TRANSPOWER

NZGP1 Scenarios Update

NZGP1 Scenarios and modelling results for an unconstrained transmission grid

December 2021

Executive Summary

This update describes the scenarios we will be using for our Net Zero Grid Pathways 1 (NZGP1) Major Capex Project investigation.

Electricity will play an important role in reducing New Zealand's greenhouse gas emissions. The demand for electricity is likely to rise significantly in the coming decades and the supply of electricity will reduce from being reliant on fossil fuels to an increasing reliance on renewable energy sources.

Such changes create considerable commercial opportunities and our electricity industry is currently in a phase where existing and new participants are exploring ideas. This creates considerable uncertainty for Transpower and the services that will be required from the transmission grid.

We use scenarios to consider the effect of such uncertainty and are required to use the Electricity Demand and Generation Scenarios (EDGS) or reasonable variations of them, in our investment cases where we seek Commerce Commission approval for a Major Capex Project (MCP).

As a first step in our NZGP1 MCP investigation, we reviewed the latest EDGS, produced in 2019 (EDGS 2019) and concluded they needed to be updated.

After seeking advice from an expert panel and three written consultations, we have settled on a suitable set of scenarios, which are described in this document as our NZGP1 scenarios. The scenarios are described in detail in this document and compared to the EDGS 2019. Given the significant transmission grid investment that will likely result from our NZGP1 and ongoing NZGP investigations, this provides transparency for those interested in the drivers for identified investments.

Our NZGP1 scenarios are variations of the EDGS 2019 and in our view, meet the Commerce Commission's requirements for being considered reasonable variations.

There are five scenarios, and we have varied input assumptions between the scenarios in a very similar way to the EDGS 2019. Accepting that our scenarios are reasonable EDGS 2019 variations, we are using the same scenario names as used by the Ministry of Business, Innovation and Employment (MBIE).

This report also describes the outcome from our generation expansion model, for each of these scenarios, assuming an unconstrained transmission grid. These generation expansion plans will not appear in our Investment Test application, but they do provide relevant directional information on what future electricity generation might be built.

Given the considerable uncertainty in future electricity demand and supply, there are some potential futures which are possible but not yet certain enough to include in the NZGP1 scenarios. Some of these have significant transmission implications and to ensure they are not ignored, we have developed a set of sensitivity scenarios as well. These are listed in this document. Our NZGP1 investigation will explore some sensitivity scenarios, including variations on Southland supply and demand and the transmission implications of Lake Onslow being developed for dry year reserve.

Our wider Net Zero Grid Pathways Project (NZGP) is also considering issues beyond those being investigated in NZGP1 and includes a broader range of uncertainties. We will update interested parties separately on that project.

Stephen Jones - Grid Planning and Investment Manager

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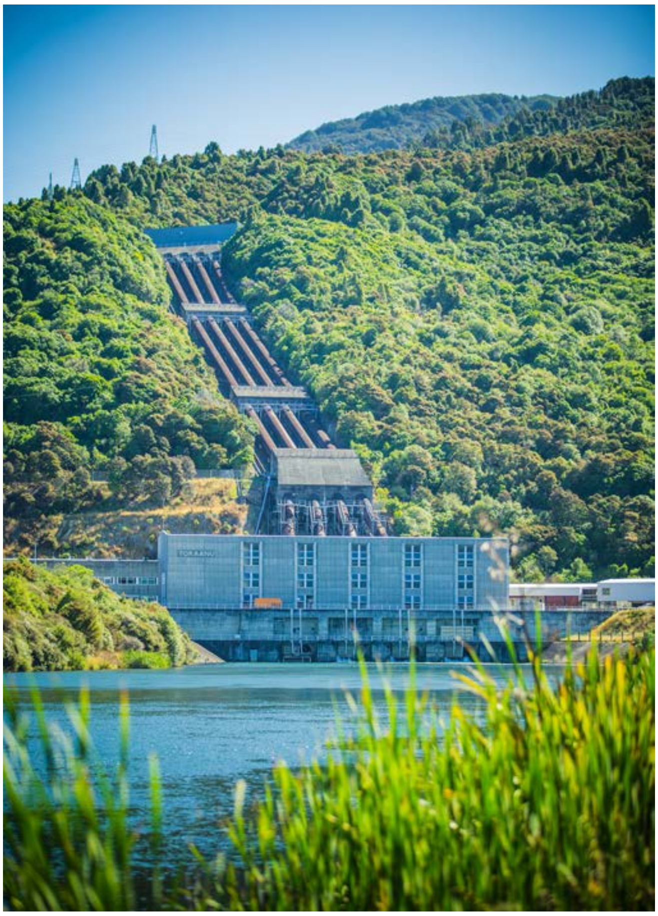


Our Net Zero Grid Pathways project

In responding to climate change, New Zealand is pursuing a goal to be net zero carbon by 2050. Electricity demand is expected to increase as New Zealand decarbonises its energy use and transitions away from fossil-fuel based energy consumption.

Electricity generation will need to increase to meet this growth in demand and at the same time our existing fossil-fuelled generation is likely to be replaced by renewable and lower carbon sources of generation (hydro, geothermal, wind and solar).

Transpower has a role in enabling this future. Within our market-based electricity system, we need to ensure that new generators can connect to the transmission grid where and when they want and that the electricity they generate can be transmitted to where it is needed to power our economy as electrification replaces other forms of primary energy.

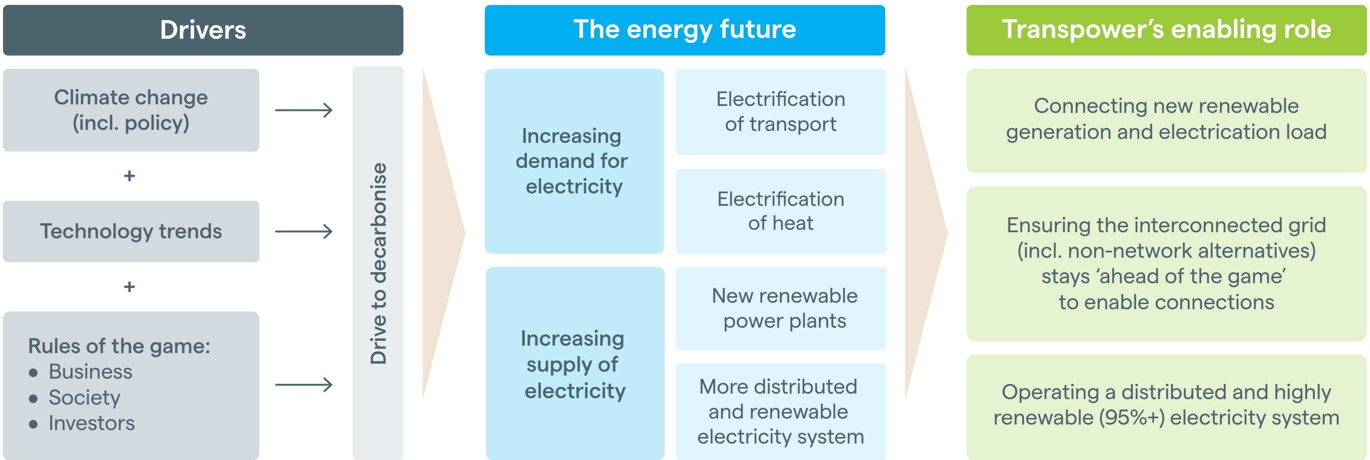


Figure ES1 – Transpower's enabling role in support of New Zealand pursuing net-zero carbon by 2050

Our Net Zero Grid Pathways (NZGP) project is investigating what is required to make the transmission grid fit for this purpose.

We are undertaking NZGP in two phases. Phase 1 is focused on the timeframe to 2035 and is primarily considering the grid backbone. Phase 2 will look out to 2050 and will identify what other changes may be needed to the grid backbone and potentially some regional grids, after 2035.

The output from the NZGP project will be a long-term transmission plan, showing how we envisage the transmission grid being developed between now and 2050.

The long-term transmission plan will be consistent with our Transmission Planning Report (TPR), but not as detailed and looking out further in time.

This plan will be important information for potential new electricity demand and generation investors, as it provides surety about future transmission grid capacity.

We expect to identify the need for transmission grid investment as the project proceeds and will prepare and submit Major Capex Proposals (MCPs) to the Commerce Commission as required.

This document describes the scenarios we will use in our first MCP investigation, named NZGP1. They are described in detail to capture the outcomes from our consultation. We also describe the outcome from our generation expansion model, for each of these scenarios, assuming an unconstrained transmission grid. These descriptions will assist those interested to understand how we have varied from the EDGS 2019 and the potential rationale behind future investment cases.

NZGP1

Work undertaken in late 2020 identified a series of potential grid constraints in the lower half of the North Island as electricity demand and generation grows.

Grid capacity across the Cook Strait (the High Voltage Direct Current (HVDC) link between the North Island and South Island), the 220kV grid between Bunnythorpe and Whakamaru (CNI) and the 220kV grid around the Wairakei Ring all constrain at similar times.

Recognising that the cost of relieving these (related) constraints will exceed $20 million, we established a major capex project investigation and we expect the outcome of the investigation to be a staged MCP which we will submit to the Commerce Commission[1].

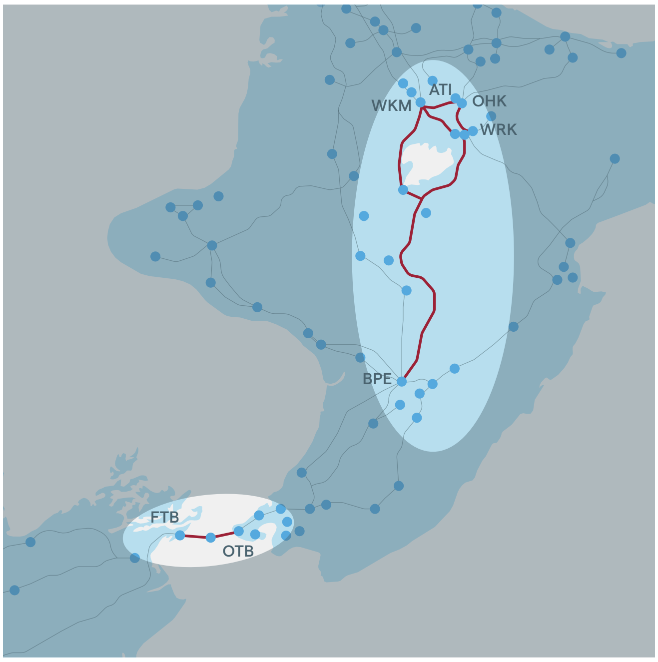
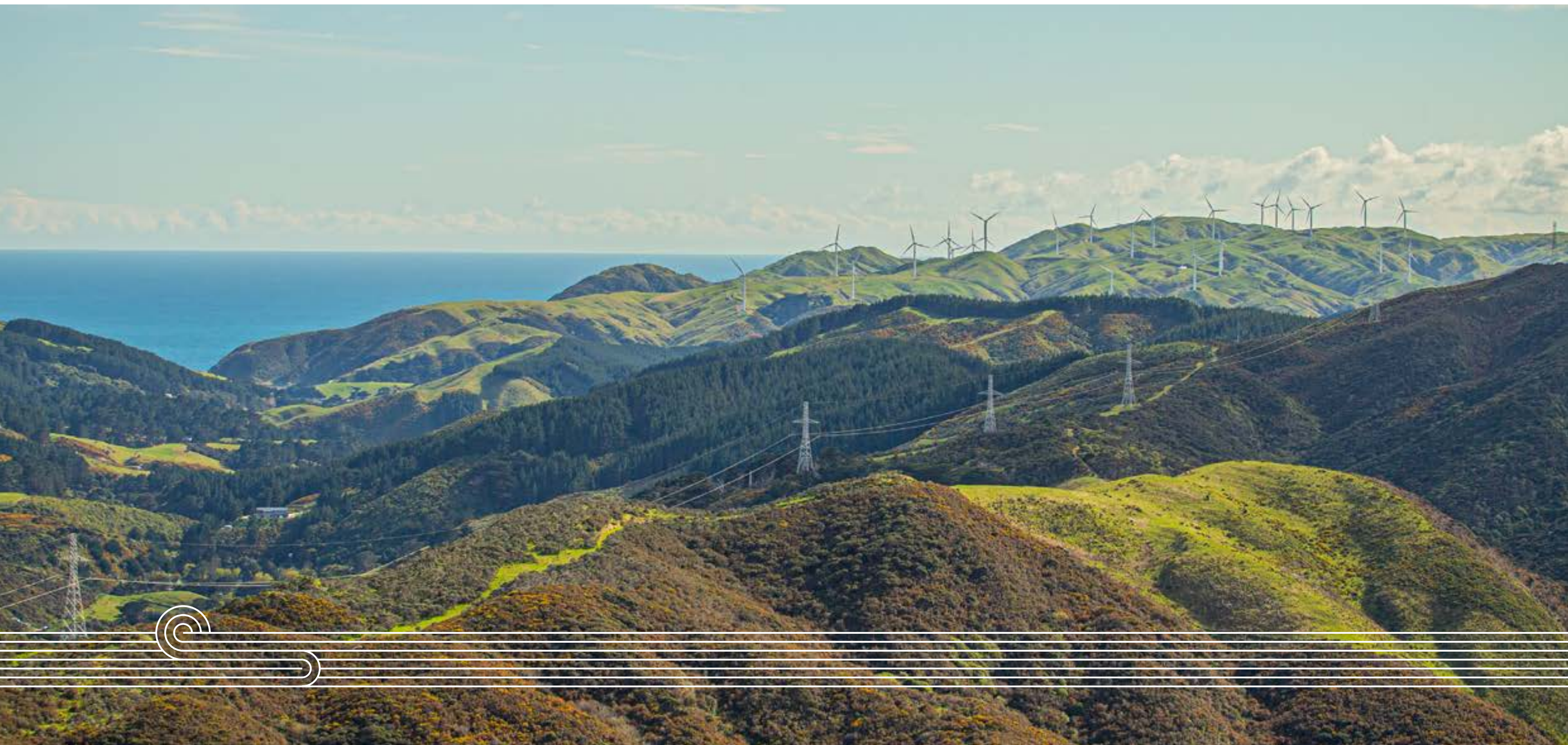


Figure ES2 – Those parts of the grid backbone (in red) which constrain first as electricity demand and generation grow

1. Transpower is required to obtain approval from the Commerce Commission, under the Consolidated Transpower capital expenditure input methodology determination as at 1 June 2018 (Capex IM), in order to recover the cost of such projects from our customers.



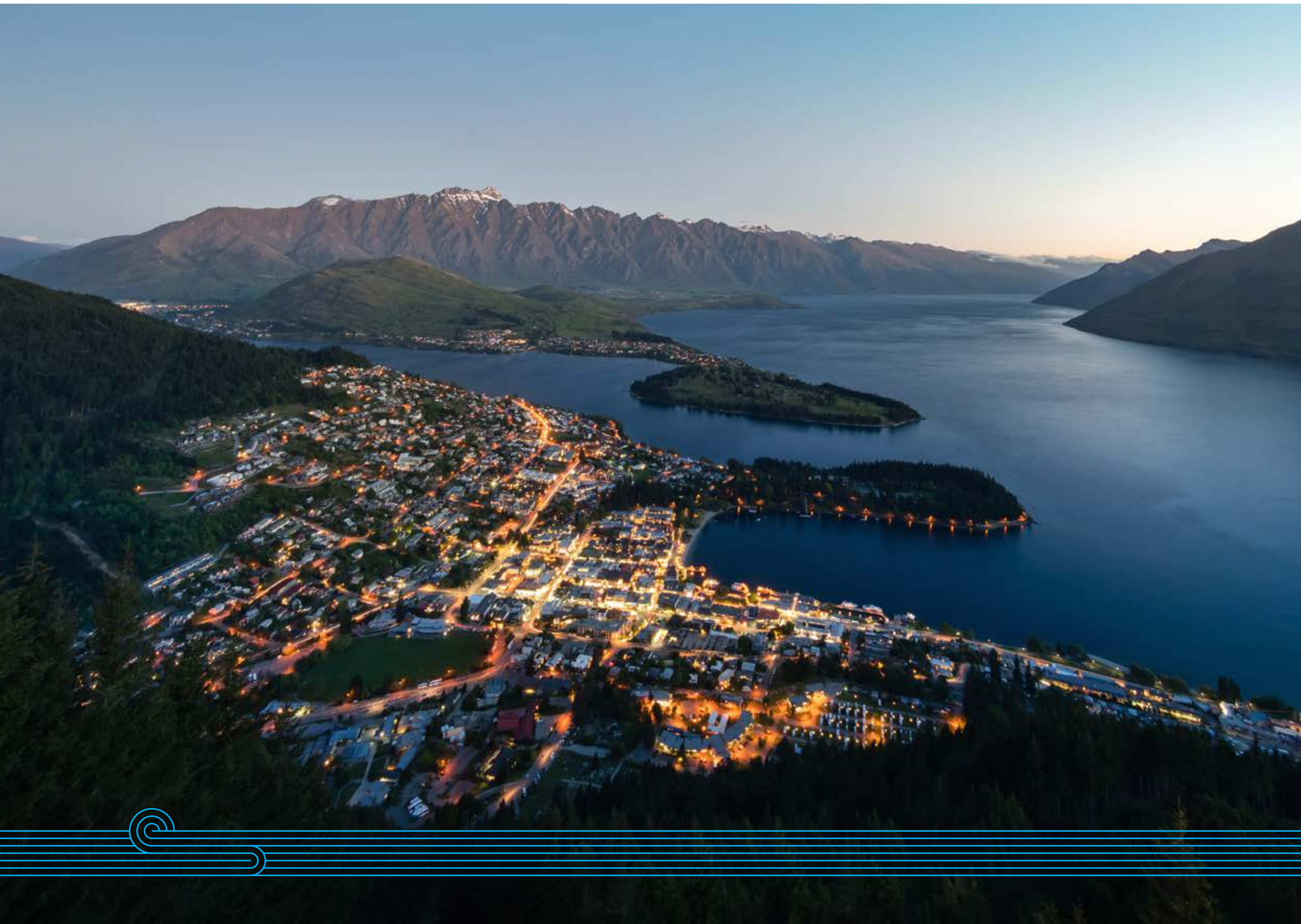
Purpose of this document

Where and when new electricity demand will arise and new generation will be built is uncertain, yet these are key determinants of the need for electricity transmission services. Our investigations consider uncertainty through the use of futures, or scenarios.

Because NZGP1 is an MCP investigation, we are complying with the requirements of the Capex Input Methodology (IM) and this obliges us to use the Electricity Demand and Generation Scenarios (EDGS), as published by MBIE, or reasonable variations of the EDGS.

Since we launched NZGP1 in 2020, we have been reviewing and consulting on the suitability of the existing EDGS for our investigation and this report describes the outcome of that consultation and the scenarios we will be using.

This paper is an update to interested parties. It reflects the conclusions we have drawn from the extremely helpful submissions parties have made to our various consultations, but it does not specifically describe how we have considered submissions. That will be included in our next formal publication, the short-list consultation, effectively being a draft of the MCP we will submit to the Commerce Commission later in 2022. We expect to publish the short-list consultation toward the middle of 2022.



Process to date

The Capex IM allows for EDGS variations to be used, where the variations are both reasonable and have regard to the views of interested persons.

