ClimateWorks

Climate change impacts

on the proposed Mt Munro wind farm

i. Projected climate change impacts on wind in the region
ii. The importance of new renewable electricity projects to New Zealand's decarbonisation goals

- **a report to Meridian Energy**

Dr Jen Purdie

ClimateWorks Ltd

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Executive summary

Meridian Energy Limited (Meridian) is seeking resource consents to construct, operate and maintain a wind farm on a site known as Mt Munro, located approximately 5km south of Eketāhuna, in the northern Wairarapa.

To meet New Zealand's decarbonisation goals, significant new renewable energy infrastructure will be needed, including many wind farms, to supply the doubling of electricity by 2050 that is projected to be required for the electrification of transport and industry.

New Zealand has an excellent wind resource, as it is located perpendicular to the prevailing mid-latitude westerly wind belt, the "roaring forties". However, the relatively rapid change in our climate as a result of anthropogenic greenhouse gas emissions will have an impact on the rainfall, temperatures, and wind speeds we have experienced in the past.

The proposed Mt Munro wind farm site receives most of it's wind from the north-west, with some also coming from the south. Average annual wind speed at the site is 9.5 ms^{-1} at 40m, and highest wind speeds at the site are in spring.

For the past few decades, globally, wind speeds have slowed over land almost everywhere, at the rate of approximately 2% per decade. In New Zealand, reductions in wind speeds since 1970 have been estimated at approximately 0.4 ms^{-1} per decade. Wind speeds are projected to increase in the South Island and lower North Island in coming decades, and decrease in the north of the North Island.

Projections for the proposed Mt Munro wind farm site (from NIWA's downscaling of Global Circulation Model outputs) show increases to winter wind speeds in the future (1-3% for low to high emissions scenarios by mid-century), and slight decreases to summer wind speeds (-0-2% for low to high emissions).

Annual changes to wind speeds by 2050 at the Mt Munro site are expected to be +0.3% (low emissions) to +1.5% (high emissions), with the most likely scenario (mid-range emissions) being an increase of +1.3% in wind speeds. The highest and lowest wind speeds are expected to increase at the same rate as the mid-range speeds. This increase is not expected to significantly alter wind generation at the site, or result in damage to turbines.

New Zealand's decarbonisation strategy, to meet Paris agreement and Zero Carbon Act goals, includes accelerated electrification, particularly of transport and industry. This electrification is projected to approximately double electricity demand by 2050, resulting in the need for significant new generation infrastructure. Projections of electricity demand vary, but all project the need for between 1 and 2 wind farms a year to be built every year from now until mid-century. With less than one wind farm a year being built in New Zealand over the last 20 years, there is some urgency around the need to build new wind farms to meet New Zealand's decarbonisation goals.

Contents

1. Introduction

To meet New Zealand's decarbonisation goals, significant electrification of transport and industry will be needed, and projections are for a potential doubling of electricity demand by 2050, resulting in the need for significant new renewable energy infrastructure.

Meridian Energy Limited (Meridian) is seeking resource consents to construct, operate and maintain a wind farm, including all ancillary activities such as earthworks, transmission lines and substations, on a site known as Mt Munro, located approximately 5km south of Eketāhuna in the northern Wairarapa.

The site is classified as having a Class I wind energy resource, being the best wind resource available. However, the climate is changing, and knowledge of how the wind resource will change in the future is important when developing this (and other) wind farms.

The focus of this work is:

a) to outline and quantify the need for significant new build of renewable electricity generation in New Zealand, to supply the mass electrification needed to meet the country's Paris climate commitments and internal climate change legislation.
b) to explore how anthropogenic climate change will impact the wind resource in the region of the proposed Mt Munro wind farm, over the life of the farm (~30 years),

2. Historical winds in New Zealand

New Zealand has an excellent wind resource, as it is located perpendicular to the prevailing mid-latitude westerly wind belt, known as the "Roaring 40s". The annual average wind speed in New Zealand is generally between 1 and 7 ms^{-1} (based on 1981-2010 data). Faster annual average wind speeds are found in some mountainous and coastal areas, with winds around Cook Strait and Foveaux straits, East Cape, Northland, and along the peaks of the Southern Alps being notably higher than in other areas (see figure 1).

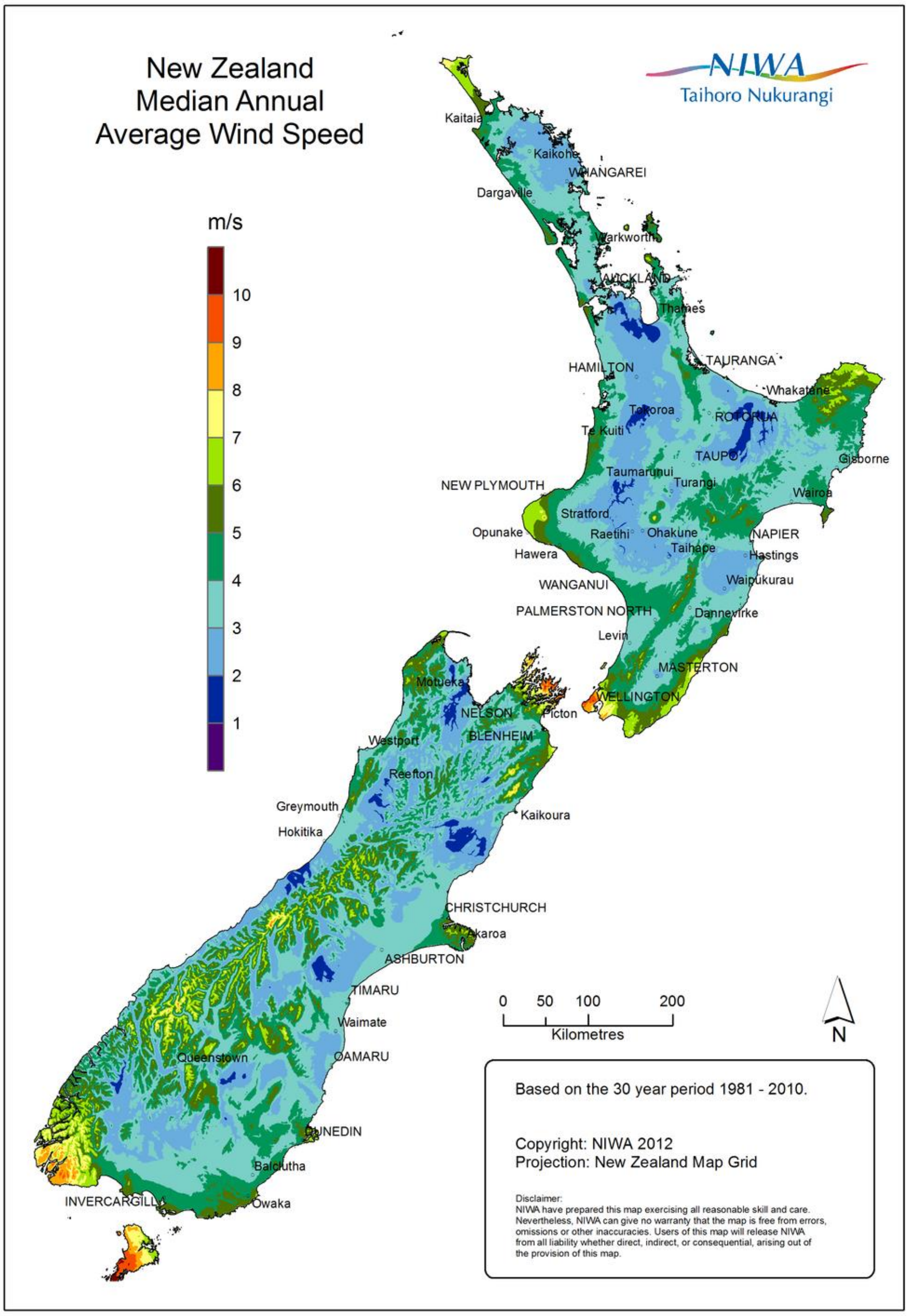

Figure 1: New Zealand Median Annual Average Wind Speed (1981-2010). (NIWA 2023)[1].

