TRANSPOWER

Demand Modelling Methodology

Te Kanapu Technical Approach

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DOCUMENT REVIEW AND APPROVAL

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1.0 Background and overview

1.1 Background

The Te Kanapu Technical Approach suite of documents outline how Transpower is working to develop its draft future grid blueprint. By publishing these documents, we are sharing all the data, inputs and information being used in this process, for review and feedback.

Within this suite of documents are publications we have completed within Transpower and work that has been commissioned from others. For an outline of all the documents published under our technical approach, please see *Technical Approach Summary.*

The work detailed in this document, *Demand Modelling Methodology*, covers a key input into how we developed the potential future scenarios that were presented in *A future grid blueprint for Aotearoa. Consultation 2: Potential Scenarios.*

In this document, we outline the methodology and approach for modelling national demand using the deep dive and Low Emissions Analysis Platform (LEAP) models, disaggregating demand to regional and grid exit point (GXP) levels and applying demand profiles to determine peaks.

The modelling framework is designed to support robust, scenario-based planning for the national grid, enabling Transpower and stakeholders to assess the implications of different energy futures and inform investment decisions.

While every effort has been made to ensure this information is of the highest possible quality, many assumptions are made across our work. This information should not be used for any purpose other than to inform discussions on a future grid blueprint.

We want to hear from you

The approach we are taking is collaborative: we are developing this future grid blueprint by gathering feedback and we welcome your input into this work.

Please get in touch by emailing feedback@transpower.co.nz.

Publishing feedback

We will publish a summary of the feedback we receive throughout this process on www.transpower.co.nz/our-work/te-kanapu; especially where we have changed our approach as a result of the feedback we hear.

Transparency is important in this process. Unless requested by you, we will include both your name and any information you provide as part of your feedback, on our website.

If there is any aspect of your feedback that is confidential, please make this clear to us.

For more information

Visit the Te Kanapu section on the Transpower website to find out more. There you will find the background to our work, previous and current consultations, and additional data and analysis that has been used in our work to date.

www.transpower.co.nz/our-work/te-kanapu

1.2 Overview

Modelling future electricity demand out to 2050 provides a key input into our future grid blueprint. In modelling future demand, we seek to understand how the use of electricity will grow, out to 2050. This is linked to how Aotearoa's economy and regions will grow, where new businesses will be located, and how our economy will change over time.

The output is the development of potential future scenarios. Scenarios enable people to compare different possible versions of the future, and the levers and actions that produce them. They help us to consider how our national electricity grid would need to develop to enable or respond to different possible outcomes.

In this document we outline the methodology we used to model potential future demand growth.

The document is in three parts. The first details how we modelled demand at a national level, through the completion of deep dives into demand drivers. These deep dives use historical trends and assumptions around fuel-switching and technological innovation to project future electricity demand. Nine models are used: aviation; shipping; data centres; process heat; heavy industries; motive power; next generation farming; residential, and road transport.

Secondly we detail how we modelled a 'whole energy system' approach, considering all existing demand for energy and how that demand may transition from one fuel to another. We have used the LEAP[1] software and configured the model to capture our unique New Zealand energy system. It has the energy system modelling capability representing demand, transformation and supply and resources of all fuels.

The final section of this document covers our modelling of demand at a regional level. After completing the national demand projections using the deep dive and LEAP models, demand has been subsequently disaggregated to regional and GXP levels to enable transmission power flow assessments.

This modelling work sits alongside the feedback we have heard through extensive stakeholder engagement and work we commissioned from Sense Partners, to provide another view of the future of Aotearoa. *Future Grid scenario modelling. Visions of the New Zealand economy to 2050*

Together, these inputs were used in the creation of our draft potential scenarios, published in October 2025 for feedback *A future grid blueprint for Aotearoa. Consultation 2: Potential Scenarios.*

At the time of writing consultation on these draft scenarios had closed, with an updated version of them expected in early 2026.

[1] Heaps, C.G., 2022. *LEAP: The Low Emissions Analysis Platform.* [Software version: 2024.4.0.15] Stockholm Environment Institute. Somerville, MA, USA. https://leap.sei.org

2.0 National demand modelling

2.1 Deep dive demand drivers

The deep dive demand models use historic data and demand drivers to project the future electricity demand, for use in our Te Kanapu potential future scenarios. Overall electricity demand has been split into nine models.

This segmentation enables Transpower to apply demand drivers tailored to specific sectors of electricity use.

The nine demand drivers are:

1. Aviation
2. Shipping
3. Data centres
4. Process heat
5. Heavy industries
6. Motive power
7. Next generation farming
8. Residential
9. Road transport

Exogenous inputs

Gross domestic product (GDP) was used as an economic driver within the deep dive energy models. Treasury's forecast of the economy was used as a baseline GDP forecast. We worked with Sense Partners to develop the report *Visions of the New Zealand economy to 2050*[2] to establish a set of aspirational growth assumptions and key drivers. We used sector specific GDP as inputs to the deep dive energy models.

Population growth is another economic driver and input into the deep dive energy models. Selected forecast scenarios from Stats NZ were used in the models.

[2] Future Grid scenario modelling Visions of the New Zealand economy to 2050.pdf

Uncertainty in demand models

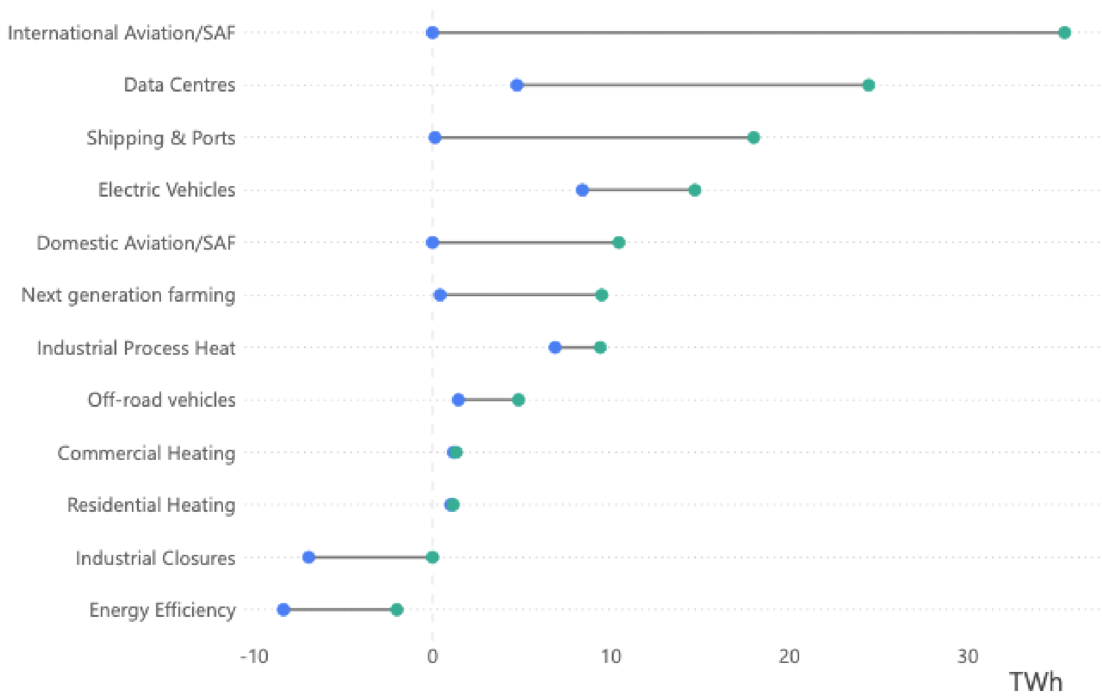
Uncertainty is inherent in all modelling and cannot be avoided, although it can be reduced. The demand models use historic data as the basis for all models, with future demand based entirely on assumptions.

We use scenarios to explore the key dimensions of uncertainty. This enables us to vary those assumptions that have large impacts on the outcomes. We consider five different scenarios; the aim with the scenarios is to represent a range of outcomes that are plausible within the uncertainty. The scenarios are not intended to accurately forecast what the future energy demand will be with low uncertainty.

For example, in aviation the fuel and technology switching assumptions to sustainable aviation fuels and electro sustainable aviation fuels (SAF/eSAF), vary a small amount across scenarios, but the proportion of SAF/eSAF made domestically varies more as this impacts the annual energy demand a lot more than the fuel switching.

Figure 1 illustrates the potential range of electricity demand increase across a selection of drivers of electricity use.

Figure 1: Potential electricity growth (or reduction) in 2050 by demand driver



2.1.1 Aviation

Aviation energy demand is split into international and domestic flights, with domestic flights split again into flight distances ranging from very short (<100 km) to very long (>1000 km). Currently aviation energy use is made up of fossil derived fuels; in future this will gradually be replaced by SAF/eSAF, direct electrification and potentially hydrogen.

Statistics on domestic and international fuel usage from the Ministry of Business, Innovation and Employment's (MBIE) Energy End Use Database[3] (EEUD) are used as the basis of the model, while the breakdown of domestic flight lengths are based on FlightRadar data[4].

The drivers of future fuel demand are both assumptions. Domestic and international fuel use is a linear increase or decrease, with system efficiency (percentage per annum) also impacting future demand. The forecast of demand is based on traditional jet fuel usage converted to useful energy; useful energy is the energy used to propel the aircraft which accounts for factors like turbine efficiency.

S-curve[5] assumptions are used for the switching of traditional jet fuel to the new technologies of SAF, direct electrification and hydrogen. Efficiencies of these new technologies are considered when converting back to consumed energy. Demand for SAF/eSAF is assumed to be a mix of imports and domestic production, while hydrogen demand will be met fully through domestic production; this is because hydrogen is difficult to transport and loses from transport would make this an unviable and expensive option.

SAF in the model is assumed to use the Alcohol-to-Jet (AtJ) fuel method; this process ferments biomass like wood chips to create alcohol that can then be turned into long carbon chains (with additional process energy) like kerosene to be used as jet fuel. eSAF is assumed to be created through combining hydrogen (created through electrolysis) and carbon (from direct air capture) directly to create a hydrocarbon like kerosene; eSAF is more energy intense to create but is not limited by raw materials like with AtJ fuel. Hydrogen for hydrogen powered aircraft is assumed to be created through electrolysis.

Figure 2 shows the simplified driver tree from aviation and **Figure 3** shows an example output from the aviation model.

[3] Energy End Use Database | EECA

[4] https://www.flightradar24.com/

[5] S-curves, also called adoption curves, are a useful analytical tool for predicting growth curves or different technologies. The curves are set by the Bass diffusion model equation.