The latest EDGS were published in 2019 but reflecting the rapid pace of change in New Zealand's energy sector at the moment, there have been several relevant and important changes which are not reflected in the EDGS 2019. These include, but are not limited to:

- MBIE generation cost stack update, which describes potential new generation plant information
- The New Zealand Aluminium Smelter at Tiwai Point's announcement to close in 2024 (and the subsequent effect on North Island thermal generators)
- Investor interest in grid-scale batteries
- Government investigation of Onslow pumped hydro scheme i.e. the NZ battery workstream.

We therefore consider it necessary to vary the EDGS 2019 for the purposes of our NZGP1 investigation. A number of other electricity scenarios have been published, including those by the Climate Change Commission (CCC) and Transpower's own Whakamana i Te Mauri Hiko (WiTMH). It would be difficult to adopt any of those and justify them as EDGS 2019 variations, so we have unpacked the EDGS 2019 and updated those elements which need updating, to ensure consistency. We compare our EDGS 2019 variations with these alternative scenarios further on in this document, as a sense check.

To ensure we reflect the views of interested persons, we have used a consultative approach to review the EDGS 2019. A full description of our interactions with stakeholders can be found on our website at:

http://www.transpower.co.nz/NZGP

In brief:

- We initially used a panel of external (to Transpower) experts to review the EDGS 2019, in November 2020 and December 2020. Recordings of the online meetings we held with them are available at the web link above.
- The conclusions from those online meetings were included in a written consultation paper, which was published on our website in December 2020. That consultation was open for 8 weeks, closing in February 2021. In that paper we concluded that demand and generation scenario variations should be determined separately. We had good information to produce reasonable EDGS 2019 demand scenario variations, but not enough information to derive generation scenario variations.
- Hence, we undertook further consultation, via a written consultation paper, in regard to generation scenarios. This was in May 2021. We targeted potential generation investors, although the consultation was open to all interested persons. That consultation was open for 6 weeks and closed in June 2021. Feedback suggested there is too much uncertainty regarding future generation possibilities for grid-connected generation in New Zealand, to reflect in just five nationally determined scenarios, as the EDGS 2019 are.
- With that feedback in mind, we published our first formal NZGP1 document – the long-list consultation document in August 2021. That consultation was open for 6 weeks and closed in October 2021. The submissions we received (excluding two that were provided on a confidential basis) are published on our website, along with this update paper.

In our long-list consultation document, we described a possible approach to developing scenarios suitable for NZGP1. That approach reflected the considerable uncertainty in regard to where new generation will be built, but was complex and necessarily involved significant judgement. Although it is a possible approach, we have decided it would be both difficult to apply, potentially contentious, and may be difficult to demonstrate to the Commerce Commission that the resultant scenarios are reasonable variations of the EDGS.

Therefore, we have changed our approach and the scenarios we are presenting here and using for our NZGP1 investigation, are aligned with EDGS 2019. We are using the same five scenarios as in EDGS 2019, but with updated inputs and the differences between scenarios is very similar to the EDGS 2019. We are calling our scenarios, NZGP1 scenarios.

Not all of the uncertainty identified in reviewing the EDGS 2019 is reflected in our NZGP1 scenarios, so we will also consider both sensitivities and some sensitivity scenarios in our MCP. Sensitivities play an important role in assessing the outcomes from the scenarios and inform the robustness of the proposed investment.

Table 1 and 2 list some of the more important parameters included in the EDGS 2019 and Tables 3 and 4 compare those parameters for both EDGS 2019 and NZGP1 scenarios.

Electricity Demand and Generation Scenarios (EDGS) 2019[2]

The Electricity Demand and Generation Scenarios (EDGS) are a description of five hypothetical future scenarios, relating to forecast electricity demand and generation. They are published by MBIE, specifically for the purpose of investigating major capex proposals. MBIE developed the existing EDGS in 2019 and they include the following five scenarios:

1. **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.

2. **Growth: Accelerated economic growth**

   This scenario assumes the past decade of slow growth in labour productivity is an aberration rather than the norm. 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 commercial sector grows to be larger than in the Reference scenario and 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.

3. **Global: International economic changes**

   In this scenario New Zealand's economy is battered by international trends, leaving little room for local growth or innovation. Some aspects are opposite to the Accelerated economic growth scenario such as the uptake of electric vehicles (EVs). This scenario also includes a higher cost for wind turbines and solar power than in the Reference scenario.

4. **Environmental: Sustainable transition**

   The New Zealand government targets more ambitious emissions reduction levels than in the Reference scenario. Strong environmental leadership, including the use of regulation and incentives (rather than technology) provides the change reflected in this scenario. Policies are introduced to support the electrification of both transport and process heat. This scenario focuses on decarbonising the economy.

5. **Disruptive: Improved technologies are developed**

   In this scenario, the electricity demand and supply implications of more advanced and sophisticated technological progress in the energy sector are reflected. A faster reduction in technology costs results in a higher uptake of both EVs and solar and more electrification of process heat.

Table 1 lists some of the more important parameters reflected in the EDGS 2019 demand scenarios:

EDGS 2019 assumptions for demand scenarios					
Scenario	**Reference**	**Growth**	**Global**	**Environmental**	**Disruptive**
Grid energy demand					
2019 electricity demand, TWh	39	39	39	39	39
2050 electricity demand, TWh	57 ↑43%	65 ↑64%	47 ↑18%	67 ↑68%	71 ↑78%
Base demand growth, pa	0.8%	1.2%	0.2%	0.9%	0.7%
Process heat demand, TWh	1.5	1.9	1.2	6.5	13.3
Electric vehicles demand, TWh[3]	4.1 (44%/13%)	5.0 (44%/13%)	3.2 (44%/13%)	7.6 (74%/45%)	7.6 (74%/45%)
Solar PV output, TWh[4]	2.3 (22%)[5]	2.8 (27%)	0.9 (9%)	4.6 (45%)	4.6 (45%)
Tiwai smelter closure	No	No	No	No	No
Grid peak demand					
2019 peak demand, GW	6.3	6.3	6.3	6.3	6.3
2050 peak demand, GW	8.5 ↑34%	9.8 ↑56%	7.1 ↑12%	9.6 ↑53%	10.2 ↑62%

Table 1 – Some important parameters for each of the EDGS 2019 demand scenarios

2. Electricity demand and generation scenarios (EDGS) | Ministry of Business, Innovation & Employment (mbie.govt.nz)
3. (x%/x%) refers to light vehicle%/heavy vehicle% of fleet which are electric by 2050
4. Transpower plans are based on electricity demand at our grid exit points (GXP's). Domestic solar PV is treated the same as other embedded generation, as a subtractor from gross (end-user) demand.
5. x% refers to the percentage of houses in New Zealand with solar PV panel installations

Table 2 lists some of the more important parameters included in the EDGS 2019 generation scenarios, along with a summary of the EDGS 2019 generation expansion plans:

EDGS 2019 assumptions used for generation scenarios					
Scenario	**Reference**	**Growth**	**Global**	**Environmental**	**Disruptive**
Generation assumptions					
Generation stack	2011	2011	2011	2011	2011
Capital cost discount rate	6%	6%	6%	6%	6%
Retirements, by 2050	2,700 MW	2,700 MW	2,700 MW	2,700 MW	2,700 MW
Wind LRMC, $/MWh	2019: $75	2019: $75	2019: $75	2019: $75	2019: $75
	2050: $65	2050: $65	2050: $70	2050: $65	2050: $55
Grid solar LRMC, $/MWh	2019: $130	2019: $130	2019: $130	2019: $130	2019: $110
	2040: $70	2040: $70	2040: $70	2040: $70	2040: $65
	2050: $65	2050: $65	2050: $65	2050: $65	2050: $60
Carbon cost, $/MT CO2e	2040: $38	2040: $38	2040: $38	2040: $73	2040: $38
	2050: $43	2050: $43	2050: $43	2050: $100	2050: $43
Gas price, $/GJ	6.70	6.70	6.70	6.70	6.70
Summary of generation scenario differences	Reference	Same as ref	Same as ref except high wind cost 2050	Same as ref except for high C cost	Same as ref except low wind/ solar cost at 2050
New generation built by 2050, MW					
Thermal	900	1,400	800	1,100	1,300
Hydro	400	1,100	800	1,100	1,400
Geothermal	1,100	1,400	600	1,400	1,700
Wind	3,400	4,100	1,300	4,500	4,700
Grid-connected solar	-	-	-	-	-
Biomass, demand response	500	1,400	300	1,500	1,500
TOTAL	6,300	9,400	3,800	9,600	10,600
Environmental outcomes					
Emissions, mt CO2e[6]	23.7 ↓28%	26.7 ↓19%	19.6 ↓40%	17.2 ↓48%	16.9 ↓48%
2050 renewable generation %	94.9	95.4	94.8	96.0	94.9

Table 2 – Some important parameters for each of the EDGS 2019 generation scenarios and new generation builds by 2050

6. 2050 energy sector emissions, reflecting changes resulting from renewable electricity generation, process heat conversions and electric vehicle uptake, compared to 2017 emissions

Summary comparison of EDGS and NZGP1 scenarios

The parameters included in Table 1 for EDGS 2019 are repeated in Table 3, along with the same parameters for our NZGP1 scenarios.

Comparison of EDGS 2019 and NZGP1 assumptions for demand scenarios										
	EDGS scenario					NZGP1 scenario				
	Reference	Growth	Global	Environmental	Disruptive	Reference	Growth	Global	Environmental	Disruptive
Grid energy demand										
2019 energy demand, TWh	39	39	39	39	39	39	39	39	39	39
2050 energy demand, TWh	57 ↑43%	65 ↑64%	47 ↑18%	67 ↑68%	71 ↑78%	51 ↑28%	56 ↑41%	44 ↑10%	60 ↑50%	64 ↑60%
Base demand growth, pa	0.8%	1.2%	0.2%	0.9%	0.7%	0.5%	0.7%	0.1%	0.6%	0.4%
Process heat demand, TWh	1.5	1.9	1.2	6.5	13.3	4.0	5.1	3.2	8.1	13.3
Electric vehicles demand, TWh	4.1 (44%/13%)	5.0 (44%/13%)	3.2 (44%/13%)	7.6 (74%/45%)	7.6 (74%/45%)	5.4 (60%/13%)	6.6 (60%/13%)	4.2 (60%/13%)	9.0 (90%/45%)	10.6 (90%/45%)
Solar PV output, TWh	2.3 (22%)[6]	2.8 (27%)	0.9 (9%)	4.6 (45%)	4.6 (45%)	3.1 (30%)	3.9 (38%)	1.1 (11%)	6.4 (63%)	6.4 (63%)
Tiwai smelter closure	No	No	No	No	No	2024	2024	2024	2024	2024
Grid peak demand										
2019 peak demand, GW	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
2050 peak demand, GW	8.5 ↑34%	9.8 ↑56%	7.1 ↑12%	9.6 ↑53%	10.2 ↑62%	8.2 ↑30%	8.6 ↑37%	7.6 ↑21%	8.6 ↑37%	9.0 ↑43%

Table 3 – A comparison of Table 1 EDGS 2019 demand scenario parameters with the equivalent NZGP1 parameters

Note that our NZGP1 scenarios all reflect Tiwai aluminium smelter closing in 2024. The EDGS 2019 assume Tiwai does not close. This difference accounts for a significant part of the difference between the NZGP1 and EDGS 2019 electricity demands and peak demands. The Tiwai aluminium smelter consumes approximately 5 TWh of electricity per annum and contributes approximately 0.6 GW of peak demand.

Table 4 includes the same comparison for the EDGS 2019 generation scenarios and our NZGP1 generation scenarios.

Comparison of EDGS 2019 and NZGP1 assumptions for generation scenarios										
	EDGS scenario					NZGP1 scenario				
	Reference	Growth	Global	Environmental	Disruptive	Reference	Growth	Global	Environmental	Disruptive
Generation assumptions										
Generation stack[7]	2011	2011	2011	2011	2011	2020 tuned	2020 tuned	2020 tuned	2020 tuned	2020 tuned
Real discount rate[8]	6%	6%	6%	6%	6%	7%	7%	7%	7%	7%
Retirements by 2050, MW	2700	2700	2700	2700	2700	2740	2740	2740	2740	2740
Wind LRMC, $/MWh	2019: $75	2019: $75	2019: $75	2019: $75	2019: $75	2021: $53	2021: $53	2021: $53	2021: $53	2021: $53
	2050: $65	2050: $65	2050: $70	2050: $65	2050: $55	2050: $31	2050: $31	2050: $38	2050: $31	2050: $22
Grid solar LRMC, $/MWh	2019: $130	2019: $130	2019: $130	2019: $130	2019: $110	2021: $72	2021: $72	2021: $72	2021: $72	2021: $72
	2050: $65	2050: $65	2050: $65	2050: $65	2050: $60	2050: $36	2050: $36	2050: $36	2050: $36	2050: $28
Carbon cost, $/MT CO2e	2040: 38	2040: 38	2040: 38	2040: 73	2040: 38	2040: 186	2040: 186	2040: 186	2040: 186	2040: 186
	2050: 43	2050: 43	2050: 43	2050: 100	2050: 43	2050: 250	2050: 250	2050: 250	2050: 250	2050: 250
Gas price in 2050, $/GJ	6.70	6.70	6.70	6.70	6.70	7.84	7.84	7.84	7.84	7.84
Summary of generation scenario differences	Reference	Same as ref	Same as ref except high wind cost 2050	Same as ref except for high C cost	Same as ref except low wind/solar cost at 2050	Reference	Same as ref	Same as ref except high wind cost 2050	Same as ref except for high C cost	Same as ref except low wind/solar cost at 2050

Table 4 – A comparison of some EDGS 2019 and NZGP1 generation scenario parameters *(continues on following page)*

7. The term "2020 tuned" is further explained in the section "Tuning the generation scenario input assumptions", page 17.
8. Excepting grid-scale solar in the NZGP1 scenarios. As discussed in the section on grid-scale solar, page 18, we have reduced the discount rate to 5% for grid-scale solar generation projects

Comparison of EDGS 2019 and NZGP1 assumptions for generation scenarios										
	EDGS scenario					NZGP1 scenario				
	Reference	Growth	Global	Environmental	Disruptive	Reference	Growth	Global	Environmental	Disruptive
New generation built by 2050, MW										
Thermal	900	1,400	800	1,100	1,300	-	100	-	-	-
Hydro	400	1,100	800	1,100	1,400	250	250	250	250	250
Geothermal	1,100	1,400	600	1,400	1,700	300	500	150	400	900
Wind	3,400	4,100	1,300	4,500	4,700	3,450	4,050	2,550	4,450	4,200
Grid-connected solar	-	-	-	-	-	700	1,250	150	1,700	2,600
Biomass, demand response	500	1,400	300	1,500	1,500	1,000	1,000	600	1,250	-
TOTAL	6,300	9,400	3,800	9,600	10,600	5,700	7,150	3,700	8,050	7,950
Environmental outcomes										
Emissions, mt CO2e	23.7 ↓28%	26.7 ↓19%	19.6 ↓40%	17.2 ↓48%	16.9 ↓48%	TBA in short-list consultation – expected to be similar to EDGS 2019				
Renewables generation, %	94.9	95.4	94.8	96.0	94.9	99.9%	99.9%	99.7%	99.9%	99.7%

Table 4 – A comparison of some EDGS 2019 and NZGP1 generation scenario parameters *(continued from previous page)*

NZGP1 demand scenarios

This section describes our NZGP1 demand scenarios in more detail and compares our scenarios to others available.

A comparison of national electricity demand (TWh), in the EDGS 2019 and our NZGP1 scenarios is shown in Figure 1. Despite the fact that our approach for developing our NZGP1 demand scenarios was akin to bottom-up, there are several similarities between the two sets of demand forecasts.

We have also compared our NZGP1 demand scenarios to the Climate Change Commission (CCC) demand scenarios[9] and Transpower's own WiTMH demand scenarios[10] and these are shown in Figure 2. Our NZGP1 demand scenarios cover a similar range of uncertainty to that reflected in the CCC and WiTMH demand scenarios,with the exception of the WiTMH Mobilise to Decarbonise scenario, which is higher. Mobilise to Decarbonise is a scenario which considers the effect on electricity demand if all energy, which can be electrified, is. This is a useful reference, but given the current interest in biofuels, we have reflected their use as a substitute for electricity, in some circumstances, in our NZGP1 scenarios. The average demand in our NZGP1 scenarios at 2050 is 55 TWh, compared to 57 TWh for the CCC scenarios and 59 TWh for the WiTMH scenarios.

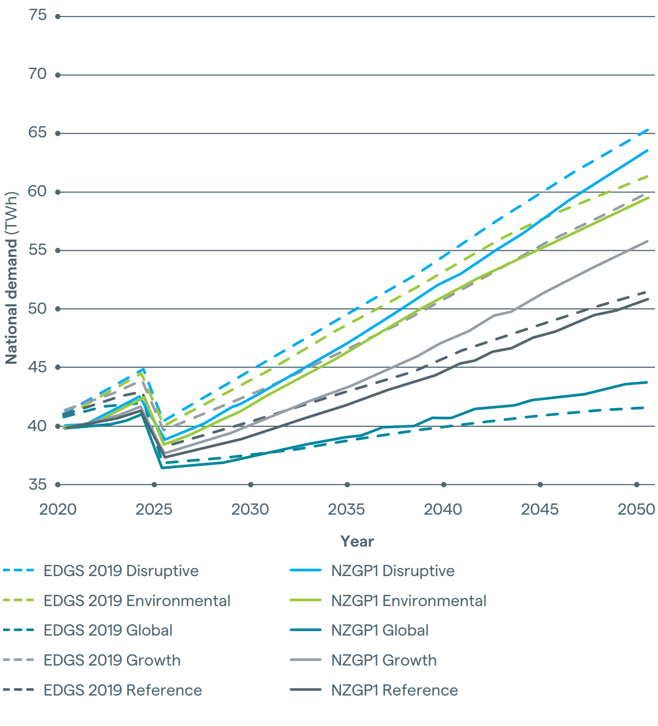


Figure 1 – Comparison of EDGS 2019 and NZGP1 national electricity demand scenarios to 2050

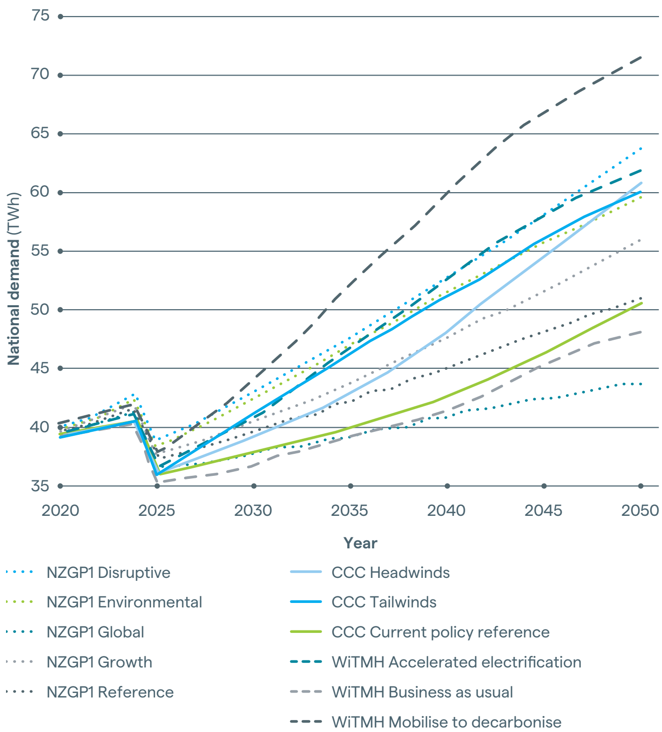


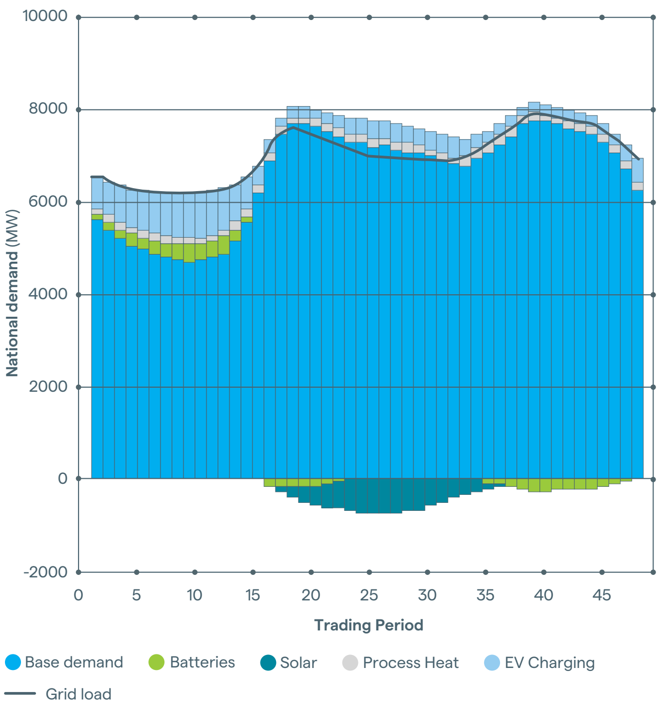
Figure 2 – Comparison of NZGP1, CCC and WiTMH national electricity demand scenarios to 2050

9. https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/inaia-tonu-nei-a-low-emissions-future-for-aotearoa/modelling/
10. Transpower report: Opportunity to decarbonise our economy | Transpower

Considering the similarity between our NZGP1 scenarios and EDGS 2019 national electricity demand scenarios, the question might be asked as to why we are using EDGS 2019 variations at all. Why not just use the original EDGS 2019 demand scenarios?