For the past few decades, globally, a phenomenon has been observed known as “global terrestrial stilling”[2]. This relates to the general slowing of wind speeds over land almost everywhere, at the rate of approximately 2% per decade, and is likely due to changes in

[1] NIWA 2023a: Regional and national climate maps. https://niwa.co.nz/climate/national-and-regional-climate-maps/national

[2] McVicar et al 2012: Global Review and synthesis of trends in observed terrestrial near surface wind speeds. In journal of Hydrology 416-417, 182-205. doi:10.1016/j.jhydrol.2011.10.024

atmospheric circulation. Some researchers have proposed that this stilling appears to have reversed in the past decade[3], although longer observations are needed to determine if the slowing and speeding up are simply inter-decadal variability.

This slowing of wind speeds has also been observed in New Zealand (see figure 2), with reductions in both the speed of maximum gusts, and the number of days per year that extreme winds occur[4]. Reductions in wind speeds have been estimated at approximately 0.5 ms^{-1}per decade in the South Island, and approximately 0.2 ms^{-1}in the North Island.

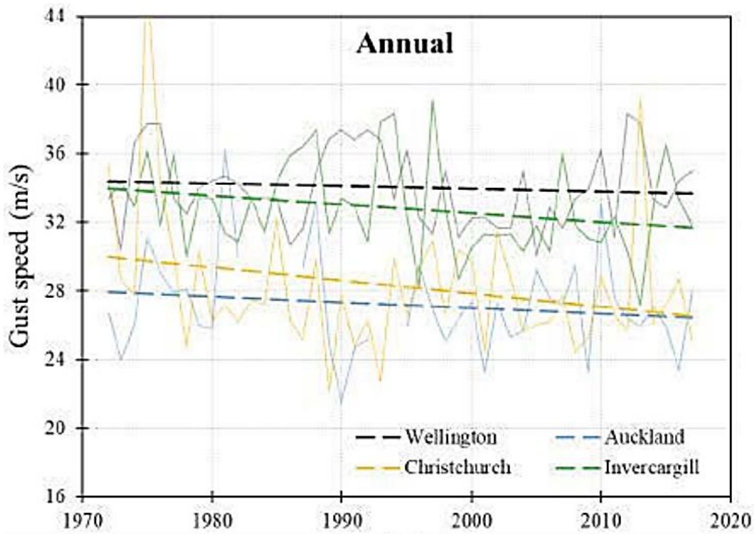

Figure 2: Trends in the magnitudes of maximum annual gust speeds.
Dashed lines are the best-fit linear trends[4].

Although the global stilling phenomenon is projected to continue in many regions of the world, other regions are projected to see increases in wind speeds in coming decades, which will be discussed in section 4.

[3] Zeng et al 2019: A reversal in global terrerstrial stilling and its implications for wind energy production. In Nature Climate Change, vol 9, Dec 2019, 979-985. https://doi.org/10.1038/s41558-019-0622-6

[4] Pirooz et al 2019: Effects of climate change on New Zealand design wind speeds. Paper presented at the Australian and new Zealand Disaster and Emergency Management Conference Gold Coast, Queensland, Australia 12-13 June 2019. In National Emergency Response, pg 14-20

3. Mt Munro wind farm site

3.1 Location

The proposed Mt Munro wind farm site is located approximately 5km south of Eketāhuna, in the northern Wairarapa (see figure 3). The site sits at ~500m elevation, in the middle of the island, approximately 50kms from the ocean to the west or east.

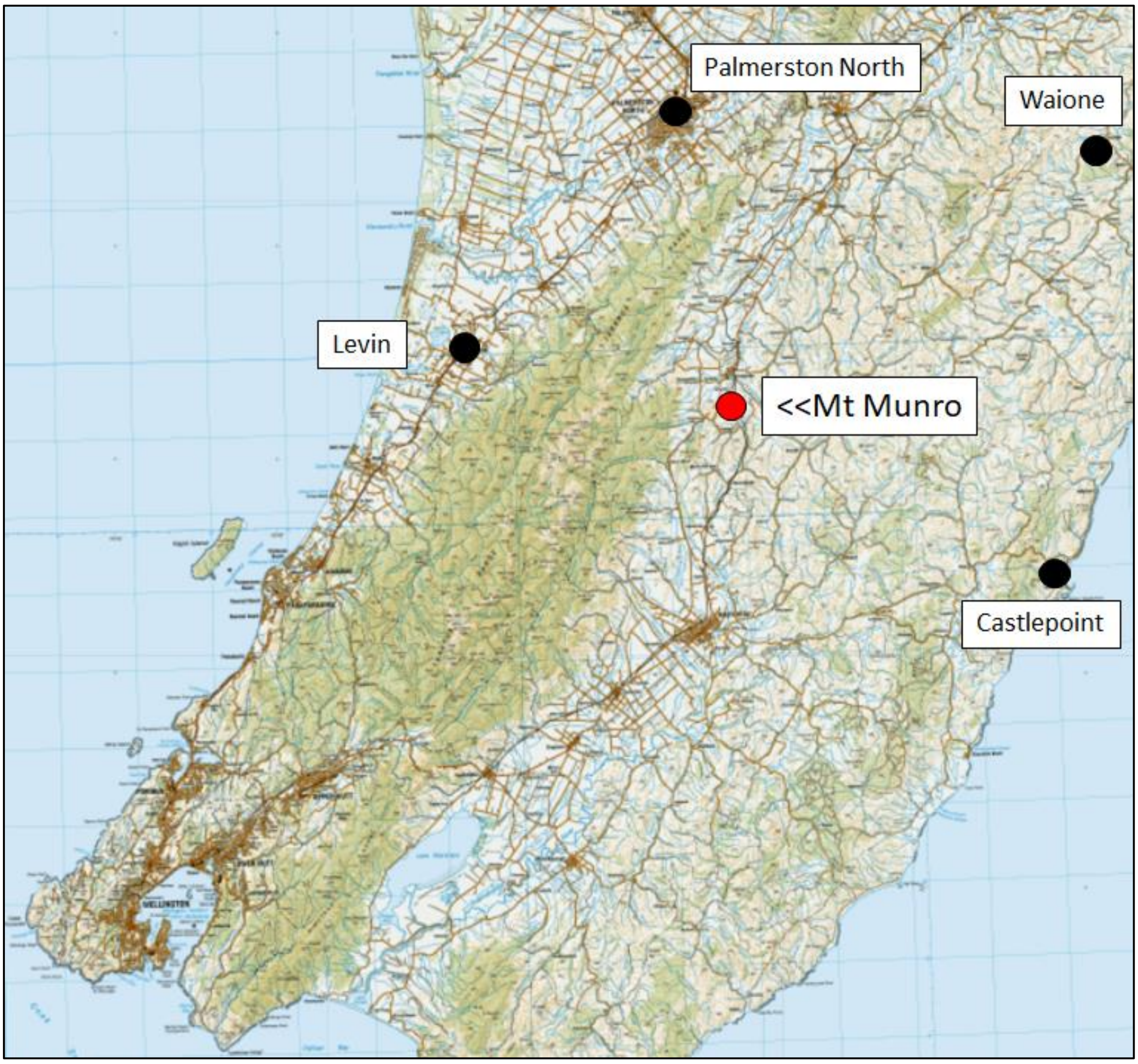

Figure 3: Map of the site of Mt Munro, in the lower North Island of New Zealand, and proximal NIWA wind recording stations.

3.2 Wind in the lower North Island

Winds in the lower North Island are strongly modified by the topography, including the Tararua ranges, which lie perpendicular to the prevailing westerlies. Long term average monthly and annual wind speeds at various sites in the lower North Island are shown in Table 1. The available recording sites closest (and roughly equidistant) to the Mt Munro site are Levin, Palmerston North, Waione, and Castlepoint. It can be seen that these sites have a diversity of normal wind speeds, with the eastern coastal site, Castlepoint, having the highest speeds.

Table 1: Mean monthly and annual wind speeds at 10m height in the lower North Island (ms^{-1})[5], [6].

