The impact of the RCPD charge removal on peak demand

Executive Summary

Compared to previous years, 2022 had a high number of periods where available supply of electricity was tight compared to electricity demand. These tight periods are referred to as low residual situations. When the difference between national consumption and available generation capacity is forecast to be less than 200MW, the system operator sends out a Customer Advice Notice of a low residual situation.

These low residual situations are usually due to a combination of cold weather leading to high consumption, low wind, generation outages, and unavailability of slow start generation, indicating operational coordination issues. When low residual situations are anticipated ahead of time by the system operator, generators are requested to increase available generation capacity to ensure sufficient capacity to meet national demand and prevent a possible grid emergency (that is, when consumption is higher than available generation capacity).

It has been widely quoted that the removal of the Regional Coincident Peak Demand (RCPD) price signal, effective from September 2021, contributed to the increase in low residual situations by increasing peak consumption, i.e., during winter mornings and evenings. The RCPD price signal provided an incentive to reduce peak consumption for the purpose of minimising transmission charges and was removed due to the transition to the new transmission pricing methodology (TPM).

The RCPD charge was found to be substantially higher than the economic cost of congestion in peak periods, and therefore its removal should encourage more efficient use of the grid and more efficient investment in transmission and generation. However, while some lines companies may continue to control load for their network management purposes and large consumers may reduce peak consumption for the purpose of reducing their wholesale electricity costs, the incentive may be weaker than that provided by the RCPD charge.

Our analysis finds that underlying peak consumption has been increasing. Peak consumption (the highest 300 total consumption trading periods) has been growing by between 10-20MW (or 0.4%) per year over the last nine years. However, the increase in peak consumption in 2022 was higher than this underlying growth would suggest and not accounted for by colder weather, given 2022 was a relatively warm year.

We found evidence that some large industrials have changed their electricity consumption over peak periods—they previously decreased or shifted consumption in peak periods to reduce their RCPD charge—but did not appear to do this in 2022. We estimate that removing the RCPD charge increased daily peak consumption by around 150MW during the top 300 consumption periods in 2022. This is much larger than the underlying growth in peak consumption, but relatively small in the context of the New Zealand electricity market. From late this year, for example, one new geothermal plant will add another 174MW to the generation fleet.

An increase in peak demand due to the RCPD charge removal was anticipated by the Authority and was signalled to the industry in the Authority's consultation on new TPM guidelines.[1] Transpower added 2 percent to its New Zealand Generation Balance[2] (NZGB) forecast peak demand to assess risk in 2022 to account for this.

The Authority is currently preparing for the impact of increased peak demand for winter 2023. A consultation paper was published at the end of last year discussing possible options to better manage supply risk.[3] The Authority has prioritised which options to progress in light of submissions received, with a decision paper published on 9 March 2023 here. The Authority is also encouraging distributors to set prices reflecting congestion on their own networks, as part of the move to more efficient distribution pricing.[4] The Authority's wholesale market competition review is also looking at options to promote competition for the long-term benefit of consumers, including opportunities to strengthen current market settings, and speed up investment in new generation. The Market

1 2019 TPM Issues paper, p.33. Long-form report (ea.govt.nz)
2 TPM - Removal of Regional Coincident Peak Demand Charge, p.5. (amazonaws.com)
3 https://www.ea.govt.nz/development/work-programme/risk-management/winter-2023/
4 https://www.ea.govt.nz/assets/dms-assets/30/Letter-to-distributors-re-pricing-September-2022.pdf

Development Advisory Group (MDAG) are also looking at changes that may be needed for the longer-term if we transition to a 100 percent renewable electricity system.

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1. Background on the RCPD charge

1.1. Under the old Transmission Pricing Methodology (TPM), transmission charges were split into connection, interconnection, and HVDC charges. 70 percent of Transpower's revenue came from interconnection charges with rates based on each customer's contribution to the Regional Coincident Peak Demand (RCPD).

1.2. For a given pricing year, this interconnection charge was allocated based on each customer's contribution to the RCPD in the previous year's Capacity Measurement Period (CMP). For example, in the 2022 pricing year (starting 1 April 2022), which is the final year using the old TPM:

(a) The CMP for the Upper South Island was from 1 September 2020 to 31 August 2021.

(b) The CMP for the Upper North Island, the Lower North Island, and the Lower South Island was from 1 September 2020 to 31 October 2020 and 1 May 2021 to 31 August 2021.

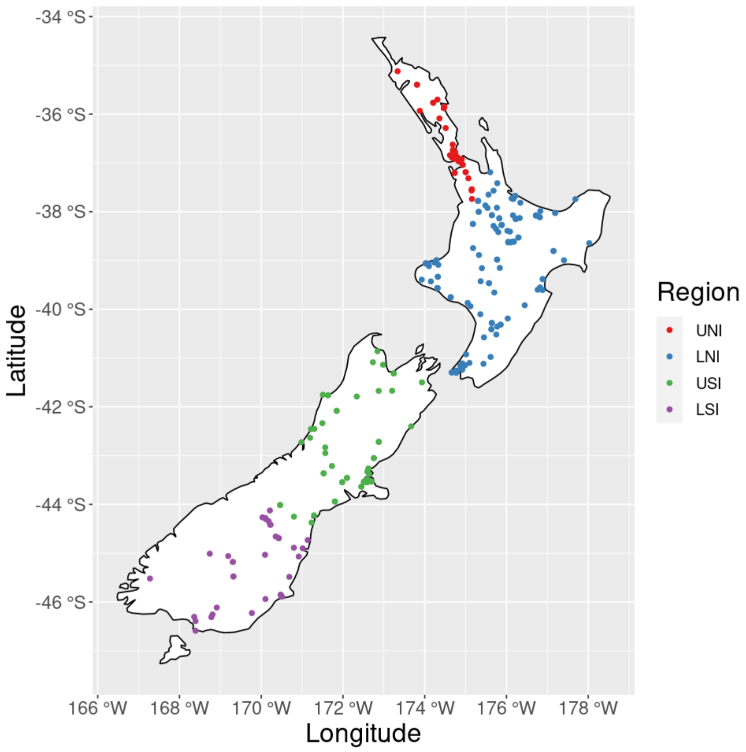
(c) The total RCPD is calculated as the sum of each region's average consumption during the 100 highest consumption trading periods during the CMP.

