

## Four seasons in a day

*Forecasting intermittent generation in New Zealand*

### Introduction

New Zealand has a relatively high proportion of renewable generation. Over the 5-year period (2016-2020), 83%<sup>1</sup> of New Zealand generated electricity came from renewable sources (59% hydro, 18% geothermal, 5% wind, with the remaining 2% from biogas, wood and solar) as shown in Figure 1. New Zealand's commitments to reduce greenhouse gas emissions, the falling costs of renewable generation technology (such as wind and solar)<sup>2</sup> and changing social sentiment towards environmental sustainability point towards a future where it seems more likely than not that we will have a higher proportion of our electricity needs being supplied by renewable generation.

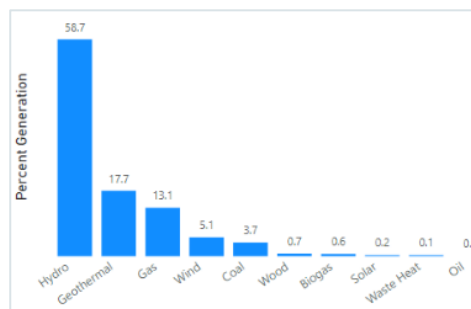


Figure 1

Increased wind and solar generation will likely play a large role in the future renewable generation fleet, however they both are intermittent generation sources<sup>3</sup> which poses challenges in managing the power system. Intermittency means the electricity produced from these generation sources is:

- variable as it depends on the amount of wind that's blowing and its direction and sunlight<sup>4</sup> which can change (sometimes quickly)
- uncertain as weather conditions affecting its output (such as wind speed and direction and amount of sunlight) is generally difficult to forecast further into the future.<sup>5</sup>

The electric power system needs to be operated within its stable operating range. This means ensuring assets are not overloaded or at risk of overloading and the power system generation-load balance is always maintained<sup>6</sup>. Therefore, understanding the variability and uncertainty in output from intermittent generation sources and the impact it may have on asset loading and the generation-load balance is important for the system operator who is responsible<sup>7</sup> for managing the real-time power system and operating the wholesale electricity market. It is also important for the electricity market, as more accurate forecasts and greater understanding of the uncertainty in wind and solar generation can be used to provide better price information for market participants to make more efficient production and consumption decisions.

<sup>1</sup> Ministry of Business Innovation and Employment (MBIE) ([electricity statistics](#))

<sup>2</sup> See studies undertaken by [Transpower](#) and the [Climate Change Commission](#).

<sup>3</sup> Installation of on-site batteries can help smooth the output from intermittent generation sources. Energy stored in the battery is injected into the grid when the output from the wind or solar generation site unexpectedly drops-off thus compensating for the reduced output. Installing batteries as part of the wind or solar generation project increases the project costs and therefore can impact the viability of the generation project however battery costs are reducing.

<sup>4</sup> Some other key factors affecting solar PV output are temperature and relative humidity.

<sup>5</sup> As anyone who has had to suddenly grab the washing off the line would know too well.

<sup>6</sup> There are also electrical losses in transporting power across the grid. In this assessment we consider this as part of the load. The generation-load balance is sometimes called supply-demand balance.

<sup>7</sup> In managing the real-time power system and operating the wholesale electricity market, the system operator is dependent on the information provided to it by market participants (such as asset capability and availability) and the actions of participants.





Forecasting tools can provide benefits in helping the system operator and market participants better understand intermittent generation uncertainty and with an increase in intermittent generation sources expected, this benefit is likely to increase. This insights paper looks at some of these issues and some of the future work the system operator has planned for intermittent generation forecasting.

### Wind and solar generation

#### Current status

New Zealand currently has approximately 823 MW of installed wind generation capacity, including the recently added Waipipi wind farm (133 MW), which came online in November 2020. At the time of writing this report, a further 222 MW is under construction at Mercury’s Turitea wind farm, which is expected to be online in the coming months. This will bring the total installed wind generation capacity up to 1,045 MW<sup>8</sup>.