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Levin AWS	2.8	2.6	2.6	2.3	2.4	2.6	2.4	2.8	3.0	3.5	3.4	3.2	2.8
Palmerston North AWS	4.4	4.3	4.3	3.6	3.8	3.8	3.9	3.9	4.3	4.7	4.9	4.5	4.2
Waione RAWS	2.5	2.3	2.2	1.9	1.9	2.1	1.9	2.1	2.2	2.7	2.8	2.7	2.3
Castlepoint AWS	8.4	7.9	8.3	7.4	8.1	8.7	7.8	8.5	9.2	9.9	9.8	9.2	8.6

3.3 Mt Munro site – exploratory data mast 2013-23

An exploratory wind mast has been in place at the Mt Munro wind farm site for the past ten years. Data from this site show that wind is predominantly from the north-west (see figure 4), with a smaller amount from the south. It is a windy site, with much of the wind in the higher wind speed bracket.

[5] Chappell, P.R. 2014. The climate and weather of Wellington. NIWA Science and Technology Series 65, 44 pp.
[6] Chappell, P.R. 2015. The climate and weather of Manawatu-Wanganui. NIWA Science and Technology Series 66, 40 pp.

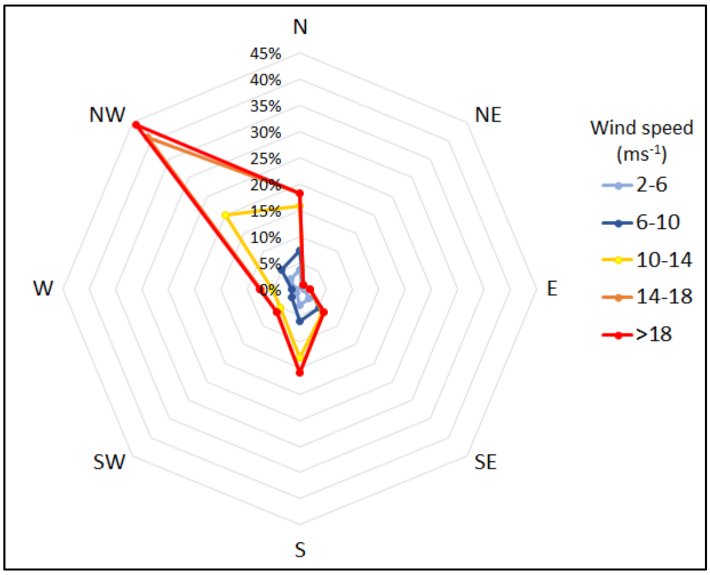

Figure 4: Wind rose for Mt Munro wind farm exploratory mast wind speed and direction data (daily averages), 40m height, 2013-23. Colours are different daily average wind speed bands in ms^{-1}. Percent lines are the % of time wind of that speed comes from that direction.

Average monthly wind speeds at the monitoring mast at the Mt Munro site at 40m height range from 8.7 to 10.6 ms^{-1}, and wind speeds have some seasonality, with speeds normally being highest in spring and lowest in early autumn and winter (see figure 5). Annual average wind speed is 9.5 ms^{-1}. Measurements at this site were taken at 40 metres above ground, so cannot be directly compared with the sites in table 2.

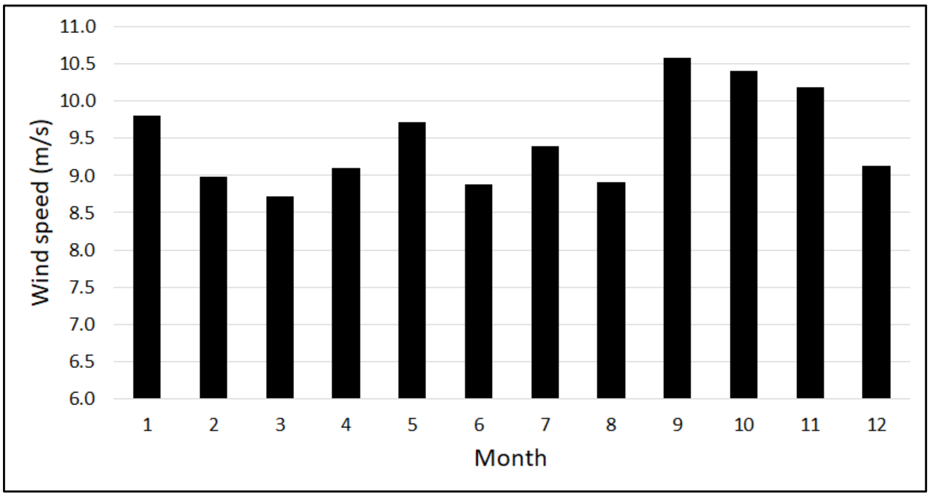

Figure 5: Average monthly wind speeds (ms^{-1}) 2013-2023 at 40 metres at Mt Munro site.

However, there is significant variability around these averages, with the minimum 3 second wind speed recorded over the ten year period being 0 ms^{-1}, and the maximum 3 second wind speed over the ten year period being 53 ms^{-1}, recorded on 24th May 2014 (see figure 6). The maximum wind speeds tend to be higher May through to December, and lower January to April, but there is much variability.

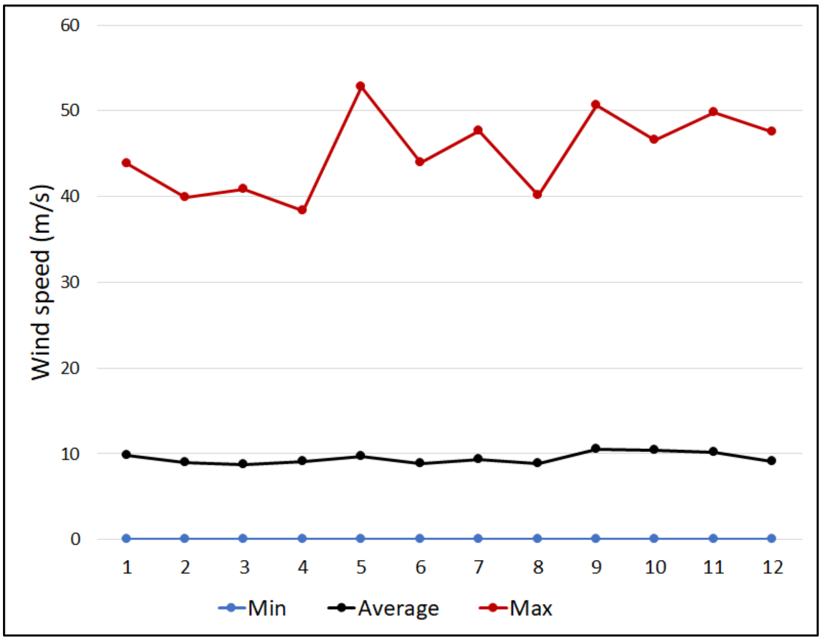

Figure 6: Min, mean, and max 3 second wind speed for each month (2013-2023) recorded at 40 metre height at the Mt Munro site.

The following section discusses what changes are likely to occur globally, nationally, and at the Mt Munro site, in future decades as a result of climate change.

4. Future climate change projections

It is now "unequivocal" that the relatively rapid change in our climate is as a result of human activities[7]. This changing climate will have an impact on the rainfall, temperatures, and wind speeds we will experience in future, relative to the past.

New Zealand has warmed 1.2 degrees over the last century[8]. Increasing trends in annual New Zealand rainfall since the mid-1900s has been noted in most South Island sites, and central North Island sites. Decreasing rainfall trends were noted in Taranaki, Bay of Plenty, Auckland, and Northland.[9]

Trends in annual New Zealand rainfall over the past century are not statistically significant, although some regional and seasonal changes have occurred. Extreme rainfalls (the

[7] IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

[8] NIWA 2024: Annual Climate Summary 2023. https://niwa.co.nz/climate/summaries/annual-climate-summary-2023.

[9] Statistics New Zealand 2024: Rainfall. https://www.stats.govt.nz/indicators/rainfall/

number of days with rainfall over 25mm) have generally increased in the west and decreased in the east in New Zealand over the past century

4.1 Global projections – wind speed

Global projections of future wind speeds are regionally diverse. Although the global stilling phenomenon is projected to continue in many regions, other regions are projected to see increases in wind speeds in coming decades, as atmospheric circulation changes, largely due to differential heating in different regions (see figure 7).

