MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Electricity demand and generation scenarios: Scenario and results summary

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Purpose of the Electricity Demand and Generation Scenarios

This report presents results of the Electricity Demand and Generation Scenarios (EDGS) modelling performed by the Ministry of Business, Innovation & Employment (MBIE).

The purpose of EDGS is to enable the Commerce Commission to assess Transpower's planning proposals for future capital expenditure on the electricity transmission grid.

Modelling potential futures

This report presents a refresh of the EDGS modelling which was last published in 2016 (referred to as 'EDGS 2016'). Similar models and processes to EDGS 2016 have been used, with updated input datasets. For more information about the modelling process, see Appendix B – Overview of EDGS modelling.

To inform the Commerce Commission's assessment of Transpower's proposals, we model five scenarios. The objective of the scenarios is to explore a range of hypothetical futures, considering different demographic, economic, policy, and technology dimensions. These scenarios model the period from 2018 to 2050. Note that all prices are in 2017 dollars.

The scenarios are:

- Reference: Current trends continue
- Growth: Accelerated economic growth
- Global: International economic changes
- Environmental: Sustainable transition
- Disruptive: Improved technologies are developed

Results

Key results obtained from each scenario in 2050 (including percentage change relative to 2017) are summarised in Table 1 below.

Table 1. Summary of key results

Variable	**Scenario**				
	Reference	Growth	Global	Environmental	Disruptive
Electricity Demand					
Total (TWh)	57 (+43%)	65 (+64%)	47 (+18%)	67 (+68%)	71 (+78%)
Process heat (TWh)	1.5	1.9	1.2	6.5	13.3
Electric vehicles (TWh)	4.1	5.0	3.2	7.6	7.6
Peak demand (GW)	8.5 (+34%)	9.8 (+56%)	7.1 (+12%)	9.6 (+53%)	10.2 (+62%)
Generation					
New capacity (MW)	6,300	9,400	3,800	9,600	10,600
Roof-top solar (TWh)	2.3	2.8	0.9	4.6	4.6
Renewables (%)	94.9	95.4	94.8	96.0	94.9
Energy sector greenhouse gases (2017 value = 32.9 Mt CO2-e)					
Emissions (Mt CO_2-e)	23.7 (-28%)	26.7 (-19%)	19.6 (-40%)	17.2 (-48%)	16.9 (-48%)

Conclusions

New generation capacity is required to meet increased electricity demand

The range of electricity demand projections is larger than in EDGS 2016, reflecting uncertainty in both policy and economic growth. Across the scenarios, electricity demand is projected to grow between 18 and 78 per cent over the projection period.

This growth includes electrification of process heat and the energy required to charge electric vehicles (EV). In addition, the size of the economy is assumed to grow by between 42 per cent and 132 per cent over the same period.

In all scenarios, 2,700 MW of existing generation capacity is retired by 2050. This includes the retirement of all remaining large coal-fired and baseload gas generation capacity, as they reach the end of their economic lives.

Renewable share of generation increases in all scenarios

The combination of continued declines in the cost of solar and wind technology, and limited supply of gas, means that the majority of new build generation is renewable. Therefore the share of electricity generation from renewable sources is expected to rise. This produces tightly clustered results for renewable electricity shares across all scenarios. Renewable shares are projected to increase from 82 per cent in 2017 to around 95 per cent in all scenarios.

Our modelling results also show that because of the intermittent nature of wind as a source of generation, there is an inherent limit to the proportion of wind in the overall generation capacity. Furthermore, the extent to which electrification is able to reduce greenhouse gas emissions is limited if the renewable electricity percentage reaches above 95 per cent.
Total energy sector greenhouse gas emissions fall significantly across all scenarios by 2050. In the Environmental and Disruptive scenarios, emissions are almost half of 2017 level.

Additional information

This document provides a summary of the EDGS scenarios and results. Further information is available on the MBIE website[1].

[1] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/electricity-demand-and-generation-scenarios

Purpose of the EDGS

The role of the Electricity Demand and Generation Scenarios (EDGS) is set out in the Commerce Commission's "Transpower Capital Expenditure Input Methodology Determination (Capex IM)".

Under the Capex IM, Transpower is required to use the EDGS, and reasonable variations, when preparing its proposals for major capital expenditure on the electricity transmission grid. Specifically:

> "Demand and generation scenario means a description of a hypothetical future situation relating to forecast electricity demand and generation published by the Ministry of Business, Innovation and Employment (or other agency which subsequently assumes the responsibility) for the purpose of the preparation or evaluation of major capex proposals." [2]

[2] Source: Commerce Commission, "Transpower Capital Expenditure Input Methodology Determination 2012 (Principal Determination)", 1 June 2018, section D3 (1), page 65.

Introduction

This EDGS refresh is driven by policy and technological changes

Since the release of EDGS 2016, there have been many changes in the policy environment. In addition, the electricity sector has benefited significantly from rapidly changing technology and new innovations.

It is therefore necessary to refresh the EDGS projections to see how both the economy and electricity sector have evolved since the EDGS 2016 projections.

The uptake of new technologies is highly uncertain, depending on many factors such as policies, costs and economic growth.

In order to test the bounds of projections, the range of assumptions used in this report is larger than EDGS 2016, reflecting that uncertainty in both policy and economic growth.

The key changes in these areas since the release of EDGS 2016 are summarised below.

The cost of renewable generation has fallen quickly

The cost of renewable electricity generation from wind and solar has fallen faster than expected and is projected to fall further. Bloomberg New Energy Finance projects that wind and solar technology will meet almost 59 per cent of global electricity demand by 2050[3]. Therefore, we project a shift in the way electricity is generated in the future in New Zealand.

A net zero emissions target introduced

Recently, the Government has introduced the Climate Change Response (Zero Carbon) Amendment Bill, which if passed, will set a target of net-zero carbon emissions by 2050. We expect that the extent of changes in electricity sector technology over the next 30 years will be a crucial factor and driver in determining the path of decarbonisation.

Conversion of process heat to use electricity

Process heat is the energy used as heat mainly by industrial and commercial sectors for industrial processes, manufacturing, and warming spaces. Process heat contributes about 8 per cent of New Zealand's total greenhouse gas emissions. Therefore, the ability of organisations to switch to lower-emission fuel is crucial for New Zealand to meet the target of net-zero carbon emissions. However, the ability and incentives for organisations to switch to electricity is dependent on both the relative price of electricity and the future of process heat technology.

Projected uptake of electric vehicles

Nearly 20 per cent of emissions in New Zealand come from road transport. Thus, the uptake of new transport technologies such as electric vehicles (EV) and hydrogen fuel cell cars will have important impact on carbon dioxide (CO_2) emissions as well as the future demand for electricity.

Growing use of solar panels

Similarly, the increasing uptake of solar panels will change the tradition method of generating electricity.

Organisation of this report

The report is organised as follows. The next section presents the definition of the scenarios, followed by the key drivers and assumptions used in modelling each scenario. We then present the key results of the modelling, the next steps, and the appendices.

[3] New Energy Outlook 2018.

Scenario definitions

Overview of scenarios

This report presents projections for five different scenarios which are designed to take into account the uncertainty surrounding future economic growth, technological progress and policy changes. The five scenarios are:

- Reference: Current trends continue
- Growth: Accelerated economic growth
- Global: International economic changes
- Environmental: Sustainable transition
- Disruptive: Improved technologies are developed

The modelling covers the period 2018 to 2050. Note that the scenario assumptions, and results, are inherently more uncertain further in the future they occur.

This section presents a board overview of the scenarios. More details about the scenario features, dimensions, and uncertainties are described in Appendix A – Approach to scenario modelling. Economic growth is one of the key factors that determine the demand for energy. Quantifying uncertainty about economic growth helps policy makers understand the size of risks around energy projections. The macroeconomic backdrop of the scenarios is described in "Box 1: Economic backdrop".

Elements common across the scenarios

Apart from the Environmental scenario, carbon prices are assumed to increase from NZD$25 per tonne of carbon dioxide in 2019 to NZD$66 per tonne by 2050 in all the scenarios. This assumption is in line with IEA's Current Policies Scenario for the European Union so that the carbon price in New Zealand is going to be aligned with its trading partners. In the Environmental scenario, carbon prices rise to NZD$154 (USD$100) per tonne by 2050.

There are several reasons why a wide range of carbon prices were not experimented with. Primarily, this is because there are numerous studies that have been published about the Emissions Trading Scheme (ETS) in supporting New Zealand's transition to a low emissions economy.

Another reason is that the point elasticities used for fuel switching in our model may not be appropriate if changes in the relative fuel prices are large[4]. In this report, our approach to fuel switching is to group of the process heat into three categories: low, medium and high grade heat. Then we apply our judgement on the proportion of process heat for fuel switching (see page 16 for more details). In the Reference scenario we assumed that 15 per cent of process heat will be electrified.

In all scenarios, there will be a limited supply of gas as result of no new offshore exploration permits. Expectations of gas supply affect what new generation plants are built in the future, and also operation decisions of major gas users.

[4] Organisations might not respond to price changes as the model predicts if the price level has changed significantly from when the estimates were made. Furthermore, many large industrial users have a long-term contract with their fuel suppliers and the actual fuel costs to those large users are different from the wholesale price used in the estimation. The demand curve for this market is a staircase of discrete steps rather than a continuous downward sloping curve. In this situation, organisations will exit the market once the price increases to a certain point rather than adjusting their demand.

Reference: Current trends continue

The "Current trends continue" scenario is one view of how the electricity system could evolve under current policies and technology trends if no major changes occur. This scenario is used as a reference, against which the other scenarios are compared.

Growth: Accelerated economic growth

This scenario assumes that the past decade of slow growth in labour productivity is an aberration rather than the norm. The central theme of this scenario is that higher economic growth drives higher immigration while policy and investment focuses on priorities other than the energy sector. The economy is transformed to put emphasis on high technology. The share of the commercial sector is therefore larger than projected in the Reference scenario. In this scenario, higher income growth leads to higher uptake of electric vehicles. This scenario provides an assessment of what level electricity demand could reach if the economy is doing well.

Global: International economic changes

The central theme of this scenario is that New Zealand's economy is battered by international trends, leaving little room for local growth or innovation. Some aspects of this scenario are opposite to the Accelerated economic growth scenario such as the uptake of EVs. In this scenario, we also explore higher cost for wind turbines and solar power than in the Reference scenario.

Environmental: Sustainable transition

In this scenario, the government targets more ambitious emissions reduction levels than in the Reference scenario. Strong environmental leadership driven by regulation and incentives (rather than technology) provides the platform for the achievement of this policy target. Policies are introduced to support the electrification of both transport and process heat. This scenario is intended to provide a sense of what settings are required for decarbonising the economy, and helps understand the relationship between the reduction of emissions and its associated costs.

Disruptive: Improved technologies are developed

The pace of future uptake of EVs and solar PV, and the future level of electrification in process heat are highly uncertain. In this scenario, we assess the electricity demand and supply implications of more advanced and sophisticated technological progress in the energy sector. This in turn leads to a faster reduction in technology costs and higher uptake of both EVs and solar than the Reference scenario. The extent of the electrification of process heat is even greater than in the Environmental scenario. The central theme of this scenario is that new and improved technologies enable rapid electrification of both transport and process heat.

While we have surveyed emerging technologies which may be influential in the future (see Box 2: Emerging technology of a potential future), these are not incorporated in the model. Instead this scenario focuses solely on the increased uptake of EVs, solar PV, and electrification of process heat.