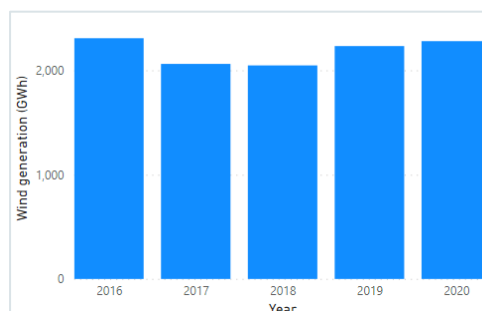


Figure 2

In the last five years there has not been much wind generation build with annual wind generation fluctuating between 2-2.3 TWh (Figure 2) with an average capacity factor<sup>9</sup> of 36%. Over this 5-year period the annual average wind generation was 2.18 TWh<sup>10</sup>. The addition of Waipipi and Turitea is expected to increase this annual output by 1.3 TWh<sup>11</sup> to 3.48 TWh (a 56% increase).

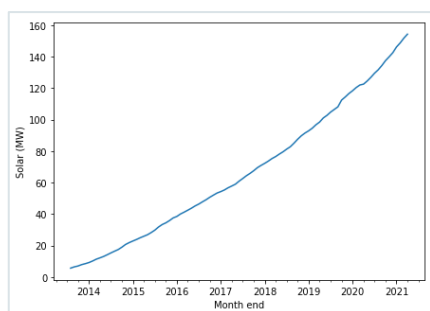


Figure 3

Most of the current installed solar generation in New Zealand is from photovoltaics<sup>12</sup> (PV) installed on distribution networks. The Electricity Authority’s emi database indicates the installed capacity of solar PV generation of ~155 MW as at 30 April 2021, which has been increasing<sup>13</sup> steadily though from a much smaller base as shown in Figure 3. MBIE estimates solar generation for 2020 was 159 GWh<sup>14</sup> which indicates an average annual capacity factor of 14%<sup>15</sup>.

<sup>8</sup> For details on the different wind farms, see [New Zealand Wind Energy Association](#)

<sup>9</sup> Capacity factor measures the average hourly energy output relative to the installed capacity. This can indicate how much the installed capacity is being utilised to deliver energy. A higher capacity factor indicates greater utilisation of the installed capacity.

<sup>10</sup> Excluding the Waipipi generation from November 2020.

<sup>11</sup> Based on expected annual energy outputs of 455 GWh from Waipipi (as reported by [Tilt](#)) and 840 GWh from Turitea (as reported by [Mercury](#)).

<sup>12</sup> Photovoltaics (PV) is the conversion of light into electricity using solar cells made of materials that exhibit the photoelectric effect. This causes them to absorb light and release electrons which when captured can provide electric energy.

<sup>13</sup> This does not include the recent addition of the 2.1MW [Kapuni solar farm](#).

<sup>14</sup> MBIE’s energy statistics estimated distributed solar PV generation has been estimated using Electricity Authority data.

<sup>15</sup> Calculated using the average installed capacity of distributed solar generation in 2020 which was 122 MW.





In the 2020 calendar year, wind generation made up 5% of the total energy generated with an estimated 0.4% from solar generation.

The variability of intermittent generation such as wind and solar is not captured when looking at annual energy outputs. For this we need to look at shorter timescales. Figure 4 shows the half-hourly generation at several New Zealand wind farms during a week in April 2021. Here we see variation in output across both location and time based on local wind conditions and plant outages.