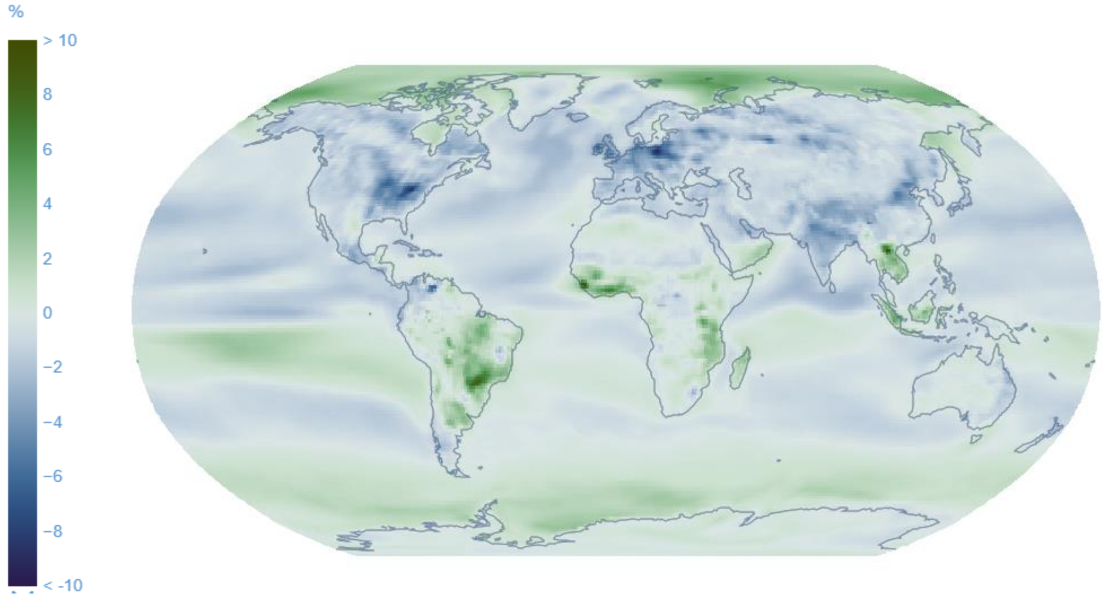

Figure 7: Projected changes to surface wind 2021-2040 (relative to 1981-2010) – CMIP6, Annual, 29 Models. From IPCC (2023)[10]

Projections of wind speed in New Zealand, and how they are estimated, are focussed on in the following sections.

4.2 Downscaling climate change projections for New Zealand

To estimate the impact of climate change on New Zealand, the National Institute of Water and Atmosphere (NIWA) uses ocean-atmosphere state projections out to 2100 from six Global Climate Models (GCMs) (as part of the Global Coupled Model Intercomparison Project Phase 5 (CMIP5)[11] and phase 6[5]). The global models have a resolution of approximately 100-300km, and sea surface temperatures and pressures from these are

[10] IPCC 2023: Interactive Atlas of climate change projections: https://interactive-atlas.ipcc.ch

[11] IPCC 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013; p. 1535.

downscaled initially with the HadRM3P regional atmosphere model (resolution ~27km)[12], and then further statistically downscaled to a 5km grid over the whole of NZ. This process produces projections of such variables as rainfall, temperature, and wind speeds out to 2100, to enable the closer examination of the regional impacts of climate change in New Zealand[13].

Models are run from 1970-2100, so the model can be validated and bias-corrected against recorded observations from the past, to provide error estimates around future projections.

4.3 Representation Concentration Pathways (RCPs)

The higher the global greenhouse gas (GHG) emissions in coming decades, the bigger the impact will be on global climate, including New Zealand climate. The International Panel on Climate Change (IPCC) uses four Representative Concentration Pathways (RCPs) to represent the impact on the climate from low, moderate, moderate-high, and high emissions pathways. These RCPs are denoted RCP 2.6, 4.5, 6.0, and 8.5 and represent the change in radiation reaching the earth by 2100, (expressed in watts per square metre; Wm^{-2}) which will be caused by the emissions scenario they represent. The latest IPCC report[5] uses a different nomenclature for future pathways, that of "Shared Socioeconomic Pathways", or SSPs. Whereas RCPs describe the amount of greenhouse gases in the atmosphere and the resulting likely warming, SSPs describe the Socioeconomic pathways that would lead to those RCPs. As current NIWA downscaling uses RCPs, those are reported on here.

NIWA uses the RCPs in their modelling, so that projections of New Zealand climate variables can be compared between low and high emissions futures[14]. See Table 2 for a list of the RCPs and their corresponding emissions trajectory. The IPCC (2014)[15] denotes RCP4.5 and 6.0 as the mid-range "stabilisation" pathways. The actual pathway will depend on international geopolitics around emissions reductions, which is changing constantly. A recent paper suggests RCP 3.4 may be the most likely outcome[16], but as modelling of NZ wind speeds is only available in either RCP 2.6 or RCP 4.5, RCP4.5 is used as the "most likely" future scenario in this report.

[12] Ackerley et al 2012 Regional climate modelling in New Zealand: Comparison to gridded and satellite observations. Weather Clim. 2012, 32, 3–22.

[13] MfE 2018: Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition. Wellington: Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/Climate-changeprojections-2nd-edition-final.pdf

[14] Sood and Mullan 2020: Projected changes in New Zealand drought risk: an updated assessment using multiple drought indicators. NIWA Client Report 202001WN1

[15] IPCC 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[16] Pielke JR., Roger 2021: "Most plausible 2005-2040 emissions scenarios project less than 2.5 degrees C or warming by 2100". osf.io. doi:10.31235/osf.io/m4fdu.

Table 2: Representative Concentration Pathways and their corresponding emissions trajectory

RCP	Emissions trajectory
2.6	Low
4.5	Mid
6.0	Mid-high
8.5	High

4.4 Climate projections for NZ

4.4.1 Temperature and rainfall projections

New Zealand is expected to warm by 0.5 to 1.5 degrees by mid-century. It is projected to get wetter in the south and west of the country, and drier in the north and east, on an annual basis, over time. Figure8 shows projected changes to temperatures and rainfall by end of century under a mid-range emissions scenario.

