Future Grid scenario modelling

Visions of the New Zealand economy to 2050

Final report, 24 July 2025

SENSE PARTNERS
DATA LOGIC ACTION

Key points

We have modelled a range of future economic scenarios out to 2050

We used a dynamic model of the New Zealand economy to estimate the macroeconomic and industry impacts of four alternative, illustrative economic development scenarios:

- **Baseline** scenario: BAU growth path, no major structural changes in the economy or advances in technology or energy.
- **Rapid Transition**: Accelerated uptake of new energy technologies, the emergence of new energy export sectors, and enhanced attractiveness as a clean, green tourism destination.
- **Transform and Grow**: New Zealand focuses on its existing goods sectors, supporting them to be 'greener' and grow more rapidly in response to strong global demand for sustainable products.
- **Tech Haven**: AI is rapidly adopted, new data centres are built and a vibrant tech community establishes itself here. IT-intensive services drive growth and 'digital nomads' flood to our shores.

Thematic findings matter more than the precise impacts modelled

- This report outlines the global context and strategic plays that New Zealand makes in each scenario, along with estimates of their economic and industry impacts.
- The results are all positive in terms of GDP and vary in terms of industry outcomes (see section 4). Rather than repeat the details here, for the purpose of stimulating discussion around the future of New Zealand's energy system it is perhaps more useful to tease out the key learnings from the quantitative exercise and accompanying engagement with Transpower and other stakeholders.

The global energy transition presents an array of challenges and opportunities to New Zealand

- Many potential growth opportunities such as AI, data centres, e-fuels, synthetic food production, etc. depend heavily on the availability of clean renewable electricity to succeed.
- This is a point of comparative advantage for New Zealand relative to other countries.
- However, the upstream and downstream impacts of initiatives to aggressively grow a particular industry within the economy need to be carefully considered.
- Resource constraints in the form of labour, capital, land, etc. can easily bind, pushing up costs for the wider economy and prices for households.
- While one industry grows, others will contract and the distribution of growth can be uneven across sectors, regions and households. This holds as true for the energy sector as it does the dairy processing, construction or tourism industries.

The keys to releasing these binding constraints are technology and productivity

- As long as resources are limited, scarcity and opportunity costs will be ever-present.
- But over the medium term at least, we can find better ways of using resources.
- Innovation and R&D generated in New Zealand can help us get more bang for our buck from each unit of labour, land, capital or energy. Greater investments in education can boost labour productivity over time. Global technological change will push down the costs of production and make capital more affordable, including in renewable energy.
- This offers opportunities to potentially reduce the displacement effects of any one industry growing very rapidly.

Bold in our aspirations but pragmatic in our execution of strategies

- As a relatively small country, distant from many markets, and with a set of natural resources that lean towards certain industry advantages (at least in the short- to medium-term), New Zealand can't change the world by itself.
- So what the rest of the world does matters. New Zealand relies on the global economy for importing vital equipment and technologies and exporting our wares. We will struggle if we try to swim against the current of global preferences.
- We have to be selective in our investment efforts, build on what we are good at while being ready to jump opportunistically on prospects that fall in our path.
- This doesn't mean we can't be world leaders in certain industries, products or technologies. Aspirations, brilliance and blue-sky thinking are necessary, interesting and exciting. But to be compelling and sustained, brilliant ideas need to be grounded in evidence-based analysis that considers trade-offs in a world of limited resources.

The rewards are material if a path can be charted; energy sector coordination is important

- Our scenario modelling indicates the New Zealand economy could be up to $73bn larger than BAU by 2050 if certain technologies come to fruition and other aspirational assumptions hold true. Per capita GDP could be up to $7,000 higher.
- But much relies on ensuring the energy sector moves in a coordinated way so that demand doesn't rapidly outstrip supply, driving up costs for industry and reduced spending for households. So Transpower needs to work hand-in-glove with other key stakeholders within the energy sector and across the economy as it seeks to enable productivity and prosperity.
- Coordination across the energy sector is a vital ingredient toward enabling positive outcomes for New Zealand. From this perspective, a long-term grid blueprint that supports the industry by providing greater certainty around the timing and scale of new transmission investment will improve the likelihood of success.

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1. Scope of research

1.1. Our brief

Transpower is working towards the goal of decarbonising the New Zealand economy. As part of its Te Kanapu Future Grid project, it wants to consider a range of future economic scenarios and their implications for delivering a reliable and affordable electricity supply to support a thriving net zero economy out to 2050.[1]

Sense Partners, supported by our US-based partner Phylleos, has been commissioned by Transpower to:

- design three future economic scenarios plus a baseline scenario
- determine how these scenarios affect the industry composition and growth of the economy
- explore potential impacts on the electricity sector.

We use a dynamic Computable General Equilibrium (CGE) model of the New Zealand economy, named GSM-New Zealand, for this analysis.

1.2. Scope and caveats of analysis

See NZIER and Infometrics (2009) for an overview of general limitations associated with CGE modelling.

This is not an exercise in forecasting what *will* happen. Rather we explore what *could* happen to the economy under future scenarios that reflect alternative pathways for the development of the economy out to 2050, given certain assumptions about the ways households, firms and government respond to relative price shocks, technological change, implicit structural change, and other response factors.

Analysing the New Zealand economy out 25 years is challenging, especially at a time of rapid technological change and considerable global geopolitical uncertainty.

The "what if?" narratives developed and scenarios modelled were designed in conjunction with Transpower. We do not put any probabilities on any of the scenarios occurring and they are illustrative only. And while each scenario delivers costs and benefits in terms of the distributional of impacts across industries, this is not a social cost-benefit analysis. We have not sought to cost the various initiatives or drivers of growth in the scenarios.

Our focus is on New Zealand-wide economic impacts. While our CGE model has a considerable amount of detail on energy use and emissions, it is not a spatial electricity network model.

[1] For more information on Te Kanapu, see https://www.transpower.co.nz/our-work/te-kanapu

Our modelling framework does not take into account completely novel industries emerging. While we adjust the nature of existing industries to make them more energy efficient, less labour-intensive, more reliant on AI, etc., no economic model alone can predict the development of industries that do not exist yet in the data.

We see this work as a contribution to ongoing discussions within Transpower and with its stakeholders about the future shape of the New Zealand economy and how that may drive changes within the energy sector.[2]

[2] For example, a Transpower panel discussion on 29 June 2025 provided a valuable opportunity to share views on this topic with around 100 stakeholders.

2. GSM-NZ modelling framework

2.1. Origin of GSM-NZ

The Global Systems New Zealand (GSM-NZ) model is a highly advanced and flexible dynamic Computable General Equilibrium (CGE) model. It was developed for Sense Partners in 2019 by Dr Ashley Winston of Phylleos Inc. in Washington, D.C.

The New Zealand GSM CGE modelling suite[3] is built on the foundation of the pathbreaking and proven US GSM model. Versions of the GSM modelling framework have informed key policy reform and other economic matters in dozens of countries, including advising The White House on US biofuels and other energy reform issues.

We have used GSM-NZ[4] for several New Zealand clients including MBIE, MoT, KiwiRail, Oji Fibre Solutions, New Zealand Carbon Farming, The Treasury, Auckland Airport, and a group of Economic Development Agencies.

2.2. CGE basics

A CGE model considers the entire economy as an inter-linked system

GSM-NZ explores how the entire economy adjusts over time to changes in policy settings or shifts in the economic environment. It captures the interlinkages between industries, households, government, workers, investors, etc ('economic agents') and the emissions associated with production and consumption.

In its initial baseline equilibrium:

- Supply equals demand in all commodities (i.e. goods and services), including intermediate inputs.
- Supply equals demand in all factor markets (i.e. labour, capital, land, energy).[5]
- The economy is on a pathway to meet its Net Zero emissions targets.
- Firms make normal profits, so output prices equal the costs of production.
- Households maximise utility by using their disposable incomes to buy goods and services and saving some of that income.
- Government spending equals tax revenue plus any assumptions around borrowing (which must be funded via interest payments) and the size of the fiscal balance.

[3] We have a variety of modelling solutions, including comparative static, recursive dynamic, top-down regional, and bottom-up regional versions, with different levels of industry and commodity detail.
[4] Earlier versions of GSM-NZ were called MDG-NZ.
[5] However, in practice we allow for periods where labour demand and supply can be temporarily unbalanced, recognising that labour markets do not clear perfectly or immediately all the time.

- Export revenue less spending on imports determines the balance of trade, which must either be balanced via changes to the exchange rate or accompanied with increases in overseas borrowing (depending on the model closure assumptions selected in each scenario).

In a dynamic model, we project the economy in a BAU scenario and then 'shock' it off its equilibrium to reflect different future scenarios

Changes in industry, investor or household behaviour in future scenarios are driven primarily by **changes in relative prices**. Each relative price shift has multiple flow-on effects, which filter through industries and the wider economy. For example:

- A shift in export demand towards more sustainably-produced products will push up the world price of (say) New Zealand's clean aluminium. This induces greater production by the aluminium industry.
- More aluminium production requires more inputs (unless it's all due to a productivity improvement). The demand for electricity rises, pushing up its price.
- This higher price for electricity pushes other electricity-using industries (e.g. pulp and paper) to either reduce output or seek other inputs to use instead to maintain output levels.
- Higher aluminium exports leads to overseas buyers purchasing more New Zealand dollars. This pushes up the nominal exchange rate (the price of New Zealand's currency), which in turn makes other exporters less competitive.
- Other exporters reduce their output, including in labour-intensive industries such as tourism or tertiary education. This puts downwards pressure on wages (the price of labour).
- Cheaper labour benefits the labour-intensive, non-tradable part of the economy, such as personal services like hairdressing or food services (restaurants, bars, etc.).
- Due to the exchange rate appreciation, imports become cheaper. This benefits households as the purchasing power of their wages rises. And it benefits industries using a lot of imported materials, such as road passenger transport (for both vehicles and petrol/diesel) and construction.

The chain of logic extends a long way. In any scenario, there are many thousands of prices changes – some of which we input into the model as exogenous variables as 'shocks', and others which adjust as the economy reacts. In each scenario, the price of every input to production changes, as does the price of every industry's output.

These price changes flow into the demand functions of households, overseas buyers, investors and the government sector. The extent of changes in quantities demanded and supplied as prices move – **behavioural change – is determined by thousands of elasticities of demand and elasticities of substitution.**[6] The larger the elasticity, the more demand or supply adjust.

Following the introduction of shocks to represent future scenarios, supply and demand iteratively adjust across commodity and factor markets until a new equilibrium is reached.

Results represent the difference between the initial and new equilibriums

The model produces results for every year of the projections, including macroeconomic aggregates (e.g. GDP, household spending) and a huge amount of detail at the industry level – output, value added, exports, employment and wages, capital investment, etc.

Fiscal impacts are modelled in considerable detail, with the government having multiple tax levers at its disposable it can use to fund government spending or reduce a fiscal deficit (depending on the 'closure' assumptions' employed).

A key benefit of CGE models is that they explicitly take resource constraints into account. In any year, the amount of labour, capital, land, energy and intermediate inputs to production are fixed, and resources flow to their most valuable use.

This means there are 'no free lunches' in any period. If one industry uses more of an input as demand for its good or service rises, there is less available to other industries.[7] There will always be winners and losers in a CGE modelling exercise.

For more details on GSM-NZ, see Appendix B.

2.3. Key features

GSM-NZ is a Monash-style recursive dynamic model representing the New Zealand economy at a highly detailed level, comprising 140 industries that produce 220 goods and services based on (but extended from) the latest official input-output tables from StatsNZ.

Core dynamic features of GSM-NZ include 'sticky wages' labour market adjustment, capital accumulation based on expected rates of return, the accumulation of net foreign liabilities to fund current account deficits, and public sector debt that accounts for fiscal deficits over time.

In the interests of reducing computational time for solving the model, we have aggregated and diagonalised the database in this project to 123 single-product sectors, and not utilised the regional module.

The greenhouse gas emissions associated with each sector's activities, and those of end users such as households, are also incorporated into our database.

[6] Our model elasticities are drawn from the international CGE modelling literature and are at commonly accepted levels. They can be easily adjusted if clients have industry- or product-specific data or information on behavioural responses.
[7] The exception is if the scenarios include technological change or efficiency/productivity improvements, as many of the scenarios here do. In this case, the crowding out effects are moderated.

The database for this project incorporates:

- 123 single-product industries, comprising:
    - 9 primary sector industries and 5 primary processing industries
    - 5 extractive industries
    - 17 manufacturing industries
    - 15 fuel industries
    - 8 types of electricity generation[8]
    - 5 utilities industries
    - 11 freight and passenger transport and logistics industries
    - 48 government, business and recreational services industries.
- 10 natural resource endowments[9]
- 18 fuel types[10]
- 17 types of greenhouse gas emitting activities[11], producing 8 different gases[12]
- 8 labour market occupations[13] in each industry
- Dozens of different tax and government spending instruments.