Figure 2: Simplified driver tree of annual energy demand from aviation

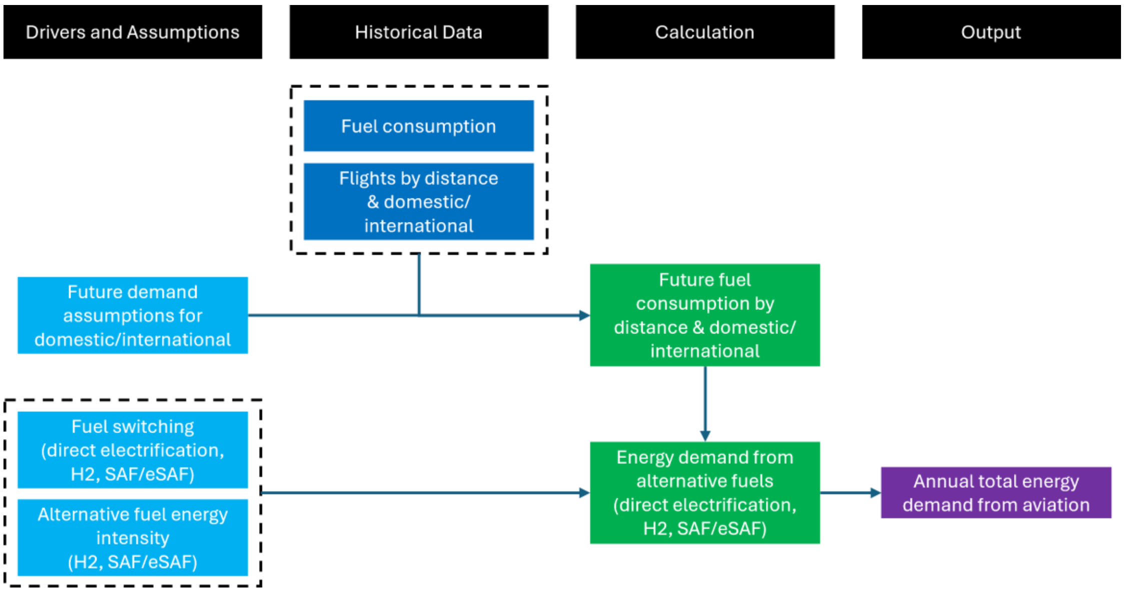
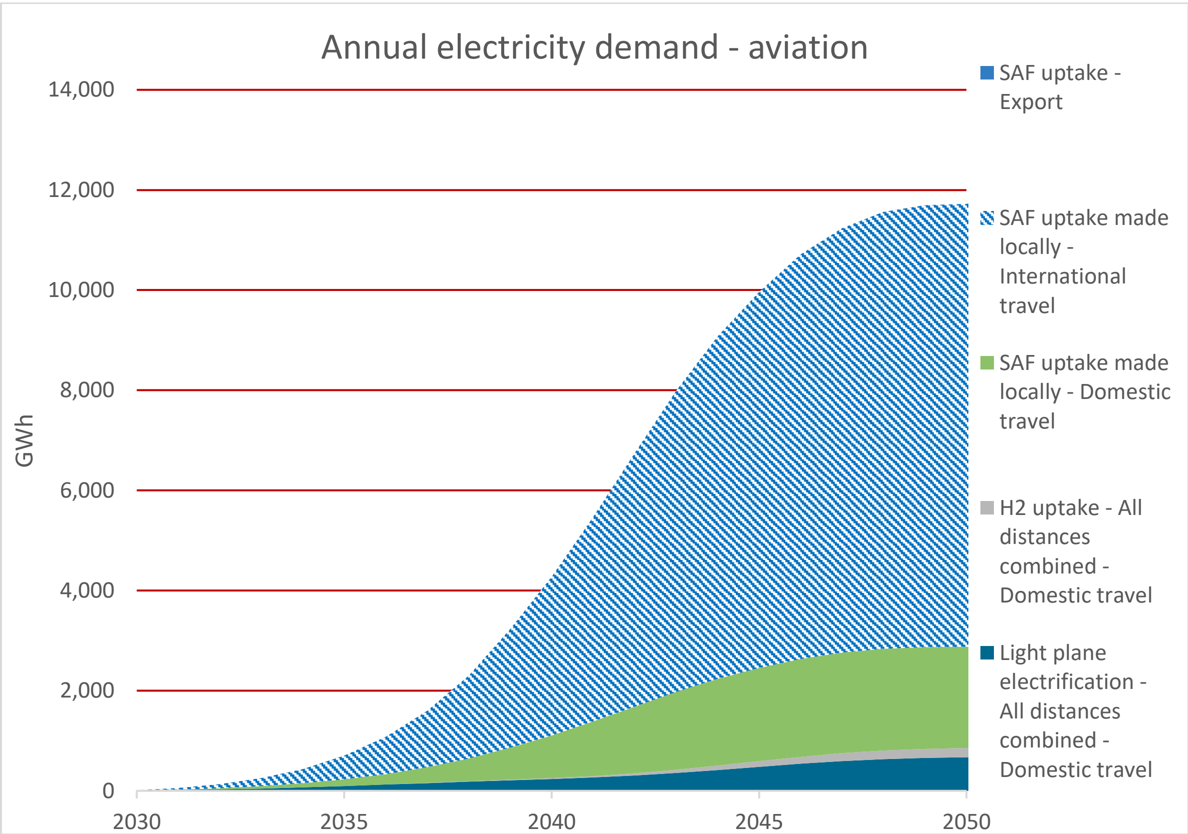


Figure 3: Stacked area graph of annual energy demand from aviation



2.1.2 Shipping

Shipping energy demand is broken down into three categories: Domestic/international marine fuel oil (MFO) usage, ferry fuel usage, and shore to ship power. Shore to ship power is not currently used in New Zealand but will play a role in reducing carbon emissions in the shipping sector; it involves using a port connection to the grid to power ships while they are docked, allowing ships (mainly cruise and container ships) to stop using auxiliary engines to produce electricity. For future demand, direct electrification of ships and the use and domestic production of eMethanol is considered. eMethanol is methanol created from renewable electricity, carbon and hydrogen. It is considered a viable path for decarbonising shipping[6].

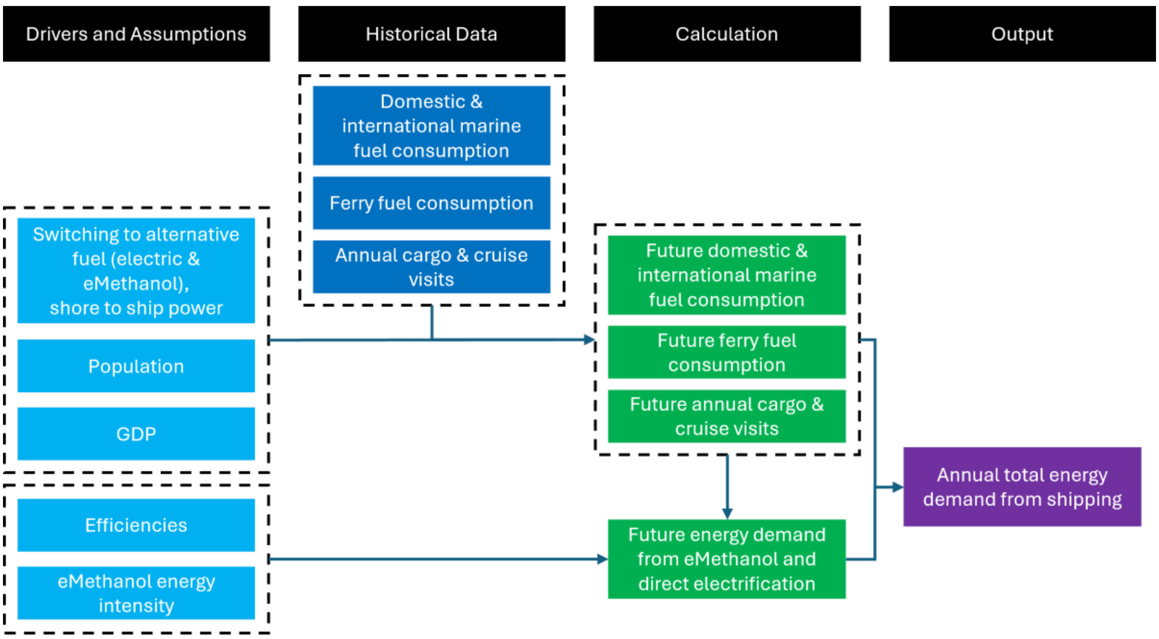
MFO usage statistics from the EEUD and ferry passenger statistics from Auckland Transport form the basis of the shipping model. Annual cruise and cargo visit statistics are estimates based on data from Auckland and Tauranga ports, and more.

GDP is the main driver for future MFO demand, with assumptions on the increase or decrease of fossil fuel imports and exports being a secondary driver. Population is the main driver for future demand of ferries. Port visits use the international demand for MFO as the main driver for future port visits.

S-curves assumptions are used to switch from fossil fuels to electrification and eMethanol. The energy for direct electrification is assumed to be satisfied domestically while eMethanol demand is assumed to be met mostly by importing and a portion met by domestic production.

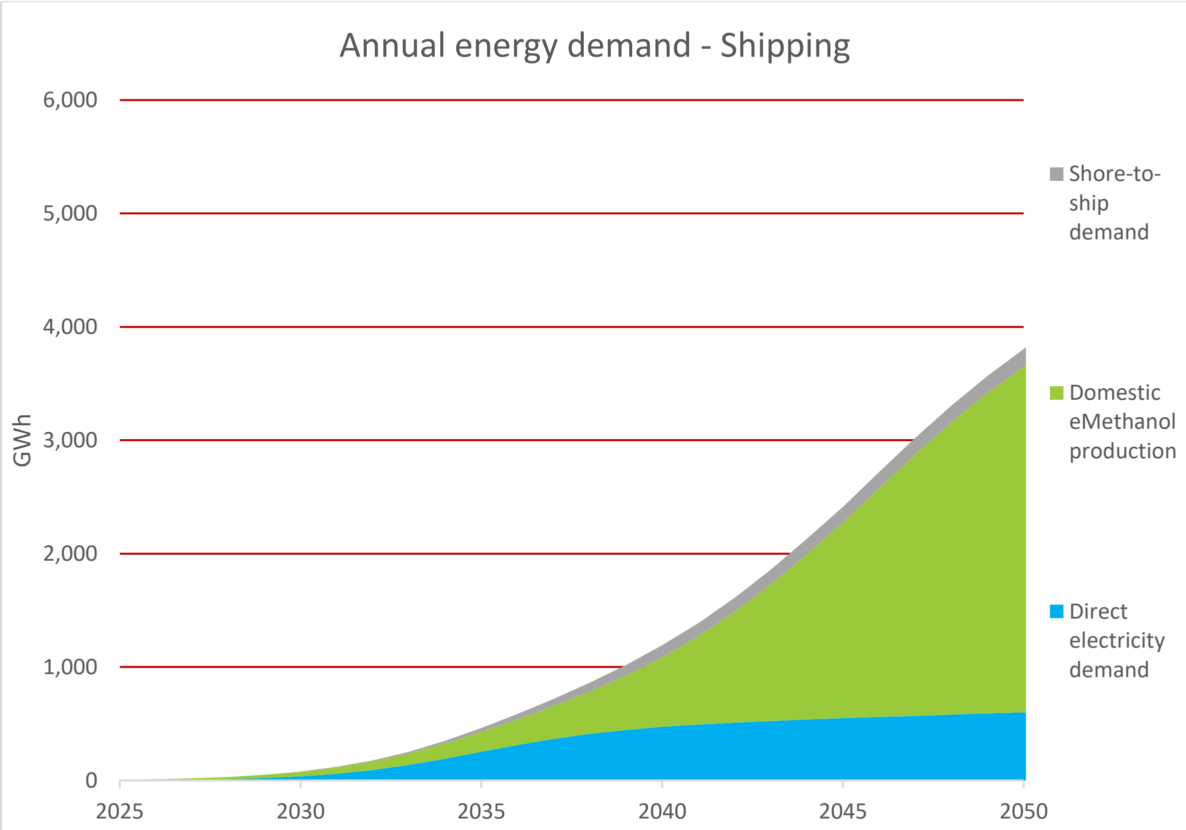
Figure 4 shows the simplified driver tree from shipping and **Figure 5** shows an example output from the shipping model.

Figure 4: Simplified driver tree of annual energy demands from shipping



[6] eMethanol may also play a role in the chemical industry.

Figure 5: Stacked area graph of annual energy demand from shipping



2.1.3 Data centres

Data centre energy demand is the electricity usage of the data centres. Electricity usage is based on the MW capacity of the data centre; this capacity accounts for:

- servers (IT equipment) – 50-60% of capacity
- cooling – 30-40% of capacity
- power infrastructure – the loses of the data centre through power transformation and distribution, < 10% of capacity
- auxiliary loads – Lighting etc. usually < 2% of capacity

The data centre model uses the existing overall demand in MW as the basis, with data for capacity coming from NZTech[7].

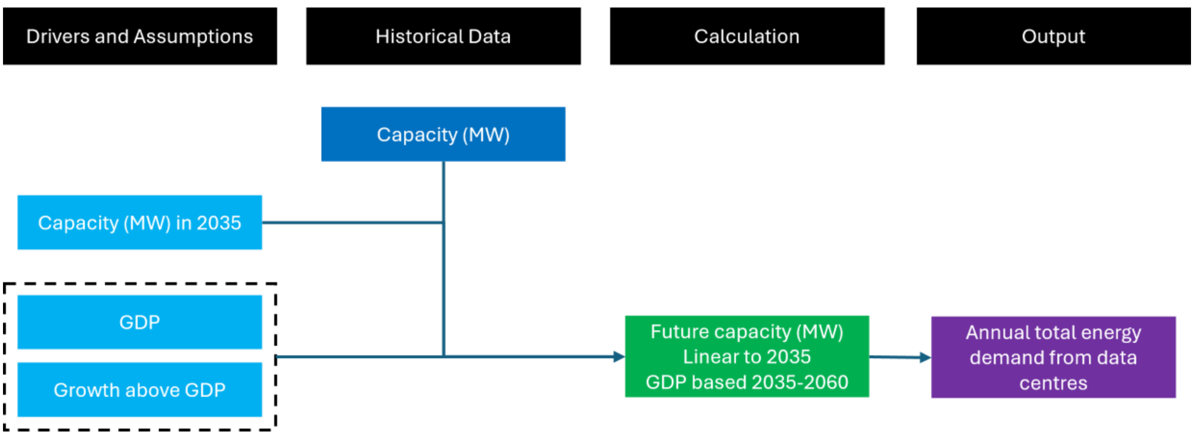
The drivers for future demand are:

- an assumption of the capacity in 2035; a linear increase
- GDP from 2035-2060, where the capacity increases based on the compound annual growth rate (CAGR) and assumptions of growth above GDP

We separate the future horizon into 'before 2035' and 'after 2035' to recognise the intense growth phase that data centres are presently experiencing[8], and that this growth phase is not sustainable longer term. The model uses the capacity, a load factor assumption and hours in a year to calculate the total energy use per year. The load factor is an assumption of how often data centres are operating on average.

