# Electricity Demand and Generation Scenarios: Results summary

JULY 2024

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Te Kāwanatanga o Aotearoa
New Zealand Government

MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

## Ministry of Business, Innovation and Employment (MBIE) Hīkina Whakatutuki – Lifting to make successful

MBIE develops and delivers policy, services, advice and regulation to support economic growth and the prosperity and wellbeing of New Zealanders.

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July 2024

# Key results

## Total electricity demand increases across all our scenarios to 2050

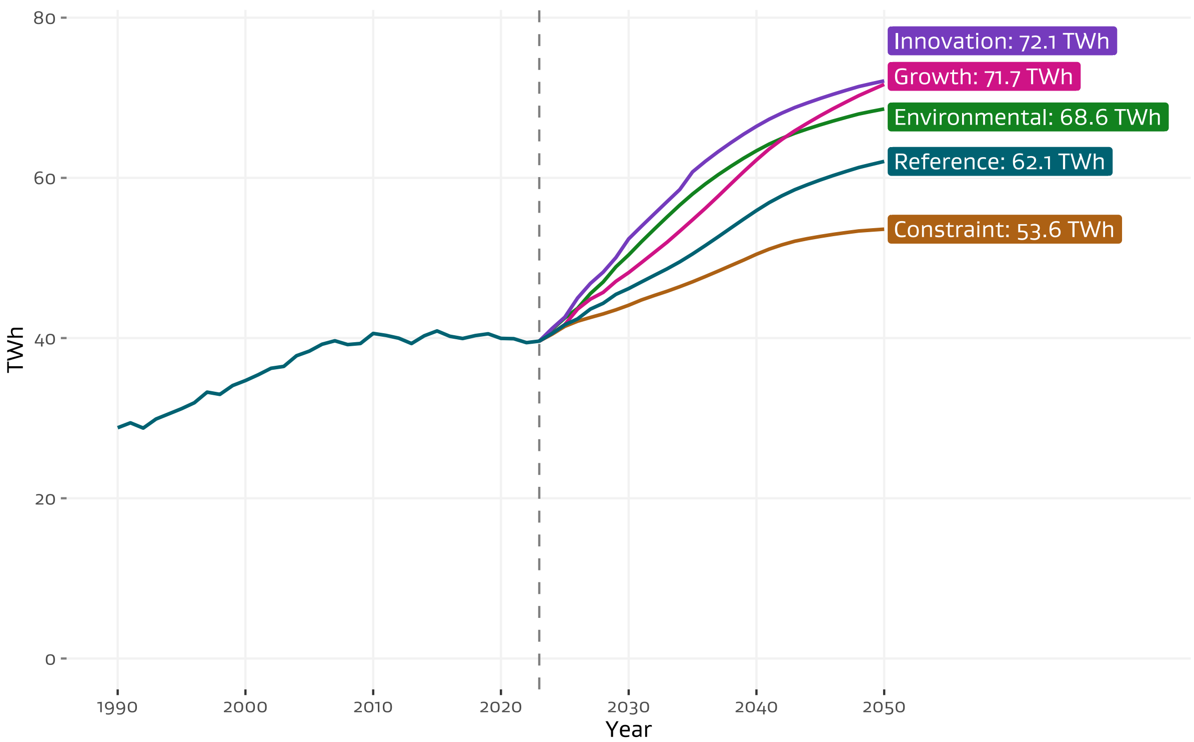
Total electricity demand grows between 35.3 per cent and 82.0 per cent by 2050, reaching 62.1 TWh (terawatt hours) in the Reference scenario. By 2050, across our scenarios around half of all energy demand will be met by electricity.

In the short term, the commercial and industrial sectors are the main sectors driving this growth. From the late 2030s, electrification of transport plays a larger role with increased uptake of electric vehicles (EVs).

Contributing to higher demand is the level of switching of existing fossil fuel use to electricity, which is a key uncertainty. Alternative electrical heating technologies may become more attractive over time. With the same heating demand, users may increasingly convert to electrical heating, depending on investment and running costs.

The increase in total demand drives an increase in peak demand to between 9.1 GW and 12.5 GW by 2050. A key contributor is higher residential demand for heating, which will drive higher winter demand peaks.

***Figure 1: Total electricity demand***



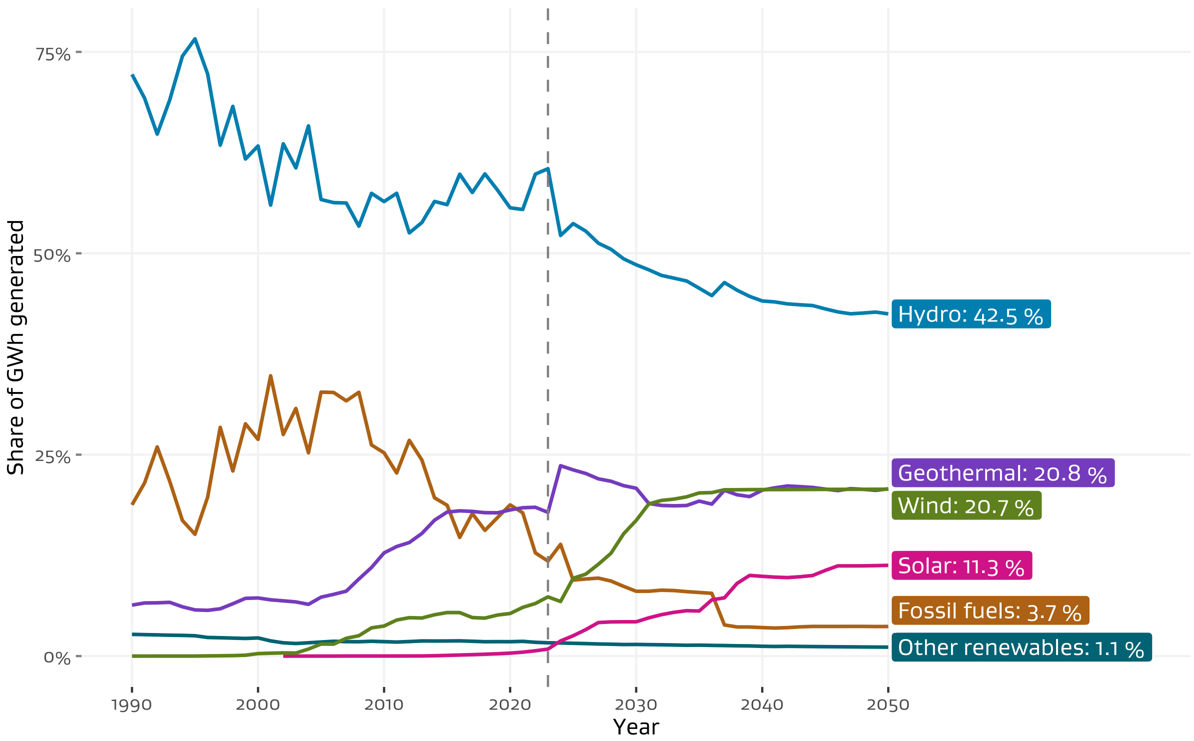
## To meet this increased demand, new generation build is mostly onshore wind and solar

The least cost solution to meet most new demand is onshore wind and solar generation. We also expect to see some new hydro and geothermal plants built.

To ensure enough firm capacity to reliably meet peak demand, new gas peakers are required to provide firming in all scenarios.

The level of support that is needed in the system to meet peak demand differs by scenario. More efficient load distribution and higher levels of battery installation in the Environmental and Innovation scenarios mean that less overall capacity is required to meet peak demand.

***Figure 2: Share of electricity generation by commodity in Reference scenario***

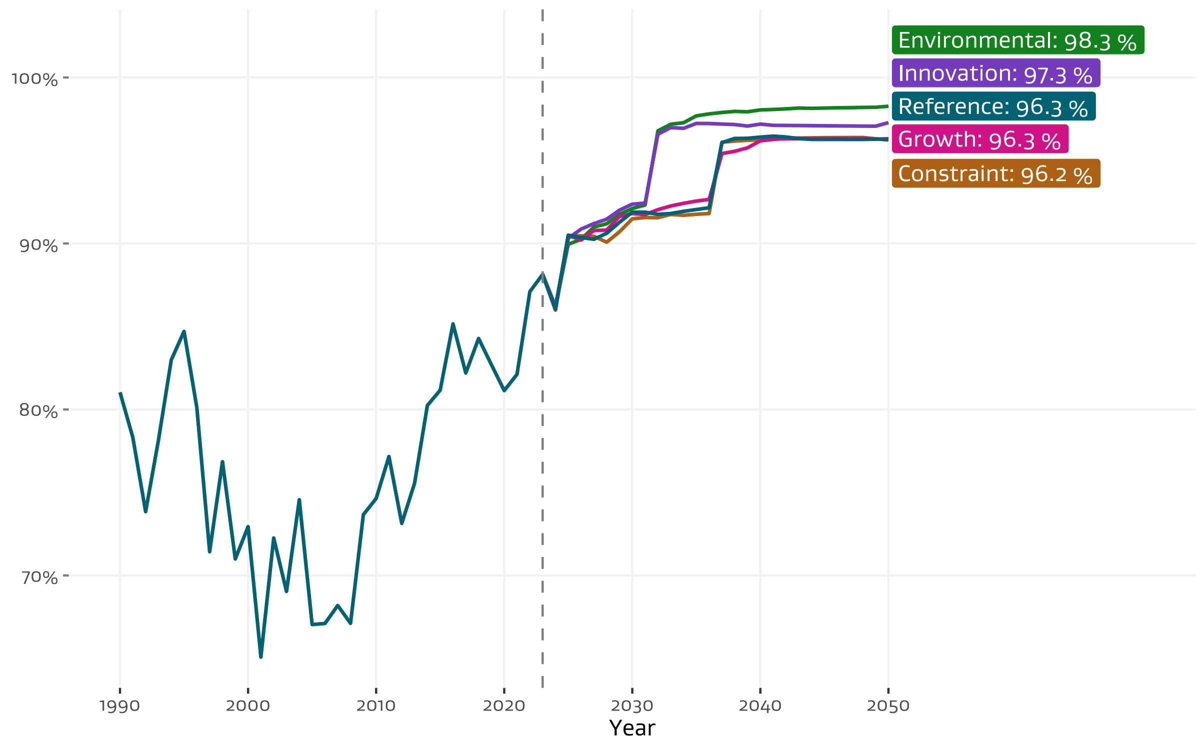


## The renewable share of electricity generation could reach as high as 98.3%

The renewable share of generation reaches between 96.2 per cent and 98.3 per cent by 2050.

A key uncertainty on the future level of renewable generation is the future of coal use at the Huntly Power Station. While Genesis Energy have signalled that they expect to reduce coal use in the Rankine units, there may be continued demand. This is likely in the case of limited alternatives for firming and constraints on natural gas availability.

***Figure 3: Renewable share of electricity generation***



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# Purpose

MBIE prepares an independent set of scenarios called the Electricity Demand and Generation Scenarios (EDGS) that explore potential future electricity demand and the generation capacity required to meet that demand.

These scenarios are used by the Commerce Commission to assess Transpower's planning proposals for future capital investment in the electricity transmission grid. The Commerce Commission is responsible for approving any major investments in transmission assets by Transpower.

EDGS has an explicit role in the investment test for approving Transpower's proposals under the Transpower Capital Expenditure Input Methodology (Capex IM). The Capex IM is part of the Commerce Commission's individual price-quality path regulation of Transpower's electricity transmission services, under Subpart 7 of Part 4 of the Commerce Act 1986[1].

The scenarios are designed to investigate key uncertainties in the electricity sector including:

- The type and location of electricity generation supply, considering:
    - Technology costs (for existing and emerging generation technologies)
    - Resource availability and cost (particularly for natural gas)
- The characteristics and location of electricity demand, considering:
    - The size and structure of the economy
    - The future of heavy industry in New Zealand, particularly the Tiwai Point aluminium smelter
    - The price of electricity compared with alternative energy sources
    - Energy efficiency and demand side participation in the electricity market
    - Uptake rate of new technology such as electric vehicles and Solar PV

## EDGS is being refreshed to better represent the potential futures of a changing nation

The last release of EDGS was published in July 2019. After consulting with stakeholders, we temporarily put the next update of EDGS on hold due to the difficulty in accurately forecasting the impact of the coronavirus (COVID-19) pandemic on domestic and global economic activity.

Considering the changes in the economy that have occurred since 2019, announcements made by participants in New Zealand's energy sector on their future operations, and ongoing technological development, there is a need for a refresh of the potential future scenarios of the electricity sector in New Zealand.

This report presents the results of this work and reflects our thinking, with the input from a range of stakeholders, on a range of potential futures of New Zealand's electricity system.

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[1] For more information about the Capex IM, see the Transpower input methodologies on the Commerce Commission website (https://comcom.govt.nz/regulated-industries/input-methodologies/input-methodologies-for-electricity-gas-and-airports/transpower-input-methodologies).

# Development of EDGS 2024

As part of the development of EDGS 2024, we undertook a public consultation over May and June 2023 on a set of draft assumptions about the future state of the electricity system.

In this consultation, we sought feedback from stakeholders to ensure that the scenarios, and resulting modelling, accurately reflect the range of potential pathways that the electricity sector could take. For more information on the consultation and to read individual submissions, see the EDGS 2023 consultation webpage[2].

We received 19 submissions from stakeholders which were used to shape the scenarios used in EDGS 2024.

The consultation document proposed refreshing four of the scenarios presented in EDGS 2019. This included a scenario looking at current trends continuing, two scenarios looking at differing economic conditions, and a fourth scenario considering accelerated technological development.

## Stakeholders wanted a scenario focussed on climate change action

We had proposed removing the Environmental scenario which considered a range of levers for driving emissions reductions in the energy sector. It was instead proposed to incorporate these levers into every scenario rather than having a separate scenario examining this.

Several stakeholders expressed a need for either reinstating the Environmental scenario or adopting scenarios with similar aims and assumptions.

We therefore decided to retain an Environmental scenario, resulting in this EDGS update examining five potential futures. This Environmental scenario was, however, not a direct replication of the previous scenario, but an updated version to represent more current thinking and assumptions.

## There was a need for more variation across scenarios

Stakeholders conveyed a need for more variation across both supply and demand in the scenarios to explore the range of potential futures.

We have considered this in our modelling through building more variation into our demand and supply assumptions across scenarios and creating new methods and processes to support this.

For example, we have incorporated the ability to vary the generation stack fed into our electricity model. This meant we could vary the potential plants our model "chooses" to

[2] https://www.mbie.govt.nz/have-your-say/electricity-demand-and-generation-scenarios-edgs-2023-consultation

build from to reflect different states of the world across scenarios (such as costs of technology and the investment environment).

## Aligning fuel switching assumptions with the future worlds that we're modelling

We received feedback on the need to consider the ease and speed that fuel switching can happen for different applications, and how this would differ by scenario. For example, in a state of the world with more rapid technological development, alternatives may be more cost effective and easier to access so fuel switching is relatively easier and would happen at a larger scale sooner.

In response to this we have extended how we apply fuel switching in our model by introducing an adjustment to account for the speed at which fuel switching occurs.

## Submitters asked for more information on assumptions and results

Several submitters stated that they wanted more information on the assumptions underpinning the EDGS scenarios and associated modelling, as well as more detailed results. This was important for ensuring that the information is transparent and easily accessible to stakeholders.

In response to this we have published two data files alongside this report – one containing the assumptions that have been used into our scenarios, and the other containing the results of our modelling.

# Our scenarios

For EDGS 2024, five scenarios were developed to explore a range of potential futures of electricity demand and generation in New Zealand.

These scenarios build off those used in EDGS 2019 and have been updated to reflect developments in the energy sector, the wider economy, and available technologies.

Each of the five scenarios illustrate a **possible future** based on several high-level assumptions (which will differ from scenario to scenario). The scenarios are:

- **Reference**: Current trends continue with anticipated changes
- **Growth**: Higher economic growth drives immigration while policy and investment focus on priorities other than the energy sector
- **Innovation**: Current economic trends continue, alongside accelerated technological uptake and learning rates
- **Constraint**: International trends leave little room for domestic growth or innovation
- **Environmental**: New Zealand targets more ambitious reductions in emissions.

## Interpretation of scenarios

These scenarios do not represent forecasts of the future and should not be interpreted as such. They are also not expected to cover all possible futures. Instead, they aim to provide a useful and representative sample of potential outcomes which span the space of potential futures by examining plausible combinations of key assumptions.

The following should be considered when interpreting the scenarios and analysing results of our modelling:

- No significance should be attributed to the scenario names, which are used to help readers identify the scenarios and distinguish between them. The names are not intended to convey an indication that any scenario is better or worse than any other.
- Due to updates in our thinking around our scenarios, the scenarios in EDGS 2024 that have the same names as those in EDGS 2019 may not be directly comparable.
- We have not quantified the likelihood of any scenario relative to the others. For analytical purposes, it is most appropriate to assign all scenarios an equal weight.
- We have not assessed every combination of every scenario input.

## We have modelled five scenarios to capture a range of potential futures

### Reference

The Reference scenario is our baseline scenario and considers both current trends and anticipated changes. It is the scenario against which the other scenarios are compared.

We assume that economic, technological, and policy trends continue at the pace experienced in recent years. We account for currently implemented and upcoming policies and assume further electrification uptake.

## Growth

The Growth scenario models accelerated economic growth and corresponding increased demands on the energy system relative to the Reference scenario. The Growth scenario indicates what electricity demand could look like if the economy is growing quickly, but we are not investing in electrification at greater rates.

We assume that New Zealand experiences both higher economic growth and increased immigration, while policy and investment are focused on priorities other than the energy sector. The economy transforms to emphasise high technology (resulting in an increased share of the commercial sector), while higher income growth and personal wealth drive higher uptake of new technologies such as electric vehicles (EVs). Carbon costs are lower.

## Constraint

The Constraint scenario models slower economic growth which leads to lower energy demand growth. This scenario is essentially the inverse of the Growth scenario.

We assume that adverse international trends negatively impact New Zealand's economy, leaving little room for local growth or innovation. Lower income growth means lower uptake of technology such as EVs. At the same time, decreased international activity and slower technological development results in higher costs for wind turbines and solar panels than in the Reference scenario.