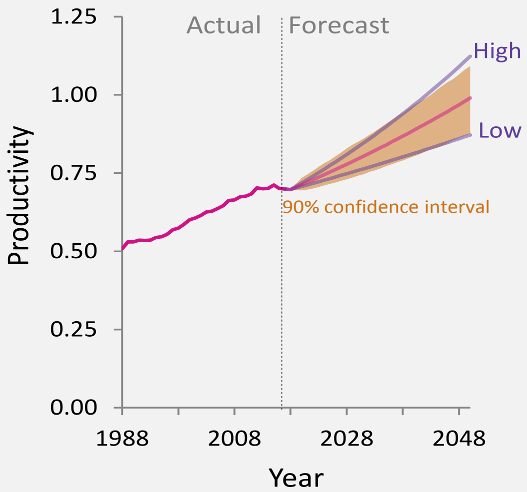
Box 1: Economic backdrop

Economic variables

Labour productivity growth

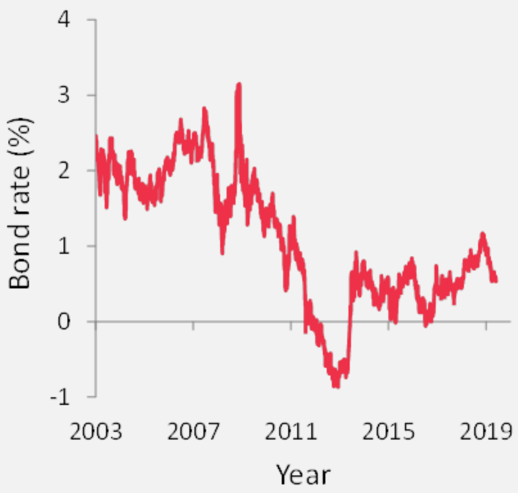
Like most other advanced economies, the global financial crisis (GFC) of 2008 had a lasting impact on New Zealand's economy[5]. The GFC created a productivity puzzle for many countries – with labour productivity growth measured as growth in real gross domestic product (GDP) per hour worked well below its pre-GFC trend[6,7]. Figure 1 shows New Zealand's labour productivity growth averaged 1.4 per cent per year from 1988 to 2007.

Figure 1. New Zealand labour productivity



Since 2007, labour productivity growth has dropped to 0.5 per cent per year on average. The 90th percentile of the labour productivity projection is shown by the shaded area in Figure 1. In other words, there is a 10 per cent chance that the actual outcome will fall outside the shaded area. The central solid line represents the projection of labour productivity with a growth rate of 1.1 per cent per annum, used in the Reference scenario. The High and Low lines represent growth rates of 1.5 per cent and 0.7 per cent per annum respectively. While some forecasters expect the slowdown in labour productivity growth to be temporary, we assume that this slowdown will continue for the Reference scenario[8]. Combined with the 50th percentile population projection, real GDP is expected to be 84 per cent larger in 2050 than in 2017[9].

Figure 2. US inflation indexed bond



Real discount rate

The real discount rate is one factor used to determine the long-run marginal cost (LRMC) of electricity generation. A lower discount rate can decrease calculated LRMC. United State (US) inflation indexed bond (IIB) yield is a good proxy for risk-free real discount rates. The US IIB yield fell after the GFC, as shown in Figure 2.

One of the implications of the global slowdown in labour productivity is that long-term bond rates for many countries remain low after the GFC[10]. As a result, we

5 "The economic scars of crises and recessions", IMF, March 2018
6 "The fall in productivity growth: causes and implications", Bank of England, January 2018
7 "The productivity puzzle: A closer look at the United States", McKinsey, March 2017
8 Labour productivity is assumed to be 1.5 per cent per annum in the Long-term Treasury Fiscal Model and the Fiscal Strategy Model.
9 Statistics New Zealand Population Projections (2016 base)
10 "Why are interest rates so low? Causes and implications", Federal Reserve, October 2016

use a real discount rate of 6 per cent (compared with 8 per cent in the EDGS 2016). A lower discount rate has a material impact on the long-run marginal cost of electricity generation (see Box 3: Sensitivity of LRMC to real discount rate).

Scenario narratives

Global: International economic changes scenario

In the Global scenario we have a decoupling of the global supply chain and countries develop their own home-grown, high-tech industries. In this scenario, technology globalisation of the last twenty years becomes a thing of the past and the world economy enters a new phase of regionalisation. In this alternative world structure, there are three main trading blocs: US, China, and Europe. As a result access to technology is restricted, global economic growth is much slower compared with the Reference scenario, and this spills over into the New Zealand economy.

In this scenario, the growth rate of labour productivity is 0.7 per cent per annum. Population growth is also lower in this scenario because of barriers to migration between countries and the size of the economy is only 42 per cent larger in 2050 compared to that in 2017.

Additionally, the lower global growth outlook on the long-term interest rate is offset by higher risk and tighter access to finance owing to trade conflicts. Therefore, we assumed that the real discount rate is the same as that in the Reference scenario. However, the progress in renewable energy technologies is expected to be slower and the cost of renewable electricity generation is higher in comparison with that in the Reference scenario.

Accelerated economic growth

The New Zealand economy is transformed into a high tech economy. The commercial sector contributes 70 per cent of total GDP in 2050 in comparison to 67 per cent in the Reference scenario. The electricity intensity of the commercial sector is about 30 per cent of the general industry sector's electricity intensity in 2017. Changing economic structure will therefore have significant implications on the demand for electricity. In this scenario, labour productivity grows at an annual rate of 1.5 per cent and New Zealand becomes a popular destination for migrants. As a result, the economy is 132 per cent larger relative to that in 2017. The global outlook is the same as that in the Reference scenario.

Environmental scenario

Quantifying the potential economic impacts of transitioning to a low-carbon economy through regulations and incentives is beyond the scope of this report. Therefore, we assume that both the global and domestic economic environments will follow the same pathway as in the Reference scenario.

Disruptive scenario

Over the past decade, although global economic growth has been subdued, the technology of the clean-energy sector has changed significantly. The cost of solar panels, batteries, wind turbines and electric cars has declined rapidly. For example, between 2009 and 2017, the price of solar panels and turbines has fallen 76 per cent and 34 per cent respectively[11]. In the Disruptive scenario, we explore what happens if the technology of the clean-energy sector evolves more rapidly than envisaged in the Reference scenario (refer to page 8 for more detailed description of the scenario). In this scenario, apart from higher uptake rates of all the clean-energy technology and cheaper costs of renewable electricity, both the global and domestic economic environments will be the same as in the Reference scenario.

[11] Falling costs make wind, solar more affordable, IMF Blog April 2019.

Box 2: Emerging technology of a potential future

Imagine a hypothetical future, decades from now, where advances in technology have changed the world in ways we could not even imagine back in 2019.

Consumer-side technologies

Continued decentralisation, digitisation and democratisation have paved the way for the rise of the ‘prosumer’ – the producer-consumer. The development of microgrids, virtual power plants and peer-to-peer trading has been accompanied by growth in home automation, the Internet-of-Things (IoT) and the application of swarm theory. The human life experience is greatly augmented by technology. Artificial intelligence, virtual reality and wearable devices are pervasive. Large sections of the workforce have been disrupted by automation, putting a strain on social cohesion. Governments and regulators around the world have struggled to keep abreast of these changes.

Transport

New and improved battery chemistries have been developed leading to lower cost battery-electric vehicles with improved performance.

The development of other technologies has increased the choice available to consumers. Hydrogen fuel cell technology has also accelerated leading to competitive pricing of hydrogen fuel cell electric vehicles (FCEV). Hydrogen FCEVs are efficient, and in comparison with EVs have a larger range and can be refilled in minutes. Many view electric vehicles as a transition technology.

A lot of freight is transported using low-emissions liquefied natural gas (LNG)-fuelled trucks and ships. The fuel consumption of LNG trucks is lower than diesel trucks and their CO_2 emissions are 20 per cent lower.

Hydrogen

A green hydrogen production facility is being constructed in New Plymouth. Surplus wind power will be used to produce hydrogen be part of New Zealand’s energy landscape. There is potential for hydrogen production to become a major export industry as New Zealand is recognised as having a world-class wind resource. The electricity used in producing hydrogen can be diverted to meet peak demand for the domestic electricity market. This load shifting forms an important part of energy demand management.

Dairy processing energy use

The dairy industry has implemented numerous innovations to improve the energy efficiency of the entire F2F2F (farm to factory to foreign market) supply chain. For example, milk is first concentrated on farms using renewable energy before being transported by hydrogen powered trucks. Advanced process engineering has been applied to the following unit operations of milk processing to reduce energy consumption and integrate renewables:

- Pre-treatment; solar thermal and radio-frequency heating pasteurization
- Concentration; reverse osmosis concentration and membrane distillation
- Drying; mono-disperse spray drying and dehumidification using forward osmosis membrane contactors.

Synthetic milk has been developed that is nearly indistinguishable from standard milk. This synthetic milk is produced from crops that are less resource intensive, and less energy is required to produce the powdered form for export.

Thermal Storage

Inexpensive energy storage is the ideal technology to solve the mismatch between the output of intermittent renewables and our society's variable demand for electricity. Technologies coming to market range from liquid metal batteries and flow cells, to larger scale pumped-hydro and compressed air energy storage (CAES) systems. Thermal storage falls somewhere in between the range of these other technologies, and has been developed as a cost effective method to store energy over short or long timeframes. Solar thermal energy can be stored directly for later use, or excess electricity can be converted to heat, stored and then reconverted back to electricity when needed.

Many industrial processes in New Zealand with heating (or cooling) requirements have implemented various thermal storage technologies to allow the integration of high levels of renewable energy. A number of different technologies are used to accomplish the storage depending on the duration and temperature requirements. For instance by using molten silicon at 1,414 degrees Celsius, a large amount of energy can be stored for high temperature applications. Other versions employ pumped-heat electricity storage, where a reversible heat-pump system is used to store energy based on the temperature difference between a hot and a cold reservoir.

Modelling assumptions

Summary of key assumptions

The key scenario assumptions are summarized in Table 2. Further details, and additional assumptions, are presented in the following sections.