2.4. Modelling process

We first project the economy and emissions each year out to 2050, drawing on official Treasury forecasts and emissions estimates from MfE and the CCC. We draw on forestry sequestration estimates from previous work for a New Zealand forestry organisation. This forms our baseline scenario (see section 3.2).

We then 'shock' the model from this baseline by changing key parameters to generate a range of counterfactual or 'policy' scenarios, described below in sections 3.3 to 3.5.

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[8] Hydro; Geothermal; Wind; Solar; Gas; Coal; Oil; Biomass.
[9] Forests; Fish; Coal; Oil; Gas; Metals and minerals; Arable land; Semi-arable land; Marginal land; Non-arable land.
[10] Coal, coke, and tar products; Natural gas; Petrol; Diesel; Advanced Aviation Fuel; Heavy Fuel Oil; Other Petroleum Products; Ethanol; Biodiesel; Advanced Marine Fuel; Biomass Fuel; Hydrogen; Light Vehicle Fuel blend; Heavy Vehicle Fuel blend; Aviation Fuel blend; Marine Fuel blend; Manufactured gas.
[11] Enteric fermentation; Manure management; Ag soils - excreta + other; Ag soils – fertiliser; Urea - CO2; Liming; Field burning; Coal mining fugitive; Gas fugitive; Oil fugitive; Chemicals production; Non-metallic minerals production; Metals production; Geothermal fugitive; Sewerage treatment fugitive; Waste processing fugitive; Land use, land use change & forestry. Other emissions come via fuel combustion associated with the various fuel industries.
[12] Carbon Dioxide; Methane; Nitrous Oxide; Fluorinated gases; Nitrogen Oxides; Carbon Monoxide; Non-methane Volatile Organic Compounds; Sulphur Dioxide.
[13] Managers; Professionals; Technicians and tradespeople; Community and personal services; Clerical and administration; Sales; machine operators and drivers; Labourers.

In each policy scenario, the economy adjusts to a new equilibrium as economic agents respond to these shocks via changes in relative prices. The differences between the initial and post-shock equilibriums are the economic and emissions impacts of the shocks introduced.

The model's results are generally presented as percentage changes from the baseline, but it also generates certain impacts as changes from the baseline in 'ordinary' measures (dollars, PJs, MT CO2-e, etc.)

3. Scenario descriptions

3.1. Overview of scenarios

We have developed four scenarios for this analysis:

(i) **Baseline** – acts as the comparator for the other scenarios and generally assumes no significant shifts in the composition of the economy.

(ii) **Rapid Transition** – considers a New Zealand economy with accelerated uptake of new energy technologies, the emergence of new energy export sectors, and enhanced attractiveness as a clean, green tourism destination.

(iii) **Transform and Grow** – explores a future where New Zealand focuses on its existing goods sectors, supporting them to be 'greener' and grow more rapidly in response to strong global demand for sustainable products.

(iv) **Tech Haven** – analyses a technology-centred New Zealand economy where AI is rapidly adopted, new data centres are built, and a vibrant tech community establishes itself here. IT-intensive services drive growth. New Zealand builds a reputation as a great place for digital nomads to live, work and play.

The global context and New Zealand's strategic plays in response for each scenario are described below. Each counterfactual scenario (Rapid Transition, Transform and Grow, Tech Haven) contains several elements around a common theme.

The details of the shocks modelled to approximate each scenario are contained in Appendix A.

3.2. Baseline scenario

The baseline scenario is our BAU, which incorporates known policies and 'normal' expectations around the domestic and international economic environment. The aim is to project the economy out to 2050 on the basis that there won't be significant shifts in policy direction, technology or the way New Zealand produces and consumes goods and services.

3.2.1. Economic assumptions in baseline

We take Treasury's latest macroeconomic forecasts (i.e. in their Half Year Economic and Fiscal Update) for the first 5 years, and then Treasury's Long-Term Fiscal Model projections out to 2050. This gives us economic growth projections that determine the overall size of the economy.

We then apportion the economy between the 123 industries in our model. We do this using historical trends in industry growth rates plus moderate assumptions around technological change in each industry.

The projections are therefore essentially a continuation of historic trends in the composition of the economy, without any large structural change or disruptive technologies being introduced. For example, over time New Zealand has become less dependent on heavy manufacturing and more focused on business services. We assume these trends will continue, unless there is a good reason to moderate them.

The sole exception to our historical trend projection is that, based on guidance from Transpower, we assume that Methanex is phased down by the early 2030s.[14]

3.2.2. Climate policy assumptions in baseline

Based on our economic projections by industry, and industry-specific assumptions around the emissions-intensity of activity, the baseline economic projections generate a set of baseline emissions projections. In this way, economic activity and emissions projections are internally consistent.

New Zealand has domestic and international legal obligations around emissions targets. Our usual practice is to incorporate these obligations in our baseline. For this project we set economy-wide emissions on a track to meet our domestic legal commitments:

- Net zero by 2050 for all gases other than biogenic methane.
- The midpoint of the biogenic methane target, being 35.5% below 2017 levels by 2050.

Incorporating the net zero target requires an assumption on how much of the work will be done by forestry, with gross emissions cuts being the balance. We base this off forestry projections we first developed in 2023 for a forestry sector client, using their in-house afforestation and deforestation assumptions. We have since updated these projections to incorporate another two years of actual data.

To ensure the economic activity and emissions projections align, we allow the emissions price to vary in the baseline to ensure the net zero targets are hit.

3.3. Rapid transition (RT) scenario

3.3.1. The global context

The impacts of climate change become ever more apparent. Governments of major emitting countries take decarbonisation much more seriously due to visible signs of climate change becoming more apparent – more wildfires, droughts, sea surges, floods, etc.

These events cause economic and social harm and jolt the collective conscience into action. Major economies embark on programmes of government and private investment in new technology.[15]

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[14] We do this by reducing the output of the 'Basic Chemicals' industry by around 50% by 2032, and reducing to almost zero this industry's use of gas.

[15] Recent examples of this investment are the US's CHIPS and Science Act and the Inflation Reduction Act, and the EU's Net-Zero Industry Act.

These programmes lead to dramatic cost reductions in green energy technology; particularly solar, wind and batteries. With batteries currently being a major contributor to cost, the advances also flow through to reducing the cost of electric vehicles (EVs).

By rapidly removing emissions from transport and electricity, there is less pressure on hard-to-abate sectors such as international aviation and shipping. Sustainable aviation fuel (SAF) takes a biomass-based route which supplements, but does not replace, conventional jet fuel.

The US moderates but continues its play to boost its own manufacturing sector. Global competition for green manufacturing, including EV-related supply chains, creates trade imbalances including periods of surplus production in other parts of the world.

3.3.2. New Zealand's strategic plays

New Zealand invests heavily in STEM education initiatives and R&D in energy-related areas to complement the global boom in new technologies. This investment pays off through higher labour productivity in the manufacturing and energy sectors. Higher productivity enables these sectors to switch from fossil fuels to renewables.

By strategically targeting key trade relationships, New Zealand lowers the cost for its transition to EVs.

Regulatory reform (such as the RMA) enables electricity market dynamics to play out in a coordinated fashion with new electricity supply moving in lockstep with demand increases, thereby moderating price shocks associated with supply deficits.

Natural gas and coal fired generators are kept in the mix and used sparingly during extended periods of low renewables generation to minimise prices. This improves the case for electrification without straining the emissions budget.

With a rapid and early decarbonisation of the transport and electricity sector, gross emissions fall more rapidly than in the baseline, reducing the demand for afforestation (within the ETS) and green hydrogen. Reducing forestry within the ETS enables local manufacturing of biomass-based SAF, which reduces New Zealand's reliance on imported fuel.

New Zealand successfully attracts foreign capital to fund energy projects and capital costs associated with switching manufacturing away from fossil fuels.

The higher cost of air travel creates headwinds for the tourism sector, prompting a shift in focus from high volumes to tourists prepared to pay a premium for the clean, green New Zealand experience.

To model the emissions impacts of this scenario, we hold emissions to their net zero baseline track, letting the emissions price vary within the model. To the extent that this scenario makes it easier to get to net zero by 2050, the emissions price will be lower than the baseline.

3.3.3. Overview of shocks

The key shocks in the RT scenario relative to the baseline are:

- More affordable foreign-made EVs flow into New Zealand

- Labour productivity gains in manufacturing and energy due to government initiatives around STEM education and energy R&D.
- As a result of lower-cost renewables and a 'twist' in fuel use preferences, manufacturing switches away from fossil fuels to renewables by 2035.
- The cost of solar and wind electricity installations falls by 35% from baseline, and other electricity generation types experience innovation-driven technological improvements that lead to price falls.
- Additional renewable electricity demand is met by concomitant supply expansion funded by foreign investment. [16]
- Biomass-based SAF develops.
- Tourism targets high value visitors over volumes.
- Less afforestation needed to meet net zero targets.

3.4. Transform and grow (T&G)

3.4.1. The global context

The world continues its ebb and flow approach toward tackling climate change. Progress is uneven across countries, with some governments going hard and fast, others soft and slow before attempting to play 'catch up'.

The governments of major emitters flip-flop around climate policy priorities. As such, initiatives are kick-started then cancelled in quick succession and before benefits materialise.

While progress is made towards decarbonisation, it occurs with a level of inefficiency and backsliding due to indecision. This subdued progress, combined with more evidence of the damaging effects of climate change, eventually triggers a concerted international push for more drastic responses. Mandates eventually emerge for green fuels in international shipping and aviation. Carbon Border Adjustment Mechanisms (CBAMs) become more popular.

Global trade barriers continue to decline and the provenance of goods – the way they are produced, not solely their cost – starts to become more important to consumers.

3.4.2. New Zealand's strategic plays

[16] Earlier versions of this scenario and T&G did not include this 'supply matches demand' assumption. We found via our initial modelling that when additional electricity supply lags rapid electricity demand growth – even by a couple of years – electricity prices spike. This generates cost pressures for electricity-intensive industries that leads them to produce and export less. In addition, households see a sharp increase in their spending on electricity that eats into their disposable income, suppressing spending elsewhere. The combined effect of these outcomes was that it was hard to generate any sustained additional GDP growth, and there were significant deindustrialisation pressures. This highlights the importance of coordinated whole-of-system planning around electricity demand and supply to support New Zealand's growth aspirations.

With less clarity emerging from the global community on climate actions, New Zealand doubles down on what it is already great at rather than seeking to diversify the economy rapidly into new, technology-focused sectors.

Business and government work more closely together to position New Zealand as a world leader in exporting more sustainable versions of what we already sell, driving overseas consumer preferences in New Zealand's favour.

Targeted R&D investment in primary sectors, particularly methane inhibitors, reduces the emissions intensity of the agricultural sector and unlocks a first-mover advantage in this technology. The investment also unlocks a boost in labour productivity within agriculture support services.

New Zealand's dairy, meat, and horticultural exports attract a green premium offshore, boosting export income without placing additional strain on land, labour, capital or energy.

New Zealand's existing steel and aluminium industries respond to New Zealand's favourable global position by boosting production. Regulatory reform enables New Zealand's mining industry to export more critical and rare earth minerals.

The appearance of global green fuel mandates creates an opportunity for New Zealand. Export scale production of e-SAF and e-methanol occurs in New Zealand, due to New Zealand's low-carbon electricity sector, access to the Asia/Pacific market and ease of scalability. This green fuel expansion opportunity is funded primarily by foreign investment.

A closely coordinated approach is taken to electricity demand and supply dynamics, ensuring additional supply comes onstream rapidly as anticipated demand increases.

3.4.3. Overview of shocks

The key shocks in the T&G scenario relative to the baseline are:

- More emissions-efficient farming techniques in response to export markets putting a green premium on food imports, supported by broader labour and land productivity improvements across the primary sector.
- Higher labour productivity in agricultural support services (e.g. science, vets, etc.) to reflect more rapid scientific innovation.
- Stronger export growth in high-quality, low-emissions steel and aluminium, which will be in high demand due to overseas regulations such as CBAMs.
- Rapid production growth and export of critical minerals as New Zealand embraces carefully-managed mineral sands mining as a key driver of regional economic activity.
- e-SAF and sustainable marine fuel industries develop in the 2030s, drawing on overlapping skills and processes in these areas. This reduces the energy requirements and costs associated with transporting goods from New Zealand to

export markets, moderating the 'tyranny of distance' from an emissions perspective.

- Additional renewable electricity demand met by concomitant supply expansion funded by foreign investment, moderating price impacts.

3.5. Tech haven (Tech) scenario

3.5.1. The global context

Emerging AI technologies transform the global economy even faster than currently expected. Workers increasingly pivot toward information technology, creative and professional services, fuelling productivity gains but exacerbating disruptions in traditional industries such as manufacturing and routine administrative roles.