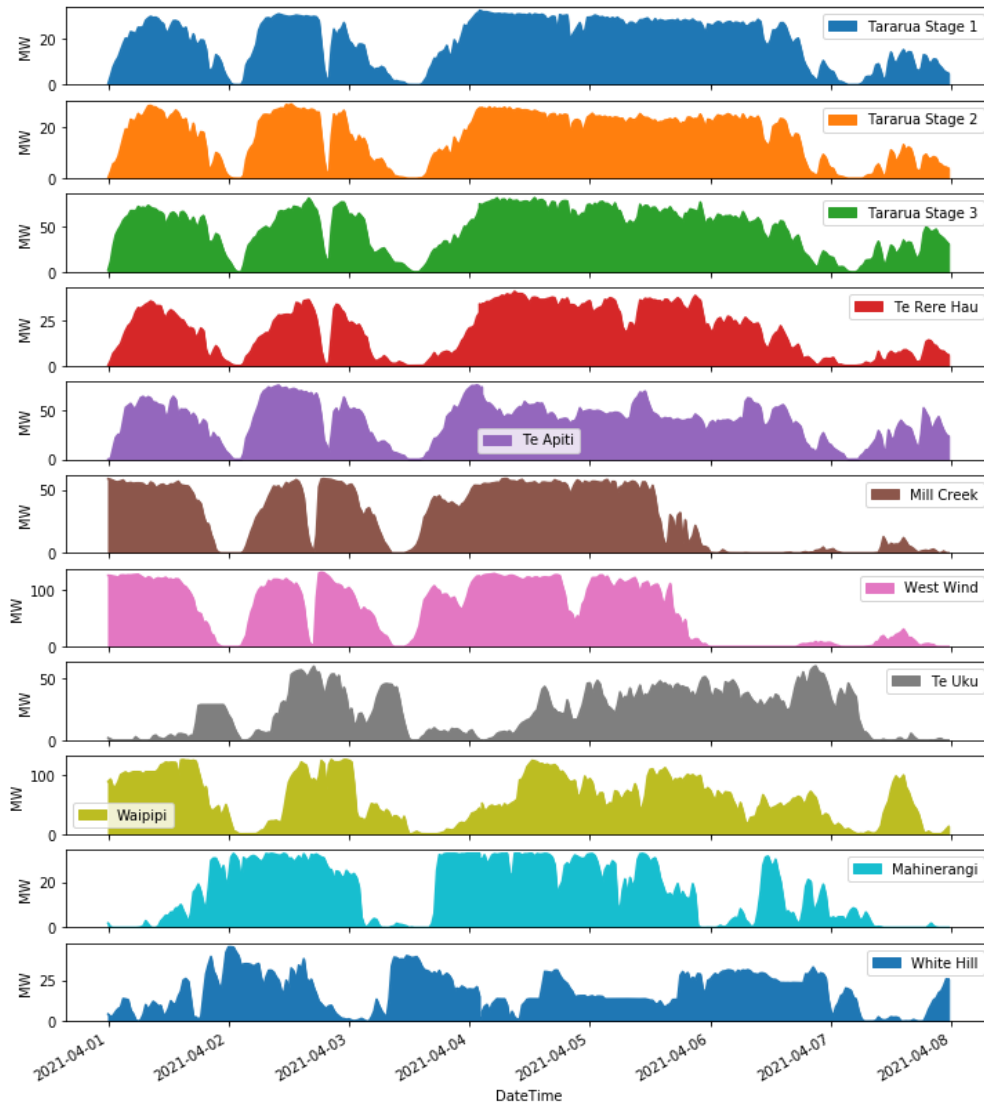


Figure 4

Wind farms located in relatively close proximity are exposed to the similar wind conditions and tend to have positively correlated outputs, as seen in the generation profiles of the Tararua, Te Rere Hau and Te Apiti wind farms all located near Palmerston North and the West Wind and Mill Creek wind





farms located near Wellington. The wind generation output at other locations are less well correlated<sup>16</sup>.

Most of our current solar generation is “behind-the-meter” for which we do not have half-hourly metering. To demonstrate potential variations at these shorter-time scales, we used simulated hourly outputs of a 1kW solar PV array (with no tracking) at several different locations in New Zealand<sup>17</sup>. While the simulated solar PV output at the different sites have the distinctive daily profiles, even at the hourly timescale, we observe variations in output at the different locations due to variations in sunlight<sup>18</sup> at the different locations as shown in Figure 5.