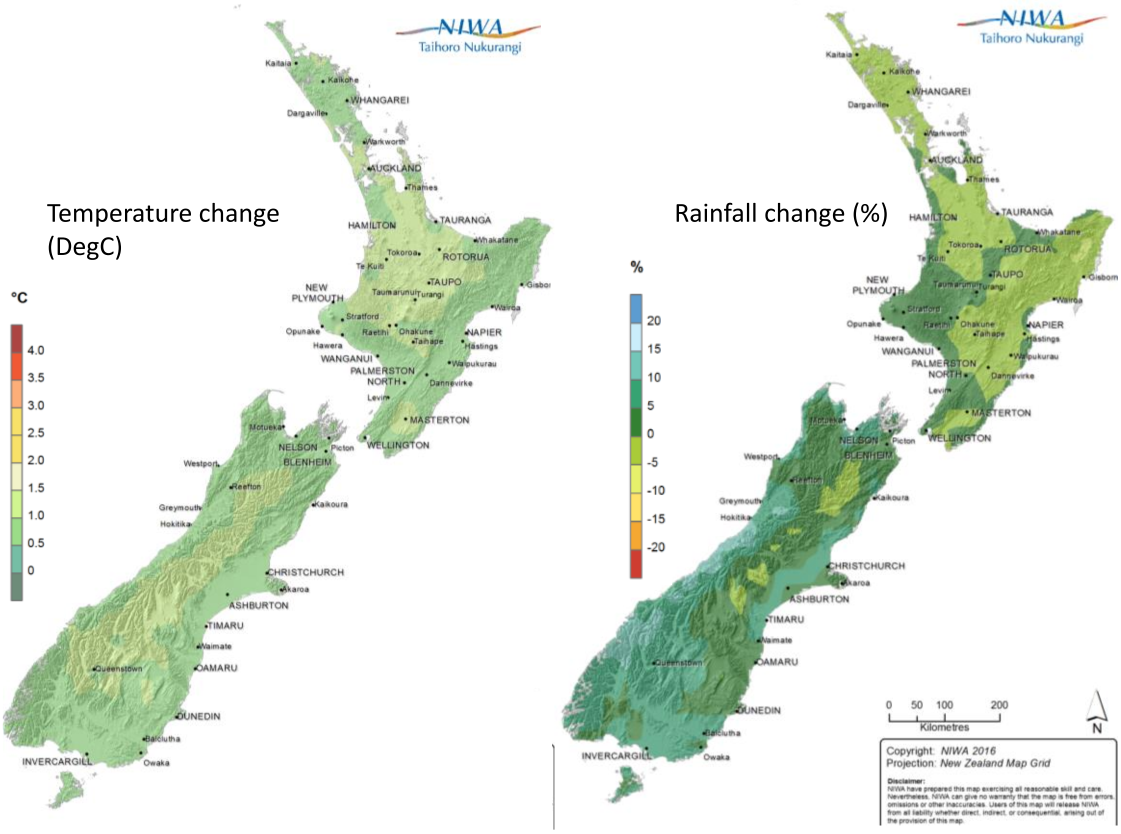

Figure 8: Projections of annual temperature (left) and precipitation (right) change between 1995 and 2050 under RCP6 (mid-high emissions scenario) (OFCNZ 2023)[17].

[17] Our Future Climate New Zealand 2023: https://ofcnz.niwa.co.nz/#/home

Inland areas of New Zealand are expected to warm about half a degree more than the coast, which is moderated by the proximity of the ocean. Rainfall is expected to get generally wetter in the west and south of New Zealand, and drier in the north and east.

4.4.2 Wind speed projections

Regional atmospheric circulation changes are likely to result in increased wind speeds in the South Island, and reduced wind speeds in the North Island, generally. Projected changes to strong winds by the end of the century under a high emissions scenario can be seen in figure 9.

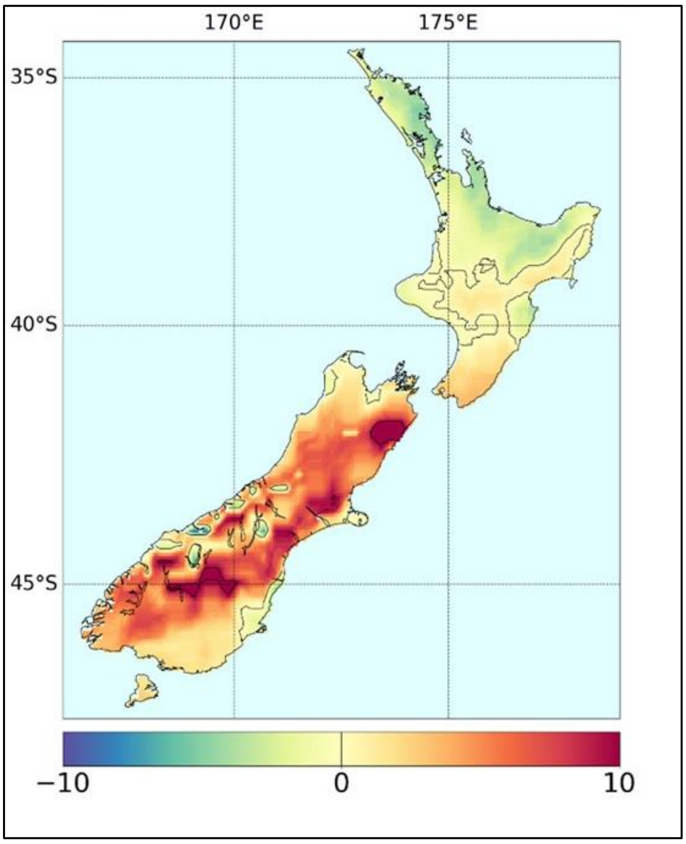

Figure 9: Projected changes in extreme (99th%ile) daily wind speed (%) by 2090, for the mean of 6 climate models under RCP8.5 from the IPCC 5th Assessment (NIWA 2023b)[18]

[18] NIWA 2023b: Climate scenarios. https://www.niwa.co.nz/our-science/climate/information-andresources/clivar/scenarios

4.5 Projections of future wind at Mt Munro site

Impacts from anthropogenic climate change are already being felt around the world, and changes to wind speeds will likely be seen over the life of the Mt Munro wind farm.

As was seen in figure 9, NIWA's future wind projections show larger impacts in the far north (lighter wind speeds) and far south (stronger wind speeds) of New Zealand. Mt Munro's site, located close to the centre of these two extremes, is only expecting small changes to wind speeds over the next few decades.

Figure 10 shows projected changes (%) to wind speeds at different times of the year for the Mt Munro wind farm region by 2050, for low, mid, and high range emissions scenarios.

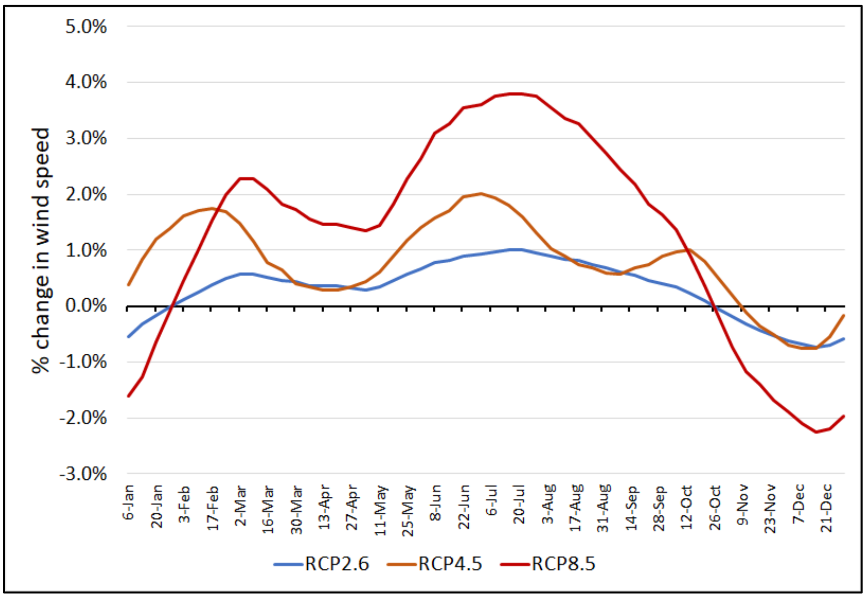

Figure 10: Projected changes to wind speed by mid-century (relative to 2000-20) at Mt Munro wind farm site, for a low emissions (RCP2.6), mid-road (RCP4.5) and high emissions (RCP8.5) future. Data from Dr Richard Turner, NIWA.

Wind speeds are expected to get faster in winter, and slower in summer, in future.

When these wind speed changes are added to Mt Munro historical wind speeds from a ten year exploratory met mast record, average weekly wind speeds for 2050 can be projected (see figure 11).

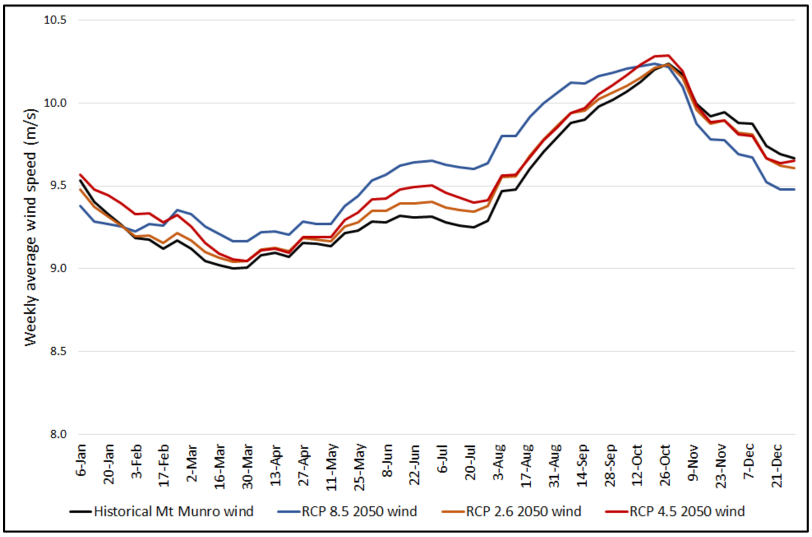

Figure 11: Mt Munro average weekly wind speed 2013-23, and average weekly wind speed adjusted for 2050 future projected wind speed under three different emissions scenarios: RCP2.6, RCP 4.5, RCP 8.5.

