE) model. These are a class of models commonly used to help understand some of the economic effects of climate change mitigation.[1] They are also commonly used in other areas of economic policy, such as trade policy.

CGE models estimate the optimal allocation of resources like labour and capital within an economy, while meeting constraints and assumptions about behaviour. This allocation of resources determines how much each sector produces. If we make a change in the model that changes how resources are allocated, we can then see how the effects flow through to each sector.

To understand the implications of different emissions trajectories we impose a constraint on the level of emissions in the model. We can also change the technologies available in the model. The model will then find emissions values that allow it to meet this constraint, adjusting the mix of technologies used and the output of different sectors in order to meet the constraint.

C-PLAN is specifically designed to model the effects of technologies or actions intended to reduce greenhouse gas emissions in Aotearoa New Zealand. It includes values for emissions, the ability to switch between energy sources including away from fossil fuels to renewable sources, and a range of emissions-reducing technologies.

A full description of C-PLAN, as it was in 2022, is given in the article *The Climate PoLicy ANalysis (C-PLAN) Model, Version 1.0*[2,ii]. For this draft advice, we have added several new emissions-reducing technologies to the model and updated the data, but we have not made fundamental changes to any other aspect of the model. We have also strengthened the links with ENZ in places so that more of the inputs for C-PLAN come from ENZ.

Emissions values from C-PLAN

In C-PLAN, the emissions values play a larger role than they do in ENZ as most choices are based on prices. Emissions values change the relative prices of inputs and outputs of production, and the relative price changes impact demand for goods and services. This affects how much of each good or service is produced, and what is used to produce that good or service. Where there are external constraints, like total biomass availability for process heat, it is still price driven but there is a constraint on how much can be used. There is no mechanism to drive uptake of non-economic mitigation technologies apart from (rarely applied) subsidies.

In the reference scenario[iii] in C-PLAN, emissions values are provided to the model, and (like ENZ) they are the government's estimated emissions values to 2050. There are separate values specified for biogenic methane, all other greenhouse gases other than biogenic methane, and forestry emissions. The model then calculates emissions levels based on those values and the mitigations in the model. These mitigations include new technologies, fuel switching, and reducing the level of output from sectors.

In all scenarios and paths modelled, except for the reference scenario, the model solves for the emissions values needed to ensure the emissions constraints are met. Separate emissions constraints are input for biogenic methane and all other greenhouse gases other than biogenic methane. The level of carbon removals by forests are also input as an assumption.

As is the case with ENZ, the emissions values calculated by C-PLAN are not a projection of the NZ ETS price. These values should not be used as any indication of prices that the NZ ETS might require to meet the 2050 target. The emissions prices required to meet the target will depend on a number of choices, including the role of pricing and other policies to meet the target.

Moreover, as an economy wide model, the opportunities for emissions reductions in C-PLAN through technology uptake and systems change are a subset of the larger set of opportunities included in the ENZ model. This manifests as high emissions values for the more ambitious reductions in emissions modelled. For example, the emissions values for non-biogenic methane emissions in 2050 in the *C-PLAN results for draft EB4 advice* spreadsheet reach around $1,200/t$CO_2$e in the demonstration path, with much of the price rise happening in the 2040s when ENZ has a number of emissions reductions available that C-PLAN does not. The emissions cap represents what is feasible in ENZ, which is more than C-PLAN can do, and so in C-PLAN it is a tighter constraint which pushes emissions values up artificially.

[ii] Niven Winchester and Dominic White, the authors of this paper, led the development of C-PLAN. This development was funded by the Commission.

[iii] See *Chapter 3: Developing the proposed path to the fourth emissions budget*

Limitations of C-PLAN

As with our approach for ENZ, we have selected a modelling approach that balances the level of complexity with the required outputs and insights. As with any modelling, our approach has some limitations.[iv] Like all models, C-PLAN is a simplified representation of a complex real-world system. It is one of several tools we use in combination to aid our thinking and help us understand the implications of our proposals. It is not appropriate to consider the output as forecasts.

CGE models are designed to show how a change in one part of the economy has impacts on other parts of the economy through changes in costs, and supply and demand for goods and for resources. For example, if we place a price on emissions, some sectors like wind electricity will benefit because of greater demand for low-emissions energy (because high-emissions energy is now more expensive). This helps us to see the big-picture effect of our proposals on the economy as well as how things shift between sectors within the economy. When we understand how things shift, we can also use that to infer who will be most affected by changes.

C-PLAN provides a high-level representation of all sectors of the economy, and the interactions between them. It does not include the detailed representation of technologies and mitigations which are able to be included in ENZ.

C-PLAN is not an endogenous technological change model. As such, it does not include any induced innovation in response to prices. This means emissions values (and other prices) in C-PLAN will encourage the uptake of emissions-reducing technologies that are available in the model, but will not result in the invention and deployment of new technologies. New technologies can easily be expected in the future and allow a sector to reduce its emissions cost effectively, rather than reducing output to reduce emissions. Since the scenarios represent the economic outcomes of a given set of assumptions, it is reasonable to assume that the impact on GDP and emissions prices is likely to be upward biased.

Like many CGE models, the model assumes that businesses and households are able to adjust perfectly in response to the changes happening in the EB4 demonstration path. In reality, financial, behavioural or technological constraints may mean that this is not possible.

The inputs to the model are based on the current structure of the economy. We cannot be sure that the parameters in the model will stay the same, especially if there are large changes in the economy and/or society.

C-PLAN does not consider the expected effects of the physical impacts of climate change (such as droughts, floods, forest fires, changing weather patterns) on economic output. Experience from recent extreme weather events suggests the impact of these events could be substantial. While recovery from these events could boost economic activity in the short term, it diverts resources from other productive uses.

Additional modelling that supports our work

Alongside the modelling work undertaken by the Commission, we have procured additional modelling work. This additional modelling helps to address some of the limitations of our internal models as well as giving deeper insights into topics not covered in detail by our own models.

[iv] To obtain a more complete picture on the economic impacts of reducing emissions, in addition to our modelling we also reviewed a wide range of relevant research, global and local, on the likely benefits and costs of climate action. We provide details on this approach in our main report, most notably in *Chapter 5: The impacts of meeting the fourth emissions budget on New Zealanders.*.

Detailed electricity market modelling

The purpose of this work was to inform the Commission's evidence base and subsequent conclusions and recommendations regarding the construction of new generation assets, retirement of existing assets, and the role of thermal generation in the electricity system. This was done with a view of understanding the emissions consequences of these elements while also considering security of supply and affordability. Specifically, the purpose was to:

- complement and validate the basic electricity system modelling of ENZ with Energy Link's more detailed modelling suite (E-Market and I-Gen models)
- test the impact of varying hydro inflows on the wholesale price of electricity
- validate ENZ outputs such as the future generation stack and thermal operation
- gain insight into the impact of varying gas and carbon prices.

Methodology

The approach is detailed below. It largely follows that of modelling undertaken with Energy Link to support and inform previous pieces of the Commission's advice, including, *Ināia tonu nei*[3], *Advice on NZ ETS unit limits and price control settings for 2023-2027*[4], and *Advice on the direction of policy for the Government's second emissions reduction plan.*[5]

- Scenarios are modelled in ENZ and the electricity demand output from ENZ is used as an input for the Energy Link models.
- We also provide fuel prices, carbon prices, a pathway for distributed solar generation, and levelised costs of electricity as inputs for Energy Link's models. We work with Energy Link to determine some of these factors.
- The market structure is assumed not to change.
- E-Market and I-Gen are run iteratively until a suitable match between supply and demand is reached.[v,6]

Results

High level results are presented in *Chapter 5: The impacts of meeting the fourth emissions budget on New Zealanders* with details available in the accompanying spreadsheet:
https://www.climatecommission.govt.nz/public/Uploads/EB4/supporting-docs/EB4-08-Electricity-market-modelling-datasets-for-draft-EB4-advice.xlsx

NZ process heat decarbonisation workforce modelling

We procured modelling to understand the workforce requirements for process heat decarbonisation. The decarbonisation of process heat is a critical part of reducing energy emissions. A key constraint and challenge faced is ensuring there are sufficient skilled workers who are able to deliver all aspects of the decarbonisation. DETA provided detailed modelling which considered the different kinds of workers needed to deliver decarbonisation projects. They estimated the likely size of the workforce needed and compared this to Ministry of Education data on the numbers of students graduating with the relevant qualifications, as well as

[v] For every scenario a 'build' of new generation is established which balances growth in demand and changes in operation of existing generation using a simulation of how market participants decide to build new generation, with future price expectation and earnings as key decision variables. The build sequence is generally from lower cost project to higher cost project, although location on the grid and the generation output profile of different types of renewable generation also play a part. The timing of project development is iteratively refined to ensure that new generation meets its earnings targets. If projects are developed too early, then the market price becomes supressed, and the projects can fail to cover their costs.

immigration data. The results showed that some key skills are likely to be in short supply and concentrated efforts may be needed to lift the number of students studying in these areas.

The *NZ Process heat decarbonisation report* and *NZ Process heat decarbonisation workforce modelling* are published in full on our website and can be found here: https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/preparing-advice-on-emissions-budgets/advice-on-the-fourth-emissions-budget/modelling-and-data-for-our-draft-advice-on-the-fourth-emissions-budget-20362040/

Updates to our internal models

In preparation for this draft advice, we made improvements to our modelling. These included adding new features and technologies and improved reporting and structural changes which improved model stability and ease of use. These changes are described in **Table 2** below.

Table 2: *New features added to our modelling since our 2022 ETS advice*

Feature	Description
ENZ	
Improved aviation sector representation	We added a more detailed representation of aviation emissions. This included estimating capital and fuel costs associated with new technologies like battery and hydrogen aircraft. We also added low-carbon liquid fuel blending.
Incorporate vehicle feebate and standard policies	Allow for the inclusion of feebate and emissions standard policies into ENZ.
Added air pollution volume and cost to ENZ	ENZ now projects common air pollutants CO, NOx, and PM 2.5 and uses damage costs to calculate the social cost associated with each pollutant. Pollution volumes were based on fleet averages from Waka Kotahi's Vehicle Emissions Prediction Model (VEPM)[7] and published damage costs using the Health and Air Pollution in New Zealand methodology (HAPINZ 3.0)[8].
Dynamic stock turnover	Updated stock turnover approach allows for more vehicle turnover when there is a low or negative growth in vehicle travel. This allows for better representation of fleet dynamics.
Process heat decarbonisation pathways	Allows non-price driven dynamics to be incorporated into process heat decarbonisation pathways.
Rooftop solar and grid scale batteries	ENZ now has functionality to project residential rooftop solar and grid-scale batteries as part of its electricity generation projections.
Urea production from hydrogen	ENZ now includes functionality to switch some, or all, urea production to being produced using green hydrogen.
Steel making	ENZ now includes functionality to project steel making produced with an electric arc furnace, green hydrogen, or a combination of the two.
Zero carbon anodes	We have added zero carbon anodes as a mitigation technology available for aluminium production.

Allowing for new industrial electricity demand	ENZ now has functionality to allow for additional electricity load from new green hydrogen or data centre industries.
Demand driven uptake of low carbon liquid fuels	Demand for low carbon liquid fuels can be specified in land, aviation, and marine sectors.
More detailed representation of domestic and international aviation	We added a basic stock model and more detailed representation of the aviation sector to allow better tracking of costs.
Improved approach to costs analysis	This focused on better representing the capital requirement to build electricity to meet demand from sectors like transport and industry. Previously in these sectors we treated electricity supply as a fuel cost amortised over the lifetime of the infrastructure.
Improved modelling of electricity and fossil gas distribution network costs	The transmission and distribution networks for both electricity and fossil gas are now modelled in greater detail. This allows for improved cost estimates.
Improved reporting	We have updated the way in which ENZ presents the outputs of each model run to be more user friendly for processing and displaying.
C-PLAN	
Technologies for iron and steel production	C-PLAN now includes functionality to project steel making produced with an electric arc furnace, green hydrogen, or a combination of the two. Like the methane-reducing technology for agriculture used in *Ināia tonu nei*, these technologies create the same product from different inputs, partially replacing production from the current method.
Green hydrogen for ammonia and urea production	Green hydrogen is introduced as an optional substitute for coal and gas in the production of ammonia and urea, which make up about 10% of the chemicals, rubber, and plastics industry in C-PLAN.
Zero carbon anodes for aluminium production	Zero carbon anodes were made available as a technology for reducing emissions from aluminium production in some scenarios. This works by providing emissions credits in the model for the reductions, rather than as a substitute method of production.
Changes to EV uptake	EV uptake is now managed using a constraint on uptake, based on ENZ results. Where appropriate, this allows a greater difference than the previous method between the uptake in the reference scenario and the uptake in other paths and scenarios.
N_2O inhibitor for dairy farming	An N_2O inhibitor was made available as a technology for reducing emissions from dairy farming in some scenarios. This works by providing emissions credits in the model for the reductions, allowing it to be used alongside the methane-reducing technologies and other emissions-reducing technologies in agriculture. Due to the high price of the inhibitor, it is not usually taken up by the model.
Improved genetics for livestock	Improved genetics for sheep and beef cattle are included implicitly in the data from ENZ that is used for the reference scenario. Improved genetics for dairy cattle are included as a technology for reducing emissions from dairy farming in some

	scenarios. Like the N_2O inhibitor, this works by providing emissions credits in the model for the reductions, allowing it to be used alongside the methane-reducing technologies and other emissions-reducing technologies in agriculture.
Closer links to ENZ results	C-PLAN, as used for this work, has closer links to ENZ results for both the reference scenarios and the general scenario and demonstration paths. This includes aligning agricultural productivity and the demand for road transport with the appropriate ENZ values.
Greater use of Inventory data	For this draft advice, C-PLAN uses much more of the detailed data in the NZ Greenhouse Gas Inventory than it did for *Ināia tonu nei* (which relied more on GTAP data for NZ emissions).

Review of our models

Our modelling builds on the Commission's previous analysis. Our models have been developed by internationally renowned experts with a comprehensive understanding of the context and sectors that are represented. Additionally, as part of developing our advice for *Ināia tonu nei*, experts from Aotearoa New Zealand and around the world reviewed them prior to the release of our draft advice. Our economic models are robust and fit for purpose. Expert reviewers said that they were "impressed by both the scope and detail of the modelling efforts and believe that these provide a robust quantitative framework to support ambitious climate policy proposals for Aotearoa."[vi] In addition to our previous reviews for this analysis we engaged further expertise to support us in development and to review the changes to the models.

We are also likely to make further changes to our modelling as a result of feedback received during consultation.

Concept Consulting

We engaged Concept Consulting to improve and develop the ENZ model in preparation for our draft advice. For each of the features added to ENZ listed in **Table 2** above, a review process was undertaken by the Commission's staff and/or experts from Concept Consulting. For key areas like modelling the electricity sector modelling, we engaged additional external expertise to cross check results coming out of ENZ.

