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Review of emissions data and modelling systems (Phase 1) Report

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Caroline Fyfe, Phoebe Taptiklis, Dominic White, Niven Winchester

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Author contact details

Caroline Fyfe: caroline.fyfe@motu.org.nz

Phoebe Taptiklis: phoebe.taptiklis@motu.org.nz

Dominic White: dominic.white@motu.org.nz

Niven Winchester: niven.winchester@motu.org.nz

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Motu Economic and Public Policy Research

PO Box 24390 info@motu.org.nz +64 4 9394250

Wellington www.motu.org.nz

New Zealand

Abstract

The purpose of this report is to review greenhouse gas (GHG) emissions and climate change mitigation data and models.

Building an evidence base to monitor and assess the impacts of initiatives is explicitly mentioned in Aotearoa New Zealand's First Emissions Reduction Plan (05/2022). Economic-Environmental modelling plays an important role in decision making to achieve emission reduction targets.

Data is hosted by a range of organisations and collected using different frameworks and methodologies. There is less awareness of data available through Stats NZ which may have led to it being underused. Main collated data sources are the GHG emissions account and the GHG emissions inventory. Sector specific data are available through relevant agencies.

A detailed stock-take of New Zealand's modelling capacity identified 84 climate change or climate change mitigation models: 13 multi-sector models, 23 land use and agricultural models, 25 energy models, and 23 transport models. The stock-take identified at least one model for each sector of the ERP, except for Building and Construction. Modelling capacity varies between sectors with those that are more developed, demonstrating greater interdependency between models. Almost all modelling takes a production-based approach. Capacity for a consumption-based approach was much more limited.

Two examples of formal collaboration are identified through the review. No formal international collaboration (outside of international reporting requirements) was identified.

A preference was expressed for modelling in-house to facilitate alignment with policy development. However, this may have contributed to lack of collaboration on progress towards common targets. Connections with groups outside of government are also limited.

JEL codes

C31, D58, Q4, Q54, Q58.

Keywords

Greenhouse gas emissions, Emissions abatement, Climate change modelling, Data management, Policy analysis

Summary haiku

Model climate change,

To see our future planet,

Can we help shape it?

Table of Contents

Table of Contents iii

Executive Summary 1

Recommendations 2

1. Introduction 3

1.1 Purpose 3

1.2 Key research questions 3

1.3 Research methods 3

2 Background 4

2.1 Emissions reduction plan 4

2.2 Approaches to calculating emissions targets 5

2.3 The role of modelling 6

3 International Guidelines 7

3.1. UNFCCC 7

3.2. SEEA 7

3.3. IPCC 8

4 Data sources 9

4.1. The GHG Inventory 10

4.2. The Quarterly GHG Emissions (Household and Industry) 10

4.3. Energy data 10

4.4. Land use data 11

4.5. Economic data 11

4.6. Employment data 11

4.7. Additional information sources 11

5 Modelling capacity 13

5.1 Multi sector models 16

5.2 Transport 16

5.3 Energy and Industry 17

5.4 Building and Construction 17

5.5 Agriculture and land use 18

5.6 Forestry (LULUCF) 19

5.7 Waste 19

5.8 Fluorinated gases 19

5.9 Aggregated impacts 20

5.10 Disaggregated impacts 20

6 Collaboration 21

6.1. MoU: Development of a shared evidence base on climate change 21

6.2. Interagency Climate Change Data and Modelling Network 22

6.3. International Collaboration 23

7 Risks and opportunities 24

7.1 Modelling capacity 24

7.2 Data quality and availability 24

7.3 Alignment with international guidelines 25

7.4 Oversight and transparency 26

8 Summary and recommendations 27

8.1 Modelling capacity 27

8.2 Data availability and accessibility 27

8.3 Oversight 27

References 29

Appendix 1: Stock take table of climate change models - 45 -

Appendix 2: Publicly available datasets used in the models - 71 -

Appendix 3: List of Acronyms - 74 -

Executive Summary

"*Te hau mārohi ki anamata - Towards a productive, sustainable and inclusive economy: Aotearoa New Zealand's First Emissions Reduction Plan*" (05/2022), sets out a series of strategies, policies, and actions for achieving the first emissions budget (2022-2025), required by the Climate Change Response Act 2002. Building an evidence base to monitor and assess the impacts of initiatives is explicitly mentioned in the document. Economic-environmental modelling will play an important role in decision making to achieve the targets required for New Zealand to achieve net-zero GHG emissions by 2050.

This report provides an updated review of New Zealand's capacity for modelling climate change and climate change mitigation. A stock take of economic models that operate from a regional level upwards was done, and major sources of input data identified. Documentation about the models was extracted from publicly available sources. Not all models in the stock take are in use. These are included as there was sufficient documentation for their use in the future.

There is a wide range of publicly available climate change data used in the models, sometimes supplemented from sources with restricted access. Major aggregated data sources align with international accounting frameworks, for example UNFCCC and the SEEA. Annual updates are considered sufficient for modelling requirements. Reducing the time lag between the end of the reporting period and data (for example the GHG inventory) becoming available is seen as a greater priority.

The stock-take identified at least one model for each sector listed in the Emissions Reduction Plan (ERP), except for Building and Construction. Modelling capacity varies between sectors, although in some cases sectors overlap, or smaller sectors are subsectors of larger ones. Almost all modelling takes a production-based approach. Capacity for a consumption-based approach is much more limited, although it is currently being developed. Sectors where modelling capacity is more developed demonstrate a higher degree of interdependency between models.

A preference was expressed (by those responsible for ERP reporting) for modelling to be done within government agencies, to better manage timelines and align with policy development. However, this may contribute to a lack of collaboration between agencies towards common targets. Collaboration on modelling allows for interdependencies between models and avoids duplication. A collaborative approach helps build capacity within the modelling community through learning opportunities and peer review. Some formal examples of collaboration are identified through the review. No formal international collaboration (outside of international reporting requirements) is found and connections with groups outside of government were also limited.

Recommendations

I. Data collection methodologies are documented to an agreed format and aligned with specified international frameworks, and relevant domestic classifications and standards.

II. A standard level of documentation detailing the purpose, use, output and limitations of each model is agreed, that is of sufficient quality to enable sharing with external organisations.

III. Agreement is reached between agencies on key assumptions and breakdown by industry type and region.

IV. Sufficient resourcing is provided to ensure the recently developed interagency Network has long term stability and Network members can be proactive in maintaining, developing and updating climate change models and datasets.

V. A means of data sharing is agreed between government agencies and within the wider New Zealand climate change modelling community.

VI. A centralised repository for climate change modelling data is developed.

VII. A system of external peer review is established to improve quality assurance of climate change modelling.

VIII. A protocol is agreed for the development of modelling using a consumption-based approach.

IX. A Community of Practice is established, to encourage greater cooperation across organisations and internationally, and to share good practice with sectors where modelling capacity is less well developed.

1. Introduction

1.1 Purpose

The Climate Change Response (Zero Carbon) Amendment Act 2019 commits New Zealand to reducing greenhouse gas (GHG) emissions (except for biogenic methane) to net zero by 2050 through a series of five-year emissions budgets. The target for biogenic methane is a reduction of 10% of 2017 levels by 2030 and a 24-47% reduction by 2050 (Climate Change Response (Zero Carbon) Amendment Act, 2019). The purpose of this report is to review data and models related to GHG emissions and climate change mitigation –and to provide an overview of their capacity to inform policymakers on New Zealand's progress towards net zero emissions by 2050. This report is informed by previous work on climate change modelling by Motu Research (Hendy et al. 2018; White et al. 2018; & Winchester et al. 2019).

1.2 Key research questions

- Are current models sufficient to measure the impact of policy on high-level indicators, and to produce the required reporting on GHG emissions in all sectors?
- Is there sufficient, publicly available, data to satisfy the input requirements of the models?
- Is there a synthesis of modelling methodologies across different sectors of the economy?
- Does data collection and modelling in New Zealand align with international reporting guidelines?

1.3 Research methods

Research questions were examined through:

- a stock-take of models informing climate change reporting,
- a review of frequently used data sources feeding into these models
- key informant interviews with modellers at government agencies contributing to the development of the First Emissions Reduction Plan (ERP).

2 Background

2.1 Emissions reduction plan

"*Te hau mārohi ki anamata - Towards a productive, sustainable and inclusive economy: Aotearoa New Zealand's First Emissions Reduction Plan*" (05/2022), henceforward referred to as the ERP, sets out a series of strategies, policies and actions for achieving the first emissions budget (2022-2025), required by the Climate Change Response Act 2002 (MfE, 2022a). This limits emissions to 290 Mt CO_2e (megatonnes of carbon dioxide equivalent GHG)[1], (72.4 Mt CO_2e per year), 5.4% below the five-year average for 2017-2021. Each budget thereafter limits emissions further. Emissions budget two (2026-2030) will limit emissions to 305 Mt CO_2e (61 Mt CO_2e per year) [in principle] 13.4% below the five-year average for 2017-2021. Emissions budget three (2030-2035) will limit emissions to 240 Mt CO_2e (48 Mt CO_2e per year) [in principle] 35% below the five-year average for 2017-2021. Later emissions budgets are yet to be announced.

The ERP lists high level intermediate indicators to reduce emissions across seven sectors:

I. Transport
II. Energy and Industry
III. Building and Construction
IV. Agriculture
V. Forestry
VI. Waste
VII. Fluorinated gasses

Figures for projected emissions, with and without the ERP, and an estimate of the reduction achieved through abatement actions are given for each sector. These are based on the 2019 figures (published in the GHG inventory in April 2022 (MfE, 2022b). 2020 figures, although available, were considered to be distorted by COVID-19 and therefore not representative. Projected and estimated emissions are converted to CO_2e values using global warming potential over 100 years (GWP100) metric values from the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report (AR5). Projections are based on reporting requirements of the United Nations Framework Convention on Climate Change (UNFCCC – *see 4.1*). They are produced by the relevant Government agency for each sector, with some assumptions agreed between agencies[2]. Based on the modelling used, the greatest emissions reductions for the first budget (ERP1) are expected to be from industry, energy and transport. Synthesis of the projection to calculate overall targets and trajectories, including accounting for overlaps between sectors, is done by the Ministry for the Environment (MfE)[3].

[1] GHG values have been converted to megatonnes of carbon dioxide equivalent (Mt CO_2-e). CO_2-e is calculated by multiplying the quantity of GHG by its global warming potential.
[2] Personal communication Climate Change Commission.
[3] Personal communication MfE.

Key actions listed to achieve the targets set out in the ERP include:

- emissions pricing through the Emissions Trading Scheme (ETS)
- mandatory climate reporting
- reform of the resource management system to promote lower emissions and climate resilience
- support for innovation of low emissions technology
- transition to a circular economy.

Building an evidence base to monitor and assess the impacts of initiatives is explicitly mentioned in Objective 4 of the plan, specifically:

- tracking a range of existing measures to assess the impact of the emissions pricing
- developing modelling and research – around distributional impact analysis
- improve data collection and availability and use of statistics in monitoring and forecasting

2.2 Approaches to calculating emissions targets

Two approaches are used to calculate national emissions statistics:

The production (supply side) approach calculates emissions that pass from human activity to the environment. This approach includes exports but omits imports and uses two methods of measurement:

- **Territory based:** emissions produced within a country's territorial boundaries. Gross emissions include total emissions from agriculture, energy, industrial processes, and product use (IPPU). Net emissions include all gross emissions plus GHG emissions and removal from land use, land use change and forestry (LULUCF).
- **Residency based:** emissions produced by economic residents – industry and household – both within New Zealand and overseas. The advantage of residency-based reporting is it accounts for 'emissions leakage' where New Zealand based businesses move production offshore to countries with less stringent regulation on GHG emissions. It does not, however, cover leakage from overseas firms operating in New Zealand[4].

The consumption (demand side) approach calculates emissions embodied in goods and services resulting from activity throughout the supply chain, that are consumed by economic residents. This approach includes imports but excludes exports (Stats NZ, 2020).

[4] Personal communication CCC

2.3 The role of modelling

Economic-environmental modelling will play an important role in decision making to achieve emission reduction targets on two levels. Firstly, to calculate the impact of policies and initiatives on GHG emissions – for example, transitioning from petrol/diesel to electric vehicles. –. Secondly to determine progress towards future climate change mitigation targets, using baseline data to map trajectories based on different scenarios.

To obtain the best evidence-base, models need to be:

- consistent in their use of base-case scenarios, assumptions, units of measurement and accounting frameworks
- well maintained with source data updated regularly and modelling adjusted to reflect advances in scientific understanding of climate change and the development of new, low-carbon technologies
- aligned with international guidelines.

Additionally, when considered collectively, models should be:

- comprehensive to cover all required domains
- disaggregated to provide estimates at a regional level.

Different modelling methods are needed for different sectors of the economy. This means it is not possible to calculate total estimated emissions reductions from aggregating values from each sector. For example, in the ERP[5] a consumption approach is used for the building and construction sector which incorporates embodied carbon within a life-cycle analysis. This includes transportation of resources and disposal of waste, both of which are also independent sectors in the ERP and measured using a production approach. As such, modelling and 'adding up' of total emissions reductions needs to incorporate a means of adjusting for where different accounting methods cause sectors to overlap.

3 International Guidelines

This section outlines international guidelines, mainly developed for reporting purposes. Later sections will identify where data and models meet the guidelines.

3.1. UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1994 and has since been ratified by 197 countries. It acknowledges the existence of climate change and gives a commitment to return GHG emissions to a level that "…prevent(s) dangerous anthropogenic interference with the climate system" (Kuh, 2018). The UNFCCC was used as a basis for the Kyoto Protocol (1997) and the Paris Agreement (2015). It "supports common but different approaches to climate change" (Stats NZ, 2020). The UNFCCC instituted a process for countries to share data about GHG emissions, with all countries required to submit inventories. In addition, it provides a framework for developing national, legally binding GHG emissions reduction targets for more economically developed countries.

3.2. SEEA

The System of Environmental and Economic Accounting framework (SEEA) was adopted by the United Nations (UN) Statistics Commission in 2012 as the international standard for measuring the interactions between the environment and the economy. It aligns with the System of National Accounts (SNA) which Statistics New Zealand (Stats NZ) uses to produce economic statistics such as GDP.5 SEEA includes economic and environmental data in a common framework to facilitate direct comparisons between the two (UN, n.d.a), such as tracking GHG emissions in relation to economic growth.