Table 2. Summary of scenario assumptions

Assumption	Scenario				
	Reference	Growth	Global	Environmental	Disruptive
Labour productivity	1.1% per annum	1.5% per annum	0.7% per annum	Same as Reference	Same as Reference
Population	50th percentile	90th percentile	10th percentile	Same as Reference	Same as Reference
Exchange rates NZD/USD	0.65	Same as Reference	Same as Reference	Same as Reference	Same as Reference
Real discount rate	6%	Same as Reference	Same as Reference	Same as Reference	Same as Reference
Residential energy intensity	Decrease by 2030, then flat	Same as Reference	Same as Reference	Same as Reference	Decrease by 2040, then flat
Process heat electrification by 2050	~15% (low only)	Same as Reference	Same as Reference	~55% (low and medium)	~83% (low, medium, & high)
Electric vehicles uptake	Moderate	Adjusted for higher GDP	Adjusted for lower GDP	High, due to interventions	High due to technology
Residential solar generation	Moderate	adjusted for GDP	adjusted for GDP and prices	High	High
Wind LRMC \$/MWh	2019: ~\$75 2050: ~\$65	Same as Reference	2019: ~\$75 2050:~\$70	Same as Reference	2019: ~\$75 2050: ~\$55
Grid solar LRMC \$/MWh	2019: ~\$130 2040: ~\$70 2050:~\$65	Same as Reference	Same as Reference	Same as Reference	2019: ~\$110 2035: ~\$65 2050:~\$60
Carbon price USD\$/tCO_2	2040: \$38 2050: \$43	Same as Reference	Same as Reference	2040: \$73 2050: \$100	Same as Reference

Electricity intensity

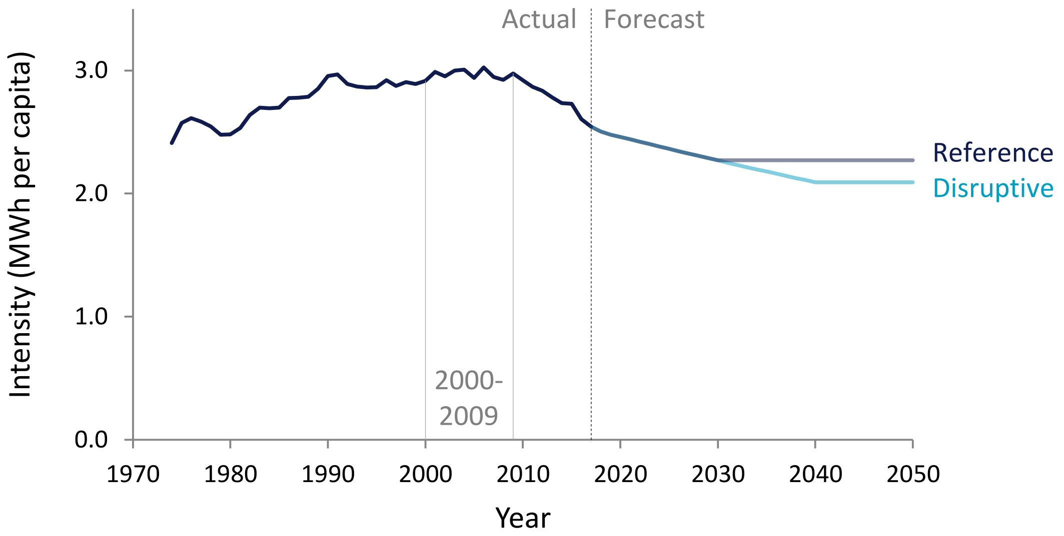
An important driver of future demand for electricity is the electricity intensity of each sector. This is measured in different ways across different sectors, but is essentially a measure of how much electricity we use relative to economic activity.

Residential sector

Electricity intensity in the residential sector is a measure of electricity used per capita. In relation to EDGS 2016, we have made a substantial change to our methodology and judgement on the projected trend of electricity intensity of the residential sector. In EDGS 2016, we assumed that electricity intensity would revert to the average of the last decade. However, the trend has continued to decline since the release of EDGS 2016.

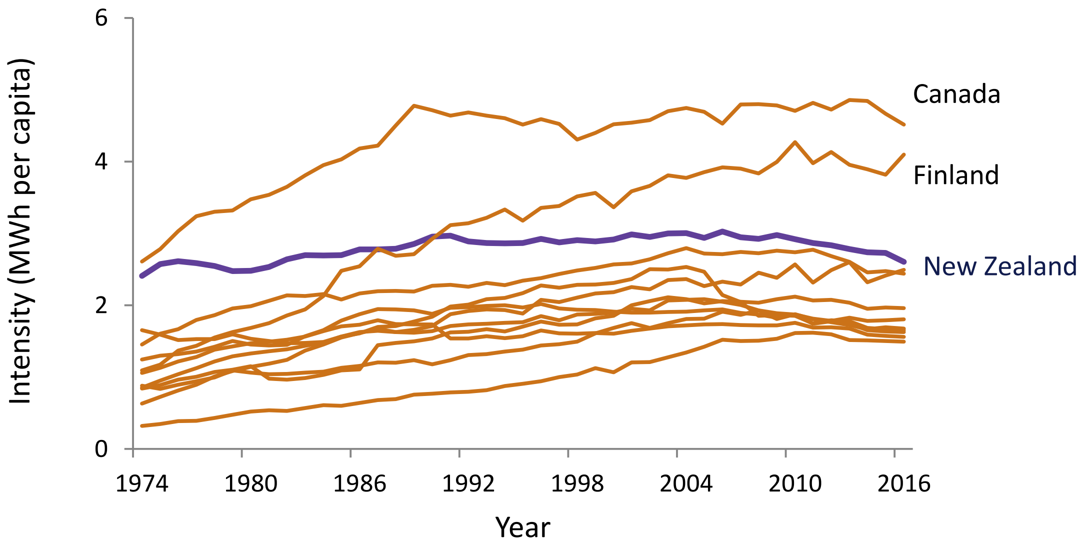
Looking back over a longer historical period, electricity intensity trended upward over the period 1974 to 2000 and then stabilised around 3 MWh per capita for the next decade or so (see Figure 3). Since 2009 electricity intensity has fallen by 15 per cent.

Figure 3. Actual and projected residential electricity intensity



It is interesting to note that most advanced countries have displayed similar trends in the electricity intensity for the residential sector (see Figure 4).

Figure 4. International residential electricity intensity



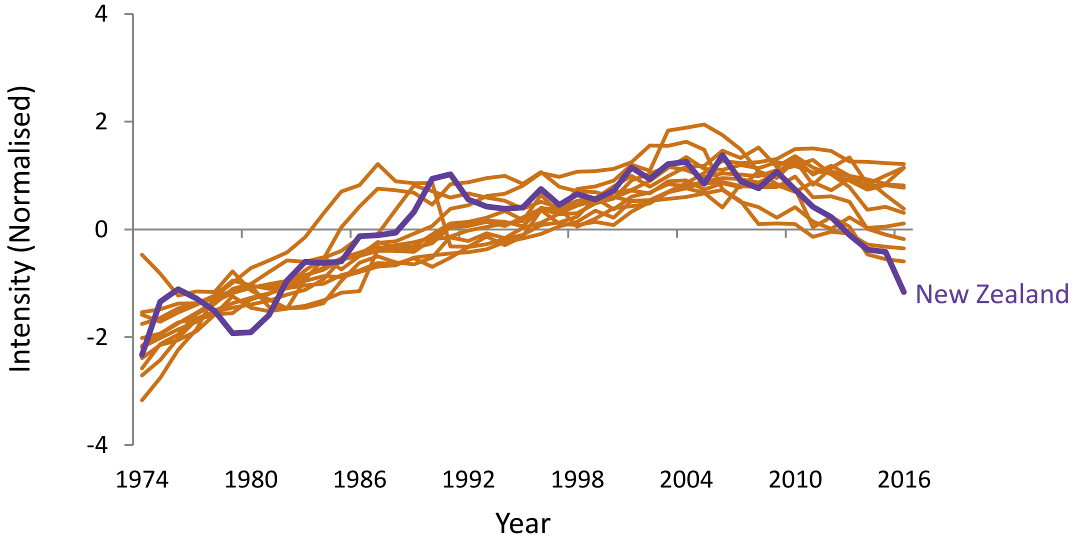
While the reasons for this trend are not fully understood, a common driver is technology. Between 1974 and 2000, technology had two impacts: making electronic appliances cheaper, and increasing the range of appliances available. This led to an increase in electricity intensity over that period. From 2000 onwards, we surmise that greater awareness of environment issues and more energy efficient appliances have resulted in the decline of the trend.

Figure 5 presents the same information as in Figure 4, except that the data is normalised[12].

[12] Normalisation is a process of transforming the data to have a mean of zero and a standard deviation of 1.

New Zealand has experienced a sharper decline in electricity intensity compared with other advanced OECD countries. Apart from technology, there are country-specific factors in New Zealand that may be contributing to the falling electricity intensity in New Zealand, including energy efficiency regulations, housing policy on insulation, building code requirements on insulation and more environmentally conscious consumers. Our empirical models suggest that recent increases in household size have also played a part in lowering electricity intensity.

Figure 5. Normalised international residential electricity intensity

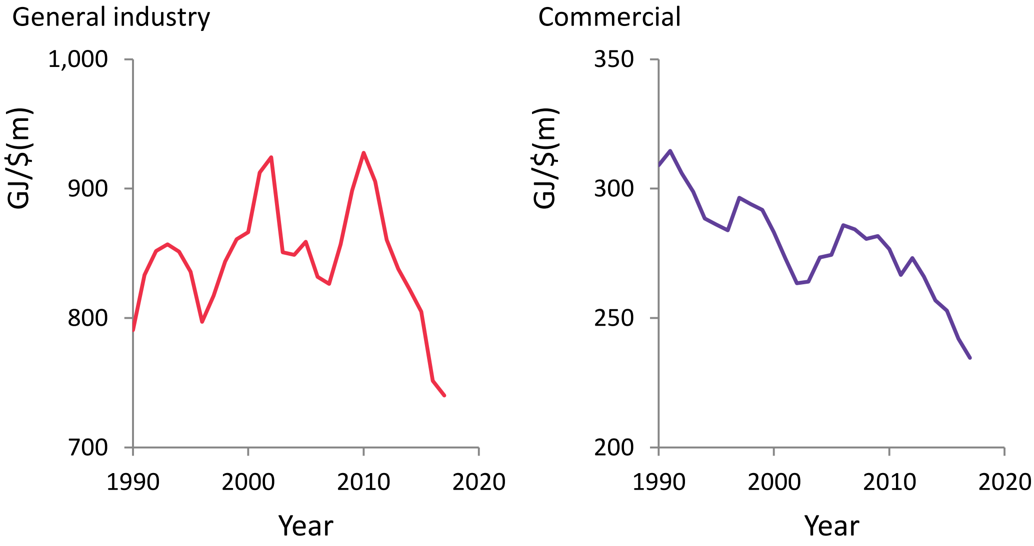


Our assumption in this EDGS refresh is that residential electricity intensity will fall further. The trend will continue to decline at a rate of around 0.8 per cent per annum until 2030 in all scenarios. In the Disruptive scenario, we explore the possibility that the declining trend continues until 2040. In this report, additional electricity demand from EV uptake is not included in the residential sector but included under transport electricity demand.

Commercial sector and General Industry sector

Electricity intensity for both Commercial and General Industry sectors is a measure of electricity used per unit of production. The production is measured as gross domestic product (Statistics New Zealand Chain-Volume Series 2009/10 prices) for the corresponding sector. Figure 6 shows that the two sectors have exhibited different quantities and trends of electricity intensity over the period 1990-2017.

Figure 6. Electricity intensity for General Industry and Commercial sectors



The underlying trend for the Commercial sector has been a decline 0.8 per cent per annum over the observation period. Driving this is strong growth in the less electricity-intensive portion of the sector, and the uptake of new and more efficient technology.

There is no downward trend for the General Industry sector before 2010[13]. However, since 2010, the intensity has fallen rapidly. Our analysis has found that recent low prices for hard commodities (for example iron ore) could partly contribute to the recent decline in electricity intensity for the General Industry sector. As the General Industry sector includes metal manufacturers, lower hard commodity prices mean demand for their products is weak or prices received for their products are low. This in turn lowers their production. Consequently, the electricity intensity of the General Industry sector falls as most metal manufacturers are highly electricity intensive.

Looking ahead to 2050, the improvement in electricity intensity for the Commercial sector is expected to continue. Higher carbon prices, which encourage organisations to reduce greenhouse gas emissions through electrification of process heat, will dampen the rate of decline in electricity intensity. For the General Industry sector, electricity intensity is expected to increase from the current level due to organisations switching from fossil fuel to electricity in their production process. The extent of increase in electricity intensity varies over different scenarios.