Emission Impossible

Emission Impossible Ltd was commissioned to review the analysis of the impacts of air pollution from road transport within ENZ. Emission Impossible is an expert consultancy focusing on air pollution. The team includes co-authors of the Health and Air Pollution in New Zealand study (HAPINZ 3.0), a key piece of evidence about the impacts of air pollution in Aotearoa New Zealand.[9,vii]

They found that our analysis was in line with published methodologies and the results were comparable when adjusted for inflation with other Aotearoa New Zealand studies. Overall, the review found that our analysis of costs was appropriate and robust.

[vi] The reviews are available on the Commission's website https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/inaia-tonu-nei-a-low-emissions-future-for-aotearoa/modelling/

[vii] A key finding of this study is that air pollution, from anthropogenic/human sources, is responsible for an estimated 3,300 premature deaths per year in Aotearoa New Zealand, with a social cost estimated at $15.6 billion per year.

Professor Niven Winchester

To support the development of this draft advice, we engaged Professor Niven Winchester, the original developer of the C-PLAN model, to update the model to account for new technologies, including those listed in **Table 2.** A small number of additional features added by Commission staff were reviewed by Professor Winchester, who also reviewed our overall approach to using C-PLAN for this draft advice.

The data we have used

Greenhouse gas inventory

New Zealand's Greenhouse Gas Inventory (the inventory) is the official annual report of all anthropogenic (human induced) emissions and removals of greenhouse gases in Aotearoa New Zealand. It is produced annually by MfE. For our draft advice we have used the 2023 inventory which contains data from 1990 to 2021. In our final advice we will use the 2024 inventory (expected to be released 18 April 2024), which will contain data from 1990 to 2022.

Every year, methodological improvements are made to the way emissions are estimated. These changes follow the Intergovernmental Panel on Climate Change's guidelines for the preparation and continuous improvement of national greenhouse gas inventories. The changes are reviewed by an international team of experts certified by the United Nations Convention on Climate Change. A consequence of methodological changes is that historical data in the inventory can change from year to year as improvements are made, which can in turn result in changes to the projections of future emissions levels.

The Ministry for the Environment have advised that the 2024 inventory will have methodological improvements incorporated, which are largely focussed on the agricultural sector. Any changes, as well as the new year of emissions data (2022), will be incorporated in our final advice.

Government projections

Every year the government produces emissions projections to 2050 based on the latest inventory data.

The set of projections released in December 2023 included a 'with existing measures' (WEM) scenario, which includes policies implemented or adopted by the Government by 1 July 2023, along with the economic conditions and other assumptions as of that date. In addition to the WEM scenario, the set of projections included WEM low and WEM high.

We have used the WEM projection released in December 2023 as part of calibrating our reference scenario, as these are the most up to date projections available. We note that there have been a number of policy changes since 1 July 2023, which we understand will be incorporated into the 2024 government projections.

We plan to update our reference scenario for our final advice, though this is dependent on updated WEM projections being available in time.

Some government agencies provided additional details and assumptions that underpinned the WEM projections.

Other key data sources

In addition to the greenhouse gas inventory and the government projections data, we have used external data from a range of sources. These data are used to better model the underlying drivers of emissions and/or provide the economic inputs needed for the Commission's models.

The key external data sources used are listed in **Table 3**.

Table 3: *Key external data sources*

Source	Description
2021 fleet statistics (Ministry of transport)	Historical data (up to 2021) on all road vehicles, vehicle age, travel by vehicle and fuel type. Used to update base year fleet information across the ENZ transport model, including the number of vehicles entering and exiting, proportion of new and used vehicles and age profile of the fleet.
Vehicle fleet emission model 2023 update (VFEM) **(Ministry of transport)**	We also included updated data on vehicle entry from the motor vehicle register which is released monthly.
Oil price	Near-term oil prices have been updated using the U.S Energy Information Agency (EIA) short-term oil price outlook 2023-2024. Long-term oil prices taken from the International Energy Agency (IEA)
GDP	GDP forecasts are taken from Treasury's latest Economic and Fiscal Update. https://www.treasury.govt.nz/publications/budgets/forecasts
Electricity and other energy data	Historical electricity generation and energy use data from the Ministry of Business, Innovation and Employment. We also use the Energy Efficiency and Conservation Authority's Energy End-Use Database which contains historical energy use by fuel type linked to the end use the energy fuels. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/
Ministry for the Environment F-gas projections	ENZ does not have any functionality to model HFC stocks and emissions directly. Instead, we have relied on projection estimates supplied by MfE.
Forestry costs	We commissioned Scion to provide an analysis of cost estimates for establishment, tending, harvesting, and log transport.
GTAP	The Global Trade Analysis Project (GTAP) dataset has data on inputs and outputs for all industries and almost all countries, balanced to meet accounting identities and set up for use in CGE models. C-PLAN uses the 2014 data from GTAP10 as a major data source, including for greenhouse gas emissions in the rest of the world. https://www.gtap.agecon.purdue.edu/databases/v10/index.aspx
OECD and IEA	For C-PLAN, global GDP projections and global electricity projections by generation type come from the OECD and the IEA respectively. Global emissions prices are derived from the IEA's *Global Energy and Climate Model Documentation Announced Pledges Scenario* https://iea.blob.core.windows.net/assets/2db1f4ab-85c0-4dd0-9a57-32e542556a49/GlobalEnergyandClimateModelDocumentation2022.pdf

Assessment of emissions reduction and removal opportunities

A requirement in the Act is to consider how emissions budgets may realistically be met. There is a vast amount of evidence available from within Aotearoa New Zealand and internationally that has underpinned our analysis.

We have reviewed the evidence that underpinned the analysis in *Ināia tonu nei*, focussing our attention on mitigations in sectors that have the most impact on Aotearoa New Zealand's emissions, while also considering their expected costs.

Where we identified significant gaps in the required evidence, we engaged external expertise to assist in developing an evidence base. The key externally-supplied evidence is discussed below.

Report on agricultural greenhouse gas mitigation technologies

We are aware of a number of methane-reducing technologies that could become commercially viable before the start of the fourth emissions budget period. Given their high potential for emissions reductions, and uncertainties on their availability (including timelines and costs), we sought an up-to-date independent assessment on these technologies. In particular, we wanted to understand what these technologies are and to further understand their:

- timeline to implementation
- barriers to use in Aotearoa New Zealand
- potential costs associated with the technologies
- potential adoption rates
- potential efficacy.

We commissioned The Agribusiness Group to undertake this analysis. The report informed our assumptions for agricultural technologies in our modelling. These technologies are described in greater detail in *Chapter 2: Proposed level for the fourth emissions budget* and *Chapter 4: Sector contributions to meeting the fourth emissions budget*. The *Report on agricultural greenhouse gas mitigation technologies* is published in full on our website and can be found here: https://www.climatecommission.govt.nz/public/Uploads/EB4/supporting-docs/Report-on-agricultural-mitigation-technologies-Final.pdf

NZ process heat decarbonisation report

One of the areas identified for further investigation was to explore process heat decarbonisation in greater depth. In particular we wanted to understand the capability of Aotearoa New Zealand to deliver process heat decarbonisation projects and in what time frame decarbonisation could be completed. We commissioned DETA to undertake this analysis. Their analysis estimated the amount of effort required to complete decarbonisation, as well as considering constraints including supply chain, electricity supply and workforce.

This report was used to inform our assumptions on the phase out of fossil fuels in process heat. The report on *NZ process heat decarbonisation* and *NZ process heat decarbonisation workforce modelling* is published in full on our website and can be found here: https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/preparing-advice-on-emissions-budgets/advice-on-the-fourth-emissions-budget/modelling-and-data-for-our-draft-advice-on-the-fourth-emissions-budget-20362040/

Reference scenario alignment

Alongside our four scenarios to 2050 (detailed in *Chapter 3: Developing the proposed path to the fourth emissions budget*) we have also developed a reference scenario. This scenario is designed to represent what projected emissions would look like if there were no further emission reductions policies or measures implemented, other than those in place as of 1 July 2023.

Where possible, we have aligned our reference scenario to the Government's WEM. This approach was used because it provides a common point of comparison with government agencies and incorporates their assessment of current policies as of 1 July 2023.

The reference scenario does not perfectly replicate the WEM scenario. This is not unexpected as achieving perfect alignment between different models is always challenging. Furthermore, in some areas we have not received sufficient detail of the assumptions driving the WEM projections and therefore cannot compare it to the assumptions in the reference scenario.

Our reference scenario will be updated for our final advice to account for changes in policy that have occurred since 1 July 2023.

Transport sector alignment approach

The reference scenario in the road sector was developed using the VFEM model results provided by the Ministry of Transport (MoT). The VFEM modelling provided included three scenarios for EV uptake: base, fast, and slow. We based our reference scenario on the base EV uptake scenario.

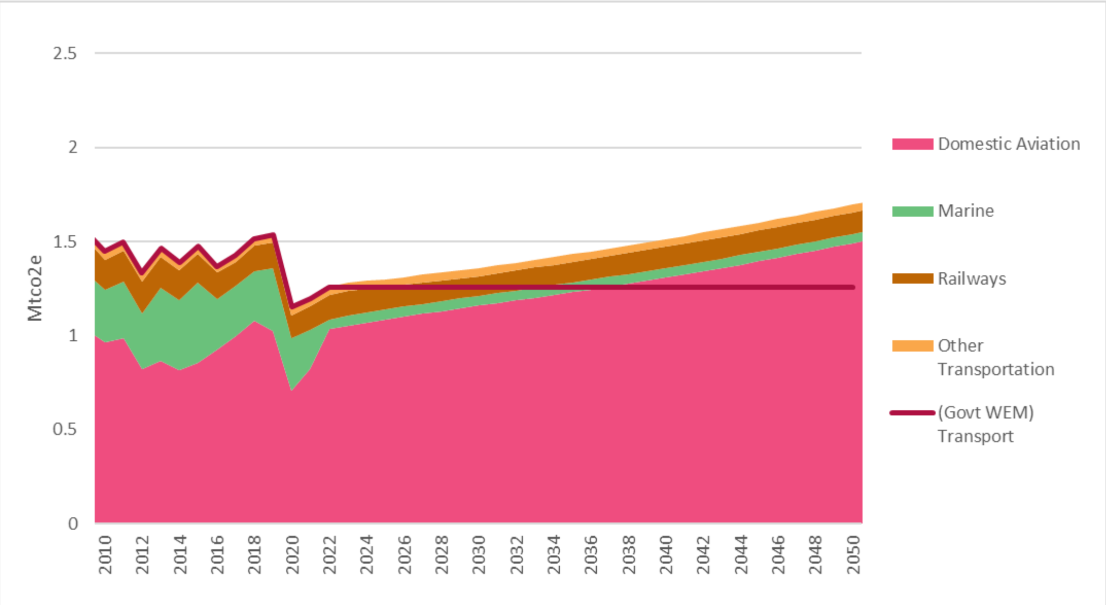
In addition to the exogenous inputs, the ENZ model was calibrated against VFEM to achieve closer alignment between the reference and the WEM scenarios. Calibration involved adjusting a range of assumptions to align the two models as closely as possible.

For non-road sectors, only the emissions outcomes were available. We aligned our reference scenario on the first year of projections, which fit with published energy data for 2022. Projections beyond this point were based on our assumptions about subsector activity, efficiency, and technology adoption.

Road transport emissions projections in the WEM and reference scenario are closely aligned until 2030. After 2030, different vehicle stock modelling, including vehicle turnover, vehicle travel by age, uptake of rate of non-EV fuel types leads to deviating emissions. The cumulative result in the reference scenario is 1 $MtCO_2e$ fewer emissions in 2050 than the VFEM.

For non-road sectors, the Government's projections are held flat at 1.26 $MtCO_2e$. In ENZ, activity demand projections were combined with efficiency, technology adoption, and fuel switching assumptions to project future demand in non-road sectors. The result is a gradual upward trend in emissions primarily driven by the aviation sector (**Figure 2**). In the reference scenario, marine emissions in 2022 are only one quarter of their 2021 level from 0.2 $MtCO_2e$ to 0.05 $MtCO_2e$. This drop-off is also shown in quarterly energy statistics. A change of this magnitude is not reflected in the available activity statistics. Notable changes that have occurred include the closing of the Marsden point oil refinery resulting in less oil deliveries in 2022.

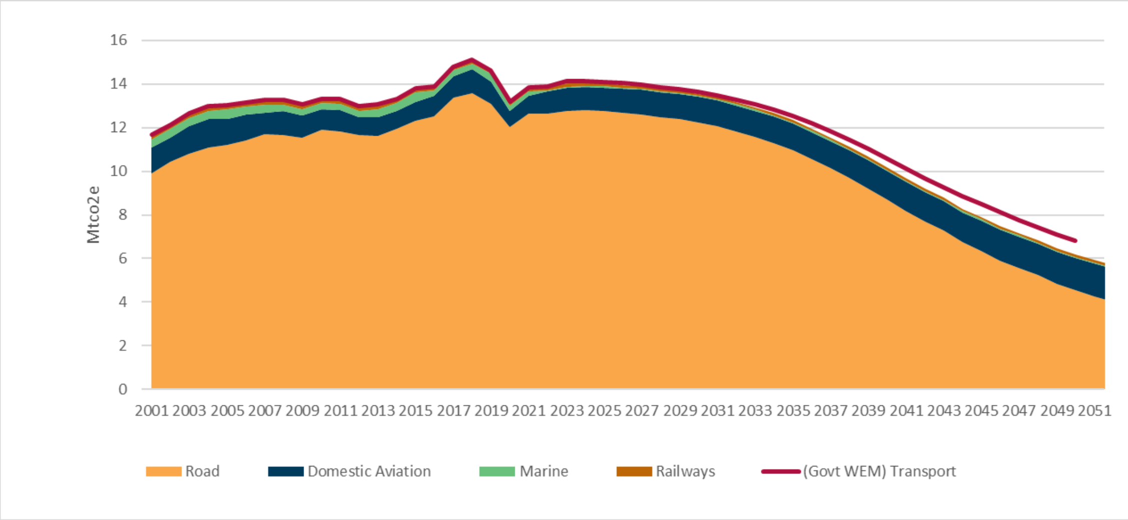
Figure 2: *Non-road emissions compared with the government WEM*



Source: Commission analysis

Overall, when both sectors are aggregated the overall difference between the reference scenario and the Government's WEM is reduced. In 2050, the two scenarios deviate by only 10% or 0.6 $MtCO_2e$ (**Figure 3**)

Figure 3: *Transport emissions by subsector in the reference scenario and total projected emissions in the WEM*



Source: Commission analysis

Agriculture, forestry, and waste

The reference scenario for agriculture, forestry, and waste align closely to WEM. For agriculture, the reference scenario replicates WEM historical and projected values. This covers aspects such as stock numbers and land use areas. The ENZ model uses its own productivity and emissions intensity data using Ministry for Primary Industries (MPI) data as inputs.

For forestry, MPI historic and projections data for afforestation and deforestation are used for the reference path to align with the WEM. ENZ models subsequent growth and sequestration using these MPI figures.

Waste uses MfE projections for different waste types and volumes, these projections are then modelled in ENZ to determine decomposition, levels of methane and gas capture rates.