The answer is that while the national electricity demand scenarios are similar, the peak demand profiles (on an hourly basis) behind each scenario, are more significantly different. Figure 3 compares the daily national demand profile for a typical winter day in 2050 for both the EDGS 2019 and our NZGP1 scenarios. Our NZGP1 forecasts have been built up from a base electricity forecast plus individual forecasts for process heat, electric vehicles and rooftop solar PV and these are shown individually.

Daily demand profile EDGS 2019 Reference Scenarios winter day 2050



Daily demand profile NZGP1 Reference Scenarios winter day 2050

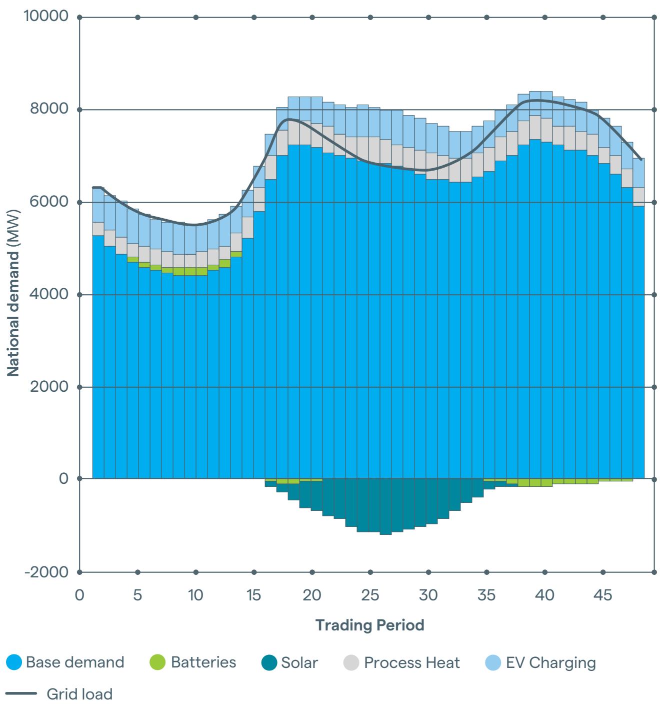


Figure 3 – Comparison of a daily demand profile for a typical winter day in both the EDGS 2019 and NZGP1 Reference scenarios

Not only do the individual forecasts that make up each scenario differ, but the overall peak demand for that day differs. Figure 4 compares the total peak demand lines from Figure 3 on a graph.

As seen, the NZGP1 peak demand is higher and this is the case across all scenarios. This is important from a transmission planning perspective as the transmission grid capacity we plan for depends upon peak electricity demand. The peak differences between the EDGS 2019 and NZGP1 demand scenarios is the reason for using the NZGP1 demand scenarios.

The reason they differ is due to many factors, including assumptions around "smartness" ie mostly in relation to how electric vehicles (EV) will charge in the future. A smart EV will be able to charge at electricity system off-peak times, rather than coinciding with peak times and this will reduce peak demand. The smartness of NZGP1 scenarios is lower than reflected in the EDGS 2019, a change suggested by our expert panel in 2020. For interest, our NZGP1 "smartness" assumptions, by scenario, are:

Comparison of EDGS 2019 and NZGP1 daily demand profiles Reference Scenario of a winter day 2050

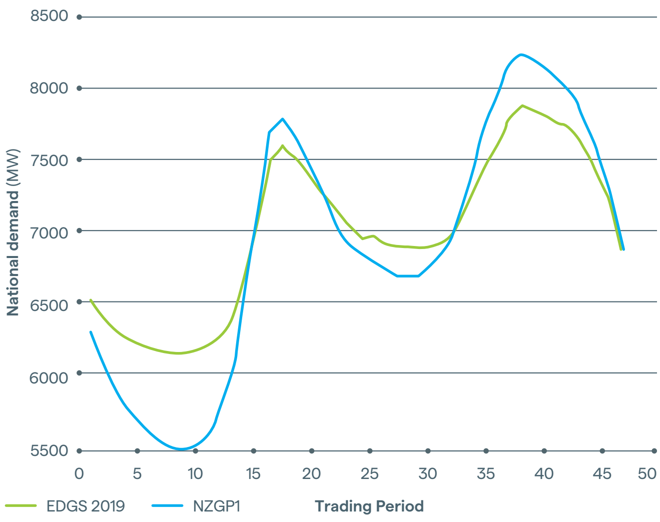


Figure 4 – Comparison of EDGS 2019 and NZGP1 daily demand profiles for a typical winter day in the Reference scenario

	Global	Reference	Growth	Environmental	Disruptive
Smart charging %	20%	40%	50%	60%	60%
Solar PV storage used for peak shaving	Same as used in EDGS 2019				
Electric vehicle storage used for peak shaving	0%	1%	1%	1%	1%

Table 5 – NZGP1 "smartness" assumptions, by scenario, by 2050

Although these smartness settings contribute toward a higher peak demand in the Reference scenario, that is not the case in all scenarios. The national 2050 peak demand in our NZGP1 scenarios, compared to the EDGS 2019 scenarios, by scenario, is shown in Figure 5. The EDGS 2019 peaks have been adjusted to reflect Tiwai aluminium smelter closure, to provide a more meaningful comparison.

For further interest, comparisons of the process heat electrification, electric vehicle demand and household rooftop solar PV electricity demands in 2050, for both the EDGS 2019 and NZGP1 demand scenarios are included in Appendix 2.

2050 Peak

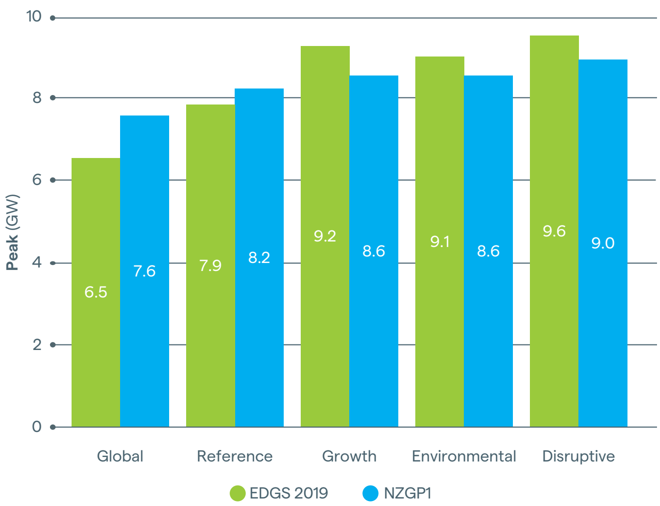


Figure 5 – Comparison of 2050 peak demand in NZGP1 and EDGS 2019 scenarios, by scenario

Observations relating to NZGP1 demand scenarios

We can make several observations about our NZGP1 demand scenarios, from Figures 1 and 2:

- The range of national demand forecasts in our NZGP1 scenarios cover the range of demand uncertainty reflected in the EDGS 2019, CCC and WiTMH scenarios (excepting the WiTMH Mobilise to Decarbonise scenario).
- We note that most of the EDGS 2019, the CCC's Current Policy Reference scenario and the WiTMH Business as Usual scenario, are not aligned with a net zero carbon by 2050 target, whereas the other scenarios are.
- The weighted average demand of our proposed NZGP1 scenarios is 55 TWh. The average of the CCC's aligned scenarios (Headwinds and Tailwinds) scenarios is 60 TWh and the average of the WiTMH aligned scenarios (Accelerated Electrification, Measured Action and Mobilise to Decarbonize) scenarios is 63 TWh.

This indicates that the national electricity demand reflected in our Investment Test analysis, which averages 55 TWh, will be below that forecast to be consistent with a net zero carbon by 2050 target as forecast by others.

However, we also note that the national electricity demand forecast in the NZGP1 environmental scenario (varied EDGS) is 60 TWh and that this scenario is closely aligned with a net zero carbon by 2050 target.

In our Investment Test analysis, we will report the outcome of each scenario separately, particularly noting the outcome for the NZGP1 Environmental scenario.

NZGP1 generation scenarios

Developing a set of generation scenarios suitable for NZGP1 has not been simple.

Since the EDGS 2019 were developed, MBIE have updated the new generation stack (thermal, hydro, geothermal, wind and solar generation were all reviewed) and the stack of new wind and solar projects, in particular, has changed significantly. In addition, significant other uncertainties have emerged since the EDGS 2019 were developed and are not reflected in those scenarios eg the potential for different peaking and dry year reserve options.

We have developed a set of five generation scenarios, which are aligned to EDGS 2019 and these are described in more detail below.

These scenarios have been produced using a generation expansion model with an unconstrained grid. The generation expansion plans show what generation would be built if there were no grid constraints at all. These scenarios are not used per se in our MCP investigation, but provide information on where market participants are most likely to want to build generation.

When we apply the Investment Test, we will introduce the existing grid between the HVDC and Whakamaru (including the Wairakei Ring) into the model. The resultant generation expansion plans will form our Base Case, against which we will compare the generation expansion plans in which the transmission grid has been enhanced using our short list of options (including the use of any non-transmission solutions included in the short-list).

The primary benefit of enhancing the transmission grid is expected to be lower overall electricity costs as the result of a lower cost generation expansion plans.

Tuning the generation scenario input assumptions

The New Zealand electricity system is not centrally planned. It operates on the basis that an efficiently run electricity market is the best way to deliver a low cost, yet reliable supply of electricity to New Zealanders.

We attempt to plan the transmission grid in a manner which enables efficient operation of the electricity market and this requires that our generation scenarios reflect the new generation market participants are likely to want to build and that they can compete in terms of generation investment.

Generation investors take a lot of things into account in making their investment decisions – generation cost, availability of capital, their future view of wholesale electricity prices, consentability of their project, perhaps their likelihood to agree a power purchase agreement if they are a generation company only, perhaps how new generation balances their retail portfolio if they are a generator/retailer – and all of those issues depend upon their company strategy, which could be to be long, short or balanced in the wholesale market, etc.

Generation cost is the only one of these considerations included in our least-cost generation expansion model[11]. Our model effectively steps through time (out to 2050 in this case), building new generation as required to meet electricity demand. It chooses new generation from the generation stack and its overall objective is to minimise the cost of electricity over the period being considered. The model effectively ignores market behaviour and all of the other investment decision-making factors discussed above.

In our view this is reasonable, on the premise that, although our model may deliver new generation in a different order to the actual electricity market, in the long-run, electricity cost will be the major deciding factor and so the set of projects identified by our generation expansion will be pertinent.

We do compare the output from our generation expansion model to market intelligence and apply modifications where necessary to align them. For instance, the first set of generation expansion plans produced by our model reflected some areas which did not match our view of market expectations. Those plans:

a. did not include as much grid-scale solar being built as our consultation suggested

b. did not include new geothermal generation being built at all

c. always built significant Wairarapa wind generation before 2030.

As a result, we have modified inputs to the model to better align the generation expansion plans with our view of market expectations and we call this process “tuning” the generation stack.

11. Although it may be possible to derive a gaming model reflecting some of these other market behaviours, but it would only be useful for an assumed set of market participants.

Grid-scale solar

We consulted on potential new generation build in our May 2021 consultation[12].

In that consultation we discussed how cost information indicated that grid-scale wind and solar generation were likely to dominate new electricity generation build in New Zealand over the next 30 years. The cost of both technologies are forecast to drop significantly, but there is uncertainty around the future cost relativity of these two generation technologies.

We also understand that grid-scale solar has several investment characteristics compared to grid-scale wind which might make it attractive to some investors, hence a straight comparison of solar and wind capital build and operating costs may not be a good indicator of market expectations. Small solar (in MW terms) projects can be economic, whereas this less likely for wind projects. Solar projects have lower set-up costs (access roads, etc), can be built close to the existing transmission (lower transmission costs), are easier to find land for, are easier to consent and because of their smaller capital requirement, are easier to finance. In comparison, wind farms generally need to be larger to be economic.

These issues mean it is difficult to predict whether wind or grid-scale solar will dominate in the future and our least-cost model, on its own, needs guidance.

In our long-list consultation, we suggested that assuming a MW ratio of grid-scale wind : solar build (on an installed MW capacity basis) might be reasonable and proposed 80% wind : 20% solar between now and 2050. Consultation feedback was that this ratio understated the potential for grid-scale solar, so we revised the assumption to 75% wind : 25% solar.

Our preliminary set of generation expansion plan outputs reflected the MBIE generation stack information and resulted in a ratio of 84% wind : 16% solar by 2050. This is not too far from the 75% wind : 25% solar we had arrived at in our consultation, but given the advantageous characteristics of grid-scale solar not reflected in the model, we conclude the proportion of solar should be lifted.

As a result, we decided to lower the capital cost discount rate for new grid-scale solar, slightly, in our generation expansion model. The capital cost discount rate used for wind generation is 7% and for grid-scale solar is 5% in our scenarios.

The reference scenario now reflects a 74% wind: 26% solar build by 2050, which aligns with the view received in consultation feedback and the ratio varies over the scenarios, which provides a sensitivity to that assumption.

Geothermal

Our preliminary generation expansion plans did not reflect any new geothermal generation being built. This does not align with market expectations, as we received several submissions to our May 2021 consultation, acknowledging an interest in expanding geothermal generation, particularly around the Taupo-Rotorua region.

In the generation stack, the capital cost of building new geothermal generation ranges from around $4000/kW to $9000/kW and averages approximately $6500/kW. Easier to access geothermal is cheaper to build ($4000/kW), with the hardest to access being the most expensive ($9000/kW). These costs compare to less than $2500/kW for most of the grid-scale wind and solar on the generation stack. Despite the fact that geothermal generation does have a much higher stream factor (90%, compared to approximately 40% for wind and approximately 20% for solar), combined with the fact that geothermal generation does have CO2 emissions, it appears to be an expensive generation technology.

Our consultation feedback suggests that several aspects are missing from the raw capital costs included in the generation stack:

a. Geothermal generation has a lifetime of 60 years compared to wind and solar which are 30 years. This affects the annualised cost included in the generation expansion model.
b. Investigations are ongoing as to uses for the geothermal steam after it has been used for electricity generation. At that stage it is still hot and could be used for other processes. No such value is allowed for in the capital costs include in the generation stack, but would effectively reduce the initial capital cost of the project.
c. Investigations are ongoing with regard to re-injecting the steam after use, or otherwise stripping the CO2 out – both approaches would reduce the effective CO2 emissions to nearly zero. Given we are valuing CO2 emission at $250 per tonne CO2 e by 2050, this would be significant
d. One project has received a government subsidy. This effectively reduces the capital cost for that project, yet that is not reflected on our generation stack.

Based on consultation feedback, we have modified the capital cost of geothermal in the generation stack (by 50%) and eliminated the CO2 content of the emissions.

We note that, of the approximately 1000 MW potential new geothermal generation on the generation stack, there is a break-point at about 650 MW, after which the capital cost increases significantly. Our modifications mean that approximately 650 MW of new geothermal generation is cost competitive.

12. Consultation document_Prioritising the enablement of new wind and solar generation_30 April 2021.pdf (transpower.co.nz)

Wairarapa wind generation

Our preliminary generation expansion plans built significant (500 – 1000 MW) new wind generation in the Wairarapa from the late 2020's to early 2030's. We suspect this is due to the high capacity factors for wind in this region, compared to other regions, but at the same time, we note a lack of interest from generation developers in this region, who we would expect to be talking to us if such generation were to be built in that timeframe.

There are consented projects in the region which have not yet lapsed, but these projects do not appear to be of immediate interest to generation investors. Given the effect these projects would have on generation development and NZGP1 in particular, should they proceed, we have not discarded them, but they are flagged on the generation stack with a "not before 2035" flag.

Other important variations

a. Grid-scale batteries are included on our modified generation stack.

b. Wind generation plant is assumed to have a 30 year life in our model and approximately 670 MW of existing wind generation reaches the end of its life during the period 2030 – 2050. Based on consultation feedback, we have re-powered these sites, rather than assume those plants are totally decommissioned. It is expected that the cost of building a new windfarm on an existing site will be considerably lower than building a new windfarm elsewhere, so wind generators are likely to re-power their existing sites. Not only will they be re-powered but the replacement turbines are likely to be significantly bigger.

   In our modelling, we have assumed that all existing windfarms are re-powered once the existing generation reaches end-of-life and that the re-powered site will have approximately 2.1 times the capacity it had previously.

c. We have used the Climate Change Commission (CCC) gas price as reflected in their "All other CCC scenarios" assumption (included in their Emissions Budgets advice to government recently[13]), in our modelling. This equates to the following gas price assumption:

	2030	2040	2050
Gas price, $/GJ	6.65	6.89	7.84

Table 6 – Gas price assumption

d. Similarly, we have used the CCC carbon costs from their recent Emissions Budget advice to government, in our modelling. In their advice, the CCC outline carbon abatement costs that would be required to eliminate fossil-fuel emissions from those sectors where there are low-emissions alternatives and they use these costs in their analysis. This equates to the following assumption:

	2020	2030	2040	2050
Carbon cost, $/tonne CO2e	30	138	186	250

Table 7 – Carbon cost assumption

13. Ināia tonu nei: a low emissions future for Aotearoa » Climate Change Commission (climatecommission.govt.nz)

e. We have used National Renewable Energy Laboratory (NREL) learning curves to determine how the cost of wind and solar generation will reduce over time. These learning curves are widely used in the electricity industry to reflect future cost declines. They assume a cost factor of 1.0 in 2021, with a decrease over time.