(d) The interconnection rate equals the interconnection revenue divided by the total RCPD.

(e) Finally, each customer's contribution to the RCPD is their average consumption during the 100 RCPD trading periods multiplied by the interconnection rate.

1.3. Figure 1 is a map of all of the points of connection in New Zealand, indicating their RCPD region. Appendix B of Schedule 12.4 of the Electricity Industry Participation Code 2010[5] describes the rules to determine the region of any point of connection given their latitude and longitude, including for RCPD.

Figure 1: Points of connection across New Zealand, coloured by RCPD region.



5 https://www.ea.govt.nz/assets/TheCodeParts/Code-Part-12-Transport-25-July-20221366027.3.pdf

1.4. The RCPD charge is equivalent to a spot price of around $2,000/MWh[6], not including the spot market price for these trading periods, providing incentives to reduce usage, especially to industrial and large commercial customers.

The Authority's decision to remove the RCPD charge

1.5. In 2022, the Authority decided on a new TPM, which commences on 1 April 2023. The new TPM will provide significant benefits to consumers as it encourages more efficient use of the grid and more efficient investment in transmission and generation. This will reduce the cost of electricity at peak times and, over time, lead to a lower cost for delivered electricity.

1.6. One of the core aspects of the TPM reform package was removing the RCPD charge, which was substantially higher than the economic cost of congestion in peak periods,[7] essentially over-signalling to consumers, and was therefore highly distortionary:

(a) discouraging consumers from using the grid at times they value it the most, even when there is no congestion

(b) creating incentives for distributors and directly connected industrial customers to invest in batteries and/or generation (including diesel generation) simply to avoid transmission charges, which other transmission customers then had to pay for.

1.7. A key part of the reasoning for removing the RCPD charge is that wholesale electricity market nodal prices already provide a market-based signal of the cost of *using* the grid,[8] so there is no requirement for a transmission peak charge to signal the same thing.

1.8. During a consultation, stakeholders raised concerns about whether system reliability would be compromised by the removal of the RCPD charge. In response, the Authority published an information paper setting out its view in March 2020.[9] In that paper, the Authority:

(a) acknowledged that removing the RCPD peak signal was a significant change

(b) confirmed its view that the logic behind the change – not double signalling the cost of using the grid through both the nodal price and the TPM – was sound

(c) worked through the reliability arguments and acknowledged the transitional risk

(d) responded to these arguments, noting that TPM reform sat beside other market reforms that, as a package, would work to create the necessary market conditions to efficiently manage congestion (through developing flexibility markets, better demand side participation in the wholesale market, and better risk management arrangements)[10]

(e) acknowledged the timing uncertainty inherent in reform/transition

(f) acknowledged that the Authority could not be 100% sure about how different participants would react to changed incentives, including in terms of the impact on demand in year one of the new TPM, or the response of distributors re ripple control.[11]

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6 https://www.ea.govt.nz/assets/dms-assets/26/26542Peak-charges-under-proposed-TPM-guidelines-information-paper-and-next-steps-March-2020.pdf

7 "The RCPD signal is also very strong relative to the wholesale price of electricity. It can be up to $2,180/MWh depending on how many peak periods the customer is considering." Electricity Authority, 2019 Issues paper, Transmission pricing review.

8 The difference in prices between the node at which electricity is injected into the grid and where it exits the grid reflects a combination of losses and congestion.

9 Peak charges under proposed TPM guidelines information paper (ea.govt.nz)

10 Such as the introduction of real-time pricing (including scarcity pricing and dispatch notification); wholesale market reforms (e.g., better information disclosure; commercial market making); the review of distribution network regulatory settings (barriers to the development of demand side participation/flexibility markets).

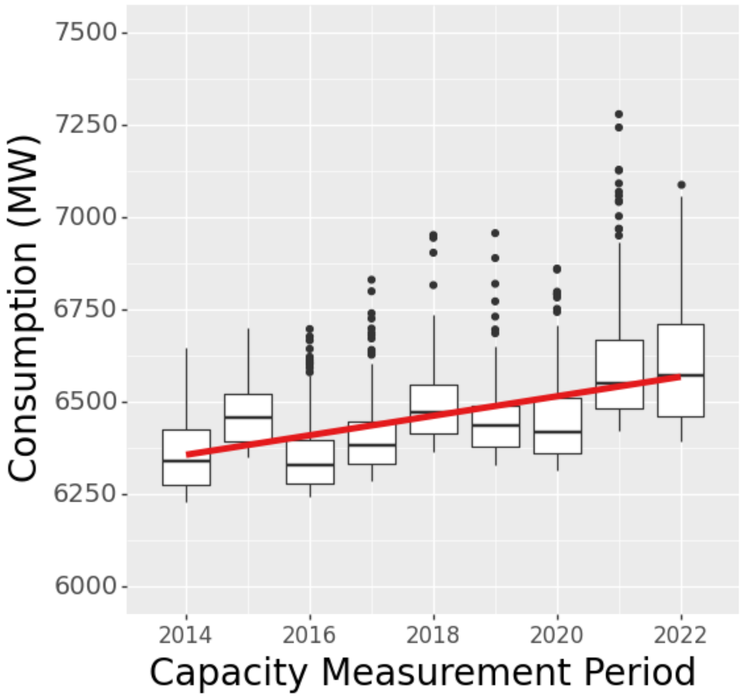
11 Noting that Concept Consulting's February 2020 winter capacity margin work found that removing the RCPD charge was not likely to cause general operational difficulties: Winter capacity margin – potential effect of possible changes to transmission pricing (ea.govt.nz).

1.9. With 2022 being the final pricing year using the old TPM, the ending of the RCPD charge has – from September 2021 onwards – removed the incentive to avoid transmission charges by reducing consumption which has changed the load profile during days with high consumption.

2. Peak Consumption was increasing before the removal of the RCPD charge

2.1. There has been an underlying upward trend in peak consumption. Figure 2 shows consumption in the top 300 trading periods each year. Overall, we see an upward trend in peak consumption, increasing by 0.4 percent annually since 2014. The increase in peak consumption has contributed to the rise in the number of low residual situations that occurred during winter 2022.