The SEEA central framework covers measurements in three main areas: environmental flows, stocks of environmental assets, and economic activity related to the environment (UN, n.d.b). It encompasses eight thematic areas: agriculture, forestry and fisheries, air emissions account, energy, environmental activity, ecosystem accounting, land accounts, material flow accounts and water.

Agriculture, forestry and fisheries, energy and water are be captured by two types of accounts:

- flow accounts: record the flow of products between the environment and the economy, with parallel monetary accounts recording the monetary value of associated transactions
- asset accounts: measure the quantity of change in resources over the accounting period. These can be recorded as physical assets with a parallel monetary account to record their financial value.

The land use accounts are based on land cover rather than product and material flows and provide an aggregated overview of environmental inputs into and output from an economy, including imports and

[5] GDP = the value of the finished domestic goods and services produced within a nation's borders.

exports. The ecosystems accounts measure environmental assets, while the environmental activity account records expenditure related to the environment.

Air emissions accounts are disaggregated by the sector (industry or household) that generated each emissions type, and for emissions from accumulation – for example through landfill.

The air emissions account closely matches the requirements of the UNFCCC however it does not account for emissions 'leakage' produced by tax-residents outside of their territory or emissions from overseas residents and companies within the territory.

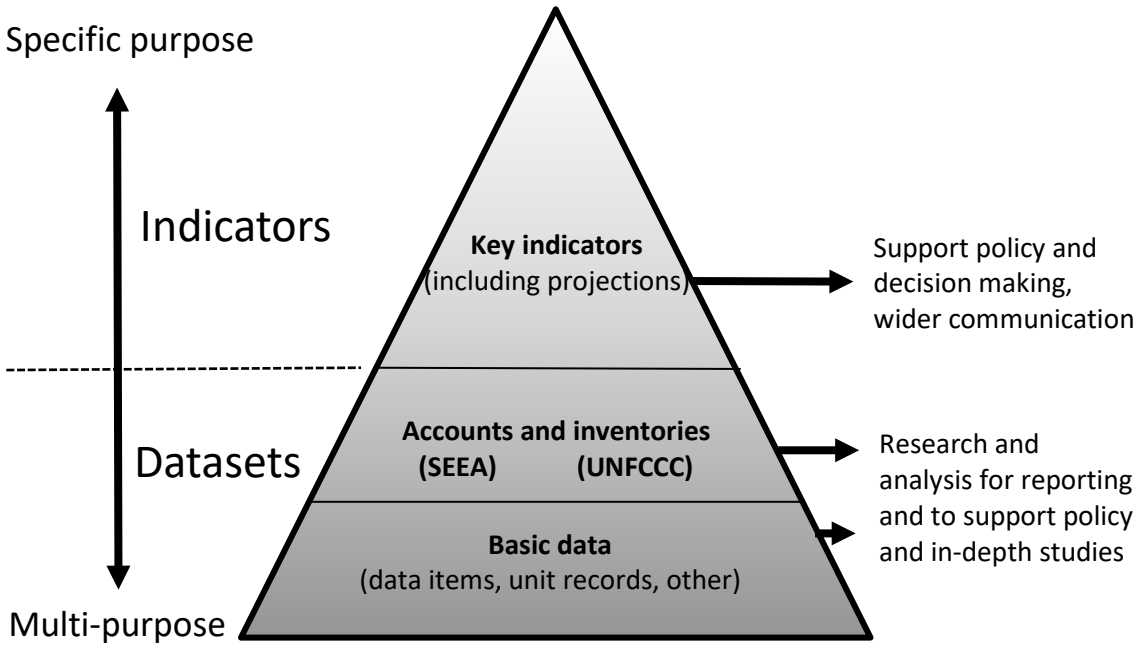
3.3. IPCC

The IPCC was established in 1988 by the World Meteorological Organisation (WMO) to assess climate change impacts, risks and opportunities for adaptation and mitigation. Its primary focus is providing governments with scientific advice for international negotiations and development of domestic climate policies (IPCC, 2023), and the development of guidelines and advice for the UNFCCC reporting frameworks. New Zealand is an active member of the IPCC and routinely contributes to Assessment Reports (NIWA, 2023).

4 Data sources

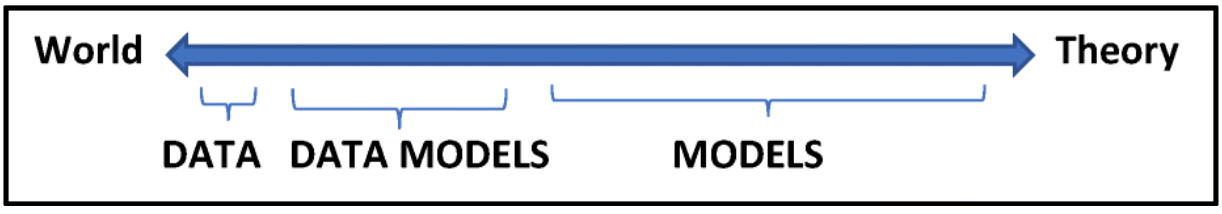
Data sources, for the purposes of this report, are defined as statistics that can be used for multiple purposes, *see figure 1*.

Figure 1: The information pyramid derived from (Farrell C. and Stout J.C., 2019)



Data can be 'raw' – for example counts, measurements and observations – or derived – for example rates or proportions. Data is tangible and measurable, while models are more conceptual and theory based, although the two sit on a continuum, *see figure 2* (Leoneli S., 2019). Examples where data has moved along the continuum (data models in figure 2) include the GHG emissions inventory and some sector specific data models. For example, raw data may be used as an input for a general model or statistical tool, and then the derived statistics may be used as inputs in other, more complex, modelling – such as a multi-sector model.

Figure 2: A representational view of data and models (Leonelli S., 2019)



An outline of frequently used data sources is given in *Appendix 2*. A brief description of different types of input data is given below.

4.1. The GHG Inventory

The GHG Inventory is produced by MfE[6]. It takes a production (territory-based) approach to collating GHG emissions data. It includes both gross emissions and net emissions. Data for the inventory is sourced from the relevant Government agencies (MfE 2022b). The GHG inventory is the official annual estimate reported to the UNFCCC, in line with IPCC methodologies (MfE 2022b) and is used for setting domestic targets. Data is available annually from 1990, in line with international reporting requirements, and updated annually.

4.2. The Quarterly GHG Emissions (Household and Industry)

The quarterly GHG emissions data is produced by Stats NZ (Stats NZ, 2020). It takes a production (residency-based) approach to collating GHG emissions data (*see 2.3*). Input data includes the relevant annual GHG emissions data and national accounts from StatsNZ. This is supplemented by data collected from the Ministry for Primary Industries (MPI) and the Ministry for Business Innovation and Employment (MBIE), to provide industry-based breakdown of emissions sources. For example, by farming type and to split mining from building and construction.

The quarterly GHG emissions data is produced using the SEEA framework and distinguishes between NZ residents and non-residents and between households and industry, although air emissions estimates exclude PM10 (particulate matter). Regional breakdowns are included as well as industry classification by 2006 *Australian and New Zealand Standard Industrial Classification* (ANSICO6) codes (Stats NZ, 2018).

The quarterly GHG emissions data only includes gross emissions from agriculture, energy and industry process and product use (IPPU) and waste. It excludes emissions and emissions reductions through land use, land use change and forestry (LULUCF), which would provide a figure for net emissions. Across the economy, individual GHG emissions are aggregated by type, for example: carbon dioxide, methane, nitrous oxides etc. At a more granular level (for example by sector) only total GHG emissions (in CO_2 equivalent units) are reported (Stats NZ, 2020).

4.3. Energy data

Energy data is publicly available through the websites of several government agencies. Capacity, supply, and demand by sector (i.e., primary industry, industrial process, commercial and residential), are published by MBIE (MBIE, 2023). These data provide end-user information for consumption-based models published by the Energy Efficiency and Conservation Authority (EECA) (EECA, 2023). Electricity generation capacity is publicly available through the Electricity Authority (EA) and is used in the General Expansion Model (GEM) (EA, 2023a) to model a range of policy and economic scenarios. These data are also used as inputs for many other models.

[6] Personal communication MfE.

4.4. Land use data

Agricultural land use data is collected through MPI by Stats NZ and is publicly available via the Stats NZ website (Stats NZ, n.d.). MPI and StatsNZ together produce the Agricultural Production Statistics, from an annual survey, calibrated against a five-yearly census. Economic data related to primary industry is published by MPI (Data.govt.nz, n.d.; & MPI, n.d.). MPI are also involved in the collection and reporting of data for the National Exotic Forest Description (NEFD), which is a Tier 1 statistic, overseen by the NEFD steering committee (Ministry for Primary industries, 2022).

Manaaki Whenua - Landcare Research (a Crown Entity) publishes a wide range of spatial data related to LULUCF as shapefiles and geodatabases (Manaaki Whenua, 2020). These cover a range of climate change modelling inputs and are publicly available through their website.

4.5. Economic data

Stats NZ provides a range of economic data including GDP, sectoral and regional output, international trade and input-output data that shows connections between sectors in the economy. Data can be accessed at a granular level through the Stats NZ Integrated Data Infrastructure (IDI) and Longitudinal Business Database (LBD) (Stats NZ, 2022a).

Data on GDP is also available through New Zealand Institute of Economic Research (NZIER) and information on price elasticities provided from Treasury models. ETS pricing is commonly used in models and publicly available, for example, from sources such as Comm Trade (Jarden Securities Ltd, 2023). Data on prices, for example for agricultural production, is available through some government agencies – such as MPI and MBIE. However more granular data is likely to be commercially sensitive and therefore either unavailable or available only on request. New Zealand economic data are also available from international organisations such as the Global Trade Analysis Project (GTAP) database (GTAP, 2023), International Energy Agency (IEA) database (IEA, 2023) and the Organisation for Economic Cooperation and Development (OECD) database (OECD, 2023) which have been used in the models.

4.6. Employment data

Stats NZ provides population-wide, administrative, census, and survey data for people and businesses through the IDI and LBD. While not publicly available, these datasets can be used by authorised people to estimate the distributional impacts of climate policies – as exemplified by the Distributional Impacts Microsimulation for Employment (DIM-E) model (Riggs, L., & Mitchell, L. (2021).

4.7. Additional information sources

Stats NZ produce provisional consumption (currently based GHG emissions data for 2020) (Stats NZ, 2022b). This includes both residential and non-residential (exports) final consumption using *2018 Classification of Individual Consumption According to Purpose* (COICOP). Underlying data on domestic

emissions is sourced from the quarterly GHG emissions. Imported emissions are converted into consumption-based categories through modelling of input-output tables, using a top-down approach (Stats NZ, 2023a).

As of January 2023, the NZ Climate Standard (MfE, 2023) requires large private sector organisations to report climate related disclosures (including climate-related metrics and targets) in their annual reports (MfE, 2022c). The purpose of this is to ensure the effects of climate change are considered in business decisions.

The Carbon Neutral Government Programme (CNGP) (MfE, n.d.), announced in December 2020, focuses on measuring and reducing emissions from core government departments and Crown Entities to accelerate public sector emissions reductions.

5 Modelling capacity

A detailed review of currently available models used to assess progress towards climate change targets for New Zealand is provided in *Appendix 1*. This review identifies a total of 84 models related to climate change or climate change mitigation in New Zealand. It includes 13 multi-sector models, 25 land use and agricultural models, 23 energy models and 23 transport models. These models are hosted by government departments, external consulting companies or independent research centres. A summary of the models, their creator, ownership, and interdependencies are provided in *Table 1*.

The review of models identified at least one for each sector listed in the ERP, except for Building and Construction (although there is work currently underway in this area)[7]. Models are predominantly owned by government agencies or crown entities, with the majority developed in-house. Modelling capacity varies between sectors with those that are more developed, demonstrating a higher degree of interdependency between models. Academic research groups are also major contributors to modelling, particularly in the energy and agriculture sectors. There are some models held by private businesses, mainly in the energy sector, although funding for their development tends to come from public sector organisations. Relatively few models are developed by international organisations, although some New Zealand models are based on international models or use those developed overseas.

Multi-sector models provide outputs related to different sectors across the New Zealand economy and often use more sector-specific climate change models as inputs for their analysis. Land use and agricultural models describe land use change, agricultural processes (such as beef and sheep production), agricultural emissions, inputs to agriculture (such as fertilizer), and/or outputs from agriculture (such as dairy products, and nutrients and sediments). Energy models evaluate the production and/or distribution of energy. Transport models describe transport fleets (such as the categorisation of vehicles on the road), transport processes (such as freight) and/or emissions related to transport. There are some linkages between different modelling categories including outputs from some models becoming inputs for others, as well as the common use of datasets (e.g., the GHG Inventory and MBIE's Electricity Tables). *Figure 3* provides an illustration of general linkages between the different model categories and databases. *Figure 4* demonstrates a New Zealand specific example of input-output dependencies between models, including how specific sector models are linked into multi-sector ones.

[7] Personal communication MBIE, MfE.

Table 1: Summary table of climate change models by sectors and type, ownership and creator. *LULUCF included agricultural (land use) models in the stock-take. ^ Included in multi-sector models in the stock-rake.