Wind capital cost projections

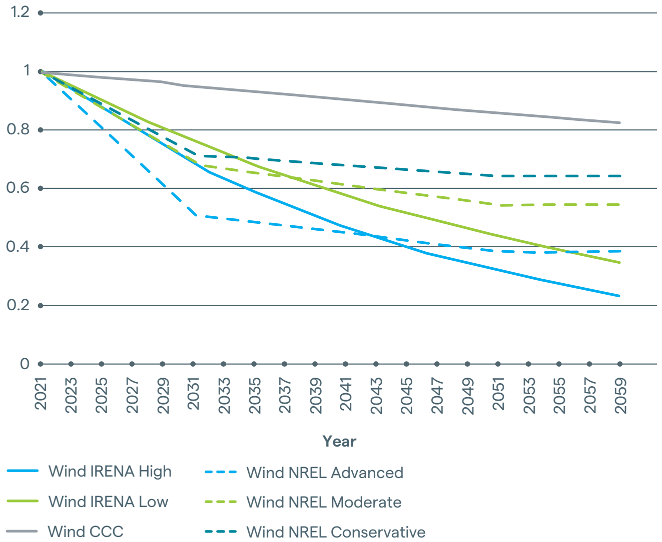


Figure 6 – Wind capital cost projections over time

The Reference scenario use the NREL moderate cost projections for both wind and grid-scale solar generation.

Solar capital cost projections

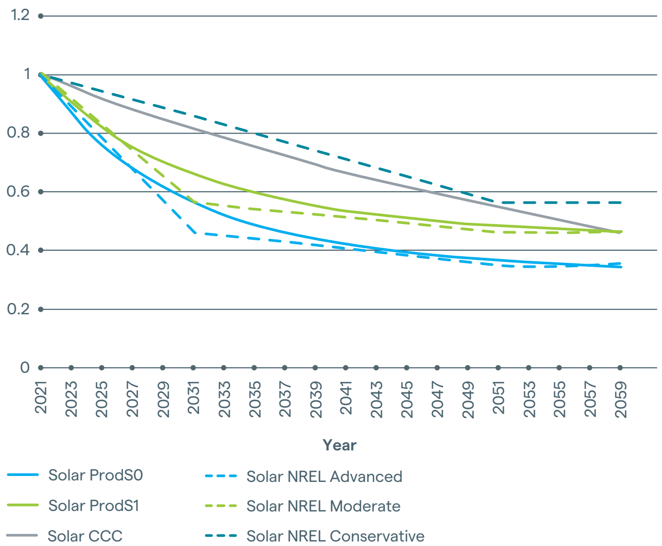


Figure 7 – Solar capital cost projections over time

Where we apply a high cost trajectory to wind or grid-scale solar generation, we use the NREL conservative cost projections and where we apply a low cost trajectory we use the NREL advanced cost projections.

Some other important assumptions

Some other important assumptions included in the NZGP1 scenarios, but which are not specific to the generation stack:

- New Zealand's Aluminium Smelter at Tiwai Point closes in 2024 in all scenarios.
- Gas peakers are available all the way through to 2050, and the model can build new gas peakers, if the model decides this is economic.
- The Stratford gas plant, TCC, closes in 2023 and the Huntly Rankine units close in 2030.
- A biofuel peaking plant can be built from 2035, if the model decides it is economic. We have nominally placed this at Huntly, however it could be connected anywhere north of Whakamaru, without affecting this particular investigation. We assume the following costs:

Cost element	Cost
Capital costs ($/kW)	1030
Fixed O&M ($/kW-year)	4.6
Fuel Cost ($/GJ)	25
Heat rate (GJ/MWh)	11.75
Variable O&M ($/MWh)	11.4

Table 8 – Generation cost assumed for a biofuel peaking plant

These cost result in relatively high cost generation, with a short-run marginal cost of $305/MWh.

Our NZGP1 scenarios

The following set of figures and tables summarise some of the important aspects of the unconstrained transmission grid outputs for our NZGP1 generation scenarios.

Total generation capacity, by year, by scenario

Global scenario

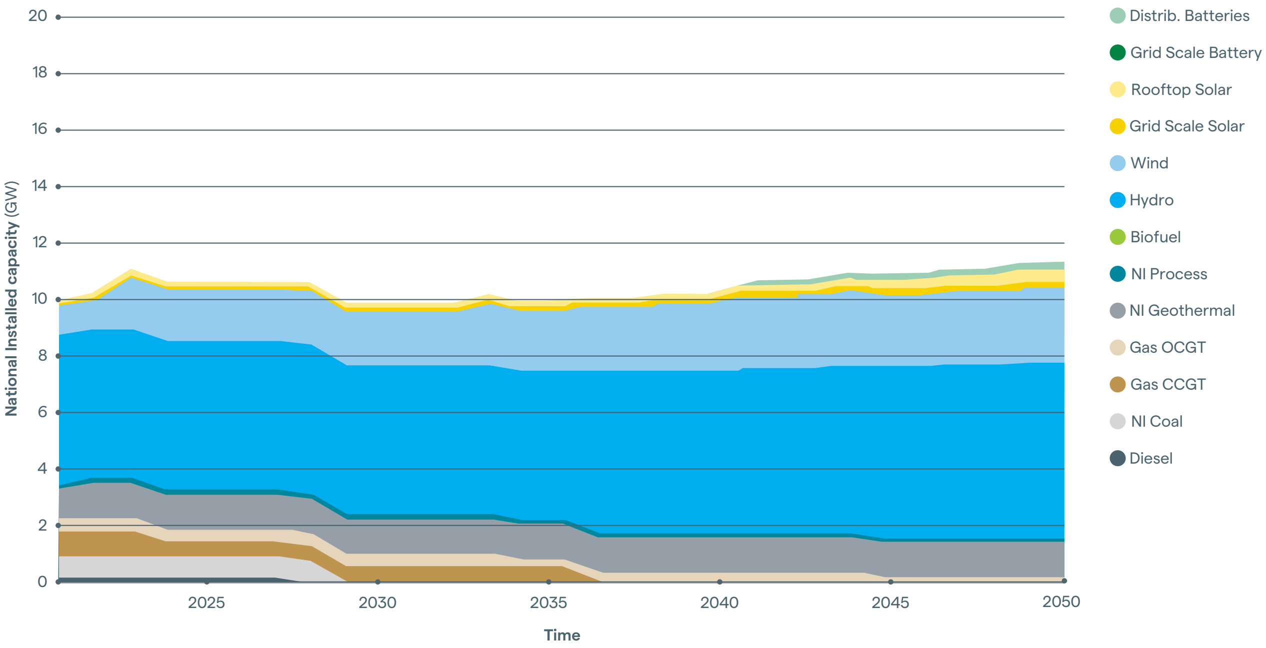


Figure 8 – Total generation capacity over time, by technology in the NZGP1 Global scenario

The Global scenario sees the least amount of new generation built by 2050. Electricity demand rises by approximately 10% compared to now, with Tiwai closure in 2024 providing a similar amount of electricity to that demand increase. The generation built is primarily to replace generation decommissioned, with the move toward a highly renewable electricity system requiring more capacity to be built (thermal generation has a high capacity factor (approximately 90%), compared to wind at approximately 40% and grid-scale solar at 20%. In this scenario 600 MW of biofuel plant is built, along with approximately 1000 MW of new wind and 150 MW of new grid-scale solar.

Reference scenario

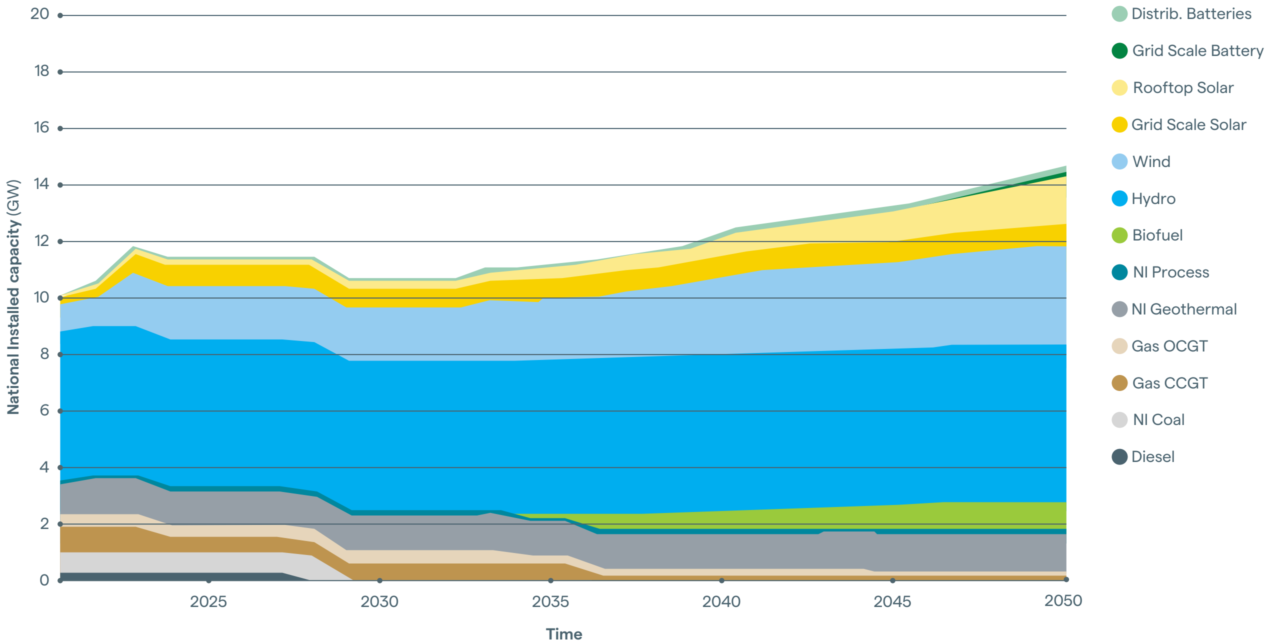


Figure 9 – Total generation capacity over time, by technology in the NZGP1 Reference scenario

In the Reference scenario, electricity demand grows by 28% by 2050, with a corresponding increase in new generation build. A biofuel plant is also built in this scenario, a small amount of new geothermal, approximately 2000 MW of new wind and 700 MW of grid-scale solar.

Growth scenario

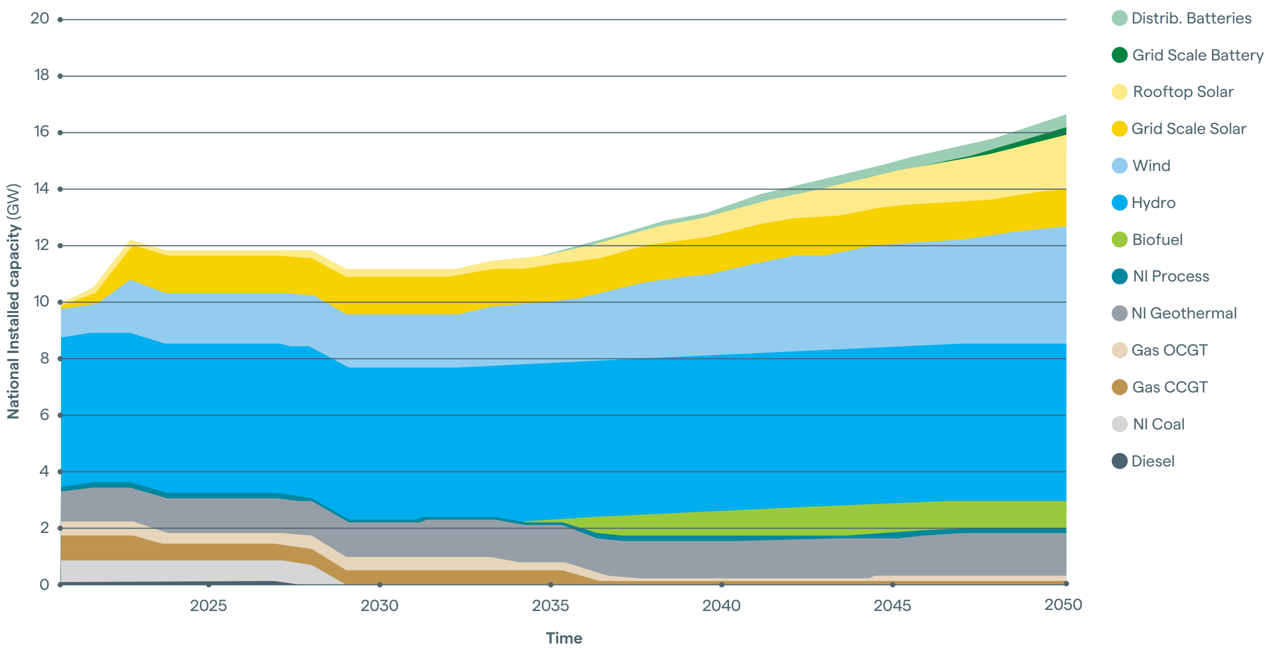


Figure 10 – Total generation capacity over time, by technology in the NZGP1 Growth scenario

In the Growth scenario, we also see a biofuel plant being built, approximately 500 MW of new geothermal generation, along with 2500 MW new wind generation and 1250 MW grid-scale solar generation.

Environmental scenario

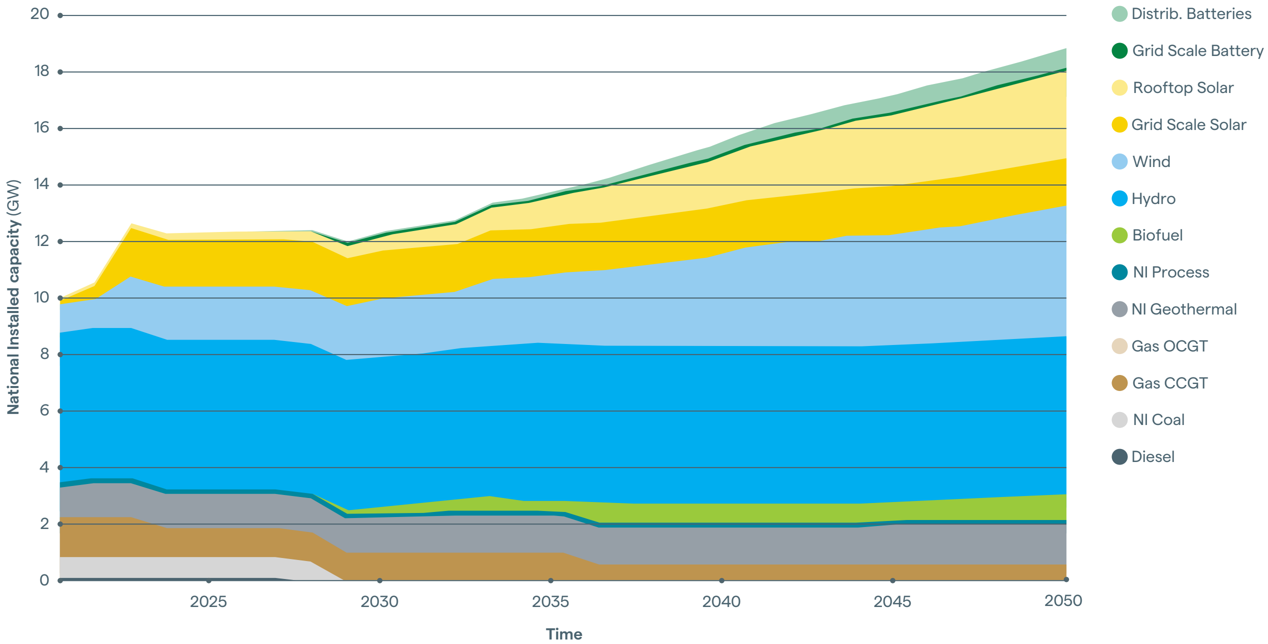


Figure 11 – Total generation capacity over time, by technology in the NZGP1 Environmental scenario

In the Environmental scenario, we also see a biofuel plant being built, approximately 400 MW geothermal, 3000 GW of new wind and 1700 MW of grid-scale solar.

Disruptive scenario

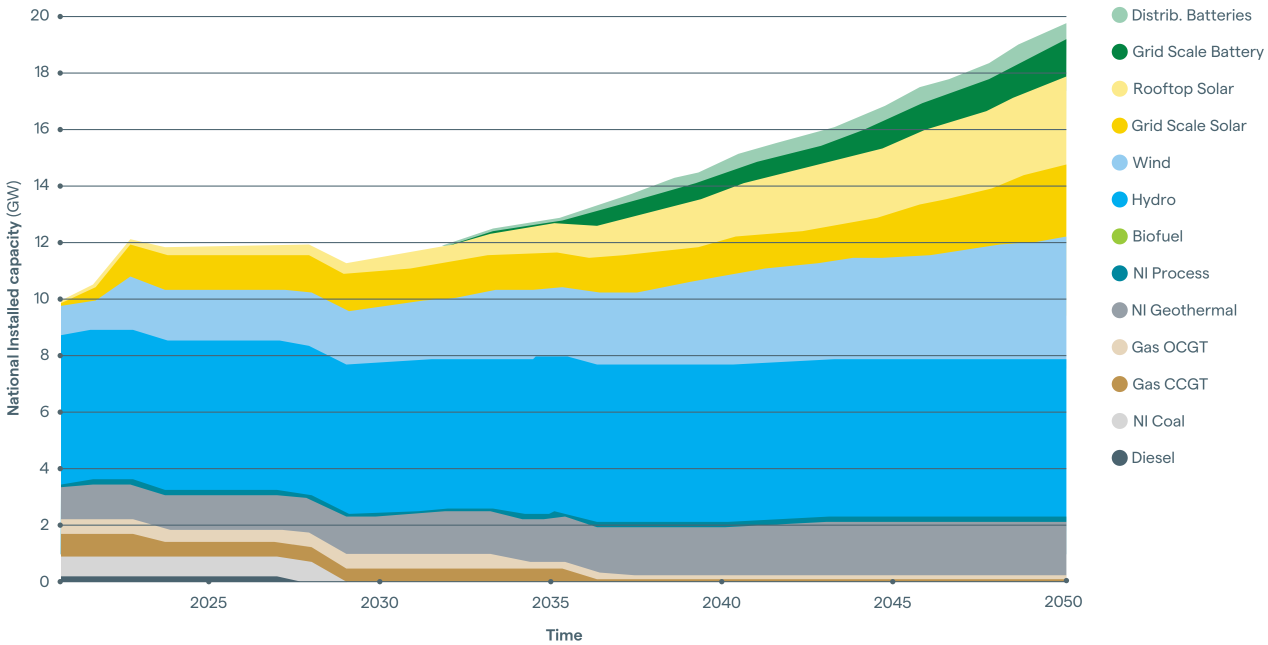


Figure 12 – Total generation capacity over time, by technology in the NZGP1 Disruptive scenario

The Disruptive scenario reflects the highest growth in electricity demand in our scenarios and the model takes a slightly different approach. It does not build a new biofuel plant. Rather it maximises geothermal build, builds a similar amount of new wind to the Environmental scenario, but 2600 MW of grid-scale solar.