Countries that swiftly adapt to this transformation by investing in education, retraining programs and digital infrastructure experience significant growth, capturing opportunities in high-value, knowledge-intensive sectors. Regions slower to transition face mounting economic disparity and employment challenges.

Global trade patterns shift markedly, reflecting altered comparative advantages. Economies with a robust technological infrastructure and a skilled, adaptable workforce dominate global supply chains, particularly in services like software development, cybersecurity, financial technology, the creative sector and data analytics.

3.5.2. New Zealand's strategic plays

As AI takes off around the world, New Zealand picks up a more-than-proportionate share of this growth. New data centres are built, and a rapidly-growing and vibrant tech community establishes itself here.

Economic growth is increasingly centred around service sectors such as space, healthcare, film and media, gaming and the creative industries.

As a result, New Zealand develops a global reputation as a great place to live, work and play. There is a concerted, bipartisan commitment to opening the economy to, and actively courting, 'digital nomads' – young, tech-savvy workers who place a high value on living in a stable, welcoming and environmentally-conscious New Zealand.

3.5.3. Overview of shocks

The key shocks in the Tech scenario relative to the baseline are:

- Higher net migration inflows which more than offset the projected decline in the New Zealand labour force as the population ages. A larger share of the workforce is highly skilled.
- Productivity boosted in advanced manufacturing, business services and creative sectors due to the skills, dynamism and innovations brought by an influx of digital nomads.

- Rapid growth in the number and scale of data centres required to house IT infrastructure, with much of the output exported.
- Greater emphasis is placed on work-life balance, supported by the efficiencies generated from a more technologically-advanced economy where AI does much of the repetitive and labour-intensive roles. The labour force works less and enjoys more leisure activities (e.g. travel, dining out, the arts, recreation and sports).

4. Modelling results

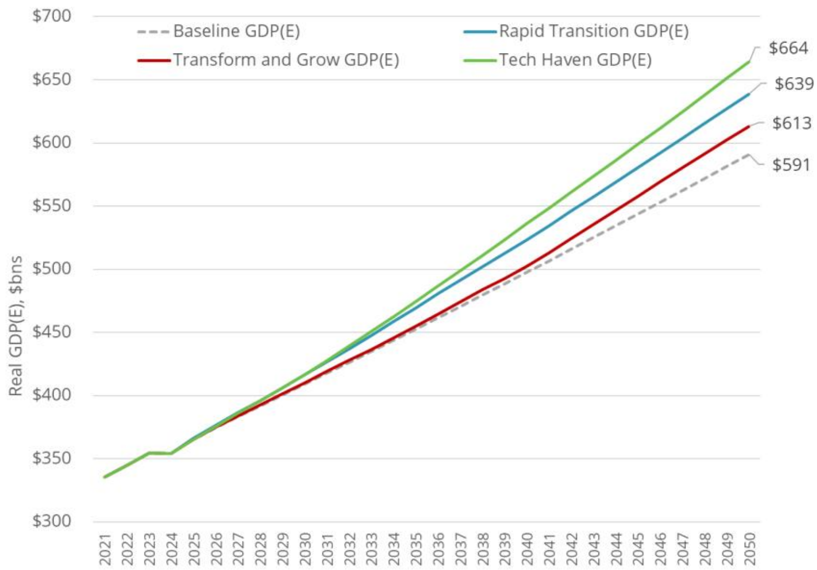
We focus our reporting on the headline macroeconomic impacts plus changes to various industries that highlight the differences between scenarios. Given there are 123 industries, we do not attempt to report on all of them for each year for each scenario. A more detailed set of results has been made available to Transpower for its internal analysis.

4.1. Comparison of macroeconomic results

Tech Haven delivers the largest GDP gains...

Based on the assumptions used in each scenario's design, Tech generates the largest increase in real GDP – around $73b (or 12%) above baseline by 2050.

FIGURE 1 GDP IMPACTS ACROSS SCENARIOS, $B



This is primarily due to the net migration and productivity assumptions employed. With net migration being around 480,000 higher than baseline by 2050, there are more consumers and highly skilled workers, especially in the services sector which accounts for around 70% of New Zealand's GDP. They generate more output, more efficiently and spend more income on goods and services. The productive capacity of the economy is larger because we have more people.

In addition, Tech sees the highest growth in export volumes of the three scenarios, especially in tech-driven industries like computer design services, electrical products, film and sound recording, scientific services, internet and data services (i.e. data centres).

The GDP impacts are lower but not trivial for RT and T&G, at $48b (8%) and $22.5b (4%) above baseline by 2050 respectively. In these scenarios, we see improved R&D, better education and concomitant productivity gains, but in narrower slices of the economy (energy and tech sectors in RT; goods production and sustainable fuels in T&G). In essence, RT and T&G are about doing more with the same amount of resources, whereas Tech is about doing more with more resources.

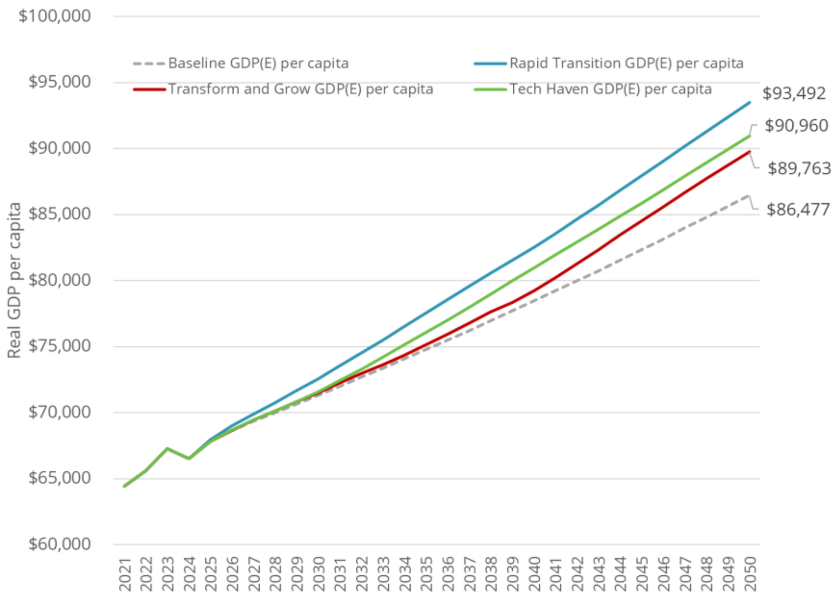
…but Rapid Transition delivers higher GDP *per capita* gains

When we adjust for population growth, recalling population is only higher than baseline in the Tech scenario, RT generates larger increases in real GDP per capita than Tech and T&G – around $7,000 per person by 2050.

This is primarily due to the energy efficiency improvements and labour and capital productivity gains encapsulated in the RT scenario. Given electricity is used by every industry and every household, the effects of lower electricity prices and transport costs relative to the baseline improves firms' profitability and households' purchasing power. This leads to more business investment and household spending.

Economy-wide wage growth in RT is the highest of all scenarios, lifting to almost 18% above baseline by 2050 (compared to 9% for Tech and 7% for T&G). This wage growth is driven by the strong and widespread labour productivity growth assumed in the high-tech manufacturing and energy sectors in RT.

FIGURE 2 REAL GDP PER CAPITA IMPACTS ACROSS SCENARIOS, $



4.2. Rapid Transition scenario results

4.2.1. Reminder of scenario description

In RT, New Zealand picks up on a significant lift in global determination to decarbonise sooner. It responds by investing heavily in STEM education and R&D in the energy sector.

Strong trade relationships support ongoing access to increasingly cheaper EVs. RMA reform and global technology improvements make the cost of installing new wind and solar electricity generation much lower, which supports rapid electrification at a low cost. Other features of this scenario are an influx of high-value eco-tourists and the development of biomass-based SAF.

4.2.2. Macroeconomic impacts

In this scenario, **real GDP lifts above baseline by around $48bn** by 2050 (Figure 3).

FIGURE 3 RAPID TRANSITION: MACROECONOMIC IMPACTS, REAL $BN RELATIVE TO THE BASELINE

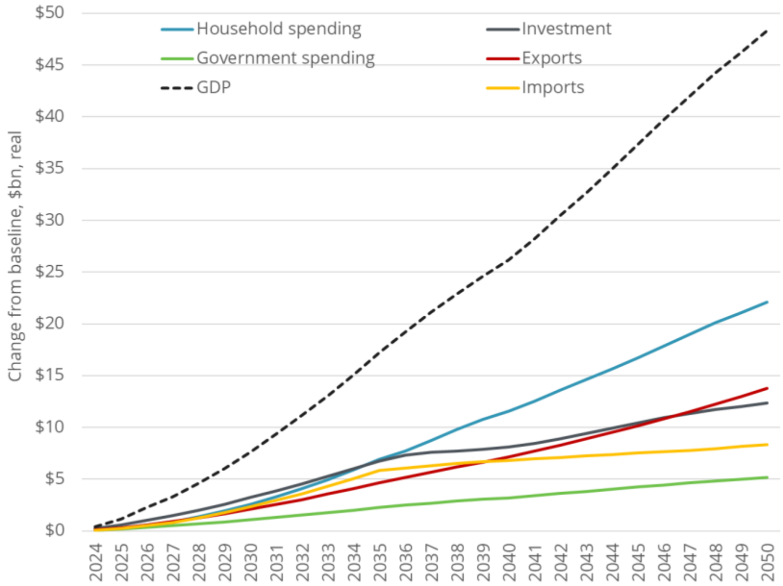
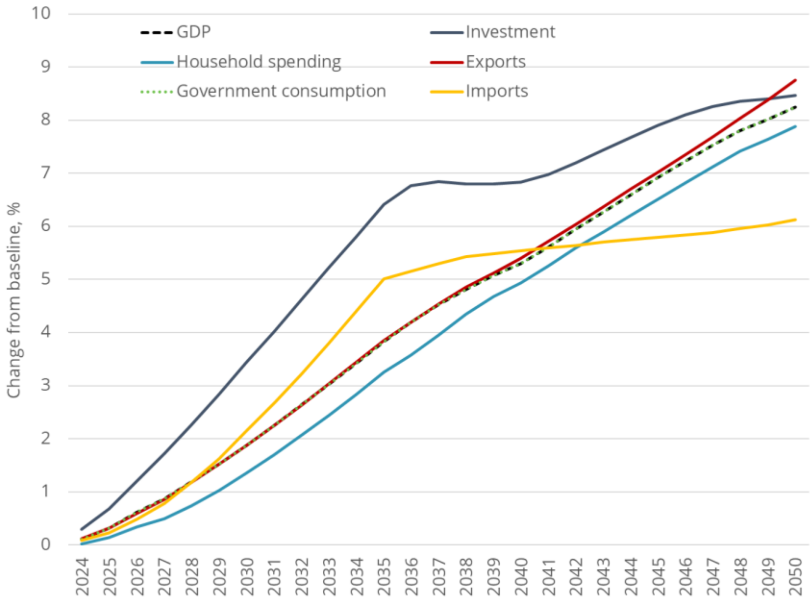


FIGURE 4 RAPID TRANSITION: MACROECONOMIC IMPACTS, % CHANGE RELATIVE TO THE BASELINE



The macroeconomic results are **driven by greater capital investment** (Figure 4) – the economy becomes more capital-deep, which supports productivity growth and output. The capital, especially in the renewable energy and airline sectors, is largely brought in from overseas, leading to a **sharp increase in imports** early in the projection period (yellow line in Figure 4).

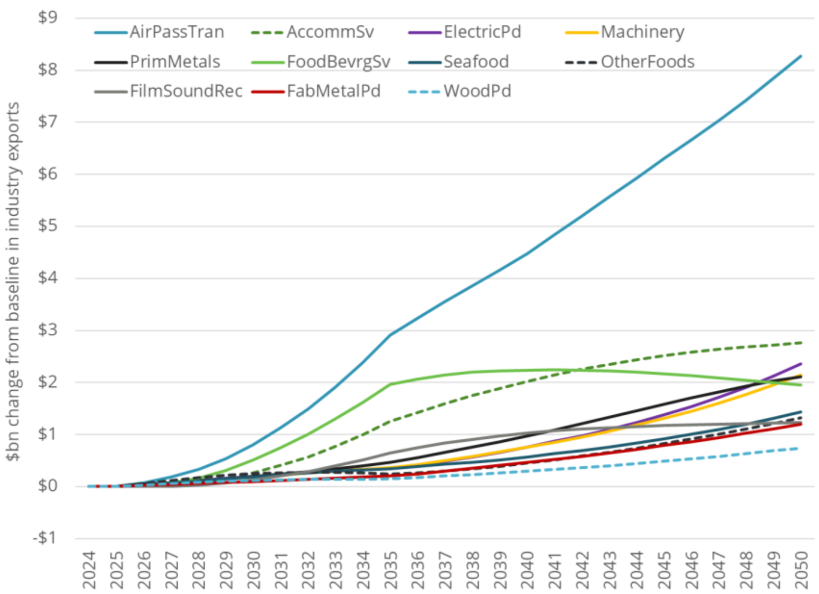
To fund the imports, exports rise too[17] (Figure 5). Export growth is particularly strong in:

- **Tourism** industries as high-value spending visitors seeking a clean, green experience come to New Zealand as our international reputation for sustainable living and production is enhanced
- Primary **metal** and fabricated metal products, which use vast amounts of now-cheaper electricity, improving their export competitiveness.
- A range of **manufacturing** sectors which benefit from higher numbers of more productive, STEM-trained workers and lower input costs (mainly electricity).