Sector		Multi-sector	Transport	Energy and Industry	Agriculture (Land use)	Forestry* (LULUCF)	Waste^	Fluorinated gasses^
Model type	Computable General Equilibrium	4		1				
	Optimisation (partial equilibrium)	1		6	3			
	Economic- type not specified	5	10	7	14	3	1	1
	Simulation	1	6	2	2			
	Predictive	2	8	5		2		
Owner	Government agency or Crown entity	13	23	13	15	4	1	1
	Academic research group		1	4	5			
	Private business			4		1		
	International organisation							
Creator	Government agency or Crown entity	10	22	10	4	4	1	1
	Academic research group	3	1	5	18			
	Private business		1	5	2	1		
	International organisation			1				
Other model dependent		5	14	7	6	2		
Total number of models		**13**	**24**	**21**	**19**	**5**	**1**	**1**

Figure 3: The data and model linkages between climate change models and data in New Zealand

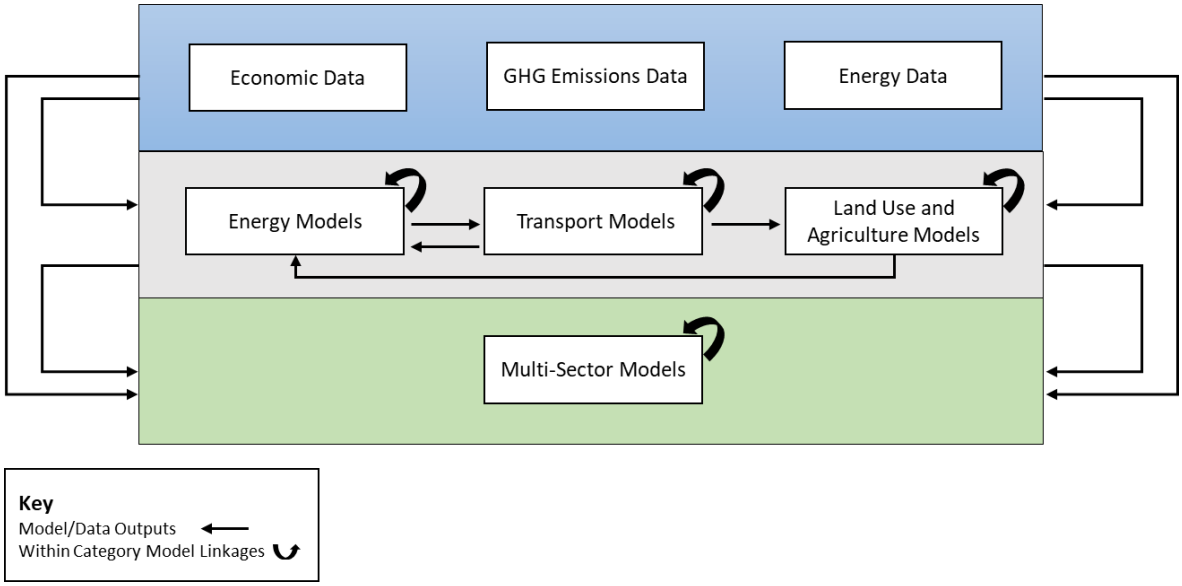
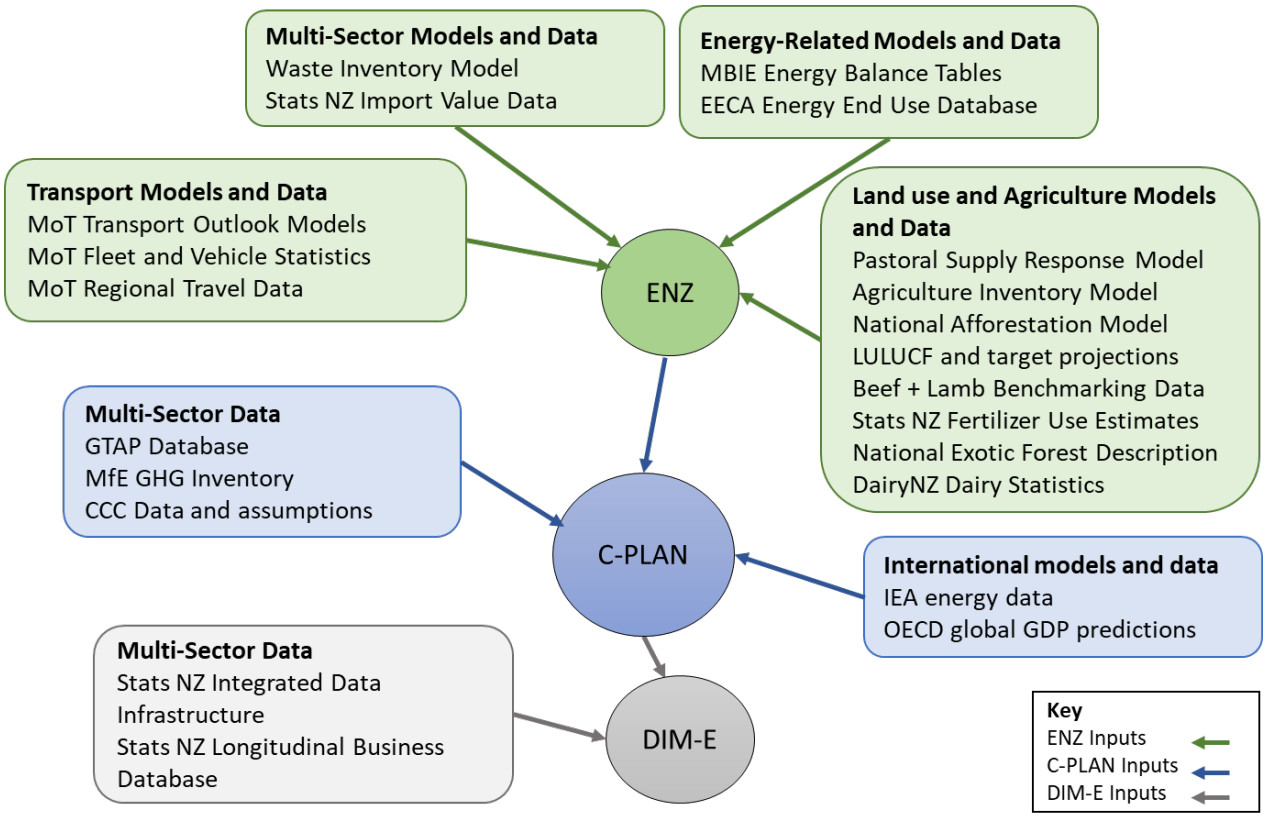


Figure 4: Example of data and model linkages between the ENZ, C-PLAN and DIM-E models.



5.1 Multi sector models

Multi-sector models use outputs from other types of models either directly or indirectly. A direct use of model outputs refers to a model using the results from another model to inform its outputs. An indirect use of model outputs refers to a model which is informed by the results of another model. An example of a direct connection between models is the ENZ model from Concept Consulting (CCC, 2021). This model uses inputs from a variety of modelling sources, such as the Ministry of Transport's (MoT's) Transport Outlook models (e.g. the Vehicle Fleet Emissions Model (MoT, 2022), and Ministry for Primary Industries (MPI) National Afforestation Model (Manley, 2018). An example of an indirect model connection can be seen in the Climate Policy Analysis (C-PLAN) model (Winchester & White, 2022), which uses outputs from the ENZ model to inform its baseline results and is illustrated in *Figure 2*.

5.2 Transport

Transport models in New Zealand are commonly linked with each other. All national transport models apart from UniTrac (Leaver & Watabe, 2016; and Watabe & Leaver, 2018) come from the MoT and the New Zealand Transport Authority (NZTA). The MoT's Transport Outlook uses 13 separate models to inform policy analysis (MoT, 2019h). These models either have an aggregated, New Zealand-wide transport focus (such as the Household Travel Model (MoT, 2017a and MoT, 2019b), the Vehicle Numbers Model (MoT, 2019a), and the Freight Model (MoT, 2019c)), or are more specific to the mode of transport (such as the Road Freight Tonne-KM by Region Model (MoT, 2019d), and the OD-based Domestic Air Passenger Model (MoT, 2017c)). Outputs from the aggregate models are usually used as inputs for the more specific models – for example cost-benefit analyses. There is also an agent-based simulation tool – MONTY – which helps assess the impact of change on the transport system based on individual travel choices[8]. The aggregate models use data inputs from sources such as Stats NZ's population projections, census information from Stats NZ, data from the New Zealand Household Travel Survey, and information from the New Zealand Motor Vehicle Register (MoT 2017a, 2019a, 2019b, and 2019c).

For the ERP, MBIE produce baseline emissions projections for the transport sector, using a production approach. These projections are based on vehicle kilometres travelled (VKT) modelled by MOT. Output from MoT's vehicle fleet emissions model (VFEM) provides input for the MBIE projections. Abatement is calculated using cost benefit analysis based on several factors, including information on vehicle registrations, public transport efficiencies and price and price elasticities. Transport is a subcategory of Energy in the GHG inventory, and this is used to adjust the VFEM against road emissions data. There is cross agency agreement on some aspects of the modelling: ETS price, GHG inventory iteration and

[8] Personal communication Ministry of Transport

MBIE fuel and electricity price projections[9]. Policy measures and assumptions used are listed in the ERP *Technical Information Annex* (MfE, 2022d).

5.3 Energy and Industry

Energy models fit into four categories: electricity generation models, energy use models, electricity models for different generation sources (e.g., hydro-electricity models), and electricity pricing and dispatch models[10]. Most electricity models are made in association with MBIE, EECA or the EA. The key datasets within these models include the EECA Energy End-Use Database (EECA, 2023), electricity generation estimates from the GEM model (Electricity Authority, 2023a), and Electricity Tables from MBIE (MBIE, 2023).

Similar to land-use and agricultural models, energy models have some variation in terms of the level of aggregation they apply to, from the individual plant level (such as the JADE model (Philpott & Downward, 2023)) up to New Zealand wide estimates of energy use (such as the GEM model (Electricity Authority, 2023a), and the vSPD model (Electricity Authority, 2023b)). There are several energy model linkages, for example MBIE's electricity and energy models contribute to a system of models, with the SADEM model sitting at the centre of this system (MBIE, 2016).

Baseline projections and emissions abatement potential for the ERP are calculated by MBIE, MfE, and EECA (MfE, 2022d). These projections exclude building and construction, which is treated as a separate sector. Projections are based on the GHG inventory. Documentation could not be found on the exact models used for abatement potential, however key policies and assumptions are detailed in the ERP *Technical Information Annex* (MfE, 2022d).

5.4 Building and Construction

There are no models identified at the time of the stock take that relate exclusively to the building and construction sector. However, work in this area is being done by several different government agencies, including MfE, StatsNZ, Ministry of Housing and Urban Development (mHUD) and MoT[11]. The WoodScape model (Barry & Hall, 2014) and (Scion, 2013) includes some types of building material. Methodologies used for calculations in the ERP were not publicly available at the time of the review[12].

In 2020, MBIE introduced a whole of life embodied carbon emissions framework (MBIE, 2020) as part of a commitment to get carbon emissions from the building and construction sector to near zero by 2050. This outlines a requirement for life cycle of embodied carbon emissions from buildings to be assessed against European (EN15804 and EN15978) and international (ISO21930) standards (MBIE,

[9] Personal communication Ministry of Transport.

[10] MBIE suggested use a different model classification method: top-down whole of energy system models, bottom-up whole of energy system models, electricity generation capacity expansion, electricity market simulation. (Personal communication MBIE).

[11] Personal communication MfE StatsNZ, mHUD and MoT.

[12] Personal communication, MBIE.

2020). A technical manual provides practical guidance on calculating whole of life emissions. The Building Research institute of New Zealand (BRANZ) has created an online calculator – CO_2NSTRUCT (BRANZ, n.d.) to estimate an embodied GHG from building materials and waste. The New Zealand Green Building Council (NZGBC) has a similar tool – Green Star NZ (NZGBC, n.d.). While these provide guidance to the building and construction industry, modelling needs to be developed to understand sector wide contribution to GHG emissions and predict the impact of building regulations.

Building and construction projections are not consistent with the GHG inventory, as a consumption approach is taken which includes embodied emissions from buildings, some of which are produced offshore (MfE, 2022e). These are produced by MBIE and used as a basis for calculating policy abatement estimates[13]. Documentation could not be found on exact models used for abatement potential, however policies and assumptions used in the modelling are detailed in the ERP *Technical Information Annex* (MfE, 2022d).

5.5 Agriculture and land use

Agriculture, forestry, and other land use models described in this section can be grouped into two key categories: modelling of biological processes that produce greenhouse gases and simulation of production, land use and animal numbers using economic models. Land use and agricultural models use the outputs of models within the same category or use inputs from individual farms to inform the modelling results. Each model tends to focus on specific aspects of land use change or agricultural processes, from the projected afforestation rate in the National Afforestation Model produced by the University of Canterbury and MPI (Manley, 2018), to the nutrient budgets produced by the Overseer Nutrient Budgets model (Overseer, 2023). MfE produce the Land Use and Carbon Analysis System (LUCAS) model which outputs maps and tables. These are based on mapping changes in land use compared to the baseline year of 1990, and have been updated for land use change in 2008, 2012 and 2016 (MfE 2023a).

There are also some models with a broader land use change focus such as the LURNZ model from Motu Economic and Public Policy Research (Kerr & Olssen, 2012; Olssen & Kerr, 2013; Anastasiadis & Kerr, 2013; Zhang & Kerr, 2013; and Timar & Kerr, 2014), and the ARLUNZ model from Manaaki Whenua - Landcare Research (Morgan & Daigneault, 2015 and Morgan, Brown & Daigneault, 2015) which use inputs from sources such as GIS databases, the GHG inventory, slope data from Landcare Research, NEFD forestry data from MPI, and Situation and Outlook for Primary Industries data from MPI.

ERP Agricultural projections are calculated by MPI based on land use, livestock numbers and agricultural production data using the methods and emission factors in the GHG inventory model. Projections for agricultural land use are consistent with LULUCF projections. Currently forecasts are developed using LULUCF projections and outputs from the Pastoral Supply Response Model (PRSM)

[13] Personal communication Ministry of Transport.

which are modified to account for expected effects of environmental policy, such as the *Action for Healthy Waterways* package and the (discounted) effect of pricing agricultural emissions[14]. Policy measures and assumptions used for recent projections are detailed in the ERP *Technical Information Annex* (MfE, 2022d).

5.6 Forestry (LULUCF)

In the stock take forestry models (which also incorporate some land use and land use change metrics) are included with land use and agricultural models. The models are predictive or economic, incorporating the use of ETS pricing. Predictive models include the impact of the ETS (through carbon price) on exotic afforestation, indigenous afforestation and forest management (MPI, 2021b). Economic models include accounting projections. These follow IPCC good practice guidance (IPCC, 2006) and the revised Kyoto Protocol guidance (IPCC 2013). Accounting projections go through both internal and external peer review, including by MfE, using UNFCCC review guidelines, (MPI, 2023). Modelling processes are well documented and publicly available from the MPI website.

The carbon stocks calculated for the GHG Inventory are based on allometric modelling. This also accounts for non-forest-based carbon sinks, for example soil and non-forest land cover. It differs from the previously mentioned modelling which does not account for these factors. This work is done by MfE (MfE, 2022b).

Forestry projections in the ERP are calculated by MPI using LULUCF annual accounting projections (MPI, 2023) and incorporating ETS pricing models and impacts. Baseline projections draw on the accounting approach taken to forestry and other land use in *New Zealand's first Nationally Determined Contribution* to the UNFCCC (UN, n.d.c.). Assumptions and policy impacts are detailed in the ERP *Technical Information Annex* (MfE, 2022d).