Electricity generation, by generation technology, by year, by scenario, in TWh

The following diagrams reflect the electricity generated and dispatched by the generation outlined in Figures 8-12, in order to meet electricity demand. We show TWh, by technology, in an average hydrological year.

Global

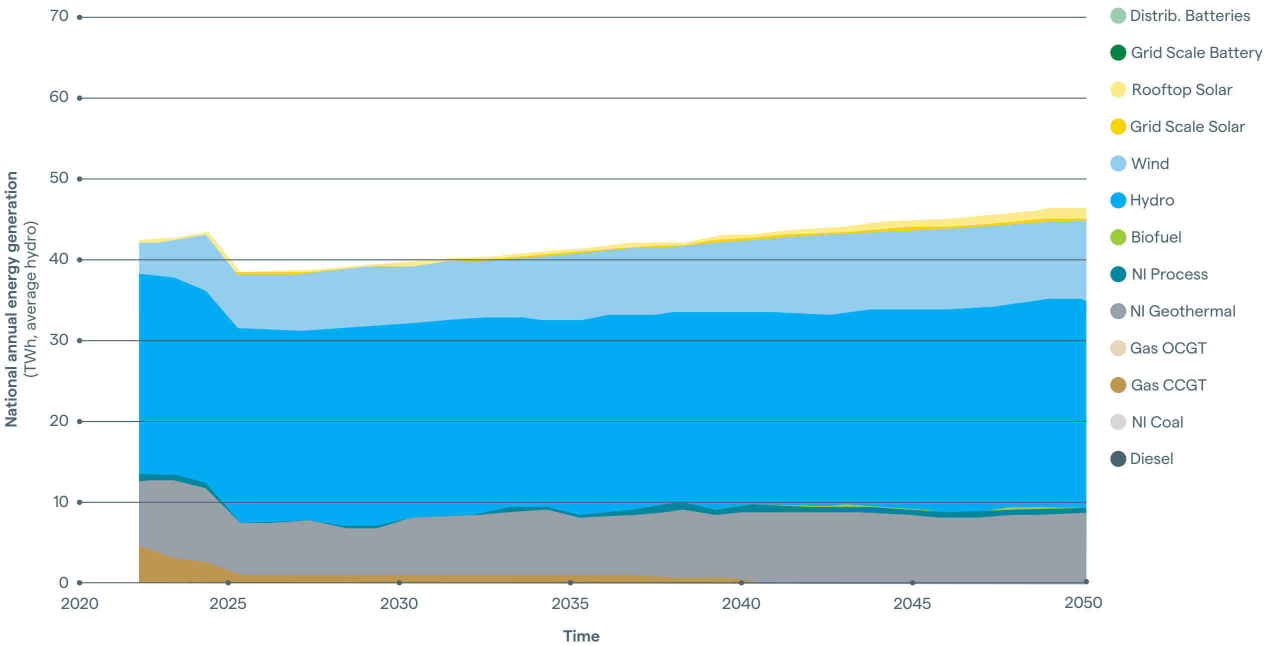


Figure 13 – Total generation over time, by technology in the NZGP1 Global scenario

Reference

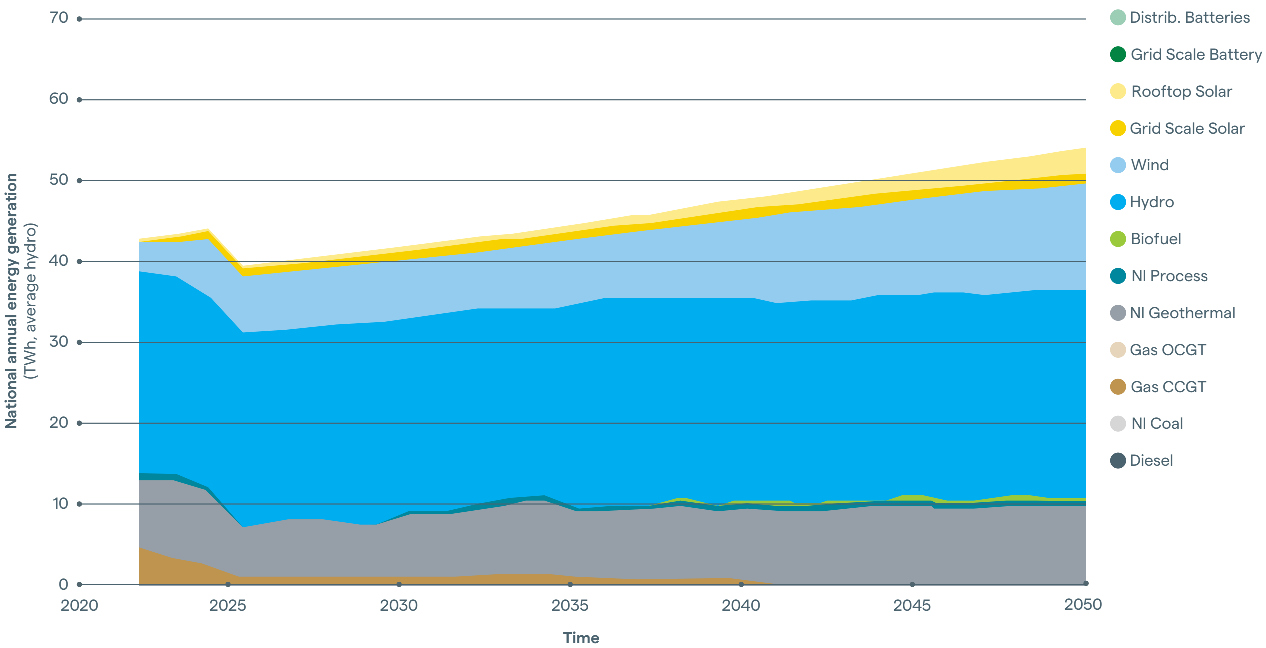


Figure 14 – Total generation over time, by technology in the NZGP1 Reference scenario

Growth

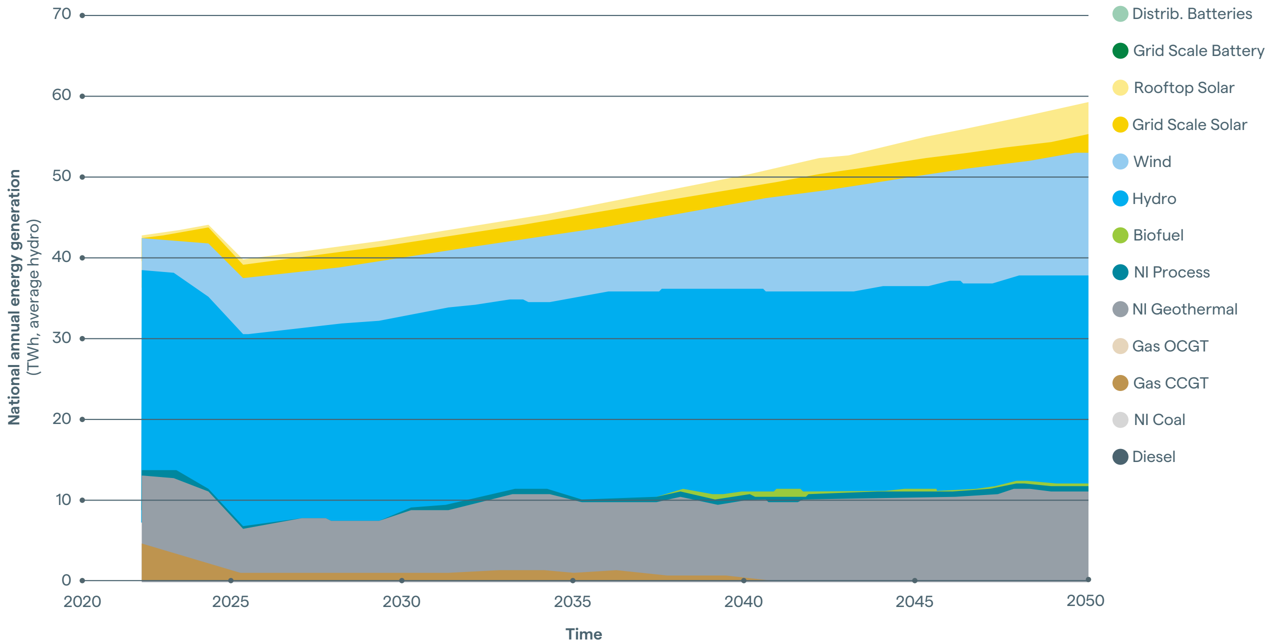


Figure 15 – Total generation over time, by technology in the NZGP1 Growth scenario

Environmental

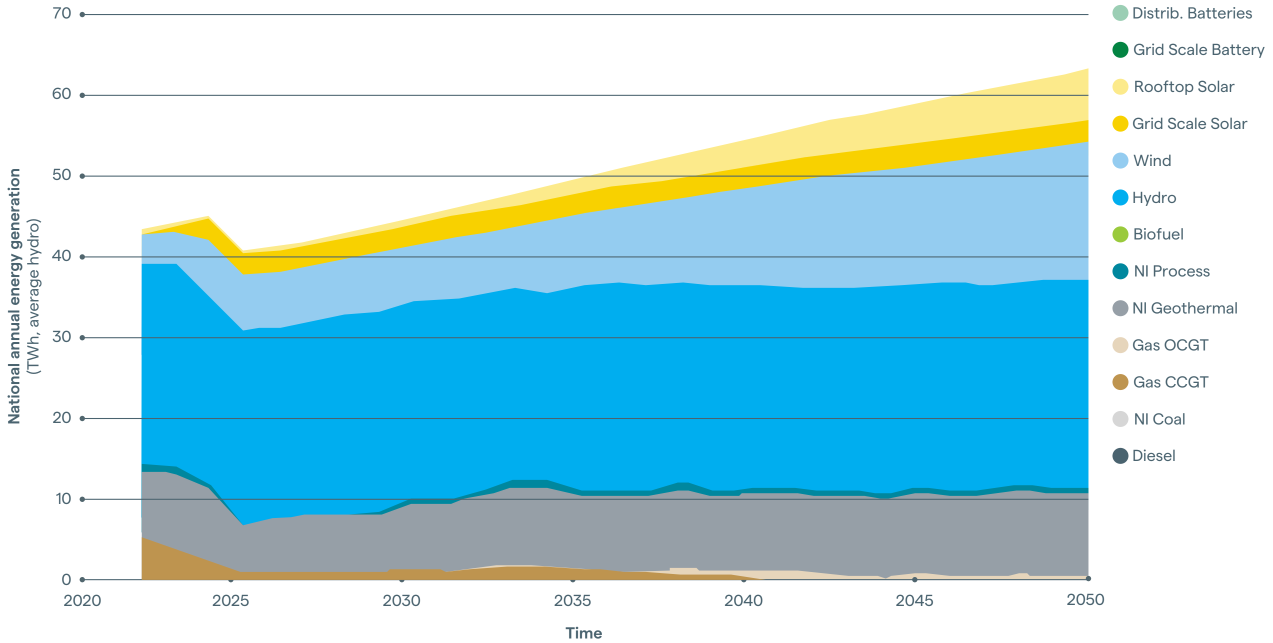


Figure 16 – Total generation over time, by technology in the NZGP1 Environmental scenario

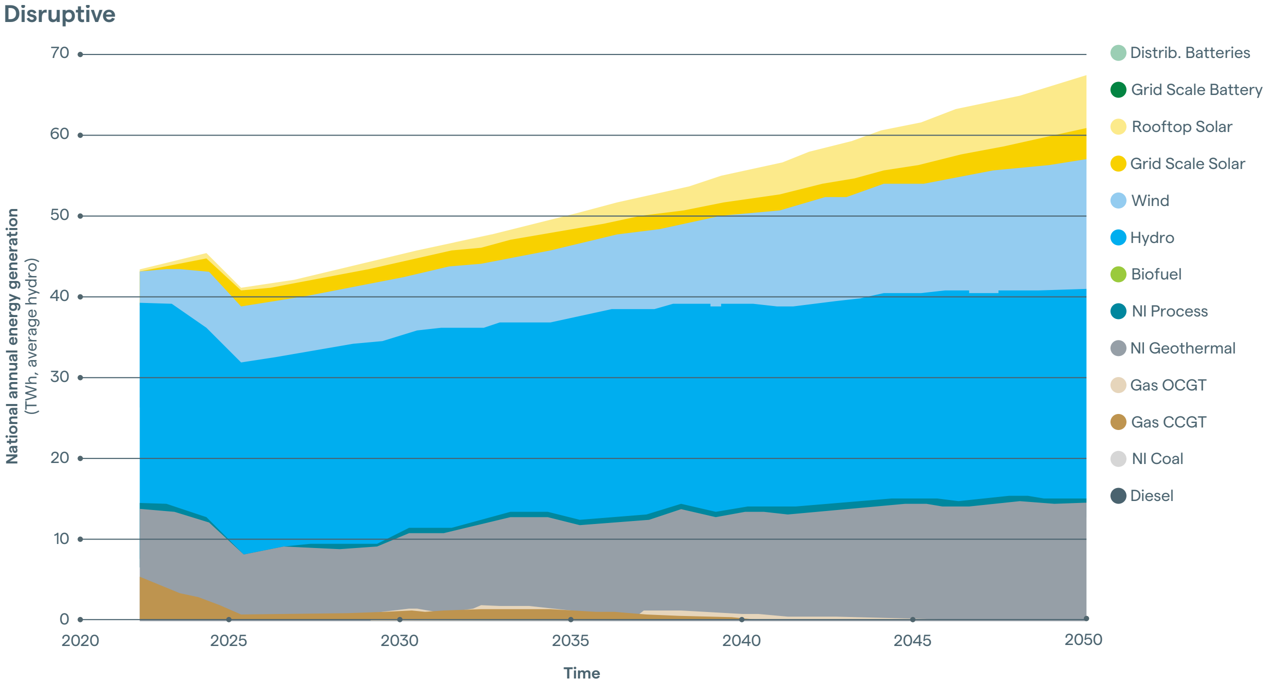


Figure 17 – Total generation over time, by technology in the NZGP1 Disruptive scenario

Other aspects of our generation scenarios

The figures and tables that follow illustrate some aspects of the scenarios. They are in no particular order of importance.

Ratio of wind : solar build

As discussed earlier, in our most recent consultation we suggested aiming for a particular ratio of wind : solar capacity build by 2050. Our suggestion was to aim for 80% wind : 20% solar, however submissions suggested the fraction of wind may be too high, so we amended that target ratio to be 75% wind : 25% solar.

The following table shows the wind : solar ratios (on an installed capacity basis) in each of our scenarios.

The Reference scenario is close to our target of 75% wind : 25% solar, so we consider these scenarios reasonably reflect the consultation feedback. The wind : solar ratio does vary across scenarios, which usefully builds in a sensitivity to this assumption. Interestingly, a higher proportion of solar is built as 2050 electricity demand increases.

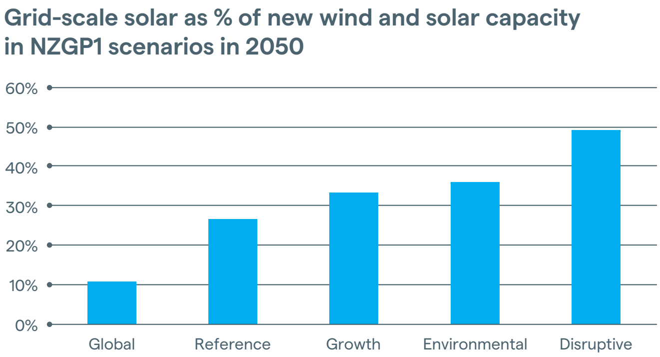


Figure 18 – Ratio of wind capacity to grid-scale solar capacity in the NZGP1 generation scenarios

Proportion of wind and grid-scale solar generation of total grid-connected generation capacity in 2050

New Zealand's desire to have a highly, if not 100% renewable electricity system will rely heavily on wind and grid-scale solar generation.

Figure 19 shows the percentage of wind and grid-scale solar generation capacity in our total generation mix, in 2050. As illustrated, these technologies reach almost 50% in the Disruptive scenario by 2050.

The ratio of wind : solar is different from Figure 18 because Figure 19 includes re-powered wind generation.

Wind and grid-scale solar generation as a % of total grid-connected capacity in 2050

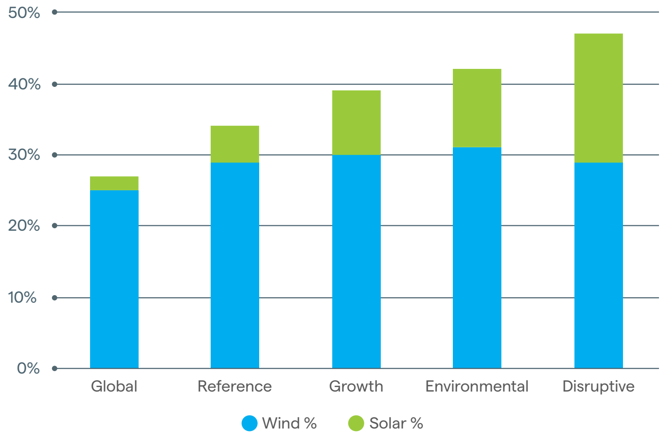


Figure 19 – Ratio of wind capacity to grid-scale solar capacity in the NZGP1 generation scenarios

Proportion of wind and grid-scale solar electricity generation as a % of total generation in 2050

Following on from the previous observation, the percentage of wind and grid-scale generation dispatched in 2050 is shown in Figure 20.

Wind and grid-scale solar generation as a % of total grid-connected energy in 2050

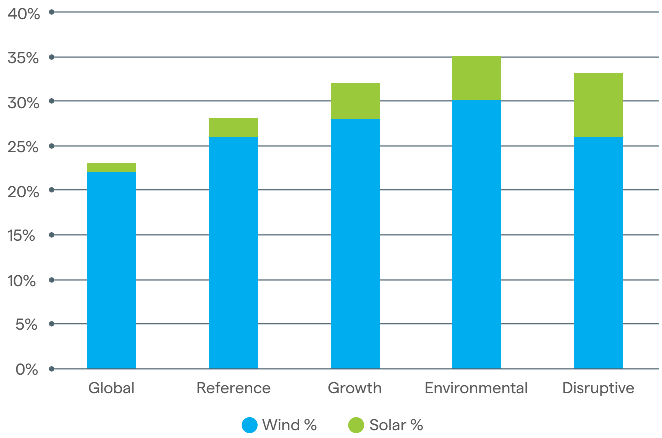


Figure 20 – Ratio of wind capacity to grid-scale solar generation in the NZGP1 generation scenarios

Proportion of electricity generated from solar generation compared to total generation in 2050

Figure 21 shows the percentage of total solar generation (both grid-scale and embedded solar PV) in New Zealand's overall generation mix in 2050.

Solar generation has a much lower capacity factor than other sources of generation and so, despite total solar being approximately 27% of the total installed generation capacity in the Environmental scenario (as an example), it produces only 14% of our electricity.