Industry, energy, and buildings alignment approach

We have not been able to source the underlying assumptions driving the WEM projections in these sectors. Therefore, we have not attempted to align our reference scenario with the WEM in these sectors.

Two key differences we are aware of between our reference scenario and the government WEM are:

- Aluminium production – in the reference scenario we assume the New Zealand Aluminium Smelter at Tiwai Point remains open until at least 2050, whereas the government WEM assumes it closes and ceases production at the end of 2024.
- Steel production – in the reference scenario we assume a 50% reduction in emissions from steel production from 2027. This is based on the deal announced between the Government and NZ Steel to install an electric arc furnace at the Glenbrook Steel Mill. The government WEM does not account for this.

Other key assumptions in the reference scenario are:

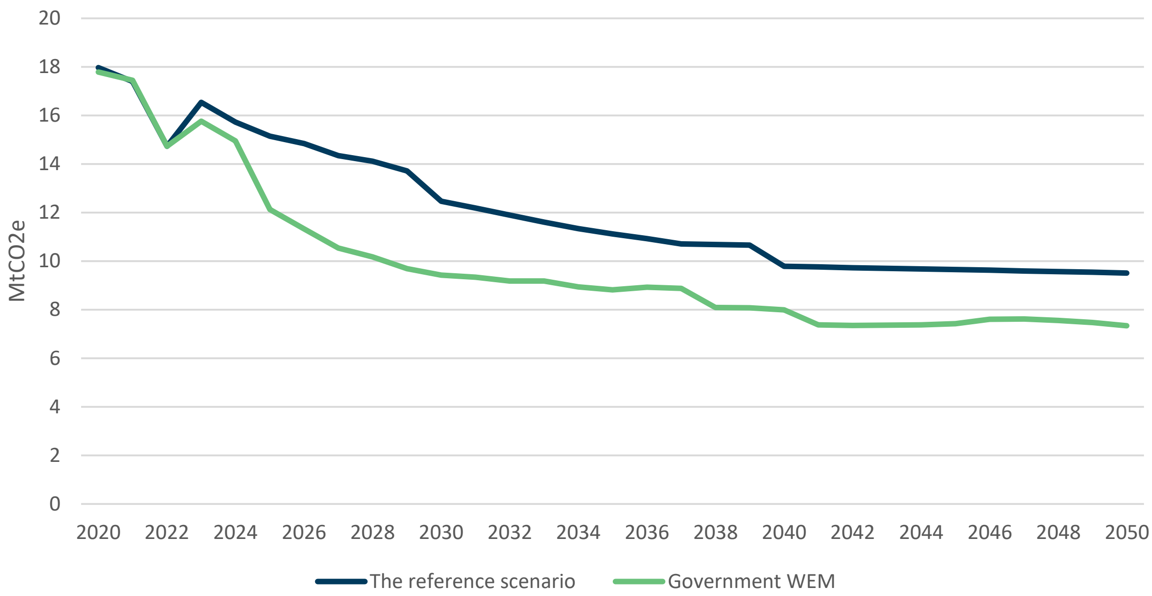
- Coal for low-medium temp process heat (including in the residential and commercial buildings sectors) is phased out by 2037 in accordance with the national policy statement.
- Methanol production is assumed to undergo a staged exit with one train closing in 2030 and the second train closing in 2040.

Non-transport energy emissions in the reference scenario

In the reference scenario, key drivers of reductions are process heat decarbonisation measures, efficiency improvements, and the substitution of fossil-fuelled baseload generation with new renewables in the electricity sector.

Figure 4 below shows the non-transport energy emissions projections under the reference scenario and the government WEM scenario.

Figure 4: *Non-transport energy emissions under the reference scenario and Government WEM projections*

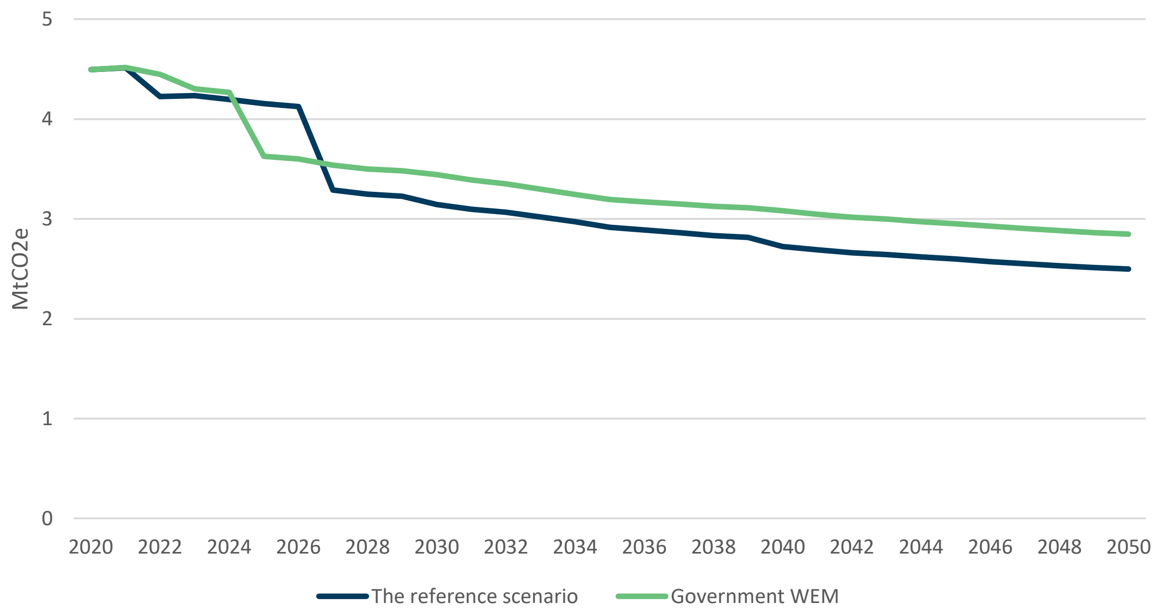


Source: Commission analysis

The government projections are significantly lower than the reference scenario. It is unclear what is driving the greater levels of emissions reductions projected in the government WEM.

Figure 5 shows the same comparison, but for industrial process and product use emissions.

Figure 5: *IPPU emissions under the reference scenario and Government WEM projections*



Source: Commission analysis

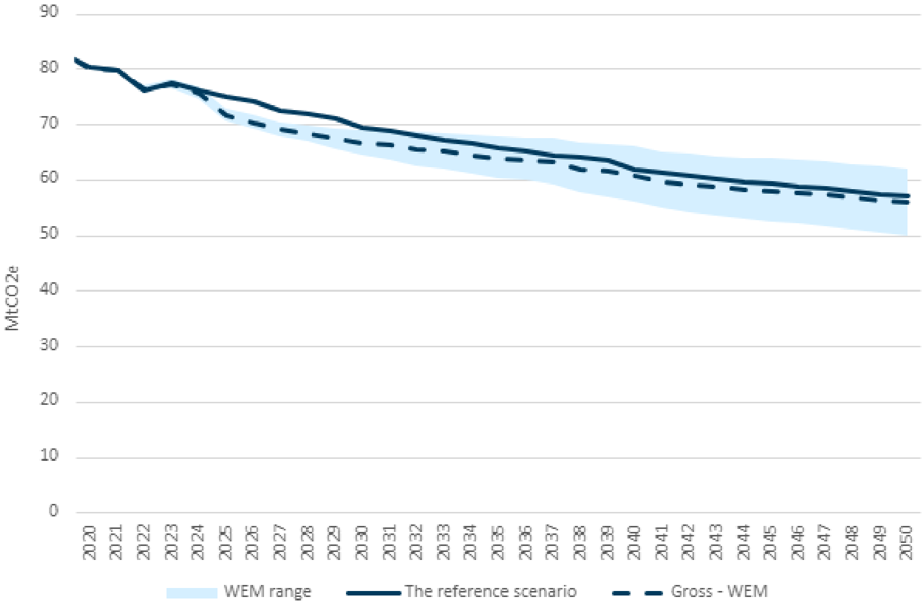
The differences between the reference scenario and the government WEM appears to be driven by the difference in assumptions on the closure of the aluminium smelter and the introduction of an electric arc furnace in steel production.

The electric arc furnace is one of the key drivers of IPPU emissions reductions in the reference scenario, accounting for the large decrease in emissions in 2027. The steady decline from 2027 onwards is largely due to reductions in HFC emissions, which follow projections provided to us by MfE.

Overall emissions outcomes

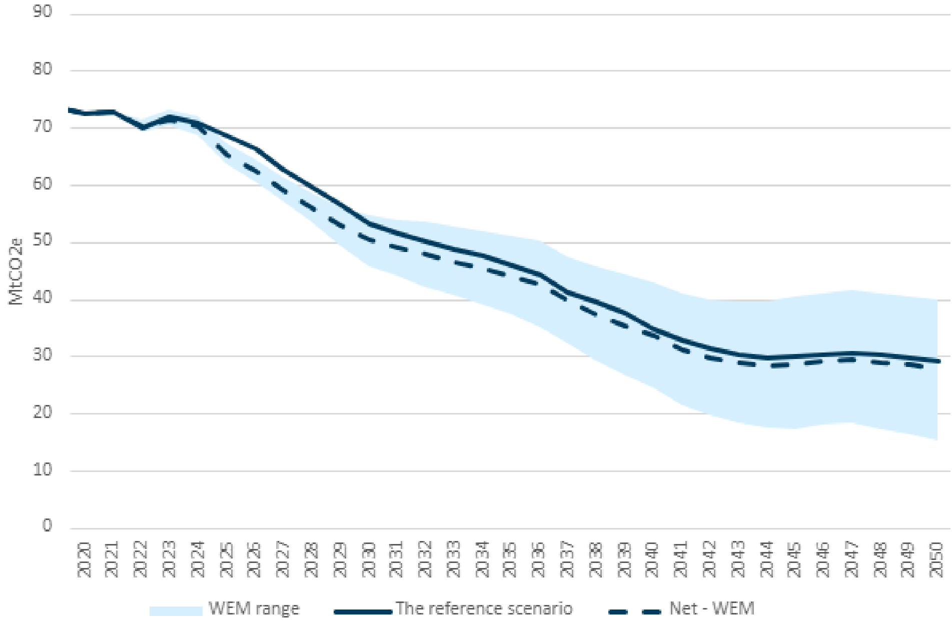
The Government WEM and the reference scenario deviate from 2024 onwards. This is primarily due to differing assumptions about major industrial closures such as NZAS aluminium smelter. The two scenarios gradually converge through to 2050. By 2050, there is 1.2 $MtCO_2e$ difference (**Figure 6**) between the WEM and reference scenarios. Removals from forestry are well aligned between WEM and reference scenarios so when computed on a net basis projections follow a very similar trend as gross emissions (**Figure 7**).

Figure 6: *Gross emissions in government WEM and reference scenarios*



Source: Commission analysis

Figure 7: *Net emissions (target accounting) in government WEM and reference scenarios*



Source: Commission analysis

Macroeconomic modelling of scenarios

This section discusses the macroeconomic modelling of our reference scenario, our four scenarios to 2050 and the EB4 demonstration path.

Our four scenarios to 2050 are named Low Technology and Low Systems change (LTLS), High Technology and Low Systems change (HTLS), Low Technology and High Systems change (LTHS) and High Technology and High Systems change (HTHS).

More information on the definitions of our modelled scenarios and pathways can be found in *Chapter 3: Developing the proposed path to the fourth emissions budget*.

The macroeconomic impacts are estimated with the C-PLAN model. In both the reference scenario and in our scenarios, as many as possible of the inputs are outputs from ENZ or are the same as inputs to ENZ. However, not all mitigations options in ENZ are available in C-PLAN, and C-PLAN takes account of interactions within the economy that ENZ does not.

Reference scenario

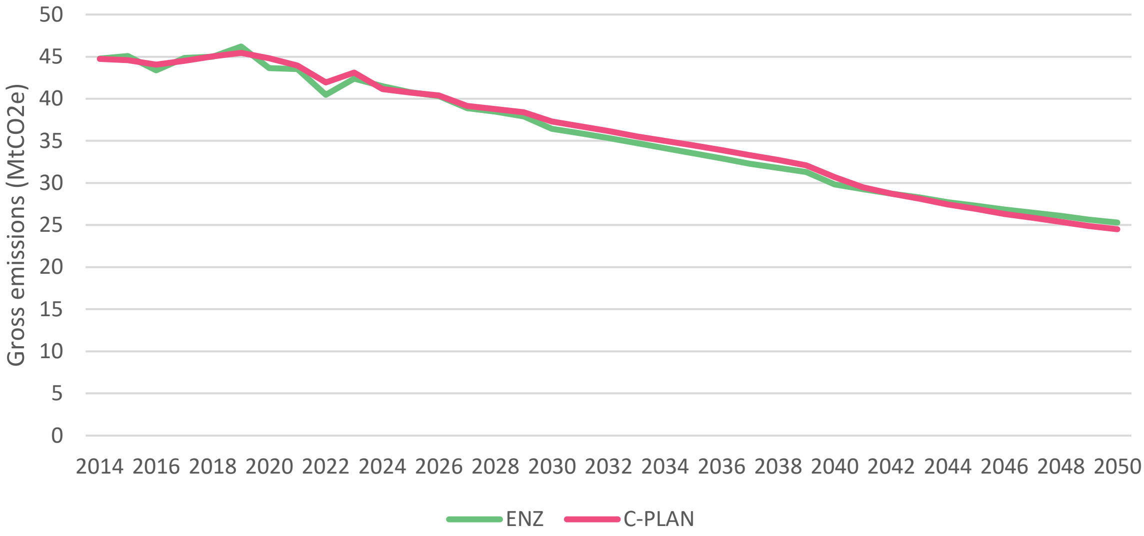
In C-PLAN, the reference scenario is used to calibrate some of the parameters in the model, and so more data is feed into the model for this scenario.