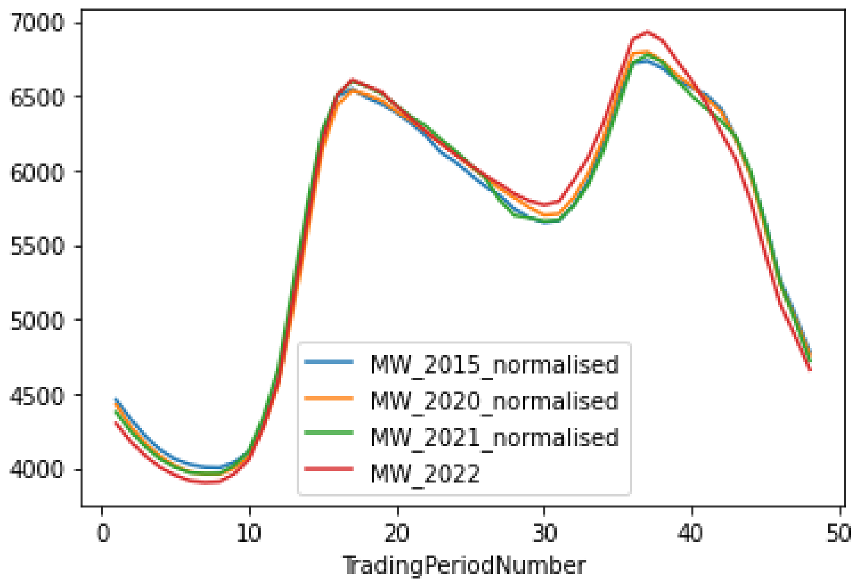
Figure 2: Plot of annual top 300 consumption trading periods between 2014 and 2022, with a trend line.



3. But the pattern of peak demand changed in 2022

3.1. Figure 3 shows the daily consumption profile of the days during which the top 20 peaks occurred each year for 2015, 2020, 2021 and 2022, normalised to total daily consumption in 2022. We see that peak consumption, particularly the evening peak, was higher in 2022 compared to other years. However, in 2015, 2020, and 2021, evening consumption stayed higher shortly after the evening peak, suggesting that the consumption peak may have been dampened by shifting the load later into the evening.

Figure 3: Plot of load profile of annual top 20 daily max consumption trading periods between 2015 and 2022.



4. And peak consumption was higher in 2022 despite warmer temperatures

4.1. Peak consumption in New Zealand typically occurs on the coldest days of the year as households and businesses increase their consumption for heating purposes. For example, the maximum consumption in 2011 coincided with a weather event that brought snow to most of the country. Therefore, we tested whether the higher consumption in 2022 may be related to colder temperatures. We found that 2022 was a relatively warm year, so temperature alone does not account for the increase in peak consumption in 2022.

4.2. Load modelling by the load forecasting solutions company Tesla showed a greater winter peak demand flex in 2021, indicating a greater sensitivity to cold weather in 2021.[12] Tesla discuss how this may be due to more people working from home, with heaters running in both homes and offices. It's possible that this effect was also present in 2022, as subsequent waves of covid required people to work from home.

4.3. Table 1 shows how many of the top 20 peak consumption days coincide with the lowest temperatures. For example, in 2022 13 of the top 20 peak consumption days occurred on days with the lowest mean temperatures. The mean temperature during a day seems to correlate more highly with peak demand compared to the minimum temperature during a day.

[12] https://www.teslaforecast.com/wp-content/uploads/2022/07/NZ-Load-Growth-Case-Study-4.pdf

Table 1: Count of the 20 Lowest temperature days (weighted by each of the city's population and only counting workdays) coinciding with the 20 Highest Consumption Days.

Capacity Measurement Period	Mean Temperature	Median Temperature	Minimum Temperature
2018	13	9	9
2019	11	11	10
2020	10	10	7
2021	13	13	11
2022	13	13	8

4.4. Figure 4 and Figure 5 show the daily mean temperature in the 20 highest peak consumption days and the 20 coldest workdays (by daily mean temperature), respectively. The population-weighted daily mean temperature in 2022 during the highest peak consumption days was about average compared to the previous four years. However, the coldest workdays were relatively warm in 2022 compared to the prior four years (only comparable to temperatures observed in 2020). The mean population-weighted temperature for all workdays in winter 2022, shown in Figure 6, was 11.7°C which is 0.7°C warmer than winter 2021.

Figure 4: Daily mean temperature in the 20 highest daily maximum consumption days.

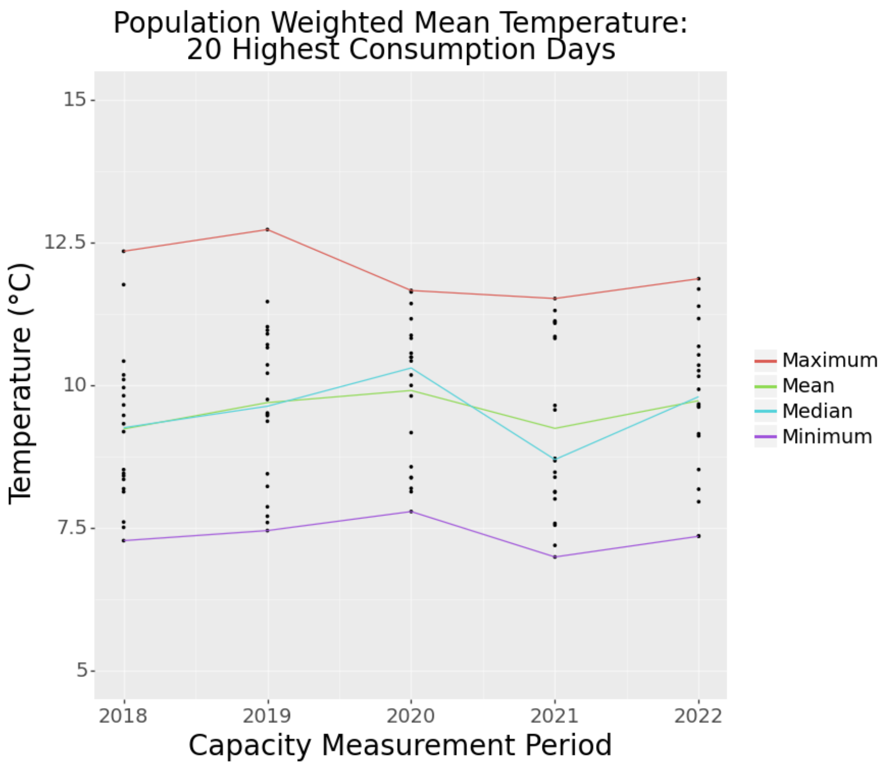


Figure 5: Daily mean temperature in the 20 coldest days (excluding weekends, public holidays, and Auckland anniversary day).