Although the maximum difference in wind speed by 2050 occurs in July in all three emissions scenarios, the average annual difference in wind speed by 2050 is small – only +1.3% under a mid-road emissions scenario (see Table 3).

Table 3: Annual projected average change in wind speed at Mt Munro site between 2020 and 2050, for different emissions trajectories.

RCP2.6	0.3%
RCP4.5	1.3%
RCP8.5	1.5%

An important factor for wind farm operation is any likely future changes to *extreme* wind events. If large increases to wind speeds did occur in future, this could result in *less* generation at wind farm sites, as turbines may reach cutoff speed more often. Stronger wind speeds may also result in more damage to turbines.

NIWA projections of wind speeds for the Mt Munro site generally show a small increase in wind speeds across the entire distribution over the next 30 years. Two sites proximal to the Mt Munro site (where projections are available), both project increases to minimum, mean, and maximum wind speeds (see Table 4), showing that wind speed increases are projected for the whole distribution. The average of projections for these two sites (Palmerston North and Waione) are used as a proxy for future changes at the Mt Munro site.

Table 4: Projected changes in different percentiles of wind speed at Palmerston North and Waione sites 2020-2050, and the average of the two sites (proxy for Mt Munro site). Change in rolling 1 year percentiles over time (data from Dr Richard Turner, NIWA).

	RCP2.6	RCP4.5	RCP8.5
Min	0.2%	1.5%	2.0%
5th%ile	-0.3%	1.2%	0.8%
Median	0.3%	1.3%	1.5%
95th%ile	0.4%	0.8%	1.3%
Max	0.4%	0.8%	1.4%

This shows that increases in minimum wind speeds (+1.5% increase) as well as increases in median wind speeds (+1.3%), and maximum wind speeds (0.8%) may be expected at the Mt Munro site over the life of the wind farm, under the most likely emissions scenario (RCP4.5). See also this data displayed in figure 12.

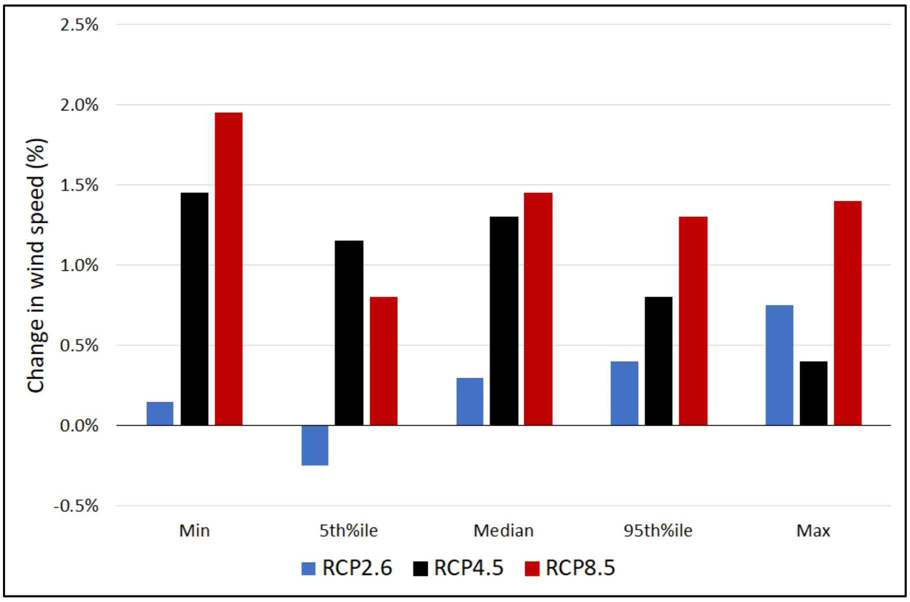

Figure 12: Projected changes in different percentiles of wind speed estimated for the Mt Munro wind farm site 2020-2050. (Data from Dr Richard Turner, NIWA).

These changes are small, and if they occur they are not expected to increase time above cutoff speed significantly, or incur major damage to turbines, relative to today's conditions.

5 The global and national energy transition

5.1 Climate change, global agreements, and national legislation

One hundred and ninety seven (197) countries have signed the Paris Agreement to reduce anthropogenic greenhouse gas emissions, in an effort to curb runaway climate change, but global emissions are still rising and a certain level of climate change is now inevitable.

New Zealand is a signatory to the Paris Agreement, and has committed, under it's Climate Change Response (Zero Carbon) Act (2019) to reduce anthropogenic long lived greenhouse gas emissions to 30% below 2005 levels by 2030, and to net zero by 2050.

The Zero Carbon Act legislated for the setting up of the Interim Climate Change Committee (ICCC), who's report[19] "Accelerated Electrification" advocated for significant electrification of transport and industrial heat as a primary means to significantly reduce GHG emissions from these sources.

The ICCC was the precursor to the Climate Change Commission (CCC), who's first report to government[20] (Climate Change Commission 2021) provided advice to the New Zealand Government on its first three emissions budgets and direction for its emissions reduction plan 2022 – 2025.

The government's first Emissions Reduction Plan (ERP) 2022 (MfE 2022) talks of the importance of using "our highly renewable electricity system to further electrify industry and transport", and the plan aims to phase out fossil fuels while "massively ramping up renewables in transport, electricity generation and industry".

5.2 New Zealand's current electricity system

New Zealand's electricity system is currently 84% renewable (average of last 5 years). Generation in 2022 was primarily from hydro generation (58%), with lesser amounts from coal (4%) and gas (12%), geothermal (18%), wind (6%), and solar (<1%). There were also small amounts of biomass based generation (1%) (see figure 13).

[19] ICCC 2019: Accelerated electrification – evidence, analysis, and recommendations, 30th April 2019, 120pp. https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ICCC-accelerated-electrification-report.pdf

[20] CCC 2021: Ināia tonu nei: a low emissions future for Aotearoa – advice to the New Zealand Government on it's first three emissions budgets and direction for it's emissions reduction plan 2022-2025, 418pp. https://www.climatecommission.govt.nz/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa.pdf

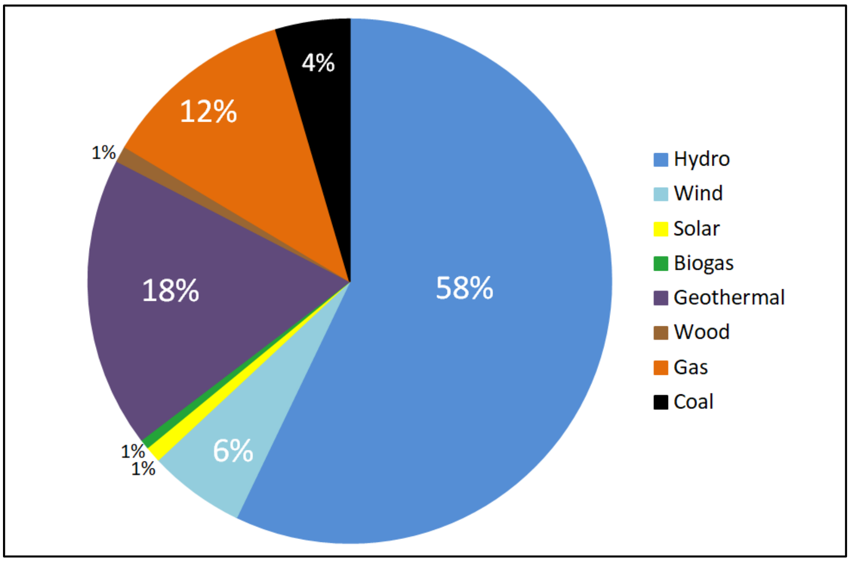

Figure 13: Current annual (2022) electricity generation by type, New Zealand[21]

The contribution of different types of generation to the electricity system is set to be transformed in coming decades, as old thermal plant is displaced by new renewable generation, and new generation plant to supply increasing demand is predominantly renewable.