Electrification of process heat

Electrification is the process of switching end-uses that have historically been met by the combustion of fossil fuels to electricity. This is viewed as a key step in reducing energy sector emissions and helping New Zealand meet its climate change goals. Already, several organisations have announced their plans to switch some of their process heat use to electricity[14]. As more organisations look to reduce the emissions from their activities, this is a trend that we will see continue.

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[13] Large energy users producing aluminium, methanol, oil products, steel, and urea production are modelled under the Specific Industry sector, not General Industry.

[14] Process heat is energy used for industrial processes, manufacturing, and heating. For more information, see the MBIE webpage “Process heat in New Zealand”.

Electrification is a key issue for the electricity sector as increased electricity use puts more demand on existing infrastructure, and increases the need for more generation capacity to be built.

We assume that only the Commercial and General Industry sector will electrify

MBIE's energy projections split the Industrial sector into two sub-sectors:

- **Specific Industry**: large energy users that are modelled individually based on their expected production, covering aluminium, methanol, oil products, steel, and urea production
- **General Industry**: all remaining industrial and primary sector activities

Organisations take many factors into account when looking to switch to electricity, including whether the electrical technology exists (or is expected to be developed) for their end-use application of process heat.

Specific Industry applications are highly specialised and tend to require very high temperatures. In particular, steel which requires high temperature heat, are hard to electrify. Based on the information available today and their relatively lower temperature requirements, we have assumed that electrification occurs only in the Commercial and General Industry sector.

All scenarios have some electrification of low grade heat

Data for the 2016 calendar year has been extracted from the Energy Efficiency and Conservation Authority's (EECA) Energy End Use Database to determine the proportion of Commercial and General Industry fuel use that can be allocated to different levels of temperature required[15].

Table 3 shows the extent of low, medium, and high grade Commercial and General Industry process heat that is electrified in each scenario.

In all scenarios, we assume that some low grade heat will be electrified. Much of this electrification can be accomplished using heat pumps that have a relatively high coefficient of performance. In the Environmental and Disruptive scenarios, we assume that additional measures are introduced that further increase the level of electrification. In the Environmental scenario, we assume that policies and/or programmes are introduced to encourage the switching of process heat to electricity. For the Disruptive scenario, we assume technology is developed that further facilitates the electrification of General Industry use of high temperature heat. The technology used to electrify these processes with have a lower coefficient of performance than that used for low grade heat.

Table 3. Commercial and General Industry process heat electrified

Scenario	Temperature requirement		
	Low	Medium	High
Reference	✓		
Growth	✓		
Global	✓		
Environmental	✓	✓	
Disruptive	✓	✓	✓

The Ministry's Supply and Demand Energy Model (SADEM) projects energy demand using econometric relationships with exogenous drivers (such as GDP) and relative price levels. Using

15 EECA's database is accessible at https://www.eeca.govt.nz/resources-and-tools/tools/energy-end-use-database/

the Energy Use Database, we have then determined how much additional fuel-switching will occur in each scenario and applied this to the SADEM projections.

Electric vehicle uptake

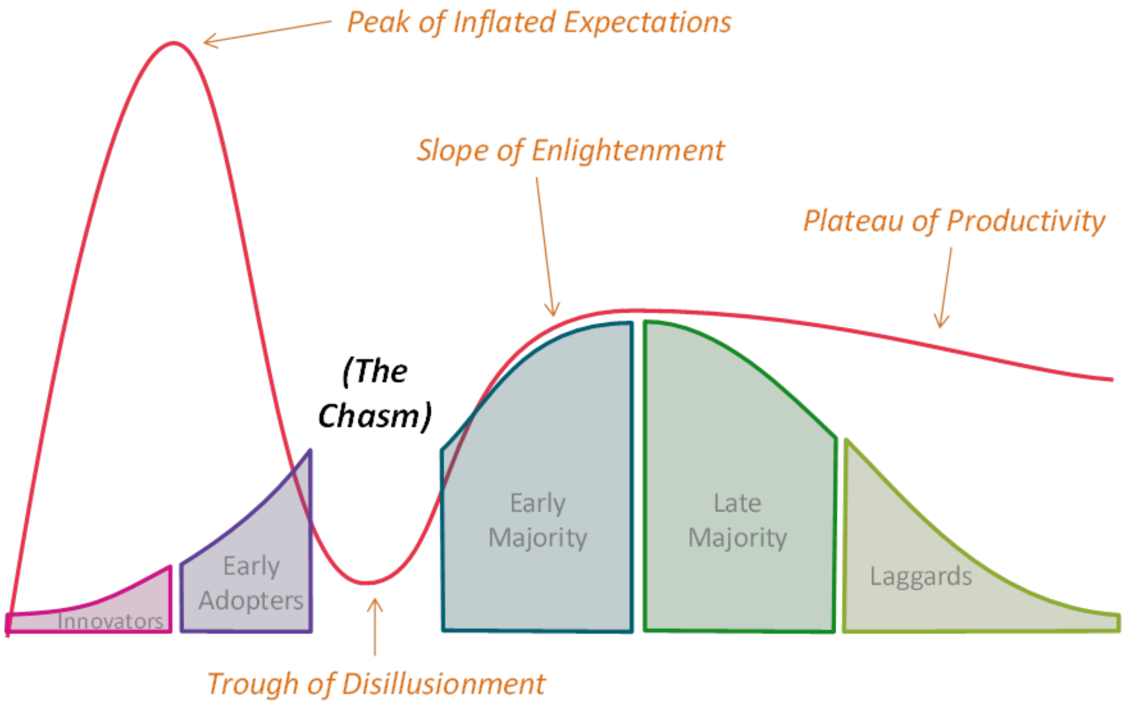
Electric vehicles have recently gained more attention as many car manufacturers have brought new and improved models to market, or have announced plans for future models. This change in mood has been reflected in a sharp increase in our EV assumptions for EDGS 2019 compared with EDGS 2016. However, the rate of future uptake of EVs by the general population is highly uncertain.

This is highlighted in Figure 7, which illustrates schematically the adoption of new technologies by market segments[16]. Although the sight of an EV on the streets is becoming more common, these drivers are still among the 'innovators'. We are yet to reach the 'early adopters' and there is a long way to go before reaching the 'early majority'.

On the supply-side of the equation, we see various risks such as supply bottlenecks and infrastructure constraints which could slow uptake. Furthermore, there is the prospect of alternative technologies being developed which compete for market share, such as hydrogen and LNG especially in the heavy vehicle space.

The Reference scenario assumes that EVs comprise 44 per cent of the light vehicle fleet, and 13 per cent of the heavy vehicle fleet by 2050. For scenarios with a higher uptake, we assume EVs comprise 74 per cent of the light vehicle fleet, and 45 per cent of the heavy vehicle fleet by 2050. This range reflects the current level of uncertainty. In the Disruptive scenario, the falling costs of batteries and EVs accelerate their uptake, along with the deployment of autonomous vehicle technology. In the Environmental scenario, a higher uptake of EVs is induced by both polices and regulations. In the Global and Growth scenarios, the uptake rate of EVs is based on the assumptions of the Reference scenario but allows for the impact of GDP.

Figure 7. Adoption of new technologies by market segments



16 Source: Adapted from Graves, 2016, Technology-adoption.

The growth of distributed solar generation

The growing use of distributed solar generation is expected to be one of the major electricity sector trends over the next few decades.

As at January 2019, there were 22,000 small-scale (less than 10 kW capacity) solar panel installations, of which 21,000 installations were residential. The total capacity of those installations was 80 MW, with an average of 3.6 kW. The number of installations has grown at around 4,000 per annum in each of the last four years[17].

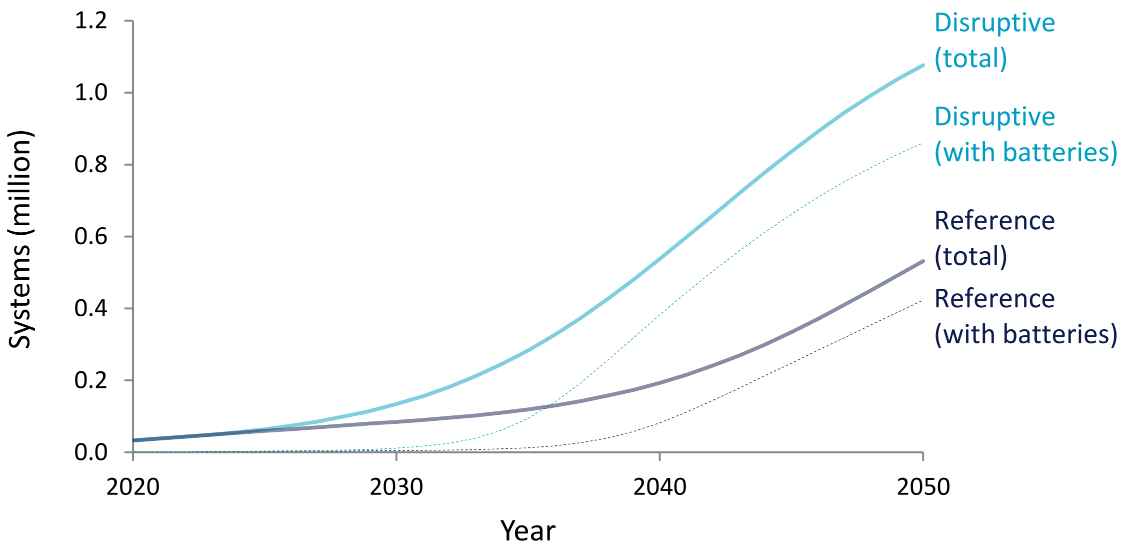
The outlook for solar installations is positive. Costs have fallen and are expected to continue falling. For most residential consumers, solar is not yet economically viable. However, if costs continue to fall, then roof-top solar can be expected to become a more common choice for households.

There are currently 1.8 million dwellings in New Zealand, and this is expected to grow to 2.4 million by 2050.

We make two sets of assumptions: greater uptake of solar generation in the Disruptive and Environmental scenarios, and a baseline uptake in the Reference scenario. For the other two scenarios, the assumption is based on a variant of the Reference case, adjusted for GDP and the cost of solar.

The Reference scenario assumes that solar installations initially grow slowly, reaching 22 per cent of all dwellings by 2050, compared with 1.2 per cent now. As shown in Figure 8, the Disruptive scenario assumes faster and earlier growth, driven by improved technology available at a lower cost, to reach 45 per cent of all dwellings by 2050. Electricity generation from residential solar in 2050 is expected to be 2,200 GWh per annum (18 per cent of total residential electricity demand in 2017) in the Reference scenario and 4,500 GWh (37 per cent of total residential electricity demand in 2017) in the Disruptive scenario. In the Environmental scenario, the uptake of solar is as high as in the Disruptive scenario.