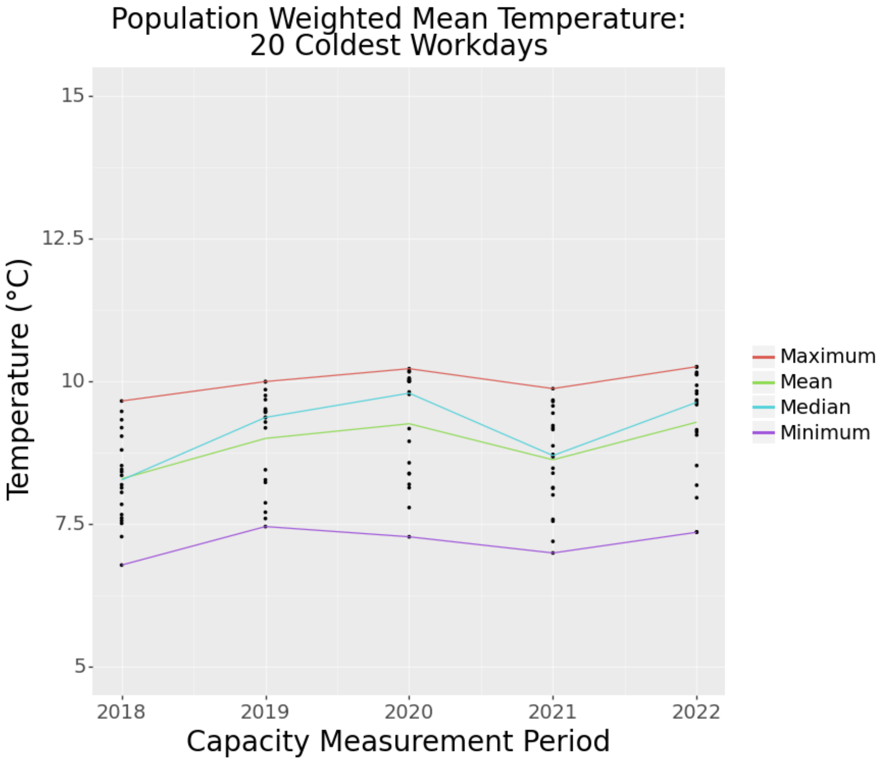
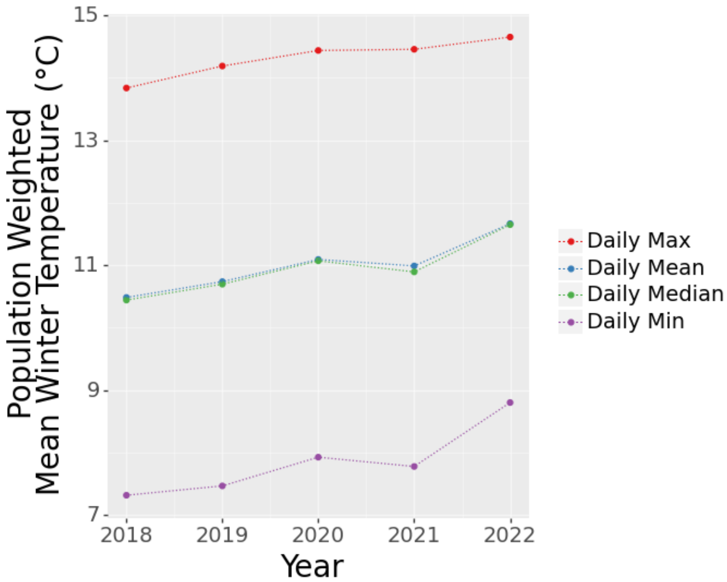


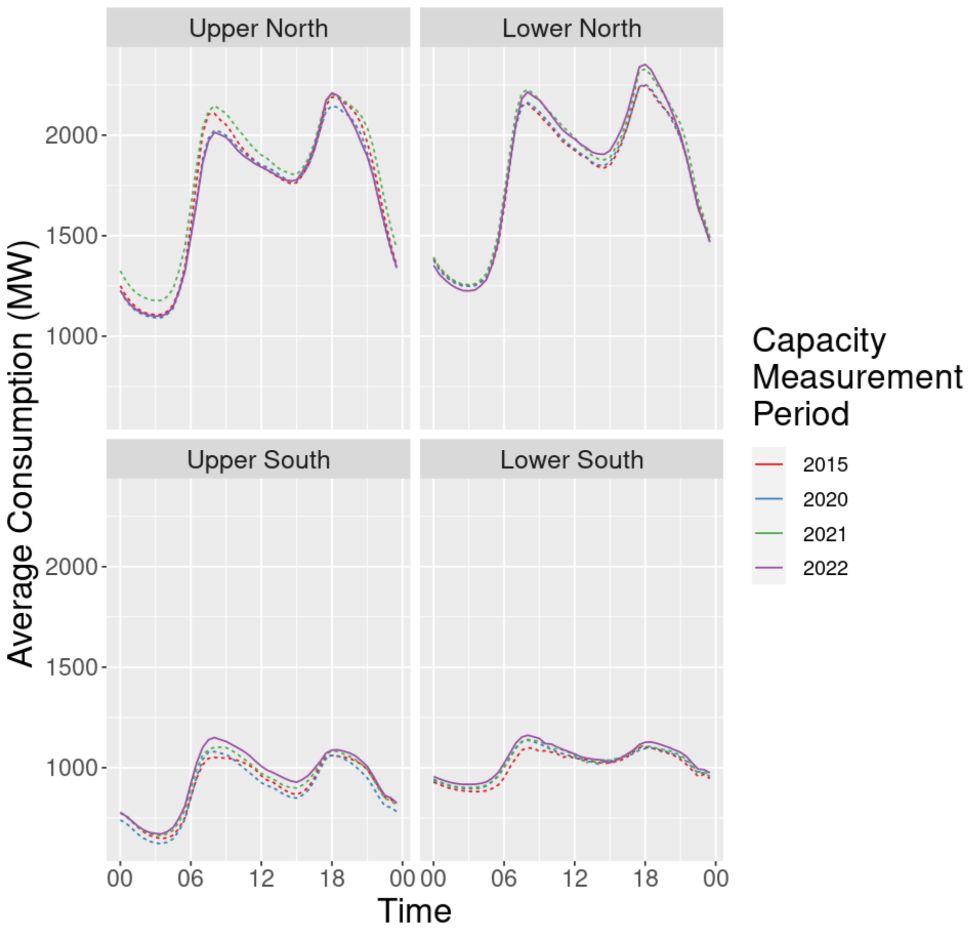
Figure 6: Daily population weighted temperature statistics averaged across winter (June, July, August)