Solar (grid-connected+embedded) generation as a % of total energy in 2050

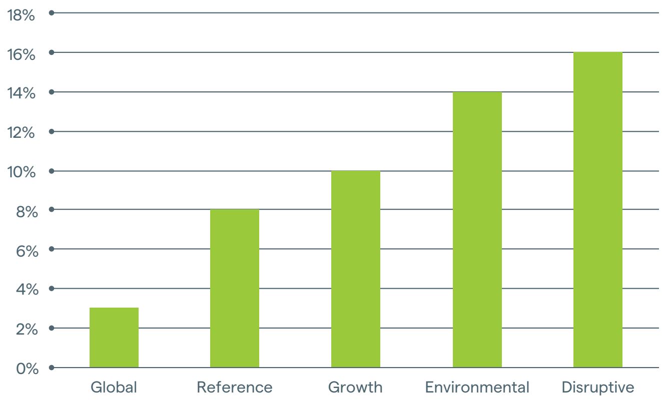


Figure 21 – Percentage of total electricity produced from total solar, by scenario, in 2050

Wind generation repowering

Figure 22 shows the MW of wind generation which reaches end-of-life in our scenarios and the re-powered wind generation assumed to be built on the same site. Older technology turbines are assumed to be replaced by newer and larger turbines, but fewer of them. The repowered capacity of these windfarms is approximately 2.1 times the capacity of the retired windfarm.

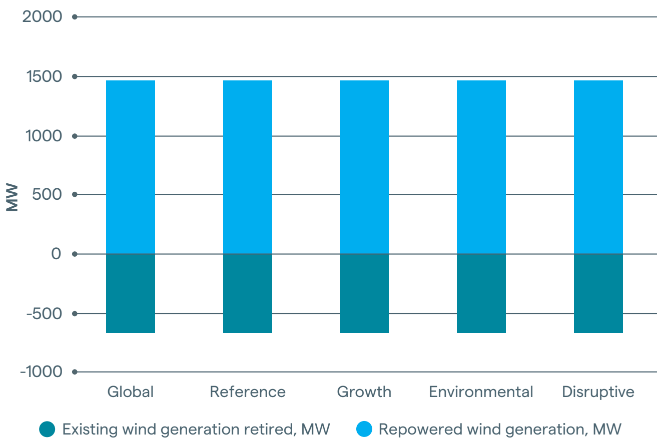
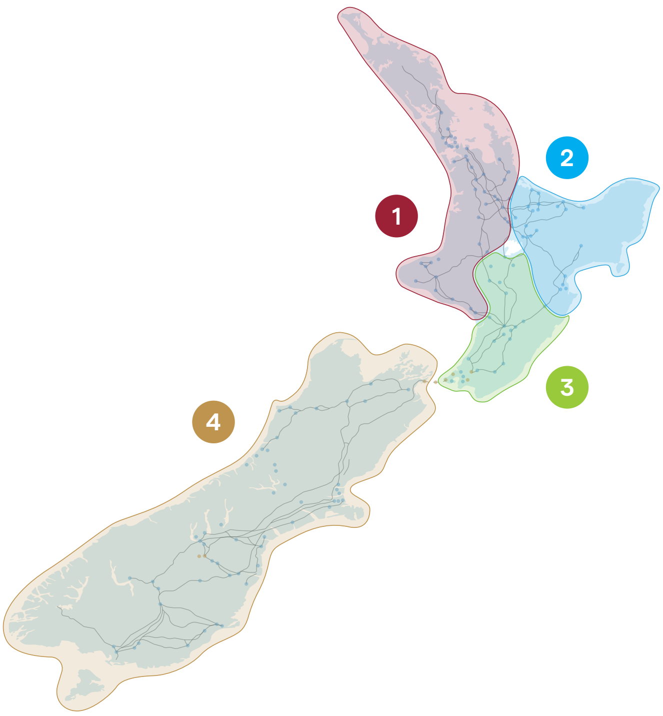


Figure 22 – Retired and repowered wind generation capacity in all scenarios

Repowered wind generation by region

In our long-list consultation document, we suggested that there were 4 distinct regions in New Zealand relevant to our NZGP1 investigation. In that document we went on to derive a matrix of scenarios which considered diversity in the new generation mix, between these regions. Even though we have now moved away from that approach, the description of those regions is still relevant in terms of our investigation. For reference, the regions are as follows:



1 Region 1 contains significant North Island demand centres. Generation expansion within this region is likely to reduce the need for upgrades in the Central North Island, Wairakei ring, and on the HVDC.

2 Region 2 includes the Bay of Plenty, Taupo volcanic zone, and Hawkes Bay. Generation expansion withing this region is likely to exacerbate the transmission constraint on the Wairakei ring while reducing the need for upgrades in the Central North Island and on the HVDC.

3 Region 3 includes the lower North Island, stretching up to Tokaanu Generation expansion within this region is likely to primarily exacerbate the transmission constraint in the Central North Island. The Wairakei ring is also exposed to additional flows but to a lesser extent. Generation expansion within the region has potential to reduce the need for upgrades on the HVDC.

4 Region 4 includes the entire South Island. This region has the potential for significant step changes in both load and generation. Any such step change is likely to have an immediate impact on the capacity requirement of the HVDC. Any increase in the net export of this region would also likely exacerbate the transmission constraint in the Central North Island.

Figure 23 – Regions relevant to our NZGP1 investigation, in terms of new generation

Figure 24 shows the wind repowering by region. As seen, a significant majority occurs in Region 3.

This reflects the high proportion of our current wind generation installed in the Manawatu/Wairarapa regions. The wind capacity factor in those regions is the highest in New Zealand, which we presume is a significant factor.

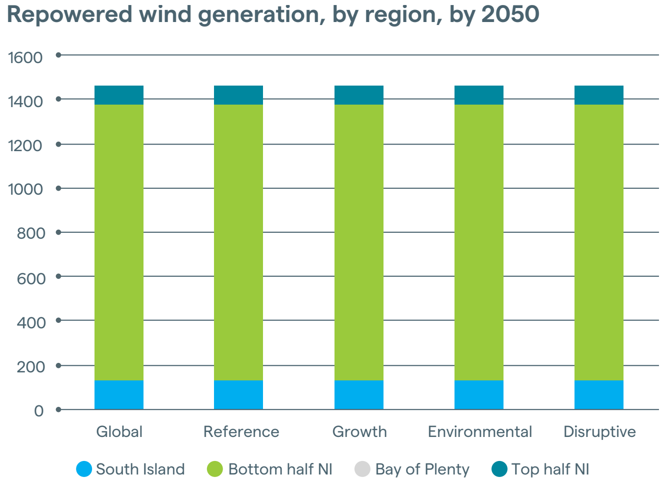


Figure 24 – Wind repowering by region

New wind generation capacity installed by region, by 2050

Figure 24 shows which regions the wind repowering occurs in and Figure 25 shows the regions in which new wind generation is built. There is also a high proportion built in the lower North Island.

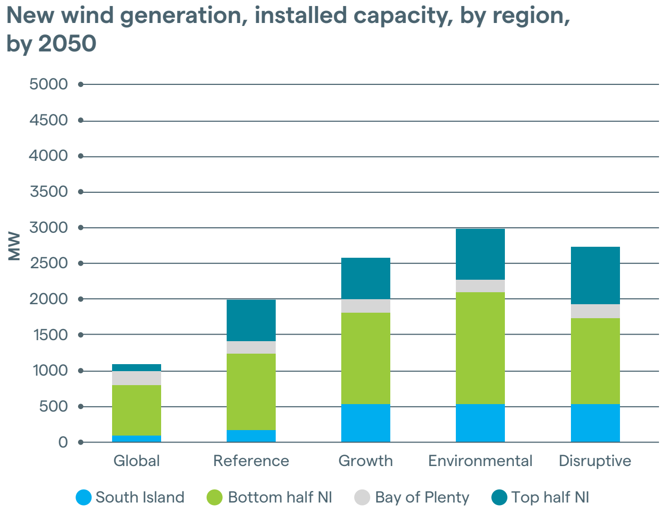


Figure 25 – New wind generation built, by region, by scenario, by 2050

Total wind generation capacity installed by region, by 2050

Figure 24 shows which regions the wind repowering occurs in. Figure 25 shows the regions in which new wind generation is built. Figure 26 adds these together to show the total wind generation installed, by region, by scenario, by 2050.

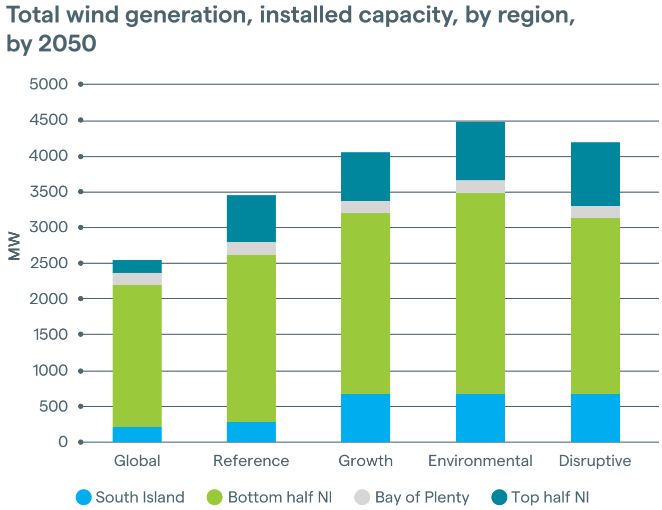


Figure 26 – Total wind generation built, by region, by scenario, by 2050

New grid-scale solar generation capacity installed by region, by 2050

Figure 27 is the equivalent of Figure 25 for wind generation, but for grid-scale solar. As seen, the model does not build any grid-scale solar in the lower North Island and builds the majority in the upper North Island. This is consistent with our view of market expectations.

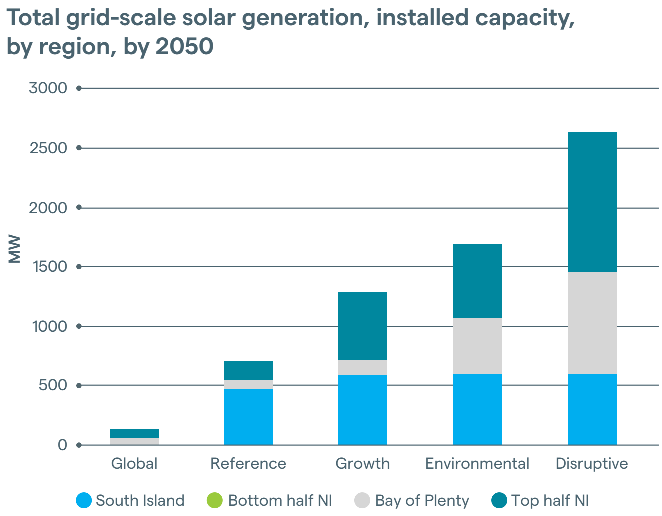


Figure 27 – Total grid-scale solar generation built, by region, by scenario, by 2050

Renewables %

Another aspect of interest in our unconstrained grid scenarios is the renewables %, being the percentage of electricity generated from renewable sources of electricity.

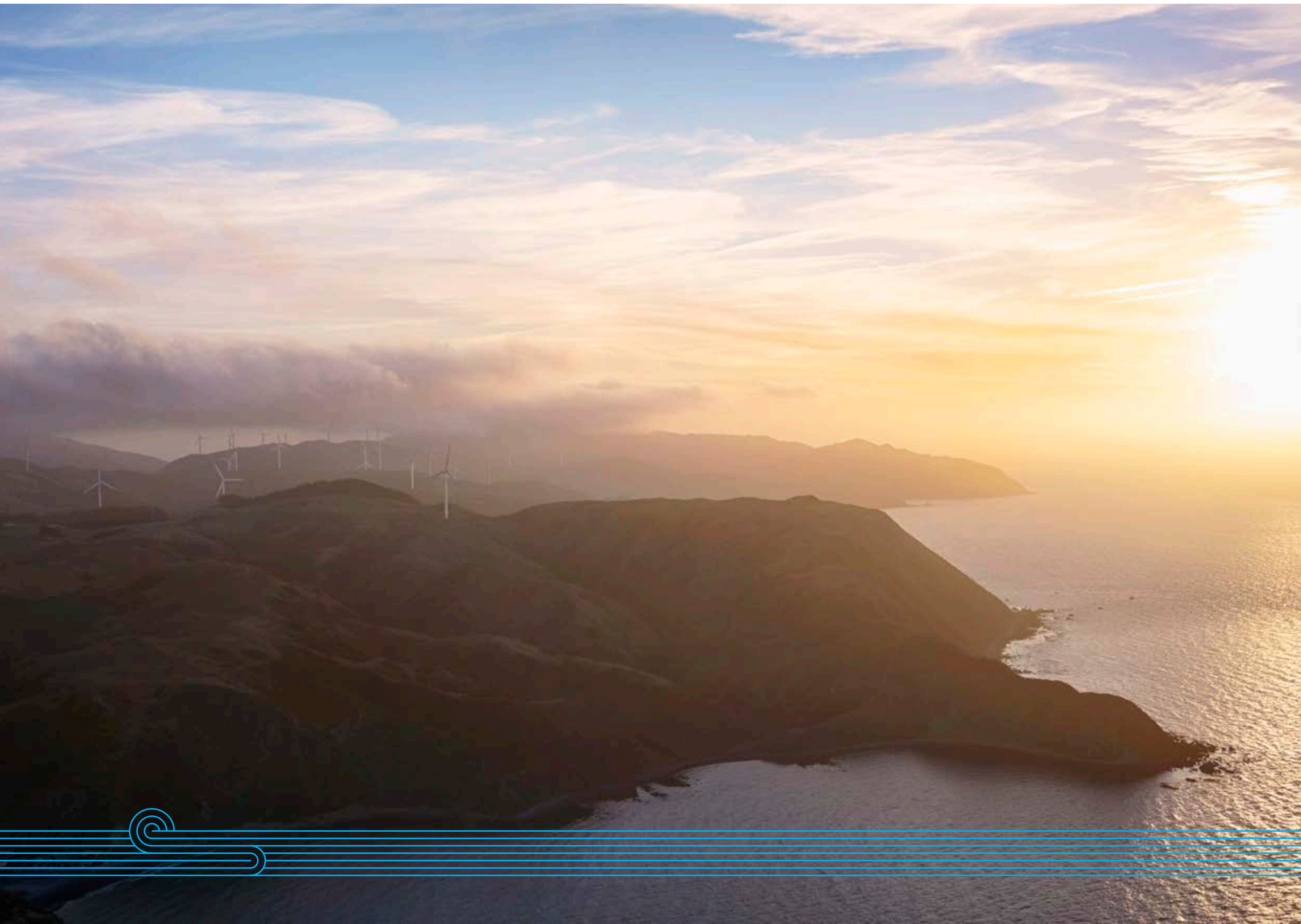
Rather than present this in diagrammatic form, we include Table 5, which shows the renewable %, by scenario, in each of 2030, 2040 and 2050.

As shown, the renewables % increases over time and by 2050 all of our scenarios are over 99% renewable. We allow gas peakers to remain in all scenarios and these still generate a small amount of electricity in 2050. It may be surprising that they do not operate more often and this is likely to be due to the high carbon cost used in our modelling ($250 per tonne by 2050). It is questionable whether it would actually economic to retain the gas peakers, given their low utilisation and in practice we may see 100% renewables by 2050 because the gas peakers have been retired.

Please note that we classify geothermal generation as renewable for this calculation. Existing geothermal generation is assumed to continue emitting CO2.

Renewables %					
	Global	Reference	Growth	Environmental	Disruptive
2030	97.6%	97.1%	97.1%	97.2%	95.4%
2040	98.9%	98.9%	98.9%	99.0%	98.6%
2050	99.9%	99.9%	99.7%	99.9%	99.7%

Table 9 – Renewables % - percentage of electricity produced from renewable generation, over time, by scenario



CO2 emissions from generating electricity

The CO2 emissions from electricity generation in each NZGP1 scenario, over time, are shown in Table 10. These are the median level of CO2 emissions, from an average hydrological year.

CO2 emissions from electricity generation reduce from approximately 4000 ktonnes per annum now to 100 – 400 ktonnes by 2050. This reflects the virtual elimination of coal and gas fired generation. None of our scenarios reach zero emissions by 2050, reflecting a small continued usage of gas generation and CO2 emissions in existing geothermal generation.

The benefit of these CO2 emissions reductions will be reflected in our Investment Test analysis.

The overall New Zealand CO2 emissions reduction, reflected in our NZGP1 scenarios, is far higher.

Process heat conversions and uptake of electric vehicles, as enabled by electrification, will reduce New Zealand's CO2 emissions by up to 15 million tonnes per annum, which is considerably more than the CO2 savings from electricity generation. Using a carbon cost of $250/tonne CO2e, this equates to a saving of $3.75 billion in 2050.

These savings are not electricity market benefits and are not included in the Investment Test, but they indicate the value to New Zealand of these enabling transmission investments. If Transpower does not build transmission ahead of time, to enable process heat conversion and electric vehicle uptake, as included in our NZGP1 scenarios, the effect on New Zealand's CO2 emissions reductions may be significant.

Carbon emissions, kT CO2e					
	Global	Reference	Growth	Environmental	Disruptive
2021	~4000	~4000	~4000	~4000	~4000
2030	561	597	599	641	746
2050	135	170	243	183	374
Reduction	~3800	~3800	~3700	~3800	~3600

Table 10 – Emissions reductions by 2050, kT CO2e, by scenario

HVDC transfers

The following figures show electricity transfers across the HVDC inter-island link with an unconstrained HVDC link, i.e. not limited by the capacity of the link today. The Investment Test will be used to determine the capacity which can be economically justified under NZGP1. Northward (from the South Island to the North Island) transfers are shown as positive and southward (from the North Island to the South Island) transfers as negative. Each set of three graphs show a snapshot in 2030, 2040 and 2050 respectively.