Household spending rises readily as real wages increase in line with enhanced labour productivity and a faster-growing economy boosting labour demand. The continued availability of relatively affordable EVs from countries such as China induces greater spending on these items and supports a shift to the car fleet becoming 100% electric by 2050.

Government spending is tied to GDP as a ratio in our closure design, so it grows at the same rate (meaning the lines overlap in Figure 4).

FIGURE 5 EXPORT IMPACTS, $B CHANGE FROM BASELINE, SELECTED INDUSTRIES



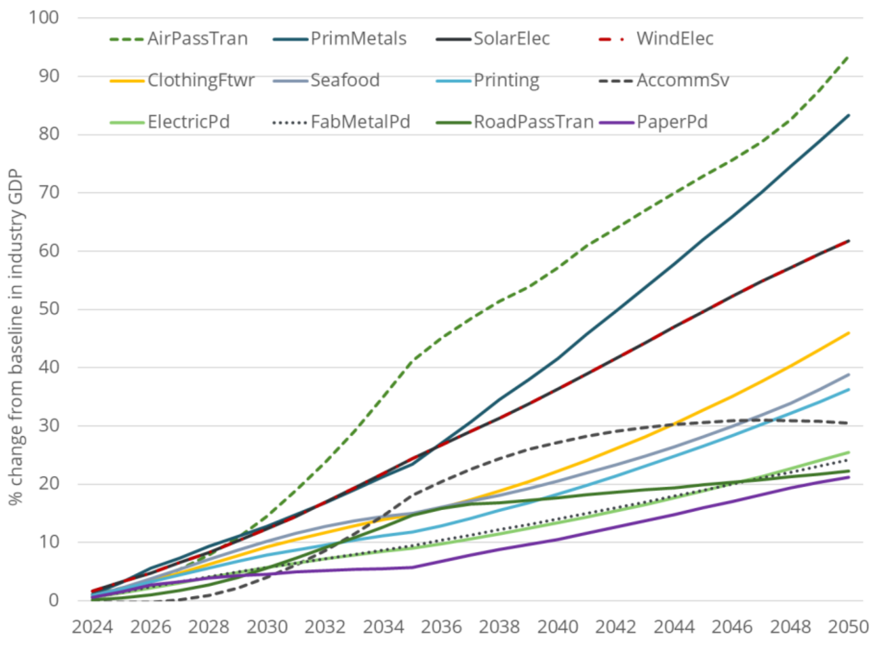
[17] Our closure settings effectively assume that, on average, the balance of trade as a share of GDP stays at baseline levels – a standard closure choice.

4.2.3. Industry impacts

The biggest winners of our 123 industries in terms of percentage change in industry GDP (also called 'value added') are shown in Figure 6:

- Reflecting the decarbonisation and electrification aspects of this scenario, there is **strong growth above baseline in the wind and solar electricity generation** industries (although solar is from a low starting point in levels terms).
- **Heavy users of electricity**, such as primary metals (i.e. steel and aluminium), paper products, printing, electrical product manufacturing and seafood processing benefit strongly from lower electricity prices.
- **Tourism**-related industries such as air passenger transport and accommodation services expand above baseline as the 'healthy, wealthy and wise' flock to New Zealand, spending more per visit than in the baseline.
- Road passenger transport grows strongly due to cheap EVs and falling electricity prices.

FIGURE 6 INDUSTRY GDP, % CHANGE FROM BASELINE, SELECTED INDUSTRIES

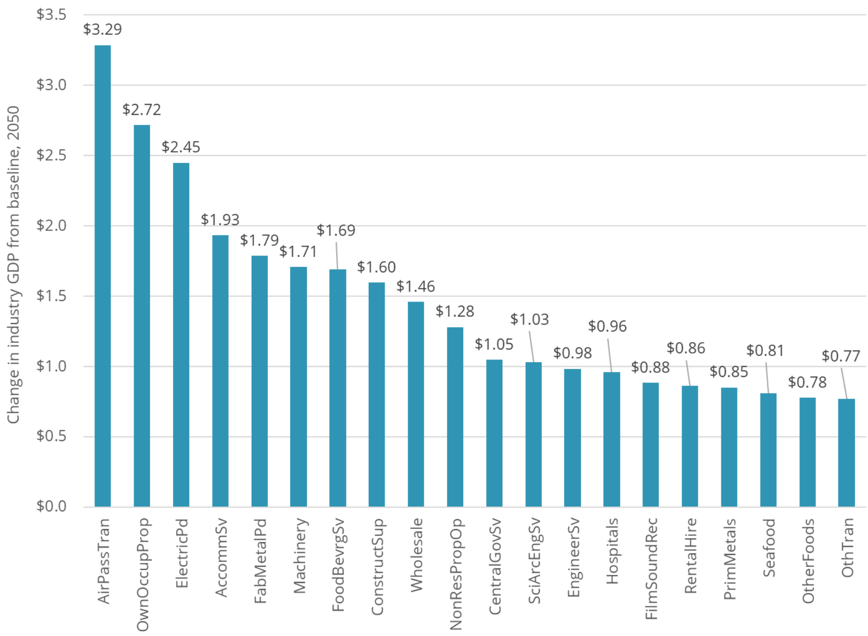


In dollar terms, Figure 7 shows the industries that expand the most by 2050, relative to baseline. The largest gains come in industries that are:

- Electricity-intensive, such as electrical products manufacturing, fabricated metals products manufacturing, machinery manufacturing, primary metal manufacturing.
- Tourism-related, such as air passenger transport, accommodation services, food and beverage services.

- Construction-related, such as construction support services, non-residential property operation, rental hire – all of which benefit from strong manufacturing sector expansion and capital deepening.
- STEM-related services, such as the film and sound recording sector and the scientific, architecture and engineering services sector.

FIGURE 7 INDUSTRY GDP, $BN CHANGE FROM BASELINE, 2050, SELECTED INDUSTRIES

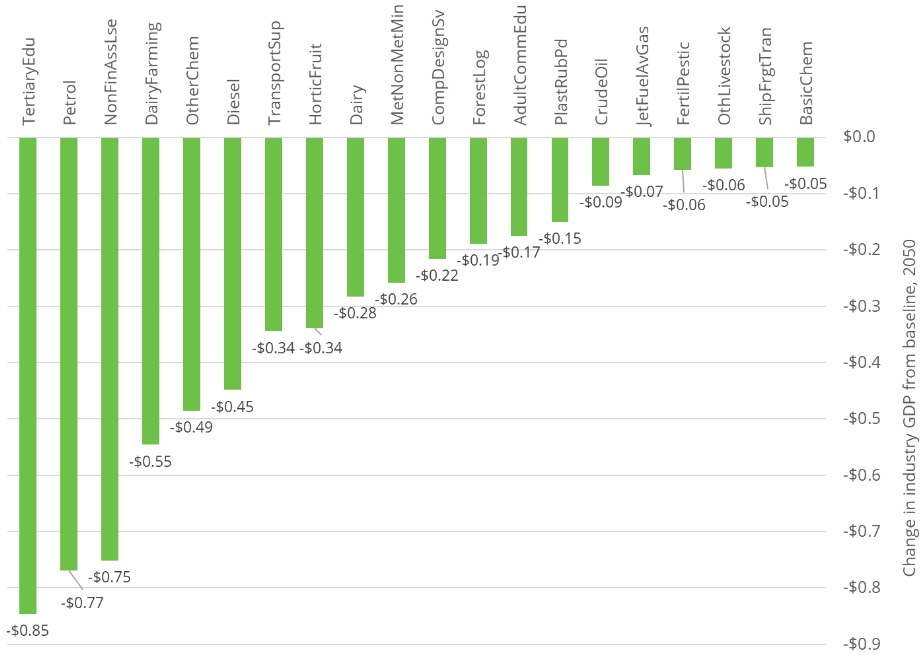


Industries that fare less well as they compete for limited resources with the expanding tourism, manufacturing, construction and STEM sectors are shown below in Figure 8.

Key drivers of contractions in these industries by 2050 include:

- **Higher wage costs in labour-intensive activities** such as tertiary education, adult and community education, and computer design services.
- Decarbonisation **reducing the demand for fossil fuels** such as petrol and diesel, crude oil refining, and supporting transport services.
- Biomass-based SAF (partly woody biomass, partly crop-based) **drawing land and labour resources away from forestry production and horticulture**.
- Competition for land reducing dairy farming output slightly. This reduces the demand for fertilisers and pest control products. In addition, the **higher exchange rate worsens the competitiveness of dairy processing**, reducing its need for raw milk.

FIGURE 8 INDUSTRY GDP, $BN CHANGE FROM BASELINE, 2050, SELECTED INDUSTRIES



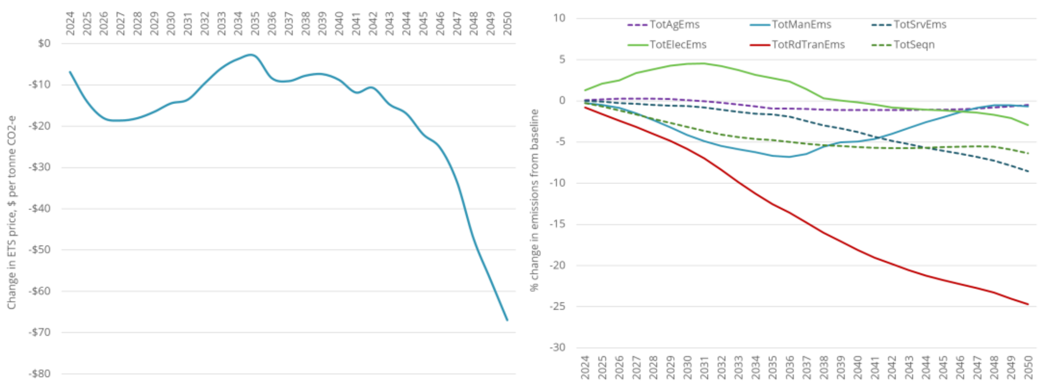
4.2.4. Emissions impacts

As would be expected in a rapid decarbonisation and electrification-centric scenario, there are significant emissions benefits in RT. While we keep the 2050 date for hitting our Net Zero targets in our closure settings, we achieve the targets with:

- 8.2% more economic activity.
- An ETS price that is materially lower than the baseline (left hand panel of Figure 9).
- Significant decreases in road transport emissions, sequestration required, manufacturing sector and services sector emissions (right hand panel).

That is, the **emissions-intensity of the economy falls, it is cheaper to get to Net Zero and there are no losses in living standards** relative to the baseline.

FIGURE 9 EMISSIONS PRICE AND VOLUME IMPACTS, CHANGE FROM BASELINE



4.3. Transform and grow scenario results

4.3.1. Reminder of scenario description

In T&G, global attitudes towards climate change wax and wane, and there is no rapid decarbonisation. Instead, New Zealand focuses on its traditional goods-producing strengths and seeks to produce primary products more sustainably. There is greater public and private investment in primary sector-related R&D, skills development and education.

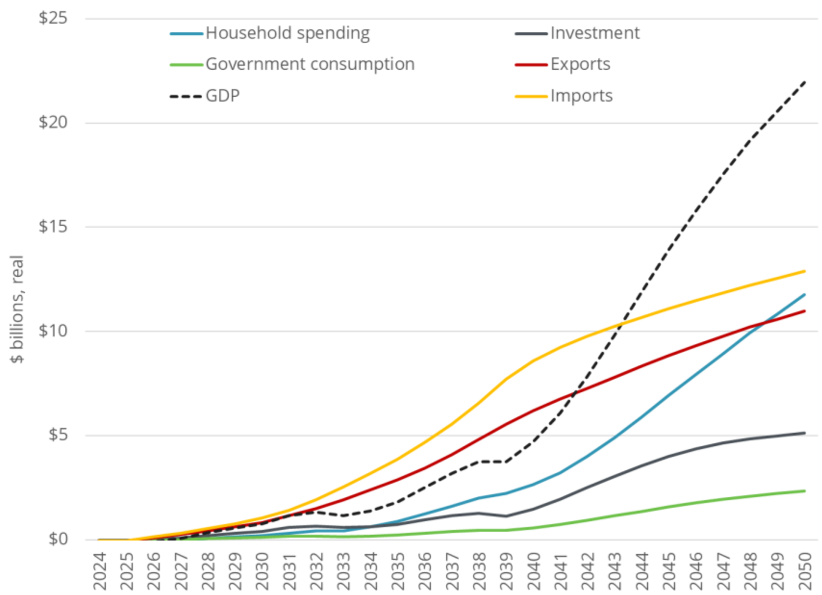
'Green' steel and aluminium production increases as carbon border adjustment mechanisms proliferate, making low-emissions metals more attractive in export markets. New Zealand's mining sector focuses more on sustainably-mined rare earth minerals.