5.7 Waste

There is only one, predictive, model for waste in the stock take. This has potential to restrict analysis of the impact of policies on waste emissions and the cost of reducing these emissions. However, waste reduction may be incorporated into other sector models.

Waste projections in the ERP are calculated by MfE and are based on GHG inventory models. Details of the exact model used could not be found. Assumptions related to policy impacts are provided in the ERP Technical Information Annex (MfE, 2022d).

5.8 Fluorinated gases

Only one model explicitly stated it included fluorinated gases. In the ERP, projections for fluorinated gases are calculated by MfE using ETS pricing, synthetic GHG levy and phasedown of HFC gases. Details

[14] Personal communication Ministry for Primary Industries.

of exact the model used could not be found but is likely to be based on the IPPU GHG emissions inventory model.

5.9 Aggregated impacts

In the ERP, aggregated total projected emissions (with an estimated uncertainty range and including estimated contribution from each sector at different policy impact levels) are given for the three emissions budgets, (2022-2025, 2026-2030 and 2031-2035) (Electricity Authority, 2023a). These are based on MfE GHG emissions projections published in March 2022 and are largely aligned with the CCC *Current Policy Reference* (CPR) case projections (May 2021). Assumptions and uncertainties are listed in detail in the *Technical Information Annex* (MfE, 2022d). There is agreement between agencies on some high-level assumptions, for example which version of the GHG inventory to use, GDP estimates, population projections, and ETS price, but not carbon price outside of the ETS.[15] Documentation could not be found for (1) the exact models used, (2) potential duplication of emissions and emissions reduction potential avoided, (3) and how different assumptions are reconciled.

5.10 Disaggregated impacts

Modelling of distributional impacts of climate mitigation policy is limited to DIM-E. This is a gap the CCC indicated they currently rely on Treasury's Tax and Welfare Analysis (TAWA) model to fill. TAWA is not a climate change mitigation model but can be used for certain types of distributional analysis.

[15] Personal communication Ministry of Transport, Climate Change Commission.

6 Collaboration

Collaboration on modelling between different Government agencies allows for greater coordination (for example of key assumptions), facilitates interdependencies between models through sharing of data and information, and avoids duplication. A collaborative approach helps build capacity within the modelling community through learning opportunities and peer review. Two examples of collaboration are identified by the review, an MoU developed by the Climate Change Commission[16] (CCC) and an Interagency Climate Change Data and Modelling Network[17] (the Network) developed by MfE. Both are exclusive to Government agencies (*see 6.1 and 6.2*).

Government agencies contacted expressed a preference to maintain in-house modelling capacity while acknowledging the need for greater collaboration. On occasion, contractors were used if output was needed, and timing and resources did not allow for in-house models to be developed. There is measured interest in a suggestion by the research team of widening the Network to academic institutions, but some concern expressed regarding the sensitivity of Government information and working to short timeframes.

6.1. MoU: Development of a shared evidence base on climate change

The memorandum of understanding (MoU) was developed at the request of the Minister for Climate Change in his December 2019 annual letter of expectations. It was initiated by the CCC and agreed by seven Government agencies involved in climate change mitigation policy and reporting:

- Ministry for the Environment (MfE)
- Ministry for Primary Industries (MPI)
- Ministry of Business, Innovation and Employment (MBIE)
- Ministry of Transport (MoT)
- Waka Kotahi NZ Transport Agency (Waka Kotahi)
- The Treasury
- Energy Efficiency and Conservation Authority (EECA)

The purpose of the MoU is to develop a shared evidence-base related to climate change mitigation and adaptation through greater coordination, a common understanding of expectations and good working relationships. The initial focus of the MoU is emissions budgets, with wider reference to data, information, research and qualitative evidence related to GHG emissions and climate change.

The MoU includes a framework and principles for sharing evidence, the outline of a governance structure, an outline for collaboration, guidelines on information security and privacy, and a structure for review.

[16] Personal communication Climate Change Commission.
[17] Personal communication Ministry for the Environment.

Sharing and collaborating on evidence is intended to make efficient use of public resources and promote high quality evidence-based advice throughout the system. The MoU does not create any obligations on the parties to agree on or share draft advice or conclusions, noting the need to maintain the CCC's independence and to preserve agencies' ability to serve the Government of the day.[18]

6.2. Interagency Climate Change Data and Modelling Network

The Interagency Climate Change Data and Modelling Network (hereafter the Network) was developed from the 2013 Climate Change Policy, Information and Modelling Group (CCPIM) – the group responsible for developing the ERP. The revamped Network was guided by Motu Working Paper 91-12 (Winchester et al, 2019). Network members are from Government agencies:

- Ministry for the Environment (MfE)
- Ministry for Primary Industries (MPI)
- Ministry of Business, Innovation and Employment (MBIE)
- Ministry of Transport (MoT)
- Waka Kotahi NZ Transport Agency (Waka Kotahi)
- Energy Efficiency and Conservation Authority (EECA)
- The Treasury
- Environmental Protection Agency (EPA)
- Climate Change Commission (CCC)
- Statistics New Zealand (Stats NZ).

Network objectives are to:

1. Strengthen climate change emissions reduction data and modelling evidence base. To ensure it is fit for the purpose of modelling and reporting on GHG emissions targets and budgets and inform climate change policy.
2. Identify areas for improvement, including gaps in data and modelling systems.
3. Develop processes for how data and models are used (including assumptions), and outputs captured and transferred between agencies.

The Network is structured across three tiers. A Steering Group is responsible for oversight and strategic direction and priorities. A Technical Advisory Group (TAG) reports to the Steering Group. The TAG provides advice to the Steering Group, manages the work programme and coordinates guidance on data sharing and alignment of modelling methods and assumptions. A proposal has been made to set up a series of temporary Working Groups, coordinated by the TAG to deliver specific projects.

[18] Personal communication CCC

6.3. International Collaboration

The Review did not identify any formal international collaborations, outside of international reporting requirements. Most peer review of models is done within the New Zealand modelling community.[19] There are ongoing discussions between MfE and the Organisation for Economic Cooperation and Development (OECD) forum on carbon mitigation approaches in modelling, however these are around guidance rather than peer review.

[19] Personal communication MfE.

7 Risks and opportunities

7.1 Modelling capacity

Are current models sufficient to measure the impact of policy on high-level indicators, and to produce the required reporting on GHG emissions in all sectors?

The range of models indicates there is sufficient modelling capacity in the energy, transport, agricultural land-use and forestry sectors and in multi-sectorial modelling. A substantial work programme underway at MfE is working towards improved estimates of non-forest carbon stocks, which will benefit future estimates. Regional breakdowns have been noted in modelling of some sectors – most notably for land-use and transport. There is limited evidence of capacity for modelling waste and fluoridated gases.

Outside of the *ERP Technical Annex* there is no documentation related to climate change modelling in the building and construction sector. Unlike other sector and multi-sector models, building and construction is more suited to a consumption-based approach that includes embodied carbon emissions, potentially produced outside of New Zealand. Some work has been done by Stats NZ on GHG emissions using the consumption approach which may aid the development of a model. Crucial to this would be the development of a standard method for calculating consumption, based on the SEEA framework[20].

A strong appetite for modelling to be done in-house is evident from key informant interviews. This related to maintaining links between modelers and policy analysts to provide an evidence base for policy development. However, two issues arise from the in-house approach. (1) Maintaining and running the models is vulnerable to staff turnover, something exacerbated (in general) by a lack of documentation within agencies on how models are set up and run. (2) A lack of interaction between modelers makes it difficult to bring model outputs together in a cohesive way or get system-wide oversight.

Greater links with academia were welcomed in the key informant interviews as a means of maintaining longer term continuity and development of models. Longer term funding was also cited by multiple sources – to allow a more proactive approach to be taken towards climate change mitigation commitments.

7.2 Data quality and availability

Is there sufficient, publicly available, data to satisfy the input requirements of the models?

Most models use sufficient New Zealand based data, but not all this data is publicly available. Where data is not publicly available, additional assumptions are required in the models, or the data needs to

[20] Personal communication StatsNZ.

be sourced either in-house or via request from another agency. Data for consumption-based models is limited with no standard method for collection. There is also a lack of awareness of some publicly available data, for example through Stats NZ.

Government agencies generally agree annual reporting of the GHG inventory is sufficient to satisfy input requirements. An improvement in the timeliness of some input data is needed to accurately measure progress towards targets.

The StatsNZ quarterly GHG Emissions (household and industry) were not identified as source data for any of the models outlined in the stock-take. These StatsNZ quarterly statistics use relevant annual GHG emissions data and national accounts from StatsNZ, supplemented by data collected directly from relevant government agencies to produce estimates using the SEEA framework. It is therefore potentially useful where frequent reporting is required. There is currently a six-month time-lag in the biannual publication of the StatsNZ quarterly GHG Emissions (household and industry) and granularity has increased from four, to eighteen to twenty sectors.[21] Agencies identified a lack of awareness about the StatsNZ quarterly GHG Emissions and as a result it was underused. Increasing awareness of data available through Stats NZ has the potential to support more frequent reporting schedules.

Outside of the GHG inventory and StatsNZ quarterly GHG Emissions, publicly available data were accessed from agency websites such as Manaaki Whenua, MPI, MBIE, EECA, Stats NZ, and Treasury or the data.govt.nz catalogue. Where data was not publicly available, it was either sourced in-house or requested from the relevant government agencies. As such it is not publicly available, in some cases due to commercial sensitivity. The 2023 NZ Climate Standard and the CNGP provide more detailed publicly available information sources that could be used in the construction of bottom-up models.

A centralised repository for modelling data would increase accessibility and knowledge of content. Where commercial sensitivity is an issue a secure server, along the lines of the IDI, could be used.

7.3 Alignment with international guidelines

Does data collection and modelling in New Zealand align with international reporting guidelines?

International guidelines are followed in the production of most models and datasets. Of the two main GHG emissions datasets the GHG inventory uses IPCC methodologies, required for UNFCCC reporting requirements and the Quarterly GHG Emissions uses the SEEA framework. However, they are not always fully covered. For example, the Quarterly GHG Emissions does not include particulate matter ($PM_{2.5}$, PM_{10}) which is required for the SEEA air account.

Five models are identified in the stock take as having been developed through international collaborations – including the TIMES-NZ multi-sector model and the APSIM agricultural system model.

[21] Personal communication StatsNZ.

Inputs from international data sources are used in some models, for example the GTAP database in C-PLAN, OECD economic forecast data in the freight model, and IEA fuel price trends in the TIMES-NZ model.

Evidence from both the modelling review and key informant interviews suggests very limited international collaboration. CCC models were reviewed in late 2020 by an EU and US modeller as well as being reviewed within New Zealand[22]. This is a process that could be replicated in a systematic way for other organisations hosting climate change models. It is recognised such a process would require additional resourcing.

7.4 Oversight and transparency

Is there a synthesis of modelling methodologies across different sectors of the economy?

There is a lack of synthesis of modelling methodologies. As detailed in section 5.9, there is some agreement between the agencies that modelled different sectors of the ERP on some high-level assumptions, but projections and policy impact estimates are otherwise developed independently of one another. A lack of consistent documentation hinders comparison between methodologies, and the robustness of models being tested. It also increases the risk of double counting when aggregating emissions, for example where the same source of emissions relates to several different sectors. A lack of collaboration between agencies as well as the absence of external peer review further reduces oversight across sectors involved in climate change mitigation.

There was general agreement among the Government agencies spoken to that future ERP's would benefit from greater coordination, transparency and clearer oversight. Specific mention was given to agreeing on key methodological approaches, for example including uncertainties and price elasticities into estimates and integrating model outputs.

The CCC's MoU, and the development of the Network, provide a basis for greater transparency and oversight. This may be inhibited by restricting membership to government agencies. These initiatives would benefit from including external groups, such as academic research organisations, that could provide independent advice and oversight including peer review. Work programmes for the Network should prioritise requirements for the development of ERP2, including agreeing on key methodologies for projections.

[22] https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/inaia-tonu-nei-a-low-emissions-future-for-aotearoa/modelling/

8 Summary and recommendations

8.1 Modelling capacity

Modelling capacity is sufficient for some sectors – such as energy, transport and agricultural land use which are well developed. Other sectors, such as construction and waste, need to build capacity. In some cases, sectors overlap, or smaller sectors are subsectors of larger ones – for example forestry within land use. Almost all modelling takes a production-based approach. Capacity for a consumption-based approach is much more limited. Some collaboration between organisations involved in climate change modelling is noted, but at the time of reporting this was in the developmental stage and did not include organisations outside of the government.

We recommend:

- a Community of Practice is established, to encourage greater cooperation across organisations and internationally, and to share good practice with sectors where modelling capacity is less well developed
- Agreement is reached between agencies on key assumptions and breakdown by industry type and region
- A protocol is agreed for the development of modelling using a consumption-based approach
- A standard level of documentation detailing the purpose, use, output and limitations of each model is agreed that is of sufficient quality to enable sharing with external organisations.

8.2 Data availability and accessibility

There is a wide range of data from public sources to feed into climate change models. This is sometimes supplemented with data from sources with restricted access, particularly where more granular data is required. Data is stored by a range of different organisations and collected using different frameworks and methodologies. Not all data sources align with international frameworks. Where frameworks are used the type depends on the type of data collected and the purpose for their collection.

We recommend:

- data collection methodologies are documented to an agreed format and aligned with specified international frameworks, and relevant domestic classifications and standards
- a centralised repository for climate change modelling data is developed
- a mechanism for data sharing is agreed between government agencies and within the wider New Zealand climate change modelling community.

8.3 Oversight

There is a lack of synthesis of modelling methodologies. There was a preference expressed by government agencies for modelling to be done in house to facilitate alignment with policy development. As a result, there is a lack of collaboration and peer review, as well as oversight, on

progress towards common targets. Connections with groups outside of government and in other countries are also limited.

We recommend:

- Sufficient resourcing is provided to ensure the recently established interagency Network has long term sustainability and Network members can be proactive in maintaining, developing, and updating climate change models and datasets.
- A system of external peer review is established to improve quality assurance of climate change modelling.