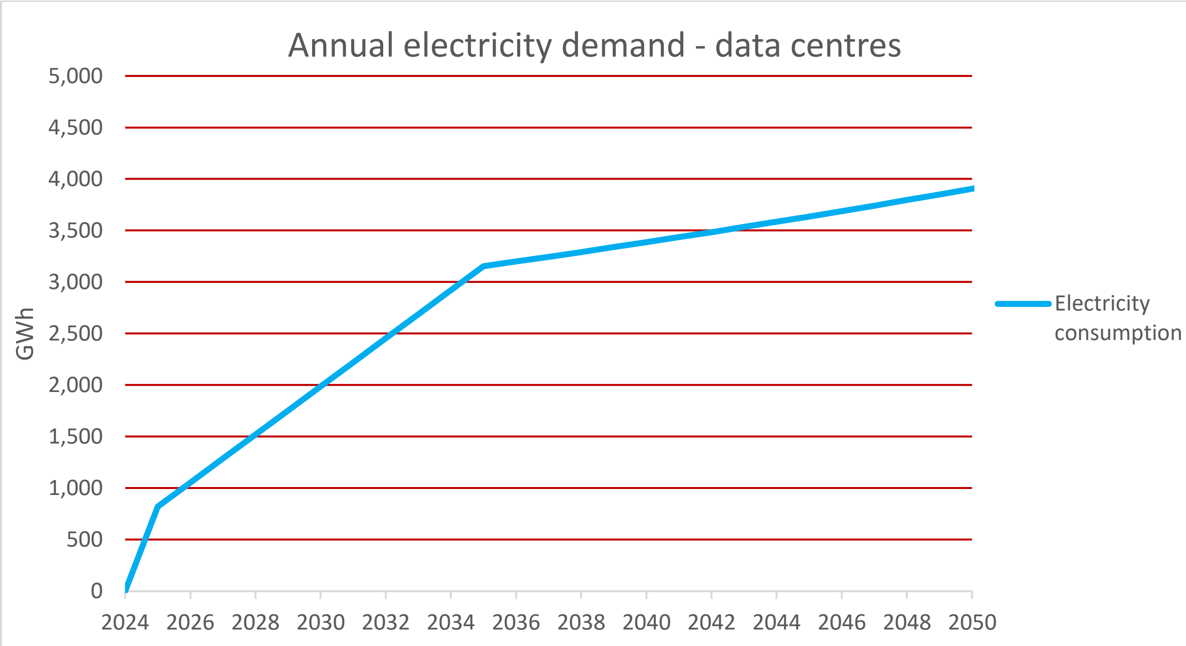
Figure 6 shows the simplified data centre driver tree, and **Figure 7** shows an example output of the data centre model; note the graph starts at 2024 as Transpower could not verify the demand for previous years.

Figure 6: Simplified driver tree of annual energy demands from data centres



[7] NZTech-Data-Centres-Report-Final-DIGITAL-002.pdf
[8] Due to artificial intelligence, for example.

Figure 7: Line graph of annual energy demands from data centres



2.1.4 Process heat

Process heat energy demand is the heat that industrial, commercial and agricultural businesses use to make their products. The most common uses of process heat are in the industrial sector with steam generation, and dairy and food processing. Process heat used in steel making and aluminium smelting is considered in the separate *heavy industries* model.

The model uses the data from the EEUD as its basis, broken down into four categories:

- space/water heating
- low temperature process heat (<100°C)
- medium temperature process heat (100°C -300°C)
- high temperature process heat (>300°C)

The EEUD also categorises the fuels used for each of these end uses.

Future demand is driven by the sector's GDP and system efficiency gains. GDP growth generally increases demand, while system efficiency reduces demand as processes are continually improved.

S-curve assumptions drive the shift away from different fossil fuels. We use the concept of useful energy to calculate how much energy needs to be shifted to renewables. Another set of s-curve assumptions drive the split across different renewable fuel sources and technologies, e.g. biomass boilers, heat pumps, geothermal. Any converted useful energy proportion that is not directly switched with the s-curves is assumed to be switched to electric boilers.

Differences in technology efficiencies are factored into the model as well; energy use is converted into useful energy for fuel switching and then converted back to consumed energy. Technology efficiencies from the NZ Energy Scenarios TIMES-NZ[9] model are used.

Figure 8 illustrates the simplified driver tree of the process heat model, and **Figure 9** provides an example output of the model for commercial process heat and others.

The process heat model also includes modelling of the auxiliary electricity demand – other demand – for commercial, industrial and agricultural businesses. Other demand is made up of lighting and electronics and uses the respective GDPs as the main driver with efficiency gains also impacting demand.

[9] New Zealand Energy Scenarios TIMES-NZ 2.0 | EECA

Figure 8: Simplified driver tree of annual energy demands from process heat and others

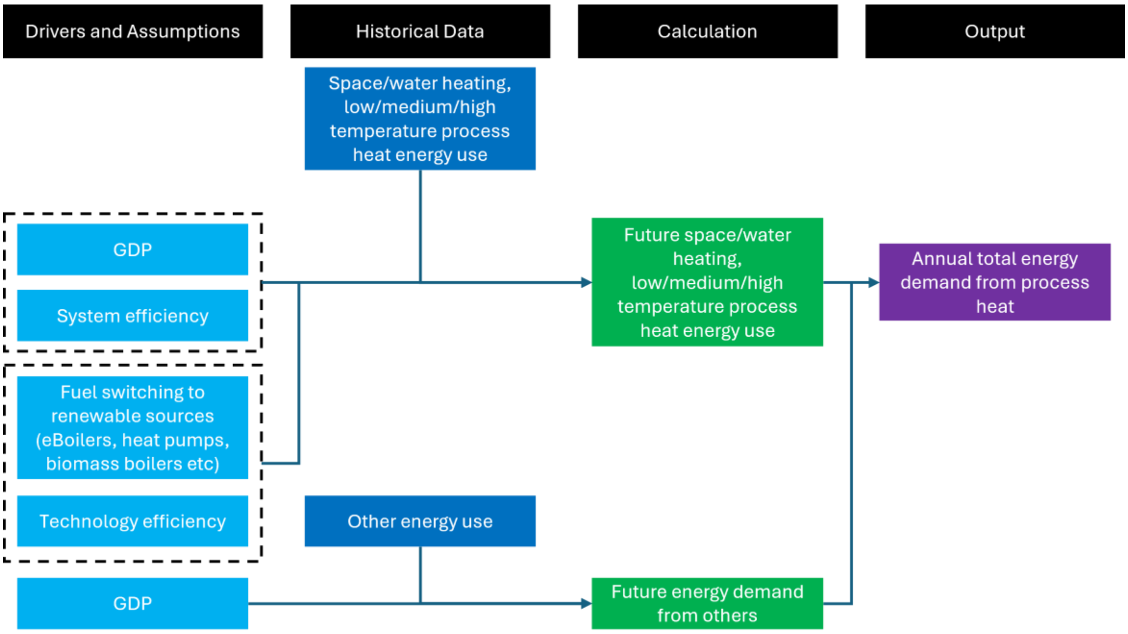
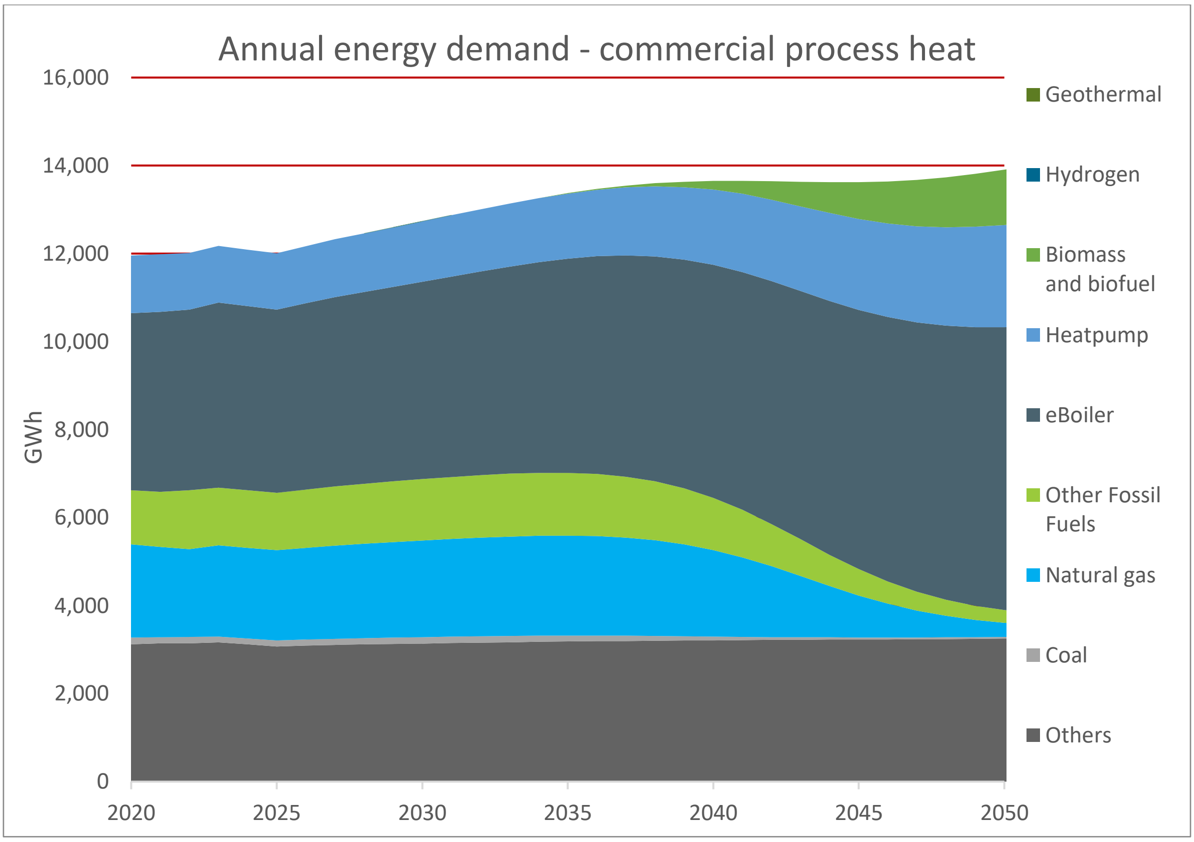


Figure 9: Stacked area graph of annual energy demand from commercial process heat and others



2.1.5 Heavy industries

Here demand is made up of four existing industrial sites that consume a substantially large portion of electricity and gas in New Zealand.

These are:

- NZ Aluminium Smelters (NZAS, Tiwai Point), the largest single user of electricity in the country
- NZ Steel (Glenbrook Steel Mill), a large electricity user also consuming ~400,000 tonnes of coal per year
- Methanex, the single largest consumer of gas, consuming 30-45% of all gas produced in the country
- Ballance (Kapuni site), the second largest gas consumer, consuming ~12% of all gas produced in the country

These industrial sites were separated from the process heat and motive power models because of their large energy consumption.

Electricity and fossil fuel usage statistics are a mix of EEUD data, the Electricity Authority's Electricity Market Information (EMI)[10], and each companies' websites.

The main drivers of demand for Methanex and Ballance Kapuni are increasing gas costs and the decline of available gas. In our scenarios, Methanex is assumed to scale down production from 2027, and to close by 2031, while Ballance Kapuni is assumed to close in 2026. These dates are not definitive but serve as placeholder dates within our scenarios.

The main drivers of demand for NZ Steel and NZAS are efficiency gains that reduce demand, and output growth which will increase demand. For NZ Steel the output growth is modelled as step changes as new electric arc furnaces are installed, and a small increase per year in the auxiliary demand. For NZAS, the output growth is entirely based on step change assumptions as new smelting potlines are added.

Figure 10 provides a simplified driver tree of the heavy industries model, while **Figure 11** provides an example output from the model.