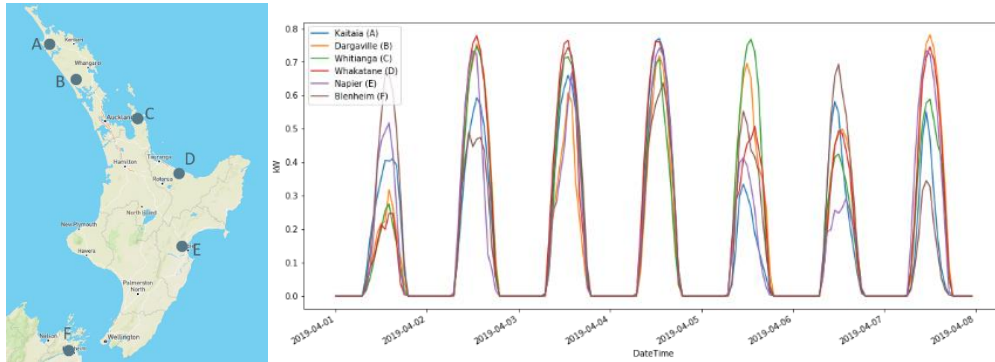


Figure 5

As indicated earlier, understanding and forecasting shorter-term variations in intermittent generation output is important for the system operator to manage the potential impact this variation may have on grid constraints and the generation-load balance.

There are also potential market impacts. Intermittent generators such as wind and solar PV have low short-run marginal costs as the primary fuel (wind and sunlight) is free. There are however operating and maintenance costs. Therefore, these generators would tend to have lower-priced energy offers if participating in the wholesale electricity market. Alternatively, if these generators are installed “behind-the-meter” they would reduce the demand in the wholesale market and the variability would be visible through increased variation in the wholesale market demand. When wholesale prices are elevated (such as when lake levels are lower than expected), the wholesale electricity supply curve can be sensitive to small changes in demand or supply capability. Under these conditions, the output of intermittent generation can have larger impacts on the wholesale spot price. Figure 6 provides an illustration of this relationship in the first five months of 2021 when there

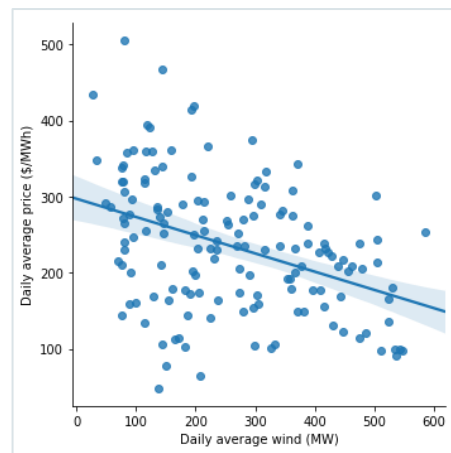


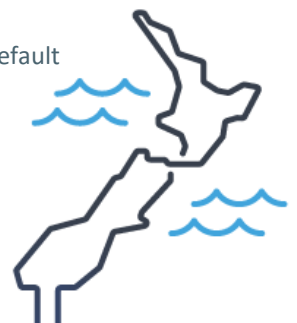
Figure 6

Figure 6 provides an illustration of this relationship in the first five months of 2021 when there

<sup>16</sup> A more detailed illustration of the cross-correlation of output across the different wind farms during this week is provided in the Appendix.

<sup>17</sup> Simulated profiles were from the following site: <https://www.renewables.ninja/> using the default assumptions on the website for the solar PV array.

<sup>18</sup> For example due to cloud cover or shading.





were reduced hydro inflows and elevated wholesale market prices<sup>19</sup>. Here we see the trend of increased wholesale spot prices during days with lower wind generation.

More accurate forecasts of intermittent generation in the market can provide better price signals. As an example, if the forecasted amount of intermittent generation is too low, it could result in forecast prices being too high which might result in some price-responsive demand reducing output in anticipation of higher spot prices that do not eventuate. These elevated forecast prices could also incentivise higher-cost generation with minimum running constraints to choose to continue generating in the expectation of higher spot prices that do not eventuate as the wind generation increases and reduces prices during real-time. In this scenario, both the load and generator could have made different consumption and production decisions had the price forecast been more accurate. Over-forecasting intermittent generation would have opposite effects due to forecast prices being too low.