Figure 8. Projected growth of installed residential solar systems



We assume that inclusion of batteries lags solar systems, due to the current high cost of batteries, as shown in Figure 9. The combined use of solar and batteries allows households to reduce their peak demand. However, unlike countries where peak demand occurs in summer, New Zealand's winter evening peak limits the value of solar for managing peak demand. This

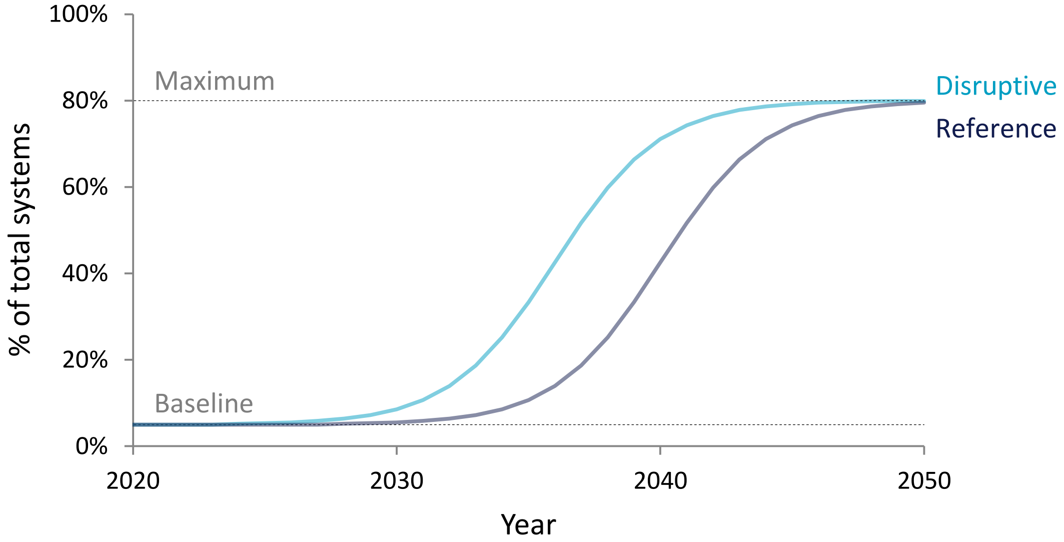
[17] Electricity Authority "Installed distributed generation trends".

mismatch somewhat undermines the potential value of solar in the New Zealand electricity system.

In the Reference scenario, widespread adoption of batteries commences in the mid-2030s, growing to almost 80 per cent of all solar installations by 2050 (on the basis that batteries are not suitable for 20 per cent of installations, for example where batteries are not economic or the solar energy is used as it is produced). The Disruptive scenario assumes earlier and faster adoption of batteries, again driven by improved technology available at a lower cost, starting from 2030 and growing to almost 80 per cent of solar installations by the mid-2040s.

In all scenarios, solar makes a material contribution to meeting our energy needs. In particular, solar energy production displaces other potential energy sources, such as coal-fired and gas-fired electricity generators. Consequently, growth in solar generation will contribute towards reducing energy sector greenhouse gas emissions.

Figure 9. Projected residential proportion of solar systems with batteries

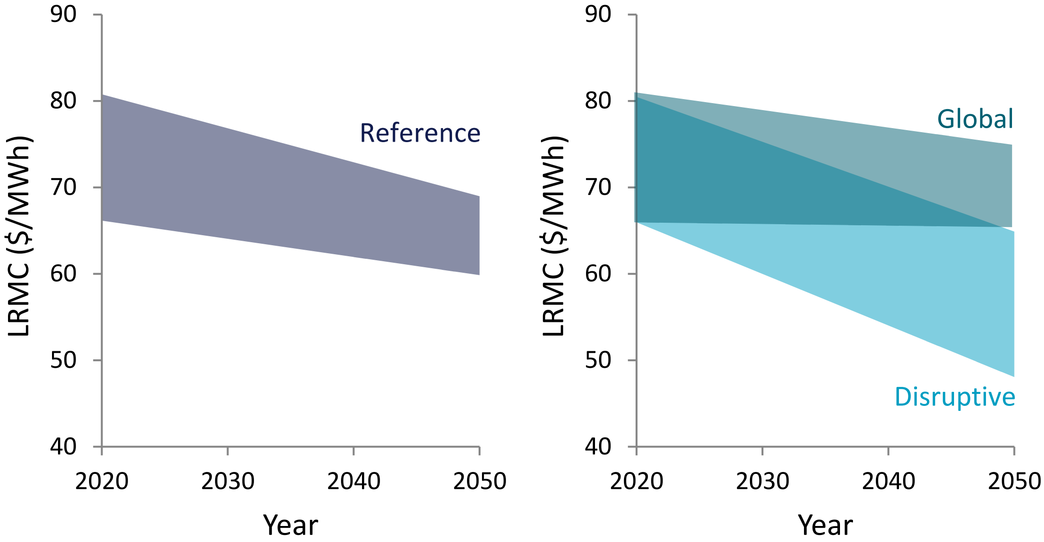


Wind generation

Figure 10 shows the range of wind generation long-run marginal costs (LRMC). There are a number of factors which affect the cost of wind generation. Each wind project has its unique set of factors such as wind speeds, access to sites and transportation, applications for resource consents and sources of funding.

Box 3 explores the sensitivity of the LRMC to changes in the real discount rate. In our modelling, we use a range of LRMCs to reflect the uncertainty of the LRMC. In the Reference scenario, we assume that the LRMC falls roughly from $75/MWh in 2019 to $65/MWh in 2050. In the Disruptive scenario, the LRMC declines to around $55/MWh. In the Global scenario, the LRMC is not expected to fall significantly.

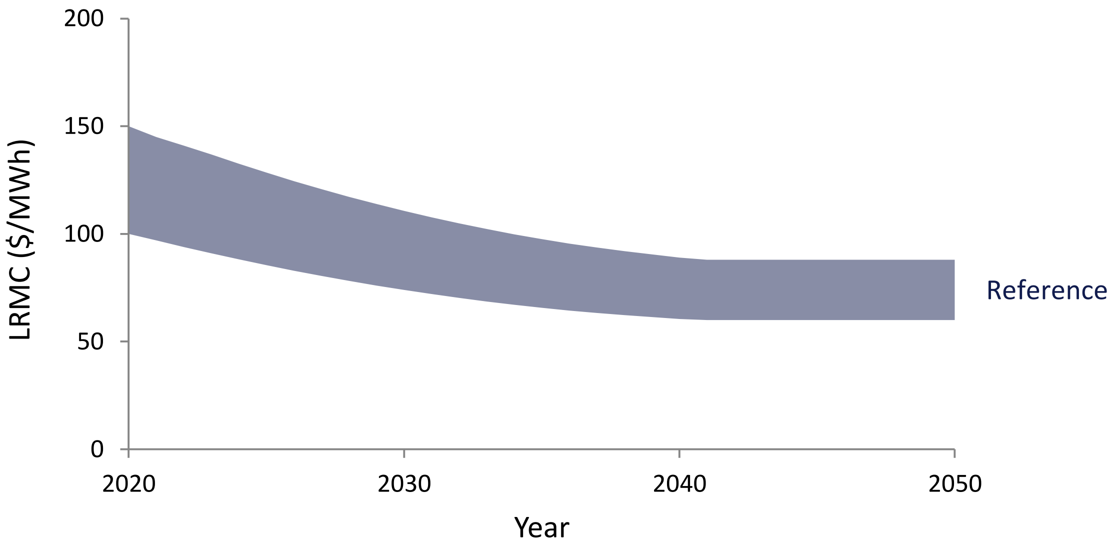
Figure 10. Projected wind generation LRMC



Grid solar generation

Figure 11 shows the assumed range of grid solar costs over the modelling period. We assume that the Long Run Marginal Cost (LRMC) of grid solar falls steadily until around the year 2040. Currently, there is no utility grid scale solar generation in New Zealand. Currently, the LRMC is assumed to be an average of around $130/MWh in the Reference scenario and expected to fall to around $65/MWh by 2050. In the Disruptive scenario, the starting LRMC is around $100/MWh, reaching $65/MWh by 2035.

Figure 11. Projected grid solar LRMC



Box 3: Sensitivity of LRMC to real discount rates

Impact of reducing the discount rate

The real discount rate plays a fundamental part in deciding on the commercial viability of a project.

By way of illustration, Figure 12 shows the long-run marginal cost (LRMC) of new wind generation capacity for different real discount rates.

The top line is based on a real discount rate of 6 per cent. In this analysis, the wind LRMC in 2019 is estimated to be about $75/MWh, falling to $60/MWh in 2050.

All else being equal, in 2019 a discount rate of 5 per cent will reduce the current LRMC to $69/MWh. If the rate is 4 per cent, then the current LRMC will drop to $63/MWh.

Our modelling uses a real discount rate of 6 per cent. The impact of a lower discount rate may explain why the reported LRMC of some projects is lower than the assumptions used in this report.

Components of the discount rate

The real discount rate consists of two components: risk free rate of return and premium for risk of operating a business.

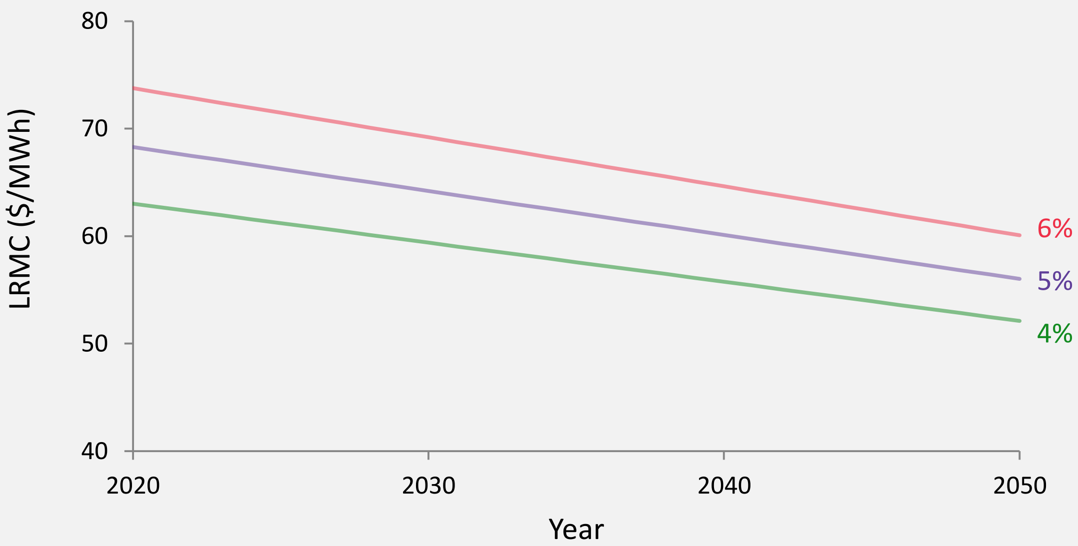
Reducing the uncertainty of the revenue stream will result in a lower risk premium, which in turn reduces the discount rate used in determining the LRMC.

Victorian Renewable Energy Targets

The Victorian Government in Australia has established a renewable energy auction scheme to support achievement of the Victorian Renewable Energy Targets.

Under the scheme, the government guarantees that the developer will receive a fixed price for 15 years. In other words, the government bears the risk of investment. The most recent auction result has a supply contract of about AU$52/MWh (NZ$55/MWh) for wind.

Figure 12. Wind LRMC for different discount rates



Results

The following sections present key results for each scenario. Further detail is available in the data workbook, available from the MBIE website[18].

Electricity demand

Total energy demand

Total electricity demand projections are shown in Table 4. It is important to note that demand projections are highly uncertain, especially over a time period of decades and the nature of the exercise in developing scenarios is to test the plausible boundary of the projections. Therefore, the scenarios have a wide range of possible electricity demand by 2050.

Electricity demand is projected to grow between 18 and 78 per cent over the projection period. In the Reference scenario, electricity demand grows on average at a rate of 1.1 per cent per year and total electricity demand rises 43 per cent by 2050. In this scenario, economic drivers accounts for 67 per cent of the increase[19]. The electrification of process heat accounts for 9 per cent of the increase. The rest of the increase is owing to the uptake of EVs.

Under the Global scenario, the recent trend in electricity demand continues and grows at a rate of 0.5 per cent per annum and economic drivers accounts for 37 per cent of the increase. Around half of the increase comes from the electrification of road transport.