[10] Electricity Authority - EMI (market statistics and tools)

Figure 10: Simplified driver tree of annual energy demands from heavy industry

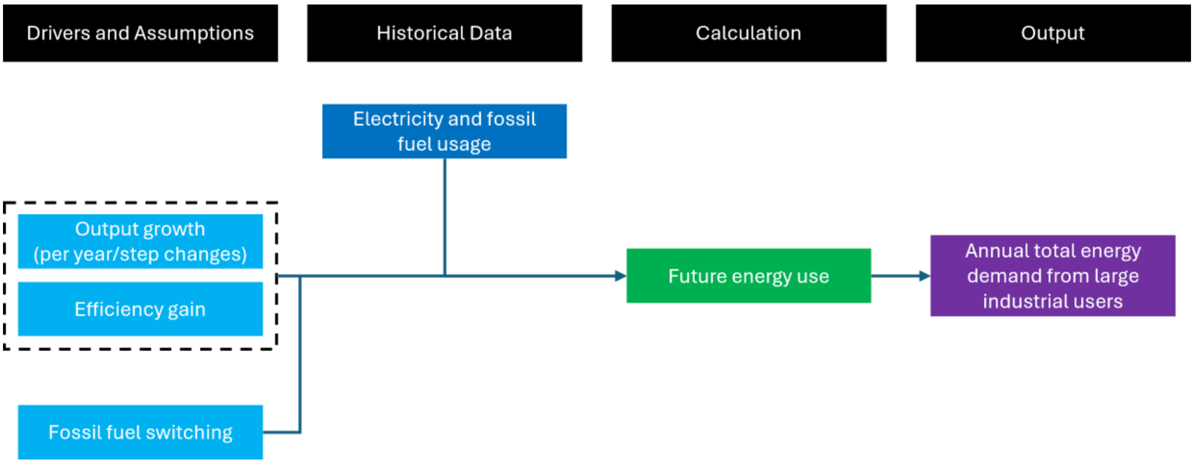
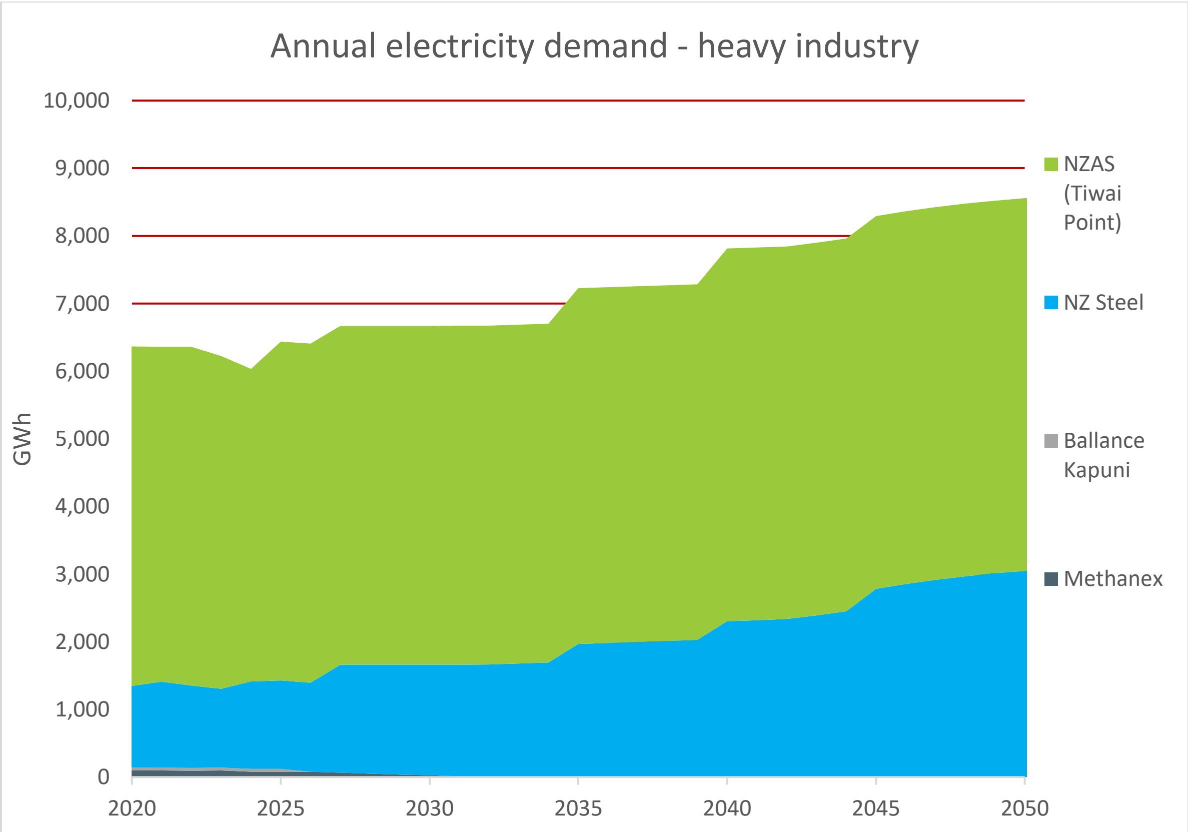


Figure 11: Stacked area graph of annual energy demand from heavy industry



2.1.6 Motive power

Motive power is the energy used to create motion that is not road transport. It is divided into two categories: stationary motors and mobile motors. Stationary motors include things such as pumps, conveyor belts and elevators while mobile motors include machinery such as tractors, cranes and forklifts. Mobile motive power also includes vehicles that are for industrial, commercial or agricultural purposes but are not traditionally found on the road.

This model uses the EEUD data as its basis. The EEUD breaks down motive power energy use by sector, stationary verses mobile, and by fuel type. Fuel switching in the motive power model is done through s-curves assumptions.

The model uses GDP and sector intensity as the main drivers of demand. Typically, rising GDP boosts demand, whereas sector intensity lowers it due to technological and process efficiency improvements, especially in stationary industrial motors.

S-curves are used in a motor stock model to calculate the percentage of motors that are electric. The stock model is divided into slow, medium and fast motors where an assumption is used for the lifetime of the motors.

A new motor's technology is calculated from the s-curves. As most stationary motors are already electric (80-100%), the motor stock model mostly influences mobile motors.

Figure 12 provides the simplified driver tree of the motive power model, and **Figure 13** provides an example output from the model.

Figure 12: Simplified driver tree of annual energy demands from motive power

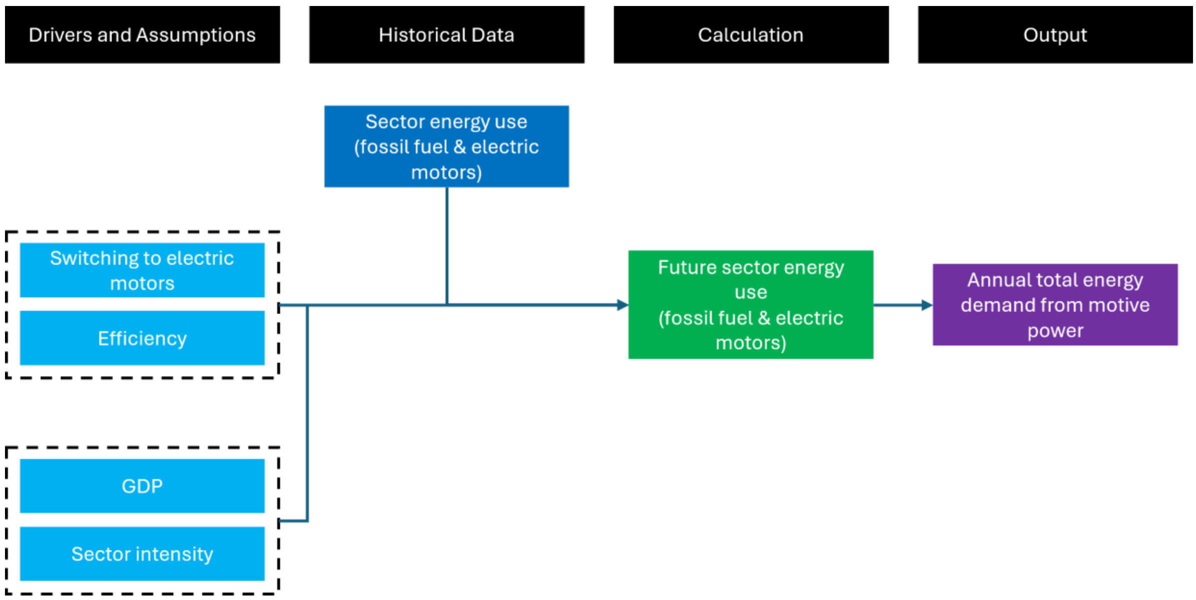
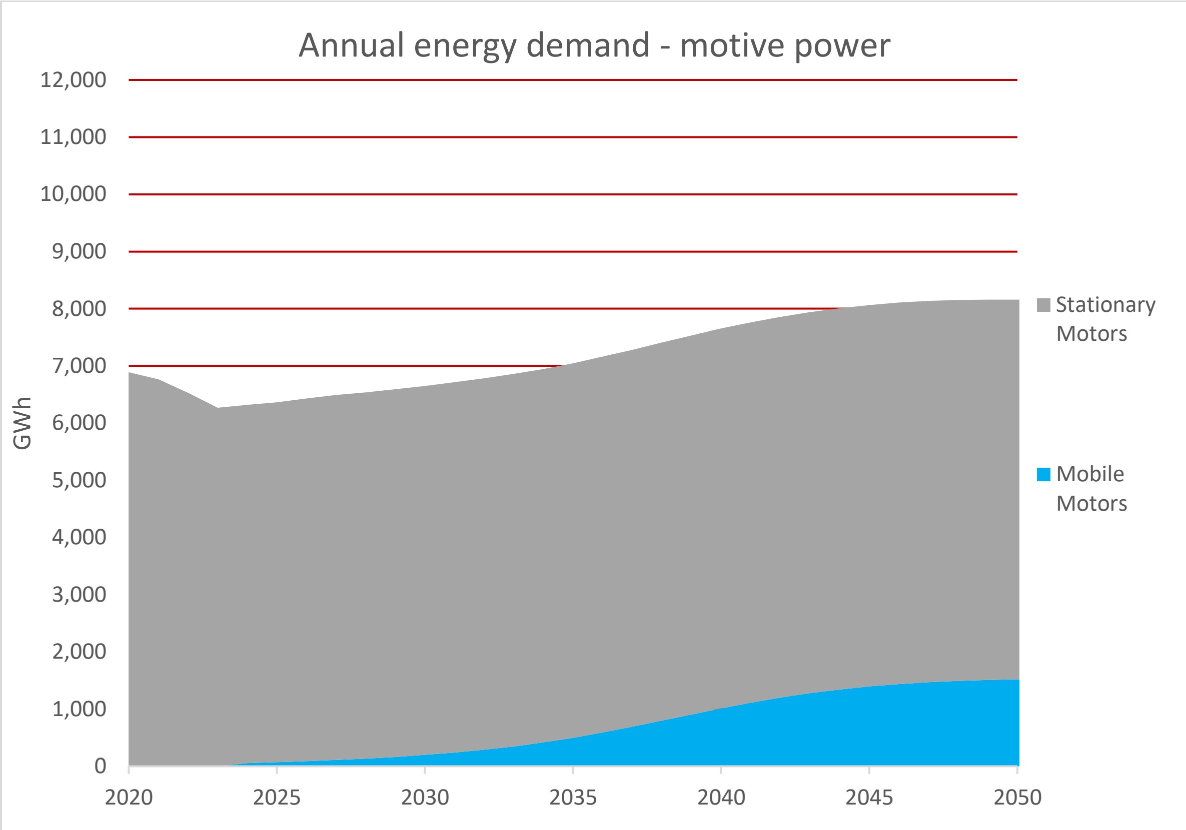


Figure 13: Stacked area graph of annual energy demand from motive power



2.1.7 Next generation farming

Next generation farming demand is the energy used for precision fermentation; a synthetic way to create milk solids without cows, not currently used in New Zealand. Precision fermentation is energy intensive, hence the need for a model.

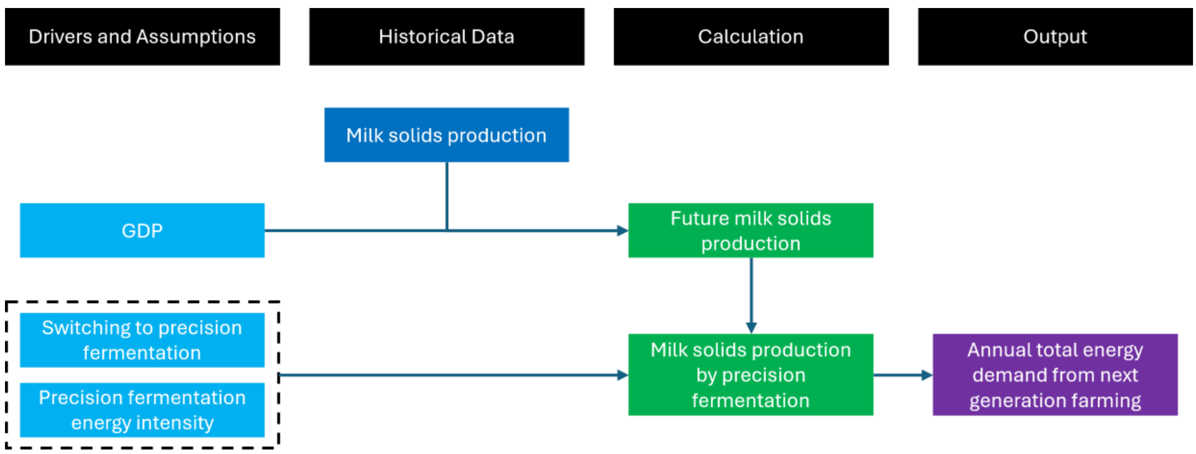
Milk solids production statistics are from Statista[11] and form the basis for the model.

Milk solids production is the main driver for next generation farming demand and the increase in output is driven by increasing dairy GDP.