5.3 New Zealand's future electricity system

The drive for electrification to decarbonise facets of society is expected to increase electricity demand significantly in coming decades. In the absence of a definitive plan to reduce agricultural emissions, electrification is currently the strongest tool in New Zealand's decarbonisation toolbox.

The Climate Change Commission estimates that all new light vehicles entering New Zealand's vehicle fleet will be electric by 2035, and Concept Consulting[22] estimates that by 2040 ~40% of New Zealand's overall vehicle fleet will be electric. There will also be significant electrification of process heat and other industrial processes. Transpower (2020)[23] estimates that, due to the decarbonisation imperative, an ever- increasing portion of our energy use will come from electricity. They estimate that electricity as a proportion of total delivered energy demand will increase from 25% today to 58% by 2050. This increase in electricity demand will require significant new build of generation capacity.

[21] MBIE 2023: Electricity Statistics. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/

[22] Concept consulting 2018: Driving change - Issues and options to maximise the opportunities from large-scale electric vehicle uptake in New Zealand, Mar 2018. https://www.concept.co.nz/uploads/1/2/8/3/128396759/ev_study_v1.0.pdf

[23] Transpower 2020: Whakamana i te Mauri Hiko Empowering our Energy Future, Mar 2020, 89pp. https://tpow-corp-production.s3.ap-southeast-2.amazonaws.com/public/publications/resources/TP%20Whakamana%20i%20Te%20Mauri%20Hiko.pdf?VersionId=FljQmfxCk6MZ9mIvpNws63xFEBXwhX7f

As well as electrification, other factors influencing electricity demand over the next few decades include the prospect of new, energy intensive industry in New Zealand. For example, a large green hydrogen plant is planned for Southland[24], potentially requiring 600MW of electricity, and several data centres (20-100MW each) are likely to be built in New Zealand in coming years[25]. Tiwai point Aluminium smelter is exploring remaining open, beyond their current close date of 2024[26]. ONE new large industry, such as those mentioned, would result in the need for another 6-7 wind or solar farms the size of the proposed Mt Munro wind farm.

The New Zealand electricity system will therefore have three main tasks in the near future:

- Firstly, existing fossil fuel electricity generation plant (coal, gas, diesel) will have to be replaced by renewable generation as it retires (likely by 2035).
- Secondly, significant new generation will be required for a) the mass electrification of transport and industrial heat, and b) the electricity requirements of any new industry.
- And thirdly, retiring renewable plant nearing end of life will require replacement. This is difficult to quantify, as many renewable generators are likely to just have key components replaced and keep generating, but it could equal approximately 1-5 TWh of plant over the next 30 years.

5.4 Impact of decarbonisation on electricity demand

There will be large increases in electricity demand resulting from the three drivers mentioned above. Estimates of demand increases vary depending on the assumptions included in various models, but all result in large increases from today's ~43TWh national annual electricity demand. Estimates of total New Zealand electricity demand range from 70TWh[20] to 80-100TWh[27] by 2050. The Climate Change Commission[17] estimates that 1 TWh of new electricity generation will be needed every year from 2026 to 2035, and will increase after that.

Most of this demand increase is from the electrification of the transport and industrial heat sectors (see figure 14). Increases to base demand (due to growing population and productivity) are expected to be offset by increases in efficiency, particularly in the NZ housing stock, keeping this increase small. Base demand from increases in population and productivity is expected to rise at <1% per year, totalling a 14% increase by 2050[20]. In Transpower's modelling[20], vehicle electrification is expected to increase electricity demand

[24] Stuff, 2023: Partner confidence high for Southern Green Hydrogen. Newspaper article. https://www.stuff.co.nz/southland-times/news/132145485/partner-confidence-high-for-southern-green-hydrogen

[25] Driver 2022: Aotearoa, land of the digital cloud. North and South magazine, July 2022 edition, pg44. https://northandsouth.co.nz/2022/06/12/data-farming-data-grid-new-zealand/

[26] Newsroom 2023: Tiwai smelter sees path to remain open. https://www.newsroom.co.nz/tiwai-smelter-sees-path-to-remain-until-2039#:~:text=In%20a%20letter%20to%20Government,current%20closure%20date%20of%202024.

[27] Business Energy Council 2019: New Zealand Energy Scenarios TIMES-NZ 2.0, https://times.bec.org.nz/

by 38% by 2050, and process heat is expected to increase it by 16% which, with base increases, may result in a total increase in electricity demand of 68% by 2050 (to 70TWh).

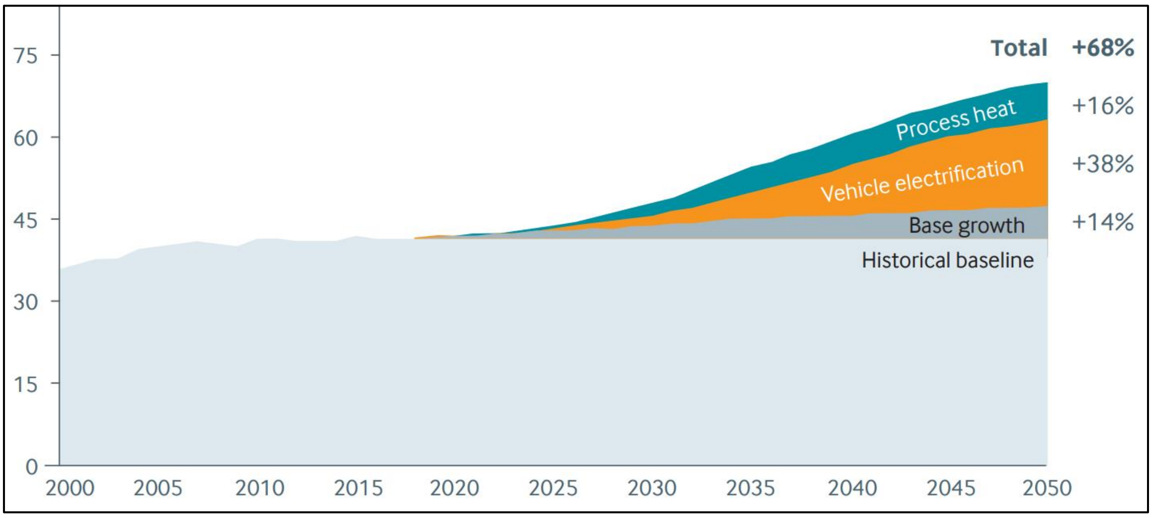

Figure 14: Electricity demand projection out to 2050, showing different drivers behind generation growth[20]

New Zealand's electricity infrastructure will have to grow to cater for this increased demand.

5.5 New capacity build

To largely electrify the transport and industrial heat sectors, and to move towards a 100% renewable electricity system, will require significant new infrastructure build, and this building is needed at pace.

The lion's share of new build is projected to be wind generation, and to a lesser extent solar generation. Hydro generation capacity is not expected to increase much in the next few decades, due to the significant regulatory and policy barriers in building new large hydro schemes, as well as the difficulty in getting public acceptance for flooding land to create hydro storage lakes. Some new geothermal generation will be built, but will be limited by the small number of new sites with geothermal resource which are available for development. A projection of the potential future generation mix can be seen in figure 15[28]

[28] MDAG 2022: Market Development Advisory Group – Price discovery under 100% renewable electricity supply – issues discussion paper, 2nd February 2022. https://www.ea.govt.nz/projects/all/pricing-in-a-renewables-based-electricity-system/consultation/price-discovery-under-100-renewable-electricity-supply/