### Looking ahead

There appears to be broad consensus that wind and solar generation will play a larger role in New Zealand's electricity generation future with declining costs for these generation types with technological advancements and efficiencies of scale with increased global uptake, New Zealand's emission reduction commitments and the changing social attitudes towards environmental sustainability.

Figure 7 provides a comparison of the current wind and solar generation capability and potential future wind and solar generation capability from different studies of future generation and demand<sup>20</sup>. These studies indicate wind generation is expected to increase from 5% in 2020 to ~15-35% of total generated electricity by 2035. The TIMES-NZ 2.0 scenarios<sup>21</sup> indicate minimal solar generation development prior to 2045 with solar remaining largely at its current proportion of total generation by 2035 (i.e. ~0.4%). Given the recent announcements by [Lodestone Energy](#) on the addition of 400 GWh of solar generation (which is ~2.5 times existing solar generation), we consider it reasonable for the future solar capability to include at least an additional 400 GWh of solar generation over the current levels. Using this adjustment, Figure 7 shows a potential increase in solar generation as a proportion of total generation from the current level of ~0.4% to 1.1-8%<sup>22</sup>.

<sup>19</sup> This was discussed in one of our [weekly market summary](#) reports.

<sup>20</sup> These include studies undertaken by [Transpower](#), [Climate Change Commission](#), [BusinessNZ Energy Council \(BEC\)](#) and [Energy Efficiency and Conservation Authority \(EECA\)](#).

<sup>21</sup> EECA and BEC delivered the Times-NZ 2.0 scenarios in partnership.

<sup>22</sup> As indicated by the dashed lines from the current levels.