S-curve assumptions are used to determine the amount of milk solids that are produced through precision fermentation.

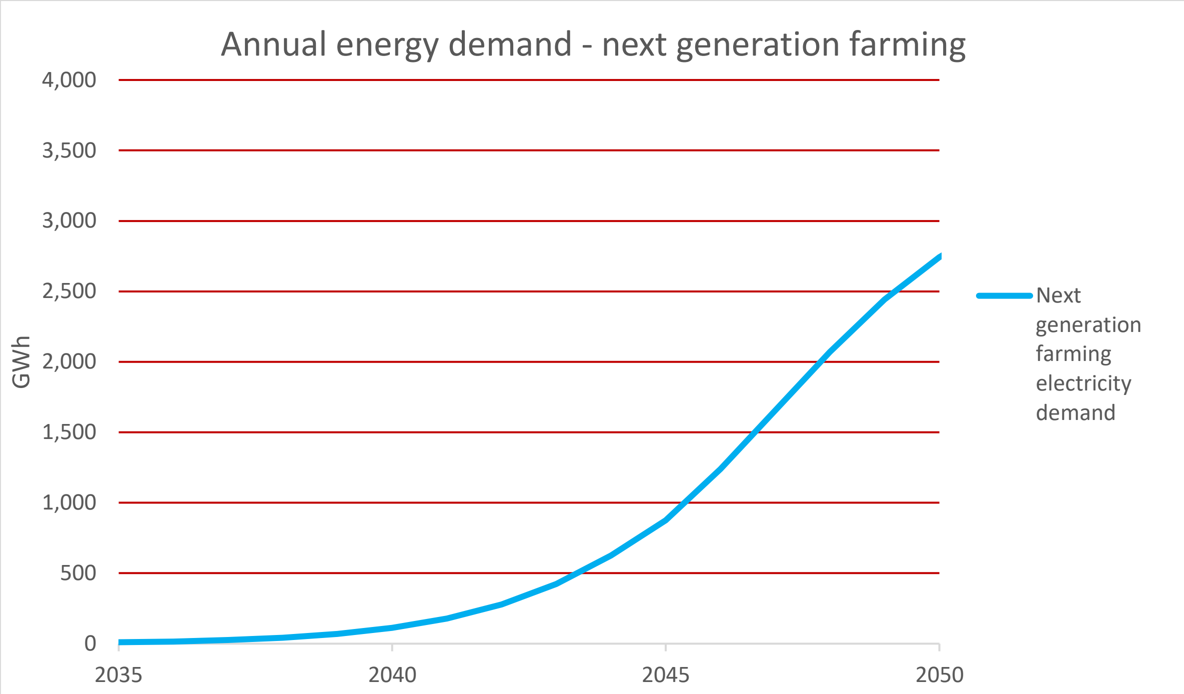
Figure 14 provides for the simplified driver tree of the next generation farming model, while **Figure 15** provides an example output from the model.

Figure 14: Simplified driver tree of annual energy demands from next generation farming



[11] Dairy industry in New Zealand - statistics & facts | Statista

Figure 15: Line graph of annual energy demand from next generation farming



2.1.8 Residential

Residential demand is broken down into four main categories: 1) space and water heating; 2) space and water cooling; 3) cooking; and 4) other, such as lighting, wall power, and refrigeration.

The EEUD details residential energy demand in these four categories, broken down further into energy use by fuel type. The residential demand forecast model uses the EEUD data along with housing stock data from Stats NZ as historical data.

Assumptions and population are used with the historical data to create the future demand forecast, as illustrated in **Figure 16**. **Figure 17** shows an example output from the residential driver model.

The assumptions include:

- **fuel switching:** changing from fossil fuel water boilers to electric, gas or wood cooktops to electric and fossil fuel heating to heat pumps
- **housing:** new homes built, homes renovated, types of homes (houses, apartments flats etc), average persons per household, heating energy intensity (accounts for insulation and efficiency)
- **temperature impacts:** as climate change continues, average heating demand will decrease, and cooling demand will increase

Figure 16: Simplified driver tree of residential heating/cooling and cooking energy demands

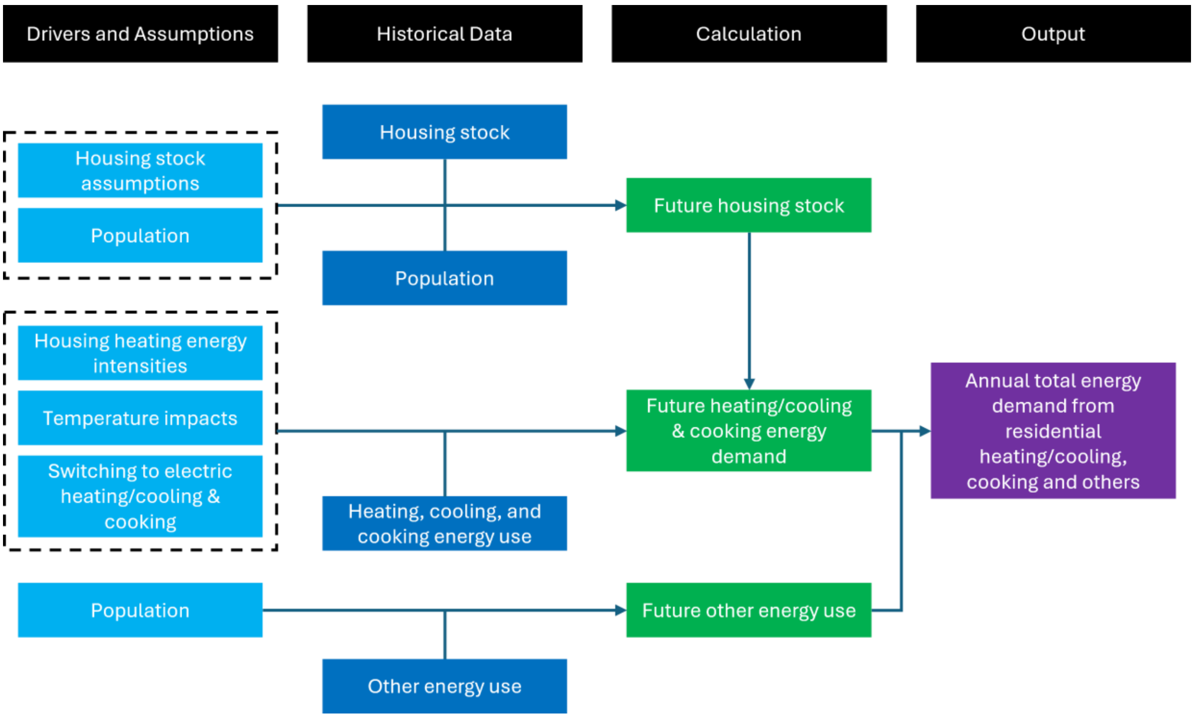
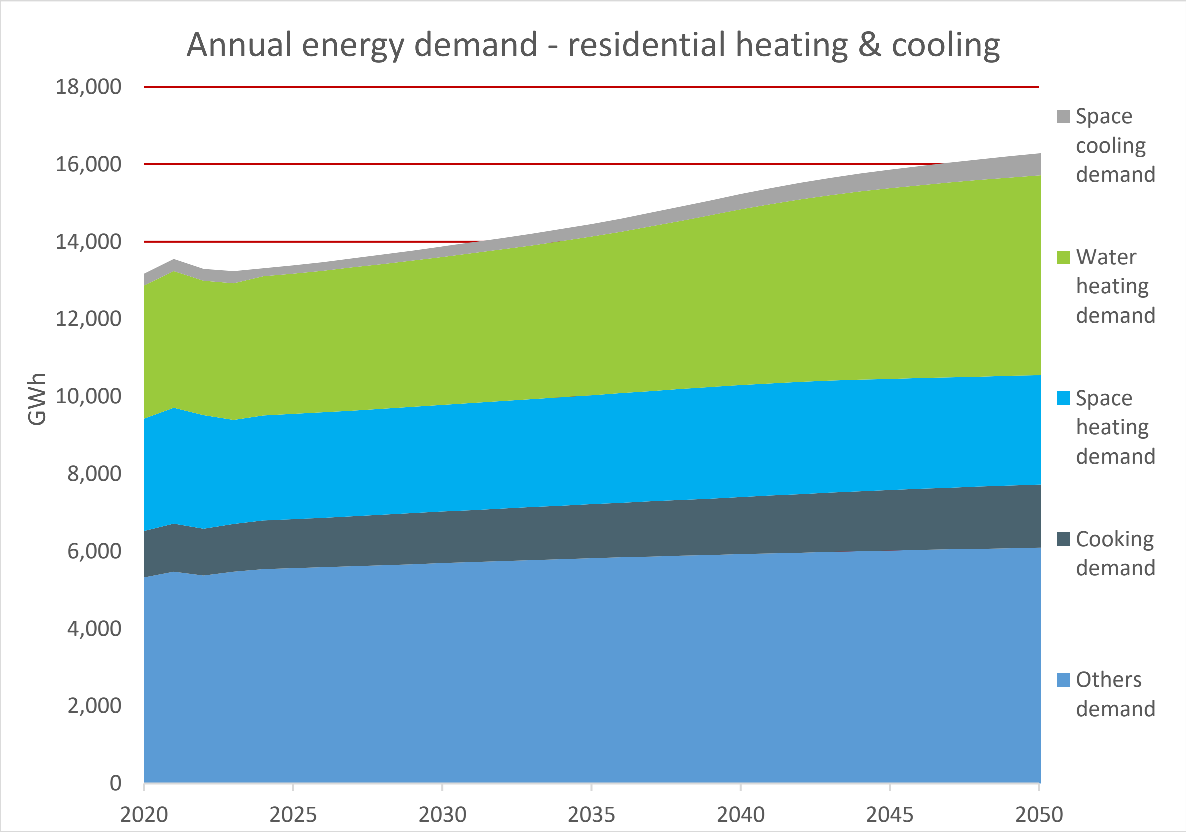


Figure 17: Stacked area graph of annual energy demand from residential heating, cooling, cooking and others



2.1.9 Road transport

Road transport demand is the energy needed to power electric vehicles and create the hydrogen needed for hydrogen cars. It also includes traditional diesel, petrol and biofuels; biofuels for road transport are assumed to be imported like petrol and diesel. Vehicles are split into five categories: light passenger vehicles (LPVs), light commercial vehicles (LCVs), buses, medium trucks, and heavy trucks.

Statistics for the vehicle fleet and vehicle kilometres travelled (VKT) come from the Ministry of Transport while fuel use is from the EEUD. These form the basis of the road transport model. The model uses assumptions on fuel efficiency (based on total fuel use) for each type of vehicle with the VKTs to calculate how much fuel or energy is needed.

Population and the sectoral GDP of the commercial, industrial and agriculture sectors are drivers of the future demand. These drivers are measured VKTs per capita or per GDP.

The model uses s-curve assumptions for the switching of car technology, from internal combustion engines (ICE) to electric, hydrogen powered (assumed fuel cell technology not ICE), or biofuel. The s-curves are used in calculating the percentage of new vehicles bought that are of the given technology.

The model also includes energy demand forecasting for rail; the drivers for this demand is total New Zealand GDP and efficiency.

The model also includes two other integral assumptions:

- **Mode shift:** which accounts for shifts between vehicle travel and other modes of transport, such as cycling, scooters, or walking. Mode shifting impacts the VKTs per capita/GDP and can increase or decrease, directly impacting the total VKTs and therefore fuel and energy demand.
- **Scrap rates:** a percentage of the fleet per technology that is scrapped each year. This impacts how many new cars are needed each year and with the s-curves, defines the diffusion of new technologies into the overall fleet.

Figure 18 illustrates the simplified driver tree. **Figure 19** shows an example output of the road transport driver model.