Table 4: *Selected data fed into the reference scenario for C-PLAN*

	New Zealand	Rest of World
GDP	ENZ/WEM (with smoothing for covid-related fluctuations)	OECD
Labour force growth	Estimated from ENZ population	Calculated in model
Electricity generation	ENZ	IEA
2014 emissions data	NZ Greenhouse Inventory, supplemented with GTAP and other data	GTAP10
Land use	ENZ	Calculated in model
Agricultural productivity	ENZ	Calculated in model
Removals	ENZ	NA
Waste emissions	ENZ	Calculated in model
Proportion EVs	ENZ	Calculated in model
Land transport output	Calibrated to match ENZ results	Calculated in model
Emissions prices	ENZ/WEM	OECD
Global oil price	NA	ENZ

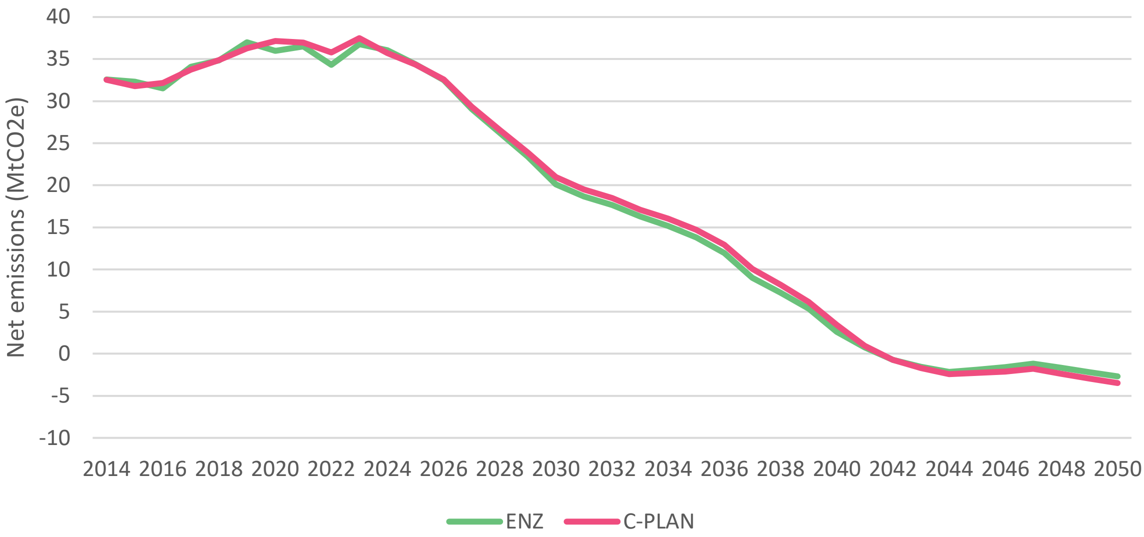
Emissions in C-PLAN in the reference scenario generally match well with ENZ, as shown in the figures below. Note that emissions removals from forestry and GDP are the same as that in ENZ because they are inputs to the model for the reference scenario.

Figure 8: *Gross emissions greenhouse gases other than biogenic methane under the reference scenario in ENZ compared to C-PLAN*



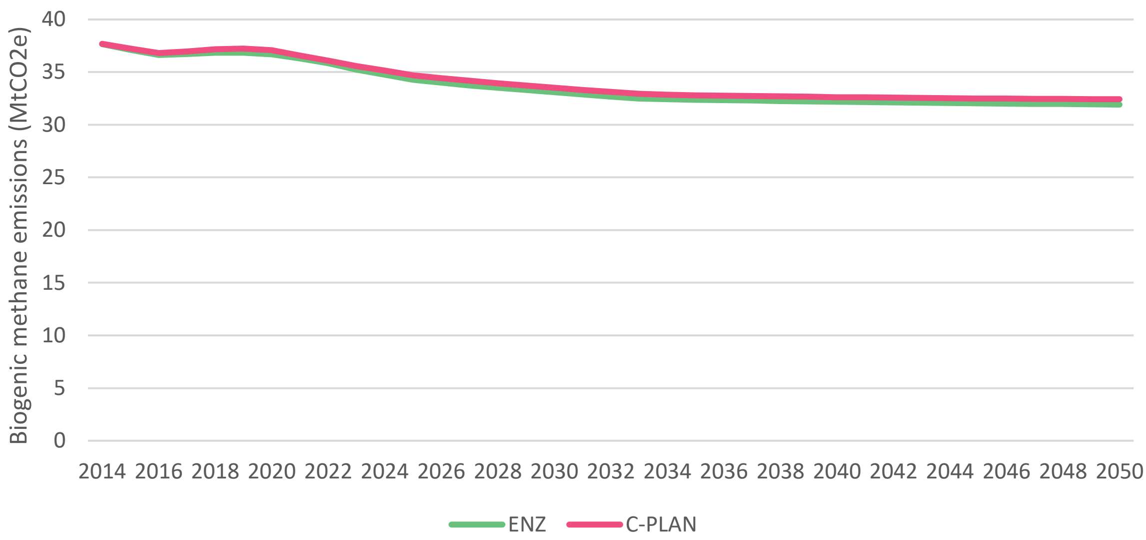
Source: Commission analysis

Figure 9: *Net emissions of greenhouse gases other than biogenic methane, under the reference scenario in ENZ compared to C-PLAN*



Source: Commission analysis

Figure 10: *Biogenic methane emissions under the reference scenario in ENZ compared to C-PLAN*



Source: Commission analysis

Our scenarios

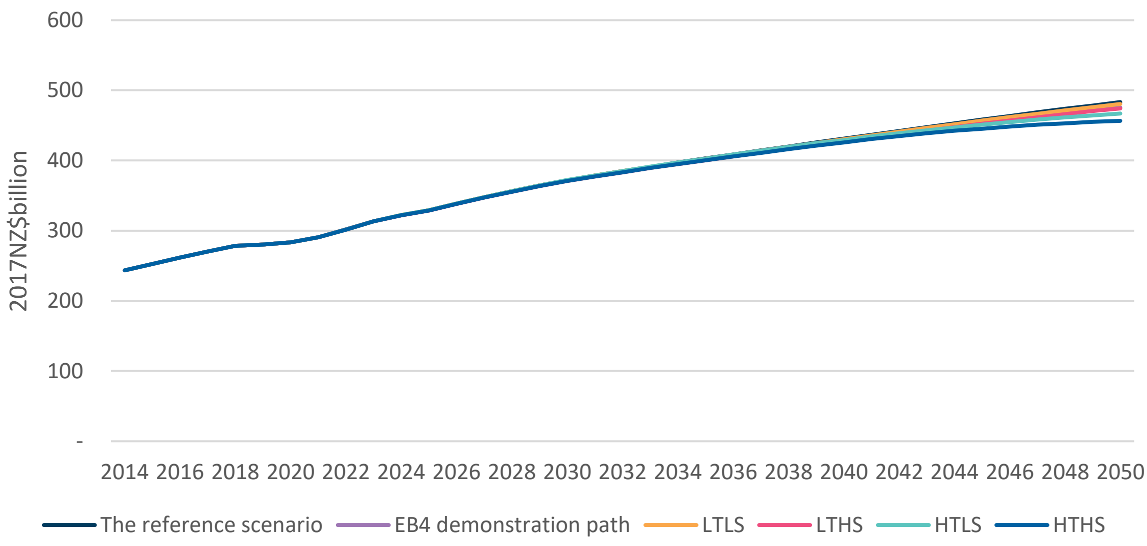
Some of the settings for our scenarios in C-PLAN come directly from ENZ results. These include emissions constraints for greenhouse gases other than biogenic methane, biogenic methane, removals, land use, agricultural productivity, proportion of EVs, and biomass available for process heat applications. The following table details the scenario settings used in C-PLAN.

Table 5: *Scenario settings used in C-PLAN*

	Settings
From ENZ	emissions constraints for greenhouse gases other than biogenic methane and biogenic methane, removals, land use, agricultural productivity, proportion of EVs, and biomass available for process heat applications
Same as in reference scenario	Labour force growth, 2014 emissions, Rest of World emissions prices, sector constraints
Calculated in model	GDP, electricity, waste emissions, land transport output, NZ emissions prices (from 2022), global oil prices
Additional technologies (turned on if also used in ENZ)	Methane-reducing technologies for agriculture (vaccine, inhibitor), EAF and green hydrogen for steel-making, green hydrogen for ammonia/urea, zero carbon anodes for aluminium, N_2O inhibitor for dairy farming, improved genetics for sheep and cattle, CCS for geothermal electricity, biomass and electrification for process heat (excluding for non-metallic minerals, e.g. cement)

As shown in the graph below, in all scenarios GDP continues to grow in all years and is around 50% (or more) higher in 2050 than in 2022. The results show the impacts on GDP are relatively small until the 2040s, when impacts increase significantly. We believe this is caused by the model having to increase the emissions values to meet the emissions reduction constraint as it runs out of modelled abatement options and is forced to reduce production instead. These results are therefore an artifact of C-PLAN not being able to incorporate the full range of mitigations which are incorporated into ENZ (and from which the emissions constraints for the scenarios were derived). In reality we expect that higher emissions prices would encourage further development of new technologies which are not currently included in C-PLAN, which would reduce the expected impacts on output.

***Figure* 11:** GDP under the four scenarios, the EB4 demonstration path and the reference scenario



Source: Commission analysis

In C-PLAN, GDP impacts are determined by how tight the emissions constraint is. The emissions constraint is tighter if less emissions are allowed compared to the reference scenario, or if there are insufficient technologies or other mitigations to reduce emissions (which then forces sectors to reduce production). If technologies in the model are not changed, each megatonne of emissions decrease in the emissions constraint will have a bigger impact on GDP than the previous megatonne did.

Emissions from international bunker fuels

To support our *Review on whether emissions from international shipping and aviation should be included in the 2050 target, and if so how*, we modelled emissions from international bunker fuels in our scenarios. The projected emissions in these scenarios do not include the emissions involved in the production of low-carbon liquid fuels. Under current accounting practices these would be accounted for within other sectors if produced domestically. International bunker fuels are reported in our national emissions inventory but are only one metric for measuring international emissions.

Key details of our analysis and how these factor into setting a target that includes international shipping and aviation are provided in *Chapter 5: Options for including these emissions in the 2050 target* of the discussion document (*Review on whether emissions from international shipping and aviation should be included in the 2050 target, and if so how)*, available on the Commission's website.

This section provides further details on emissions from international bunker fuels within our modelled scenarios.

Scenario results

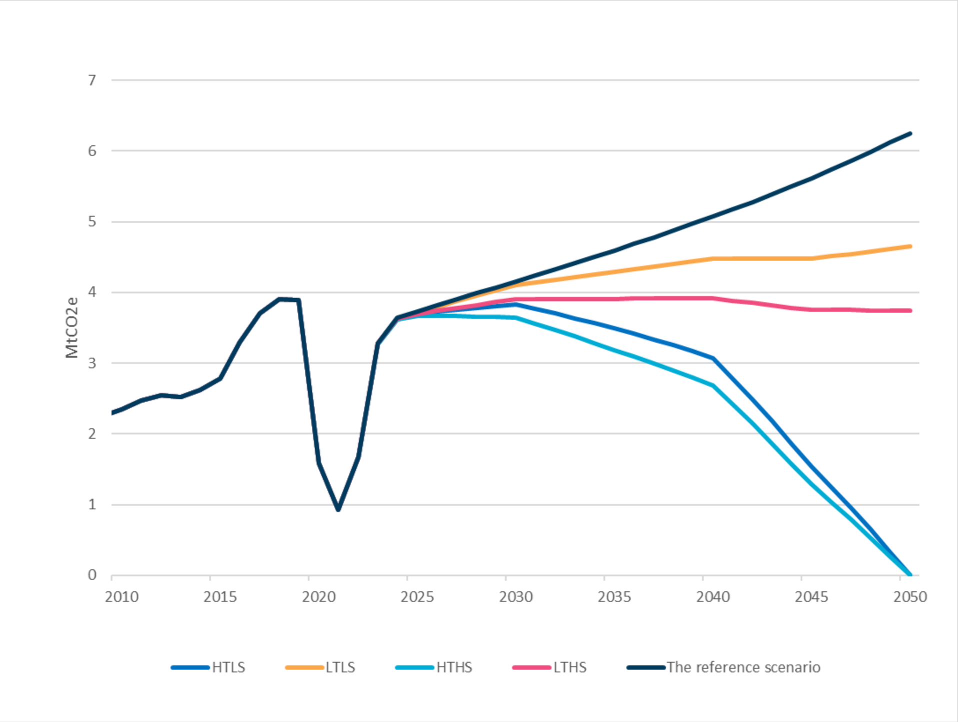
In our reference scenario, emissions from international aviation bunkers will grow by around 50%, going from pre-COVID-19 levels of 3.8 Mt CO_2e in 2019 to 6.2 Mt CO_2e in 2050 (**Figure 12**), with underlying demand increasing at an average of 3.2% in 2025 reducing to 2.9% by 2031 then holding constant to 2050. The underlying demand for international marine transport is relatively flat in the reference scenario. This flat demand profile combined with 1% per annum annual efficiency improvements, leads to a decline in international marine bunker emissions in the reference scenario. Underlying demand for both aviation and marine sectors was based on future state modelling from the Ministry of Transport.

By 2050, emissions from aviation bunkers are reduced by between 26% in the LTLS scenario and 100% in the HTLS and HTHS scenarios. These reductions are achieved through a combination of enhanced efficiency measures, demand reduction, and the use of low-carbon liquid fuels.

In the LTHS and HTHS scenarios, a 20% reduction in demand for international aviation fuels is assumed based on the IEA net zero pathway.[10] Low carbon liquid fuels are used in all scenarios. In the low technology scenario, blending will gradually increase, reaching 22% by 2050. In the high technology scenarios, fossil fuels will be entirely replaced by 2050.

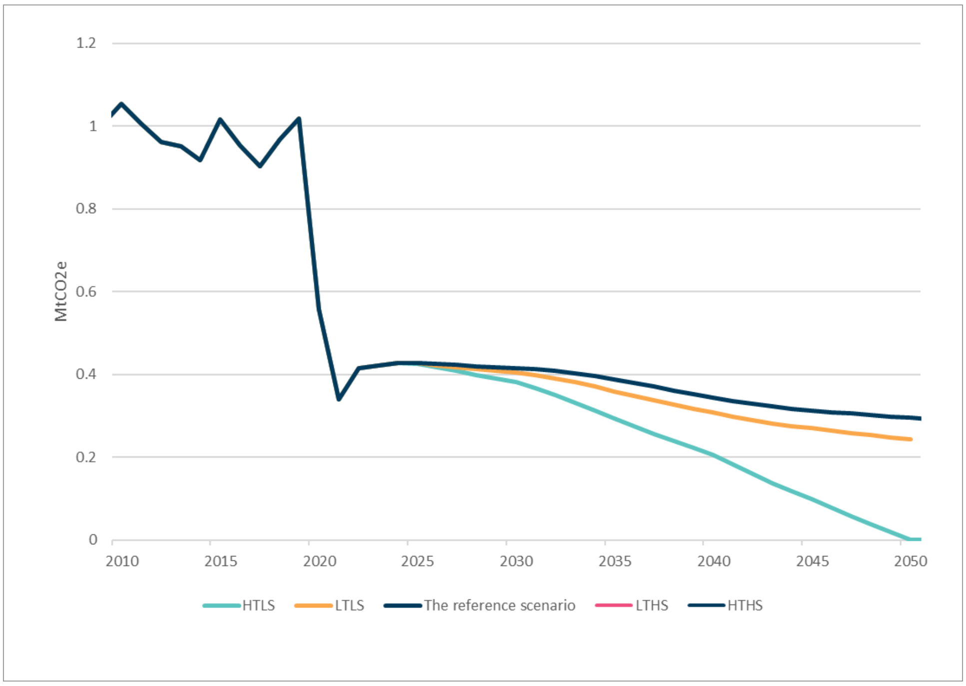
Emissions from international marine bunkers decline in all scenarios (**Figure 13**). In the LTLS, efficiency improves 25% per year faster than the reference scenario and by 2050 a 12% low carbon liquid fuel use is used. In the high-tech scenarios efficiency improves 50% per year faster than the reference scenario and by 2050 low carbon liquid fuels entirely replace conventional fuel.