Global scenario – 2030

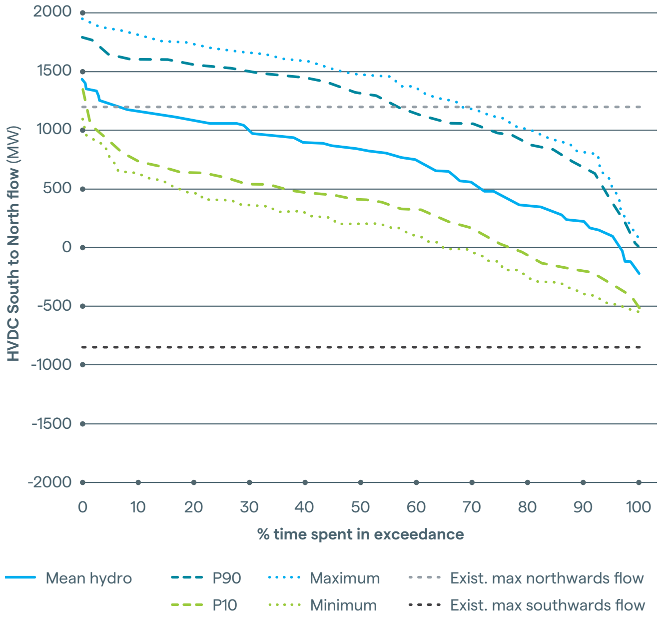


Figure 28 – HVDC transfers in 2030 in the NZGP1 Global scenario

Global scenario – 2040

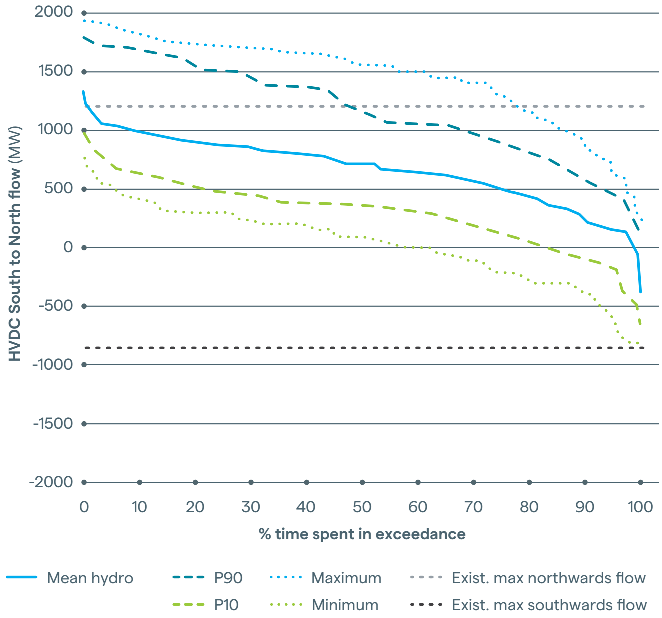


Figure 29 – HVDC transfers in 2040 in the NZGP1 Global scenario

Global scenario – 2050

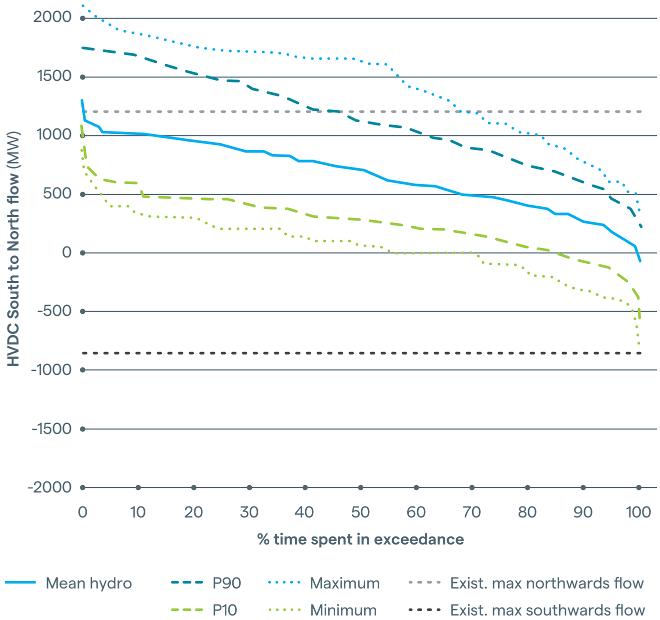


Figure 30 – HVDC transfers in 2050 in the NZGP1 Global scenario

Reference scenario – 2030

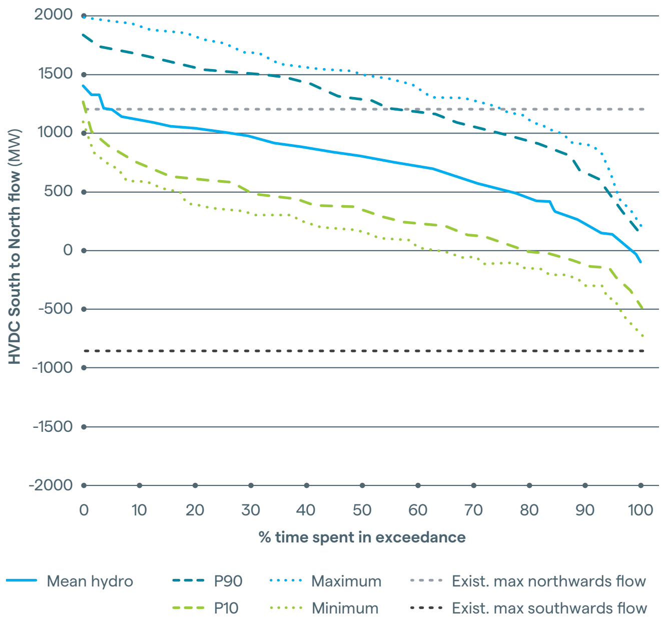


Figure 31 – HVDC transfers in 2030 in the NZGP1 Reference scenario

Reference scenario – 2040

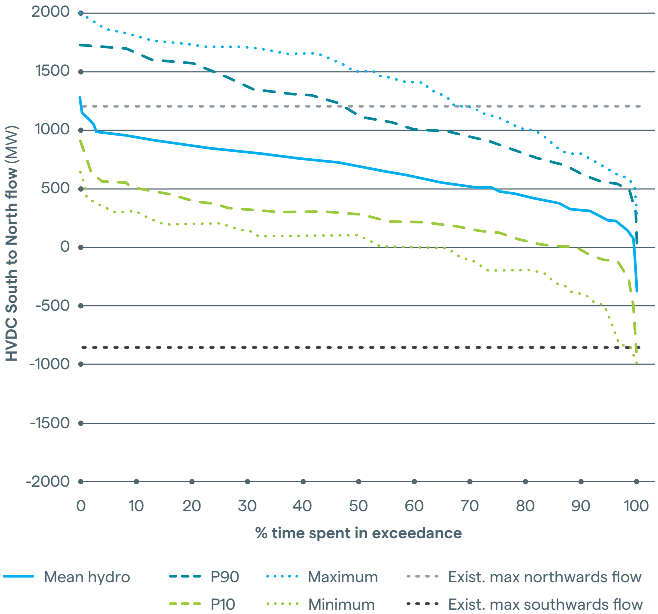


Figure 32 – HVDC transfers in 2040 in the NZGP1 Reference scenario

Reference scenario – 2050

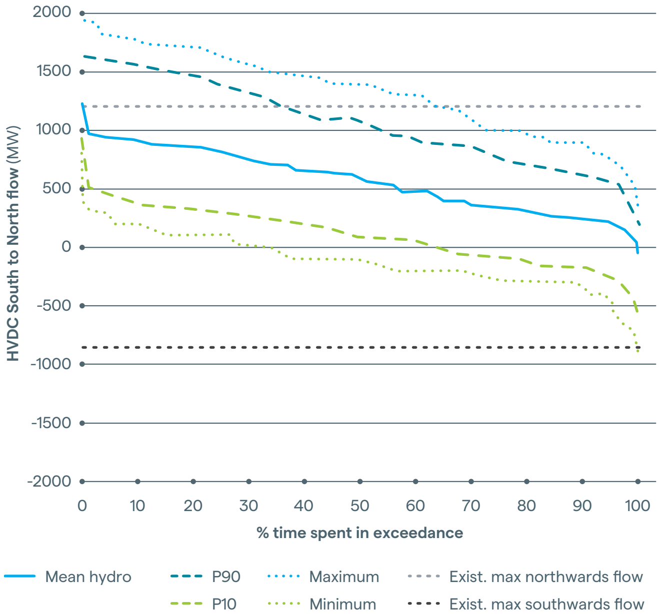


Figure 33 – HVDC transfers in 2050 in the NZGP1 Reference scenario

Growth scenario – 2030

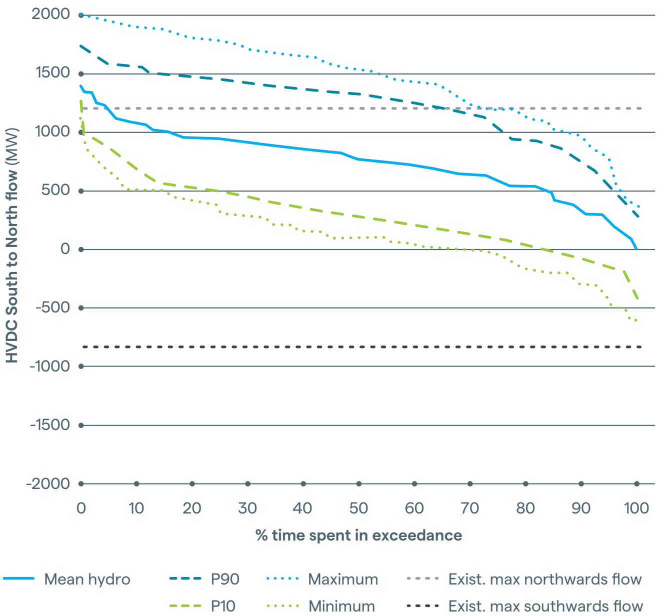


Figure 34 – HVDC transfers in 2030 in the NZGP1 Growth scenario

Growth scenario – 2040

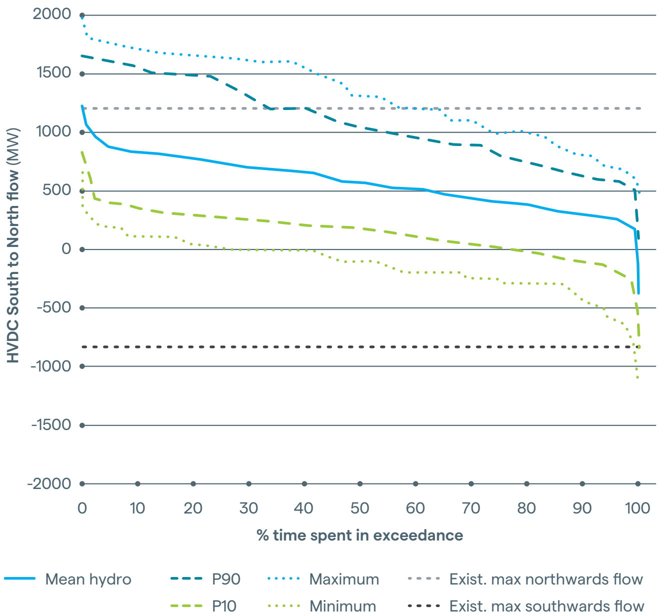


Figure 35 – HVDC transfers in 2040 in the NZGP1 Growth scenario

Growth scenario – 2050

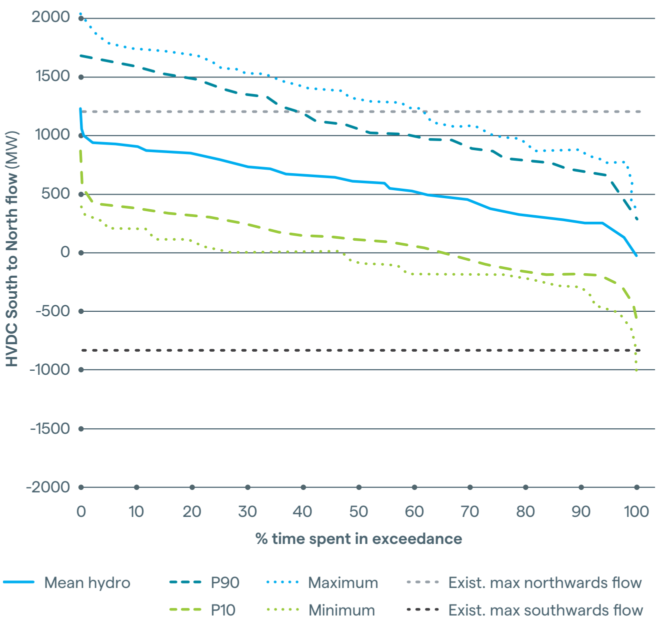


Figure 36 – HVDC transfers in 2050 in the NZGP1 Growth scenario

Environmental scenario – 2030

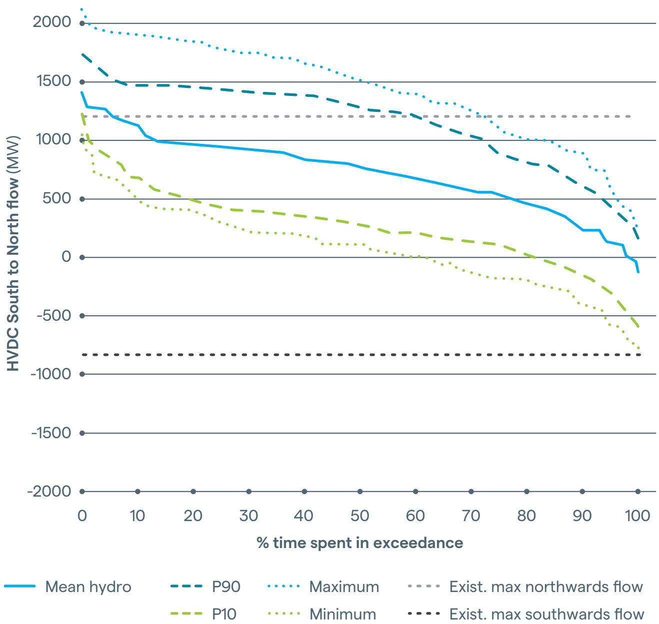


Figure 37 – HVDC transfers in 2030 in the NZGP1 Environmental scenario

Environmental scenario – 2040

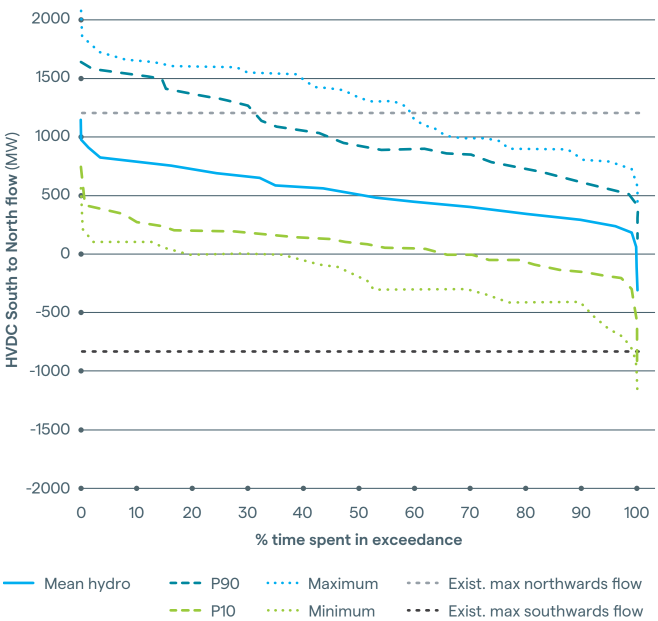


Figure 38 – HVDC transfers in 2040 in the NZGP1 Environmental scenario

Environmental scenario – 2050

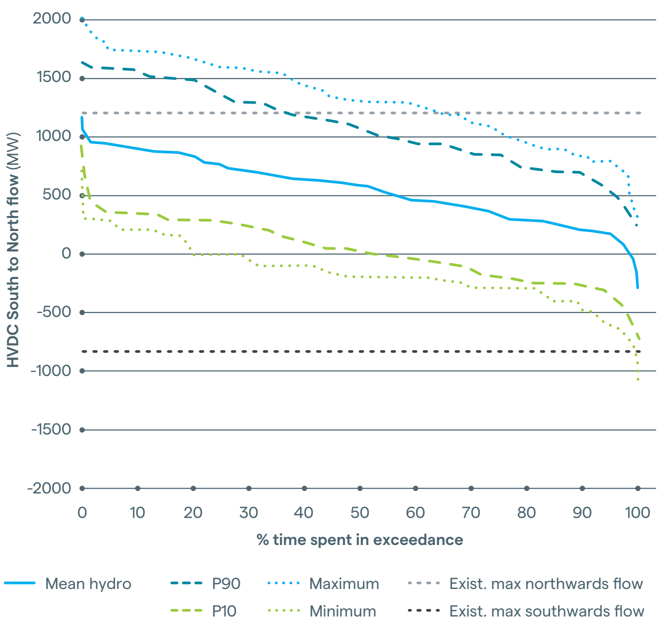


Figure 39 – HVDC transfers in 2050 in the NZGP1 Environmental scenario

Disruptive scenario – 2030

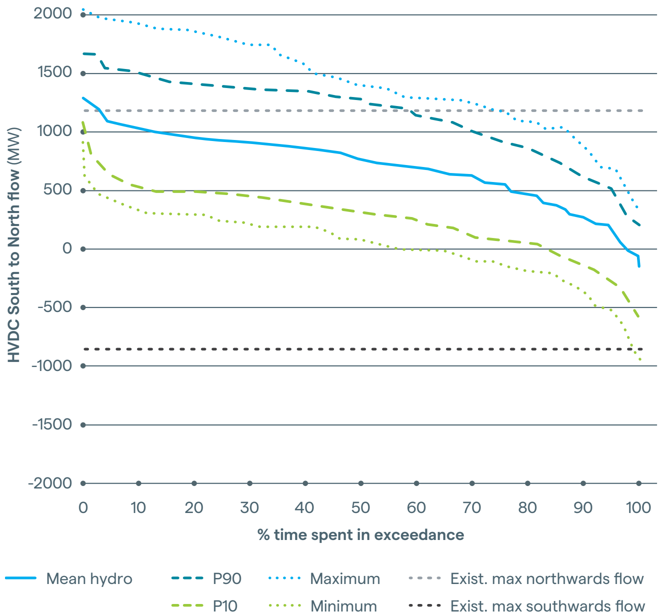


Figure 40 – HVDC transfers in 2030 in the NZGP1 Disruptive scenario

Disruptive scenario – 2040

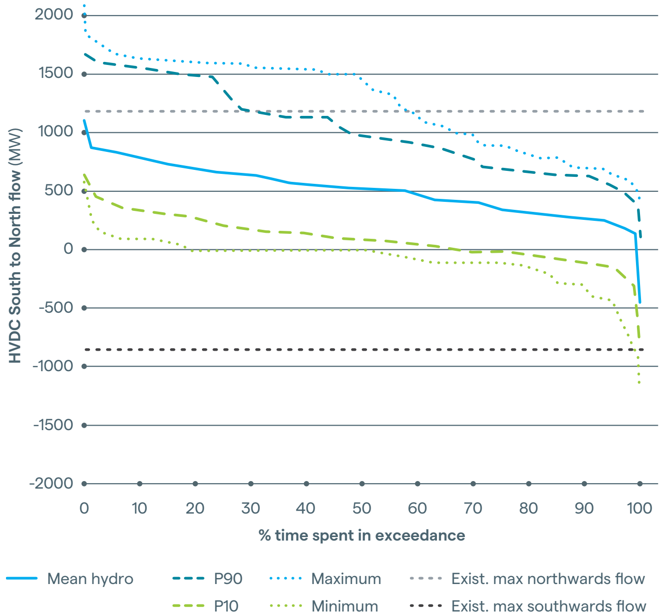


Figure 41 – HVDC transfers in 2040 in the NZGP1 Disruptive scenario

Disruptive scenario – 2050

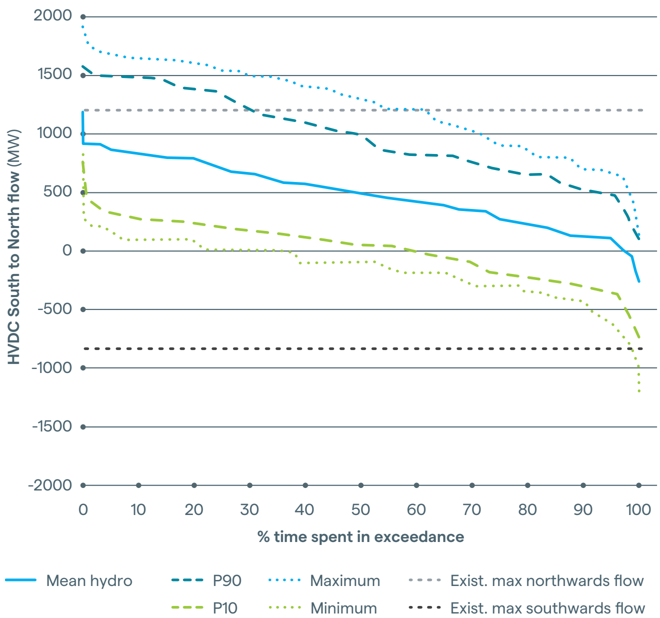


Figure 42– HVDC transfers in 2050 in the NZGP1 Disruptive scenario

In all scenarios, maximum northward flows (in the most extreme dry year) exceed the capacity of the existing HVDC link and would also exceed the capacity of a 1400 MW transfer limit. This is due to Tiwai closure in 2024, which creates a surplus of SI hydro generation.