## Innovation

The Innovation scenario models increased rates of development and uptake of new technologies. We assume that new and improved technologies enable rapid electrification of both transport and process heat. This results in a faster reduction in technology costs across the economy (e.g., wind and solar generation and EVs).

While the rate of technological change and electrification is increased, total population and demand growth remains the same as in the Reference scenario.

## Environmental

More ambitious national emissions reduction targets are set than in the Reference scenario. Technology is more readily available due to regulation, incentives, or other measures. Initiatives are introduced to support both transport and process heat switching to lower emissions alternatives. Carbon prices are significantly higher, in line with government projections.

# Modelling assumptions

This section provides an overview of the assumptions that have been used for our modelling.

The accompanying assumptions file has time series and values for some of these series where applicable.

## Macroeconomic assumptions

Table 1 contains a summary of the key macroeconomic assumptions used across our scenarios. The discount rate, exchange rate, and coal import price are kept the same across scenarios. The rest of the assumptions vary as follows:

- GDP and population are varied across the Reference, Growth and Constraint scenarios to reflect different economic conditions. For the Innovation and Environmental scenarios, the Reference scenario settings for these variables are used as we choose to vary other assumptions to test outcomes.
- Higher rates of technology uptake are assumed in the Innovation scenario. A more decentralised economy sees an increasing share of national electricity demand in the South Island.
- Carbon prices falling in most scenarios to align with the latest market data. In contrast, the Environmental scenario has a rising price to align with 2023 government projections[3].

[3] New Zealand's projected greenhouse gas emissions to 2050 | Ministry for the Environment [(https://environment.govt.nz/facts-and-science/climate-change/new-zealands-projected-greenhouse-gas-emissions-to-2050/)](https://environment.govt.nz/facts-and-science/climate-change/new-zealands-projected-greenhouse-gas-emissions-to-2050/)

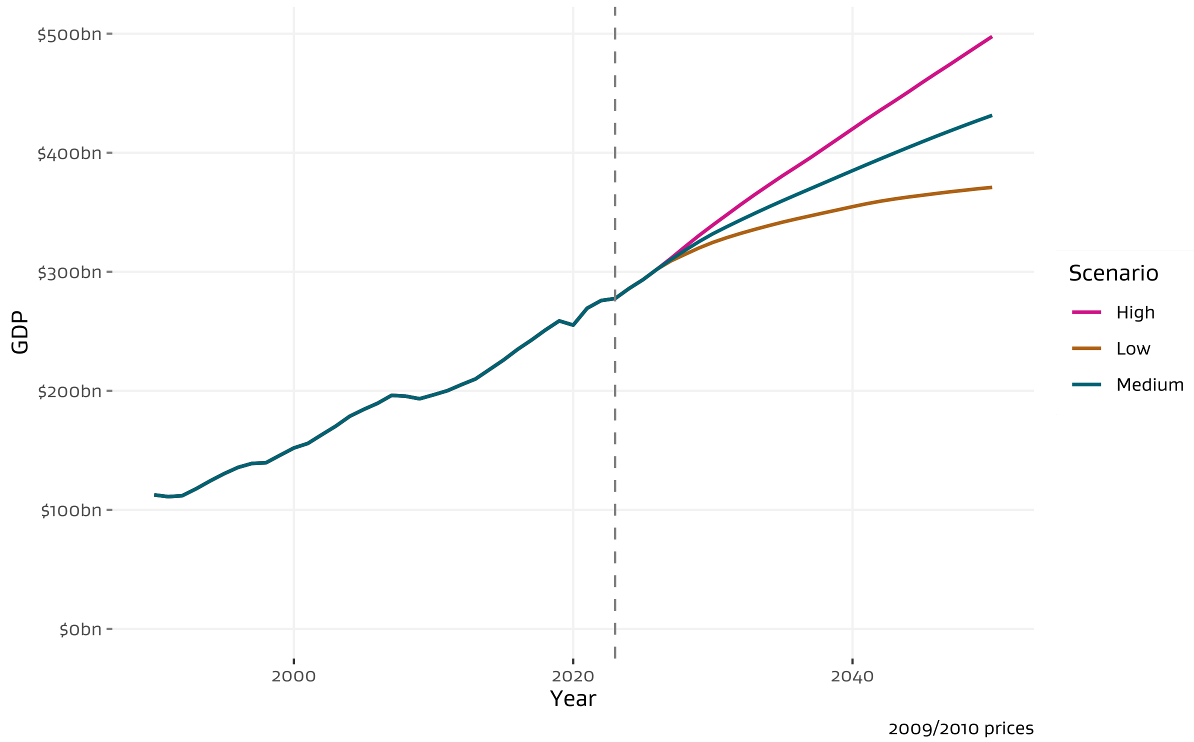
*Table 1: Summary of key macroeconomic assumptions*

| Assumption | Reference | Growth | Constraint | Innovation | Environmental |
|---|---|---|---|---|---|
| **GDP growth** | Treasury forecast (median) | Treasury forecast (top 90%) | Treasury forecast (bottom 10%) | Reference | Reference |
| **Discount rate** | 5% | Reference | Reference | Reference | Reference |
| **Exchange rate** | 0.65 USD/NZD | Reference | Reference | Reference | Reference |
| **Population growth** | Stats NZ forecast (median) | Stats NZ forecast (top 95%) | Stats NZ forecast (bottom 5%) | Reference | Reference |
| **Carbon price $/tonne** | Falling to $50 | Falling to $35 | Reference | Reference | Rising to $230 |
| **Crude oil price** | IEA crude forecast (Stated Policies) | Reference | 10% higher | Reference | IEA crude forecast (Net Zero) |
| **Coal import price** | IEA coal price forecast | Reference | Reference | Reference | Reference |
| **Natural gas domestic wholesale price** | Rising 2% p.a. in real terms | Reference | Rising 4% p.a. in real terms | Reference | Reference |
| **Vehicle kilometres travelled** | Ministry of Transport base forecast | Increased | Decreased | Reference | Decreased |
| **North Island share of national electricity demand** | 61.2% | Reference | Reference | Falling 0.2% pa | Reference |

## Gross Domestic Product (GDP)

Gross Domestic Product (GDP) is a key driver of industrial and commercial electricity demand. It is also used to adjust our transport demand projections, as higher economic activity tends to correlate with increased heavy vehicle commercial use. GDP projections are sourced from Treasury Budget Economic and Fiscal Updates.

***Figure 4: GDP projection assumptions***




## Population

Population is a key driver of residential electricity demand. Population projections are also used to adjust our transport demand projections, as higher population is likely to lead to higher driving activity for personal transport.

Stats NZ produces regular long-term population projections including probability ranges and different scenarios. We can therefore adjust our projections using the provided probability ranges. We use the median range for our reference scenario, the 95$^{th}$ percentile for "High" population, and the 5$^{th}$ percentile forecast for "Low".

Following unexpectedly high net migration during 2023, Stats NZ have advised that their most recent forecast is inappropriate for short-term use but is still appropriate for "projected trends beyond the late 2020s"[4]. We have therefore built a composite model using the most appropriate projections for short and long-term population projections, in line with this advice. We interpolate projections for the years where Stats NZ does not provide these.

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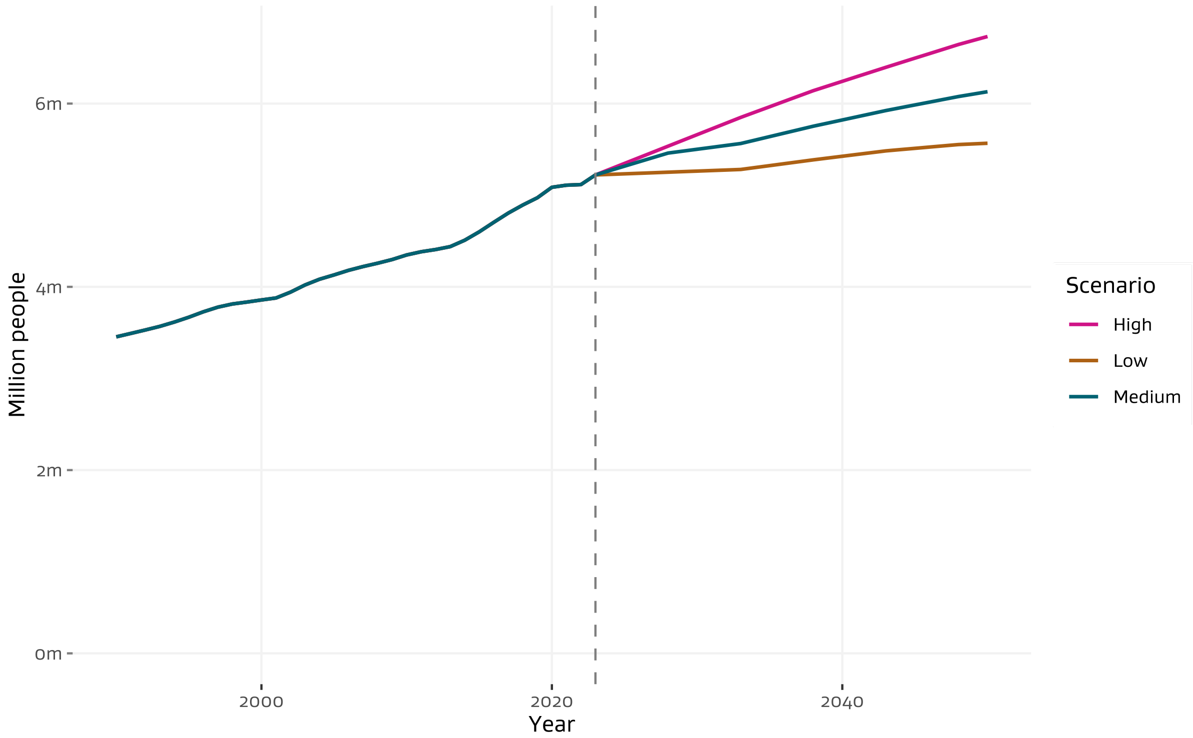
[4] Key advice for using updated 2018-base projections published in 2022 and 2023 | Stats NZ (https://www.stats.govt.nz/reports/key-advice-for-using-updated-2018-base-projections-published-in-2022-and-2023/)

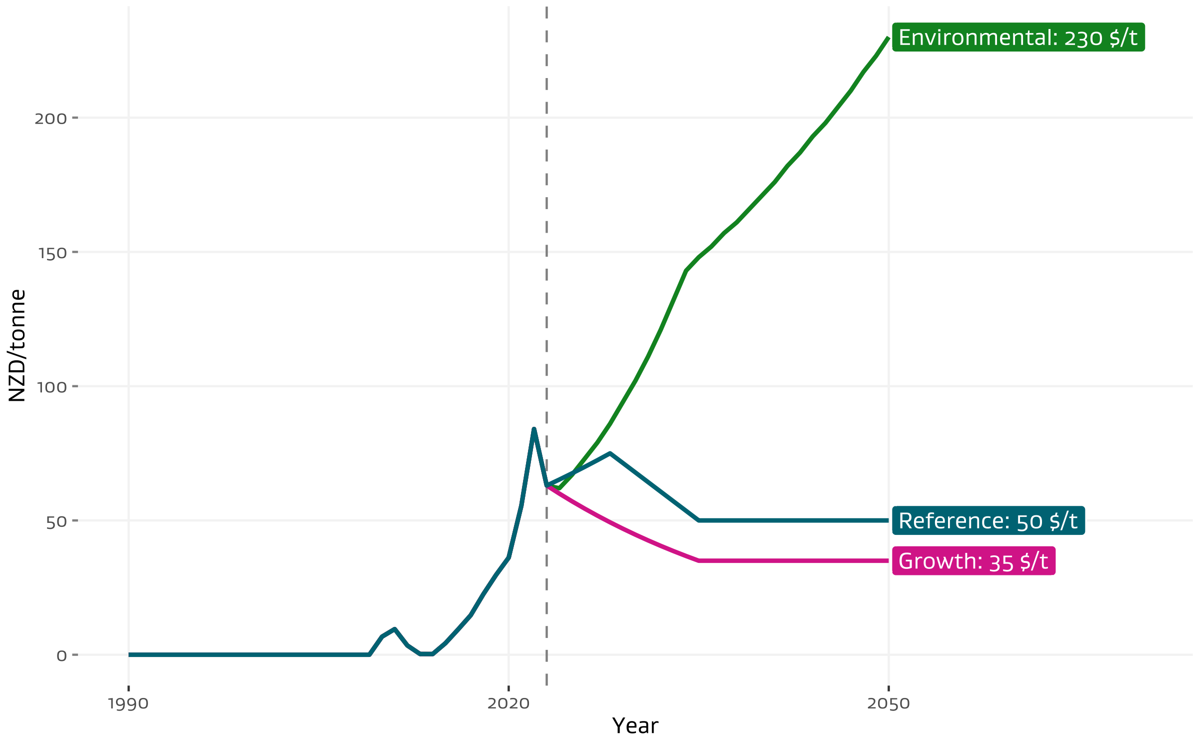
*Figure 5: Population projection assumptions*




## Carbon price

The carbon price is an exogenous assumption we input into the model. All else being equal, a higher carbon price would lead to higher costs for fossil fuels, and consumers may be more incentivised to switch to lower emissions fuels. Electricity generators are also incentivised to use less coal, gas, or diesel when possible. Sensitivity testing shows that industrial users and electricity generators are most sensitive to a higher carbon price. The carbon price path remains a key uncertainty in our modelling and so we have modified this across scenarios.

*Figure 6: Carbon price projection assumptions*




In the Reference scenario, carbon prices fall to $50/tonne by 2050. This projection is based on modelling from the Ministry for the Environment and Ministry of Primary Industries. Under current ETS settings, it is expected that carbon prices will approach the cost of planting enough additional forest to absorb another tonne of carbon. This was projected at a range of $25-$75/per tonne, with a midpoint of $50.

The Growth scenario drops the price further, to $35/tonne. In the Environmental scenario, we increase carbon prices to $230/tonne by 2050, in line with 2023 government emissions projections.

## Large energy users

New Zealand has several large energy users that produce specific products such as aluminium, methanol, steel, and ammonia-urea. For each of these users, assumptions on future operations are made on a case-by-case basis.

- Ammonia-urea production is assumed to stay at 2023 levels across all scenarios.
- The May 2024 energy supply agreement for the Tiwai Point aluminium smelter goes out to 2044, and we assume this level of demand stays in the system out to 2050. Aluminium production is assumed to stay at 2023 levels across all scenarios.
- For methanol production, we assume that Methanex's Waitara Valley plant remains mothballed and the two Motonui trains are closed in 2026 and 2030.
- For steel production, we assume that NZ Steel's Electric Arc Furnace sees a 50 per cent reduction in coal use at the Glenbrook steel mill for 2027 onwards.

## Electricity demand assumptions

Table 2 contains a summary of the key electricity demand assumptions used across our scenarios.

The rate of electric vehicle (EV) uptake is based on the Ministry of Transport's (MOT) uptake modelling, with EDGS scenarios using MOT's scenarios for baseline, slow, and fast rates of uptake.

Fuel switching (particularly electrification) rates and speeds have been adjusted across scenarios to represent variance in possible technological uptake. In some scenarios, some current energy demand is switched to hydrogen, which we then assume requires electricity demand for electrolysis.

We modify potential datacentre load across scenarios to represent a range of potential future demand from this sector.

Peak demand is a function of total demand and how consumers shift their demand between peak and off-peak times. There is a need to ensure that electricity supply can meet peak demand. In the Innovation and Environmental scenarios, we assume that users can more efficiently shift their demand, leading to relatively lower peak demand.

***Table 2: Summary of key electricity demand assumptions***

| Assumption | Reference | Growth | Constraint | Innovation | Environmental |
|---|---|---|---|---|---|
| **EV uptake rate** | Ministry of Transport (MOT) base scenario | Reference | MOT slow uptake scenario | MOT fast uptake scenario | MOT fast uptake scenario |
| **Fuel switching (exogenous assumption)** | MBIE projection | Reference | Reference | More activities switch, some to hydrogen | More activities switch, some to hydrogen |
| **Fuel switching speed** | MBIE projection | Reference | Reference | Switching curve brought forward | Switching curve brought forward |

| Assumption | Reference | Growth | Constraint | Innovation | Environmental |
|---|---|---|---|---|---|
| **Hydrogen production**[5] | Limited | Reference | Reference | Meet increased demand | Meet increased demand |
| **Datacentre load** | 233 MW by 2029 | 383 MW by 2029 | 113 MW by 2026 | 583 MW by 2035 | Reference |
| **Peak ratio** | Keep at latest historical levels | Reference | Reference | Moderate decline | Gradual decline |

## Fuel switching assumptions

Our energy model projects fuel use across different sectors based on exogenous inputs (such as GDP or population growth) and historical relationships between prices and energy intensities. However historical relationships between price and fuel intensities may not necessarily hold in the future, and this will not adequately capture expected changes in consumption brought about by technology change or government initiatives. We therefore modify the projections further to capture expected future trends.

Exogenous and explicit fuel switching rates are applied to fuel use within each sector. End use data comes from the Energy Efficiency and Conservation Authority's Energy End-Use Database (EEUD)[6]. We then apply assumed switching rates to each fuel, depending on the scenario.

Table 3 lists default assumptions for each use. For each use, we assume these are the proportions that are switched from fossil fuel use by 2050. The use is either electrified, switched to some combination of biomass and electricity, or switched to hydrogen in the case of high temperature heat.

Fuel switching rates are assumptions only. They are intended to capture expected future trends. This includes the impact of programmes such as already committed projects from the now closed Government Investment in Decarbonising Industry (GIDI) fund. However, they are not forecasts.