Figure 18: Simplified driver tree of annual energy demands from road transport

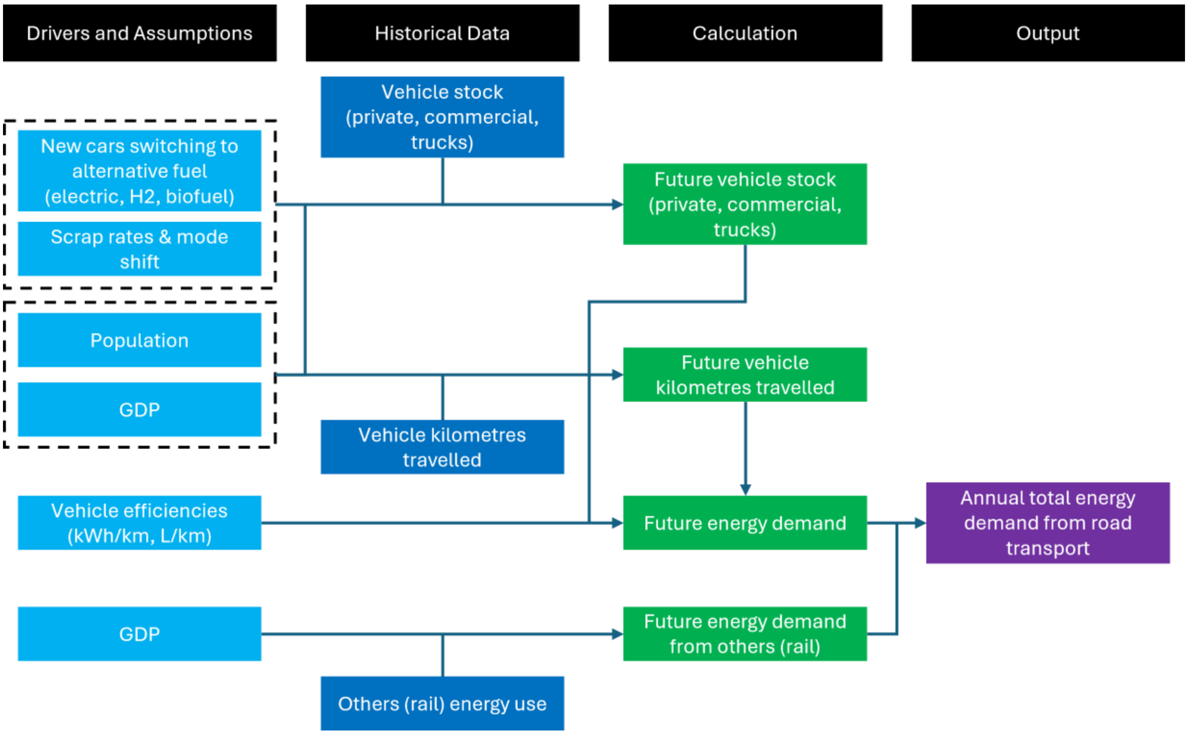
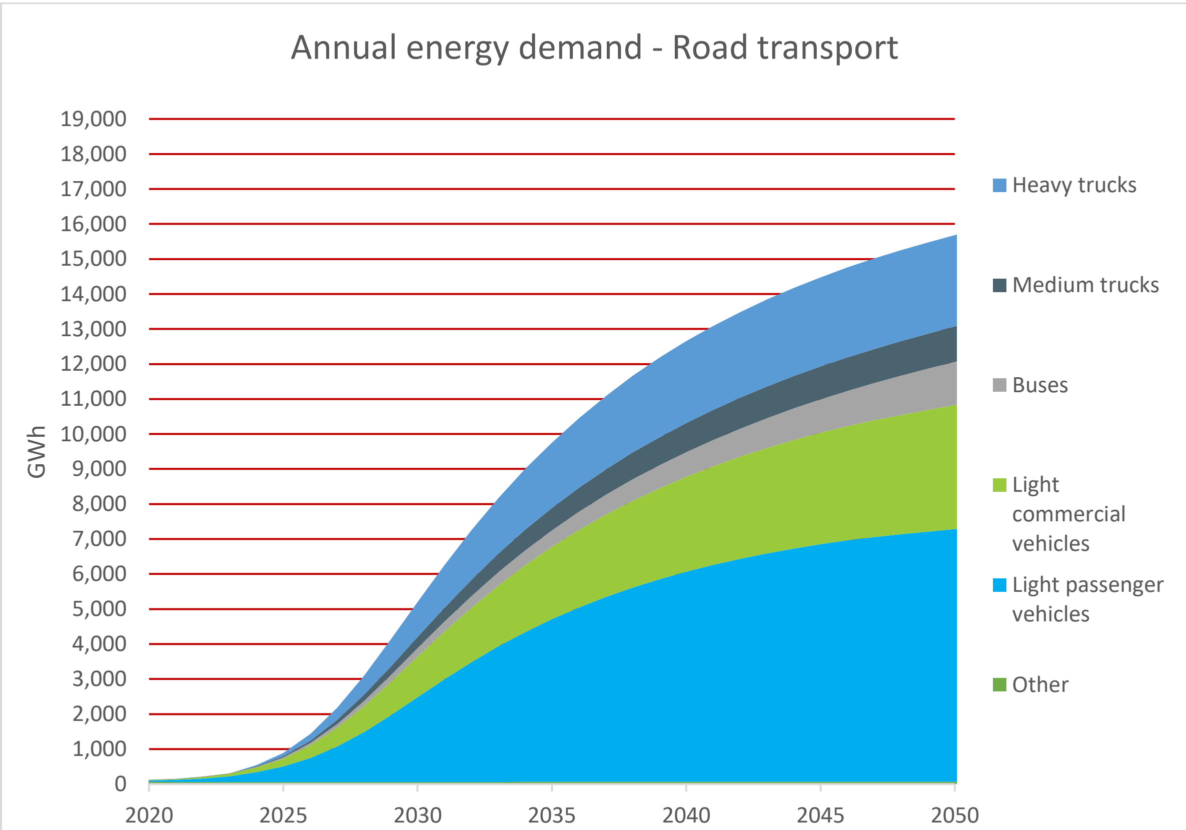


Figure 19: Stacked area graph of annual energy demand from road transport



2.2 Whole energy system model

A whole energy system approach considers all existing demand for energy and how that demand may transition from one fuel to another, for example from a fossil fuel to electricity. In addition, it can consider new economic growth and related energy demand. Taking this approach ensures that our scenarios consider the total potential impact on the electricity system of our assumptions and allows us to assess net-zero compatibility and residual fossil fuel use within our scenarios.

To complement the deep dive models which focus on the projection of electricity demand, we also developed a whole energy system model capturing other fuels and emissions. The Low Emissions Analysis Platform (LEAP)[12] software was developed by the Stockholm Environmental Institute and is well known worldwide. It has the energy system modelling capability representing demand, transformation and supply and resources of all fuels.

We configured the model to capture our unique New Zealand energy system. We were able to represent long-term scenarios of the evolution of our energy system considering decarbonisation and other drivers in this model. The LEAP model also aids in evaluating key interactions between sectors and implications of fuel switching.

Within the LEAP model, the electricity demand and generation are considered within the boundaries of the broader energy system.

The LEAP model functions as a comprehensive calculator that aggregates the energy system implications of a given set of scenario assumptions. Our application of the LEAP model uses deep dive models as inputs. Model outputs include annual fuel consumption, electricity demand and emissions. These outputs are reported at varying levels of detail (i.e. by demand sector, fuel type, and end-use category), with options to present results in aggregated form or retain full granularity.

For example, the annual electricity demand by sector is shown in **Figure 20** while a more detailed transport electricity demand breakdown is illustrated in **Figure 21**.

[12] Heaps, C.G., 2022. *LEAP: The Low Emissions Analysis Platform.* [Software version: 2024.4.0.15] Stockholm Environment Institute. Somerville, MA, USA. https://leap.sei.org

Figure 20: Energy final units per sector (Scenario: Aotearoa Electrified)

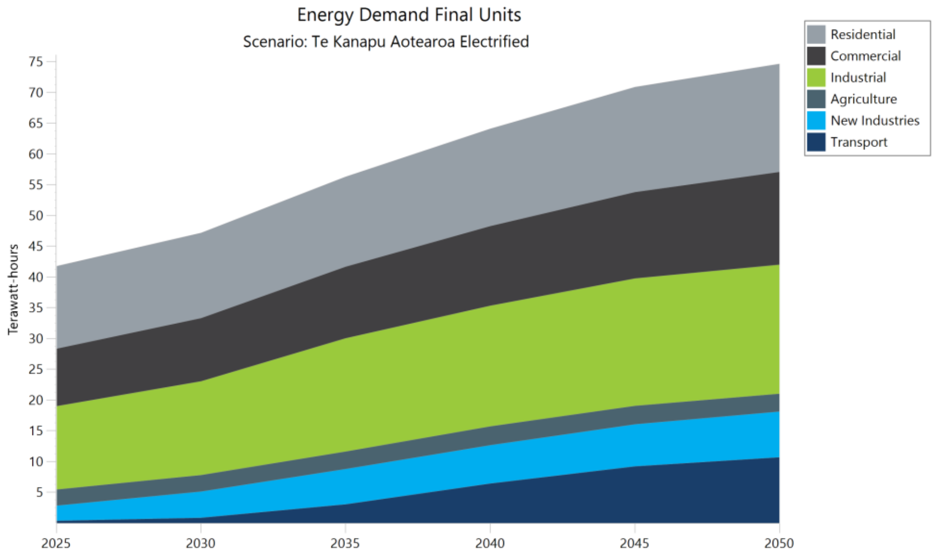
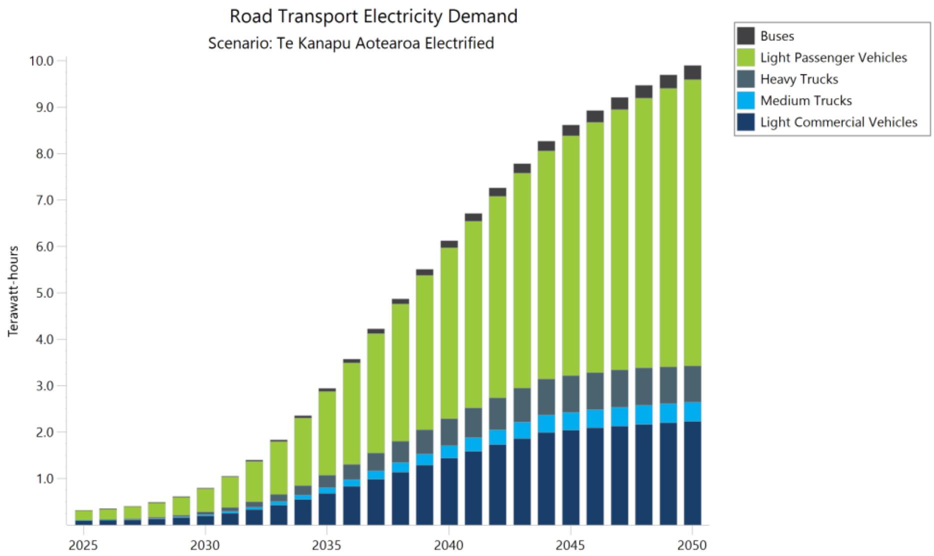


Figure 21: Road transport electricity demand per vehicle type (Scenario: Aotearoa Electrified)



2.2.1 Demand

The LEAP demand analysis adopts an end-use-based approach to model New Zealand's energy system. Our implementation provides a detailed representation of both current and future demand sectors. We have structured the model to include sectors, subsectors, end-uses, and technologies, as outlined in **Table 1**.

Table 1: LEAP Model branches

<table>
<tr><th colspan="2">Sectors</th><th>Energy end use</th><th>Fuel switching</th></tr>
<tr>
<td>
Residential
Commercial
Industrial

Construction
Dairy
Metal
Mineral
Mining
Other Food & Meat
Wood
Heavy

NZAS
NZ Steel
Balance
Methanex

Other

Agriculture

Dairy
Fishing Hunting & Trapping
Forestry & Logging
Indoor Cropping
Non-Dairy Agriculture
Next generation farming

</td>
<td>
New industries

Data centres

Transport

Road transport

Light passenger vehicles
Light commercial vehicles
Buses
Medium trucks
Heavy trucks

Rail
Aviation (domestic & international)
Shipping (domestic & international)

</td>
<td>
Heating

Space & water heating
Low temp pH
Med temp pH
High temp pH
Cooking

Space cooling
Mobile motive power (off-road vehicles)
Stationary motive power (machinery)
Other electricity use (e.g. lighting and electronics)
Irrigation (agriculture)
Alternative fuel production (e.g. eMethanol, eSAF, hydrogen) – captured in Transformation
</td>
<td>From:

Coal
Natural gas
Liquid fossil fuels

To:

Electricity (differentiating between resistance heaters, boilers and heat pumps for heating)
Biomass/biofuels
Hydrogen + derivatives
</td>
</tr>
</table>

Key sectors captured in the model include residential, commercial, industrial, agriculture, and transport. The industrial sector is further disaggregated into subsectors to reflect varying degrees and rates of transition to electrification and alternative fuels. Energy consumption for major industrial consumers (i.e. NZAS, NZ Steel, Ballance, and Methanex) is modelled separately due to their significant impact on national demand. Additionally, we have incorporated precision fermentation as a next generation farming technology, representing an emerging industry within agriculture. Data centres are also explicitly modelled. For the transport sector, the model accounts for road, rail, aviation, and shipping.

Within each sector or subsector, we modelled the energy end-uses. We captured the end-use detail from Energy Efficiency and Conservation Authority's (EECA's) energy end-use database for all other sectors. This demand representation has been calibrated to align with national energy and emission inventory datasets. The major end-uses include space heating and cooling, water heating, cooking, different levels of process heat (low, medium and high), motive power (stationary and mobile), and other miscellaneous uses such as refrigeration, lighting and electronics.