Figure 12: *Emissions from international aviation bunker emissions in reference and LTLS, LTHS, HTLS and HTHS scenarios*



Source: Commission analysis

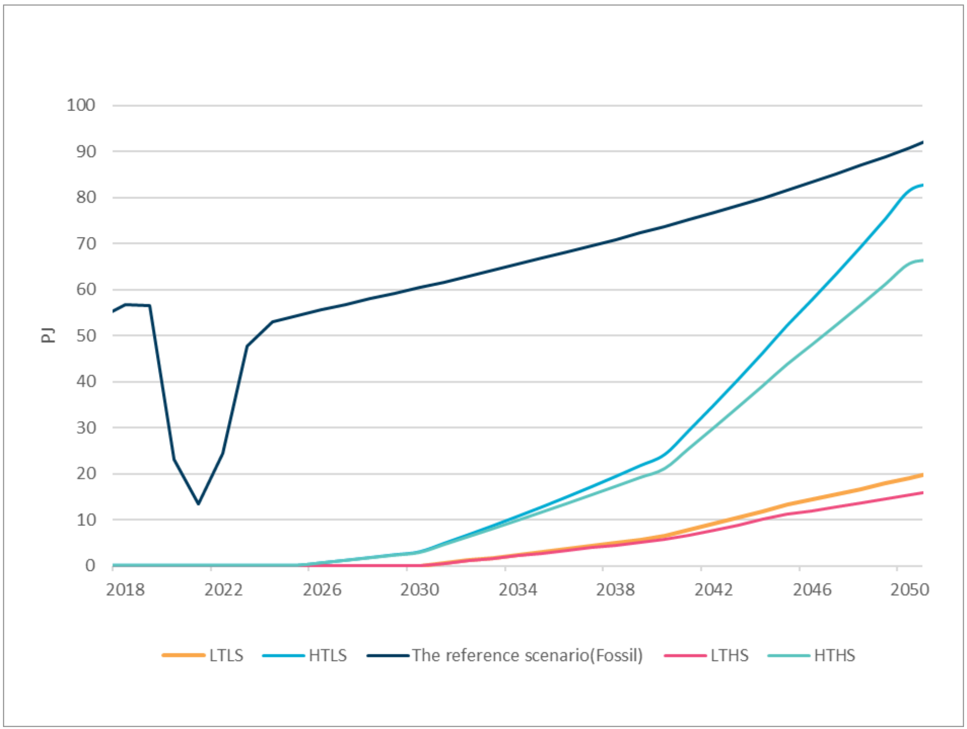
Figure 13: *International marine bunker emissions in reference, LTLS, LTHS, HTLS and HTHS scenarios*



Source: Commission analysis

By 2050, international transport is the largest consumer of low-carbon liquid fuels in our scenarios. Achieving a high degree of decarbonisation in these sectors will require the use of low-carbon liquid fuels as there are limited alternative mitigation technologies. In 2050, between 15 and 90 PJ of low-carbon liquid fuels are required to meet the demand for international bunkering (**Figure 14**).

***Figure 14:** Low carbon liquid fuels used in international aviation in reference and LTLS, LTHS, HTLS and HTHS scenarios*



Source: Commission analysis

Temperature response modelling

As part of our *Review of the 2050 emissions reduction target,* we have modelled the warming from the country's past and possible future emissions and how that makes a contribution to global efforts to limit warming to 1.5°C. This was to provide a range of perspectives on how Aotearoa New Zealand's efforts contribute to limiting warming.

Temperature response modelling uses a simplified climate model to convert emissions of greenhouse gases into concentrations, and then to the temperature effect directly. This allows us to compare the warming outcome from different targets and pathways, and accurately reflect how emissions of each gas contributes to warming.

Key results and what it means for Aotearoa New Zealand's contribution to global efforts to limit warming can be found in *Chapter 2: Assessing the current 2050 target's contribution to limiting global warming* of our discussion document *Review of the 2050 emissions reduction target.*

This section provides further information on results, how the modelling was undertaken, as well as important assumptions and parameters used so the analysis can be reproduced.

Key results

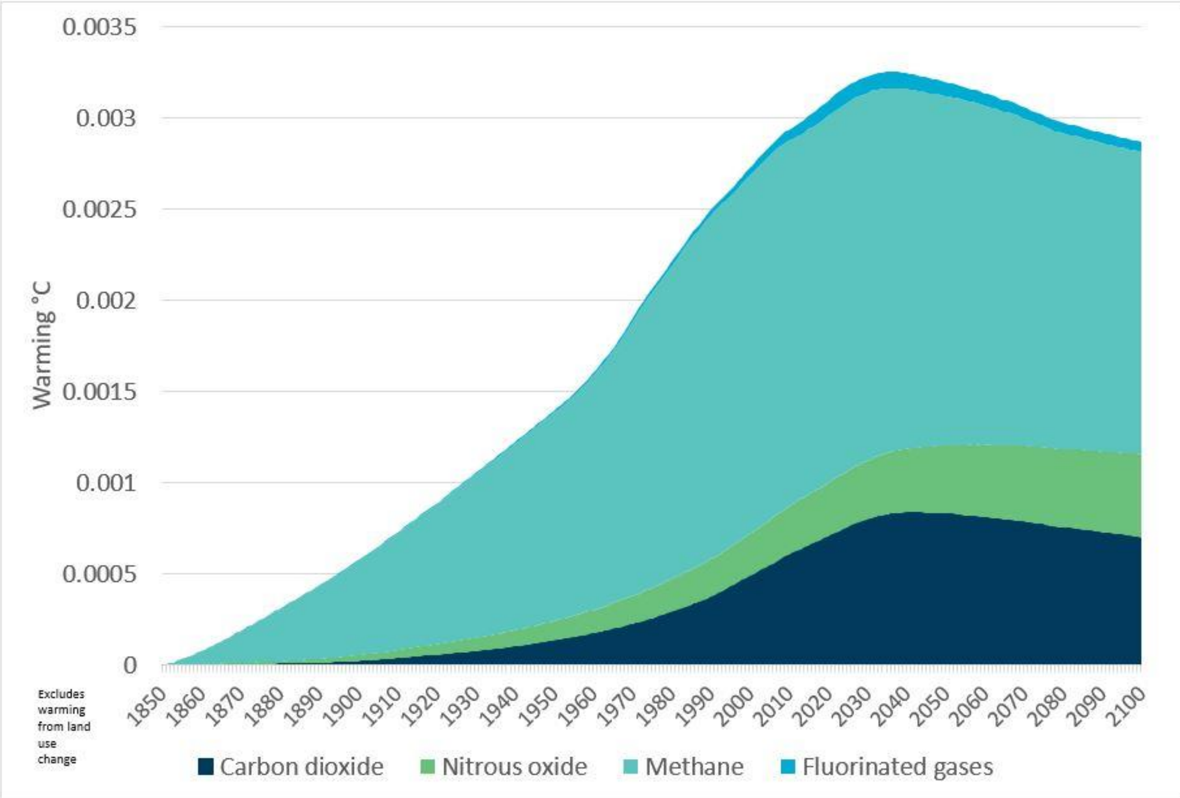
To assess the current target, the future projections are based on the low technology low systems change (LTLS) emissions pathway developed for the draft advice on Aotearoa New Zealand's fourth emissions budget. This is one possible pathway that meets the current target and can be used to draw insight about how much warming Aotearoa New Zealand would contribute if the country achieved the current target.

The results show that:

- warming is mainly from methane, carbon dioxide, and nitrous oxide
- most warming comes from methane emissions
- warming peaks in 2036 at 0.0033°C
- Aotearoa New Zealand contributes 0.0032°C in 2050 and below that at 0.0029°C in 2100.

Looking at the temperature response or 'warming' in this way allows us to understand total warming from different greenhouse gases without the use of metrics that equate other greenhouse gases to carbon dioxide.

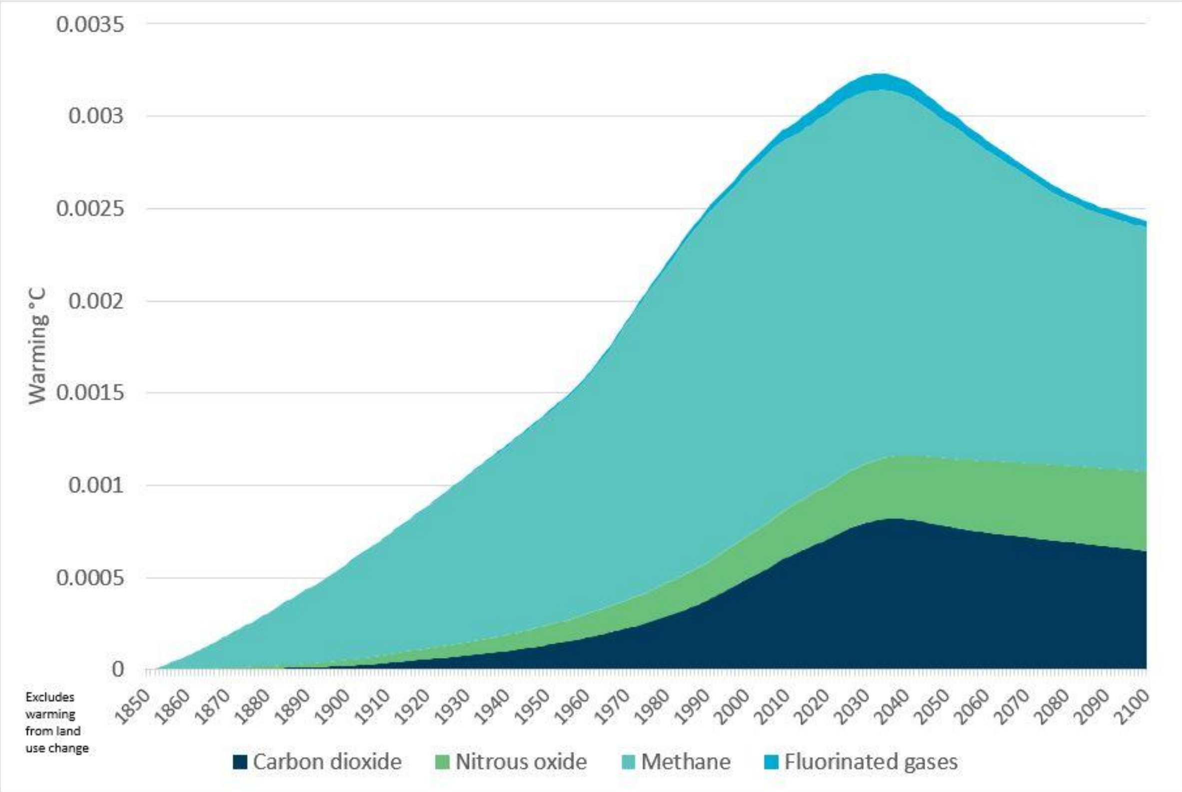
Figure 15: *Warming from Aotearoa New Zealand's emissions 1850-2100 under the LTLS scenario*



Source: Commission analysis

Under the EB4 demonstration path, warming from Aotearoa New Zealand's emissions declines further following the peak, as shown in **Figure 16** below.

Figure 16: *Warming by gas from Aotearoa New Zealand emissions 1850-2100 under the EB4 emissions pathway*



Source: Commission analysis

How the temperature response modelling was done

FaIR

The Commission used the FaIR model (Finite-amplitude Impulse Response simple climate model). Simple climate models like FaIR are designed to emulate more complex full earth system models. FaIR has been developed by a team of UK researchers and has been shown in the most recent IPCC assessment to satisfactorily simulate the global temperature change modelled by complex earth system models over the 21st century. It includes the effect of non-CO2 greenhouse gases and short lived climate forcers such as aerosols.

FaIR takes an emissions time series for the world, and can be used to simulate the warming effect of emissions from Aotearoa New Zealand based on the global warming outcome with and without Aotearoa New Zealand's emissions. This allows us to estimate the warming attributable to emissions from Aotearoa New Zealand.

FaIR does not rely on any emissions metric, rather it models the temperature response of each gas separately based on the atmospheric lifetime and radiative efficacy of each gas.

The FaIR model is publicly available at on PyPI and at GitHub. You can read more about the FaIR model at: https://homepages.see.leeds.ac.uk/~mencsm/fair.htm

Or the papers providing the official description of the model:

- Leach, N. J., Jenkins, S., Nicholls, Z., Smith, C. J., Lynch, J., Cain, M., Walsh, T., Wu, B., Tsutsui, J., and Allen, M. R. (2021): FaIRv2.0.0: a generalized impulse response model for climate uncertainty and future scenario exploration. Geosci. Model Dev., 14, 3007–3036, https://doi.org/10.5194/gmd-14-3007-2021

- Smith, C. (2023). FaIR calibration data (1.2.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.8399112

For the IPCC assessment of emulators of complex climate models, see Cross-Chapter Box 7.1 in:

- Forster, P.M. et al. (2021) 'Chapter 7: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity', in V. Masson-Delmotte et al. (eds) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Oxford, UK: Cambridge University Press.

Input assumptions and caveats

For this exercise we used FaIR version 2.1.3. We used version 1.2 of the calibration data to match the IPCC's Sixth Assessment Report.

It is important to note that this exercise excluded historic deforestation emissions, i.e. emissions associated with land clearing since human settlement until 1990, and replanting prior to 1990.

Other relevant input assumptions include:

- SSP1-2.6 as global background scenario
- Emissions from Aotearoa New Zealand are based on:
    - Estimated historical emissions from 1850 to 1989 (see below for details)
    - Net target accounting emissions based on the national GHG inventory from 1990 to 2021
    - Various scenarios for future net target accounting emissions, assuming constant emissions from 2075 onwards
- We used reported activity data for agriculture from 1930s – Present. We used linear scaling from 0 in 1840 to the known activity data from the 1930s.
- For fossil CO_2, we used existing published estimates from 1860, and a linear scale from 0 in 1840 to 1860
- To estimate the proportion of fossil methane vs biogenic methane for historical data, we assumed fossil methane emissions to be proportional to fossil CO2 emissions, using the ratio in 1990 (1990 being the earliest year greenhouse gas inventory data is available for)
- For F-gases, HFCs are assumed to be zero before 1990 – consistent with inventory data that showed zero use up until 1992
- For PFCs and SF6, we assumed 0 use in 1950, increasing linearly from there to reach the 1990 emissions levels.

Pathways modelled

We ran the model using six of the scenarios from the latest emissions budget analysis, an updated version of the demonstration path used for our advice on the Government's second emissions reduction plan, and a hypothetical scenario drawn from the contribution analysis where Aotearoa New Zealand's targets for each gas reflected a share of emissions reductions based on our relative share of global GDP (a capacity approach).