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Appendix 1: Stock take table of climate change models

Multi-sector Models

Model Name	Description	Owner/Creator/Funding Sources	Key Datasets
Climate PoLicy ANalysis (C-PLAN)*	A global, recursive dynamic computable general equilibrium (CGE) model	Owner/Funding Source – CCC. Creator - Motu Economic and Public Policy Research. Documentation – Winchester & White (2022).	The Global Trade Analysis Project Database, the GHG Inventory from MfE, outputs from the ENZ model, and data and assumptions from the CCC and other government departments.
Climate Mitigation, Adaptation and Trade in Dynamic General Equilibrium (CliMAT-DGE) *Not currently in use.*	A top-down dynamic, multi-sectoral and multiregional CGE model.	Funding Source – MfE, MPI, The Treasury, MFAT, MoT, MBIE, EECA, Department of Prime Minister and Cabinet, and NZIER Creator - Landcare Research. Documentation - Fernandez & Daigneault (2015).	The Global Trade Analysis Project Database, New Zealand Treasury, generation data from IEA, CEPII for the rest of the world's balanced growth path, and global warming potential from the IPCC third and fourth assessment report.
Energy and Emissions in New Zealand (ENZ)*	Inter-dependent modules or sub-models for to measure the impact of policy actions on demand for services.	Funding Source – A variety of government departments, most recently the CCC. Creator/Owner – Concept Consulting. Documentation- CCC (2021).	The GHG Inventory from MfE; the Energy Balance Tables from MBIE; the energy end use database from EECA; regional travel data and projections from the MoT including fleet statistics and vehicle statistics; MoT's Transport Outlook; Stats NZ import value data; MPI historic and projected data on emissions and underlying activity related to land use from the MPI Pastoral Supply Response Model, Forestry Projections model and the Agricultural Greenhouse Gas Inventory model; New Zealand Dairy Statistics from Dairy NZ; New Zealand Benchmarking Data 2018/2019 from Beef & Lamb, Stats NZ fertiliser use estimates; the National Exotic Forest Description; MfE's forestry model; and projections of future waste activity from MfE.

Distributional Impacts Microsimulation for Employment (DIM-E)	Microsimulation model of industries, workers and jobs impacted by climate change and climate change mitigation policies.	Funder - CCC Creator – Motu Economic and Public Policy Research Owner - CCC	Employment data from C-PLAN, and Stats NZ's Integrated Data Infrastructure and Longitudinal Business Database.
Energy Substitution, Social Accounting Matrix (ESSAM)	Multi-industry general equilibrium model of the New Zealand economy.	Funding Source – A variety of government departments including MfE, MFAT, MoT, MBIE, EECA and the Department of Prime minister and Cabinet. Creator/Owner – Infometrics. Documentation – Infometrics (2015).	Stats NZ Input-Output table and accompanying industry data; Stats NZ national accounts information on trade, employment, capital formation, inter-sectoral financial flows, and household expenditure; data on energy use by industries and households, and GHG emission coefficients, and non-energy emissions from agriculture and industrial processes from MBIE.
Monash-New Zealand-Green (MNZG)	A single country dynamic CGE model for New Zealand.	Funding Source – A variety of government sources including MfE. Creator – NZIER in conjunction with the Centre of Policy Studies at Victoria University in Melbourne. Owner – NZIER. Documentation – Ballingall & Pambudi (2018).	Statistics New Zealand's Inter-Industry tables, emissions data from New Zealand's 7th National Communication to the UNFCCC, industry fuel use estimates from MBIE, Stats NZ's environmental-economic accounts, Treasury's Long-term Fiscal Model, price elasticities from the Centre of Policy Studies, and energy-efficiency improvements based on historical trends and specific insights from government officials.

TIMES-NZ	A technology-based optimisation (partial equilibrium) model that represents New Zealand's energy system.	Funding Source – EECA Creator – EECA, BusinessNZ Energy Council, and the Paul Scherrer Institute (PSI) in Switzerland. It is hosted by the University of Auckland Energy Centre. Documentation – EECA (2021).	National energy supply and demand from MBIE's energy balance dataset; energy end use from EECA; IEA's Energy Technology Systems Analysis Program energy technology data; population estimates and projections, regional gross domestic product, and census data from Stats NZ; fuel price trends from IEA, Green Hydrogen production data from IEA, Element Energy, and NREL; Blue Hydrogen production data from Collodi *et al.* (2017); biomass processing technologies from Scion; existing technologies electricity generation from EA; renewable energy potentials, future technologies electricity generation, wind power costs, techno-economic data utility-scale solar, geothermal techno-economic data, hydro techno-economic data (from the Electricity Demand Generation Scenarios model), and dwelling types in new consents data from MBIE; irradiation data from Solarview, NIWA; NREL's electricity technologies data from NREL Annual Technology Baseline; solar resource profiles from NREL's PVWatts calculator; battery costs data from Lazard, NREL, and Mongrid *et al*. (2019); energy use in New Zealand households data from the Household Energy End-use Project; housing stock data from the CoreLogic dataset; Auckland energy consumption data from Heinen *et al.* (2020); regional electricity consumption data from EA; climate data from NIWA; process heat in New Zealand data from the University of Waikato, EECA, and MBIE; subsectoral GDP data from NZIER; vehicle fleet data, rail freight data, vehicle fleet technological data from MoT; aviation data from MoT and Stats NZ; transport investment costs from EECA's Total Cost of Ownership Tool; battery cost data from BNEF; vehicle costs projections from AEA technology; and irrigation data from Irrigation NZ.
Vivid Economy Wide (ViEW) *Not currently in use.*	A recursive dynamic CGE model of economic activity, energy, emissions, and trade.	Creator/Owner – McKinsey & Company (Originally owned by Vivid Economics)	The GTAP database.

Tokelau Inventory Model	A model of emissions for Tokelau with a historical component that uses the GHG Inventory waste models and projections based on a hybrid top-down and bottom-up estimates.	Creator/owner – MfE. Documentation – MfE (2022).	Data on the de facto population, the usage of fuel, on shipping trips, air conditioning and refrigeration equipment, and animal populations.
Climate Implications of Policy Assessment (CIPA)	A calculator to help agencies estimate the emission impacts from their policies.	Creator/owner – MfE. Documentation – MfE (2019).	Individual inputs from ministries and policy analysts.
Marginal Abatement Cost Curves (MACCs)	Graphs that visualise the abatement potential of greenhouse gas mitigation measures and the relative costs associated with these measures.	Creator/owner – MfE. Documentation – MfE (2020).	Inputs on costs including capital costs, land costs, maintenance costs and emissions costs depending on the analysis undertaken. So far there has been analysis on economy-wide sectors, the land sector, industry processes, transport, electricity generation, space and water heating, and waste.
Industrial Processes and Product Use Inventory Model	A historical bottom-up industrial processes and product use emissions model using the GHG inventory waste models and a projection model of the same emissions based on hybrid top-down and bottom-up estimates based on historical emissions and industry forecasts.	Creator/owner – MfE. Documentation – MfE (2022).	Information from industry forecasts, projected population data, projected GDP data, policies on the phase-down on importation of F-gases.

Waste Inventory Model	A model to estimate emissions by gas and category for waste including estimates of impacts from historical policies and measures and waste volumes using a bottom-up approach.	Creator/owner – MfE. Documentation – MfE (2022).	Data on historical waste volumes, projections of waste volumes, composition of solid waste, farm counts, waste levy, industry production, regional and national population projections, regional GDP projections, and wastewater treatment plants data.

Land Use and Agricultural Modelling

Model Name	Description	Owner/Creator/Funding Sources	Key Datasets
Land Affordability Model/National Afforestation Model	A model which forecasts afforestation in New Zealand using Land Expectation Value estimates.	Funding – MPI. Creator - Bruce Manley at University of Canterbury. Documentation - Manley (2018).	Land costs from Beef and Sheep; projections of NZ ETS liabilities from MfE; the Radiata Pine Calculator from NZ Farm Forestry; the Deforestation Intentions Survey from MPI; Carbon Look up Tables from MPI; discount rates from Manley (2014); and MPI estimates of carbon unit surrendering.
ETS surrender and allocation forecasts	A model of ETS allocation and surrenders which is based on current and projected allocation and surrenders.	Creator/owner – MPI. Documentation – Elvidge (2023a).	Data on historical unit surrenders, surrender obligations, projected population, projected GDP, afforestation and deforestation, and industry forecasts.
Wood Availability Forecast	A national and regional model projecting the harvest volumes available from planted forest estate.	Funding - MPI Owner – Margules Groome Documentation – MPI (2021).	MPI's National Exotic Forest Description data; mapping data from Manley, Morgenroth & Xu (2021); MfE's deforestation mapping report of 2015-2016; and a 2004 AsureQuality survey of small forest owners.
Lincoln Trade and Environment Model (LTEM)	A multi-country, multi-commodity partial equilibrium framework for the agricultural sector.	Funding – MPI and other government departments. Owner/Creator – Agribusiness and Economics Research Unit at Lincoln University Documentation – Cagatay & Saunders (2003).	OECD-FAO Agricultural Outlook database; the FAOSTAT database; the UN population division's 2017 Revision of World Population Prospects database; and the IMF World Economic Outlook database.
NZ-FARM	A comparative-static, non-linear, partial equilibrium	Creator/owner – Manaaki Whenua – Landcare Research.	Catchment and sub-catchments based on River Environment Classification and national land-use map based on AgriBase and LCDB4

	mathematical programming model of New Zealand which can operate at different scales. It produces outputs on land use, agriculture, nutrients and sediments and GHG emissions.	(Based on the USDA-ERS REAP model). Funding – the Sustainable Land Management and Climate Change Programme (SLMACC) of MPI, United States Department of Agriculture Economic Research Service, MBIE, and commercial funding sources. Documentation – Daigneault *et al.* (2012).	based on GIS data; historical New Zealand temperature and precipitation data; soil type data and stocking rates from the New Zealand Land Resource Inventory (NZLRI); more detailed stocking budgets estimated from animal productivity; stock purchases, electricity and fuel use, fertiliser, labour, supplementary feed, grazing fees, milk solids, dairy calves, lambs, mutton, beef, venison, grains, fruits, vegetables, and timber from MPI's farm monitoring report and Lincoln Financial Budget Manual; commodity prices from MPI; the GHG Inventory from MfE; forest sequestration based on CenW; leaching rates based on the Overseer and SPASMO models; water yield estimates from WATYIELD (Ausseil *et al.*, 2013); sediment loss data from the SedNet and NZEEM models; and *Escherichia coli* estimates from the CLUES/SPARROW model.
Agent-based Rural Land Use New Zealand (ARLUNZ)	A catchment-scale spatial model which evaluates the response of landowners to different agricultural policies.	Creator/owner/funder – Manaaki Whenua – Landcare Research Documentation – Morgan & Daigneault (2015) and Morgan, Brown & Daigneault (2015).	Data on cadastral boundaries from the LINZ data service; a land use map showing the type of land use for the segment of land being modelled from Environment Canterbury Regional Council; productivity zones from New Zealand's Land Use Capability dataset; size of farmer's social networks; farmer age; potential revenues of the farmer; net revenue of the farmer; data on yields; input cost data; and output prices.
Rural Futures MAS Model	A regional-scale spatial equilibrium model to measure the implications of farmers and agricultural policies on rural communities.	Funding – Foundation for Research, Science and Technology. Creator/owner – AgResearch and the New Zealand Institute of Economic Research as part of the Rural Futures programme. Documentation – Schilling *et al.* (2012).	GIS data on land parcels for each farm and farmer; data on the proportions of land used for dairy, sheep and beef, and forestry; data on annual input costs; data on farm related factors such as fertilizer and supplementary feed, the amount of annual output produced per hectare, and emissions from the region being analysed; data on expenses and economic information not related to the performance of the farm such as labour, depreciation, overheads, interest rates, and stock; prices for products sold on the farms including milk and wool; production costs such as cost of supplementary feeds; externality costs such as emissions costs, water costs and nitrate costs; age profile of the farmers in the region and the economic drivers and behaviour characteristics of each age group; and

			information on the availability of a successor to the farm, farmer risk profile, and social networks. Data from this mainly comes from other research in the Rural Futures programme.
Land-use Management Support System (LUMASS)*	Geospatial modelling and optimisation framework. It supports dynamic models for land-use impact assessments and land-use optimisation scenarios.	Funding – MBIE and Employment's Science and Innovation Group. Creator/owner - Manaaki Whenua – Landcare Research. Documentation – Herzig (2008) and Herzig, Ausseil & Dymond (2013).	GIS data including maps of initial land use, data on soil type, data on land quality, and data on property boundaries; and data on agricultural and conservation land use from Stats NZ, Agricultural Census, Beef + Lamb, and MfE.
Land Allocation Simulator *Not currently in use.*	A modelling framework which uses mathematical programming for equilibrium optimisation to estimate the impacts of agricultural and environmental policy with outputs which can evaluate long-run outcomes and dynamic interactions.	Funding – Dairy NZ and government departments. Creator/owner – Waikato University Documentation – Doole (2012) and Doole (2015).	Data on the hydrological network to determine the pollutants in each catchment; historical water quality data; data on farm systems; results from Overseer Nutrient Budgets; data on forestry; and data from urban land.
Waikato Integrated Scenario Explorer (WISE)	An integrated model that links land use, demography, economics, climate, hydrology, water quality and biodiversity and estimates the impacts on each of these categories.	Funding – New Zealand Foundation for Research, Science , and Technology. Creator/owner – Creating Futures project.	Data on property valuation for land parcels; rural land use data from the Agribase dataset; aerial photography of the Waikato region; district plan zoning data from councils and plans and expectations for future growth of the zoned areas; information on roads from the Waikato Transport model; census population data; assessment of dwellings within the residential land use classes; technological improvements; residential proportions and densities; external inputs