Then, each end-use consumption was allocated to the technology type and their respective fuels and efficiencies. To simplify the model, we grouped the liquid fossil fuels (i.e. diesel, gasoline, LPG) into a single fuel. The absolute or relative efficiencies of different technology types was specified within the LEAP model using the technology database in the TIMES-NZ model as a reference. In modelling the transition, electric or low-emissions alternatives to fossil fuel technologies have been defined for most energy demand categories. It has not been possible to do this for all end-uses.

For the transport sector, subsectors are categorised by vehicle type and other energy uses. Road transport is divided into buses, LPVs, LCVs, medium trucks, and heavy trucks. Rail is grouped into passenger and freight services. Aviation is grouped into domestic and international flights, with domestic flights further segmented by distance: very short, short, medium, long, and very long. Shipping is organised into ferry transport, domestic coastal shipping, international shipping, and "shore-to-ship" operations.

After establishing the LEAP structure and the EEUD, final energy units were converted to useful energy demand based on the assumed efficiencies of each technology. The useful energy demand is the part of final energy demand available to do useful work (heating, cooling, cooking, etc.) after losses within final energy consuming devices. Most of the demand drivers were projected using useful energy demand. We evolve the useful energy demand based on drivers such as economic growth, fuel shares and sector energy intensity changes.

Projections of future demand (useful energy and final consumption) are driven by assumptions of future activity and the share of this activity provided by different technology types. Future activity is largely based on established relationships between economic factors (e.g. population/GDP) and sector energy consumption. The assumptions in the deep dive models relating to the growth of activity levels were fed into LEAP to project future demand. For example, the resulting VKT from the deep dive vehicle stock model was fed into LEAP. Examples of the LEAP representation of the share of VKTs for LPVs and medium trucks are shown in **Figure 22** and **Figure 23**.

The changes in activity level are affected by fuel transition rates, efficiency gains due to replacement technologies and efficiency trends, behaviour changes to reduce or increase consumption and other unique growth assumptions (e.g. data centre growth and capacity factors).

Figure 22: Light passenger vehicles share of vehicle kilometres travelled (Scenario: Aotearoa Electrified)

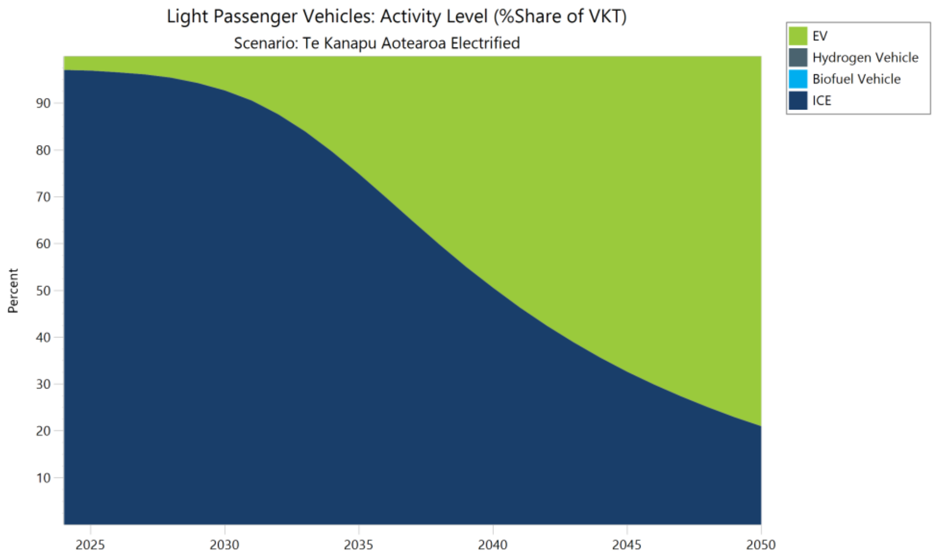
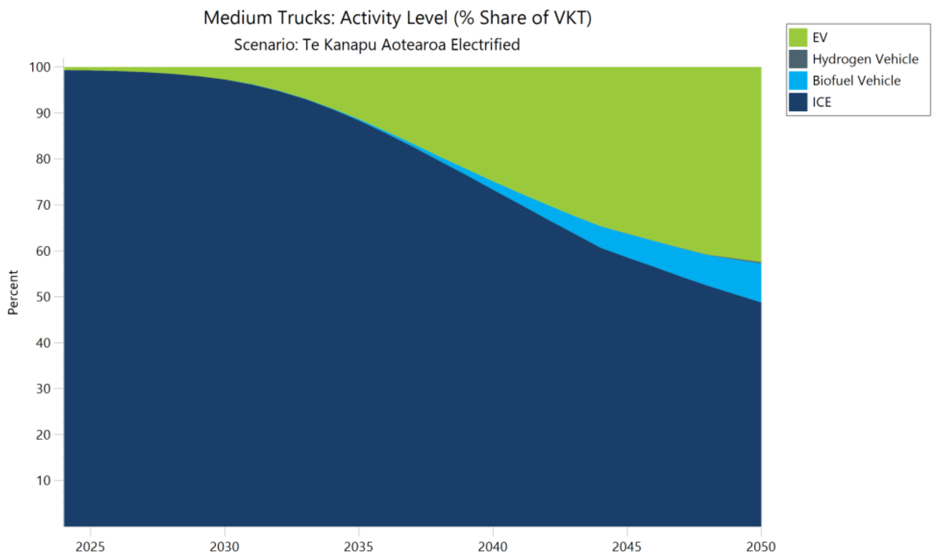


Figure 23: Medium trucks share of vehicle kilometres travelled (Scenario: Aotearoa Electrified)



Electric technology uptake assumptions are specified to set technology shares for different types of demand. For example, the share of light VKT which are electric. These fuel switching assumptions are specified year-by-year and defining their rate will be a core task of scenario creation. Fuel switching assumptions can be brought in from a variety of sources, or we could assume simple transition profiles where appropriate. The current implementation does not consider the economics of fuel switching.

2.2.2 Transformation

In addition to representing energy demand, energy transformation sectors and primary fuel demand are also represented in LEAP, although only at a very high level.

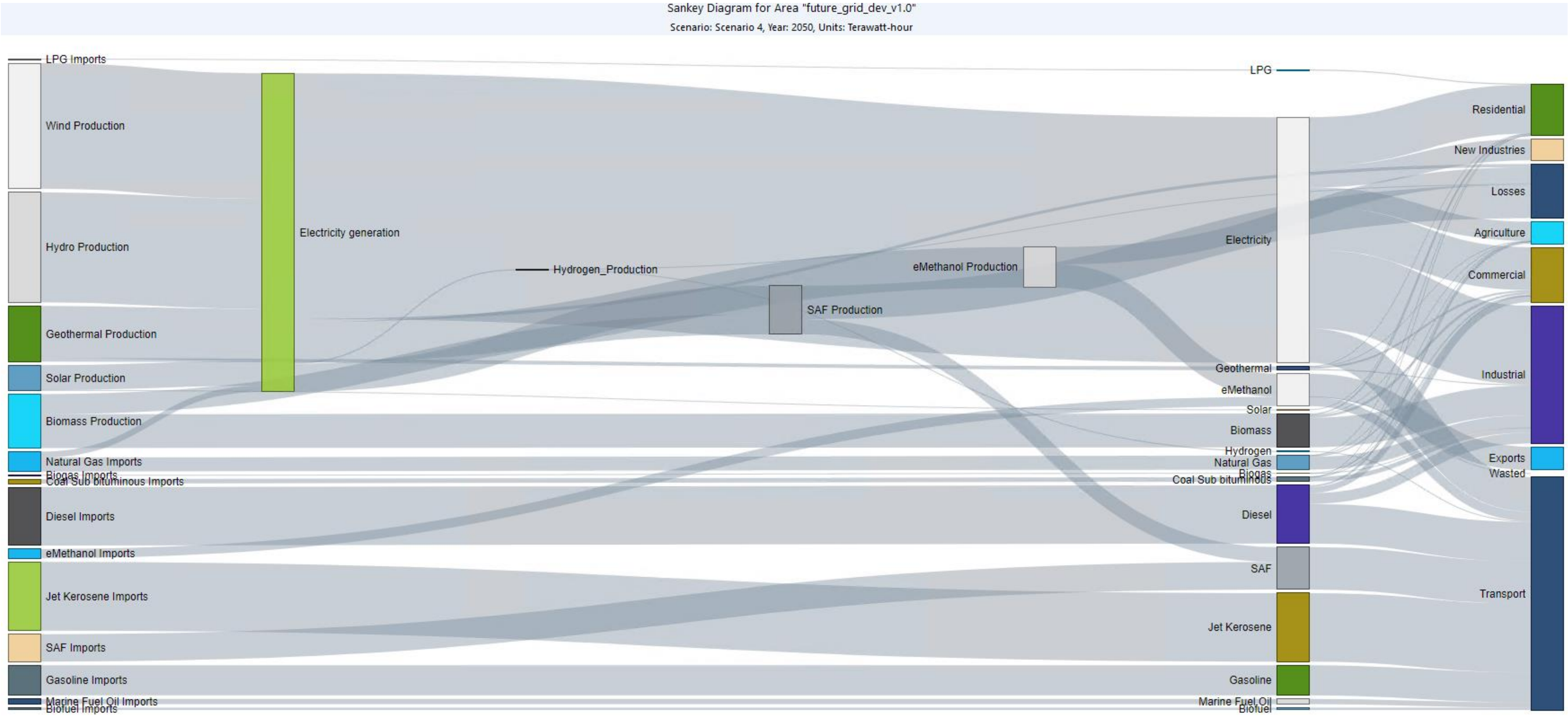
The transformation sectors represented include hydrogen, SAF and e-methanol production and electricity generation. Hydrogen and e-fuel production can be considered as electricity demand for our purposes (but they are technically, an energy transformation). We model two types: AtJ from woody biomass and Power-to-Liquid (PtL) for SAF production. We also modelled e-methanol synthesis (methanol production by combining carbon dioxide with green hydrogen). The model determines the amount of electricity and biomass to produce these fuels and to meet the modelled requirements resulting from the demand analysis.

The electricity generation implementation in LEAP is extremely high level and informed entirely by the outputs of a separate market model. It exists to support emissions quantification and total economy-wide fuel consumption reporting. LEAP takes the scenario output annual PJs for each fuel type and calculates the corresponding emissions.

2.2.3 Resources

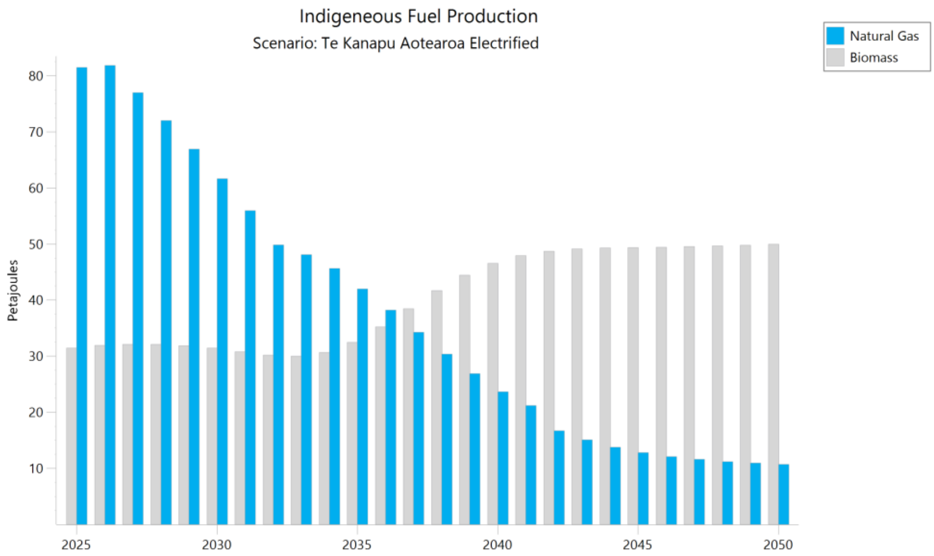
The LEAP resources module quantifies all the requirements of fuels or resources at different stages. It considers the availability of domestic production and imports for all fuels in the energy system. For example, domestic natural gas production versus import LNG and the woody biomass availability for process heat. A sample Sankey chart is shown in **Figure 24** illustrating the flow of resources from domestic production or imports to electricity generation and other transformation of fuels, up to the final sector where they are consumed, imported or considered as losses.

Figure 24: Sankey diagram for the flow of resources in 2050 (Scenario: Made in Aotearoa)



In addition, LEAP can also identify the required resources based on the scenarios. An example for natural gas and biomass resource requirement is shown in **Figure 25**.

Figure 25: Natural gas and biomass requirements (Scenario: Aotearoa Electrified)



2.2.4 Emissions

As we were able to determine the aggregated requirements for each of the different fuels over time, we can also quantify the carbon emissions for the whole energy sector.

Figure 26 shows a sample scenario for each fuel group consumption. In addition to the emissions from the energy system, we also use LEAP to collate emissions' projections from other parts of the economy (e.g. agricultural and forestry sectors). This then allows us to evaluate economy-wide emissions. With that we can verify if our scenarios can achieve the country's domestic emissions targets.