[5] Hydrogen production is modelled to meet hydrogen demand in scenarios where some end use of fuels is switched to hydrogen. This has electricity demand implications.
[6] Energy End Use Database | EECA (https://www.eeca.govt.nz/insights/data-tools/energy-end-use-database/)

*Table 3: Default fuel switching assumptions*

| End use | Reference, Constraint, Growth | Innovation & Environmental |
|---|---|---|
| High Temperature Heat (>300°C), Process Requirements | 0% | 50% |
| Intermediate Heat (100-300°C), Cooking | 5% | 50% |
| Intermediate Heat (100-300°C), Process Requirements | 50% | 70% |
| Low Temperature Heat (<100°C), Process Requirements | 80% | 95% |
| Low Temperature Heat (<100°C), Water Heating | 90% | 95% |
| Low Temperature Heat (<100°C), Space Heating | 90% | 95% |
| Motive Power | 5% | 30% |

We do not apply these assumptions in the same way to every use. For example, residential users are generally less price sensitive than commercial or industrial users, so we significantly decrease the switching rate assumptions for residential use. Further, the National Policy Statement for Greenhouse Gas Emissions on coal[7] means that coal use for low and intermediate process heat will be phased out by 2037. This means we have increased the switching rates for these activities to ensure that coal use trends towards 0 by that year.

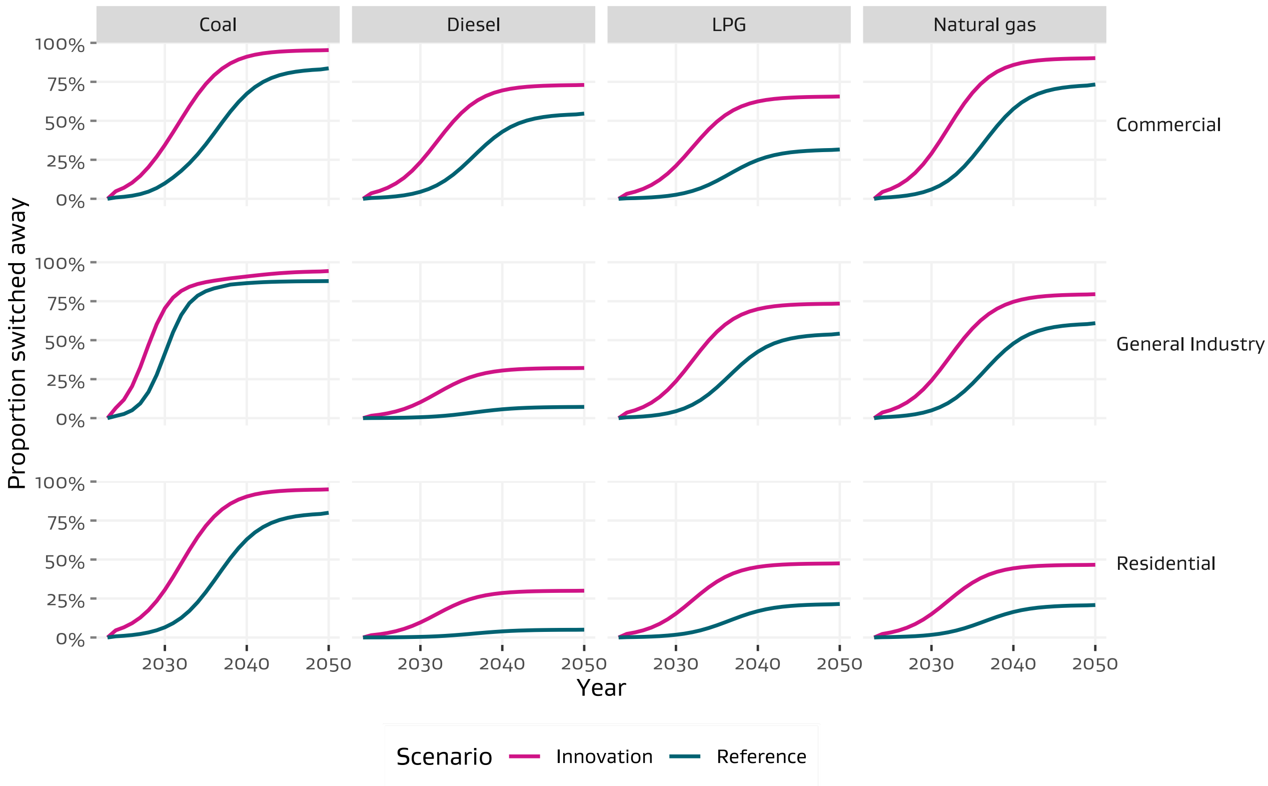
Any fuel used for high temperature process heat we assume is replaced with some mixture of electricity and hydrogen. For hydrogen production, we further assume electrolysis production at an efficiency rate of 50 per cent. This effectively means high temperature fuel uses is indirectly replaced with electricity, but at low efficiency rates.

For the Innovation/Environmental scenarios, we have also shifted forward the curves such that more of the switching happens earlier in the projected timeframe. This of course impacts the necessary generation build to meet new demand, but also the relevant energy emissions for earlier budget periods.

[7] National Policy Statement for Greenhouse Gas Emissions from Industrial Process Heat 2023 | Ministry for the Environment (https://environment.govt.nz/publications/national-policy-statement-for-greenhouse-gas-emissions-from-industrial-process-heat-2023

Each sector has quite different uses for each fuel, and so these lead to different sector switching rates. The final rates calculated are displayed in Figure 7.

***Figure 7: Fuel switching rate assumptions***[8]




## Datacentre build

Large-scale datacentre build could lead to an uptick in electricity demand that we have not previously forecast. Companies such as CDC, Microsoft, and Amazon have all expressed interest in building large-scale datacentres in New Zealand, and some have already begun operations, including DCI Datacentres. Preliminary consumption data for 2023 shows an increase in electricity intensity, which may be driven by higher demand from datacentres.

We have assessed announcements for current developer intentions and modified the expected build schedule per scenario to represent a range of possible future demand. Datacentres traditionally operate at baseload, and so we have assumed they will run with a load factor of 90 per cent. This means they draw 90 per cent of their maximum possible demand in any given year.

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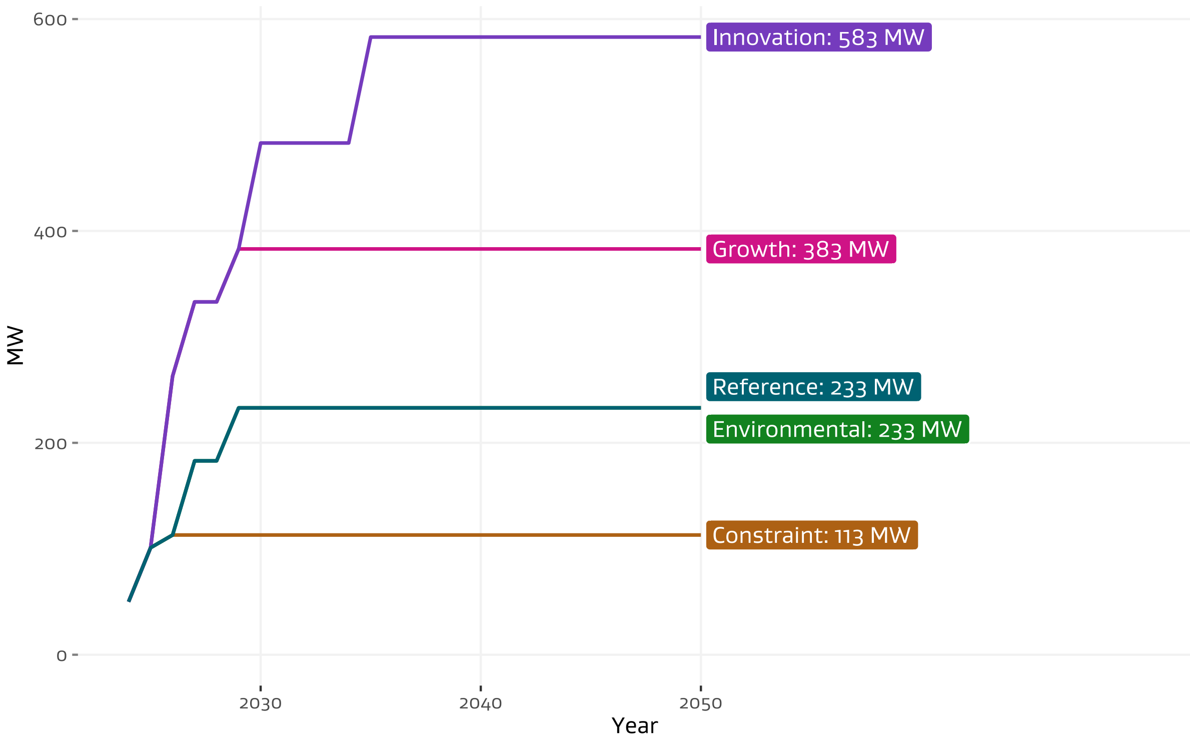
[8] "General Industry" excludes large energy users. These are modelled separately.

*Figure 8: Datacentre capacity assumptions*




In the Reference and Environmental scenarios, total datacentre demand capacity reaches 233 MW by 2029. This includes new build from Microsoft, Amazon Web Services, T4 Group, and CDC Datacentres. In the Constraint scenario, we remove some of this capacity, as some developer plans may not proceed in less favourable economic conditions. In the Growth Scenario, we instead add further signalled build in the form of a 150 MW datacentre in Makarewa, which has been proposed by Datagrid. In the Innovation scenario we add further generic datacentre load over a longer period, representing continued growth in the sector.

## Peak demand modelling

Peak electricity demand – or the highest level that demand reaches in any given year – is a key projection variable. Historically, we typically reach peak demand during winter evenings, as residential users increase demand for space and water heating. We currently project this using a peak "ratio", which is effectively the ratio between peak load and total demand. Residential consumers have the highest variance between peak and average demand, and so their peak ratio is highest. Residential demand will continue to drive higher peak ratios. Greater electrification of residential heating, as more homes move away from gas or LPG, will lead to higher peak ratios over time. However, greater baseload demand from users such as datacentres would lower the peak ratio.

When projecting peak demand, we use historical peak ratios to estimate possible peaks. It is interesting to note that these ratios have been increasing over the last few years. Six of the ten highest peaks on record occurred in 2023.

We decrease peak ratios over time in the Innovation scenario, representing increased "load-shifting" – or the ability for homes to shift their demand to off-peak hours. This might be achieved by more precise time-of-use pricing plans in combination with technology such as distributed home batteries, allowing users to shift consumption to times when it is easier on the grid.

These final levels of peak demand are a key input for modelling new generation build. The expansion model needs to build enough firm capacity to meet peak demand in any given year. When projecting whether we can meet peak, we also add a small buffer of around 700 MW, which represents the potential increased demand that could be driven by sudden cold snaps.

## Electricity generation assumptions

Table 4 contains a summary of the key electricity generation assumptions used across our scenarios.

MBIE is responsible for maintaining data on New Zealand's generation stack. This is a list containing information existing and potential new electricity generation plants in New Zealand and is a key input for GEM. There are several things to note about the generation stack used for this EDGS update:

- To ensure that the information used in our modelling is transparent, we source information for the generation stack from publicly available sources. This means that we have not included information that is commercially sensitive and unable to be disclosed publicly.
- Announcements made after June 3rd 2024 have not been included.
- GEM requires detailed information on plants including costs (both to construct and operate) and information on how plants may operate in the market once they're constructed. While some plants have been announced by developers, a lack of information means that they have not been incorporated into the generation stack.

The generation stack has been significantly overhauled for EDGS 2024, based on industry sector reports and media monitoring. This ensures the list of potential plants is as comprehensive as possible.

For some scenarios, we have constrained the pipeline by limiting the plants available to the model to reflect that not every plant that has been announced may end up being built. We have made further adjustments to capital costs, making some plants more or less economic to build depending on the scenario being run. This also impacts the wholesale electricity price indicator.

Uptake and electricity generation from distributed solar and battery connections is fed in as exogenous assumptions

*Table 4: Summary of key electricity generation assumptions*

| Assumption | Reference | Growth | Constraint | Innovation | Environmental |
|---|---|---|---|---|---|
| **Onshore wind / utility solar pipeline** | MBIE generation stack (constrained) | Reference | Reference | MBIE generation stack (unconstrained) | MBIE generation stack (unconstrained) |
| **Onshore wind / utility solar costs** | MBIE generation stack, moderate consenting cost adjustment | Reference | Capex 10% more costly | Capex reduced 15% | Full consenting cost adjustment |
| **Demand side response** | MBIE generation stack | Reference | 10% more costly | Reference | Reference |
| **Stratford peaker retirement** | 2053 | Reference | Reference | 2035 | 2035 |
| **Huntly Unit 5 retirement** | 2037 | Reference | Reference | 2032 | 2032 |
| **Huntly Rankine unit retirement** | N/A | Reference | Reference | In 2032 | In 2032 |
| **Huntly biomass use** | No | Reference | Reference | From 2032 | From 2032 |
| **Distributed solar/battery uptake** | MBIE BAU projection | Faster uptake | Slower uptake | Faster uptake | Faster uptake |
| **Grid scale battery capacity** | 733 MW by 2029 | Reference | Reference | 1700 MW by 2049 | 1700 MW by 2049 |

## Future operation of existing thermal plants

Contact's 377 MW Taranaki Combined Cycle plant (TCC) is expected to close at the end of 2024[9]. In the Environmental and Innovation scenarios, we also assume that the adjacent Stratford peaker units close in 2035. In most scenarios, we also assume Genesis Energy's Unit 5 combined cycle plant (previously known as e3p) will close in 2037 after 30 years of life. In the Innovation and Environmental scenarios, Unit 5 instead closes in 2032.

We also change the way in which the Huntly dual-fuel Rankine units are operated in the Innovation and Environmental scenarios, as they are refitted for biomass use rather than being decommissioned. We otherwise assume that these remain operational out to 2050[10].

## Consenting cost adjustments

The Electrify NZ work programme includes initiatives designed to create a more enabling consenting environment for renewable energy projects. We have included the impact of this in our modelling by reducing the capital costs for all plants in our pipeline that are not already consented, as outlined in Table 5.

Consenting costs are a function of plant size. There is some research on current consenting costs, but we are still building up our understanding of the exact impacts of this policy. For EDGS, we have reduced plant capital expenditure costs by halving the assumed consenting cost[11] for each technology in the Reference scenario. We have applied a larger adjustment in the Environmental scenario.

*Table 5: Consenting cost adjustments*

| Plant Type | Moderate consenting cost adjustment | Full consenting cost adjustment |
|---|---|---|
| **Solar** | -1.4% | -2.8% |
| **Wind** | -1.4% | -2.8% |
| **Biogas** | -1.3% | -2.6% |
| **Geothermal** | -0.765% | -1.53% |
| **Hydro** | -0.455% | -0.91% |

[9] CEN performance demonstrates underlying business health: (https://www.nzx.com/announcements/426369)

[10] We currently only model two Huntly Rankine units. Theoretically three could be operational, but the third unit is currently kept it in reserve and made available to the market on as needed basis.

[11] Infrastructure Consenting for Climate Targets: (https://media.umbraco.io/te-waihanga-30-year-strategy/z50ht3nz/infrastructure-consenting-for-climate-targets.pdf) – Table 19

This has the impact of marginally decreasing the wholesale electricity cost indicator that we model. This then leads to a slight increase in demand in our model. However, other inputs such as carbon price or GDP have much larger impacts on electricity demand and therefore required generation build.

## Distributed solar uptake

We project a range of uptake rates for distributed solar photovoltaic (PV) connections. These are solar installations connected to individual dwellings or businesses, rather than the electricity grid. With around a third of dwellings being rentals and some dwellings being unsuitable for installations of solar PV systems (due to factors such as shading or the type of building), we expect to see that maximum uptake would be materially less than 100 per cent of all dwellings. However, uncertainty around future costs and the relative economics, as well as potential future regulatory changes, mean that there are a range of potential trajectories for uptake of distributed solar PV.

### Approach to modelling distributed solar

Almost all distributed generation is modelled in SADEM rather than GEM. This means that distributed generation is not optimised alongside other generation types in GEM and instead has assumptions fed in about how it will change over time.

For distributed solar PV connections in particular, a satellite model is used to project the number of new connections, and associated capacity and electricity generation[12]. These projections are then fed in as exogenous assumptions to SADEM. This satellite model builds off data published on the Electricity Authority's Electricity Market Information website (EMI) on installed distributed generation in New Zealand.

### Projecting total connections

In recent years, data published on EMI shows average annual growth rates of around 20 per cent in connections with solar PV. We expect to see these growth rates for the next several years, but these are unlikely to be sustained in the longer term.

For each sector and scenario, we specify long term growth rates that we transition to over time. We apply these by starting with growth rates of 20 per cent in 2024. We then transition linearly to the longer-term growth rates as outlined in the following table that are applied for 2030 to 2050. Note that the same growth rates are applied for both solar only and solar with battery connections.