Finally, green fuel mandates drive up the demand and prices for hydrogen-based e-SAF and e-methanol, incentivising New Zealand production due to its comparatively low carbon energy system. Similar patterns around solar and wind technology exist to those assumed in RT.

4.3.2. Macroeconomic impacts

In this scenario, **real GDP lifts above baseline by around $22bn** or 3.8% by 2050 (Figure 10).

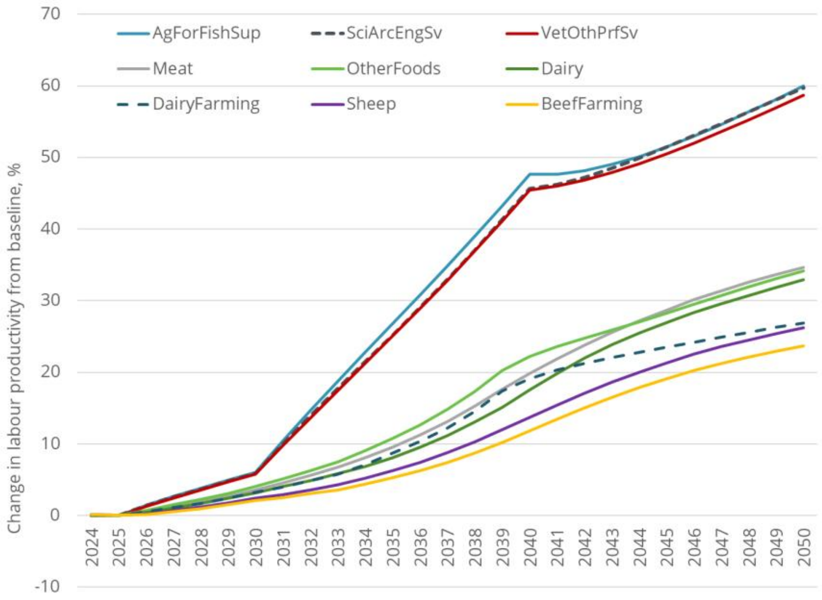
FIGURE 10 TRANSFORM AND GROW: MACROECONOMIC IMPACTS, REAL $BN RELATIVE TO THE BASELINE



The macroeconomic results in T&G are **much more goods export-driven** than in RT. Also see Figure 12 below). The GDP impacts are more moderate early in the projection period because it takes time for the primary sector to ramp up production, given limited land availability and a lower rate of increase in capital accumulation than assumed in RT.

The labour productivity improvements we assume (Figure 11) also take a few years to ramp up, as the impacts of increased funding for agricultural science and R&D take some time to bear fruit.

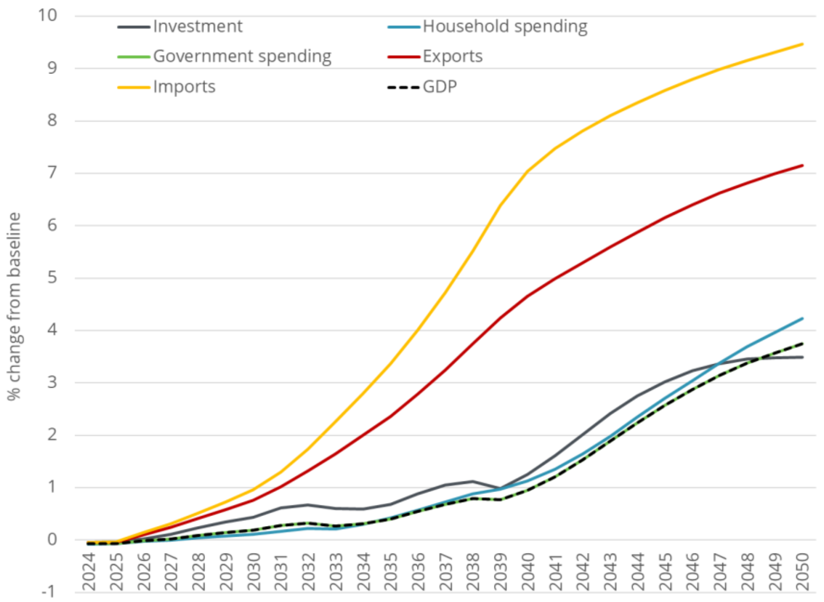
FIGURE 11 LABOUR PRODUCTIVITY, % CHANGE RELATIVE TO THE BASELINE, SELECTED PRIMARY SECTOR INDUSTRIES



Imports increase by significantly more than exports in this scenario (see yellow line compared to red line in Figure 10 and Figure 12).

That is largely because more domestic resources (land, labour, capital etc.) are directed to producing New Zealand's traditional goods exports. This leaves less available for supplying the domestic market and hits the services sector particularly hard. Instead of buying from local sources, households and firms import more goods and services instead.

FIGURE 12 TRANSFORM AND GROW: MACROECONOMIC IMPACTS, % CHANGE RELATIVE TO THE BASELINE



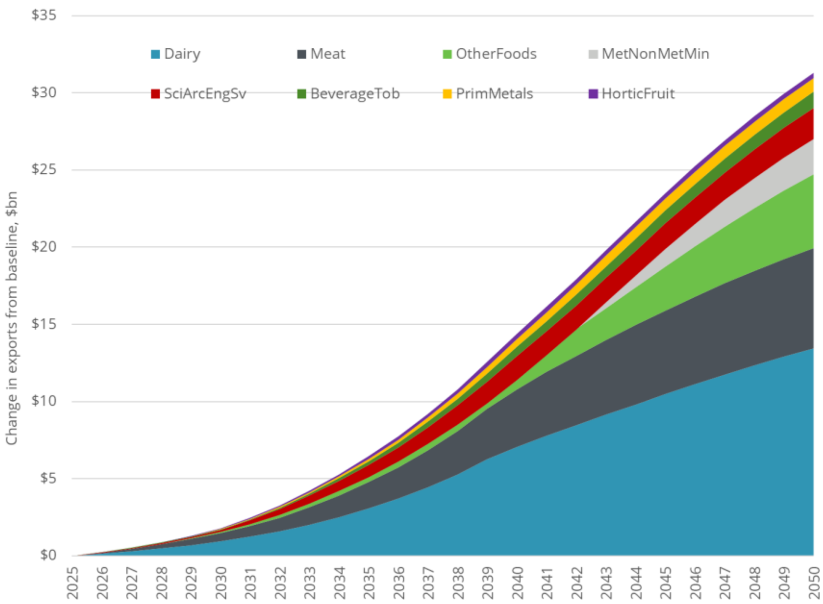
In this scenario, **export growth is centred largely on our traditional areas of comparative advantage** (see Figure 13). Primary products such as dairy products, meat, beverages and tobacco (almost entirely wine), other foods and horticulture (e.g. kiwifruit, apples, pears) all fare well as overseas consumers search for high quality, low emissions, sustainably produced food.

New Zealand's exports of metal and non-metallic mining products, including critical and rare earth minerals like garnet, ilmenite and zirconium, expand significantly as offshore buyers look to diversify their import sources away from politically instable or less sustainability-focused competitors. Our steel and aluminium exports increase as export markets look for low-carbon products that won't trigger CBAM penalties in the EU and potentially elsewhere.

New Zealand's **expertise in science-related services becomes increasingly recognised offshore**, leading to significant increases in exports of these services (scientists travelling overseas to deliver advice to major agribusinesses, etc.).

Despite the emergence of sustainable marine fuel and e-SAF industries, exports remain limited. This reflects competition for resources across the economy crowding out any rapid export growth – most is consumed domestically. Both forms of fuel remain relatively expensive compared to alternatives, and despite their sustainable features, overseas consumers are not yet prepared to absorb large cost premiums for small volumes.

FIGURE 13 EXPORT IMPACTS, $B CHANGE FROM BASELINE, SELECTED INDUSTRIES



Household spending rises slowly at first, mainly because a larger share of their disposable income is saved in order to fund (at a macroeconomic level) more investment as the economy expands. As **labour productivity gains start to accelerate, household incomes and spending pick up in the late 2030s**.

4.3.3. Industry impacts

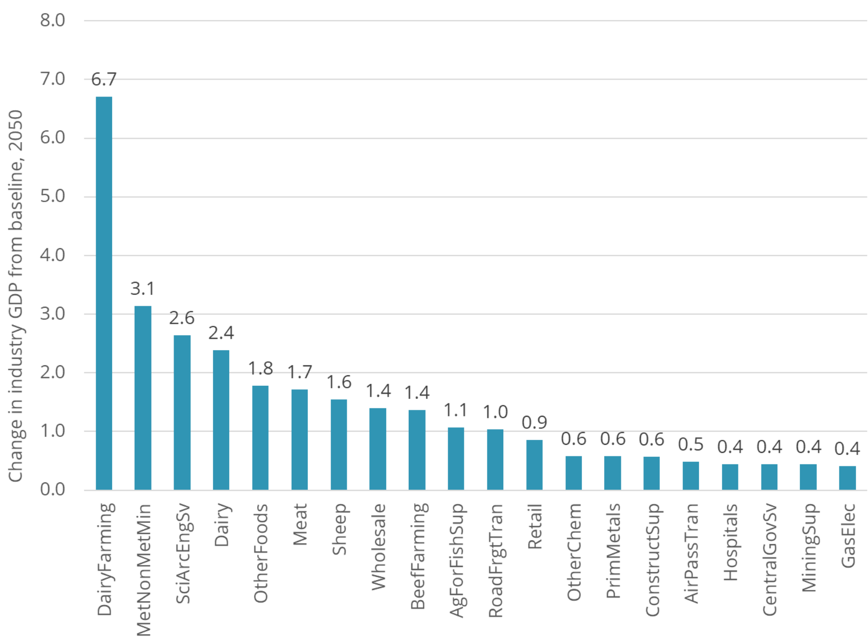
In dollar terms[18], Figure 14 shows the industries that expand the most by 2050, relative to baseline. The **largest gains are in the primary sector (farming, downstream processing, support services), mining and science-based services**.

The additional goods production generates more demand for freight transport and wholesale services as products are delivered to ports and then transported to discerning export markets.

As shown in Figure 15, industries that contract relative to the baseline by 2050 (recalling that doesn't mean they are smaller than today – just not as big as they otherwise might have been) are largely:

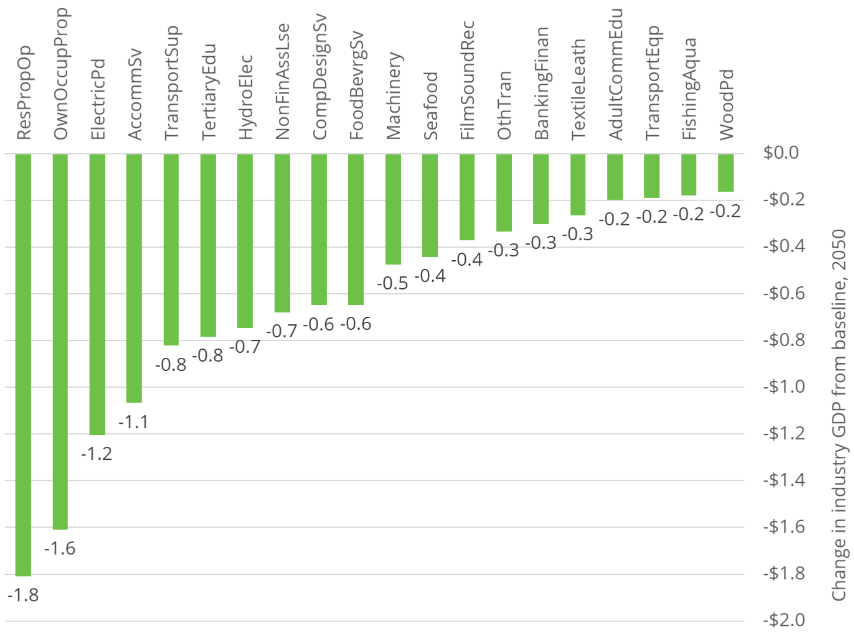
- Non-tradable services that are labour-intensive and suffer from higher economy-wide labour costs (e.g. tertiary and adult/community education, non-financial asset leasing, computer design services, banking and finance).
- Exchange rate-exposed goods and services exporters that suffer 'Dutch disease' effects from the higher exchange rate because of strong demand for New Zealand's traditional exports. (e.g. accommodation services, food and beverage services, film and sound recording, electrical product manufacturing, machinery manufacturing, seafood processing, textiles and leather products).