For example, the Aotearoa Electrified scenario will be able to meet net zero around 2040 as shown in **Figure 27**. Emissions from international shipping and aviation are excluded in this chart.

Figure 26: Energy demand final units per fuel group (Scenario: Aotearoa Electrified)

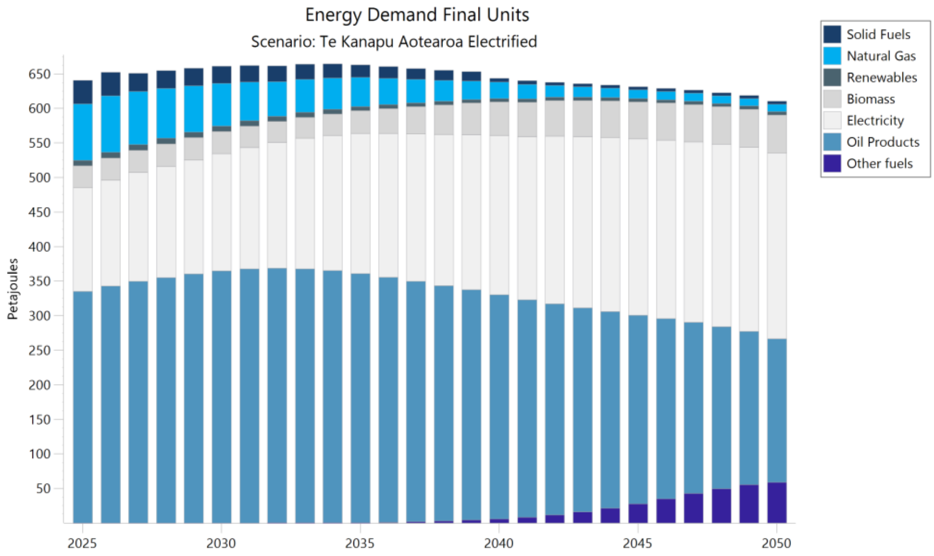
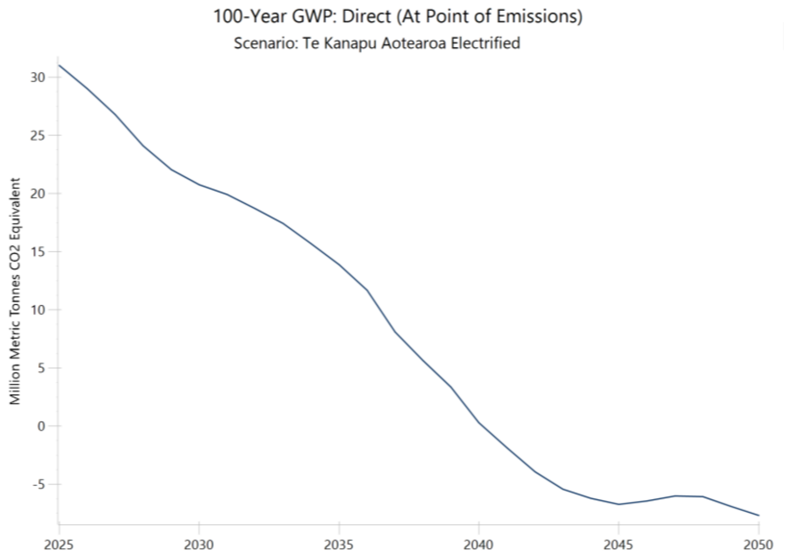


Figure 27: Projected emissions meeting net zero around 2040 (Scenario: Aotearoa Electrified)



2.3 Model integration

The deep dive model and the LEAP model are designed to integrate seamlessly, as both focus on national energy demand at an annual resolution. They share common economic growth drivers and adopt a sector-based approach to demand modelling. The demand drivers in the deep dive model are represented through LEAP branches, which capture subsectors and end-uses in detail. Each model also serves as a validation tool for the other, ensuring accuracy and helping to identify and eliminate potential errors or inconsistencies. While both models complement each other, they offer different levels of granularity; LEAP provides a broad system-level perspective, whereas the deep dive model delivers more detailed insights into specific sectors and technologies.

3.0 Regional demand modelling

3.1 Energy

After completing the national electricity demand projections using the deep dive and LEAP models, demand is subsequently disaggregated to regional and GXP levels to enable transmission power flow assessments. To construct a comprehensive demand forecast across the grid, we employ a dual-method approach:

- **Top-down disaggregation**: National demand from the Te Kanapu scenarios is proportionally allocated to regions and GXPs using a pro-rata method based on historical consumption patterns and demographic or economic indicators.
- **Bottom-up regional/GXP level projections**: Independently developed regional demand forecasts are constructed using localised data sources (e.g. electricity distribution businesses (EDBs) surveys, DETA electrification survey), including sectoral growth trends, distributed energy uptake, and regional policy drivers.

This combined methodology ensures both consistency with national-level projections and alignment to regional-specific dynamics, thereby supporting robust transmission planning and investment analysis. We ensure that the demand is reconciled at various levels (regional, island, national) to ensure the top down and bottom-up views are as consistent as can be.

3.1.1 Top-down disaggregation

We have disaggregated the national electricity demand projection proportionally across regions, considering the varying drivers of regional growth. **Figure 28** illustrates the key economic sectors currently driving activity in each region. For future projections, regional growth assumptions are informed by available data sources, including insights from the annual surveys of EDBs. The regional allocation will be further refined based on feedback and outcomes from Consultation 2, ensuring alignment with stakeholder input and evolving regional dynamics.

Figure 28: Key drivers of current economic activity at a regional level

1. Northland: agriculture, forestry, fisheries, fuel processing
2. Auckland: urbanisation, services, technology, international migration, manufacturing
3. Waikato: agriculture, dairy, energy infrastructure
4. Bay of Plenty: logistics, horticulture, tourism, energy infrastructure, manufacturing
5. Taranaki: energy (oil & gas, hydrogen), manufacturing
6. Hawkes Bay: agriculture, viticulture, food processing
7. Gisborne: forestry, agriculture
8. Manawatū-Whanganui: agriculture, logistics, education, food and fibre
9. Wellington: public sector, technology, scientific research
10. Nelson: tourism, seafood, horticulture
11. Tasman: tourism, viticulture
12. Marlborough: viticulture, tourism
13. West Coast: mining, tourism
14. Canterbury: agriculture, manufacturing, logistics, energy transition, aerospace
15. Otago: tourism, education, viticulture
16. Southland: agriculture, forestry, energy, manufacturing, seafood

We applied the disaggregation per demand driver as listed in **Table 2**.

Table 2: Approach to regional disaggregation by demand driver

Demand driver	Approach
Aviation	Regional energy demand for aviation is impacted strongly by air freight and passenger numbers. The national demand for direct flight electrification was distributed regionally based on airport sizes and locations. For instance, Auckland, Wellington and Christchurch are New Zealand's busiest airports, taking majority of the demand.
Shipping	Shipping is disaggregated by the relative size of each existing port throughout New Zealand. Tauranga being the largest port.
Data centres	Regional demand for data centres is driven by known connection requests, feedback from EDBs and publicly announced information.
Process heat	Process heat disaggregation is driven by the existing load, feedback from EDBs and the Industrial Electrification Survey[13].
Heavy industries	The demand of the four heavy industry sites mentioned in Section 2.1.5 is the sole driver for regional demand of heavy industries and are therefore allocated on their specific regions.
Motive power	Motive power is generally applicable to agricultural and industrial areas. Motive power demand is dispersed as part of the base energy across all applicable regions and GXPs.
Next generation farming	Next generation farming is assumed to be centred in rural areas. This is driven by its expected competition with traditional agriculture and farming methods. They are assigned to the regions with agriculture industry based on **Figure 28**.
Residential	Major residential centres are unlikely to see significant and relative fluctuations in population. Residential energy demand is disaggregated based on existing demand across all applicable regions and GXPs, with concentrations on major cities and urban areas.
Road transport	The national road transport demand was built per vehicle basis. It is disaggregated based on regional demand and feedback from EDBs. We expect that a large amount of transport demand will occur in our major cities, especially Auckland, Hamilton, Tauranga, Wellington, and Christchurch.

[13] Industrial Electrification Survey Summary – DETA Consulting

3.1.2 Bottom-up regional/GXP level projections

3.1.2.1 Base demand

A reconciliation process is required to create some agreement between EDB provided GXP level forecasts, various regional forecasts and the top-down scenarios developed above. To perform a consistent reconciliation across the hierarchy we first decompose the forecasts into comparable components. For this, we usually express the scenarios by their 'base demand' or sometimes referred to as organic growth.

The regional, island and national base peak forecasts are created in two independent ways:

1. An ensemble of linear regression models is used to determine future peaks, one of these models uses GDP as an exogenous variable. A correction is applied to the historical record of peak demand to remove the effect of temperature and large industrial loads are removed.
2. The base energy from the scenarios is disaggregated into regions based on historical growth rates and these are converted into base peak though a peak to energy ratio measured from historical values.

These forecasts are combined to create regional, island and national base peak forecasts for all scenarios. The GXP level forecasts provided to us by EDBs are typically an 'expected' forecast. We create scenario-specific GXP level forecast through scaling the expected base peak forecasts consistent with the regional base peak forecasts.

The forecasts are reconciled at the profile level described in Section 3.2.

3.1.2.2 Step loads

Assumed profiles from step load profiles and other demand components are then added on. For step loads we take information from a range of sources including the customer responses to the Transmission Planning Report[14] survey, and for process heat the Regional Energy Transition Accelerator (RETA)[15] reports and DETA electrification survey, and thermal fuel studies (DETA). These are added on to the base demand forecast at an assumed date and specific GXP.

The step loads from customer forecasts tend to be highly prudent in terms of both the timing and magnitude of peak loads. At a national level when they are added up, the demand growth arising from customer steps can exceed our top-down forecasts. To manage this, we ask electricity distribution businesses to comment on the likelihood of each step load. We include steps in each scenario according to the likelihood of the step and the top-down energy growth in the scenario. The lower growth scenarios only include the most likely steps, higher growth scenarios include almost all the speculative steps.

The increase in electricity demand from process heat electrification in our scenarios are separated from the base demand and is considered as step loads to avoid double counting. Then, we ensure that the timing and capacities of the step loads are consistent between our scenarios and the RETA reports.

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[14] FINAL 2025 Transmission Planning Report.pdf

[15] Regional Energy Transition Accelerator | EECA

3.2 Demand profiles

The annual energy projections and bottom-up peak forecasts are converted into continuous demand profiles across our study horizon. We synthesise half-hourly profiles for each region out to 2050.

Some of this profile creation is managed by the existing Transpower Grid Investment demand forecasting models. We also plan to capture demand flexibility in modelling profiles. The continuous demand profile is created as a combination of the following steps:

- The base demand component of the profiles is based on historical profiles from a reference year and initially scaled so the peak is consistent with the base peak forecasts at all levels of the hierarchy, the base profiles are then reconciled at the trading period level to ensure consistency. Typically, the reconciliation process is weighted strongly towards the GXP level forecasts in the early part of the horizon.
- The profiles are then reconciled to match the top-down energy forecast.
- For step loads, an applicable profile needs to be specified from a small number of generalised profiles (e.g. flat, dairy, regional residential). The model scales the profile to be consistent with the MW step and applies it on top of the base profile at the nominated timing and GXP.
- For transport energy the existing code base has considerable functionality around optimised smart charging which targets network peaks.

A summary of the associated demand profiles used for each demand driver is listed in **Table 3**.

Table 3: Demand profiles used per demand driver

Demand driver	Demand profile
Aviation	A profile based on charging to accommodate existing aviation demand
Shipping	A profile based on charging to accommodate existing shipping demand
Data centres	Generally flat profile; peak on summer mid-day for cooling
Process heat	General industry profile: Dairy profile has been synthesised from analysis of gas gate data
Heavy industries	Based on specific site profile
Motive power	Base demand profile
Next generation farming	Generally flat but a slight commercial modulation
Residential	Base demand profile
Road transport	Electric vehicle charging profile based on known convenience charging profiles and smartness assumptions

In modelling the road transport electrification, the fraction of smart charging EVs grows during the forecast period. Smart charging EVs behind a GXP are assumed to be attempting to avoid the region peak. Smart charging EVs can occasionally contribute to the GXP peak but will not add to the region peak. EVs that do not smart charge will add to the peaks.

3.3 Final outputs

Electricity demand forecasts at all levels (i.e. national, island, regional, and GXP) represent the projected quantity of electricity required to meet future consumption based on our demand scenarios. These demand outputs are subsequently transformed into suitable inputs for the next phase of the Te Kanapu process, which focuses on supply-side modelling.

For Te Kanapu purposes, distributed solar and battery uptake are incorporated into the supply-side model alongside other generation technologies. Once the generation expansion plans are established, the next step involves identifying optimal transmission investment options to ensure the grid can reliably meet future electricity needs.

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