5. All regions contributed to the increase in peak consumption in 2022

5.1. In Figure 7, we see that all regions seem to contribute to the growth in peak consumption that we've seen in the 2022 CMP. However, there was relatively low consumption during the morning peak in the Upper North Island, similar to 2020. The year 2020 also had relatively mild temperatures, as shown in Figure 5 (where high morning peaks tend to be much more temperature driven compared to evening peaks).

Figure 7: Load profile of each region's 30 highest daily max consumption days.



6. Network participants appear to react to RCPD charges

6.1. The RCPD charge incentivises network participants to reduce their consumption during the top 100 trading periods during the CMP to reduce what they are required to pay. When examining the consumption patterns of network participants, they reduce or delay consumption during trading periods that fall in the top 100 during the CMP but rarely at other times. Figure 8 and Figure 9 illustrate this response to the RCPD charge, which plots New Zealand Steel Limited's (NZ Steel) consumption in the Upper North Island region and Pan Pacific Forest Industries' consumption in the Lower North Island.

6.2. In the Upper North Island, during the 2018 CMP, the day with the most trading periods that are a part of the top 100 highest consumption trading periods (thus used in the calculation of transmission charges) occurred on 27 June 2018. In the Lower North Island, during the 2018 CMP, the day with the most trading periods used as part of the calculation of transmission charges occurred on 4 July 2018.

6.3. The red vertical lines in Figure 8 indicate trading periods on 27 June 2018 in the Upper North Island that are part of the calculation of transmission charges. The red vertical lines in Figure 9 indicate trading periods on 4 July 2018 in the Lower North Island that are part of the calculation of transmission charges.

6.4. The other days in both figures were either not part of the top 100 consumption trading periods (22 October 2018) or occurred after the RCPD incentive ended (22 June 2022 and 11 August 2022).

6.5. In Figure 8, we see that on 27 June 2018, NZ Steel's consumption reduced at the beginning of the morning and evening peaks. Spot prices averaged $292/MWh nationally this day.

6.6. In Figure 9, we see that on 4 July 2018, Pan Pac Forest Products Limited's (Pan Pac) consumption reduced drastically during the morning and evening peaks. Spot prices averaged $105/MWh nationally this day.

6.7. With low hydro storage levels, national daily spot prices averaged around $350/MWh in mid to late October 2018. Specifically, on 22 October, national spot prices averaged $427/MWh. Despite these high spot prices, 22 October does not show the same signs of demand response for both NZ Steel and Pan Pac, indicating that these network participants reacted explicitly to the RCPD charge.

6.8. Since the ending of the RCPD incentive on 1 September 2021, in the Upper North Island, the day with the most trading periods that are a part of the top 100 highest consumption trading periods was 6 June 2022. Again, this day does not show the same signs of demand response from NZ Steel, again indicating that the demand response we saw on 27 June 2018 was due to the price incentive of the RCPD charge.

6.9. Similarly, in the Lower North Island, the day with the most trading periods that were part of the top 100 highest consumption trading periods was 22 June 2022. With no sign of demand response during either the morning or evening peaks for Pan Pac, this further supports the finding that the demand response we saw on 4 July 2018 was due to the price incentive of the RCPD charge.

6.10. In Figure 10, we see the mean consumption for NZ Steel and Pan Pac during the trading periods when the RCPD charge was applied (or would have been applied in the 2022 CMP year). We see that peak consumption increased to historic highs in 2022 for both industrial consumers, further supporting the idea that the ending of the RCPD caused the increase in peak consumption for both consumers.

Figure 8: NZ Steel's consumption (part of the Upper North Island) on three select days.

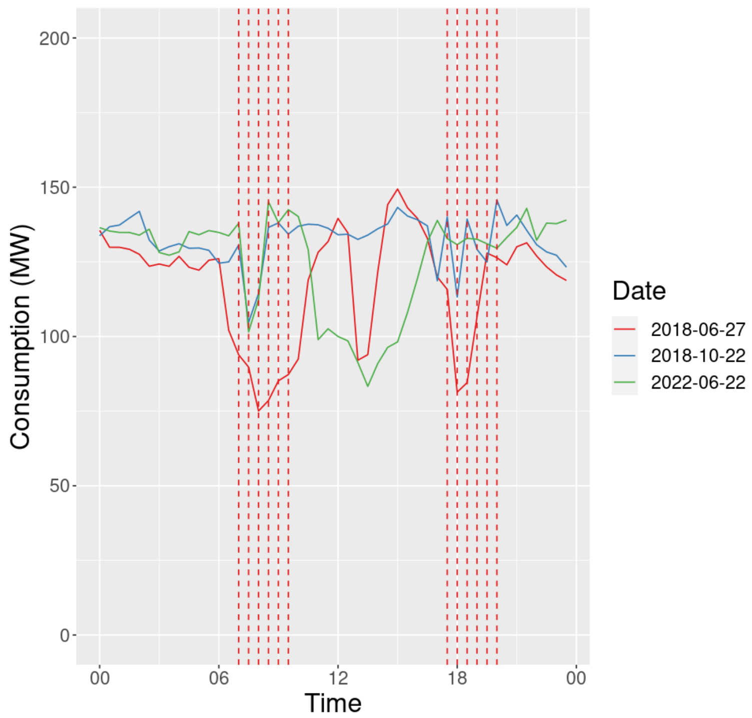


Figure 9: Pan Pacific Forest Industries' consumption (part of the Lower North Island) on three select days.