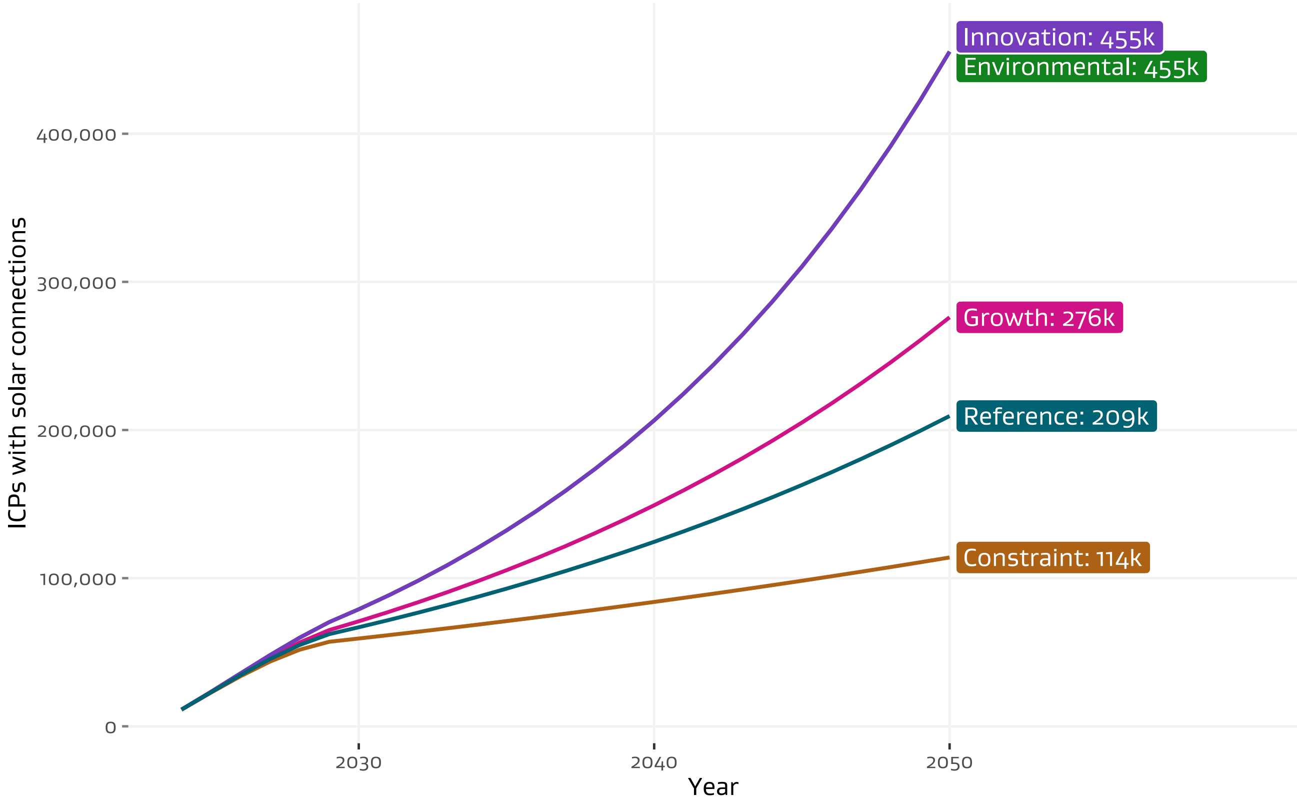
***Table 6: Distributed solar long-term growth rates***

| Sector | Reference | Growth | Constraint | Innovation | Environmental |
|---|---|---|---|---|---|
| **Commercial** | 3.0% | 4.0% | 1.5% | 5.0% | 5.0% |
| **Industrial** | 2.0% | 3.0% | 1.0% | 4.0% | 4.0% |
| **Residential** | 4.0% | 5.0% | 2.0% | 7.0% | 7.0% |

[12] For existing connections, the last historical values are carried forward to 2050.

We assume the lowest growth rates in the Constraint scenario, as higher cost of technologies and lower income growth leads to lower uptake of technology. The Growth scenario sees higher growth rates than the Reference scenario, as an increased focus on technology and higher income growth sees more households and businesses choosing to adopt solar PV systems. The Innovation and Environmental scenarios see the highest growth rates due to higher availability of technology and the introduction of other measures to encourage uptake of these technologies.

*Figure 9: Projected new distributed solar connections*




### Projecting installed new capacity

Once new connections have been projected, the number of cumulative new connections in each year are determined. That is, we determine the number of new connections in each year relative to 2023.

The following assumptions are made on the installed capacity by new connection for each combination of sector and system type. These have been derived by analysing recent data published on EMI[13]. There is more uncertainty in average capacity per connection for the industrial and commercial sectors, but these account for a lower proportion of total distributed solar capacity.

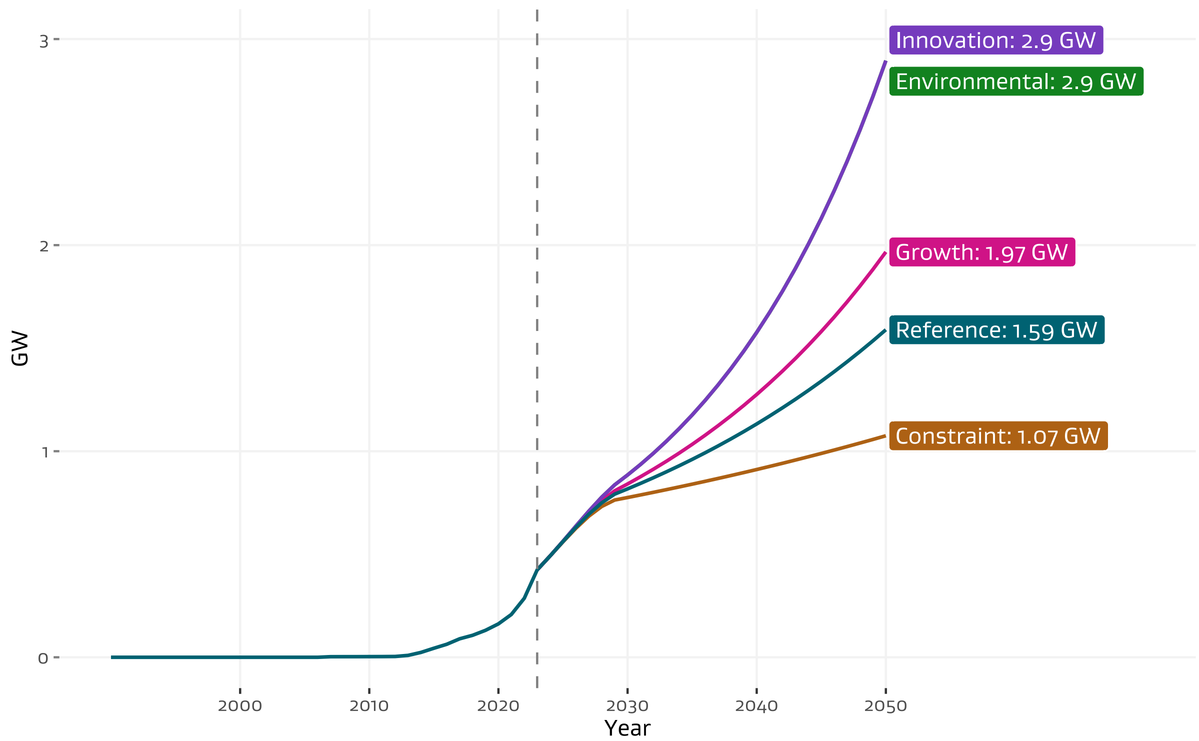
[13] Electricity Authority - EMI (https://www.emi.ea.govt.nz/Retail/Reports/GUEHMT)

*Table 7: Distributed solar average capacity per connection*

| Sector | System type | Capacity (kW) |
|---|---|---|
| **Commercial** | Solar only | 22 |
| **Industrial** | Solar only | 25 |
| **Residential** | Solar only | 4.7 |
| **Commercial** | Solar and batteries | 15 |
| **Industrial** | Solar and batteries | 10 |
| **Residential** | Solar and batteries | 5.5 |

These are applied to the number of new connections to get the total capacity from new connections in each year out to 2050 – essentially the cumulative "new build".

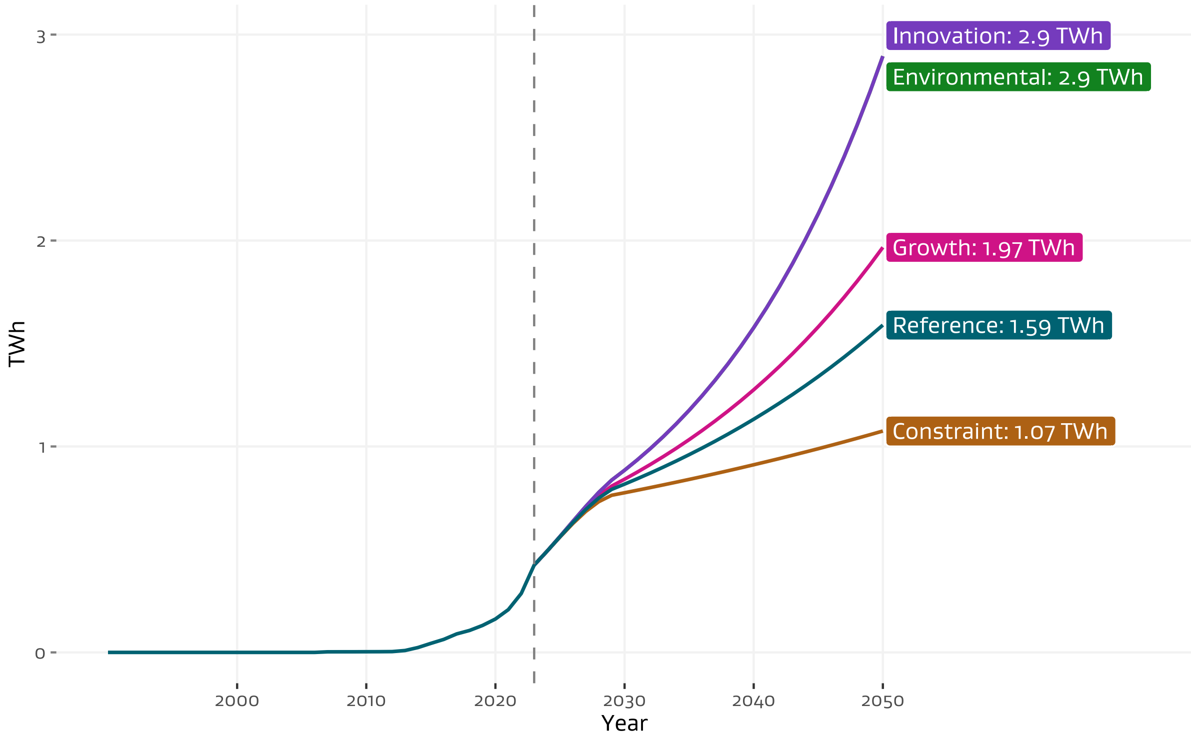
*Figure 10: Projected total distributed solar capacity*



### Overall contribution from distributed solar

As a final step, we determine the amount of electricity generation from these new connections. For this we assume a capacity factor of 14.5 per cent.

*Figure 11: Projected total distributed solar electricity generation*




## Battery Energy Storage Systems

Battery Energy Storage Systems (BESS) technology are expected to become a more important piece of the energy system in the future. These large-scale grid-connected batteries can store energy when supply is high and provide it back to the grid when demand is at a peak.

As more intermittent generation sources (such as wind and solar) are built, prices are likely to become even more volatile. This means there will be greater economic incentive for developers that can use BESS to buy electricity when prices are very low and sell back to the grid in times of tight supply.

To integrate BESS into our modelling, we compiled a list of developer battery construction intentions. These include the 4x100 MW units Genesis has proposed at Huntly, Meridian's 100 MW Ruakaka and Manawatu sites, and a Contact facility that may be built co-located with NZSteel's Glenbrook mill. We have also included several other battery sites that developers have signalled are likely to be co-located with solar farms, such as the New Zealand Clean Energy Masterton Solar & Energy Storage project.

In most scenarios, we assume that 733 MW of total BESS capacity will be built by 2029. This estimate is slightly conservative: as of October 2023, Transpower reported that around 910

MW of BESS was in their connection queue or under investigation[14]. In the Innovation and Environmental scenarios, we assume much greater BESS development over a longer time horizon, adding further generic BESS capacity to reach approximately 1,700 MW by 2049.

We do not yet have complete information on exactly when these BESS facilities are likely to be built, nor the expected costs or losses associated with charging and discharging. Where information was missing, we have made assumptions and judgements based on market expectations. This iteration of EDGS takes a high-level approach to BESS modelling through reducing peak demand by total projected battery capacity, meaning that the expansion model needs to build fewer thermal peakers to meet demand.

[14] Investment in flexible resources set to ease renewables transition | Transpower (https://www.transpower.co.nz/news/investment-flexible-resources-set-ease-renewables-transition)

# Modelling energy futures

MBIE maintains a suite of energy modelling tools that it uses to prepare projections and inform advice and analysis on the energy sector. There are two main models in the suite used for EDGS, namely the Supply and Demand Energy Model (SADEM) and the Generation Expansion Model (GEM).

SADEM is a model owned and operated by MBIE. The model projects energy demand for all sectors of the economy based on external drivers (such as population and economic growth), accounting for switching between different energy types within sectors. It also estimates energy sector greenhouse gas emissions based on projected energy supply and demand.

A version of the Electricity Authority's GEM is used to project the timing and type of new generation capacity that is built. GEM is a long-term planning model used to study capacity expansion in the electricity sector by projecting the timing and type of new generation capacity that is built.

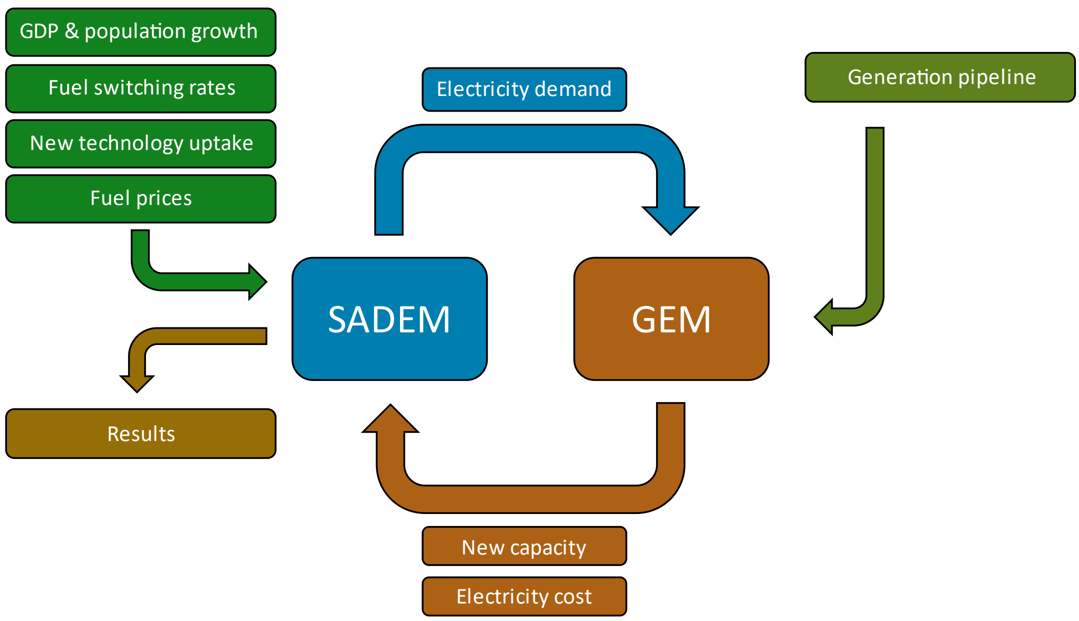
EDGS uses these two models to project energy demand across New Zealand under multiple scenarios, and to build generation capacity to meet future electricity demand while maintaining security of supply.

The cost of meeting demand through the available pipeline is a key driver of the wholesale electricity cost[15]. This cost also impacts demand through changing the relative economics between different energy types, so SADEM and GEM must be run together multiple times to converge on equilibrium demand.

[15] The "wholesale electricity cost" indicator that we produce from GEM reflects the long run marginal cost (LRMC) of new generation. It should not be viewed as a price forecast.

The following diagram provides a high-level overview of the data flows and interactions between SADEM and GEM as part of our modelling process. Appendix One provides more detailed information on how SADEM and GEM operate.

***Figure 12. SADEM and GEM overview***

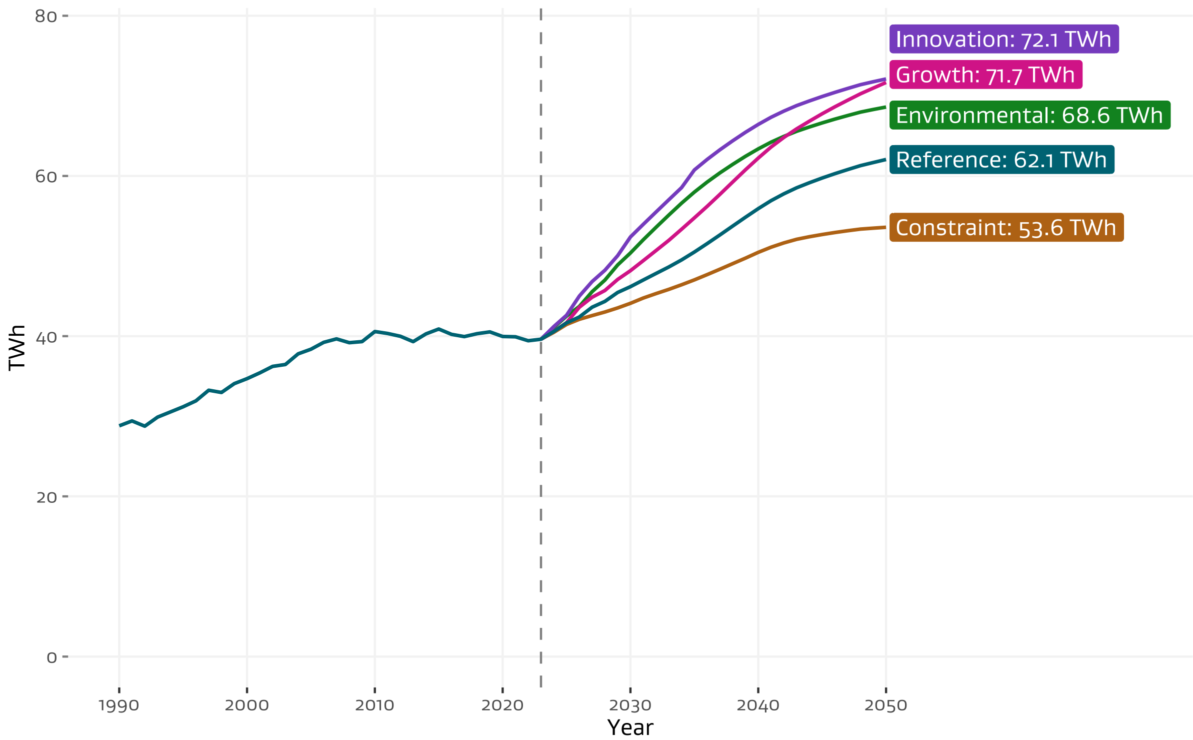


# Results

## Demand for electricity is expected to grow

All EDGS scenarios expect electricity demand to grow out to 2050, despite reasonably flat growth over the past 15 years. In the Reference scenario, total electricity consumption reaches 62.1 TWh[16] by 2050, a 56.6 per cent increase from 2023 consumption. Across the scenarios, the demand projection ranges from 53.5 TWh to 71.7 TWh.