		Documentation – Waikato Regional Council (2021).	from Market Economics and the CCC; and underlying economic data such as value added and employment.
Waikato Multiple Agent Model *Not currently in use.*	A regional model evaluates the impact of policy design on the dairy industry including farm operations.	Creator/owner – Waikato University Documentation – Doole (2010); Doole, Marsh & Ramilan (2013); and Doole (2012).	Data on farm area, farm inputs, milk production estimates, stocking rate estimates, distance from water ways, data on soil types, and climate data. This data is taken from AsureQuality, Dairy NZ, Environment Waikato, Livestock Improvement Corporation, the New Zealand Land Resources Inventory, New Zealand Climate Database, and Overseer Nutrient Budget outputs (described below).
NManager *Not currently in use.*	A catchment-scale partial equilibrium model which assess the effectiveness of different forms of nitrogen regulation with respect to dairy, sheep/beef, and plantation forest.	Funding – MBIE, MPI, MfE, the National institute for Water and Atmospheric Research, GNS Science. Creator/owner – Motu Economic and Public Policy Research. Documentation - Anastasiadis *et al.* (2011).	Data outputs from Farmax and Overseer (both described below) to determine combinations of profit and nutrient exports; maps of current land use (provided by the ROTAN model in the model documentation); and information on current or proposed regulation.
AgInform	An integrated farm optimisation and resource allocation model which produces farm-level output.	Funding – MBIE, DairyNZ, Fonterra, Beef + Lamb, DCANZ, and Deer Research. Creator/owner – AgResearch Documentation - Rendel *et al.* (2020).	Survey data from Beef + Lamb, and data from MPI farm monitoring reports. Which is used (along with other data sets) to inform data on pasture; data on crops; data on supplementary feed; data on the size, weight, and health of stock; and data on the costs of livestock and crops on each farm unit.
Agricultural Production Systems Simulator (APSIM)*	A suite of interconnected models used top simulate complex agricultural systems such as soil, crop, tree, pasture, livestock processes, and non-biological farm resources.	Funding – CSIRO, Queensland Government, The University of Queensland, AgResearch, University of Southern Queensland, Iowa State University, and Plant & Food Research.	There are models which feed the APSIM model information about plants, soil, animal, and climate. The plants models include AgPasture (Li *et al.*, 2011a), bambatsi, barley (Manschadi *et al.*, 2006), broccoli (Huth *et al.*, 2009), butterfly pea, canola (Robertson *et al.*, 1999), centro, chickpea (Robertson *et al.*, 2002), cotton (OZCOT) (Hearn, 1994), cowpea (Adiku *et al.*, 1993),

		Creator/owner – APISM Initiative. Documentation - Holzworth *et al.* (2014).	fababean (Turpin *et al.* 2003), field pea (Chen *et al.*, 2008a and Robertson *et al.*, 2002), french bean (Henderson *et al.*, 2011), GRASP (Bell *et al.*, 2008 and Rickert *et al.*, 2000), Growth (Eucalyptus species) (Huth *et al.*, 2002), Lablab (Hill *et al.*, 2006), Lucerne (Dolling *et al.,* 2005; Probert *et al.*, 1998b; and Verburg *et al.*, 2007) lupin (Farré *et al.*, 2004), maize (originally from AUSIM-maise) (Carberry & Abrecht, 1991a; and Carberry & Abrecht, 1991b), millet (van Oosterom *et al.*, 2001), mucuna (Roberston *et al.*, 2005), mungbean (Robertson *et al.*, 2002), navybean (Robertson *et al.*, 2002), oats (Peake *et al.*, 2008), oil mallee, oil palm (Huth *et al.*, 2014), pasture (Moore, *et al.*, 1997), peanut (Hammer *et al.*, 1995 and Robertson *et al.*, 2001c), pigeonpea (Robertson *et al.*, 2001b), potato (Brown *et al.*, 2011a), Rice (ORYZA) (Bouman & van Laar, 2006 and Gaydon *et al.*, 2012b), sorghum (Hammer *et al.*, 2020 and Whish *et al.*, 2005), soybean (Robertson & Carberry, 1998), stylo (Carberry *et al.*, 1998c), sugarcane (Keating *et al.*, 1999), sunflower (Chapman *et al.*, 1993), sweet corn (Henderson *et al.*, 2011), sweet sorghum, vine, weed, and wheat (Brown *et al.,* 2014; Wang *et al.*, 2003; Keating *et al.*, 2001; Meinke *et al.*, 1998; and Asseng *et al.*, 1998). The soil models include DCD (Chichota *et al.*, 2010), erosion (Freebairn *et al.*, 1989; and Littleboy *et al.*, 1992), nitrogen (SoilN) (Probert *et al.*, 1998a), phosphorus (Delve *et al.*, 2009), pond (Gaydon *et al*., 2012c), solute (Paydar *et al.*, 2005; and Poultron *et al.*, 2005), surface (Connolly *et al.*, 2001), surface OM (Probert *et al.*, 1998a), SWIM (Huth *et al.*, 2012; Connolly *et al.*, 2002; Verberg et al., 1996a; and Verburg et al., 1996b), temperature (Campbell, 1985), water (SoilWat) (Probert *et al*., 1998a; and Verberg & Bond, 2003), and water supply (Gaydon & Lisson, 2005). The animal models include DDRules, Graz (Owens *et al.*, 2009), stock (Freer *et al.*, 1997), and supplement.

			The climate models include canopy (Carberry *et al.*, 1996b), E0 (Meinke *et al.*, 2002), and MicroClimate (Snow & Huth, 2004). To view the full references for these models and datasets please see the paper by Holzworth *et al.* (2014) as they are not listed in the references for this paper.
Biome-BGC*	A biophysical model of soil-plant interactions mainly measuring pasture biomass.	Funding - MPI Creator/owner – University of Montana. Documentation – Thornton *et al.* (2002) and Keller *et al.* (2014).	Pasture growth data from Landcorp Farming, Dairy NZ, and Lincoln University Dairy Farm; data for beef and sheep from Beef + Lamb, Rosser & Ross (2011), and Smith *et al.* (2012); land use outputs and scenarios from LURNZ; climate change variables from Renwick *et al.* (2013); meteorological VCSN data from NIWA; and the New Zealand Fundamental Soil Layers data set from Manaaki Whenua –Landcare Research.
Farmax	Sheep, beef and deer, and dairy models of whole farm decision support which produce outputs of weights, pasture production/conversion efficiency, and profitability.	Funding – Dairy Insight, MAF sustainable Farming Fund, AgResearch along with government departments. Creator/owner – Farmax Ltd, and AgResearch. Documentation – FARMAX (n.d.), Bryant *et al.* (2010), and Marshall *et al.* (1991).	Data including pasture mass, pasture intake, milk weights, milk composition, stocking rates, and diet composition from a systems trial at Scott Farm owned by DairyNZ; data from a spring-calving herd at No 1 Dairy Farm owned by Massey University; breed thresholds for heat stress data from Bryant *et al.* (2007a); hybrid vigour effects for milk, fat, and protein yield from Pryce & Harris (2006) and Bryant *et al.* (2007b); and data from the Stockpol model on farm level characteristics. This is the data used for the Dairy Farmax model, similar data is used for the sheep, beef, and deer models. For each model, farmers input data and the models provide farm-level outputs.
Forest Investment Framework (FIF)	A spatial economic framework that produces maps and tables of values that can be used to	Funding – MBIE, Employment and the Forest Growers Levy Trust, the Forets Owners Association and the Farm Forestry Association.	ArcGIS 10 software to identify meshblocks; PropertyIQ to identify property data; fine-resolution terrain datasets for New Zealand from Palmer *et al.* (2009a), Palmer *et al.* (2009b), and Palmer *et al.* (2009c); data on slope, rainfall, erosion classes, river classes, and the identification of lakes and wetlands from the New Zealand Land-Use

	describe the benefits of forestry.	Creator/owner – Scion. Documentation – Barry *et al.* (2014); Yao, Harrison & Harnett (2017); and Yao *et al.* (2016).	Capability classes from AgResearch and the New Zealand Land Cover Database 2 from AsureQuality; the 300 Index; Site Index; roading costs from a costpath analysis; prices for timber from Ministry of Agriculture and Forestry; timber productivity from the C-Change carbon model; carbon prices from OM Financial Ltd; the change in sedimentation levels from afforestation using the New Zealand Empirical Erosion Model; and economic data from avoided sedimentation from city councils in New Zealand.
Forest-oriented Linear Programming Interpreter (FOLPI)	An optimisation tool for estimating forest management and investment strategies.	Creator – Scion. Owner – Integral. Documentation – Garcia (1984).	Data on initial areas by crop type and age class, product/resource and thining/maintenance tables, and total volume per hectare and other measures of yield.
Overseer Nutrient Budgets	A software service that provides farm analysis information including GHG emissions, GHG footprints, farm production and nutrient budgets on an individual farm level.	Owner/creator/funder – AgResearch, MPI, and the Fertiliser Association of New Zealand. The model is hosted by Overseer Ltd. Documentation – Overseer (2023).	Data on the structure types to describe how effluent is collected and atmospheric losses; energy requirements of animals calculated based on production; supplementary feed details including the nutrient characteristics of the feed; animal distribution on land blocks; pasture inputs of each land block including whether it is grazed or harvested; fertiliser inputs; fruit inputs including fruit type, yield, and management; crop data including cultivation, sowing, harvesting, and defoliation; NIWA data on 30-year average monthly climate characteristics; data on irrigation application and methods; soil information from S-Map developed by Manaaki Whenua - Landcare Research; data from soil tests taken from Olsen P, MAF Quick Test; data on artificial drainage systems; and data on wetlands. Many of these inputs are provided by individual farm owners.
MitAgator	A farm management support model which provides spatial understanding of where	Funding – Primary Growth Partnership programme, co-funded by MPI.	Data from an Overseer nutrient budget; a georeferenced farm map, soil, elevation data, aerial photos, fertility data, elevation data from NASA remote sensing information or from individual farms; and S-Map soil data from Manaaki Whenua.

	sediment and nutrient losses occur at the farm scale.	Creator/owner – Balance Agri-Nutrients. Documentation – Risk *et al.* (n.d.) and McDowell *et al.* (2014).	The processing of data is similar to the Overseer Nutrient Budget model (described above) and requires inputs by individual farm owners.
Pastoral Supply Response Model (PSRM)	A model to forecast land use, livestock population numbers and productivity.	Creator/owner – MPI. Documentation – Wear (2013).	Land use data, livestock number, and data from the Agricultural production Survey from Stats NZ; farm monitoring/benchmark data, and commodity price forecasts from MPI; and livestock slaughter statistics, and data from NZ Livestock Slaughter from MPI and StatsNZ.
Agriculture Inventory Model	A model to forecast agricultural GHG emissions. Used in the development of emissions budgets using input data on livestock numbers, agricultural production and fertiliser use.	Creator/owner – MPI. Documentation – MfE (2022).	Outputs from the PRSM model (described above); land use data, and livestock numbers from Stats NZ; commodity price forecasts, forestry land use projections, and expert advice on policies from MPI; and livestock slaughter statistics from MPI and Stats NZ.
Land Use and Carbon Analysis System (LUCAS)	Two allometric models to estimate carbon sinks. Carbon stock change in (1) natural and (2) planted forests	Creator/owner – MfE with Climate Change Commission Documentation – MfE GIHI (2023) Wakelin (unpublished SCION report)	Outputs carbon stock. Inputs, LUCAS land use and land use change maps from MfE; forest age profiles, growth increment, emission factors.
LULUCF and target projections	A model of carbon emissions and removals based on current and projected production and non-production forestry.	Creator/owner – MPI. Documentation – Elvidge (2023b).	Data on carbon yields, projected afforestation, harvest, deforestation rates, and carbon prices.

* Open source model.

Energy Models

Model Name	Description	Owner/Creator/Funding Sources	Key Datasets
Biomass Supply Model	A model which uses geographic Information Systems (GIS) to calculate costs related to feedstock supply and costs related to the delivery of biomass to energy plants.	Owner/creator - Scion	Data on maps of forestry resources and heat demands.
Biomass Value Chain Model (BVCM) *Not currently in use*	A mixed-integer linear programming optimisation model with a high level of geographical resolution that produces dynamic outputs of the most economically efficient and low-emission biomass value chains to achieve future liquid biofuel demand targets.	Funder – MBIE. Creator – the Energy Technologies Institute in the UK. Owner (in New Zealand) – Scion. Documentation – Samsatli, Samsatli & Shah (2015) and Suckling *et al.* (2018).	50km grid data, transport and handling costs and GHG emissions for each transport mode, delivered price for alternative uses of logs, point-source feedstock locations, port locations, and transport routes from Scion; conversion technology data such as inputs, costs, emissions, utilisation, and yields from Scion and ETI; existing plantation area by five-year age classes from the New Zealand Land Cover Database scaled by the National Exotic Forest Description; data on land opportunity cost and land value from a real estate database; data on existing forestry production schedule and residue availability from the wood availability forecasts from MPI; existing forestry log opportunity cost from delivered price at the nearest port or mill and transport cost; and data on arable crop productivity, production and harvest costs, and GHG emissions for each land class and land cell. All data from external sources has been derived by Scion to ensure it is ready to be included in the model.
Competitive Risk Averse Generation Expansion (CRAGE)	A Walrasian partial equilibrium model of the New Zealand electricity system.	Owner – Electric Power Optimisation Centre (EPOC) at the University of Auckland. Creator – EPOC at the University of Auckland in collaboration	Information on the electricity distributors around New Zealand, information on electricity demand, information on electricity prices, and information on electricity storage capacity. The documentation available does not provide specific details on data inputs.

		with Professor Michael Ferris from the University of Wisconsin-Madison. Documentation – Ferris & Philpott (2018) and Kok, Philpott & Zakeri (2018).	
JADE	A stochastic optimal control model to estimate the operating policy for hydro reservoirs to minimize the social costs of thermal fuel	Creator/ owner – EPOC at the University of Auckland. Documentation – Philpott & Downward (2023).	Regional electricity demand in 2020 from the vSPD model (described below), outputs from the SDDP model (described below), national electricity demand increases expected by 2035 from the CCC, electricity load reduction costs from the EA 2020 DOASA files, information on expected investment and costs from the NZ Battery Project, data on solar energy from NIWA, data from New Zealand Wind Energy Association, and information on energy strategy from MBIE.
Concept fuel-flexibility models	A mix of fuel-flexibility models which can analyse the capacity and costs of meeting the demand for energy flexibility within a day/week, a year, and from year to year.	Creator/owner – Concept Consulting. Documentation - These fuel-flexibility models come from a number of Concept Consulting Reports available here: https://www.concept.co.nz/updates.html.	Data on coal-fired generation, gas-fired generation, hydrogen energy potential, batteries, biomass for energy, and longer-cycle demand response. Many of this information comes from the same energy data sources used in the ENZ model (described above). The sources include EECA, the CCC, MBIE and MoT.
Dynamic Outer Approximation Sampling Algorithm (DOASA)	A model which optimises hydrological-thermal scheduling in New Zealand.	Funding – Electricity Authority. Creator – Stochastic Optimisation Limited. Owner – Electricity Authority.	Originally: the Centralised Data Set for New Zealand Wholesale Electricity Market from EA, coal prices in New Zealand markets from the New Zealand Ministry of Economic Development, New Zealand Electricity Commission database, energy data from the New Zealand Ministry of Economic Development, and Transpower POCP database of planned outages.