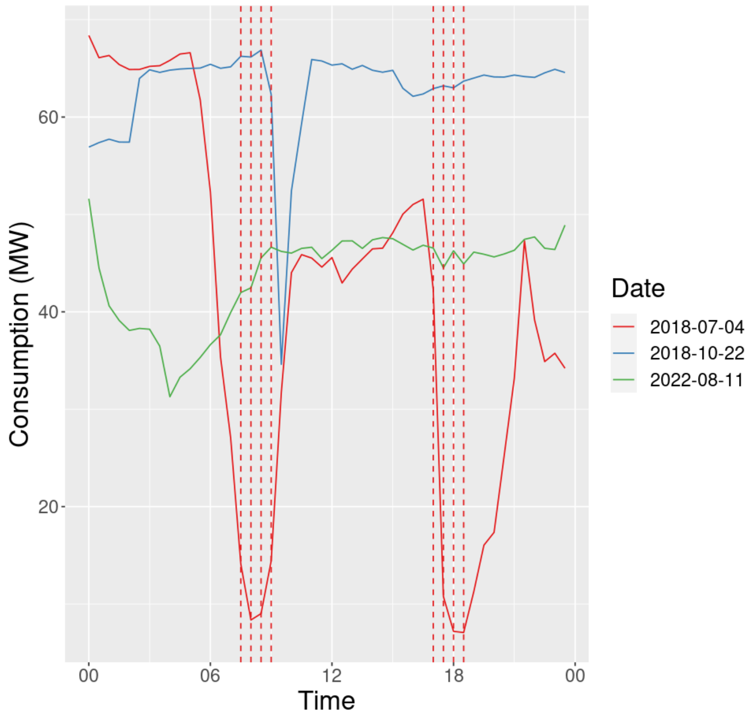
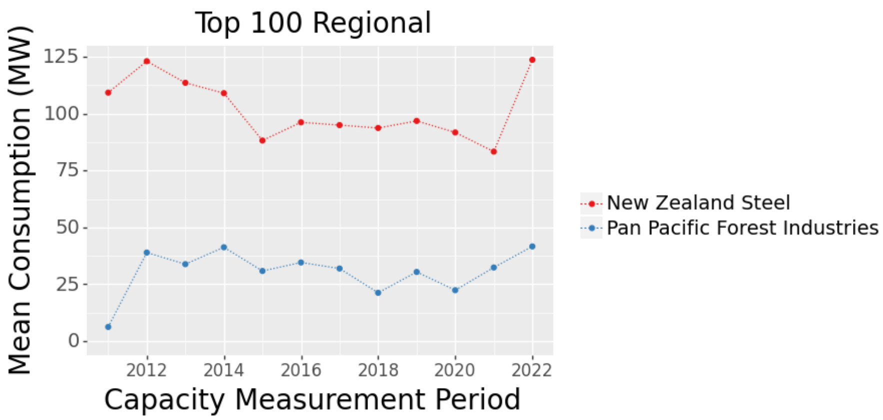


Figure 10: Mean consumption during the trading period's when the RCPD charge applies (or would've applied if it still existed in 2022).



7. We found a statistically significant effect from the RCPD charges

7.1. We analysed the relationship between daily peak consumption and the RCPD charge using a time series model. If the RCPD charge incentivised lowering or delaying consumption, the daily peak consumption would be lower on days the RCPD charge was applied compared to days with similar conditions when there was no RCPD incentive. Our models found that at a national level, there was evidence that the RCPD charge caused lower daily peak consumption by 157MW on average on days when peak consumption was within the top 300 trading periods.

7.2. Daily data was used from 1 September 2013 until 31 August 2022, providing one full year of data in which the RCPD charge was no longer an incentive to reduce consumption, enabling us to test the RCPD charge's impact. The dependent variable was the consumption of the peak trading period for each day. The variables we controlled for were:

(a) mean temperature and wind speed to capture the impact of weather,

(b) daily sunshine hours to capture seasonal effects (not accounted for by weather),

(c) dummy variables for weekends and public holidays as demand is lower on these days, and

(d) a dummy variable for the Covid alert level 4 lockdown.[13]

7.3. In order to test if the RCPD charge had an impact on peak consumption we created two dummy variables. The first was a variable which indicated if the daily peak trading period fell within the top 300 consumption trading periods for that year. We expect the coefficient of this variable to be significant and positive due to its definition. We chose the top 300 as users would not know ahead of time which trading periods will be in the top 100 so they could react (ie, reduce their consumption) to peak consumption periods that fall outside of the top 100.

7.4. The second dummy variable indicated if the day was within the CMP period in that region (and before 1 September 2021). We do not expect this dummy variable alone to have a large impact, as by definition it falls on every day within the CMP (not just the days where electricity users may reduce consumption to avoid the RCPD charge). However, if the RCPD charge did have an effect of either reducing or delaying consumption, we expect that for days which meet both conditions – ie, the day fell within the top 300 peak consumption periods and the CMP - the coefficient would be significant. That is, we are interested in the interaction between the CMP dummy variable and the 'top 300' dummy variable.

7.5. We ran the model both at a national level and at a regional level. We see the resulting coefficients for the interaction between the 'top 300' and 'RCPD' dummy variables in Table 2. We can interpret the coefficients' value as the impact of the RCPD charge's removal on the total demand during the top 300 trading periods for that region. We italicised values if they were not statistically significant at the 5% level. The second row of the table provides a confidence interval for the possible size of the impact of removing the RCPD charge. The last row in the table gives the estimated impact of the RCPD charge removal as a percentage of that region's average demand in 2022.

Table 2: Coefficients of RCPD charge related dummy variables in ARIMAX time series model, by region.