Table 4. Electricity demand (TWh)

Scenario	Year		
	2017	2035	2050
Reference	39.7	48.4	56.7
Growth	39.7	52.0	65.1
Global	39.7	44.1	46.7
Environmental	39.7	54.3	66.5
Disruptive	39.7	55.2	70.5

In the Growth scenario, economic drivers contribute over 73 per cent of the increase and total electricity demand is about 15 per cent larger than the Reference scenario in 2050. On average electricity demand grows at a rate of 1.5 per cent per annum. In this scenario, the share of the commercial sector GDP is 3 per cent higher than the reference scenario by 2050. Without increasing the commercial sector share of GDP, electricity demand would be 2.5 TWh higher by 2050.

The Environmental scenario models a pathway of achieving a better environmental outcome than the Reference scenario. Under this scenario, electricity demand in 2050 is similar to that in the Growth scenario but the size of the economy in 2050 is about 20 per cent smaller than in the Growth scenario. The amount of infrastructure investment required to meet future demand for electricity in the Environmental scenario is expected to be similar to that of the Growth scenario.

If the economy grows at a rate of 2.5 per cent per annum, it will take about 8 years to increase the size of the economy by 20 per cent. In other words, the Environmental scenario shows that

[18] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/electricity-demand-and-generation-scenarios

[19] Economic drivers include the impact of carbon prices - higher carbon prices alone account for 5 per cent of the increase in the Reference scenario.

about a decade's worth of investment in the electricity sector is required to meet higher electricity demand if New Zealand is on a path to a low-carbon economy.

In the Disruptive scenario, we access the electricity demand implications if a greater amount of process heat is electrified. Electricity consumption increases 78 per cent by 2050 and the electrification of process heat alone contributes 43 per cent of the increase. The uptake of EVs accounts for 25 per cent of the increase and economic drivers provide around the rest of the increase.

Peak demand

Peak demand for New Zealand and North Island are estimated to be around 6,300 MW and 4,250 MW respectively in 2017. Table 5 shows the peak demand in each scenario.

Table 5. Peak demand in 2050 (MW)

Scenario	New Zealand	North Island
Reference	8,462	5,726
Growth	9,831	6,649
Global	7,062	4,806
Environmental	9,640	6,474
Disruptive	10,205	6,949

In the Reference scenario, peak demand for both New Zealand and North Island are expected to increase by about 34 per cent in comparison with a 43 per cent increase in total electricity demand. The difference is due to the installation of solar and battery systems, which lower evening peaks by around 550 MW and 450 MW in 2050 for New Zealand and North Island respectively.

The impact of solar systems with batteries can be illustrated by comparing peak demand between the Growth scenario and the Environmental scenario. Electricity consumption in the Environmental scenario is 2 per cent higher but peak demand for New Zealand is 2 per cent lower in the Environmental scenario than in the Growth scenario. There are 300,000 more households installed with batteries in the Environment scenario than in the Growth scenario.

In the Disruptive scenario, demand response technologies play a significant role in smoothing electricity consumption profiles so that peak demand for both New Zealand and the North Island increases by around 63 per cent, compared with a 78 per cent increase in the total demand in 2050.

Electrification of process heat

Table 6 shows the additional electricity demand due to electrification of process heat for each scenario. The Environmental and Disruptive scenarios, in particular, have substantial electrification of process heat by 2050.

Table 6. Electrification of process heat (TWh)

Scenario	2035	2050
Reference	0.7	1.5
Growth	0.8	1.9
Global	0.6	1.2
Environmental[20]	4.2	6.5
Disruptive	6.3	13.3

[20] Does not include the impact of higher carbon prices.

Electric vehicles

Table 7 shows the projected electricity demand for charging electric vehicles. These projections are a sharp increase from the EDGS 2016 projections. The higher electricity demand reflects an assumption of strong growth in the uptake of electric vehicles – especially in the Environmental and Disruptive scenarios.

Table 7. EV electricity demand (TWh)

Scenario	Year		
	2017	2035	2050
Reference	0.0	1.4	4.1
Growth	0.0	1.5	5.0
Global	0.0	1.2	3.2
Environmental	0.0	3.3	7.6
Disruptive	0.0	3.3	7.6

Sensitivity to closure of the Tiwai aluminium smelter

The possible closure of the New Zealand Aluminium Smelter at Tiwai Point is a key uncertainty for the future of electricity demand. Therefore, we modelled the sensitivity of the Reference scenario to switching off the smelter in 2030 (coinciding with the decommissioning of 400 MW of coal-fired Huntly generation units).

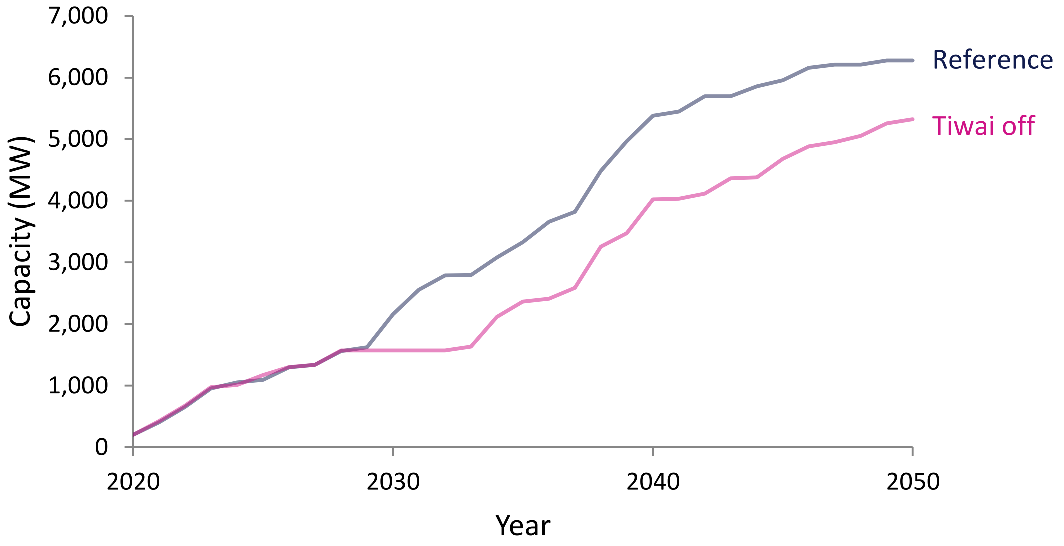
Tiwai consumes around 5 TWh each year, which is equivalent of 13 per cent of total demand in 2017. Shutting down Tiwai lowers the national peak demand by 575 MW.

The main effect of closing the smelter is to materially reduce the need for new generation capacity to be built from 2030 onwards. As shown in Figure 13, switching off the smelter results in no new generation capacity being built for four years.

By 2050, the Reference scenario has 6,300 MW of cumulative new generation capacity built, while without the Tiwai demand only 5,300 MW of capacity is built. The difference of 1,000 MW is due to the combination of two factors:

- Reduced baseload demand from the Tiwai smelter.
- Less need for new generation capacity, most of which is Wind and other renewable generation. Since the new generation build is not baseload (i.e. it has a capacity factor of less than 100 per cent, for example up to 40 per cent for Wind), the reduction in generation capacity required is significantly larger than the reduction in demand.

Figure 13. Projected new generation build capacity (MW)



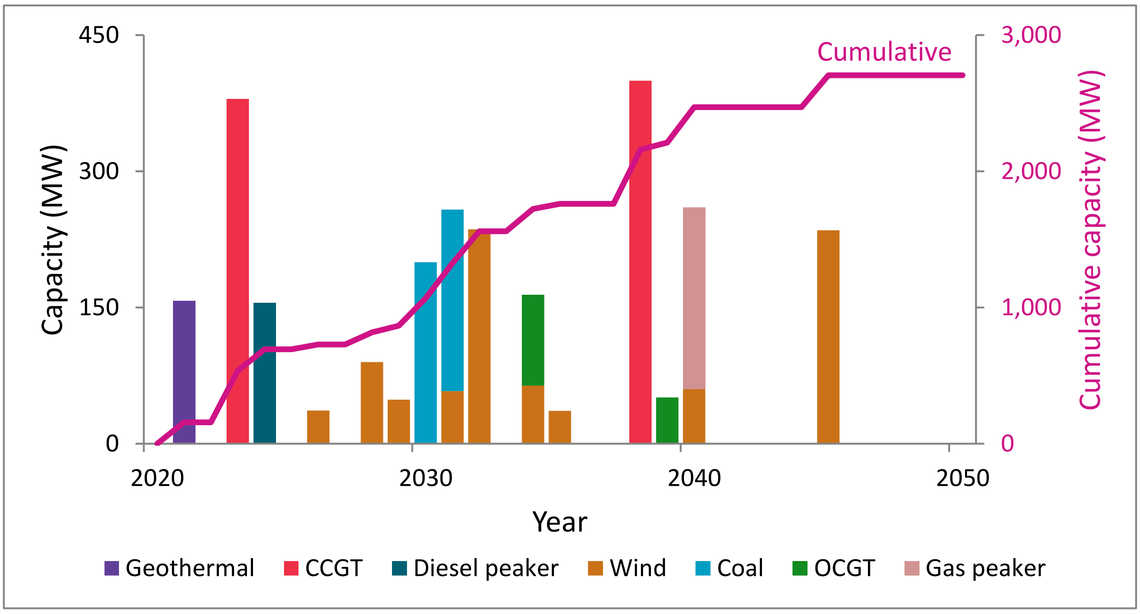
Electricity supply

Expected retirements

Generation capacity retires when it reaches the end of its economic life, and the decision is made to not refurbish. Figure 14 shows the schedule of generation plant retirements, grouped by plant type, for all scenarios.

Almost 3,000 MW of existing capacity is expected to be retired during the modelling period. Retirements include all of the existing large coal and gas capacity. The retirement of generation capacity generally prompts the building of replacement new generation capacity. Additionally, new capacity needs to be sufficient to meet demand growth over time.

Figure 14. Projected schedule of generation decommissioning



New build

Figure 15 shows the new generation build for the Reference scenario. The other scenarios are shown in Figure 16.

In the Reference scenario, by 2050 6,300 MW of electricity generation capacity is needed, with 55 per cent of the new build being wind generation. All of the gas new build capacity operates in a peaking role. Almost all of the small Other capacity is grid-connected solar generation.