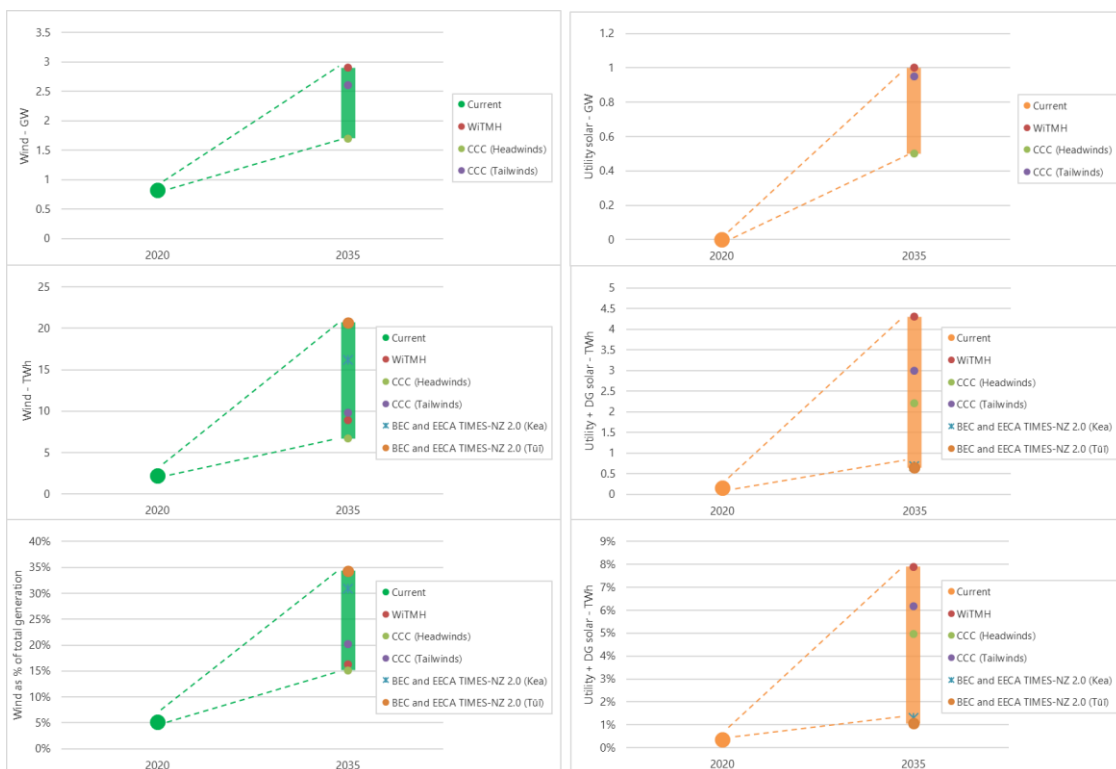


Figure 7

Recent new generation announcements have been consistent with these expectations of increased wind and solar generation with [Meridian](#) announcing the construction of the 147 MW Harapaki wind farm and as discussed above, [Lodestone Energy](#) announcing development of New Zealand’s largest solar generation development with 229 MW of utility-scale solar capacity in the upper North Island.

### Observations from our wind forecast trial

In August 2019, the system operator undertook a 10-month wind forecast trial with an external third party to better understand the differences between the quantity of wind generation offered into the wholesale electricity market compared to the quantity estimated by an external forecast model and how these compared to what actually occurred. The trial was conducted across all wind generation offered into the market with the system operator publishing summary results for the North Island on its website<sup>23</sup>. As part of this trial, the system operator only provided the external party the actual generation output<sup>24</sup> from the different wind sites. No further information (e.g. outages) or any other constraints on intermittent generator output was provided to the third party.

**Bite-sized insight into generator market offers:** Under the current market rules, all generation offered into the wholesale electricity market must have offers (quantities and prices) at least 36 hours ahead of real-time. Within 2-hours of real-time a persistence forecast is used for intermittent generators that is updated at least every trading period. Prior to 36 hours before real-time, rolled-over offers are used where real offers do not exist. Rolled-over offers use the generators offers from the same period for the previous week and are only used for the week-ahead dispatch schedule.

<sup>23</sup> This was to avoid potential identification of individual parties.

<sup>24</sup> This was historical and current generation.





Figure 8 shows a summary of results from the trial which illustrates the distribution<sup>25</sup> of wind forecast errors from generator offers and the trial forecast model at different forecast horizons (36 hours, 1.5 hours and 0.5 hours before real-time). These results show that:

- The magnitude of forecast errors from both the offers and forecast model tended to reduce the shorter the forecast horizon.
- The wind forecast model had smaller forecast error bands (as observed by the length of the vertical line showing the range between the largest positive and largest negative forecast error for a given time horizon and data source)<sup>26</sup>.
- Even at short forecast horizons (0.5 hours before real-time), for 10% of the observations the magnitude of forecast error was at least 50 MW (7% of installed capacity). This was similar for both the offers and forecast model.

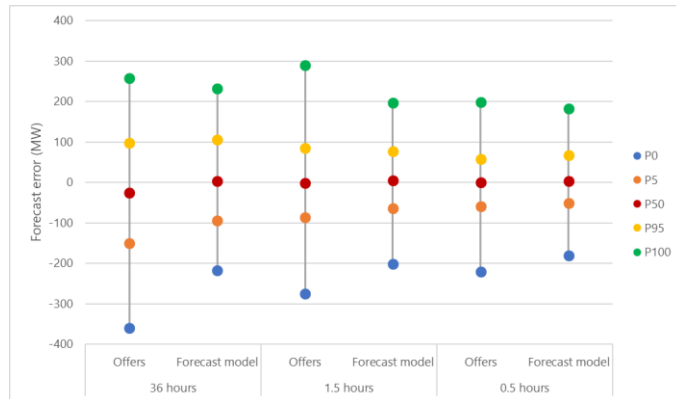


Figure 8

The trial also demonstrated that some wind generation offers have larger forecast errors compared to others. Figure 9 compares mean forecast errors as a percentage of generation capacity at two wind farms over a month. The mean forecast errors from wind farm 1's offers are similar to those from the forecast model whereas the mean errors from wind farm 2's offers are much greater than those from the forecast model. The persistence wind offers from 2 hours before real-time helped reduce the forecast errors from wind farm 2's offers at the shorter time horizons. These differences in intermittent generation forecast errors from different offers highlight the variability in forecast errors at different wind generation locations traded by different participants some of whom may be able to invest more resources towards forecasting their intermittent generation output compared to others.