	UNI	**LNI**	**USI**	**LSI**	**New Zealand**
Estimated impact from removing RCPD charge (MW)	66	71	*11*	10	157
Confidence interval 95% (MW)	(40,92)	(50,93)	*(-5,28)*	(3,16)	(103,211)
As a % of demand 2022	3.1	3.1	*1.0*	1.0	2.4

7.6. In Table 2, the results indicate that for the whole of New Zealand the removal of the RCPD charge was associated with a 157MW increase in daily peak demand on days when peak consumption was within the top 300 trading periods. For the regions in the North Island the RCPD charge removal was associated with daily peak consumption being over 65MW

13 We tried other variables in our model; other weather variables were not as good predictors as the ones included, and the other Covid alert levels were not statistically significant. To capture underlying growth, we also tried variables such as population growth, number of issued building consents, and total and residential ICPs. These were not statistically significant, so they were not included in the final model. There are a few possible reasons for the statistical insignificance of these variables' impact on peak consumption. First, the variables may not capture the causes of underlying growth. Second, the autoregressive model we used may already capture underlying growth.

higher, while in the two South Island regions the RCPD charge removal was associated with a higher daily peak consumption of around 10MW on days when peak consumption was in the top 300. However, the results were not statistically significant for the Upper South Island, indicating that either any change in peak daily demand in the Upper South Island due to the RCPD charge was too small to distinguish from noise, or there was no change in peak daily demand in this region due to the RCPD charge.

8. Removal of the RCPD charge did contribute to an increase in peak consumption, as anticipated

8.1. Many commentators in the industry have pointed to the removal of the RCPD charge as exacerbating the operational coordination issues the industry is facing during winter, as this incentive to reduce demand during peak consumption has been removed.

8.2. We found that the removal of the RCPD charge did contribute to an increase in peak consumption as anticipated by the Authority. This increase was around 150MW or 2.4% of daily peak consumption in 2022, which is similar to the additional 2% growth (or 144MW) that Transpower added to the peak consumption they used in the NZGB forecasts. This indicates that the risk assessments ahead of winter 2022 accounted sufficiently for increased consumption due to the RCPD charge removal.

8.3. The removal of the RCPD incentive changed the daily load profile, as shown in Figure 3, which could have decreased the accuracy of load forecasts during peak periods and possibly contributed to operational coordination issues. However, data from winter 2022 can be used to better forecast load during winter 2023.

8.4. The Authority is considering the impact of the RCPD charge removal in its ongoing work ahead of winter 2023.

Appendix A Modelling Daily Peak Demand to understand the impact of the RCPD charges

1.1 The models detailed below were created with the intention to understand if the RCPD charges decreased demand and what impact the removal of the RCPD charge had on peak demand. For this reason, we modelled daily peak demand using an auto-regressive integrated moving averages with variables (ARIMAX) models. In total, five models were produced, one for all of New Zealand and one for each of the RCPD regions.

1.2 Daily data was used from 1 September 2013 until 31 August 2022. This provided one full year of data in which the RCPD charge was no longer an incentive to reduce consumption and be able to compare to the previous years. Daily peak demand was used to estimate the impact of the RCPD charges on demand, as while several trading periods on a given day were impacted by the RCPD charge, we expect any response to the charge would have been most apparent at the daily peak. Daily peak demand was calculated as the trading period each day with the highest demand.

1.3 The variables used in the final model were mean temperature in degrees Celsius and wind speed in knots to account for the impact of weather, daily sunshine hours to account for seasonal effects, dummy variables for both weekends and public holiday when demand is lower, and a dummy variable for the Covid alert level 4 lockdown, when non-essential businesses were shut down, including several large industrial processes.

1.4 Weather data was based on observations from Auckland Airport for the Upper North Island, Wellington Airport for the Lower North Island, Christchurch Airport for the Upper South Island and Dunedin Airport for the Lower South Island. The average of these four was used for all of New Zealand. Other weather variables besides mean temperature and wind speed were modelled, such as minimum temperature and humidity but they were not as good predictors as mean temperature and wind speed. We also tested dummy variables for the other Covid alert levels which were not significant. This is likely due to only alert level 4 requiring non-essential businesses to close.

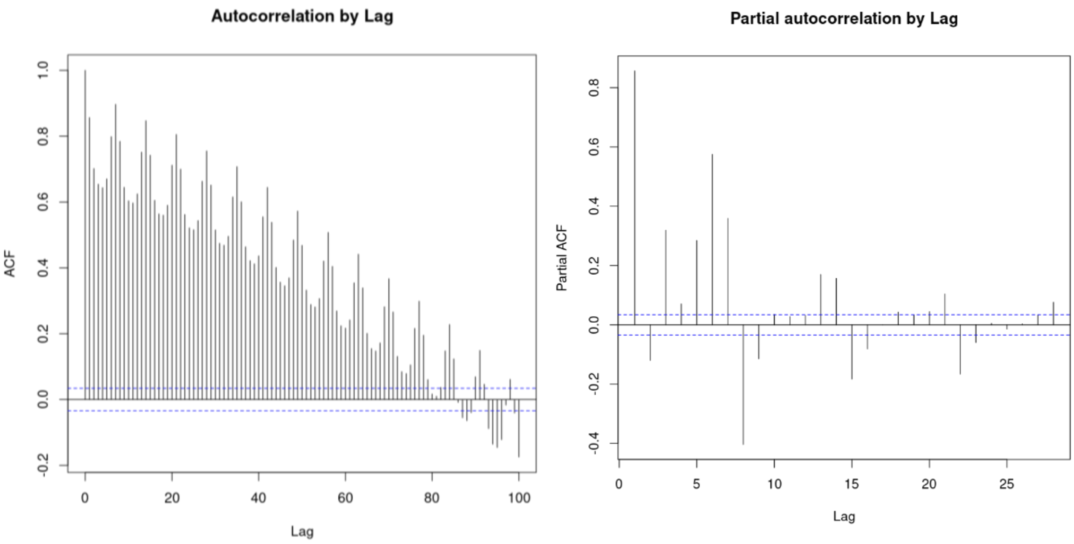
1.5 We also tried variables including population growth, issued building consents, and total and residential ICPs, to try to capture factors that may be underlying growth in demand, but these were not statistically significant so were not included in the final model. It may be that these variables do not accurately capture the causes of underlying growth or that the model already captured underlying growth with its autoregressive variables.