The eight scenarios ran were:

- Low technology and low systems change (LTLS)
- High technology and low systems change (HTLS)
- Low technology and high systems change (LTHS)
- High technology and high systems change (HTHS)
- The demonstration path for the fourth emissions budget (EB4 demonstration path)
- Reference scenario
- ERP2 updated demonstration path
- Hypothetical Capacity target path

Outputs

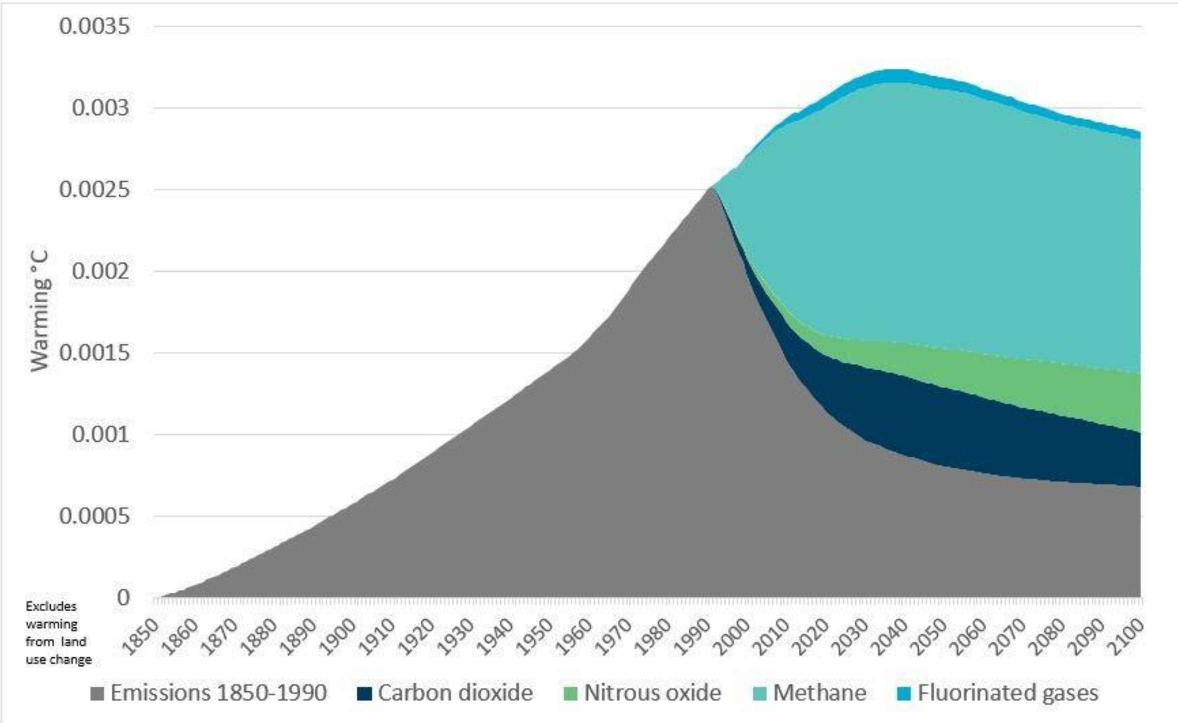
For each scenario, three sets of results were produced:

- Total warming by gas 1750-2300 (across the four categories of CO_2, CH_4, N_2O and other which encompasses fluorinated gases)
- Warming by gas split into warming from emissions up until 1990, and from emissions occurring after 1990
- Warming by gas split into warming from emissions up until 2023, and from emissions occurring after 2023

Estimates of warming from pre and post-2023 emissions show how past and future emissions contribute to warming. Estimates of warming from pre and post 1990 emissions informed assessments of Aotearoa's New Zealand's target under a responsibility approach. These results are illustrated for the low technology low systems change scenario in **Figures 17** and **18** below.

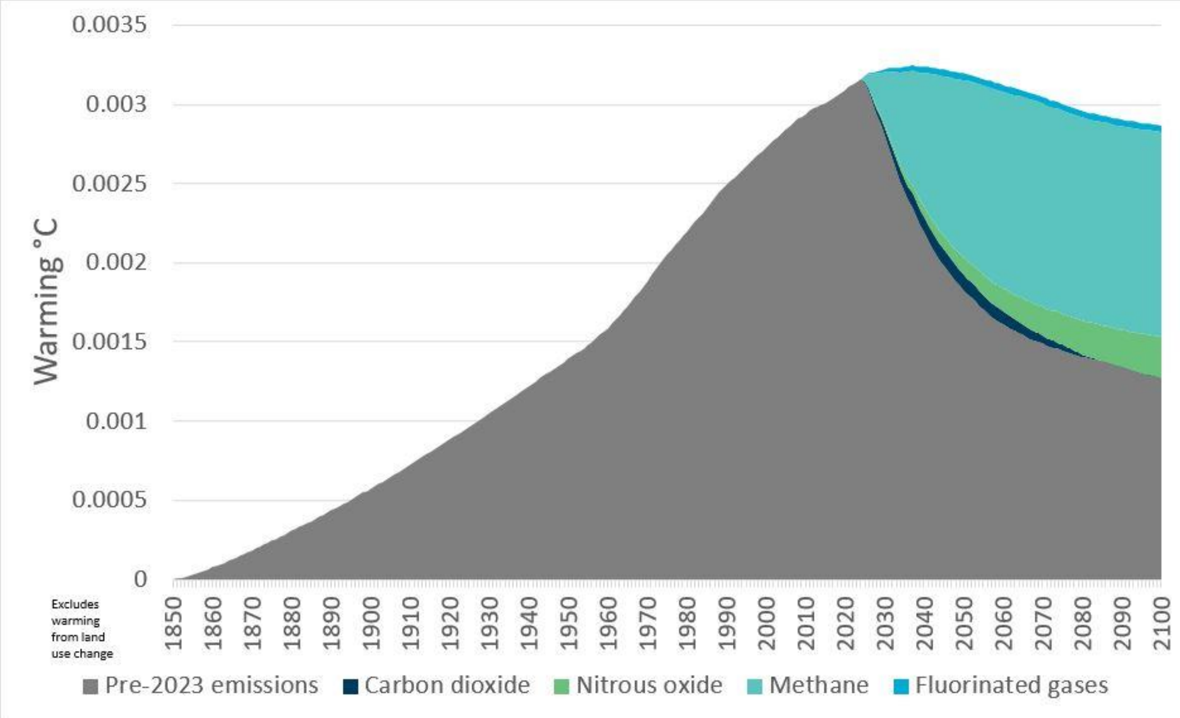
Full results are available on our website and can be found here: https://www.climatecommission.govt.nz/public/Uploads/Targets/supporting-docs/Temperature-modelling-full-results.xlsx

Figure 17: *Warming from Aotearoa New Zealand's emissions 1850-2100 under the LTLS scenario showing the effect of emissions from before and after 1990*



Source: Commission analysis

Figure 18: *Warming from Aotearoa New Zealand's emissions under LTLS path 1850-2100 showing the effect of emissions from before and after 2023*



Source: Commission analysis

Review and quality assurance

The modelling for this draft advice was done by Dr Andy Reisinger[viii] using the FaIR model. The process and outputs were independently reviewed by FaIR developer Dr Chris Smith. He was able to reproduce the outputs of the analysis and confirmed that the work was done correctly. His conclusion was as follows:

> *From my review, I conclude that FaIR is an appropriate tool for the analysis which has been conducted correctly.*

The full review is available on our website and can be found here: https://www.climatecommission.govt.nz/public/Uploads/Targets/supporting-docs/TR-02-Review-of-NZCCC-analysis-March-2024.pdf

Revisions to budgets

As part of our *Draft advice on Aotearoa New Zealand's fourth emissions budget,* we must consider whether revisions are needed to the first three emissions budgets to account for methodological or significant change. Our analysis and recommendations are set out in C*hapter 6: Proposed revisions to the first, second and third emissions budgets of* the consultation document. This section provides further details on:

[viii] Dr Andy Reisinger undertook this work as an independent expert and not as part of his role as a Commissioner at the Climate Change Commission.

- the procedure used to incorporate methodological improvements to New Zealand's Greenhouse Gas Inventory.
- our detailed initial assessments of significant change.

Methodological improvements to the inventory

Approach

Under section 5ZE of the Act, emissions budgets may be revised where there have been methodological improvements to the way that emissions are measured and reported. Changes to the inventory are summarised annually by MfE[11][12]. Our method used to assess the impact of methodological improvements on the emissions budgets involved the following steps:

1. We took the ENZ model used to create the demonstration path in *Ināia tonu nei*, and adjusted it for the changes made when the government set the emissions budgets. This constituted a single change to the level of afforestation.
2. The model was updated to be based upon AR5 global warming potentials.
3. We took this modified model and revised the inventory data using the 2023 version of the national inventory. We only revised the inventory data for the years 1990-2019, since this is the original timeframe used at the time the emissions budgets were set. Direct inventory data from 2020 and 2021 would include changes made other than for methodological improvements, so were not applied.
4. For agriculture and transport sectors we updated the models with the 2023 projections provided by the appropriate Ministries. These provided exogenous inputs to the model which were necessary to project the methodological changes through to 2050. Some of the specific updates included:
    a. revised carbon yields (1990-2050) for exotic and native forests
    b. transport - VFEM estimations for 1990-2019 and liquid fuel efficiency of vehicles 1990-2019
    c. agriculture - regional land area, emissions per head, stocking rate and dairy kgMS/head
    d. HFCs - The 2020 Verum study[13] provided updated basis for phasedown scenarios of HFC
    e. forests - MPI WEM forecast data
5. The revised model was run to get a new demonstration path and a projection of emissions through to 2050.
6. The revised emissions budgets due to methodological improvements were assessed as the cumulative emissions occurring between 2022-2025 (for EB1), 2026-2030 (for EB2) and 2031-2035 (for EB3).

Impact of changes on sectoral emissions

The impacts of the methodological changes are shown in the main report. The impacts of the changes on the pathway for sector emissions are shown in **Figure 20**.

Transport

For transport emissions, methodological changes were greatest in the first budget period. By 2050 the difference between the set budgets and revised with methodological changes was small due to the shift away from fossil fuel use. The majority of the difference could be accounted for due to the reassignment of liquid fuel use to the residential sector.

IPPU

The change in IPPU emissions is almost entirely due to methodological improvements to the HFC data, and revised projections for the phasedown of HFCs.

Non-transport energy

The non-transport energy sector has seen an increase in the projected emissions. The increase in emissions is due predominantly to the reallocation of liquid fuel use from the transport sector. The magnitude of the increase is less than the corresponding decrease observed in transport emissions due to other changes occurring in the non-transport energy sector. For example, reductions in coal emissions within food processing, a reduction in liquid fuel emissions from mining and quarrying, and changes to assumptions on fugitive emissions.

Agriculture

Methodological changes to the agriculture sector result in lower emissions across the first to third budget periods. The changes arise from the inclusion of non-pasture feed in the inventory model, changes to the fraction of nitrogen that is leached and accounting rules for agricultural lime.

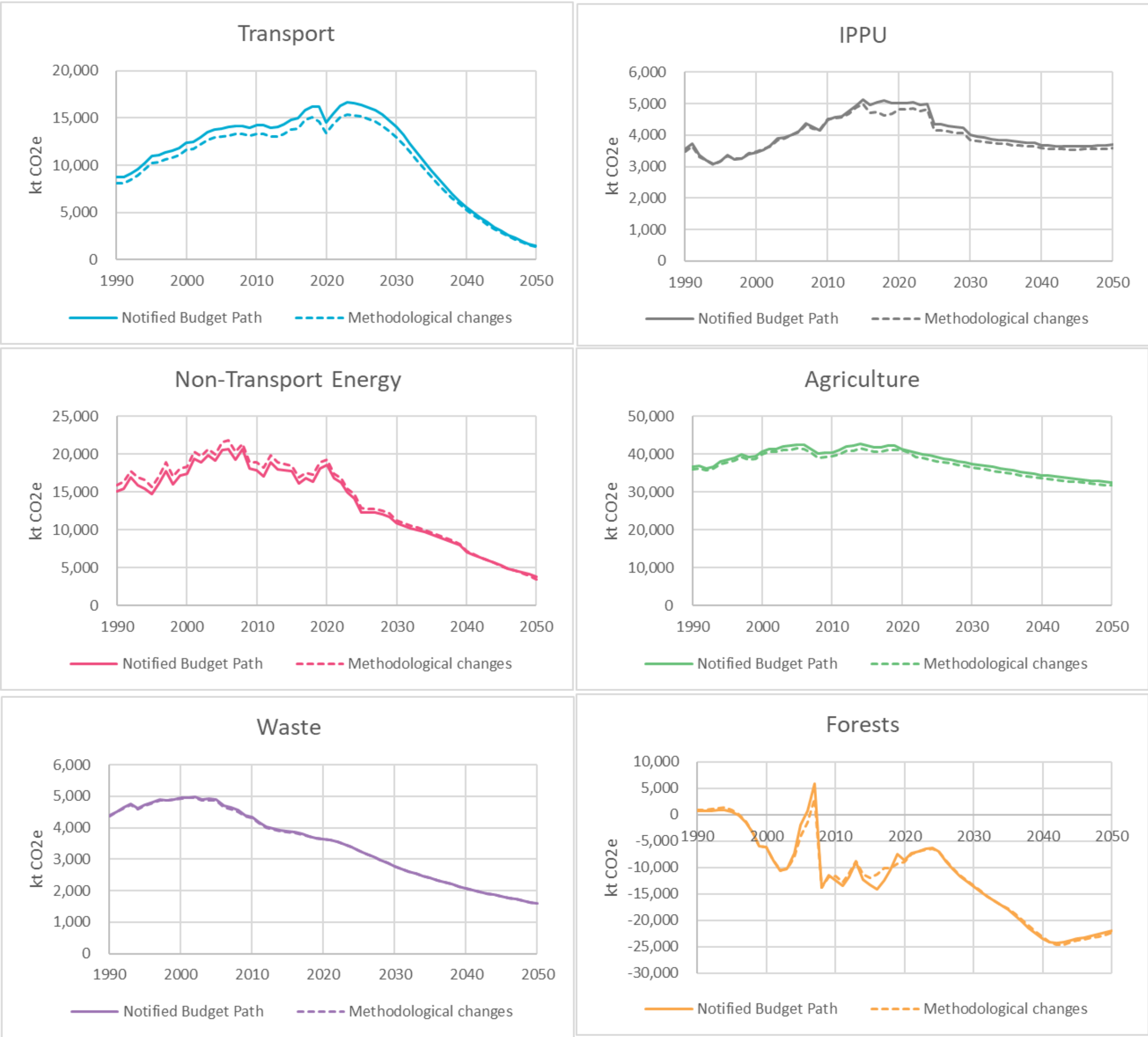
Waste

There were no methodological improvements in waste that contributed to a change in projections.

Forests

A number of methodological changes in forest emissions [14][15] occurred which were incorporated in MPI projections. Notably this included changes to carbon yields.

Figure 20: *Summary of impact on pathway profile of methodological changes by sector (AR5)*



Significant change

Approach

A change can be recommended to set emissions budgets if there has been revisions made because of one or more significant changes affecting the considerations listed in section 5ZC(2) of the Act, on which an emissions budget was based. The purpose of making changes under section 5ZC(2) is to ensure that the Commission's advice on emissions budgets continues to be technically, socially, and economically achievable, while remaining ambitious.