		Documentation - Philpott & Pritchard (2013) and Guan & Philpott (2018).	In a more recent update: data tables for electricity and prices from MBIE; conversion factors of power stations, the heat rate for the Stratford peakers, the operating and maintenance costs for New Plymouth and Stratford peaks, upper and lower bounds on the flows in the river-valley hydro network, and break points in water value from the EMBER 1.0 project; operating and maintenance costs reported in the GEM (described below); and existing generation plant data, specific energy (derived for scheme), infrastructure and hydro constraint attributes, lake storage, and flows from electricity market information hosted by the Electricity Authority.
EMarket	A model to simulate New Zealand's energy market with a high level of resolution and with nodal-level dispatch.	Creator/owner – Energy Link Limited. Documentation – no documentation available publicly.	Data on 86 years of historical inflows, grid configuration and capacity, demand estimates and profiles, generator capacity and offer curves, information on potential grid expansion. Data is from both EECA and Energy Link Limited.
Generation Expansion model in a STOchastic and Noisy Environment (GEMstone)	A group of stochastic programming capacity expansion models representing the New Zealand electricity system.	Creator/owner – EPOC at the University of Auckland.	
Generation Expansion Model (GEM)*	A long-term planning model using mixed integer programming to estimate capacity expansion in the New Zealand electricity sector.	Creator/owner – the Electricity Authority and used by MBIE. Documentation – Electricity Authority (2023a).	MBIE Electricity Demand and Generation Scenarios (EDGS) plant and demand data, David Hume's transmission capacity and cost data, and information from MBIE's mixed renewables net demand scenario.
Hydro-Sim	A hydro-thermal optimisation model which schedules the daily and yearly hydro storage releases and station	Funding – MfE. Owner – Concept Consulting.	Information on hydro generation, generation costs, production costs, generation weighted spot price, and time weighted average price.

	dispatch (every half hour) for the major hydro systems in New Zealand.	Documentation – there is no obvious documentation publicly available.	
Hydro Vectorised Scheduling, Pricing and Dispatch (HydrovSPD)*	A multi-stage deterministic version of Scheduling, Pricing and Dispatch (SPD) (the New Zealand electricity market dispatch software) to compute the distribution of power in each half hour of the day with a focus on hydro-electric systems.	Owner – EPOC at the University of Auckland. Documentation – Guan & Philpott (2018), Philpott & Downward (2021), and EPOC (n.d.).	Infrastructure and hydro constraint attributes, specific energy (derived for scheme), and flows data from Electricity Market Information hosted by the Electricity Authority; storage capacities of head ponds, and lower and upper bounds of flows in the hydro network from the EMBER 1.0 project; and data tables for electricity and prices from MBIE.
Vectorised Scheduling, Pricing and Dispatch (vSPD)*	An audited mathematical replica of Scheduling, Pricing and Dispatch (SPD) which is a model used to schedule, price and dispatch electricity in New Zealand.	Creator/owner – the Electricity Authority. Documentation – Electricity Authority (2023b).	Retail datasets from Electricity Market Information hosted by the Electricity Authority. This includes market share in network reporting regions, metering configurations, and shape files.
Oil and Gas Simulation Model *Not currently in use*	A simulation model using the Monte Carlo technique to determine future oil and gas discoveries.	Creator/owner – MBIE Documentation – there is no clear documentation but some information of the model is available in MBIE (2016).	Potential resources in frontier basins, technical field size by basin, discovery year, number of exploration well failures, and cost of exploring and developing new fields.
Oil and gas financial model *Not currently in use*	A discounted cashflow model which determines whether oil and gas discoveries meet commercial thresholds.	Creator/owner – MBIE Documentation –MBIE (2016).	Data inputs of oil prices, capital cost, and production and finance assumptions.

OptGen	A computational tool for estimating the most efficient (least cost) expansion of multi-regional hydrothermal systems. It takes into account inflow uncertainties, emission constraints, and minimum capacity constraints.	Owner – Power System Modelling. Documentation – PSR (n.d.a) and PSR (n.d.b).	Users of the model must input investment and operating data for all components of the electrical energy system. All operating input data is put through the SDDP model (described below).
Process Heat Emissions Reduction *Not currently in use.*	A process integration framework based on pinch analysis to estimate sector, regional, and national GHG emission-reduction potentials within the industrial process heat sector and MAC curves.	Funding – MBIE, EECA and MfE. Creator/owner – the Energy Research Group at the University of Waikato. Documentation – Atkins (2019).	The EECA Energy End-Use Database, the Modified EECA Heat Plant Database, electricity prices and the Heavy Industry Report from MBIE.
Project Rank Model (PRM) *Not currently in use.*	A model to help set the earliest commissioning years for individual plants modelled in GEM.	Creator/owner – MBIE. Documentation –MBIE (2016).	Not described.
Stochastic Dynamic Dual Programming (SDDP)	A hydrothermal dispatch model that calculates the least cost stochastic operating policy of the system and represents the transmission network.	Funding – MfE and the Electricity Authority. Creator/owner – Power System Modelling. Documentation – PSR (n.d.c) and Halliburton (2008).	Outputs from the GEM (described above), data on the hydro system inflow data files prepared by Opus Consultants published by the Electricity Authority, and assumptions from MFE.

Supply and Demand Energy Model (SADEM)	A collection of models that econometrically estimates energy quantities across different fuel types and sectors to describe energy demand.	Creator/owner – MBIE. Documentation - MBIE (2016).	MBIE fuel data (supply, demand, prices, and emissions), electricity generation from GEM (described above); road transport demand from VFM (described below) financial and economic information such as population, and GDP data from Stats NZ.
UniSyD	A decision-making model of New Zealand's energy economy which splits New Zealand into 13 distinctive geographical regions and it identifies primary energy resource use, electricity generation, the composition of the vehicle fleet, and GHG emissions.	Funding – CRL Energy and Industrial Research Ltd. Creator/owner – Unitec and University of Iceland with Kanagawa University as an associate partner. Documentation – Leaver, Gillingham & Leaver (2009); Shafiei, Leaver & Davidsdottir (2017); and EnergyPLAN (n.d.).	New Zealand Energy Balances, and electricity tables from MBIE; New Zealand Energy GHG Emissions; maintenance costs for light duty vehicles from the EU Coalition Study; average battery costs from Nykvist & Nilsson (2015) and Bubeck *et al*. (2016); the effect of battery size on cost data from Wu *et al.* (2015); vehicle fuel economies from JRC (2014), Dodds & Ekins (2014), and Leaver *et al.* (2012); New Zealand vehicle fleet statistics, and annual fleet statistics from the MoT; supply infrastructure data; energy resources data; consumer behaviour; and socio-economic data from Stats NZ.
WoodScape	A techno-economic model designed to analyse and compare a range of diverse processing options for the wood processing industry.	Funding – Wood Council of New Zealand Creator/owner – Scion. Documentation – Barry, L. & Hall, P. (2014) and Scion (2013).	Manufacturing multipliers from the government; forestry and logging information from MPI; and quarterly GDP data, GDP data, and hours worked in employment data from Stats NZ.

Transport Models

Model Name	Description	Owner/Creator/Funding Sources	Key Datasets
UniTrac *Not currently in use.*	A model to track the comparative ownership costs and emissions between advanced technology vehicles and conventional vehicles across owners of a single vehicle. It is a sub-set of UniSyD (described above).	Creator/owner – Unitec and Kanagawa University. Documentation – there is not clear documentation but in White *et al.* (2018) the citation provided is Leaver & Watabe (2016) and Watabe & Leaver (2018).	Estimations of ownership costs for battery electric and hydrogen-fuel-cell light vehicles, costs of conventional vehicles, estimations of fuel and maintenance, and interest and depreciation of vehicles.
Vehicle Fleet Emissions Model	A model designed to project the makeup of future vehicle fleets and their kilometres travelled, energy use and GHG emissions.	Creator/owner – Ministry of Transport. Documentation – MoT (2022).	Historic fleet mix by vehicle type, size, age, fuel type, and engine technology, historic annual vehicle travel, historic scrappage pattern, and historic vehicle registrations from the Motor Vehicle Register database from the Transport Agency; historic GHG emissions from road transport from the GHG Inventory; historic fuel use by road transport from MBIE's oil statistics; energy use per 100 km travelled by a vehicle from Emission Impossible; future vehicle registration mixes; future fleet size, and future fleet travel from the Vehicle Numbers Model; future and historic amounts of GHG produced for every kilowatt hour of electricity used from MBIE.
Vehicle Emissions Prediction Model (VEPM)*	A model to predict emissions from vehicles in the New Zealand fleet under typical road, traffic and operating conditions.	Creator/owner – NZ Transport Agency and Auckland Council. Documentation – Metcalfe & Peeters (2022).	Data on New Zealand-relevant emissions factors from the European COPERT model, emissions from the Transport Model Emissions Tool, the Motor Vehicle Registry, vehicle emissions data from the Vehicle Fleet Emissions Model (described below), and brake and tyre wear.
VKT/Vehicle Numbers Model*	A model to project New Zealand's vehicle-kilometres travelled and number of vehicles in the	Creator/owner – Ministry of Transport. Documentation – MoT (2019a).	Outputs from the Household Travel model (described below) including projections of household person-kilometres travelled by different vehicles and household light vehicle ownership by region; projections of tonne-kilometres moved by heavy truck by region from the

	fleet by region for five types of vehicles.		Transport Outlook TonneKM by Region Model (described below); projections of GDP by region and tourist days by region from the Transport Outlook Population and GDP model; and data on the historical vehicle travel kilometres, and number of vehicles by vehicle type, region and owner type from the New Zealand Motor Vehicle Register.
Household Travel Model*	A model which provides estimates household travel New Zealand-wide for ten modes of transport from 2012/13 to 2042/43 for the SAS model and by region for five vehicle types for 2012/13 to 2057/58 for the postprocessor model in five-year intervals.	Creator/owner – MoT. Documentation – MoT (2017a) and MoT (2019b).	SAS programmes – projected family household types from the "subnational family and household projections" dataset in the census, national family and household projections from the "national family and household projections, population by living arrangement type" dataset, and special vehicle ownership tabulation from the census; vehicle ownership shift, territorial authorities to region conversion file, and income class change probabilities from the New Zealand Household Travel Survey; and GDP assumptions from the Population and GDP Assumptions Model. Postprocessor model – projections of travel demand by region and mode to 2042/43 from the Household Travel Model SAS Programmes; projections of regional populations, and other assumptions from the Transport Outlook Population and GDP Model; and public transport projections provided by Auckland Transport and the Greater Wellington Regional Council.
Freight Model* *To be updated.*	A model to project New Zealand's region-to-region freight flows for 19 commodity groups from 2012/13 to 2052/53 in ten year increments.	Creator/owner – MoT. Documentation – MoT (2019c).	Data on regional populations, regional GDPs, and world GDP from the Population and GDP assumptions Model and the OECD Economic Outlook; data from the National Freight Demand Study; and the projected total growth in New Zealand petroleum demand from MBIE's Energy Outlook.
Road freight tonne-km by region model* *To be updated.*	A model to project total New Zealand road freight flows on the roads of each region in billions of tonne-kilometres from	Creator/owner – MoT. Documentation – MoT (2019d).	Projections of region-to-region freight flows from the Freight Model (described above); routings and nearest towns to regional boundaries from Local Government New Zealand maps; distances between towns/cities in the regions from Automobile Association distance

	2012/13 to 2052/53 in ten year increments.		calculator; and freight distances from the National Freight Demand Study.
Rail freight tonne-km by region model* *To be updated.*	A model to project New Zealand's freight flows over the rail lines of each region in billions of tonne-kilometres from 2012/13 to 2052/53 in ten year increments.	Creator/owner – MoT. Documentation – MoT (2019e).	Projections of region-to-region freight flows in millions of tonnes from the Freight Model (described above); the nearest towns to regional boundaries from Local Government New Zealand Maps; rail distances from Kiwirail's "Rail Operating Procedures"; and freight distances from the National Freight Demand Study.
Coastal shipping tonne-km model* *To be updated.*	A model to project total coastal freight flows between ports in New Zealand from 2012/13 to 2052/53 in ten year increments.	Creator/owner – MoT. Documentation – MoT (2019f).	Projections of region-to-region freight flows from the Freight Model (described above), and distances between regional ports from the New Zealand Nautical Almanac.
Origin and Destination-based international air passenger model* *To be updated.*	A model to project international air passenger flows from each region in New Zealand from 2018 to 2043 in five year increments.	Creator/owner – MoT. Documentation – MoT (2017b)	A projection of international departures by New Zealand residents at a national level from the air pax departures forecast model; projections of international departures by overseas visitors at a national level from MBIE's tourism forecasting programme; and population projections from Stats NZ.
Origin and Destination-based domestic air passenger model* *To be updated.*	A model to project New Zealand region-to-region domestic air passenger flows from 2018 to 2043 in five year increments.	Creator/owner – MoT. Documentation – MoT (2017c).	Information on real GDP, population (at both origin and destination), number of overseas visitor arrivals, distance between airports, domestic real airfares, and variables for the quality of air services from Stats NZ's population projections, Treasury's GDP projections, and MBIE's tourist projections.
Leg-based air passenger model*	A model to project domestic air passenger departures from each of	Creator/owner – MoT. Documentation – MoT (2017d).	Domestic air passenger projections from the Origin and Destination-Based Domestic Ait Passenger Model (described above); international air passenger projections from the Origin and Destination-Based

To be updated.	the regions in New Zealand and international departures from 2018 to 2043 in five year increments.		International Air Passenger Model (described above); national total passenger air data from the Civil Aviation Authority; and international passenger departure data from Stats NZ.
Aircraft Movement and Greenhouse Gas Emission Model* *To be updated.*	A model to project aircraft-kilometre travelled for domestic air services in New Zealand as well as fuel use and GHG emissions from domestic air travel from 2018 to 2043 in five year increments.	Creator/owner – MoT. Documentation – MoT (2017e).	Projections of domestic air passenger-kilometres travelled from the Origin and Destination-Based Domestic Air Passenger Model (described above); data on the current operating fleet, airlines' future fleet projections, and information on the economic life of aircraft to project the aircraft fleet evolution; and projected aircraft efficiency improvements from the UK's Department of Transport.
Cost and Benefit Analysis for Transport Model *Not currently in use.*	A model built for the evaluation of congestion pricing, emissions, and safety. It uses the net present value of the transport user benefits which arise from each policy option.	Documentation – MoT (2019g).	The datasets depend on the policy being analysed. Congestion, for example, uses outputs from the Auckland Macro Strategic Model including network statistics, daily emissions totals, and population forecasts; values of time, vehicle operating costs, valuation of emissions, and update factors from NZ Transport Agency's Economic Evaluation Manual; and capital and operating costs from D'Artagnan Consulting.
Vehicle Emissions Mapping Tool.	A Geographical Information Systems bottom-up model that can estimate 'tailpipe' emissions for roads in New Zealand.	Creator/owner – NZTA Documentation – NZ Transport Agency (2021a) and AECOM (2020).	Data on the traffic count, and the profile of the transport fleet on the road from Core Logic; travel speed data from Ably; information on gradients around New Zealand from Land Information New Zealand; and Territorial Local Authority Boundaries from Stats NZ.
New Zealand Transport Agency Mega Maps	A model to identify high benefit locations for speed management interventions for the short and medium term.	Creator/owner – NZTA. Documentation – NZ Transport Agency (n.d.a).	Road datasets, land use data, Infrastructure Risk Rating, One Network Road Classification, geospatial base maps, Street View data, vehicle operating speeds data, regional council boundaries from Stats NZ, and Crash Analysis System outputs.