FIGURE 14 INDUSTRY GDP, $BN CHANGE FROM BASELINE, 2050, SELECTED INDUSTRIES



[18] In percentage change terms, the sustainable marine fuel and sustainable aviation fuel (e-SAF) industries expand massively. However, they start from such a low initial base that the change in dollar terms is not large.

FIGURE 15 INDUSTRY GDP, $BN CHANGE FROM BASELINE, 2050, SELECTED INDUSTRIES



4.3.4. Emissions impacts

As in RT, **New Zealand continues to meet its Net Zero targets by 2050 while expanding the economy. So we are generating more GDP per tonne of emissions**.

Figure 16 shows the percentage change from the baseline in emissions for several of the most affected industries. There are good news emissions stories for many:

- The increased R&D and investment in science sees cost-effective methane inhibitors introduced early in the farming sector, leading to sharp declines in methane emissions in dairy, sheep and beef farming.
- Emissions from air passenger transport decline slightly, because of lower tourism demand (which has flow on demand impacts for domestic flights) and an increase in the use of domestically produced e-SAF. A similar pattern emerges for ship passenger transport.
- Emissions from seafood processing decline due to it using less fossil fuel-based energy for storing fish and transforming it into consumer products.

Several industries see their emissions increase, including:

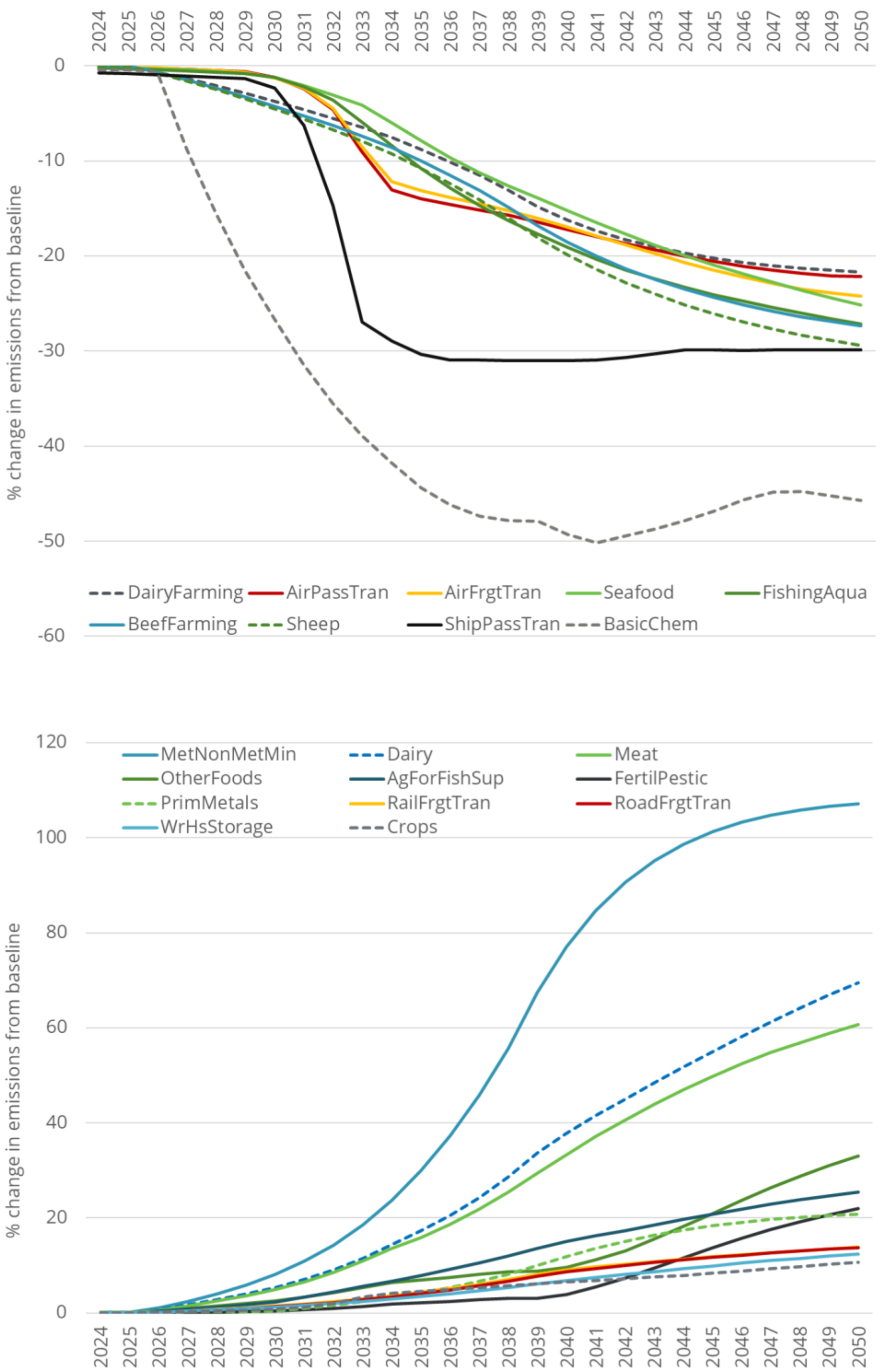
- Metal and non-metallic mining is an emissions-intensive industry, and its emissions grow sharply as the industry expands.
- Food processing (dairy, meat, other foods) emissions increase due to an increase in demand for their products in export markets, plus an increase in the supply of raw inputs (milk, meat, fruit and vegetables) from more efficient on-farm techniques.

- The road and rail freight industries' emissions increase to move the extra bulk of primary products around the country. The warehouse and storage industry's emissions rise above baseline as these supply chains grow.

In this scenario, the **ETS price increases above the baseline. Much of the additional export and GDP growth in this scenario comes from highly emissions-intensive industries**, notably food processing, mining and freight transport. While we assume a degree of emissions-reducing technological change in these industries, it is less than assumed in the RT scenario.

More activity means more emissions, requiring the purchase of more surrender obligations. The additional demand for units pushes the ETS price up above baseline from the mid-2030s, ending around $180 higher than baseline by 2050.

FIGURE 16 EMISSIONS IMPACTS, % CHANGE FROM BASELINE, SELECTED INDUSTRIES



4.4. Tech haven scenario results

4.4.1. Reminder of scenario description

In this Tech scenario, New Zealand opens its border aggressively to young, mobile 'digital nomads'. Net migration increases from 25,000 per year to 60,000, leading to the population being almost 500,000 larger by 2050. These digital nomads are predominantly young, highly skilled/productive and want to work in the creative and tech industries. This sees rapid expansion of tech-based industries, including extra output and exports from data centres, computer design services and other tech-related services.

In this scenario AI plays a large role in transforming the economy, lifting capital productivity in high-tech manufacturing and commercial services. It also frees up more leisure time for the labour force, allowing them to spend more on activities such as recreation and cultural activities.

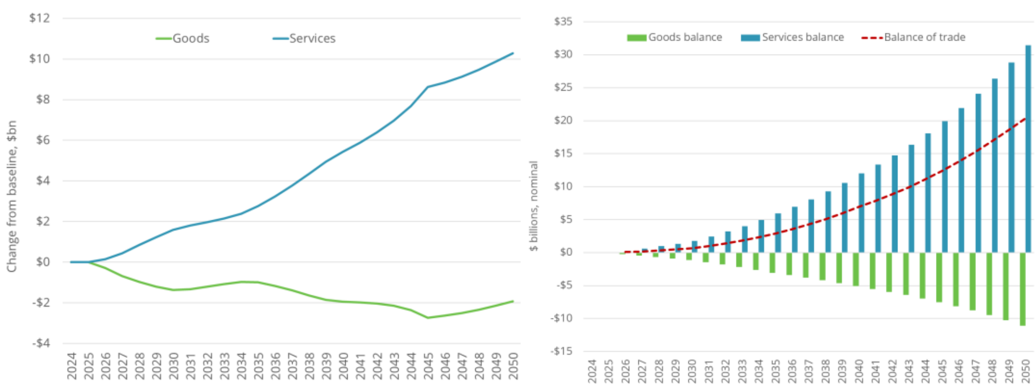
4.4.2. Macroeconomic impacts

In this scenario, **real GDP lifts above baseline by around $73bn** or 12.5% by 2050 (Figure 18 and Figure 19). This scenario is relatively simple from a conceptual perspective: New Zealand has more workers and consumers than in the baseline, and those **workers are younger, tech-savvy and highly productive**. And with the ever-accelerating role of AI in the economy, industries incorporating repetitive tasks become more productive.

The main impacts of this scenario are:

- The **export sector becomes more weighted towards tech services** and tech-intensive goods. Our traditional goods exports decline relative to the baseline (left panel in Figure 17). Total export revenue lifts strongly, by around 14% above baseline by 2050.

FIGURE 17 EXPORTS OF GOODS AND SERVICES, $B CHANGE FROM BASELINE



- Imports increase too, but at a slower rate. This is because of the shift in spending patterns of the average household, away from imported goods towards locally produced non-tradable creative and leisure services.

- **Real wages increase as workers become more productive**, and industries become more profitable. This, along with a larger population, boosts household spending.
- **Investment rises faster than GDP in the early years of the projection as industries invest heavily in AI.** This, along with greater labour and capital productivity, further boosts gross operating surplus (i.e. profitability) and generates another round of capital expenditure as output grows.

FIGURE 18 MACROECONOMIC IMPACTS, $B CHANGE FROM BASELINE

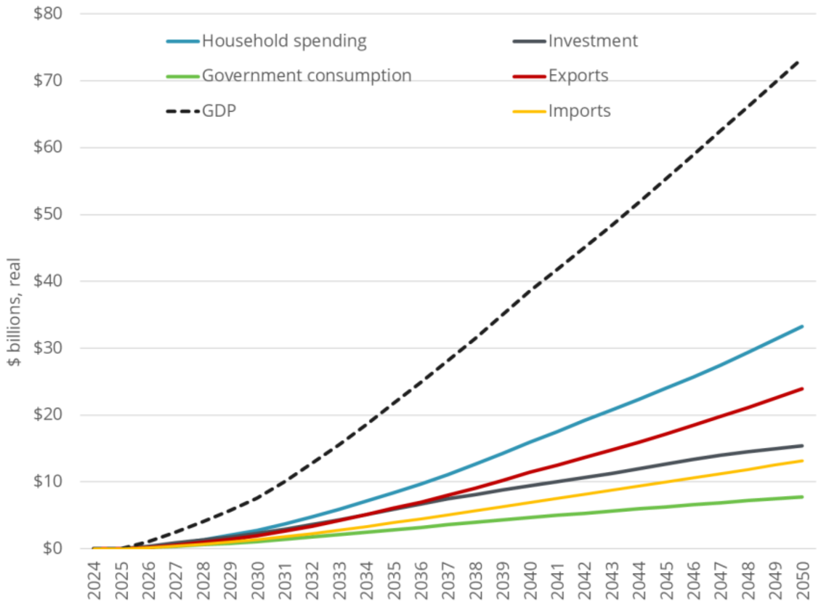
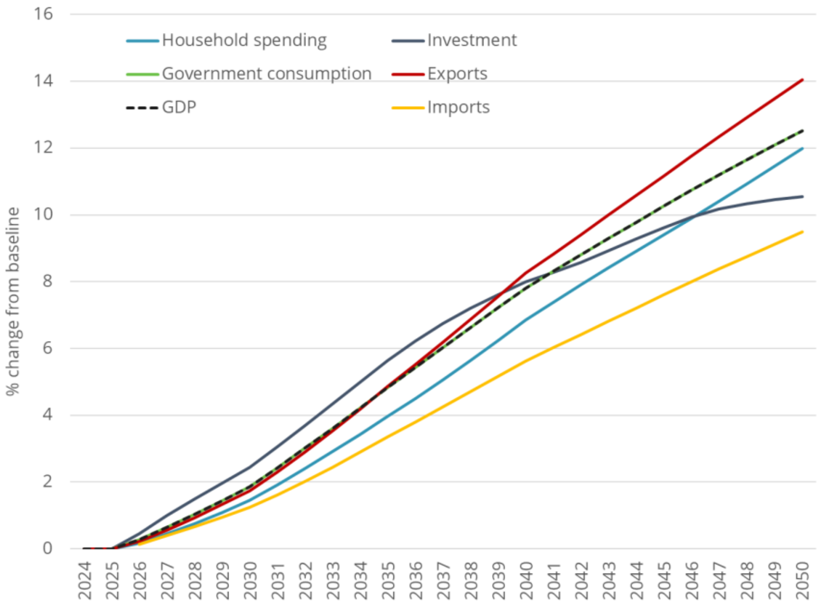


FIGURE 19 MACROECONOMIC IMPACTS, % CHANGE FROM BASELINE



4.4.3. Industry impacts

The **'servicification' of the New Zealand economy** can be seen in Figure 20. Industries like computer design services; scientific, architecture and engineering services; legal and accounting services; advertising and management consulting services; internet and data services (i.e. data centres) and film and sound recording services all expand significantly.