Figure 15. Projected cumulative new generation build – Reference scenario

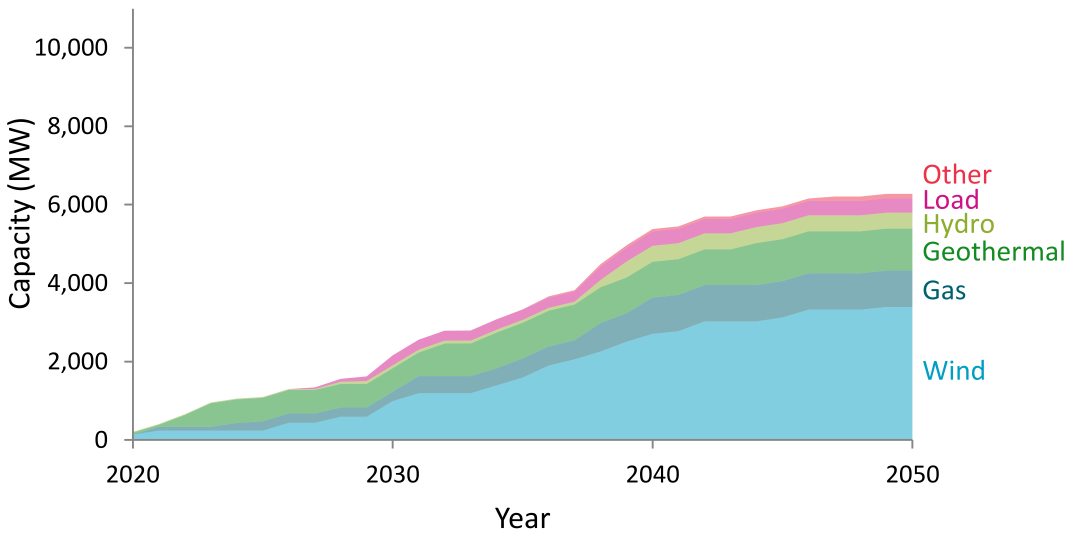
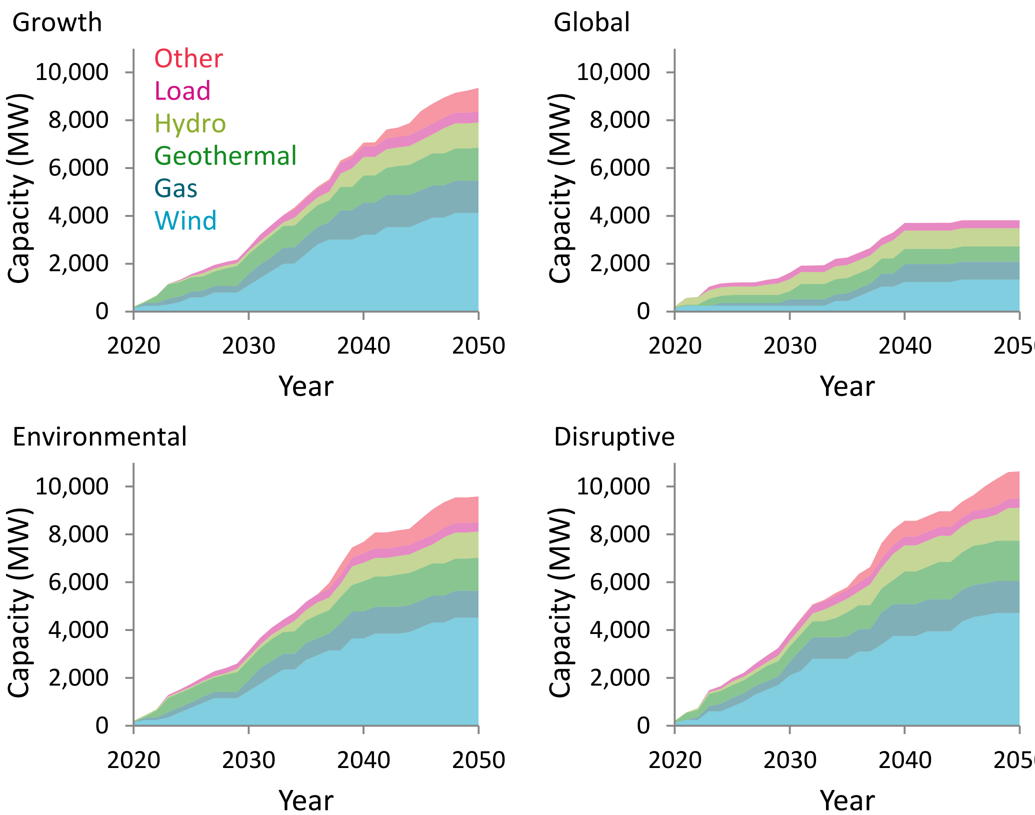


Figure 16. Projected cumulative new generation build – other scenarios



An increase in demand for electricity means we need to build more new generation. Thus, the amount of investment in building new electricity generation is ultimately dependent on the future demand for electricity.

Table 8 shows that between 3,800 and 10,600 MW of new electricity capacity is required by 2050 to meet the growing electricity demand. The capital expenditure on new electricity capacity ranges between $7.3b and $23.6b. However, wholesale electricity prices[21] in real terms are expected to remain at the current level, reflecting that the majority of new build generation is wind and the long-run marginal cost of wind is projected to fall over the projection period.

Table 8. New generation build capacity (excluding rooftop solar) in 2050

Scenario	New build	
	MW	Capex $b
Reference	6,300	13.0
Growth	9,400	20.2
Global	3,800	7.3
Environmental	9,600	21.1
Disruptive	10,600	23.6

Capex in billions of 2017 dollars

Table 9 shows the roof-top solar generation for each scenario.

Table 9. Roof-top solar generation (TWh)

Scenario	Year		
	2017	2035	2050
Reference	0.0	0.5	2.3
Growth	0.0	0.6	2.8
Global	0.0	0.2	0.9
Environmental	0.0	1.2	4.6
Disruptive	0.0	1.2	4.6

One of the main insights from the modelling is the mix of generation build. Most of the new build in the Reference scenario is wind generation, as the cost of wind technology is expected to fall further and the price to build new wind generation is comparable to the cost of running gas/coal fired power plants.

Under the Environmental scenario, an additional 3,300 MW of new generation capacity is required on top of 6,300 MW from the Reference scenario. Among the additional electricity generation, only 34 per cent comes from wind. In the Disruptive scenario, another 1,000 MW of capacity is needed to meet demand, with wind accounting for 20 per cent of the new build. It is relevant to note that the long-run marginal cost of wind technology in the Disruptive scenario falls more than other scenarios, as shown in Figure 10.

The results of the modelling show that the impact of a reduction in the cost of wind technology becomes less important once wind power provides a certain proportion of electricity generation. Owing to the intermittent nature of wind power, there is limit[22] to the

[21] In our methodology, wholesale prices are set based on the long-run marginal cost of new build entering the market.

[22] The more wind power capacity a grid has, the higher chance peak demand is not met and additional reserves are required to ensure the same level of grid reliability. One way to overcome the limitations of

proportion of wind power in the overall generation capacity. To deal with the variability of wind power, more new gas peaking plant and geothermal plants are built to meet the additional demand in the Disruptive scenario in comparison with the Environmental scenario. This has significant implications for both the level of renewable generation and greenhouse gas emissions.

Energy from renewable generation

Table 10 shows the share of electricity generation from renewable sources, which is projected to be around 95 per cent in 2050 in all scenarios, compared with 82 per cent in 2017.

Table 10. Average renewable generation (per cent)

Scenario	Year		
	2017	2035	2050
Reference	81.7	90.6	94.9
Growth	81.7	91.2	95.4
Global	81.7	89.7	94.5
Environmental	81.7	91.6	96.0
Disruptive	81.7	91.0	94.9

As mentioned in the previous section, there is a limit to renewable electricity sources. To address the variability of renewable generation, gas peaking capacity is built to provide back-up whenever there is a spike in demand.

This result is based on assumptions about available technologies. For example, hydrogen storage and fuel cell technology mentioned in Box 2 could help fix the renewable energy storage problem in the future.

Currently, batteries are costly and able to store enough energy to back up the grid for only a few hours. For New Zealand, we need technologies to harvest and store renewable energy in summer and release the stored energy in winter when the demand for electricity is high.

Greenhouse gas emissions

The levels of greenhouse gas (GHG) emissions over the projected time series have been estimated based on the fuel consumption from the model results and the fuel emission factors. The emissions levels should be viewed as approximate values and only indicative of the trend given the uncertainties involved in allocating fuel use to particular sectors and applying appropriate emission factors.

We use historical emission factors to estimate future emissions; however there is inherent uncertainty around the impact of new energy developments, particularly for instance the location and nature of future geothermal fields and the technologies used to extract and generate electricity from geothermal fluids. The emissions are presented in units of carbon dioxide equivalents (CO_2-e).

Stationary energy sector

Figure 17 shows historical GHG emissions from 1990-2017 and projected emissions from 2018-2050 for the stationary (non-transport) energy subsector[23]. Emissions from stationary energy activities are expected to be steady in the short term, before declining in all scenarios.

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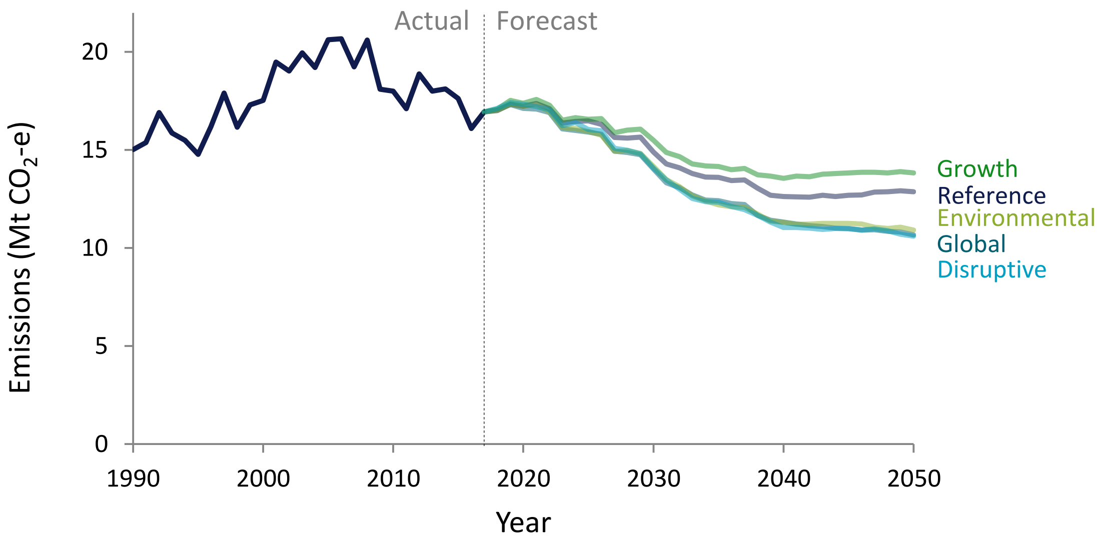
wind power is to overbuild wind capacity. However, it will lower the utilisation rate of wind generation, which in turn leads to higher LRMC. Our modelling results show the optimal level of wind penetration is estimated to be around 25 per cent of total installed capacity.

[23] Stationary energy emissions includes all non-transport energy sector emissions.

In the long term the main driver for the GHG emissions is economic activity. Total energy demand is expected to continue to grow throughout the modelled period, but at the same time the emissions intensity of energy (emissions per unit of energy delivered) is expected to decline.

The largest reduction in stationary energy emissions occurs in the Global scenario. However, both policy and technology can play a key role in lowering GHG emissions, as shown by the Environmental and Disruptive scenarios. Thermal baseload generation is expected to be replaced mainly by a combination of wind, geothermal and gas-fired peaking plants resulting in very low emissions. Generally speaking across the scenarios, manufacturing is projected to be the largest contributor to emissions, with smaller amounts coming from the primary and residential subsectors.

Figure 17. Actual and projected greenhouse gas emissions for stationary energy



Transport sector

Figure 18 presents shows historical GHG emissions from 1990-2017 and projected emissions from 2018-2050 for the transport subsector. In particular, replacing internal combustion engine (ICE) vehicles with EVs will have a significant impact on emissions. Emissions from transport activities are also expected to rise in the short term, and plateau, before declining in all scenarios due to the projected uptake of EVs in all scenarios.