Climate Assessment of Transport Investment (CATI)	A methodology to inform programme-level investment decision making during programme development related to land transport investment to understand whether actions are likely to increase or decrease emissions.	Creator/owner – NZTA. Documentation – NZ Transport Agency (2023).	The inputs to this model are project specific and include the estimated value of investment, the type of project or work category, and whether the work is urban or non-urban.
Project Emissions Estimation Tool (PEET)*	A greenhouse gas emissions estimation tool for land transport infrastructure.	Creator/owner – NZTA. Documentation - NZ Transport Agency (n.d.b).	Information on state highways, local roads, and rail from Auckland Transport, KiwiRail and NZTA; information on construction projects in NZ and Australia; and data from the VEPM (described above).
MONTY	An Agent Based simulation tool to help evaluate the impact of change on the transport system by using an understanding of the travel choices individuals make.	Creator/owner – MoT.	Data on: the population from the Stats NZ census, the Motor Vehicle Register from NZTA, the Income/Expenditure Survey from Stats NZ, the Household Travel Survey from MoT, freight transport information from MoT, future land use and population projections, public transport information, the road network, the ferries, active transport modes, domestic air transport, future transport networks, and future infrastructure projects.
Cross=cutting	Modelling and projections of vehicle use including light vehicle VKT and GHG emissions and past and future trends for all vehicle uses.	Creator/owner – NZTA. Documentation - Albuquerque & Morrison (2022); and McKibbin, Sewell & Li (2022).	Quarterly VKT data and Household Travel Survey from MoT; GDP, labour force statistics, exports, imports and demographic data from Stats NZ; petrol and diesel prices from MBIE; data from the Traffic Monitoring System (TMS); Road Assessment and Maintenance Management (RAMM); NZTA VKT and emissions data and models; MoT VKT and emissions data and models; local government and regional transport models; MoT 2020 Vehicle Fleet; NZTA National Fleet; and Benchmarking Sustainable Urban Mobility.

Infrastructure Sustainability Council of Australia (ISCA)	An infrastructure sustainability rating scheme which is used to help achieve sustainability outcomes on infrastructure projects.	Creator/owner – the Infrastructure Sustainability Council. Used by – NZTA. Documentation – NZ Transport Agency (n.d.c).	The inputs here are individual for each project and the business case, design, and construction stages are assessed against the ISCA guidelines.
T2035 Carbon Calculator for Land Transport at a Regional Level*	A web-based tool for Local Government transport planners, designers, and operators to estimate the GHG emissions caused by vehicles and transport in their region.	Creator/owner – NZTA. Documentation – NZ Transport Agency (2021b).	Light vehicles, buses, and commercial vehicles emissions factors from MoT's Vehicle Emissions Model emissions factors for trains, and road and rail freight from MfE's Detailed Guide for Measuring Emissions; annual VKT by ICE vehicles and electric vehicles from MoT's Vehicle Emissions Model; total passenger distance travelled per year by mode from MoT's Processed Household Travel Survey Model; the passenger distance travelled and car distance travelled from the Household Travel Survey; service distance, passenger distance, and boarding for public transport from NZTA's Public Transport Performance Data; VKT for buses, motorcycles, cars, and commercial vehicles from MoT's Vehicle Fleet Statistics and Vehicle Fleet Statistics Model; train VKT data from NZTA's Public Transport Performance Data; Tonne Kilometres Travelled from MoT's Road vehicle Model and Rail Freight Model; and the passenger kilometres travelled from the Public Transport Performance Data; population data from Stats NZ.
Baselining VKT by Vehicle Types	A methodology to determine baselines for total vehicle kilometres travelled, light passenger vehicle kilometres travelled, bus vehicle kilometres travelled, and heavy goods vehicle kilometres travelled.	Creator/owner – NZTA. Documentation – Albuquerque & Morrison (2022).	Quarterly VKT data and Household Travel Survey from MoT; GDP, labour force statistics, exports, imports and demographic data from Stats NZ; and petrol and diesel prices from MBIE.

Light VKT and GHG emission distribution across the country	A methodology for estimating subnational VKT and GHG emissions baselines for 2019, 2025, 2030 and 2035.	Creator – Beca Ltd. Funder/owner – NZTA. Documentation – McKibbin, Sewell & Li (2022).	Data from the Traffic Monitoring System (TMS), Road Assessment and Maintenance Management (RAMM), NZTA VKT and emissions data and models, MoT VKT and emissions data and models, local government and regional transport models, Stats NZ census data, MoT 2020 Vehicle Fleet, NZTA National Fleet, and Benchmarking Sustainable Urban Mobility.
Resilience Risk Mapping	A range of tools and tips for interventions and agreed responses to improve the resilience of networks and nationally consistent information on the risks of high impact low frequency events.	Creator/owner – NZTA. Documentation – NZ Transport Agency (n.d.d).	Data on alternative routes, information from the One Network Road Classification, data on low frequency events such as earthquakes, resilience cost data based on network maintenance costs for key natural hazard faults, data on high probability low impact events from the TREIS database, and outputs from the Modelling the Economics of Resilient Infrastructure Tool (MERIT).
Travel Demand Management (TDM)	A toolkit for providing guidance on travel demand management to reduce travel demand or redistribute demand across various modes of transport.	Creator/owner – NZTA. Documentation – Transit New Zealand (2007).	Census data on the number of New Zealanders that travel to work by car, truck, or van; travel behaviour patterns on state highways from transit traffic monitoring; transit staff travel behaviour from the Transit Travel Plan Survey; level of congestion on state highways from the transit journey time survey; air quality related to congestion from Transit Air Quality Monitoring; and information on the level of support for transport types from Transit Highway Information Sheets.

Appendix 2: Publicly available datasets used in the models

Responsibility/Data owner	Name	Data type	Availability	update frequency	Most recent dataset/database update (data year)	model/process update
Perdue University	Global Trade Analysis Project (GTAP)	Excel	Subscription	Approximately every 3 years	2017 (published 2022)	
StatsNZ	National accounts input output tables	Excel	Public	Every 5 to 8 years	2020 data (Published Dec 2021)	
	GHG emissions (industry and household)	Excel	Public	Quarterly	Q2 (June) 2022 (published February 2023)	
	Population projections	Excel	Public	Every two years	2022 forward	Jul-22
	Agricultural production statistics	Excel	Public	annual	year to June 2022 (published Dec 2022)	
	Livestock numbers	Excel	Public	annual	2019 (published 2021) Next update 2024	
StatsNZ/MPI	Agricultural production Census	Excel	Public	Survey is annual with a census after every 4 surveys (5 yearly)	2022 census published May 2023	
StatsNZ/MBIE	Annual Enterprise Survey	Excel	Public	Annual (Jul-June)	2021 (published June 2022)	
NZIER	GDP Projections		Private	Quarterly	March 2023 (For next 36 months)	
MBIE	Electricity tables	Excel	Public	Annual	2021 data (published 2023)	
	Energy Balances	Excel	Public	Annual	2021 data (published 2023)	2020 (most recent process update)
	Operational Electricity Generation capacity by Plant type	Excel	Public	Annual	2021 data (published 2023)	

Responsibility/Data owner	Name	Data type	Availability	update frequency	Most recent dataset/database update (data year)	model/process update
	Quarterly Generation and consumption	Excel	Public	Quarterly	2022 Q4 (published March 2023)	
EECA	EEUD Energy-End Use database	Excel	Public	Annual	2021 data (published 2023)	2022 Updated transport data methods, 2018 Full data method update
MfE	GHG Inventory	Excel	Public	Annual	2020 data (published April 2022)	
	LUCAS Land use map	GIS & Excel	Public	Approximately every 4 years	2016 (published 2023)	
Responsibility/Data owner	**Name**	**Data type**	**Availability**	**update frequency**	**Most recent dataset/database update (data year)**	**model/process update**
Electricity Authority	GEM (model)	Model	Public			Oct-16
MPI	Farm Monitoring and Benchmarking	excel?	Private (by request)	Annual?		
	SOPI Situation and Outlook data for Primary Industries (Comodity Price and forecasts)	Excel	Public	six monthly (June, December)	til 30 June 2023	
	NEFD National Exotic Forest Description	Excel	Public	Annual	Year ended April 2022 (published March 2023)	
	Livestock Slaughter	Excel	Public	Monthly	March 2023	
	Wood products market data	Excel	Public	Annual	year ended June 2022	
	Commodity price forecasts	Excel	Public	six monthly (June, December)	December 2022	
	LULUFC (Afforestation accounting data and projections)				2022 (based on 2020 data from GHG Inventory)	
	Afforestation/deforestation survey	table	public	annual	2022 (published May 2023)	
DairyNZ	DairyNZ Economic Survey	PDF	Public	Annual	2021-22 Financial year	

Responsibility/Data owner	Name	Data type	Availability	update frequency	Most recent dataset/database update (data year)	model/process update
Manaaki Whenua - Landcare Research	Slope data	GIS	Public			
	Land Resource Inventory	GIS	Public			
	Land Use Capability	GIS	Public		2021	
	Highly Productive Land	GIS	Public	Update due 2025		
	Land Cover Database (LCDB	GIS	Public		2018/2019	
	Protected Natural Areas	GIS	Public		1-Apr-22	
	Threatened Indigenous Environments	GIS	Public			
	Potential Natural Vegetation	GIS	Public			
	Basic Ecosystems (2002-2008)	GIS	Public		2002-2008	
	GHG Emissions (2010-2016)	GIS	Public		2010-2016	
	Nitrate leaching (2015)	GIS	Public		2015	
	various other data	GIS	Public		various	
BRANZ	Construction transport	excel	Public	no stated updates	2016	
	Construction site waste	excel	Public	no stated updates	2016	
	Building service life	excel	Public	no stated updates	2016	
	Building materials maintenance	excel	Public	no stated updates	2016	
BRANZ	Building materials replacement	excel	Public	no stated updates	2016	
	Building operational energy	excel	Public	no stated updates	2016	
	Building operational water	excel	Public	no stated updates	2016	
	Building end of life	excel	Public	no stated updates	2016	
	Electricity Grid embodied carbon	excel	Public	no stated updates	2016	
MoT	Transport Outlook	model	Public		Base year data 2017/18	model updated 2019
	Fleet statistics	Excel	Public	Quarterly	Q4 2022	Before May 2023
Waka Kotaki (NZTA)	Data Portal	GIS/Excel	Public (Open data policy)	various including monthly and quarterly	various, including EV charge in real-time	Mar-22
	Vehicle Kilometres Travelled (VKT) projections	excel	Public (Open data policy)	no stated updates	2019 (published Nov 2022)	

Appendix 3: List of Acronyms

ANSICO6	Australia and New Zealand Standard Industrial Classification 2006
APSIM	Agricultural Production Systems Simulator
AR5	Fifth IPCC Assessment Report
BRANZ	Building Research Association of New Zealand
CERF	Climate Emergency Response Fund
CCC	Climate Change Commission
CCPIM	Climate Change Policy, Information and Modelling Group
CNGP	Carbon Neutral Government Programme
COICOP	Classification of Individual Consumption according to Purpose
C-PLAN	Climate Policy Analysis model
CPR	Current Policy Reference
CRF	Common Reporting Format
EA	Electricity Authority
EECA	Energy Efficiency and Conservation Authority
EEUD	Energy End Use Database
ERP	Emissions Reduction Plan
EPA	Environment Protection Agency
ETS	Emissions Trading Scheme
GDP	Gross Domestic Product; the value of the finished domestic goods and services produced within a nation's borders.
GEM	General Expansion Model
GHG	Greenhouse Gas(es)
GNP	Gross National Product; the value of all finished goods and services owned by a country's citizens, whether or not those goods are produced in that country.
GTAD	Global Trade Analysis Database
GTAP	Global Trade Analysis Project
GWP100	Global Warming Potential over 100 years
HFC	Hydrofluorocarbon (gases)
IDI	Integrated Data Infrastructure
IEA	International Energy Agency
IEF	Implied emission factors
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
KP-LULUCF	Land Use, Land-Use Change and Forestry activities under the Kyoto Protocol
LBD	Longitudinal Business Database
LUCAS	Land Use and Carbon Analysis System
LULUCF	Land Use, Land-Use Change and Forestry
MBIE	Ministry of Business Innovation and Employment
MfE	Ministry for the Environment
MoT	Ministry of Transport
MoU	Memorandum of Understanding
MPI	Ministry for Primary Industries
NEFD	National Exotic Forest Description
NIWA	National Institute of Weather and Atmospheric Research
NZGBC	New Zealand Green Building Council
NZIER	New Zealand Institute of Economic Research
NZTA	New Zealand Transport Agency
OECD	Organisation for Economic Cooperation and Development
PRSM	Pastoral Supply Response Model
SADEM	Supply And Demand Energy Model

SEEA	System of Environmental and Economic Accounting (UN ratified framework aligned with the SNA)
SNA	System of National Accounting
SOPI	Situation and Outlook for Primary Industries
StatsNZ	Statistics New Zealand
TAG	Technical Advisory Group
TAWA	Tax and Welfare Analysis
TSA	Tourism Satellite Account (for estimating emissions from tourism)
UN	United Nations
UNFCCC	UN Framework Convention on Climate Change
VFEM	Vehicle Fleet Emissions Model
VKT	Vehicle Kilometers Travelled (Reduction)
WMO	World Meteorological Organisation