***Figure 13. Total electricity demand***




This is chiefly driven by increased electrification in existing energy use, as well as increased uptake of some new technologies, such as electric vehicles and large-scale datacentres.

There is significantly faster growth among the Innovation, Growth, and Environmental scenarios. However, this growth is most rapid for the Innovation and Environmental scenarios, which both expect even more electrification of industrial use over the next 10-15 years. In contrast, the Growth scenario sees a more gradual increase out to 2050 as we assume steady economic growth.

While they take different trajectories, both the Growth and Innovation scenarios reach around the same total demand by 2050 of approximately 72 TWh. The Constraint scenario indicates only a 35 per cent increase in demand by 2050 due to lower economic activity and switching rates.

[16] TWh (terawatt hour) is a unit of electrical energy equivalent to 1 trillion watt-hours. New Zealand currently consumes around 40 TWh of electricity every year.

## Electrification is the main driver of increased demand

In the short term, the commercial and industrial sectors are the main sectors driving growth in national electricity demand. We also expect to see electrification of transport playing a larger role from the late 2030s onwards.

Between scenarios, the greatest variance in electricity demand projections comes from the commercial and industrial sectors. This is mostly due to assumed fuel switching of existing fossil fuel use and the level of electrification of low/medium heat industrial processes.

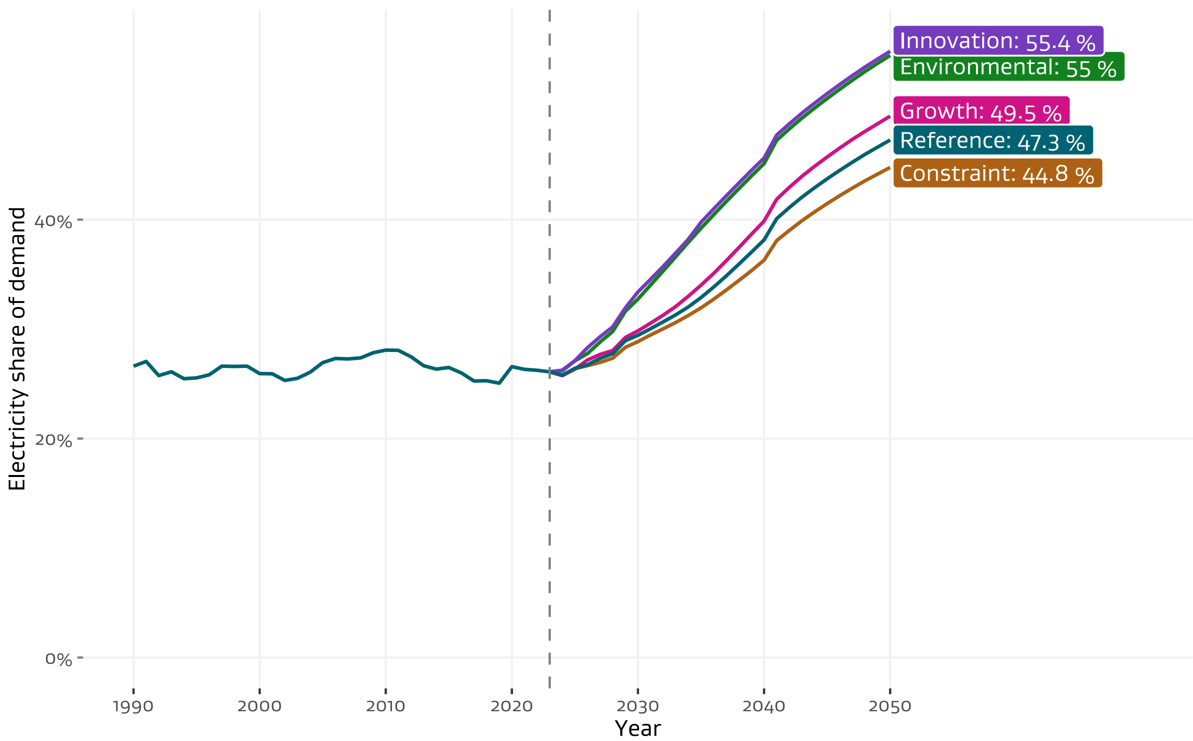
The rate and quantity of electrification is a key uncertainty that we have modified across scenarios. For example, the Innovation and Environmental scenarios assume faster electrification rates, brought about by faster technological advancement or other incentives and support, respectively. Additional demand shifts occur in the Environmental scenario, with further switching driven by a much higher assumed carbon price.

More detail on fuel switching assumptions by scenario can be found on page 17.

## By 2050 around half of all energy demand will be met by electricity

The assumed electrification across all scenarios sees existing energy use across the economy, mostly from fossil fuels, switched to electricity. We also see new demand coming online due to new technologies, such as datacentres. In 2023, only around 26 per cent of our total energy demand was for electricity, but this is estimated to increase to between 44.8 and 55.4 per cent by 2050.

***Figure 14: Electricity share of total demand***



## Industrial demand

Industrial electricity demand reaches 22.1 TWh in the Reference scenario, an increase of 38 per cent over 2023 levels. Most of this growth demand is in the medium-term, as we assume that industrial economic activity – and the associated energy demand – begins to decline in the 2040s due to a combination of flattening industrial economic activity and greater efficiency in the sector.

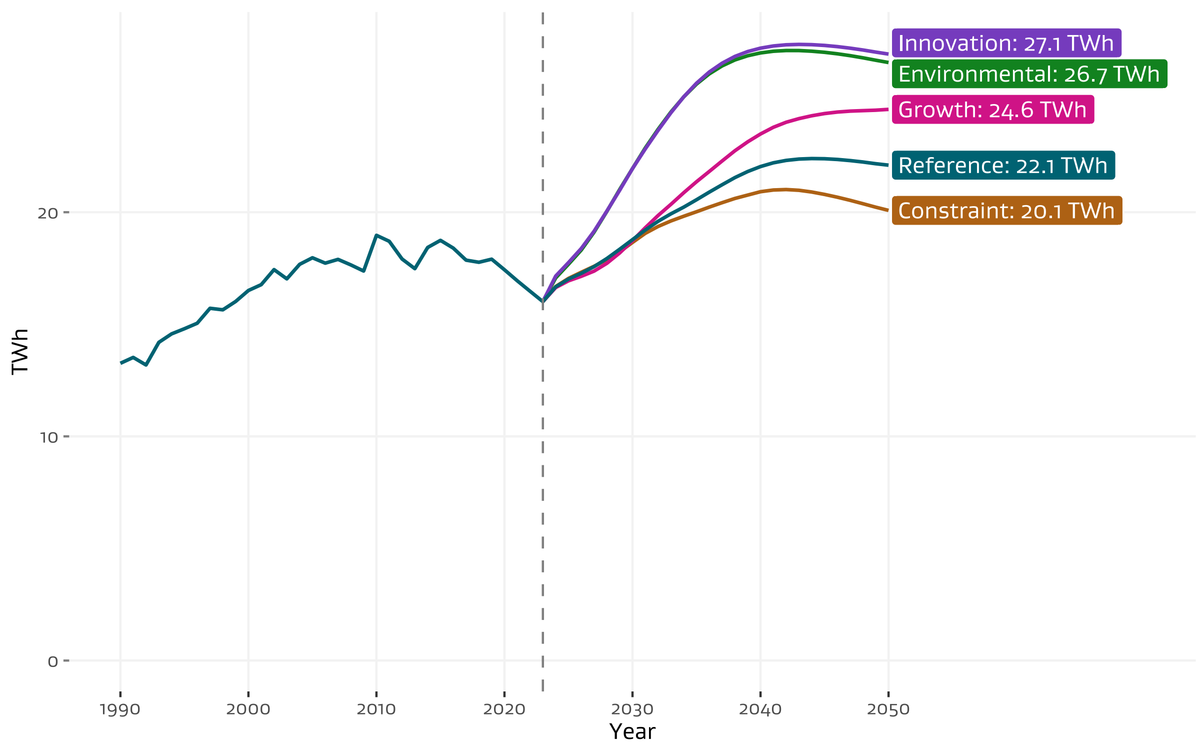
Demand in the Innovation scenario reaches 27.1 TWh in 2050, 22.6 per cent higher than the Reference scenario. The Innovation and Environmental scenarios show much higher electrification, particularly in the short-term. This is mostly due to higher rates of fuel switching being assumed in these scenarios. A large proportion of industrial demand for fossil fuels is for low and intermediate process heat, and much of this could be electrified under the right conditions.

The decline in industrial electricity demand in recent years has been in part driven by the closure of large industrial sites - such as Norske Skog's newsprint mill and the Marsden Point oil refinery. The projections of industrial sector demand reverse this trend, where all scenarios show growing electricity demand despite recent declines. There are two key reasons for this:

1) We do not assume that recent declines will continue. Unless otherwise specified, our default assumption is that large industrial sites will not close.
2) We assume that existing activity will begin to be electrified at greater rates.

We see electricity demand increase in the industrial sector. This is mostly due to assumptions of fuel switching of some low and intermediate heat processes.

***Figure 15: Industrial electricity demand***



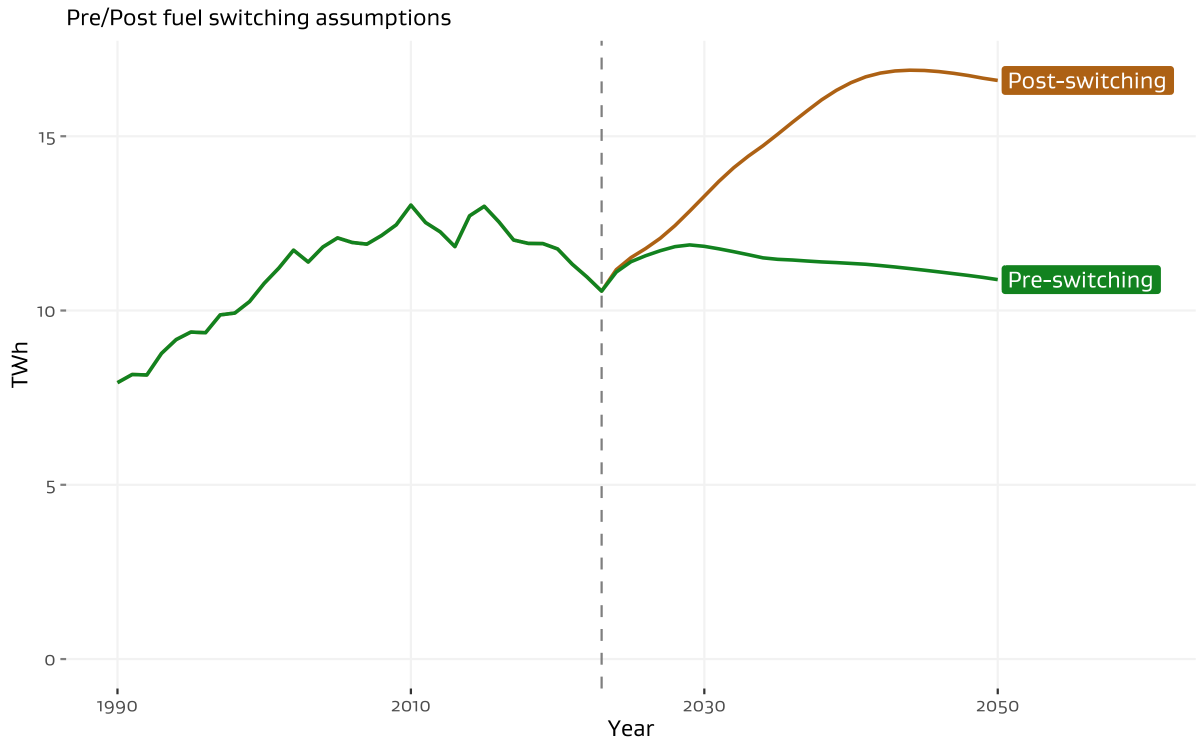
The National Policy Statement on Greenhouse Gas Emissions means that many coal boilers for low or intermediate process heat must be phased out by 2037. While some of these may be replaced with biomass boilers, we expect that many will be replaced with electric heat pumps, particularly for low-temperature applications.

Due to the time taken for some projects to be implemented, the now closed Government Investment in Decarbonising Industry (GIDI) fund will lead to some electricity demand increases from the installation of electrical heat pumps.

The impact of these electrification assumptions is significant. We have tested this by removing the impacts of our fuel switching assumptions from general industry demand[17], as illustrated in Figure 16. We then see that demand gradually declines over time in the Reference scenario. This is mostly due to expected efficiency improvements in the sector but is also a function of economic activity projections.

Industrial users are also most sensitive to shifts in carbon price, as fuel prices are integral to their outputs. Coal, natural gas, or LPG for process heat become less attractive options at a high carbon price, which further incentivises fuel switching. Lower electricity prices, such as those in the Innovation scenario, have a similar effect. Historically, industrial users are much more sensitive to fuel or electricity prices than residential or commercial users, as these make up a much larger portion of their overall costs.

***Figure 16: Fuel switching sensitivity testing on general industry demand***




[17] Note that “General Industry” excludes key industrial users such as NZ Steel or the NZ Aluminium Smelter.

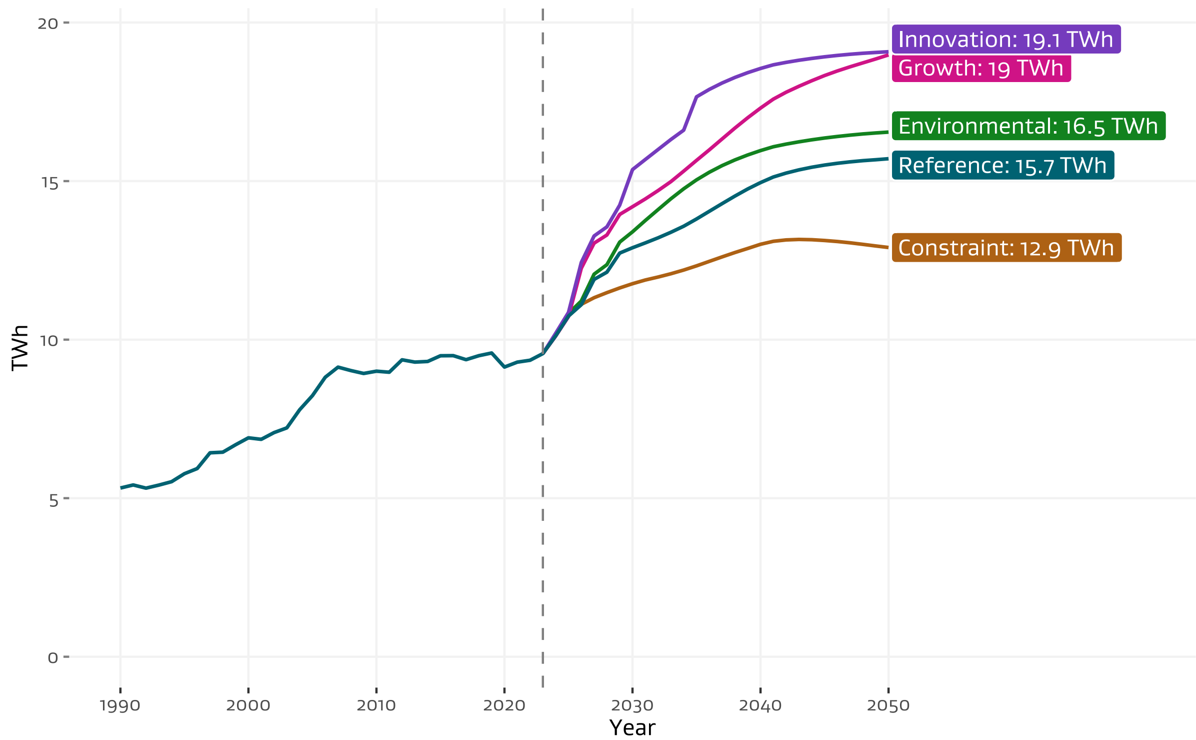
## Commercial demand

Commercial electricity demand grows from 9.6 to 15.7 TWh in the Reference scenario, an increase of 64.3 per cent over 2023 levels. In the Innovation and Growth scenarios, commercial electricity demand nearly doubles to around 19 TWh.

All scenarios show an increase in demand in the near term due to an expectation of greater electrification of existing space heating for commercial purposes, but also an expectation of planned large-scale datacentre builds, which could contribute more to electricity demand in the coming years.

The variance between scenarios is mostly explained by different assumptions of future economic activity of the commercial sector. However, we also assume different rates of large-scale datacentre build across scenarios, which drives a wide range in the resulting projections of commercial sector demand.

***Figure 17: Commercial electricity demand***

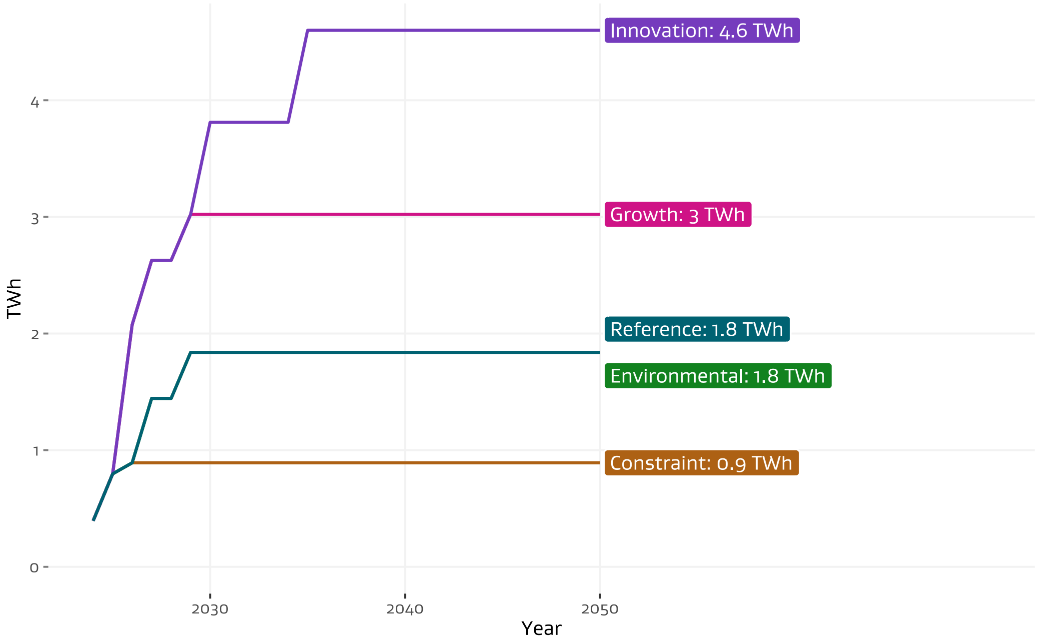



### Large-scale datacentres contributing to commercial demand growth

As it is still an emerging industry, the build of datacentres is a key uncertainty across our projections. To address this, we consider a wide range of potential datacentre build across the scenarios to analyse the impacts on demand and resulting generation build.