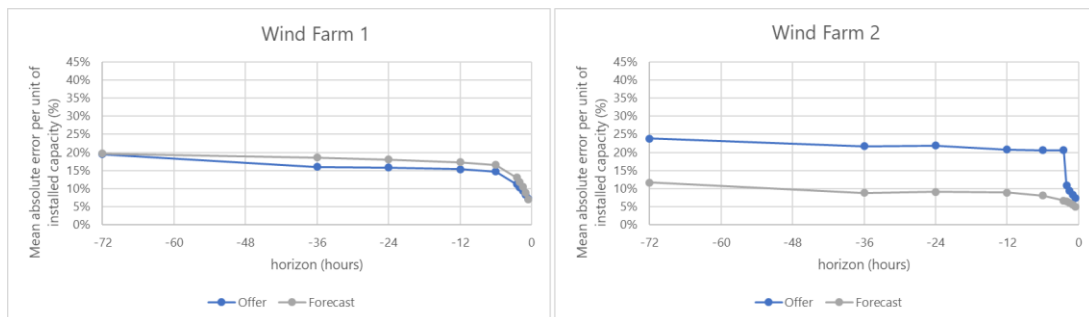


Figure 9

<sup>25</sup> Percentiles indicate the percentage of observations at or below that value. P0 would represent the minimum value, P100 the maximum and P50 the median.

<sup>26</sup> There was an exception in one month of the trial (November 2019) where the forecast model had greater forecast errors at short forecast horizons. This was due to outages and transfer of wind generation between grid injection points on which the forecast model had no information. This demonstrated that intermittent generation plant availability and outages is an important input.





The system operator's wind forecast trial indicated there are potential gains from intermittent generation forecast models to help improve the accuracy of forecast intermittent generation capacity and better understand its potential variability. This could assist with:

- the system operator's security assessments leading up to and during real-time
- more accurate price forecasts and price sensitivities<sup>27</sup> to help participants make more informed decisions
- providing a model-based benchmark on intermittent generation output forecasts
- understanding the role and benefits of potential future solutions to manage intermittent generation variability and uncertainty

These gains would be expected to increase with the increased uptake of wind and solar generation in the future<sup>28</sup>.

## Conclusion

The future generation stack in New Zealand is likely to include a greater proportion of wind and solar generation as our economy and our electricity system decarbonises. The increase in these intermittent generation types increases the variability and uncertainty of short-term generation capacity availability (all else being equal) which poses challenges for the system operator in planning and ensuring secure and stable operation of the grid and power system as well for market participants relying on accurate price signals.

As part of preparing for this future the system operator:

- is implementing changes to its market system that will enable it more agility and flexibility to better meet the future demand forecast needs as "behind-the-meter" distributed energy resources (including intermittent generation) increases. Our current expectation is for these changes to be in place within the 21/22 financial year<sup>29</sup>
- is planning to undertake further investigative work in the 21/22 financial year on intermittent generation forecasting and how this can help drive improved accuracy into its security planning and market schedules to assist with managing power system security and improve market price signals.
- has a future wind forecast service enhancement project in its roadmap. Currently this is not expected until 26/27 and subject to Electricity Authority approval. This project will also be informed by the further investigation work discussed above.

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<sup>27</sup> The system operator ran a sensitivity schedules trial in 2020 which indicated how forecast market prices varied for specified changes in demand and wind generation capability.

<sup>28</sup> In addition to increased variability on the supply side with increased intermittent generation, "behind-the-meter" load could also become less predictable with expected increases in distributed generation (including solar) and more price-responsive demand.

<sup>29</sup> This is subject to any development and procurement delays that may impact on delivery timelines.





### Appendix

Correlation of wind farm generation can be seen in the cross-scatter plots in Figure 10, which show the output of one wind farm (as shown on the x-axis) relative to another (as shown on the y-axis). The diagonals show a histogram at different output levels for each wind farm. The boxed groups of wind farms with an observable positive correlation in output are the Tararua, Te Rere Hau and Te Apiti wind farms located near Palmerston North and the West Wind and Mill Creek wind farms located near Wellington.