There are similarities to assessing significant change in relation to our review of the 2050 target. However, there are sufficient differences between these provisions of the Act that the test we have developed for emissions budgets is separate to our review of the 2050 target. In our approach we have chosen not to apply a bright line test to assess significance. There are considerations under section 5ZC(2) that collectively contribute to a significant change and in some cases the change may not be quantifiable exactly.

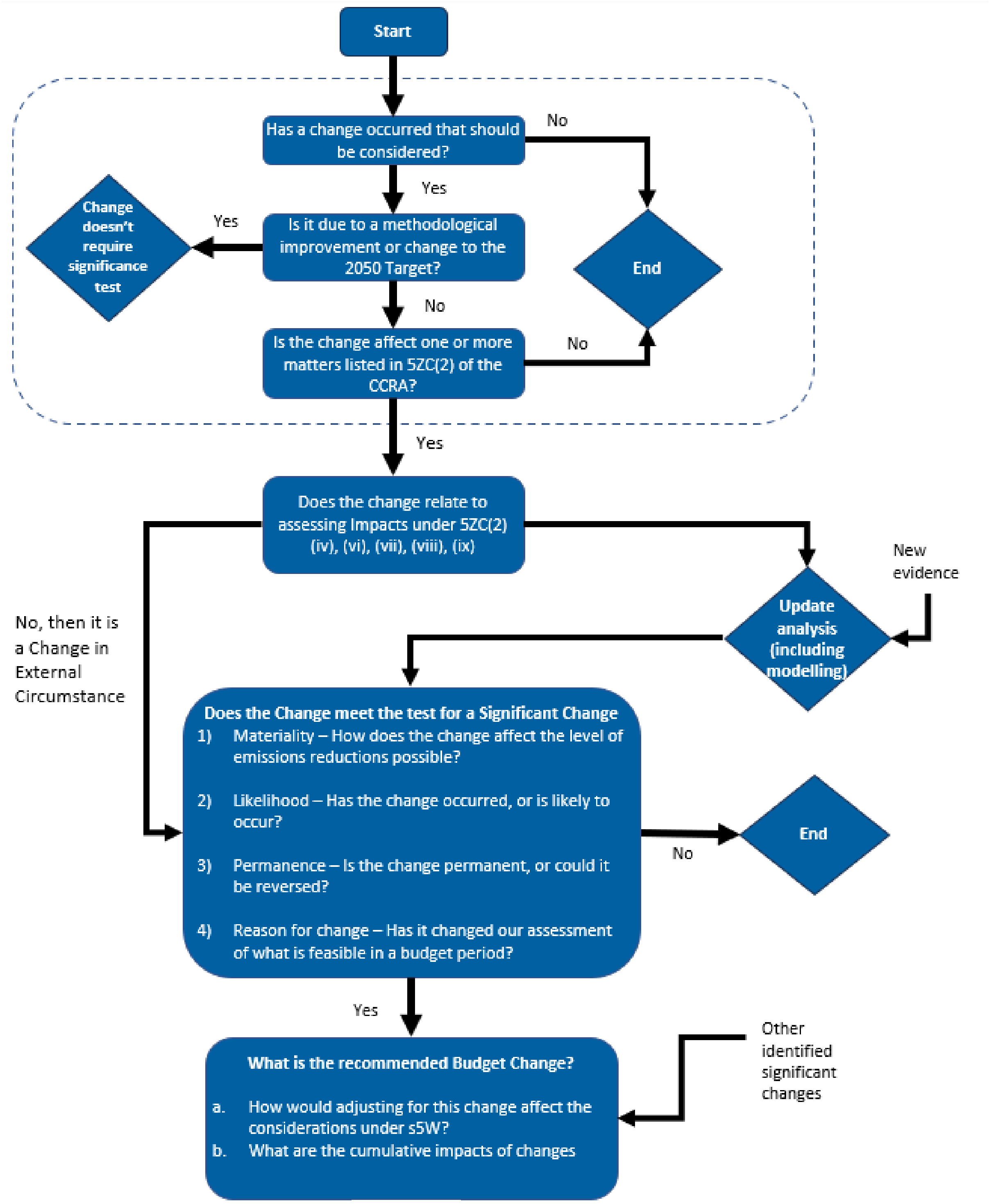
A framework was developed so that criteria could be applied consistently when changes are identified and evaluated.

Process flow diagram

The framework for evaluating significant change in the context of emissions budgets is described in *Chapter 6: Proposed changes to the first, second and third emissions budgets*. We have developed a separate test for significant change related to the 2050 target, which is detailed in our Discussion document *Review of the 2050 emissions reduction target.*

Figure 21 summarises the process for evaluating significant change in the form of a process flow diagram.

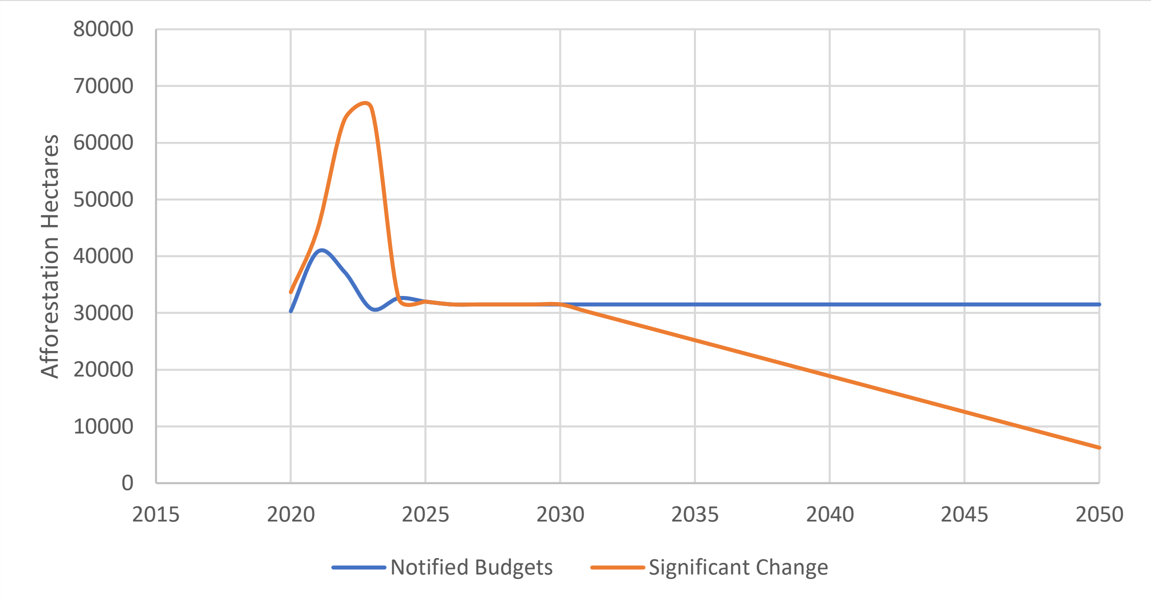
Figure 21: *Process flow chart for assessing changes to emissions budgets*



Afforestation as a significant change

Afforestation was identified as the only significant change, meeting the criteria as outlined in *Chapter 6: Proposed changes to the first, second, and third emissions budgets.* The significant change was modelled by taking the actual afforestation occurring in 2020-2023 then reverting back to the set budgets path to 2030, before tapering down to 2050 so that cumulatively the afforestation remains unchanged from *Ināia tonu nei* (**Figure 22**).

Figure 22: *Afforestation of exotics due to significant change and set budgets 2020-2050*



Source: Commission analysis

Dashboard summaries of significance tests

For changes that have been identified, the significance framework was applied. The outcome of these tests, which were not determined to be significant, are summarised in the dashboard formats below. These represent the basis of the decisions used to evaluate the significance of the changes.

1.Increase in Afforestation

Change being assessed:	Afforestation rates which have occurred between 2020-2022 and expected for 2023 are substantially higher than was predicted in the set budgets. The set budgets were published using updated afforestation rates, but are still lower than the observed afforestation occurring recently. This change models actual and expected afforestation rates occurring in 2020 to 2023 then reverts from 2024 to 2050 with government budget projections.			**CCRA Criteria**	5ZC 2b(i) the emission and removal of greenhouse gases projected for the emissions budget period
Qualitative Test for Significant Change:	**1. Material impact**: How does the change affect the level of emissions reductions possible?	**2. Likelihood**: What is the likelihood that the impact on budgets will be realised?	**3. Permanence**: Is the change permanent, or could it be reversed?	4. **Reason for change**: Has it changed our assessment of what is feasible in a budget period?	**Decision:** **Significant Change**
Findings:	The change made in the afforestation projections between *Ināia tonu nei* and the actual afforestation (2020, 2021, 2022) results in substantial changes of -11 $MtCO_2e$ and -12 $MtCO_2e$ in EB2 and EB3 respectively. **EB1**: -1Mt **EB2**: -11 Mt **EB3**: -12 Mt	The higher afforestation that has occurred, and the impact of this, will see ongoing additional removals of carbon through to 2050. Although the projected afforestation rate is uncertain, the actual afforestation to have occurred is highly likely to achieve sustained removals of CO_2.	There is a high degree of confidence that this change is permanent for the duration of the emissions budgets through to 2050. The impacts of this change are unlikely to be reversed in this time through deforestation.	The higher rate of afforestation changes the balance between net and gross emissions reductions. If the first three emissions budgets can be met without reducing gross emissions, then subsequent emissions budgets will, at worst, be unachievable and, at best, only achieved through higher-cost action later.	There has been a far higher rate of afforestation than was predicted to occur in the set budgets. This is likely to have a permanent effect over the budget periods. The level of ambition on gross emissions reductions should be maintained along with the actions necessary to ensure future budgets can be met. What we now consider feasible is greater overall reductions occurring in the second and third emissions budgets. Earlier planting has an enduring impact on emissions reductions.
Completed when deemed significant	**Consistency with purpose of budgets**. How would adjusting for this change affect the considerations under section 5W of the Act?	Higher rates of afforestation will make it easier to achieve the budgets. Adjusting the budgets down ensures the level of ambition on gross emissions is maintained. By adjusting budgets for this change, there is alignment with the purpose of the Act: contributing to the global effort limiting temperature rise to 1.5°C.			

2.Methane Inhibitor 3-NOP					
Change being assessed:	Recently, the Environmental Protection Authority (EPA) approved 3-nitrooxypropanol (3-NOP or trade name Bovaer®) for import or manufacture, as a feed additive to reduce methane emissions in livestock			**CCRA Criteria**	5ZC 2b(iii) Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand
Qualitative Test for Significant Change:	1. **Material impact**: How does the change affect the level of emissions reductions possible?	2. **Likelihood**: What is the likelihood that the impact on budgets will be realised?	3. **Permanence**: Is the change permanent, or could it be reversed?	4. **Reason for change**: Has it changed our assessment of what is feasible in a budget period?	**Decision:** **Not a Significant Change**
Findings:	The change is difficult to quantify with certainty as uptake rate and speed is hard to predict. Our estimate is ~5% reduction in emissions for feeding under Aotearoa New Zealand's systems where it cannot be applied as a total mixed ratio. This level would be materially impactful. **EB1** / **EB2** / **EB3** - / - / -	In *Ināia tonu nei* methane inhibitors were not considered to be available under the demonstration path within EB1 to EB3. The EPA approval may make it more likely for availability to occur in this time period, potentially from EB2.	To our knowledge, there is no change yet in how effectively 3-NOP could reduce emissions, how barriers that exist can be overcome (e.g. applicability to pastoral farming), or the costs to implement across Aotearoa New Zealand. This gives us low confidence regarding the change. There are a number of uncertainties. There is not a high degree of confidence that the cause of the change is permanent.	This mitigation would increase what is feasible within a budget period.	The likelihood that a methane inhibitor will be available in Aotearoa New Zealand by 2025-2030 period (EB2) has increased since the budgets were set. However, there is no change yet to the knowledge of how effectively they could reduce emissions, barriers that may exist, or the costs to implement across Aotearoa New Zealand. The uncertainties remain too large to recommend this be a significant change.

3.EV Uptake rate higher than predicted

Change being assessed:	There has been an increase in the uptake rate of electric vehicles over that predicted in the *Ināia tonu nei* modelling. Since 2021 the government has introduced a suite of policies incentivise the uptake of low emissions vehicles. EV uptake in in the *Ināia tonu nei* demonstration path, by 2023, estimated 4% of vehicles entering the fleet would be electric. In September 2023 EVs were 17% of new vehicle registrations. The level of uptake seen today was not expected to occur until EB2.			**CCRA Criteria**	5ZC 2b(iii) Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand
Qualitative Test for Significant Change:	1. **Material impact**: How does the change affect the level of emissions reductions possible?	2. **Likelihood**: What is the likelihood that the impact on budgets will be realised?	3. **Permanence**: Is the change permanent, or could it be reversed?	4. **Reason for change**: Has it changed our assessment of what is feasible in a budget period?	**Decision:** **Not a Significant Change**
Findings:	EVs made up 17% of new registrations in September 2023, and far higher than predicted. The material impact hasn't been quantified but is qualitatively an impactful difference **EB1** / **EB2** / **EB3** - / - / -	Uptake projections are inherently uncertain and changing policy settings could have significant effects on the share of EVs entering the fleet. It will impact multiple budgets, although the projected uptake rate is expected to increase to a similar level within EB2. The higher uptake seen to have occurred is real, it is unlikely that the elevated rate remains higher than was originally forecast.	The proportion of New Zealand's vehicle fleet that is electric is very unlikely to ever decline in the coming decades. The difference relative to the original projections is unlikely to be permanent. The rate of further uptake will change over time, but the share of the total vehicle fleet is very unlikely to reverse.	EV uptake is higher but is having the effect of bringing the uptake ahead of time. It does not represent a fundamental change in what is feasible in the budget periods.	Since 2021 the government has introduced a suite of policies to incentivise the uptake of low emissions vehicles. However, uptake projections are inherently uncertain and changing policy settings could have significant effects on the share of EVs entering the fleet in future.

4.NZ Steel EAF funded

Change being assessed:	In May 2023, New Zealand Steel announced a $300M co-investment with government for an electric arc furnace at Glenbrook to reduce greenhouse gas emissions. It is intended to be built within the next three years (from 2027). This was not modelled as part of the original *Ināia tonu nei* demonstration path.			**CCRA Criteria**	5ZC 2b(iii) Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand
Qualitative Test for Significant Change:	**1. Material impact**: How does the change affect the level of emissions reductions possible?	**2. Likelihood**: What is the likelihood that the impact on budgets will be realised?	**3. Permanence**: Is the change permanent, or could it be reversed?	4. **Reason for change**: Has it changed our assessment of what is feasible in a budget period?	**Decision:** **Not a Significant Change**
Findings:	It is estimated that 0.8 $MtCO_2e$/year (1% of NZs total emissions) will be eliminated. **EB1**: - **EB2**: -3 Mt **EB3**: -5 Mt	It is currently an announcement and likely to occur. The introduction within a three-year timescale could experience delays, but is still likely.	Yes, this is a process change that will permanently change the emissions profile.	This co-investment is a policy intervention by the government to meet future emissions budgets as established, it represents an alternative decarbonization pathway than evaluated in *Ināia tonu nei*.	The EAF is a change in technology and carbon emissions that was not considered in *Ināia tonu nei*. The electric arc furnace is considered one of the main initiatives for the government to meet its EB2 and EB3 targets. It is a policy response to the emission budgets being in place. The electric arc furnace is not representative of a new technological breakthrough for the industry, but represents a different path for decarbonisation.