At the upper end demand reaches 4.6 TWh, which close to current demand from the Tiwai Point aluminium smelter. For the Reference scenario, we assume 1.8 TWh of demand by 2030, which would account for 2.9 per cent of total demand in that year.

*Figure 18: Datacentre annual demand assumptions*




While there is uncertainty over the future build rate of datacentres and their electricity demand, we have already seen an increase in commercial electricity intensity in historical 2023 data due to several datacentres coming online, mostly around Auckland. If this continues it could represent a structural shift in sectoral consumption trends.

As with many EDGS assumptions, these datacentre assumptions are not intended to be forecasts, but rather are intended to explore a wide range of possible futures. More detail on datacentre assumptions by scenario, including announced datacentres that have been included, can be found on page 18.

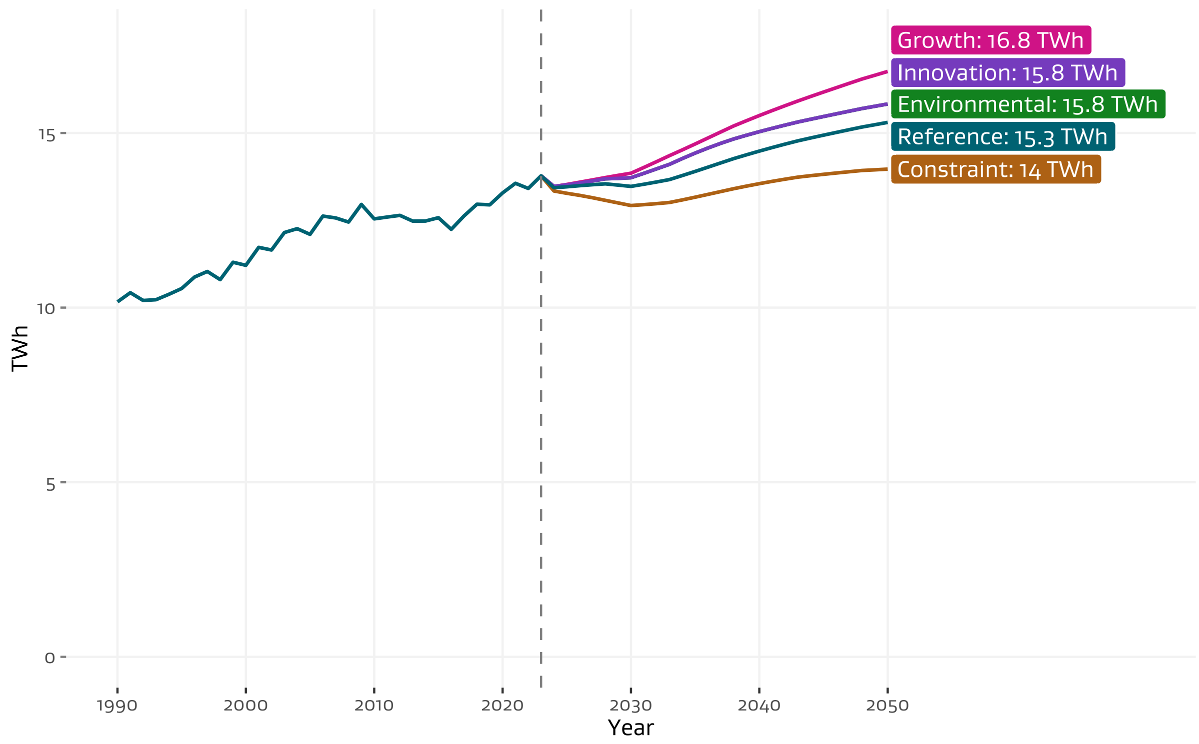
## Residential demand

Residential demand increases from the current 13.2 TWh to 15.3 TWh in the Reference scenario. The demand projection ranges between 14 and 16.8 TWh.

For the residential sector, population is the biggest driver of differences in demand between scenarios. For example, population is assumed to grow by 16 per cent in the Reference scenario and 27 per cent in the Growth scenario, which leads to the projected growth in demand.

Higher carbon prices or cheaper technology may lead to some further electrification of existing use, but greater population growth is more likely to lead to more new homes which are more likely to be built with electric heating in mind, rather than fitted with natural gas or LPG devices. It is important to note that due to a range of factors, we do not assume that residential consumers will be able to electrify consumption at the same rates as industrial or commercial users.

*Figure 19: Residential electricity demand*




## Transport demand

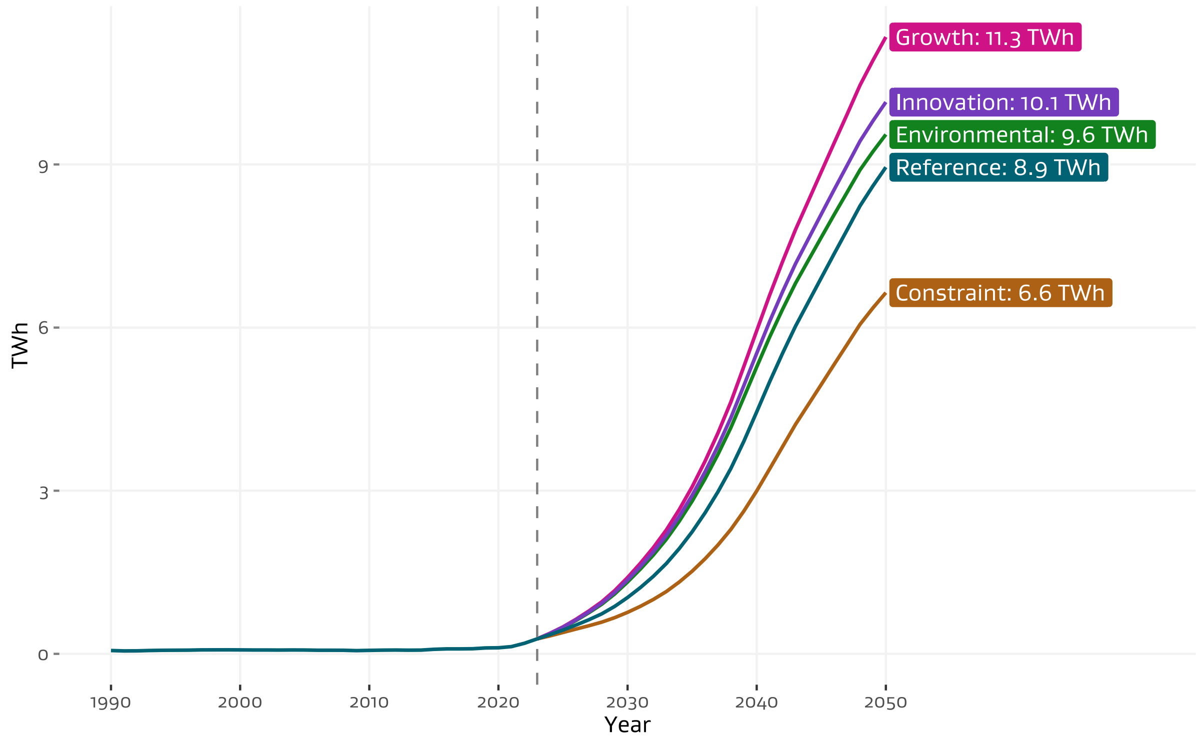
In the Reference scenario, electricity demand for road transport grows to 9.6 TWh, several magnitudes higher than the 0.27 TWh estimated in 2023. We see this growth across all scenarios, driven by Ministry of Transport projections of electric vehicle uptake rates out to 2050.

Electricity demand for road transport is effectively driven by two things – the uptake rate of electric vehicles (EVs) and "vehicle kilometres travelled" (VKT), a measure of how far New Zealanders drive in any given year.

Much of the variance between scenarios is due to different activity assumptions. In the Constraint scenario, we assume that lower population and GDP means lower demand for transport generally, both for personal and commercial use. Further, lower income growth in the Constraint scenario means that consumers are less likely to be able to invest in EVs.

In the Innovation and Environmental scenarios, we assume higher EV uptake rates, driven by either technological progress or public initiatives to make EVs more accessible. However, we also assume some mode switching in the Environmental scenario, as personal transport shifts to greater uptake of cycling or public transport. This means we project lower personal vehicle use and higher public transport use in the Environmental scenario.

*Figure 20: Transport electricity demand*




**EV uptake a key driver of transport demand**

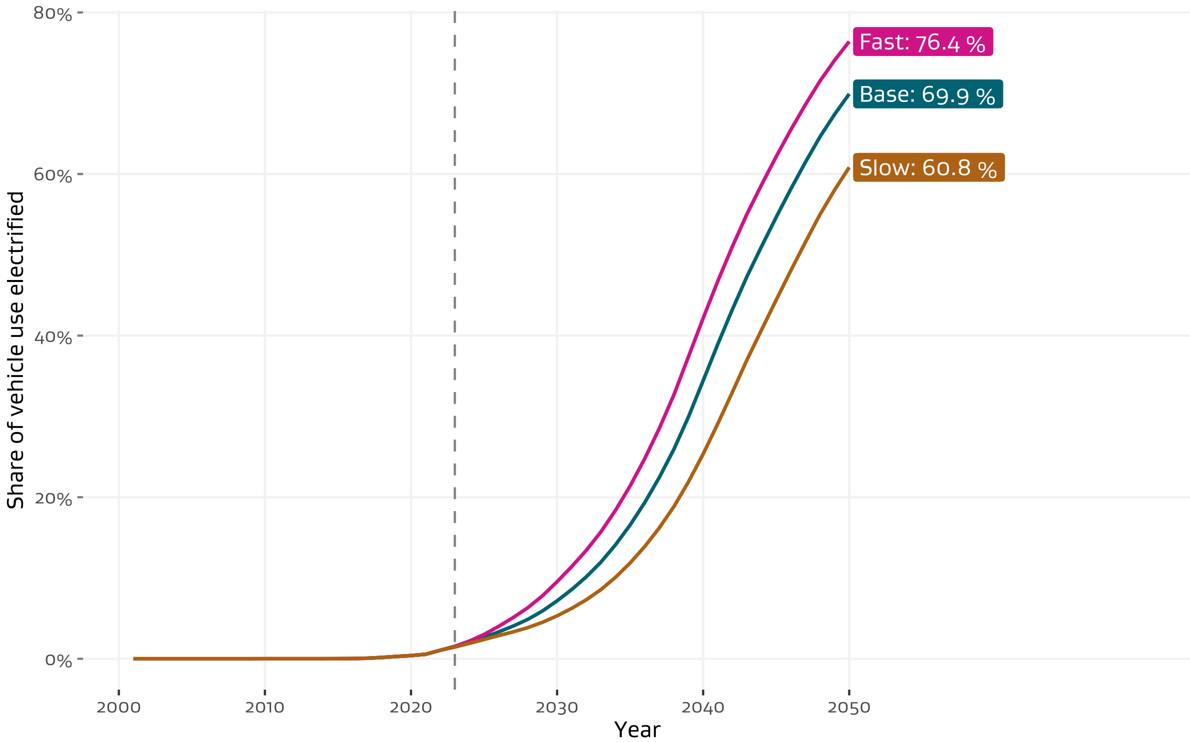
One key driver of electricity demand is EV uptake rates. The Ministry of Transport have provided MBIE with several scenarios of EV uptake rates[18]. We apply the Fast case to the Innovation and Environmental scenarios, the Slow case to the Constraint scenario, and the Base case to the Reference and Growth scenarios.

All scenarios expect significant uptake in EV use, particularly from the late 2030's onwards. However, no scenario reaches full electrification, instead ranging between 60.8 per cent and 76.4 per cent.

MBIE's modelling does not consider electrification of fleet counts, as energy requirements per unit of use is the more important metric for EDGS. The shares in Figure 20 refer to vehicle use in terms of distance travelled, not the share of vehicles that have been electrified. That is, a large commercial vehicle would usually travel much more than a personal light vehicle, so its electrification would be weighted more here.

[18] For more information on the Ministry of Transport modelling, and the Vehicle Fleet Emissions Model in particular, please see their site here: https://www.transport.govt.nz/statistics-and-insights/transport-outlook/sheet/updated-future-state-model-results

*Figure 21: EV uptake rates*



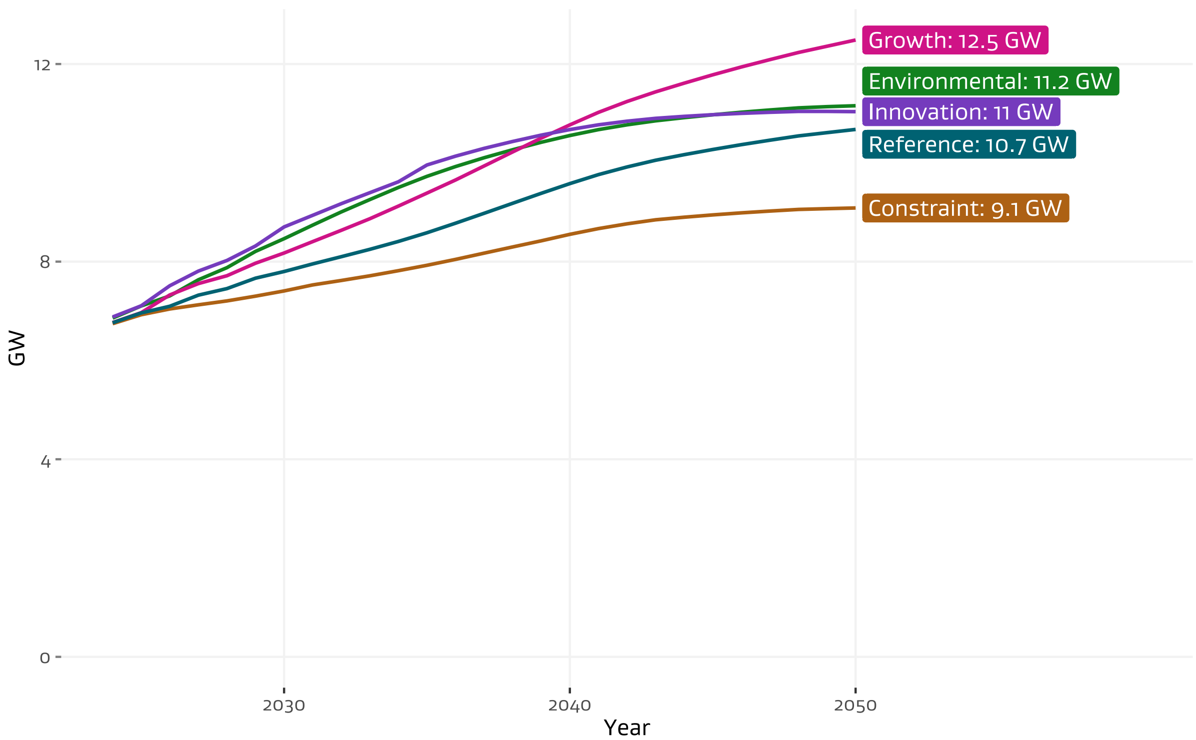

The EDGS scenarios do not currently consider electricity demand for non-road transport vehicles, nor the potential demand due to hydrogen electrolysis for fuel cell vehicles. This is not a comment on the validity of these technologies in the future, but rather that we currently have limited information on how they might work or what plausible uptake rates might be. Future EDGS releases may include further work in this area as different technologies continue to mature.

## Peak electricity demand

In 2023, peak grid demand (on a half-hourly average basis) was around 6.7 GW and is projected to grow by 59 per cent to around 10.7 GW in the Reference scenario.

Peak demand projections range between 12.5 MW and 9.1 MW across the Growth and Innovation scenarios. Despite higher overall electricity demand, peak demand begins falling in the Environmental and Innovation scenarios. This is because we assume that these scenarios engage in more efficient load-shifting. Time of use pricing, smart charging, and effective grid management would mean that electricity demand is able to be distributed more evenly across trading periods. This will lead to lower peak demand, and less need for expensive peaking solutions.

*Figure 22: New Zealand annual peak load*




It is important to note that this peak demand metric does not consider demand-side response arrangements, such as the May 2024 agreement between NZ Aluminium Smelters and Meridian Energy[19]. In this agreement, Tiwai can reduce its load by up to 185 MW if called upon by Meridian Energy (and will be offered payment for doing so). When modelling peak demand and firm generation response, we subtract relevant demand-side response from the peak demand metric here.

More information on peak demand modelling can be found on pages 19-20.