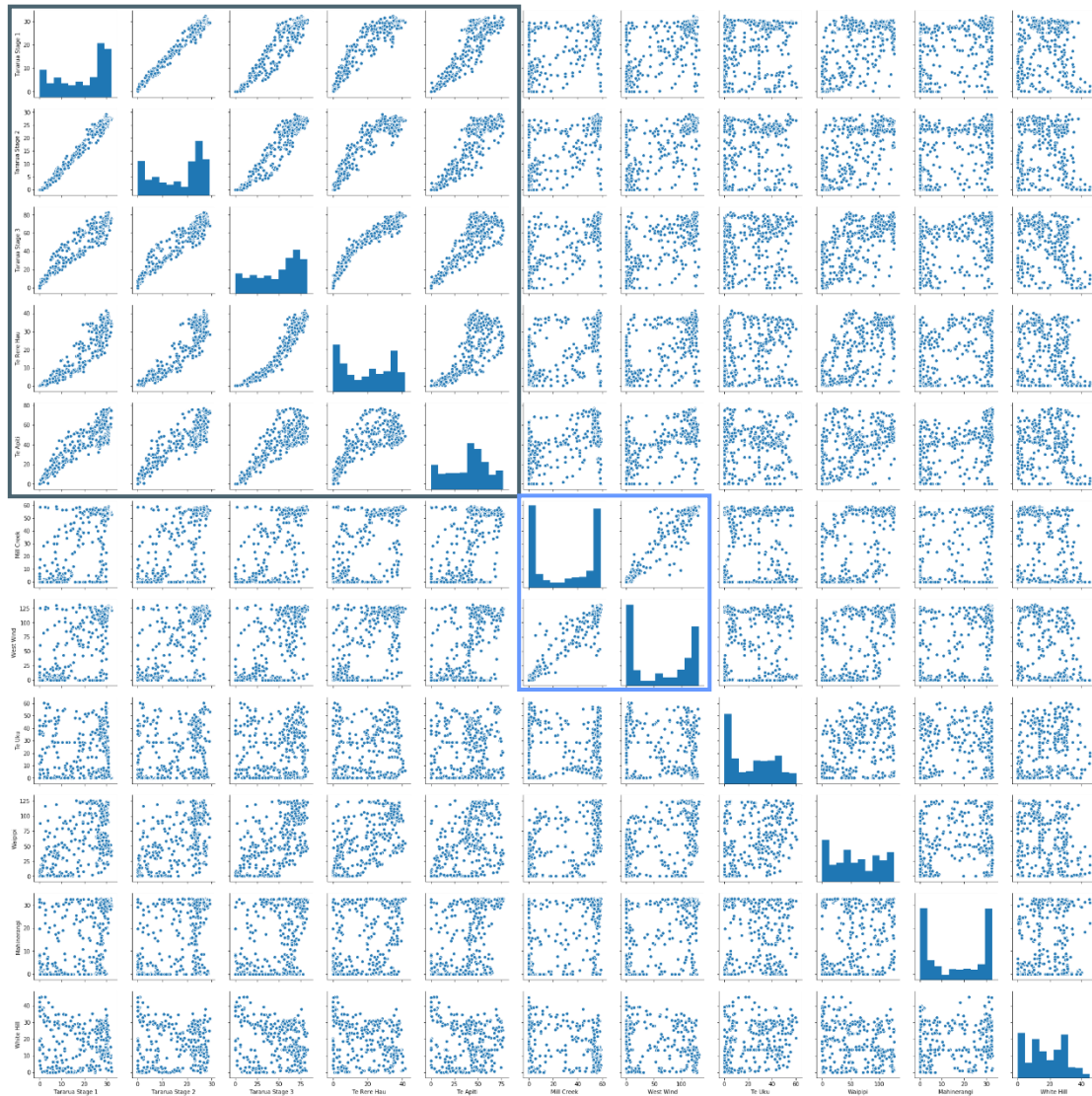


Figure 10