Many of the jobs in these industries will be flexible in terms of time and location. This amenability to working from home will suit young, creative types who have worked this way since they entered the labour force.

FIGURE 20 INDUSTRY GDP, $BN CHANGE FROM BASELINE, 2050, SELECTED INDUSTRIES

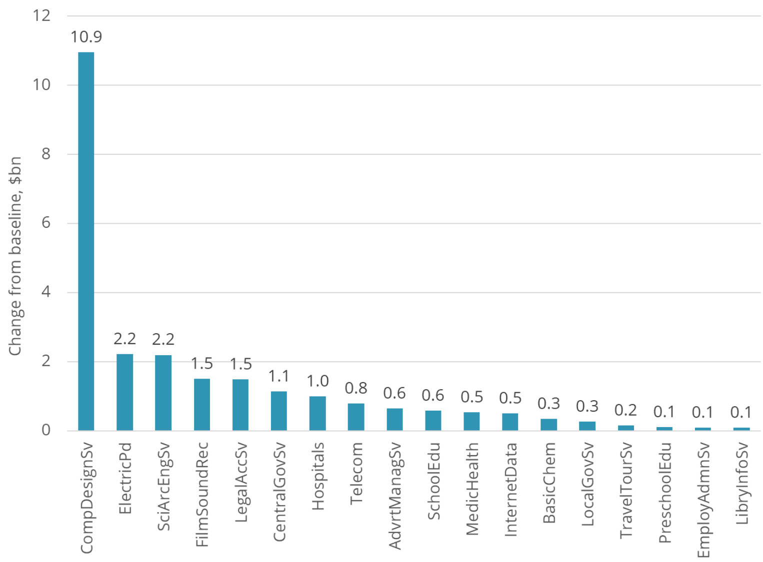
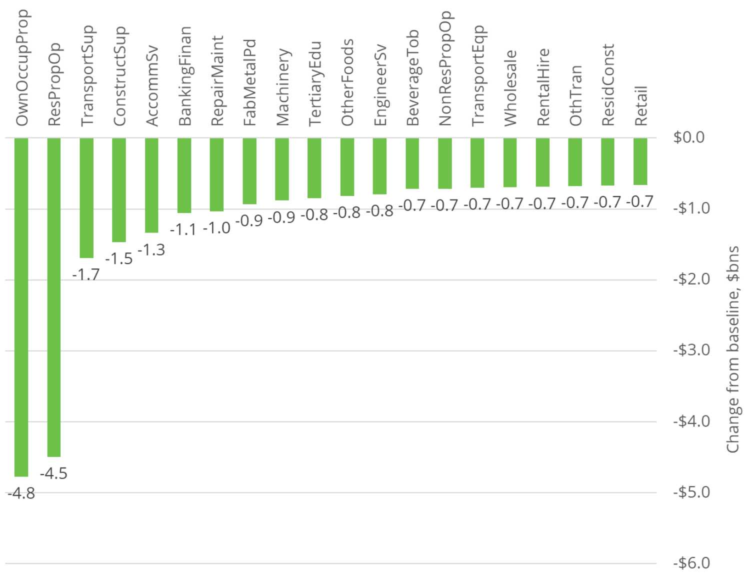


FIGURE 21 INDUSTRY GDP, $BN CHANGE FROM BASELINE, 2050, SELECTED INDUSTRIES



Government-provided services such as school education and hospitals also grow in line with the expanding population.

Not all service industries grow faster than the baseline in this scenario, however. As more and more workers look towards flexible, tech-intensive or creative services careers, **the attractiveness of more 'regular' service jobs in tourism diminishes**. This sees the accommodation and food and beverage services industries get marginally smaller than baseline by 2050.[19]

The largest 'loser' in this scenario is 'owner occupied dwellings', although this is largely a statistical artefact. It represents the implicit benefits to home-owners of living in their own homes. A decrease in value-added here can be thought of as the result of a greater share of the population renting rather than buying.

Other industries to contract slightly include heavy manufacturing (fabricated metal manufacturing, transport equipment manufacturing, machinery manufacturing, etc) **and some primary processing** industries. The latter face headwinds from the appreciation of the New Zealand dollar as services exports grow rapidly.

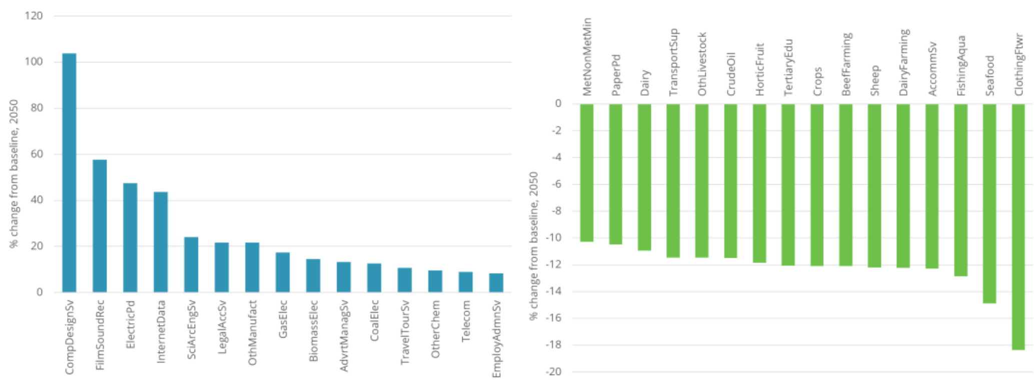
4.4.4. Emissions impacts

This scenario sees a change in the distribution of greenhouse gas emissions across industries. The tech and professional services sectors draw on more electricity to power their expansion.

Unlike in RT and T&G we do not make any specific assumptions around cheaper renewable energy in this scenario. As a result, fossil fuels use increases to generate the additional electricity demanded by the tech sector, lifting coal and gas electricity emissions.

Extractive industries such as mining, farming and primary processing all emit less than the baseline in 2050 as resources are drawn away into the services sector.

FIGURE 22 EMISSIONS IMPACTS, % CHANGE FROM BASELINE IN 2050, SELECTED INDUSTRIES



[19] The negative impacts on tourism are somewhat moderated by higher household spending on domestic tourism as AI frees up more time for leisure activities.

5. Implications and lessons

These scenarios are not forecasts of what will happen in New Zealand and our modelling of them is not intended to be a cost benefit analysis. It is very difficult to know whether the myriad assumptions embodied in each scenario are likely to occur, and if they do, to what extent and over what timeframes.

However, this illustrative modelling exercise has demonstrated that different perspectives and narratives on the future state of the world and New Zealand's policy and commercial responses to them have different implications for the size and composition of the economy.

This in turn has different implications for electricity demand and supply, and hence for Transpower's future investment strategies.

Key takeaways include:

- Our scenarios incorporated some bold assumptions around efficiency improvements, structural change and the sorts of goods and services the global economy might want to buy from New Zealand. Yet even major technological developments in energy (such as those assumed for wind and solar electricity in RT and T&G) or consumer preference shifts towards more sustainably produced exports (as in T&G) won't change the size of the economy dramatically, although its composition will change.
- This is because electricity, while obviously critical for several heavy-using industrial producers (pulp and paper, dairy processing, metals production, etc.), is less important for most other parts of the economy. On average, electricity accounts for only 4% of the cost of inputs to production across the economy. This is partly because around 2/3 of New Zealand's economy is in the services sector, and most services industries are not highly electricity intensive.
- Productivity or efficiency improvements notwithstanding, the resources available for production are limited. When one part of the economy expands, those resources necessarily have to come from somewhere else, causing other industries to contract (or grow less rapidly). And the prices of factors of production and intermediate inputs will be constantly changing in response to shifts in demand and supply.
- Modelling future economic scenarios requires recognising these resource constraints, feedback loops, crowding out and price effects. Without such constraints in place, it is easy to come up with 'unicorn' projections where all sectors can grow faster forever with no trade-offs. This provides little value for strategic planning efforts.
- The most obvious way to grow the economy is to find more resources, be that more people (as in Tech), more energy efficient capital (as in RT) or more natural resources (as in the mining sector in T&G). By unlocking more resources, the economy can expand with less crowding out of some industries as other industries expand.
- However, bringing in more resources is not easy or without cost. In the case of net migration, there will always be political challenges and infrastructure considerations. Opening up more land for mining is not always a popular move with local residents.

And new technology and capital – usually imported – is expensive for Kiwi firms who have traditionally not had the balance sheet depth or scale to make big investment purchases.

- If we want a more prosperous and vibrant economy in coming decades, boosting technology uptake and lifting productivity growth is vital. When labour, capital or land become more efficiently used, be that through better education and R&D, the use of AI or primary sector innovation, economic activity can expand and change in composition over time without the need for additional resources.
- This highlights the importance of ongoing investigations into why New Zealand's productivity record has been so modest in recent decades and the development of bipartisan, sustainable policy responses to turn around our long term decline and drive forward well-being improvements.[20]

[20] See, for example, some suggested ideas for bipartisan policy settings in Sense Partners. 2023. 'We're all in this together: How can business and government collaborate to address shared challenges out to 2050?'. Report to Business New Zealand.

Appendix A Scenario shocks

TABLE 1 CGE MODELLING SHOCKS FOR EACH SCENARIO

Rapid transition scenario	
What we modelled	How and how much
Labour productivity gains in traditional manufacturing and energy sector	Increase in labour productivity by 2% per year above baseline.
More affordable EVs	EVs 10% cheaper than baseline by 2030.
Food, cement and metals manufacturing shifts away from fossil fuels to renewables	Food manufacturing and cement manufacturing: Reduce share of coal and gas use to 0-5% by 2050, front-loaded to mid-2030s, switch to electricity. Primary metals emissions intensity declines by 25% from mid-2030s.
Solar and wind electricity prices fall	Reduce capital costs of wind and solar by around 1% per year relative to baseline; increase capital productivity by 2% per year.
Expansion of renewable energy supply to keep pace with demand	Tie renewables investment directly and contemporaneously to electricity demand rather than via lagged RoR-capital link.
Biomass SAF	From 2030, direct 12% of woody biomass to SAF production by 2050. Reduce cost of production relative to jet fuel by 50% by 2050.
Higher spending per tourist	Preference shift of international visitor demand that compensates for higher flight costs; move demand curve out by 10% using shifter.
Lower afforestation	~6% lower than baseline by 2050.
Transform and grow scenario	
What we modelled	How and how much
Labour productivity gains in agricultural support services and science	Increase in labour productivity by 2% per year above baseline.
Methane inhibitor reducing emissions	20% reduction in emissions intensity from S&B and dairy cattle farming by 2050, starting in 2035.
On-farm and primary processing capital productivity gains	Increase in MFP of ~1% per year above baseline.
Additional steel and aluminium production	50% expansion in capacity by 2030, 100% by 2032.
Expansion of land available for minerals mining	Starting in late 2020s, expand land available for mining by 50% by 2050.
e-SAF and sustainable marine fuel production	Gradually increase e-SAF share of aviation fuel use to 4% by 2050 by reducing its price relative to jet fuel by 25% by 2050. Similar assumptions for marine fuel.
Expansion of renewable energy supply to keep pace with demand	Tie renewables investment directly and contemporaneously to electricity demand rather than via lagged RoR-capital link.
Tech haven scenario	
What we modelled	How and how much

Higher net migration inflows	Additional 480,000 net migration by 2050.
Productivity gains in advanced manufacturing, business services and creative industries	Increase MFP by~2% per year above baseline
Growth of data centres	Expand capital in relevant industry by 50% by 2050, with additional production exported.
Rapid uptake of AI boosting capital productivity	Double baseline capital productivity in high-tech manufacturing and commercial services sectors by 2050.
More household spending on leisure activities	Increase share of household spending directed towards leisure activities by 10% by 2050.

Closure assumptions

TABLE 2 KEY CLOSURE FEATURES FOR SCENARIOS

Which variable is exogenous?	Implications
Change in ratio of balance of trade to GDP	Real exchange rate adjusts to ensure net exports move in line with GDP
Change in ratio of central government budget balance to GDP; ratio of government spending to real GDP	Ensures fiscal position moves in line with economic activity
Net emissions	Economy meets net zero targets in 2050; lower sequestration/more gross emissions cuts in RT
Ratio of investment to capital in electricity industry and some fuel industries	Electricity sector investment responds to demand rather than rate of return, so expands without lags
Net migration	Set at baseline levels in RT and T&G; increased by 480,000 by 2050 in Tech
Change in real government investment	For Tech only; used to proxy extra infrastructure spending to accommodate additional population
Various labour, capital, natural resource and energy efficiency parameters	Used to show benefits of additional R&D, science and education investment in various industries, AI-related capital productivity growth, methane inhibitors (T&G), and higher skill levels of digital nomads (Tech)

Appendix B The GSM-NZ model

Introducing GSM-NZ

We use an advanced dynamic CGE model of the New Zealand economy for this project. Titled GSM-NZ[21], it was built for Sense Partners in late 2019 by Dr Ashley Winston of MacroDyn Group LLC, based in Washington DC (now Phylleos Inc).