## To meet higher demand, more capacity is required

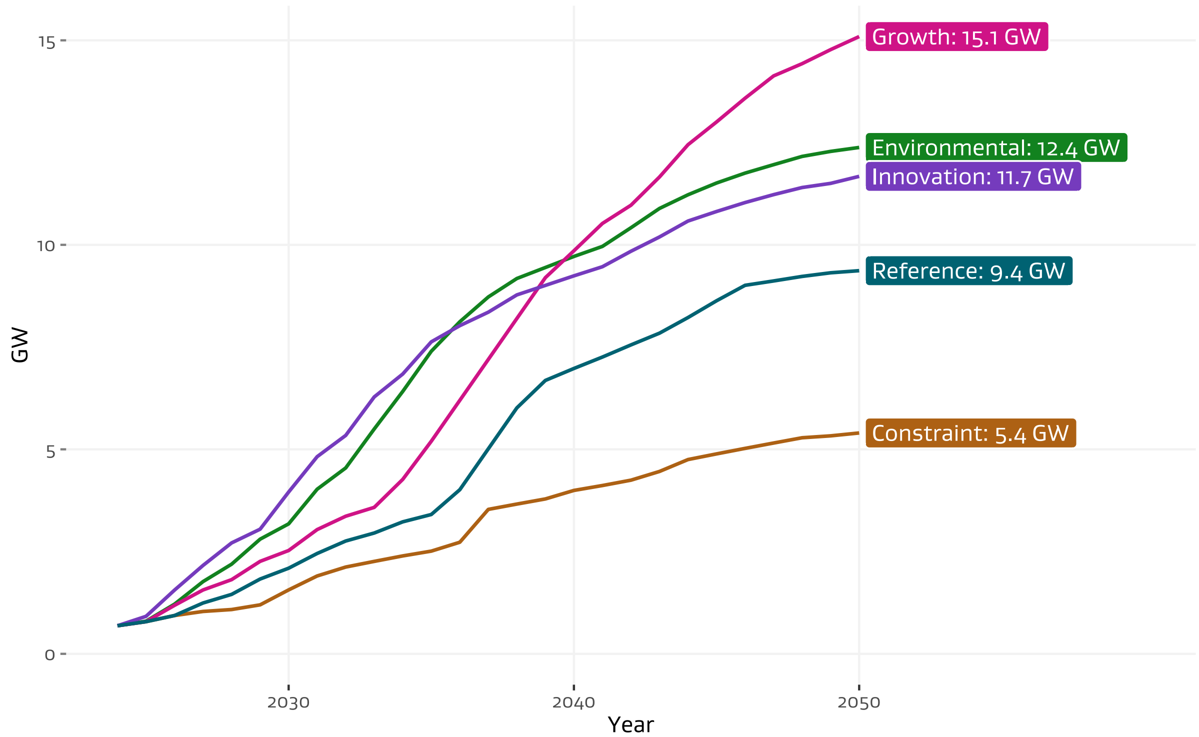
To meet future electricity demand, and to replace existing plants scheduled for retirement, 9.4GW of new capacity will be required by 2050 in the Reference scenario. As at the end of 2022, MBIE statistics show 9.85 GW of installed capacity, so this represents a gross increase of 95 per cent.

The scenarios vary by nearly 10 GW, with a lower end of 5.4 GW of new construction required in the Constraint scenario which sees lower levels for key drivers of activity. However, 5.4 GW still represents a gross capacity increase of 54.8 per cent from 2022 levels, and 15.1 GW in the Growth scenario represents a gross increase of 153 per cent. The Growth scenario has a significant amount of new solar generation capacity to account for solar generation having relatively lower capacity factors than wind plants. More efficient load

[19] Meridian and NZAS Sign Long Term Contracts | Meridian Energy (https://www.meridianenergy.co.nz/news-and-events/meridian-and-nzas-sign-long-term-contracts)

distribution and higher levels of battery installation in the Environmental and Innovation scenarios also mean that less overall capacity is required to meet peak demand.

***Figure 23: New build required***




The net capacity gain will be lower as it accounts for the loss in retired or decommissioned plants. Plant decommissioning is broadly similar across the scenarios, as it is driven by when we expect current plants to reach the end of their useful life. This impacts some older wind farms that may need to be retired after 25 years of operation, such as the farms at West Wind or Mill Creek[20].

We also expect retirements of thermal plants in the existing generation fleet. The assumed closure dates of these plants are one of the key drivers for the renewable share of electricity generation and electricity generation emissions, as mostly renewables are built to replace the decommissioned capacity. More information on these assumptions can be found on page 21.

## Most new build is wind and solar

GEM often chooses to build new capacity using wind and solar technology as they have a relatively lower overall cost than other plant types. GEM is run to minimise the cost to the system by choosing the lowest cost build schedule to meet total and peak demand in each scenario in each year. For technologies such as wind and solar where costs are relatively lower, it is likely that GEM will choose to "build" these at a greater rate. More information on GEM is available in Appendix One.

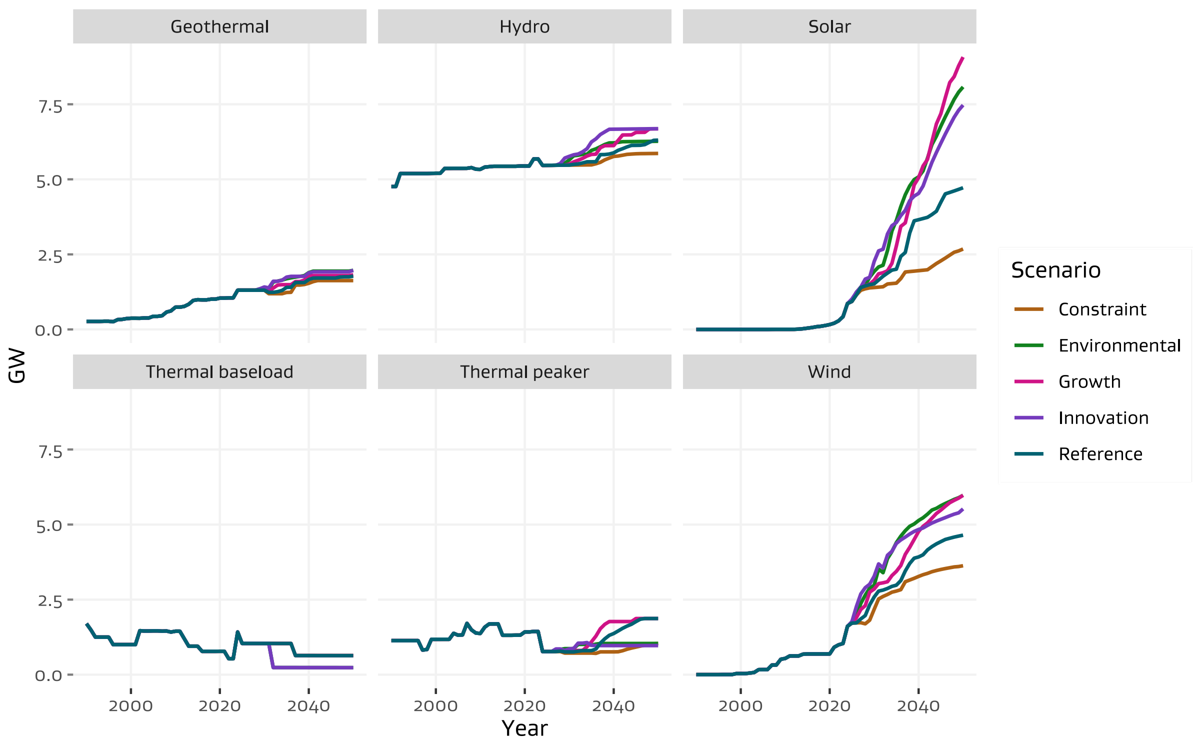
[20] Some of these plants may be repowered, and our current version of GEM treats this as new generation build due to potential differences in operation and configuration.

As a result of this, most new builds seen across the scenarios are onshore wind and solar farms. These tend to have lower capacity factors than existing thermal or hydro plants, which means more total capacity will need to be built to reach similar output levels.

In the Reference scenario solar capacity is projected to grow from 0.4 GW to 4.7 GW by 2050. It ranges between 2.7 GW and 9.1 GW depending on the scenario. Wind capacity is similarly projected to expand from 1.0 GW to 4.6 GW in the Reference scenario. Wind capacity at 2050 ranges from 3.6 GW to 6.0 GW.

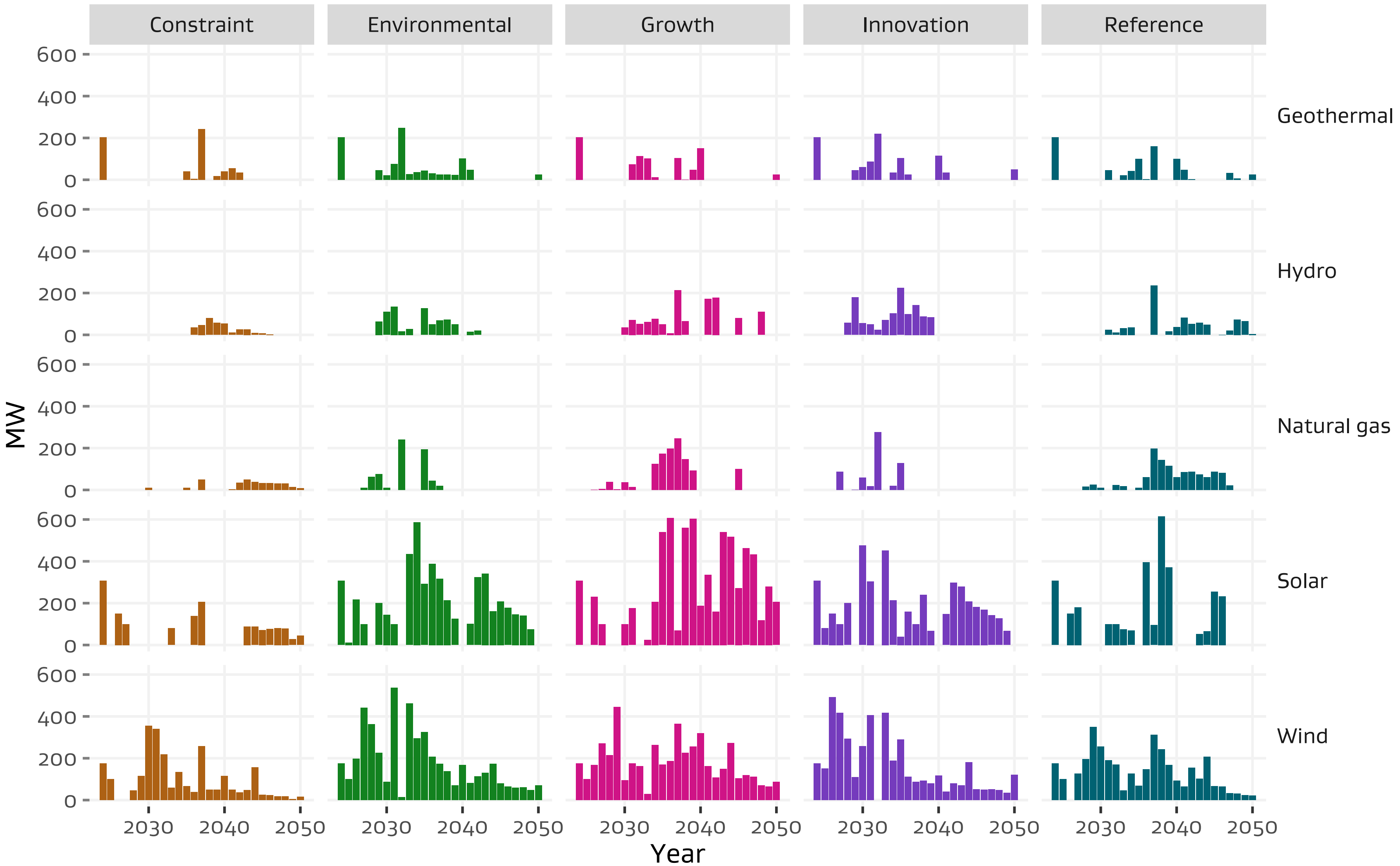
There is also some new geothermal build across all scenarios, providing further baseload generation capacity. However, this is not sufficient for firming. As a result, we see natural gas peakers and some smaller-scale hydro plants (mostly run-of-river) required later from the 2030s to provide further firming capacity. Additional thermal peakers are especially required under the Growth and Reference scenarios with between 0.8 and 0.9 GW more thermal peaking capacity required by 2050 compared to the other scenarios.

***Figure 24: Total capacity by technology[21]***




[21] "Thermal" here refers to plants that burn fossil fuels for electricity generation, such as coal and natural gas. Biomass or other renewable plants are not included in Figure 24.

*Figure 25: Generation build schedules*



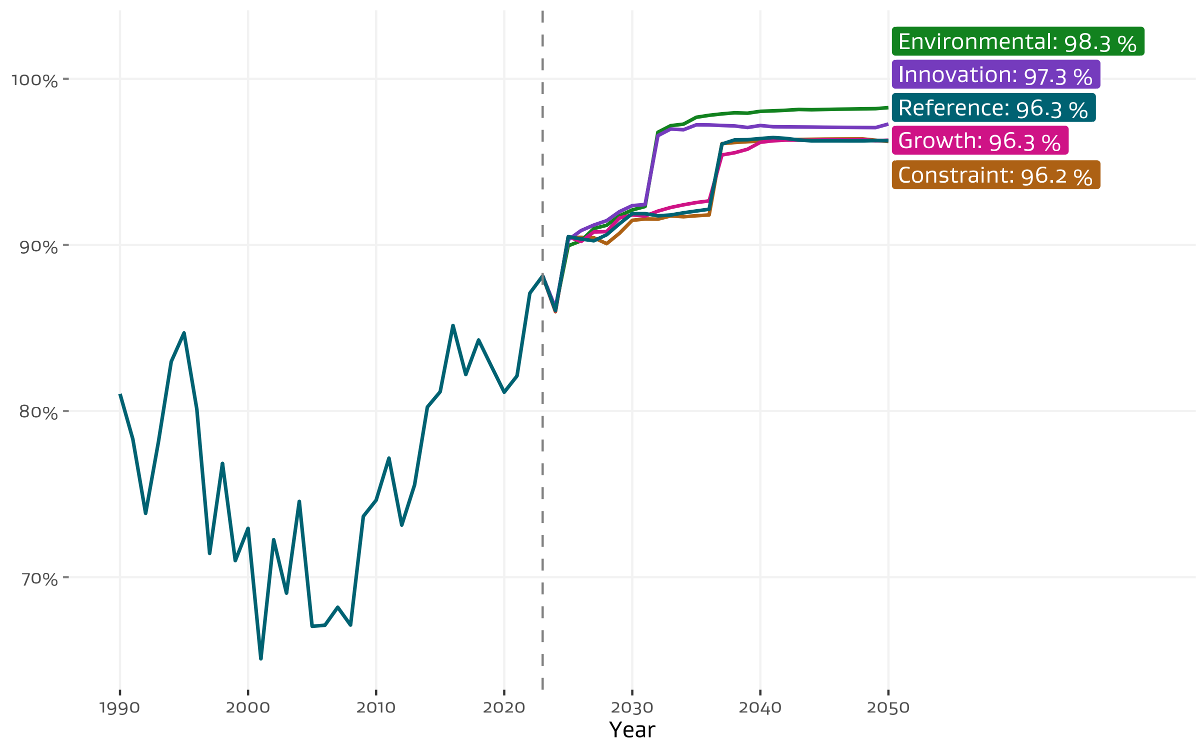
## Renewable share of electricity generation to increase

The increase in renewable generation leads to an increase in the share of electricity generation from renewable sources. The share reaches 96.3 per cent in the Reference, up from 87.1 per cent in 2022. However, natural gas peakers are still expected to play a role in all scenarios. Even under the Environmental scenario the renewable share stabilises at around 97 per cent in the 2040s before gradually climbing to 98.3 per cent by 2050, as increased carbon prices make fossil generation increasingly less attractive.

It is possible that these gas peakers may be replaced by green technologies such as biomass, biogas, waste-to-energy, or hydrogen peakers. It is also possible that peakers will become less necessary if large-scale grid batteries are deployed at scale, allowing peak demand to be met with stored renewable electricity. However, there is currently limited information on how some of these technologies would operate in practise. The EDGS scenarios cannot capture all possible futures and reflect the most plausible expectations as at the time of writing.

A key driver of increases to the renewable share of electricity generation is our assumptions on the timing of thermal plant closures. As we see gas or coal plants such as the Huntly Rankine units or the Taranaki Combined Cycle plant close, new generation comes online. To meet this gap, renewable generation such as solar or wind is built as it is relatively more economic. However, the model must also consider other implications such as variability of supply and how demand is met in peak periods.

***Figure 26: Renewable share of electricity generation***

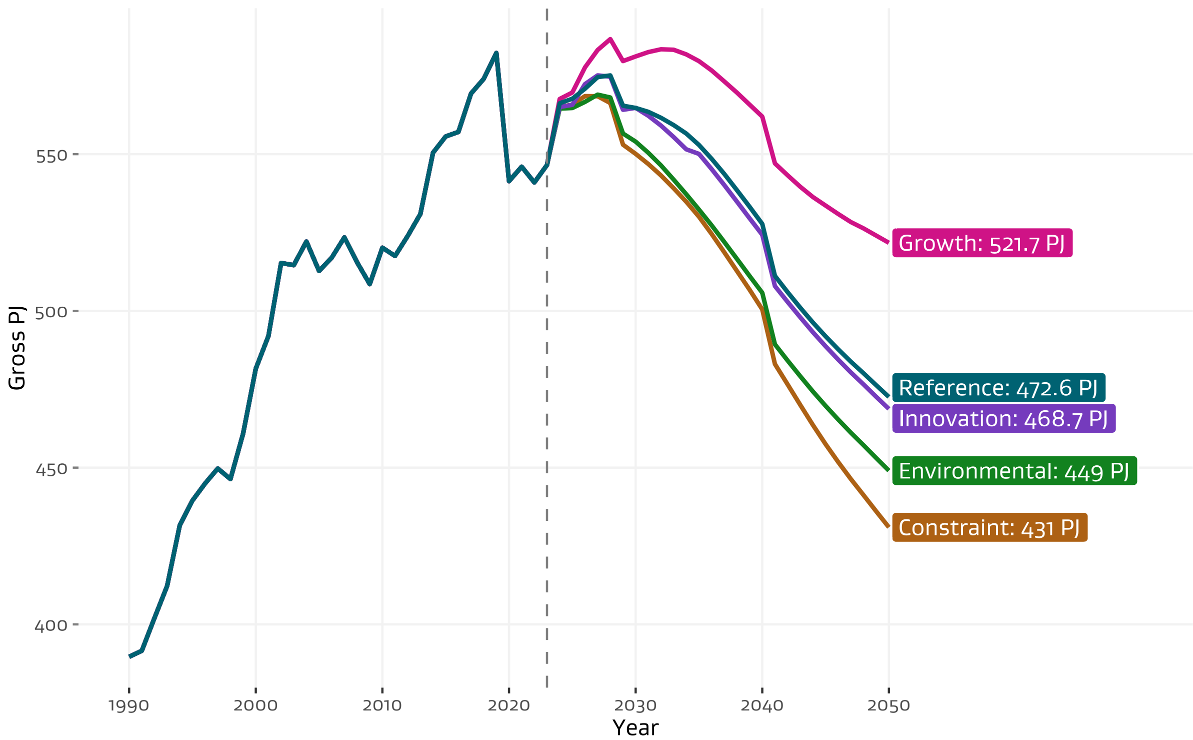


## Total energy consumption falls across our scenarios

Despite greater electrification and economic activity, we see that total energy demand declines 13.5 per cent to 472 PJ by 2050 in the Reference scenario. There is however a large variance across the scenarios, from 521 PJ in the Growth scenario to only 431 PJ in the Constraint scenario.