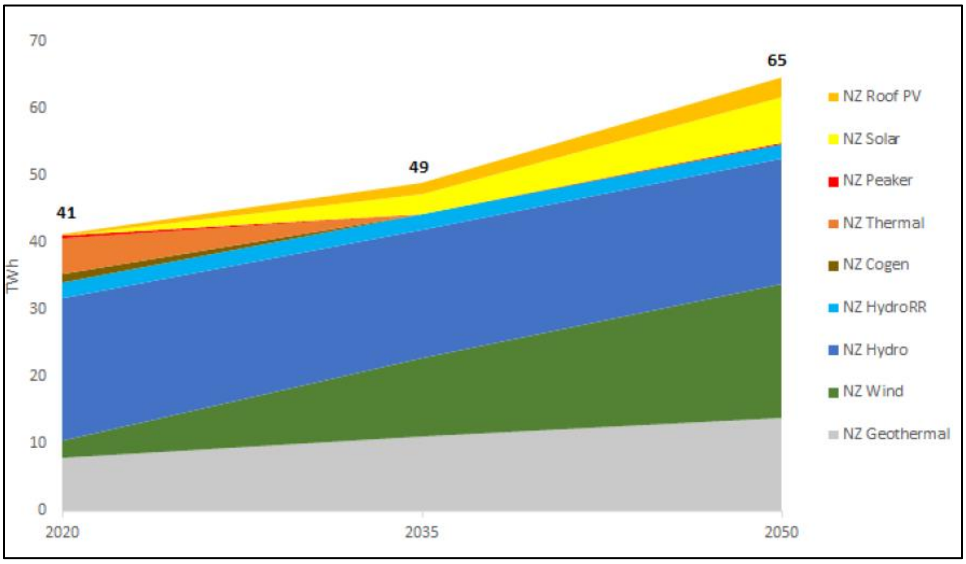

Figure 15: Projected sources of NZ electricity generation out to 2050[25].

In this scenario, almost half (47%) of total electricity supply comes from intermittent sources (wind and solar) by 2050. Wind generation grows by approximately 20TWh, which implies the need for an additional 66 wind farms the size of the proposed Mt Munro wind farm by 2050, or 2 new wind farms a year.

Mt Munro wind farm will have a capacity of 86MW, with an estimated output of ~300GWh per year (0.3TWh/yr). This is enough to supply ~42,000 households, and is a small but significant contribution to New Zealand's required capacity increase. MBIE's Electricity Demand and Generation Scenarios (2019)[29] have several scenarios of new generation build out to 2050, with different assumptions in their modelling (see figure 16). Most of their scenarios estimate 4000MW of new wind farm capacity will be needed by 2050, which is equivalent to 44 wind farms the size of the proposed Mt Munro wind farm. With less than one wind farm a year being built in New Zealand over the last 20 years, there is some urgency around the need to build new wind farms.

[29] MBIE 2019: Electricity demand and generation scenarios: Scenario and results summary, 40pp. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/electricity-demand-and-generation-scenarios/

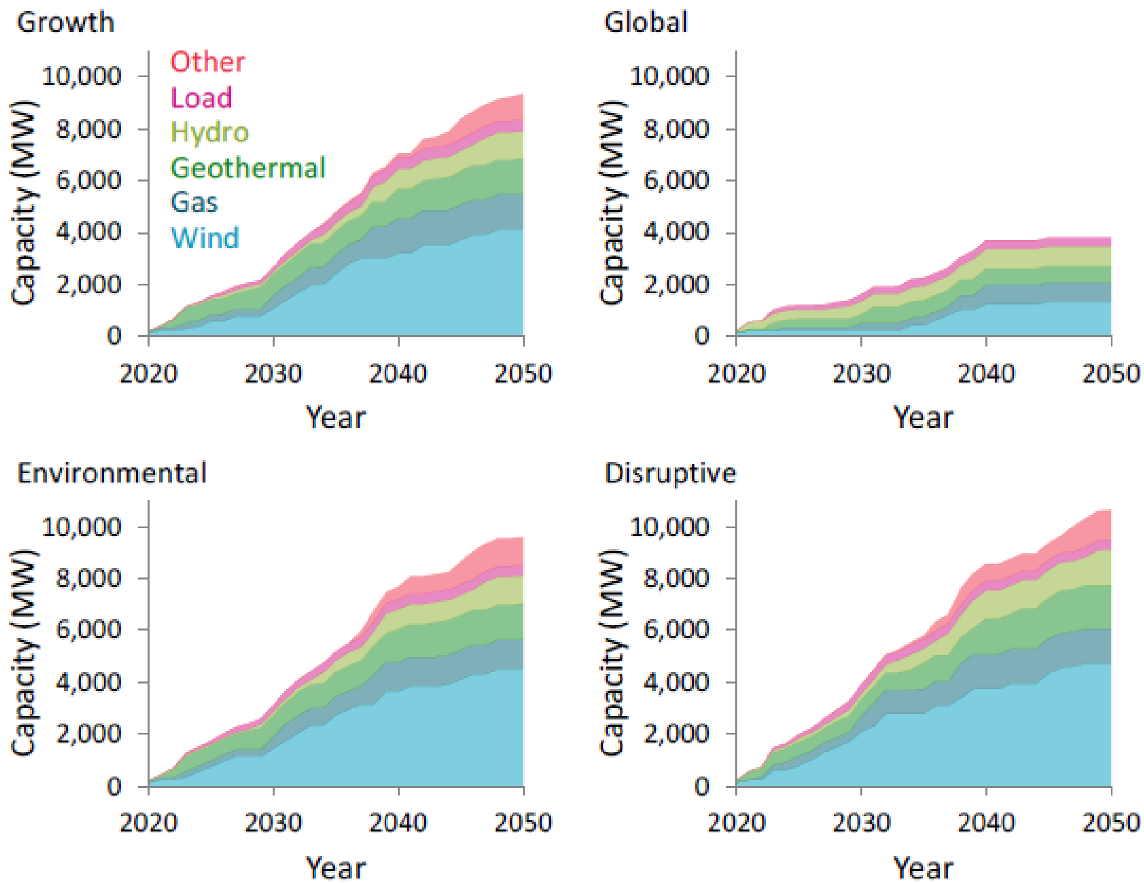

Figure 16: Four MBIE EDGS scenarios of growth of electricity generation in New Zealand, 2020-2050[30].

Since the MBIE EDGS scenarios were published in 2019, there has been a proliferation of proposals to build new solar generation in New Zealand, as the Levelised Cost of Energy (LCOE) for solar generation has plummeted in recent years. Nonetheless, wind is still estimated to be predominant in new renewable energy capacity builds in New Zealand in the next couple of decades[30]. Solar and wind generation are the cheapest forms of electricity generation available[30], and significant capacity of these generation forms are expected to be built.

5.6 Intermittency and firming

The movement of an electricity system towards 100% renewable necessitates the building of renewable generation that is inherently intermittent in it's output, as it varies with the weather and time of day and year. No electricity can be generated from these sources when the wind stops blowing or the sun stops shining. Historically, thermal generation, such as coal or gas, has been turned on or off when the hydro lakes are dry or there is little wind generation. In a 100% renewable system, an alternative to this firm dispatchable thermal plant is needed. Potential solutions to firming intermittency include hydro storage, pumped storage, grid scale batteries, or demand response (reduction in usage by electricity consumers at times of shortage of supply). A diversity of generation types and geographical locations assist in firming up intermittency, to ensure generation by *some* plant when other plant is not generating. Another potential solution is overbuild, where more capacity is built than is needed, so that there will be *some* plant generating at any given time. If overbuild is needed to counter renewable intermittency, then new capacity volumes may be much higher than currently estimated.

6 Summary

New Zealand has a good wind resource, and over most of New Zealand (except the north of the North Island), wind speeds are expected to increase over time due to anthropogenic climate change.

The proposed Mt Munro wind farm site has a good wind resource, based on 10 years of local measurements by an exploratory mast. In future these wind speeds are projected to get slightly faster in winter, slower in summer, and increase by about 1.3% annually by 2050. This small increase is not expected to significantly alter wind generation at the site, or result in damage to turbines.

New Zealand's decarbonisation strategy includes accelerated electrification, particularly of transport and industry. This electrification is projected to potentially double electricity demand by 2050, resulting in the need for significant new generation infrastructure. Projections of electricity demand vary, but all project the need for between 1 and 2 wind farms a year to be built every year from now until 2050, at least. With less than one wind farm a year being built in New Zealand over the last 20 years, there is some urgency around the need to build new wind farms to meet New Zealand's decarbonisation goals.

7 Acknowledgements

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8 Disclaimer

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