In 2030, a 1400 MW capacity HVDC link would have sufficient capacity to cope with northward flows in an average hydro year in all scenarios and southward flows in all but the most extreme year in the Disruptive scenario.

Approximately 1600 MW of northward HVDC capacity would be sufficient to ensure the P90th hydrological year (a wet year) could be transferred north without constraint across the HVDC.

We note that these unconstrained HVDC transfers are very similar in all scenarios and in 2030, 2040 and 2050. This may suggest that demand growth in both the North and South islands is mostly being met by new generation build in both islands.

Sensitivity scenarios in NZGP and NZGP1

Most of the discussion in this document has been in regard to deriving scenarios for our NZGP1 MCP investigation. We are also concerned with developing scenarios useful for our broader NZGP project. Less certain, but possible, futures are not included in our NZGP1 analysis, however some may have significant transmission implications. For that reason, we have identified a range of possible futures which we would also like to study and these are referred to as sensitivity scenarios. As mentioned, most are less certain and do not meet the threshold for inclusion in our NZGP1 scenarios, but we would like to understand their transmission implications. They will all be studied as a part of our NZGP project and a limited number in our NZGP1 project. We will report the outcomes in our short-list consultation, but they will not be included in our Investment Test analysis. The sensitivity scenarios we are likely to consider in NZGP1 are (refer to Table 6) are the High demand scenario, one or two Southland scenarios and the Peak/dry year 1 scenario.

Table 11 includes a complete list and brief description of the NZGP1 scenarios and our NZGP sensitivity scenarios.

NZGP and NZGP1 scenarios		
NZGP1 scenario	**Demand, TWh, 2050**	**Generation parameters[14]**
Global	44	Tuned gen stack with high wind costs
Reference	51	Tuned gen stack
Growth	56	Tuned gen stack
Environmental	60	Tuned gen stack with high C costs
Disruptive	64	Tuned gen stack with low wind/solar costs
Sensitivity scenario	**EDGS demand/ generation**	**Variation**
High demand		High demand per WiTMH Mobilise to Decarbonise
Southland 1	Environmental	Tiwai closes 2024, 500 MW hydrogen plant 2030
Southland 2	Environmental	Tiwai closes 2030
Southland 3	Environmental	Tiwai closes 2030, 500 MW hydrogen plant 2030
Southland 4	Environmental	Tiwai does not close
Southland 5	Environmental	Tiwai does not close, 500 MW hydrogen plant 2030
Taranaki offshore wind	Environmental	800 MW 2030, 2400 MW 2040 with 300/500 MW connection onshore
Taranaki development	Environmental	Taranaki demand grows 300 MW by 2030 and 500 MW by 2040
50 : 50 wind:solar	Environmental	A higher ratio of solar to wind
Peak/dry year 1	Environmental	Onslow – 5 TWh for dry years only
Peak/dry year 2	Environmental	Onslow – 8 TWh, w 5 TWh for dry years only, 3 TWh wholesale market
Peak/dry year 3	Environmental	North Island 100% renewables solution
Marine generation	Environmental	500 MW Cook Strait marine generation built
Climate change/risk	Environmental	Climate change effects on hydro/wind/solar profiles and transmission resilience
Hydrogen future	Environmental	North Island natural gas replaced by hydrogen
How cheap do batteries need to be, so TP is battery charging service only	Environmental	Sufficient distributed batteries that reliability of supply is no longer a grid service

Table 11 – Table of NZGP1 scenarios and sensitivity scenarios to be considered in NZGP

14. The term "tuned gen stack" means MBIE's generation stack, but altered to reflect those changes discussed in the report section "Tuning the generation scenario input assumptions", page 17.

Observations relating to NZGP1 generation scenarios

To date, we have only undertaken unconstrained grid runs to produce generation expansion plans, but we offer the following observations:

Battery build

The amount of grid-scale batteries built in our scenarios varies as shown in Table 12.

MW	Global	Reference	Growth	Environmental	Disruptive
Grid-scale battery build by 2050	10	106	172	103	1272

Table 12 – MW of grid-scale batteries built in our NZGP1 scenarios

This build may seem low (excepting in the Disruptive scenario where widescale battery build occurs to manage renewable generation intermittency) considering the amount of interest currently in building grid-scale batteries in New Zealand, the amount of batteries built worldwide and the prediction that grid-scale battery costs will decrease over time.

We observe that these grid-scale batteries are built exclusively for transmission purposes. Other grid-scale batteries may also be built, to capture other value streams for their owners, but these are not included as they would have limited use from a transmission perspective.

Emissions budgets

We have not given thought yet, whether the CCC's recommended emissions budgets for New Zealand will impact these scenarios. We will consider that in the coming months and make adjustments if necessary, before publishing a short-list consultation document in 2022.

Dry year reserve

How dry year reserve will be provided in the future is uncertain.

In our highest electricity demand scenario, hydro still provides 40% of our electricity in an average hydrological year. This drops to 33% in a dry year and that shortfall is provided using dry year reserve.

Currently the Huntly Rankine units, fuelled using coal or gas, meet that shortfall. These units are retired by 2030 in our modelling and an alternative is required to ensure security of electricity supply over time.

Such alternatives are currently being considered – by both market participants and MBIE's Battery Project, with some possibilities being:

a. Allow gas peakers to remain in the North Island, with more being built as required. This would not achieve a 100% renewables future (a feasible mix is approximately 95-97% renewables), but may be the least capital intensive.

b. Lake Onslow in the South Island is developed. A pumped hydro scheme which stores enough water to generate about the same amount of electricity as the Huntly Rankine units, or more, in a dry hydrological year.

c. A mixed North Island solution, which may include a mixture of solutions e.g.:
   - Continued use of gas peaking plant
   - Generation overbuild
   - A biofuel or hydrogen generation plant to effectively replace Huntly
   - Smaller pumped storage project/s
   - Multi-fuel plant being installed in some industrial applications. These could be powered by some mixture of electricity, gas, biofuel or hydrogen.

The alternative which has the most impact on transmission requirements is the Lake Onslow alternative. This is located in the South Island, with most electricity demand being in the North Island. If Lake Onslow is developed, existing transmission between Lake Onslow and the North Island may become congested. Although not reflected in our NZGP1 scenarios, we will consider this alternative as a sensitivity scenario in our NZGP1 analysis.

Our current modelling reflects the Huntly Rankine units being closed in 2030 and the model has several options open to it in the event of a dry hydrological year:

a. gas peakers can be used and new gas peakers built

b. generation can be "overbuilt". When this occurs, some generators are under-utilised in average hydrological years, but fully utilised when there is a dry hydrological year

c. a biofuel (and/or hydrogen) peaking plant can be built, effectively replacing the Huntly Rankine units

d. incurring deficit i.e. not meeting demand. This is a high cost option, but is included to avoid model infeasibilities.

We find that gas peakers are not used very often and no new gas peaking is built in our scenarios (excepting a small amount in the Growth scenario, in 2045). We suspect that the $250 per tonne CO2e carbon price by 2050 means that the model can minimise its cost by utilising other approaches to ensuring dry year security of supply.

We observe a range of approaches being used in our unconstrained grid scenarios and we conclude that these scenarios are fit for purpose. The economics in our scenarios do not clearly favour one approach over another and that we are not over-representing any one approach. The main approaches used are to overbuild generation (up to 200 MW of geothermal is over built in some scenarios and up to 500 MW wind in other scenarios), build a biofuel replacement for the Huntly Rankine units (which could be fuelled by biofuel or hydrogen) and in limited cases incur a small amount of deficit i.e. do not meet demand. Table 13 shows the mix of approaches used in each scenario:

Dry year approach	Year		
NZGP1 Global	**2035**	**2040**	**2045**
Biofuel	✗	✓	✓
Overbuild	✓	✓	✓
Deficit	✗	✗	✗
NZGP1 Reference	**2035**	**2040**	**2045**
Biofuel	✗	✓	✓
Overbuild	✓	✓	✓
Deficit	✗	✗	✗
NZGP1 Growth	**2035**	**2040**	**2045**
Biofuel	✓	✓	✓
Overbuild	✓	✓	✓
Deficit	✗	✗	✗
NZGP1 Environmental	**2035**	**2040**	**2045**
Biofuel	✓	✓	✓
Overbuild	✓	✓	✓
Deficit	✗	✗	✗
NZGP1 Disruptive	**2035**	**2040**	**2045**
Biofuel	✗	✗	✗
Overbuild	✓	✓	✓
Deficit	✗	✓	✓

Table 13 – Approaches used by the generation expansion model to meet the dry year reserve requirement

If our scenarios had favoured any particular (yet uncertain) approach, then we would have locked the resultant grid flows into our analysis. Because our scenarios utilise a range of approaches to meet dry year security of supply, they minimise the effect of this significant uncertainty on our analysis.

We note that this should not be taken as a suggestion that these approaches might be best for New Zealand, or that a mixed North Island solution is preferred, rather that we have minimised the effect of this major uncertainty in the scenarios to be used for our NZGP1 MCP.

NZGP1 investment drivers

Previous work identified the need for our NZGP1 investigation. It is worth noting the aspects of our unconstrained grid scenarios which support that need:

- HVDC flows north increase significantly once Tiwai aluminium smelter is closed and investment to increase the transfer capability north may be justified. Our investigation will consider senstivitiy scenarios where Tiwai closure is deferred and where new Southland demand emerges.
- The high amount of wind generation in the lower North Island may justify increasing the capacity of the grid backbone between Bunnythorpe and Whakamaru.
- Connection of new generation to the Wairakei Ring, from new geothermal and Bay of Plenty may justify increasing the capacity of the Wairakei Ring.

Next steps for NZGP1

As already mentioned, the generation expansion plans outlined in this document reflect an unconstrained transmission grid. The next step in our NZGP1 analysis is to include the existing HVDC, CNI and Wairakei Ring elements for each scenario and repeat. These will be the Base Cases for our Investment Test analysis.

We will then replace the existing grid elements with various enhancement options to see how the generation expansion plans change and to define the benefits of each option.

The preferred option will be identified in our short-list consultation paper.

We expect the preferred option will be a mix of tactical (short-term) upgrades and longer-term upgrades – perhaps even involving the building of new transmission lines. We advised the Commerce Commission that this would be a staged MCP, in anticipation of identifying least-regrets options which might be built in stages.

There will be further updates on how NZGP1 is progressing in the first half of 2022, before we publish the short-list consultation paper. At a high level, our timeline for NZGP1 is:

- Short-list consultation – mid-2022
- NZGP1 MCP submitted to Commerce Commission – late 2022
- NZGP1 MCP approved by Commerce Commission – 2023

Although it is far too early in our investigation to surmise the investment/s which may be included in our NZGP1 MCP, Table 14 describes indicative timings for various options:

HVDC		CNI		Wairakei Ring	
Enhancement option	Earliest commissioning	Enhancement option	Earliest commissioning	Enhancement option	Earliest commissioning
Reactive equipment/battery	2025-26	Re-tensioning	2024	Re-tensioning	2024
Fourth cable	2027-2032	Reconductoring	2025-2026	Reconductoring	2025-2026
		New line	2027-2030	New line	2027-2030
Non-transmission solutions	TBA		TBA		TBA

Table 14 – Earliest commissioning dates for various enhancement options being considered in NZGP1

It should also be noted that the outcome of NZGP Stage 1 and Stage 2 will likely be advised in 2022, which will provide information on the longer term.

Appendix 1 – Electricity demand (TWh) and peak demand (MW) by year, by scenario to 2050

Year	Disruptive	Environmental	Global	Growth	Reference
2020	40.1	40.0	40.0	40.0	40.0
2021	40.2	40.1	39.9	39.9	39.9
2022	41.0	40.8	40.2	40.5	40.4
2023	41.8	41.6	40.5	41.0	40.8
2024	42.8	42.5	41.1	41.9	41.6
2025	38.8	38.5	36.6	37.7	37.3
2026	39.5	39.0	36.7	38.1	37.7
2027	40.2	39.7	36.8	38.6	38.1
2028	41.2	40.6	37.0	39.2	38.6
2029	42.0	41.3	37.5	39.8	39.0
2030	43.0	42.3	37.7	40.5	39.6
2031	43.9	43.3	38.1	41.2	40.1
2032	44.7	44.1	38.2	41.7	40.6
2033	45.8	45.0	38.5	42.4	41.0
2034	46.6	45.9	39.0	43.0	41.7
2035	47.7	46.9	39.1	43.8	42.2
2036	48.8	48.0	39.7	44.6	42.9
2037	49.7	48.7	40.0	45.3	43.2
2038	50.8	49.7	40.2	46.1	44.0
2039	51.9	50.7	40.7	47.0	44.5
2040	52.7	51.5	40.9	47.7	45.2
2041	53.9	52.4	41.4	48.5	45.7
2042	55.0	53.4	41.6	49.5	46.4
2043	56.0	54.1	41.9	50.0	46.9
2044	57.2	54.9	42.3	50.9	47.6
2045	58.4	55.8	42.5	51.9	48.1
2046	59.5	56.6	42.7	52.7	48.7
2047	60.5	57.3	43.1	53.4	49.4
2048	61.6	58.1	43.4	54.3	49.9
2049	62.7	58.9	43.8	55.1	50.5
2050	63.8	59.7	43.9	56.0	51.0

Table 14 – Forecast electricity demand in TWh, by year, by NZGP1 scenario, out to 2050

Year	Disruptive	Environmental	Global	Growth	Reference
2020	6930	6920	6923	6922	6921
2021	6971	6947	6926	6926	6924
2022	7105	7072	6990	7028	7015
2023	7212	7177	7029	7096	7070
2024	7348	7312	7131	7225	7189
2025	6895	6852	6610	6740	6693
2026	6970	6917	6639	6800	6743
2027	7052	7000	6657	6862	6795
2028	7151	7094	6688	6931	6853
2029	7226	7163	6753	6998	6897
2030	7322	7264	6787	7084	6974
2031	7408	7355	6841	7160	7022
2032	7481	7430	6870	7224	7096
2033	7584	7529	6918	7309	7138
2034	7656	7606	6979	7372	7226
2035	7748	7692	7007	7467	7281
2036	7831	7770	7086	7560	7367
2037	7888	7810	7132	7631	7407
2038	7962	7868	7158	7719	7492
2039	8034	7924	7233	7803	7544
2040	8066	7955	7257	7862	7628
2041	8144	8014	7331	7939	7678
2042	8226	8075	7352	8024	7759
2043	8285	8110	7393	8064	7807
2044	8382	8173	7447	8136	7887
2045	8484	8240	7468	8220	7934
2046	8586	8316	7491	8295	8000
2047	8663	8367	7546	8347	8079
2048	8765	8445	7587	8421	8124
2049	8881	8520	7644	8498	8188
2050	8985	8593	7648	8573	8232

Table 15 – Forecast electricity peak demand in MW, by year, by NZGP1 scenario, out to 2050

Appendix 2 – Process heat and electric vehicle electricity demand and household solar PV generation included in our demand scenarios

2050 Process Heat

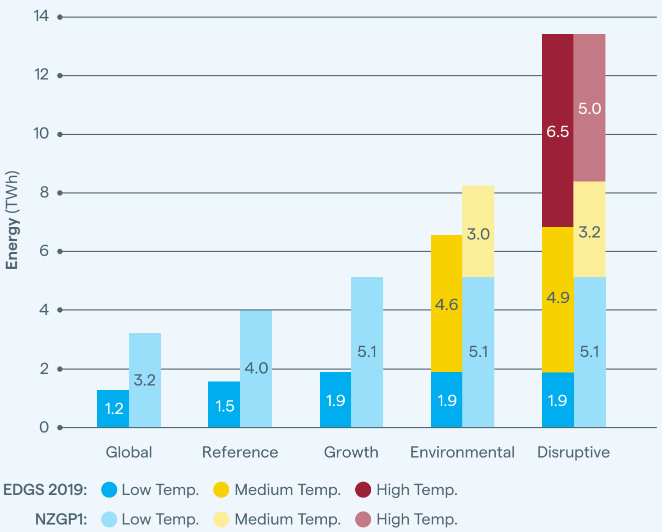


Figure 43 – Comparison of 2050 process heat conversion electricity demand, in TWh, by scenario – EDGS compared to NZGP1

2050 Electric Vehicle demand

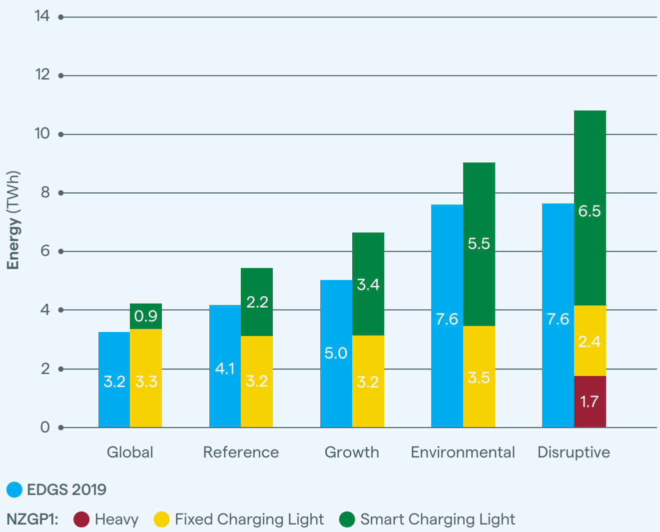


Figure 44 – Comparison of 2050 electric vehicle electricity demand, in TWh, by scenario – EDGS compared to NZGP1

2050 Solar Generation

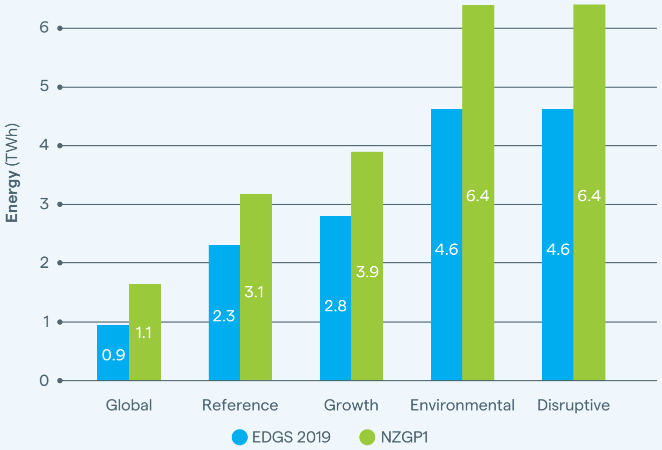


Figure 45 – Comparison of 2050 embedded solar PV production, in TWh, by scenario – EDGS compared to NZGP1

These forecasts were developed following advice from our expert panel, late in 2020.

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