We see energy demand falling overall due mostly due to expected gains in energy efficiency. Technologies such as electric heat pumps or EVs require less energy input to service the same level of demand. The greatest driver of overall decline however is the energy requirement for the transport sector, as higher electrification means less total energy input for the same activity. Transport energy demand falls 36.6 per cent (76.8 PJ) in the Reference scenario.

***Figure 27: Total final consumption***




The biggest difference between scenarios comes from the industrial and commercial sectors, where different fuel switching rates and activity assumptions lead to large differences in total energy requirements. The residential and transport sectors show narrower bands across scenarios, meaning that these sectors are less sensitive to our range of input assumptions.

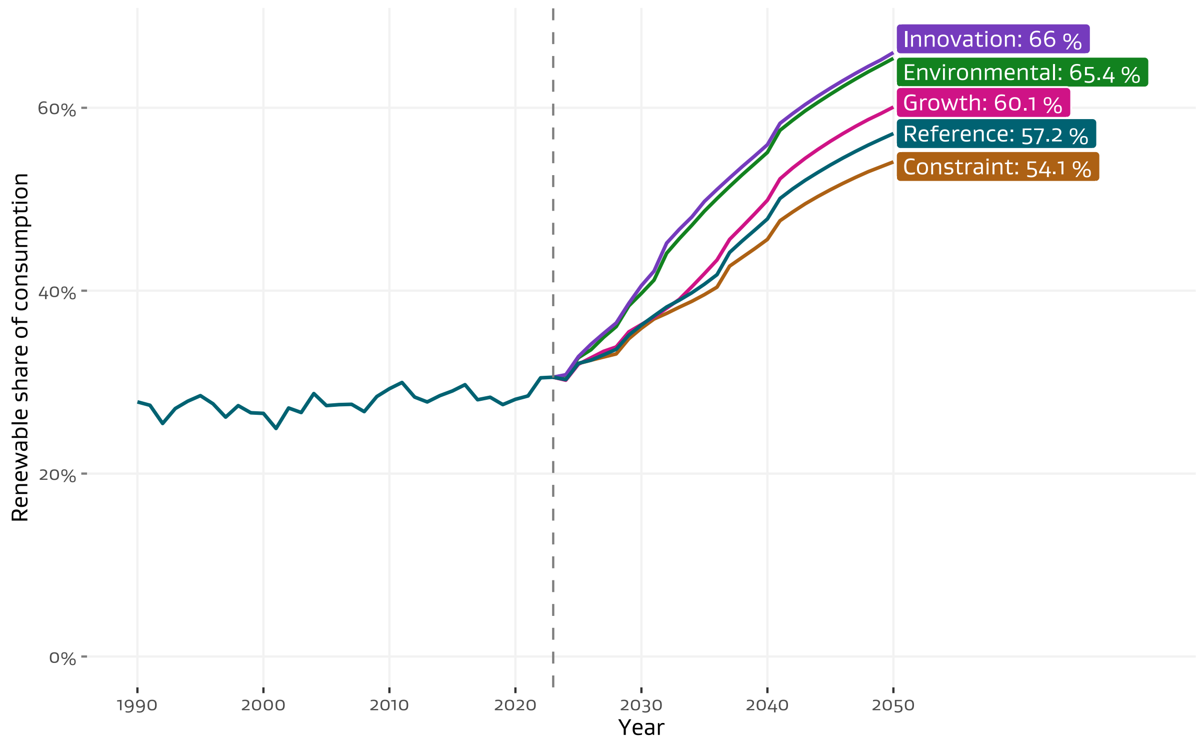
As the same assumptions on the future operation of Methanex are applied across all scenarios, there are similar shifts downwards for all scenarios as gas consumption decreases.

The dynamics of the New Zealand natural gas market are out of scope for EDGS modelling. Gas consumption for direct energy use, electricity generation, or non-energy use such as chemical manufacturing has not been restricted by projected supply in this iteration of EDGS. Comparing projected gas use to natural gas field operator projections of expected projection shows there may be a gap in supply[22].

## Renewable share of energy consumption grows with higher electricity use

The renewable share of final energy consumption is the proportion of all energy consumed produced by renewable sources, including the renewable share of consumed electricity. New Zealand's renewable share of final energy consumption reached a record high of 30 per cent in 2022. We see that this climbs to 57.2 per cent by 2050 in the Reference scenario. In the Innovation and Reference scenarios, this reaches around as high as 66 per cent, as faster rates of assumed fuel switching means less non-renewable energy is used for road transport or industrial processes.

***Figure 28: Renewable share of final energy consumption***




[22] Field operator projections are updated annually and can be found at https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/petroleum-reserves-data

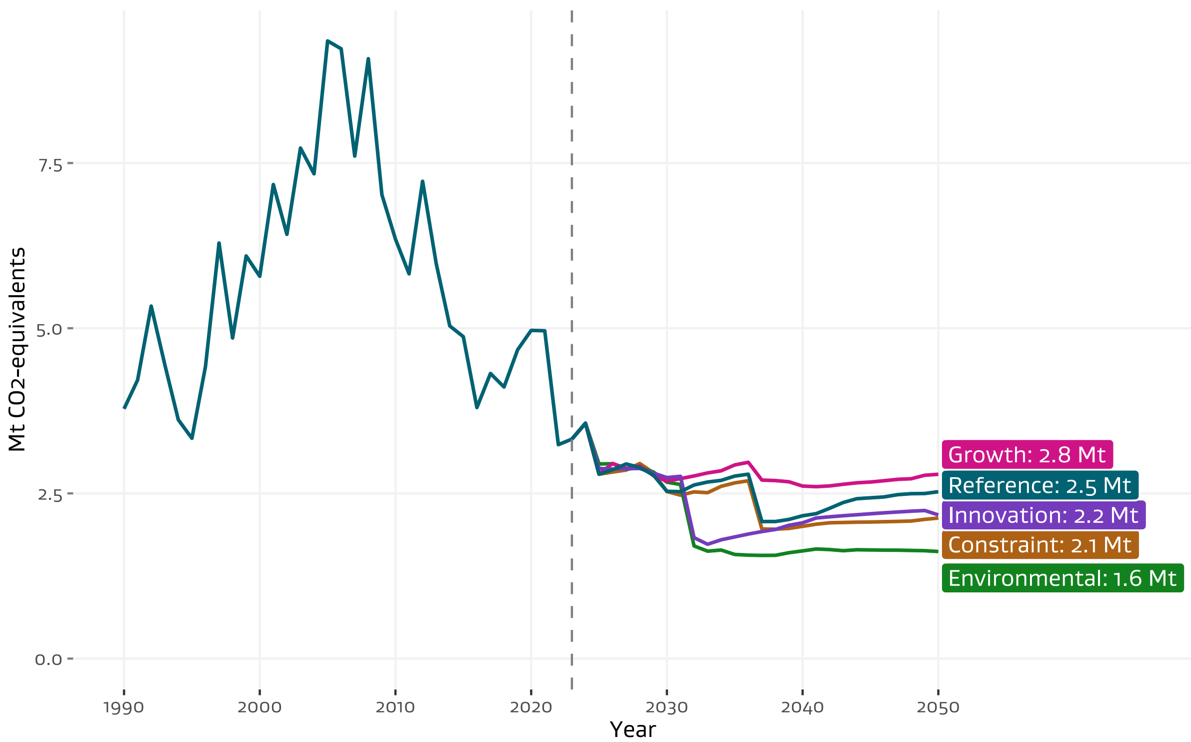
## Emissions from electricity generation are expected to flatten

Under the Reference scenario, greenhouse gas emissions for electricity generation are projected to fall to 2.5 Mt CO2-e by 2050, and across all scenarios range between 2.8 and 1.6 Mt CO2-e annually. The key uncertainty between scenarios is the closure of key thermal plants (such as Huntly's Unit 5) and whether it will be possible to convert Huntly's Rankine units to operate on renewable wood pellets. We also see more natural gas required for firming in scenarios with lower grid battery uptake. The higher carbon price in the Environmental scenario also incentivises less fossil fuel use for generation in the medium to long term.

Emissions from electricity generation include fugitive emissions from geothermal plants. This means that even if electricity generation were 100 per cent renewable, we would still expect some emissions from this sector.

Emissions are expected to fall after 2024, as Contact Energy has signalled it intends to close the Taranaki Combined Cycle gas plant at the end of this year. All scenarios show emissions remaining relatively steady in the short term and it is only in the 2030s that significant divergences occur due to the timing of thermal plant closures. By the mid-2040s all scenarios show electricity emissions stabilising at different levels.

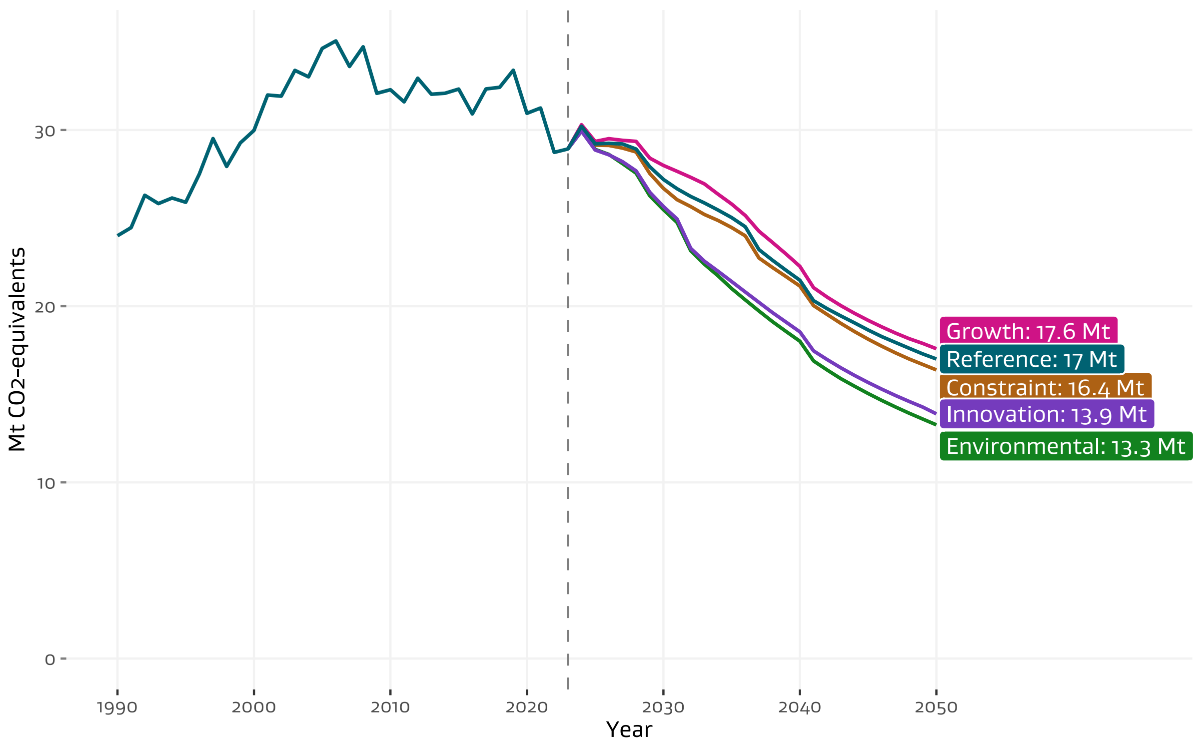
***Figure 29: Electricity generation emissions***



## Total energy sector emissions fall across all scenarios

Total energy emissions fall to 17 Mt CO2-e by 2050 in the Reference scenario. Much of this is driven by the fall in transport emissions, and fuel switching in the industrial and commercial sectors. The narrow range between the Growth and Constraint scenarios implies that much of the difference in emissions between scenarios is not related to activity, but instead fuel switching rates and other technological advancement.

***Figure 30: Total energy emissions***



# Next steps

The previous EDGS results were published in July 2019. The scenario definitions, and many of the modelling assumptions, have changed materially in this refresh. The changes are due to the pace of change in the regulatory environment, policy direction, energy industry expectations, and technology development.

To ensure that the EDGS results reflect emerging trends in a timely manner, our intention is to refresh the EDGS more frequently in the future.

In the meantime, if you have any specific requests or queries relating to the EDGS, then please contact us via email at energyinfo@mbie.govt.nz.

# Appendix One – Overview of EDGS modelling

MBIE's energy modelling work programme, including EDGS, makes use of two distinct but related models:

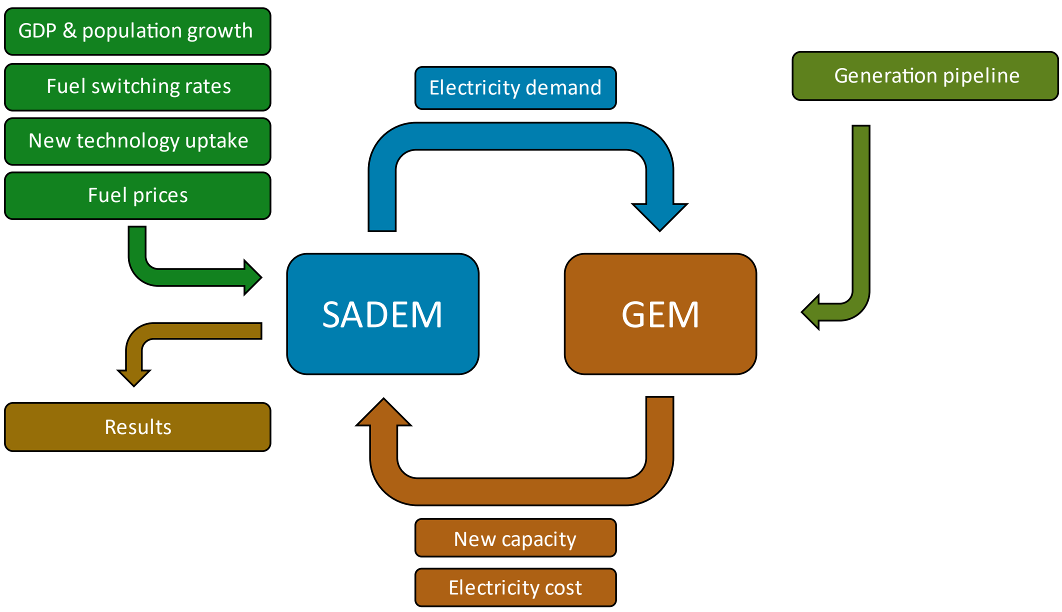
- MBIE's "Supply and Demand Energy Model" (SADEM)
- The Electricity Authority's "Generation Expansion Model" (GEM)

## Supply and Demand Energy Model (SADEM)

The Supply and Demand Energy Model (SADEM) is a partial equilibrium model of the energy sector. Key drivers such as GDP, population, and the carbon price are exogenous. This means that the potential link between variables such as energy demand and the carbon price are not modelled explicitly.

SADEM projects energy demand across the entire economy. The total and peak electricity demand are then supplied to GEM, which uses this information to develop a generation build schedule and estimate a wholesale electricity cost indicator. This wholesale cost indicator then influences electricity demand. As a result, SADEM and GEM need to be run iteratively until the models reach an equilibrium of supply and demand.

***Figure 31: SADEM and GEM overview***




***SADEM performs several key functions:***

- Provides a central hub, coordinating electricity supply information from GEM and MBIE's historical energy and activity data.

- Loads and coordinates assumptions and external projections, such as population or carbon price inputs.
- Projects energy demand for each sector and fuel using econometric relationships between demand and price and fuel switching assumptions of expected fuel switching.
- Calculates projected energy sector greenhouse gas emissions by applying emission factors.

## Generation Expansion Model (GEM)

The Generation Expansion Model (GEM) is a long-term planning model used to study capacity expansion in the New Zealand electricity sector.

GEM is used to project the timing and type of new generation capacity that is built. It does this by selecting optimal plants from the generation stack, which is MBIE's internal dataset on upcoming potential plant builds. We also provide the model with potential "generic" plants. These generic plants are those that haven't been announced by any specific developer but could theoretically be built.

GEM takes this information and designs a plant build schedule that meets total and peak demand while minimising total costs. A wholesale price estimate is then projected based on the long run marginal cost of each new plant built.

To do this, GEM:

- Selects from the pipeline of potential plants and builds those needed to meet demand or peak demand with the lowest cost in each year.
- Retires plants that reach the end of their natural lifespan, or refurbishes these if refurbishment is applicable and doing so would be cost-effective
- Runs several scenarios of different hydrology sequences, to ensure that enough capacity is built to meet wet or dry year requirements.
- Assesses the firm capacity of the current build and ensures that it is sufficient to meet SADEM's projection of peak demand.
- Dispatches different technologies based on the overall demand for any given year (for example, lowering Huntly coal use if there is enough wind or hydro generation to meet baseload requirements).

There is also the ability to manually adjust specific settings for plants, such as adjusting Huntly's Rankine units to use biomass, or exogenously setting plant retirement dates.

For more information see the Electricity Authority's webpage "Generation Expansion Model (GEM) overview[23]".

[23] Electricity Authority – Generation Expansion Model (https://www.emi.ea.govt.nz/Wholesale/Tools/GEM)