The New Zealand CGE modelling suite[22] is built on the foundation of the path breaking and proven US GSM model. GSM incorporates a wide range of policy modelling innovations created for high-profile projects in a range of countries over the last 30 years.

Versions of the GSM modelling framework continue to be used by governments in several countries, and applications have informed key policy reform and other economic matters in many dozens of countries in addition.

GSM-NZ has a lineage that traces back to the MONASH dynamic CGE model developed by the Centre of Policy Studies, then at Monash University, now at Victoria University, Melbourne.[23] Dr Winston implemented several improvements to the MONASH model as a PhD student under the tutelage of Professor Peter Dixon in the late 1990s/early 2000s.

Dr Winston continued developing dynamic CGE models throughout the next two decades, including the USAGE model of the US economy[24] and the FLAGSHIP[25] suite of models for over 20 countries, before building and continually extending the proprietary GSM suite of models from 2015.

GSM-NZ is built and run in the GEMPACK software suite.[26]

Technical documentation is under development, and a draft is available from the authors on request.

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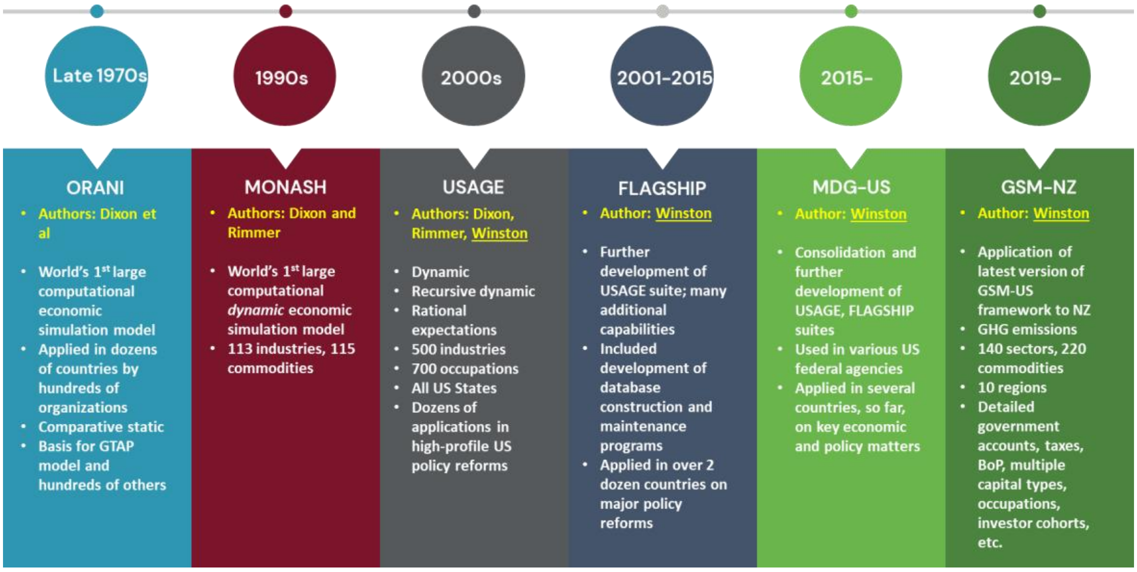
[21] Earlier versions of GSM-NZ were called MDG-NZ.
[22] We have a variety of modelling solutions, including comparative static, recursive dynamic, top-down regional, and bottom-up regional versions, with different levels of industry and commodity detail.
[23] See https://www.copsmodels.com/monmod.htm. Full documentation is in Dixon, P. and M. T. Rimmer. 2002b. *Dynamic, General Equilibrium Modelling for Forecasting and Policy: a Practical Guide and Documentation of MONASH*. Melbourne: North-Holland.
[24] See https://www.copsmodels.com/usage.htm. Dixon, P. and M. T. Rimmer. 2002a. 'USAGE-ITC: Theoretical Structure'. Centre of Policy Studies, Monash University, Australia, April 2002.
[25] See KPMG. 2015. 'Tax reform in Australia – the facts: CPA Australia commissioned study on the impacts of GST reform and tax simplification'
[26] See Horridge J.M., Jerie M., Mustakinov D. & Schiffmann F. 2018. 'GEMPACK manual'. GEMPACK Software, ISBN 978-1-921654-34-3. https://www.copsmodels.com/gpmanual.htm

FIGURE 23 45+ YEAR HISTORY OF GSM-NZ



What is a CGE model?

CGE models are commonly used tools for policy analysis. Such models typically consist of:

1. A **database** that represents an economy in a certain year based on input-output (IO) tables. The database specifies the interactions and relationships between various economic agents including firms, workers, households, the government and overseas markets.

2. Behavioural **parameters** governing agents' responses to relative price changes (e.g. elasticities).[27]

3. A **system of equations** that define the model specification or theory, which is generally based on standard economic assumptions[28], but not necessarily constrained by them (for example, in the always-and-everywhere attainment of equilibrium after shocks are imposed).

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[27] We rely on published studies for elasticity estimates to calibrate GSM-NZ. Elasticities are set at values widely understood to be valid in the modelling community and can be replaced by country- or industry-specific estimates where available for specific projects.

[28] These include, for example, consumers maximise their utility subject to their budget constraints; firms maximise their profits by buying intermediate goods and inputs (labour and capital) and selling outputs to other domestic and international firms, households and government; there is a market for each commodity (final and intermediates) and in equilibrium market prices are such that demand equals supply in all input and output markets; and under the standard assumption of constant returns to scale firms earn zero pure profit. Alternative theoretical specifications can be incorporated as required.

From an initial equilibrium where demand equals supply in all factor, final demand and intermediate input markets,[29] the system is then 'shocked' by changing one or more variables that represent a policy change or other change in economic conditions.

By comparing the pre- and post-shock databases, we can then observe the effects of the shock in question in terms of changes to GDP, employment, wages, industry output, etc.

Bringing dynamics into the picture

Static CGE models consider only 'before' and 'after' the policy shock. There is no ability to consider the nature of the adjustment path between equilibria.

A dynamic CGE model allows the user to examine in each intervening period (usually each year) how variables adjust from the time when a shock is implemented to the time when all its effects have worked through the economy (which may be several years).

GSM-NZ contains four key **dynamic mechanisms** that link successive years:

1. The deviation in the real wage rate away from its forecast path in year *t* caused by a policy shock equals the deviation in year *t-1* plus a term reflecting the gap in year *t* between the employment deviation and the deviation in labour supply. That is, real wages deviate from the baseline based on the gap between the changes in the labour supply and employment caused by a policy shock.

   Real wages are sticky in the short term, meaning labour market impacts are felt more through changes in employment. Further out in the projection period, employment gradually returns to the baseline, meaning impacts are more commonly seen through real wage changes.

2. Capital at the start of year *t* equals capital at the end of year *t-1*.

   Capital stock in an industry at the end of year *t* equals the capital stock at the start of year *t,* depreciated at a given rate, plus investment in year *t* for that industry.

   Investment in year *t* for an industry is a function of the expected rate of return (i.e. gross operating surplus) in that industry. The expected rate of return is a function of the rental and asset prices of that industry's capital in year *t*, depreciation, taxes on capital, and expected changes in those variables.[30]

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[29] This is true in both a theoretical and real-world sense. For example, goods market clear because the macroeconomic accounting used in these models accommodates inventory accumulation (or decumulation), and labour markets allow for structural unemployment and other factors that allow something like a NAIRU to act as the market-clearing condition.

[30] A novel feature of GSM-NZ is the inclusion of "slack capital" capabilities for dynamic projections using nested complementarity relationships. This allows for endogenously determined proportions of productive capital stocks and other "fixed" factors (like land and other natural endowments) to become idle at low rates of return during periods of falling demand. Along with the labour market treatment described above, the modelling suite is capable of more realistic dynamic simulations through the business cycle, tempering a standard dynamic CGE tendency to create unrealistically fast recoveries from downturns in response to low primary factor prices.

3. Net foreign liabilities at the start of year *t* equal net foreign liabilities at the end of year *t-1.* Net foreign liabilities at the end of year *t* equal net foreign liabilities at the start of year *t* plus the current account deficit for year *t.*

   The current account deficit for year *t* is imports less exports plus interest payments for foreign liabilities less exports of royalties, and less net transfers from foreigners to New Zealand residents.

4. Public sector debt at the start of year *t* equals public sector debt at the end of year *t-1*.

   Public sector debt at the end of year *t* equals public sector debt at the start of year *t* plus the public sector deficit for year *t*.

The GSM-NZ model is generally solved in recursive dynamic mode, as this has clear advantages in terms of (for example) realistic behavioural responses that can include errors in expectations.[31]

Projection periods can extend out for decades, or for one recent project, to 2100.

Emissions

We incorporate greenhouse emissions by type of gas (CO_2, CH_4, N_2O, F-Gases etc.) that enter production functions in their raw tonnages and are then converted to CO_2-equivalents via Global Warming Potential (GWP) factors.

Energy accounts are coded with primary and final energy types, stationary and transport energy use, and electric generation distinguished on generation “sent out” (net of distribution losses) and “end use” (includes distribution and transmission losses) bases. Emissions data is sourced from MfE, supplemented with existing emissions intensity of output estimates from other CGE model databases.

Economy-wide greenhouse gas emissions are initially generated from the baseline economic activity by industry projections, using emissions intensity coefficients, along with exogenously imposed energy efficiency improvements that largely reflect historical trends.

We then adjust aggregate gross emissions through technological change parameters to align with the Climate Change Commission’s (CCC) ‘Current Policy Reference’ (CPR) track out to 2050 (CCC, 2022). We trend down agricultural emissions in line with the CPR track.

The baseline also draws on the CCC’s projected NZU price for the CPR, at $35 real per unit.

The emissions baseline includes known emissions policies such as the Emissions Trading Scheme (ETS) but does not include ‘step change’ technologies such as hydrogen energy or electric planes, given uncertainty over their feasibility, effectiveness and timeframes.

[31] We can also conduct comparative static analyses of both short- and long-run timeframes, along with (much less frequently) forward-looking or ‘rational expectations’ dynamic simulations that capture anticipation effects but that impose arguably unrealistic ‘clarity of foresight’ assumptions on simulation output.

Projected forestry removals for our baseline and policy scenarios were provided to us by Climate Forestry Association (CFA) for a previous consulting project.

We assume New Zealand reaches net zero for long-lived gases around 2050. Biogenic methane emissions are reduced to be broadly consistent with the midpoint of the legislated New Zealand domestic target of a 24-47% reduction from 2017 levels.

To proxy an emissions cap, we hold economy-wide emissions covered by the ETS constant at the baseline level for all scenarios. Emissions are able to move between covered sectors as output expands or contracts in the policy scenarios, but aggregate ETS emissions do not change between the baseline and policy scenario. Agricultural emissions are not constrained.

The emissions price varies to ensure the demand and supply of emissions units balances.

Model closure

The closure of a CGE model refers to the elements that we tell the model about (**exogenous variables**) and those which we want the model to tell us about (**endogenous variables**).

In GSM-NZ the closure is extremely flexible, allowing us to incorporate a wide variety of inputs into simulations depending on the availability of data in a particular country, often including expert speciality forecasts from official or other expert sources.

We can adjust the closure assumptions from year to year, depending on the policy simulations we are considering. There is no need, for example, to assume full employment in all years.

The **deviation or 'policy' simulation** is the run that includes the shocks for the economic or policy experiment itself. The number of shocks can vary from a single shock to dozens or hundreds of shocks.

The results are reported as deviations – that is, as the difference between the baseline rerun results and the policy simulation results for each variable. This enables us to report results that capture only the impact of the experimental shocks themselves.

The policy simulation closure looks much more like a 'standard' economic closure. By this we mean that if we were to write down an economic model's equation in a standard theoretical manner, most of the left-hand side variables would be endogenous in the deviation simulation.[32]

Closure choice, across all simulation types, reflects choices about the economic environment and normally goes beyond a simple assessment of matching exogenous variables with shocks.

[32] There are some exceptions: for example, if a path has been endogenously generated for a certain productivity metric in the forecast, these results might be used as shocks in the deviation simulation if we believe that the nature of the experiment does not lead to additional productivity change. However, sometimes the deviation experiment does require further accommodation of shocks by productivity shifts, in which case we would leave it endogenous and report the difference between the baseline and deviation experiments.

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