<table>
<tr><th colspan="6">5.Heat pumps that can deliver heat >100°C</th></tr>
<tr><td>Change being assessed:</td><td colspan="3">High-temperature heat pump technologies for supply of temperatures >100 °C is an emerging technology. The development and commercialization of high temperature heat pumps will enable decarbonization through electrification of process heat applications. In Ināia tonu nei, technologies such as this were not assumed to be available until after 2035. It is now likely that high temperature heat pumps for industrial processes will be available within the EB2 period (2026-2030)</td><td>CCRA Criteria</td><td>5ZC 2b(iii) Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand</td></tr>
<tr><td>Qualitative Test for Significant Change:</td><td>1. Material impact: How does the change affect the level of emissions reductions possible?</td><td>2. Likelihood: What is the likelihood that the impact on budgets will be realised?</td><td>3. Permanence: Is the change permanent, or could it be reversed?</td><td>4. Reason for change: Has it changed our assessment of what is feasible in a budget period?</td><td>Decision:
Not a Significant Change</td></tr>
<tr><td>Findings:</td><td>This is difficult to quantify with certainty, however similar process heat reduction (maximum) potentials are in the region of 1.17 million tCO_2e annually. This would be materially impactful.
<table><tr><th>EB1</th><th>EB2</th><th>EB3</th></tr><tr><td>-</td><td>-</td><td>-</td></tr></table></td><td>There are a number of uncertainties associated with new technologies that could affect the uptake rate. Recent publications of high provenance give a reasonably high confidence that they will be available within the EB2 period. In Ināia tonu nei, technologies such as this were not assumed to be available until after 2035. Whether they are adopted in NZ will depend on how they compare to competing decarbonisation routes, and the process to be replaced.</td><td>The cause of the change is likely to be permanent.</td><td>It has not changed our assessment of what is feasible. The benefits that the technology brings were anticipated to occur through other means, it represents an alternative decarbonisation pathway.</td><td>This is an emerging technology which has continued to develop since Ināia tonu nei was published. It is likely to be an option for electrification of process heat within the EB2 period. Decarbonisation of process heat, through transition from coal, has been addressed in a recent GIDI fund awarded to Fonterra. The same emission source is already being addressed and is a competing pathway to decarbonisation for the sector. This represents an alternative decarbonisation pathway and is not sufficient justification to represent a significant change.</td></tr>
</table>

<table>
<tr><th colspan="9">6.Change in vehicle kilometres travelled (VKT) projections</th></tr>
<tr><td>Change being assessed:</td><td colspan="5">The projections for vehicle kilometers travelled (VKT) have changed since Ināia tonu nei. Although Covid resulted in a reduction in VKT, the 2023 VKT projections showed substantial changes, as the anticipated rebound in VKT following covid has not been as strong as predicted.</td><td>CCRA Criteria</td><td colspan="2">5ZC 2b(iii) Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand</td></tr>
<tr><td>Qualitative Test for Significant Change:</td><td colspan="3">1. Material impact: How does the change affect the level of emissions reductions possible?</td><td>2. Likelihood: What is the likelihood that the impact on budgets will be realised?</td><td>3. Permanence: Is the change permanent, or could it be reversed?</td><td>4. Reason for change: Has it changed our assessment of what is feasible in a budget period?</td><td colspan="2">Decision:

Not a Significant Change</td></tr>
<tr><td>Findings:</td><td colspan="3">The quantified change is reasonably large as estimated net emissions reduction for EB1 (-1.7%) and EB2 (-1.3%). The difference is smaller for EB3 (-0.3%).

<table><tr><th>EB1</th><th>EB2</th><th>EB3</th></tr><tr><td>-</td><td>-</td><td>-</td></tr></table></td><td>There is low confidence that the VKT will remain low.

Travel demand was considered within Ināia tonu nei as a mitigation, so these changes may be factored in and could just be occurring earlier than anticipated.</td><td>VKT can be expected to fluctuate in future projections from MoT, the change described here may reflect a fundamentally different assessment of future VKT, but equally the VKT could return to the pre-covid trend in future projection updates. The change is equally likely to not be permanent and could be reversed.</td><td>The projected VKT reduction has increased what is feasible in a budget period, if it were to occur.</td><td colspan="2">VKT forms the basis of emissions estimates in the ENZ model which is used to derive the level of emission budgets. Light vehicles' VKT is now estimated to be lower than that projected under Ināia tonu nei through to EB3. For heavy vehicles the VKT projections have increased, but have a smaller total VKT than light vehicles. These projections linked to demand can be harder to accurately predict than single discrete events, such as an industrial process change. This makes it an uncertain change which may not be permanent. It does not represent a significant change.</td></tr>
</table>

7.Implication of land use changes on communities					
Change being assessed:	Since *Ināia tonu nei* was published the rate of afforestation has increased faster than was predicted. The impact of land use changes (LUC) on communities was explicitly discussed in *Ināia tonu nei*, which recognised that large scale conversions to forestry could affect communities.			**CCRA Criteria**	5ZC 2b(ix) The implications, or potential implications, of land-use change for communities
Qualitative Test for Significant Change:	1. **Material impact**: How does the change affect the level of emissions reductions possible?	2. **Likelihood**: What is the likelihood that the impact on budgets will be realised?	3. **Permanence**: Is the change permanent, or could it be reversed?	4. **Reason for change**: Has it changed our assessment of what is feasible in a budget period?	**Decision:** **Not a Significant Change**
Findings:	Notable increases in net stocked area of exotic forest have occurred in the Tasman and Marlborough Districts. Although in specific areas it may be substantial enough to impact communities, in aggregate, the change in afforestation is unlikely to be impactful across Aotearoa New Zealand. **EB1** | **EB2** | **EB3** - | - | -	There is not a high degree of confidence that the impact on communities from LUC that has occurred will continue to be impactful into the future.	The higher level of land use change to forestry that has occurred is highly likely to stay in forest until 2050. However, the impact on communities is not necessarily permanent.	The increase in rate of afforestation has not affected what is feasible with respect to land use change on communities.	Since Ināia tonu nei was published the rate of afforestation has increased faster than was predicted. How this progresses in the next few years could dictate the impacts on communities. There is a limited body of literature addressing the potential social impacts of future land use changes, and were available at the time the budgets were set. No further climate policies have been announced or introduced that are likely to significantly influence land use change and impact rural communities.

<table>
<tr><th colspan="7">8.Fonterra receiving GIDI funding to reduce process heat</th></tr>
<tr><td>Change being assessed:</td><td colspan="3">The Government will co-fund up to $90 million from the GIDI fund to cut coal use at Fonterra dairy factories. This was not identified in Ināia tonu nei. It is forecast to cut coal use at six Fonterra dairy factories, halving Fonterra's manufacturing emissions by 2030. Fonterra is anticipating a combination of energy efficiency, biomass, existing heat pump technology and newer innovative solutions will deliver these reductions.</td><td>CCRA Criteria</td><td colspan="2">5ZC 2b(iii) Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand</td></tr>
<tr><td>Qualitative Test for Significant Change:</td><td>1. Material impact: How does the change affect the level of emissions reductions possible?</td><td>2. Likelihood: What is the likelihood that the impact on budgets will be realised?</td><td>3. Permanence: Is the change permanent, or could it be reversed?</td><td>4. Reason for change: Has it changed our assessment of what is feasible in a budget period?</td><td colspan="2">Decision:
Not a Significant Change</td></tr>
<tr><td>Findings:</td><td>This is estimated to deliver 2.69%of all Aotearoa New Zealand's required emission reductions between 2026-2030, or 1.17 million tCO_2e reductions. It will deliver 1.13% of the reductions required for EB3 (2031-2035). This is materially significant.
<table><tr><th>EB1</th><th>EB2</th><th>EB3</th></tr><tr><td>-</td><td>-1.17 Mt</td><td>-1.17 Mt</td></tr></table></td><td>There is high likelihood that the change will occur, and within the EB2 period.</td><td>The changes are likely to be permanent, and if installed, the technologies are unlikely to be reversed.</td><td>The GIDI fund is a policy response to meet the emission budgets through abatement of process heat. A reduction in process heat emissions was considered in the original Ināia tonu nei pathway, this represents an alternative approach to achieve the same mitigation potential and is not an increase in what is feasible.</td><td colspan="2">This initiative is a policy response by the government as a means to achieve budget reductions. Although this particular initiative was not modelled in Ināia tonu nei, the move away from coal for process heat was considered at the time. the demonstration pathway in Ināia tonu nei saw an approximately 50% reduction in food processing emissions, and about 70% reduction in coal use by 2030 relative to 2018. Coal use was modelled to be phased out by 2037. Our understanding of what is feasible is unchanged, and it should not represent a significant change.</td></tr>
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<table>
<tr><th colspan="8">9.Biofuels mandate</th></tr>
<tr><td>Change being assessed:</td><td colspan="5">In January 2021, the Government agreed in principle to implement a biofuels mandate. In June 2021 the consultation on the sustainable Biofuels Mandate was announced. The Sustainable Biofuels Obligation Bill was introduced to Parliament in November 2022. On 8 February 2023, it was announced the biofuels mandate would be discontinued, as part of the Government's policy refocus.</td><td>CCRA Criteria</td><td>5ZC 2b(iii) Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in New Zealand</td></tr>
<tr><td>Qualitative Test for Significant Change:</td><td colspan="3">1. Material impact: How does the change affect the level of emissions reductions possible?</td><td>2. Likelihood: What is the likelihood that the impact on budgets will be realised?</td><td>3. Permanence: Is the change permanent, or could it be reversed?</td><td>4. Reason for change: Has it changed our assessment of what is feasible in a budget period?</td><td>Decision:

Not a Significant Change</td></tr>
<tr><td rowspan="3">Findings:</td><td colspan="3">The government's first emissions reduction plan had a target to reduce the emissions intensity of transport fuel by 10% by 2035. The Ināia tonu nei demonstration path assumed the use of low carbon fuels to provide 5% of total liquid fuel demand by 2035.</td><td rowspan="3">The discontinuation of the biofuels mandate has occurred.</td><td rowspan="3">It is possible that it could be reversed, or a different mechanism established to promote biofuels.</td><td rowspan="3">The Biofuels Mandate was a policy option to incentivise the uptake of biofuels in Aotearoa New Zealand for decarbonisation of the transport sector. Alternative mechanisms to incentivise biofuels uptake could be implemented in the future, given biofuels were, and remain, a key consideration in the first emissions reduction plan.</td><td rowspan="3">Biofuels are part of the Ināia tonu nei demonstration path and the first emissions reduction plan. The biofuels mandate is a specific policy used to incentivise uptake. Biofuels remain a realistic tool for hard to abate sectors such as heavy freight and aviation. Therefore, the fact this policy is discontinued does not mean alternative mechanisms will not emerge, or that alternative paths cannot be sought, as is the purpose of the emissions budgets.</td></tr>
<tr><td>EB1</td><td>EB2</td><td>EB3</td></tr>
<tr><td>-</td><td>-</td><td>-</td></tr>
</table>

10. Changes to NZ obligations under international agreements

Methodology for assessment of changes to NZ obligations under international agreements	We have identified three criteria which we consider should all be met for a change to Aotearoa New Zealand's obligations to justify a change to one or more emissions budgets. The change to the obligations should be: 1. **Binding**. Many agreements, initiatives and decisions (referred to in this document as agreements) that Aotearoa New Zealand has been a party to are not enforceable. Some are agreements in principle only, while others may be precursors to future binding agreements. Unless an agreement is binding it is unlikely to have a material effect on Aotearoa New Zealand's emissions. 2. **Relevant to the 2050 target**. The agreements that Aotearoa New Zealand is party to have varying levels of relevance to the 2050 target or the NDC 3. **Sizable**. Could it contribute to a notable, important and consequential change? If it is materially significant, then it is likely that it will affect at least one other matter listed in section 5ZC. The agreement must have been agreed, or updated, in the period following the current emissions budgets being published.	**CCRA Criteria**	5ZC 2b(xi) Aotearoa New Zealand's relevant obligations under international agreements

International agreement assessed	**Is it binding?**	**Is it relevant to the 2050 target?**	**Is it notable, important or consequential. Does it affect another matter in 5ZC?**	**Decision**	**Justification**
Net zero Government Initiative	×	✓	×	**Not Significant**	This example does not meet the criteria because while it has some relation to the 2050 target, it is not binding and it currently presents no important, notable, consequential change.
EU Free Trade Agreement	×	✓	×	**Not Significant**	This agreement is not binding yet but will be once it comes into force. It includes a range of climate and environmental obligations with direct reference to the Paris Agreement and has a substantial nexus with the 2050 target.

					As this agreement has yet to be ratified, it presents no important, notable, consequential changes at this time although it is possible that it could in the future.
UK Free Trade Agreement	✓	✓	×	Not Significant	This agreement is binding and includes a disputes resolution process, it differs from the FTA with the EU as it does not include an option to use trade sanctions against a signatory if that signatory does not fulfil an obligation. This agreement has a high nexus with the 2050 target as many of its obligations cover a wide range of policy interventions that will enable Aotearoa New Zealand to meet emissions budgets and reach the 2050 target. No matters stemming from this agreement with the UK could cause or contribute to important, notable, consequential changes to emissions budgets at this time. However, because this agreement is binding and has strong nexus with the 2050 target, it is possible that it could cause or contribute to such a change in the future.
UNCLOS Marine Diversity	✓	×	×	Not Significant	UNCLOS is binding and enforceable. This agreement has a low nexus with the 2050 target as it does not include parts that set emission reductions targets. No part of this agreement could cause or contribute to important, notable, or consequential changes to emissions budgets at this time.
Friends of Fossil Fuel Subsidy Reform	×	×	×	Not Significant	The Statement was not binding and has a low nexus with the 2050 target. The Glasgow Climate Pact, to which it refers, was agreed in 2021, and could therefore have been considered when the current budgets were set. The Statement could not cause or contribute to important, notable, or consequential changes to emissions budgets at this time.
Food and Agriculture for Sustainable	×	×	×	Not Significant	The Initiative is not binding and has a low nexus with the 2050 target because of its narrow scope and focus on 2030. The Initiative could not

Transformation Initiative					cause or contribute to important, notable, consequential changes to emissions budgets at this time.
Article 6 Implementation Partnership	×	×	×	**Not Significant**	The Partnership is not binding and has a low nexus with the 2050 target. The Partnership could not cause or contribute to important, notable, consequential changes to emissions budgets at this time.
Sharm el-Sheikh Implementation Plan	×	✓	×	**Not Significant**	None of these decisions are binding. They have a generally low nexus with the 2050 target, with references to 2030 NDC targets having the strongest nexus. None of these decisions could cause or contribute to important, notable, or consequential changes to emissions budgets at this time.

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