Figure 18. Actual and projected greenhouse gas emissions for transport

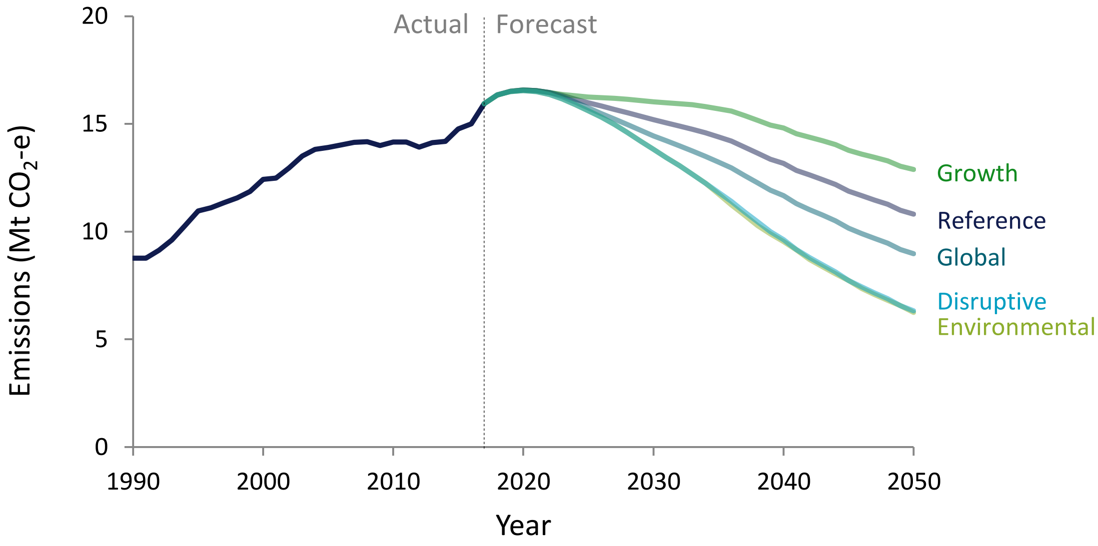
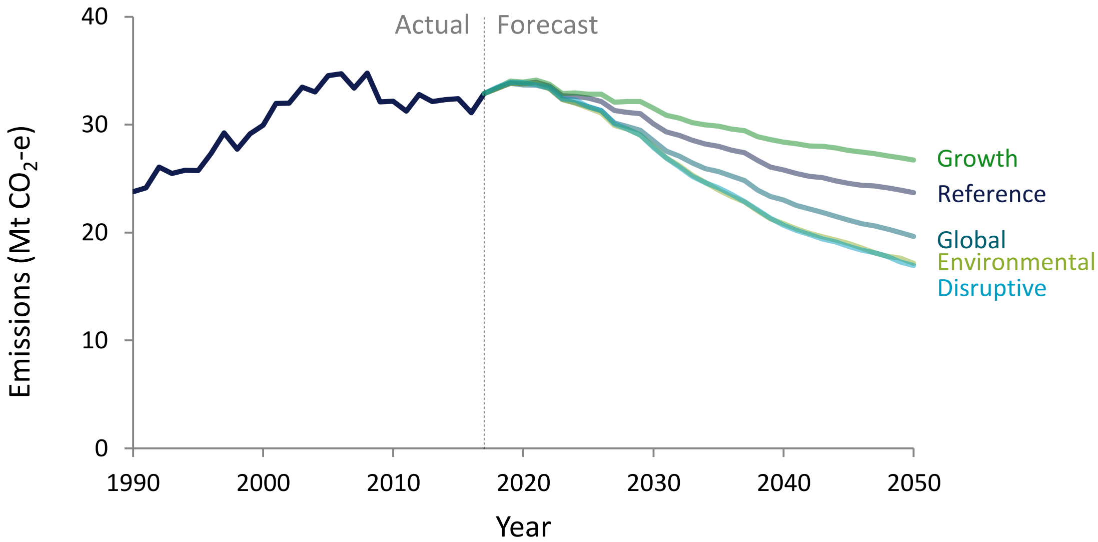


Figure 19 shows total energy sector emissions, which are the combined levels from stationary energy and transport. There are no significant differences in GHG emissions between the Environmental and Disruptive scenarios, which have the lowest levels out of the five scenarios. Under these two scenarios, total energy emissions are expected to fall to half of today's value in 2050.

As the renewable electricity percentage reaches above 95 per cent, the additional electrification of process heat, particularly high grade heat, in the Disruptive scenario, relative to the Environmental scenario, does not result in lowering the overall energy emissions because part of the electricity used in the process of electrification comes from geothermal and gas-peaking plants. In this case there are diminishing returns from extra electrification because there are no efficiency gains to be made electrifying high grade heat, and the additional electricity generation required has a higher emissions intensity. See page 17 for more information on the electrification of process heat.

Figure 19. Actual and projected total greenhouse gas emissions for energy



Next steps

The previous EDGS results were published in August 2016. 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 relating to the EDGS, then please contact us via email at energyinfo@mbie.govt.nz.

Appendix A – Approach to scenario modelling

Scenario process

We use a scenario modelling approach to fulfil the EDGS objective of exploring a range of potential futures.

Our modelling approach involves the following steps:

1) Define features that the scenarios need to have
2) Specify dimensions for variations in future assumptions
3) List the uncertainties that the scenarios are designed to explore
4) Define a set of scenarios that cover a plausible range of futures
5) Create assumptions for each of the scenarios
6) Model the scenarios
7) Present the modelling results

Interpretation of scenarios

Note that the scenarios do not represent forecasts of the future and should not be interpreted as such. We do not assign probabilities to the scenarios, on the basis that each scenario is just one of many possible futures.

No significance should be attributed to the scenario names, which have been chosen 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.

Scenario features

The scenarios are defined with the following features in mind:

- Scenarios represent a possible future
- Each scenario expresses a coherent story, based on a plausible set of assumptions and behaviours
- The scenario story does not need to define the specific mechanism by which behaviours or outcomes occur (that is beyond the scope of the EDGS)
- The scenarios are not expected to cover all possible futures
- The scenarios may not be equally likely

Scenario dimensions

In defining the scenarios we considered a range of demographic, economic, policy, and technology dimensions. These dimensions address a variety of issues, as outlined below.

Demographic:

- Population growth rate
- Urban/rural and North Island/South Island population mix

Economic:

- GDP growth
- Fuel prices
- Residential demand growth
- Demand per capita
- Retirement/replacement of existing generation

Policy:

- Carbon price
- Fossil fuels availability (exploration/extraction)
- Subsidies/incentives

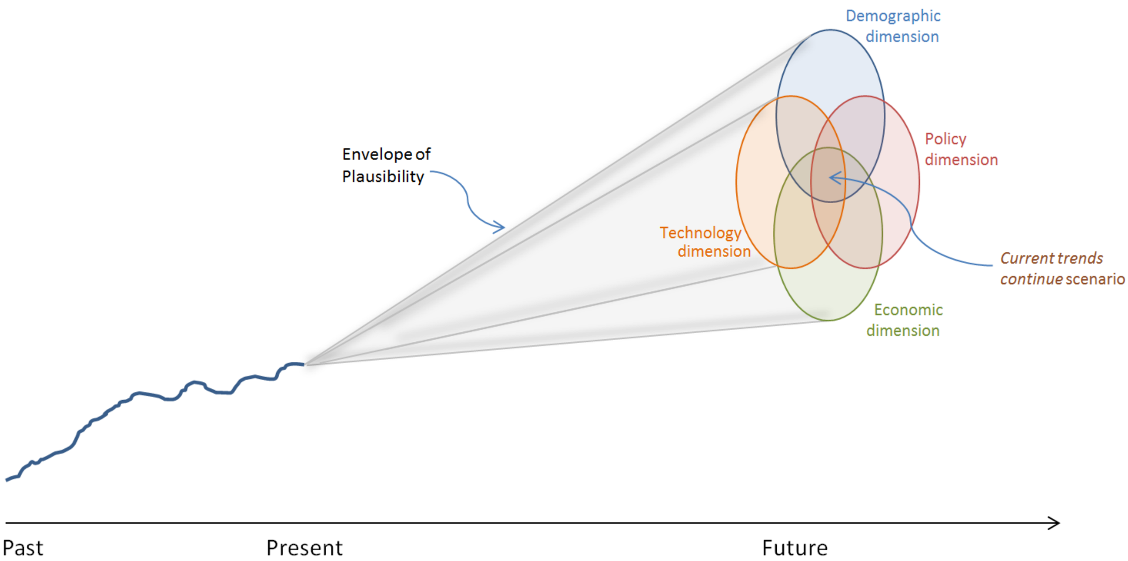
- Electricity market design (operation/structure)
- Security of supply

Technology:

- Electric vehicle (EV) volume and "smartness" of charging
- Solar electricity generation, with batteries
- Wind, geothermal, and other generation options (nuclear, tide, etc.) and factors affecting uptake

The objective of the scenarios is to explore a range of hypothetical futures, considering the scenario dimensions. This concept is illustrated schematically in Figure 20.

Figure 20. Schematic illustration of the scenario exploration space



Key uncertainties

The scenarios are designed to explore key uncertainties in the electricity sector and beyond, 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 global response to climate change (particularly the price of carbon emissions)
- 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 New Zealand Aluminium Smelter at Tiwai Point (which accounted for 13 per cent of national electricity demand in 2017)
    - The size and structure of the population
    - 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 generation

Appendix B – Overview of EDGS modelling

GEM and SADEM

The EDGS modelling makes use of two distinct, interrelated models:

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

Generation Expansion Model (GEM)

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

GEM produces a projection of new generation plant built over the next 30 years, including the expected gas demand from existing and new thermal generators. A pricing model determines the wholesale price based on the long run marginal cost (LRMC) of each new plant built.

In EDGS, GEM is the main model used to project the timing and type of new generation plant built. GEM also determines the operation of existing plant and, in conjunction with exogenous assumptions, the retirement years for existing plant.

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

Supply and Demand Energy Model (SADEM)

The Supply and Demand Energy Model (SADEM) is a partial equilibrium model of the energy sector and key drivers such as GDP and oil price are exogenous, meaning that the potential link between the price of oil and GDP is not modelled explicitly.

SADEM performs three key functions:

- Project energy demand for all sectors of the economy (with the exclusion of land transport) using econometric relationships with exogenous drivers (such as GDP and population) and relative price levels
- Provide a central hub, coordinating electricity supply information from GEM and exogenous land transport demand information
- Calculate projections of energy sector greenhouse gas emissions by applying emission factors

For more information see "SADEM model review: NZIER assessment of approach, recommendations and fitness for purpose".

Iteration of GEM and SADEM

GEM requires inputs of fuel prices and electricity demand projections from SADEM.

Some of demand projections in SADEM are based on relative fuel prices, including electricity prices. The electricity price projection is produced from the GEM build schedule which is, in turn, affected by the demand from SADEM.

Therefore, GEM and SADEM are run iteratively until equilibrium between the electricity supply (produced by GEM) and the demand for electricity (produced by SADEM) is achieved.

Appendix C – Consultation

In preparing the EDGS, we consulted with many organisations about the scenario definitions, modelling assumptions, and draft results.

We would like to acknowledge the following organisations for their contributions:

- Commerce Commission
- Contact Energy
- Electricity Authority
- Electricity Networks Association
- Electricity Retailers Association of New Zealand
- Energy Efficiency and Conservation Authority (EECA)
- First Gas
- Gas Industry Company
- Genesis Energy
- Major Electricity Users Group
- Major Gas Users Group
- Mercury Energy
- Meridian Energy
- Ministry for the Environment
- Ministry of Transport
- PowerCo
- Transpower
- Trustpower

We appreciate the feedback provided during the consultation process, as it enabled us to validate and improve the results. We would also welcome any additional comments for improving future iterations of the EDGS process.

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