1.6 In order to test if the RCPD charge had an impact on peak consumption we created two dummy variables for the top 300 trading periods and the RCPD CMP as detailed in the main text. If the RCPD charge did incentivise lowering peak consumption when in effect we would expect the coefficient of the interaction of these two variables to be negative, and to be statistically significant.

1.7 ARIMA models are suitable for time series data that is highly correlated with the outcomes of previous time periods, in this case the previous days. We tested the autocorrelation of daily peak demand and found the data was positively auto correlated with up to 80 time lags, shown in

1.8 Figure 11. Testing the partial autocorrelation found that daily peak demand is most positively correlated with the previous day's daily peak demand, with a much weaker correlation for larger lags. The observed pattern in both tests (for all regions) suggested a weekly pattern to demand, which makes sense given demand is lower during the weekend than on weekdays. This is accounted for in our model by using a dummy variable for the weekend.

Figure 11: Autocorrelation and partial correlation by lag for New Zealand



1.9 ARIMAX models require all the variables to be stationary, i.e. the mean value does not change over time. We used the augmented Dicky-Fuller test to check if each variable was stationary. Daily peak demand is non-stationary, however, the first difference of daily peak demand is stationary, so the model uses the difference in daily peak demand for the ARIMA variables. All the variables that were found to be significant in our models were stationary, while some of the additional variables tested were non-stationary, so in these cases we tested and used the first difference, which was stationary.

1.10 We fitted the data using an autoregressive model with 5 lags. The equation for the ARIMAX model can be expressed as:

$$y_t = \beta_1\, temperature_t + \beta_2\, wind.speed_t + \beta_3\, daylight_t + \beta_4\, Covidalertlevel4_t + \beta_5 Weekend_t + \beta_6 Holiday_t + \beta_7(Weekend_t * Holiday_t) + \beta_8 Top300_t + \beta_9 CMP_t + \beta_{10}(Top300_t * CMP_t) + \eta_t$$

$$\eta_t = \varphi_1(y_{t-1} - y_{t-2}) + \varphi_2(y_{t-2} - y_{t-3}) + \varphi_3(y_{t-3} - y_{t-4}) + \varphi_4(y_{t-4} - y_{t-5}) + \varphi_5(y_{t-5} - y_{t-6}) + \varepsilon_t$$

1.11 Where y_t is the daily peak demand at time t, β_{1-10} are the coefficients in Tables 1 to 5, φ_1 are the ARIMA coefficients of the lags and ε_t is the residual, or error term.

1.12 The results of the ARIMAX model for each region are shown in table 3.

1.13 Note that some variables were not significant at the 95% level for the South Island regions.

1.14 While this model was not intended to find the impact of each of these variables, the results from Table 3 can be interpreted as follows. National daily peak demand drops by about 27MW for every degree by which average temperatures increase, indicating that colder temperatures increase peak demand, daily peak demand increases by 6MW for every knot of wind speed, indicating demand is higher on windier days (likely due to wind chill factor). For every additional daylight hour daily, peak demand drops by 180MW, modelling higher demand in winter and lower in summer. The Covid Alert Level 4 decreased daily peak demand by about 200MW. Daily peak demand is about 460MW lower in the weekend than on weekdays and 370MW lower on a public holiday; if a day is both a weekend and a holiday daily peak demand is about 535MW (461 + 371 – 297). lower than an ordinary weekday

Table 3: Results from the ARIMAX model for all of New Zealand.

Variable	Coefficient	Standard Error	Signifiant (95%)
Temperature	-27	1.4	Y
Wind Speed	6	1.0	Y
Daylight	-180	32	Y
Covid Alert Level 4	-203	54	Y
Weekend	-461	6	Y
Public Holiday	-371	11	Y
Weekend*Holiday	297	35	Y
Top_300	216	26	Y
CMP	38	27	N
Top_300*CMP	-157	27	Y

Table 4: Results from the ARIMAX model for the Upper North Island.

Variable	Coefficient	Standard Error	Significant (95%)
Mean temperature	-11	0.8	Y
Wind Speed	2	0.3	Y
Daylight hour	-74	13	Y
Covid Alert Level 4	-97	28	Y
Weekend	-191	3	Y
Public Holiday	-166	7	Y
Weekend*Holiday	113	23	Y
Top_300	118	13	Y
CMP	14	6	N
Top_300*CMP	-66	14	Y

Table 5: Results from the ARIMAX model for the Lower North Island.

Variable	Coefficient	Standard Error	Significant (95%)
Mean temperature	-10	0.6	Y
Wind Speed	2	0.2	Y
Daylight hour	-81	12	Y
Covid Alert Level 4	-85	26	Y
Weekend	-131	3	Y
Public Holiday	-98	6	Y
Weekend*Holiday	75	21	Y
Top_300	113	10	Y
CMP	59	51	N
Top_300*CMP	-71	11	Y

Table 6: Results from the ARIMAX model for the Upper South Island

Variable	Coefficient	Standard Error	Significant (95%)
Mean temperature	-5	0.3	Y
Wind Speed	0.2	0.2	N
Daylight hour	-16	11	N
Covid Alert Level 4	-81	20	Y
Weekend	-95	2	Y
Public Holiday	-69	4	Y
Weekend*Holiday	90	14	Y
Top_300	25	8	Y
CMP	59	39	N
Top_300*CMP	-11	8	N

Table 7: Results from the ARIMAX model for the Lower South Island.

Variable	Coefficient	Standard Error	Significant (95%)
Mean temperature	-3	0.1	Y
Wind Speed	1.0	0.1	Y
Daylight hour	-8	4	N
Covid Alert Level 4	-30	8	Y
Weekend	-45	0.8	Y
Public Holiday	-34	2	Y
Weekend*Holiday	39	7	Y
Top_300	28	3	Y
CMP	13	17	N
Top_300*CMP	-10	3	Y

1.15 The residuals of the models are shown in Figure 12 to Figure 16. We expect residuals to look approximately like white noise, centred around 0, purely random and not correlated with each other. The residuals show that the models were usually within 200MW of the actual daily peak demand for all of New Zealand, within 100MW for the two North Island regions and USI, and within 50MW for LSI.

Figure 12: Residuals from the model for all of New Zealand.

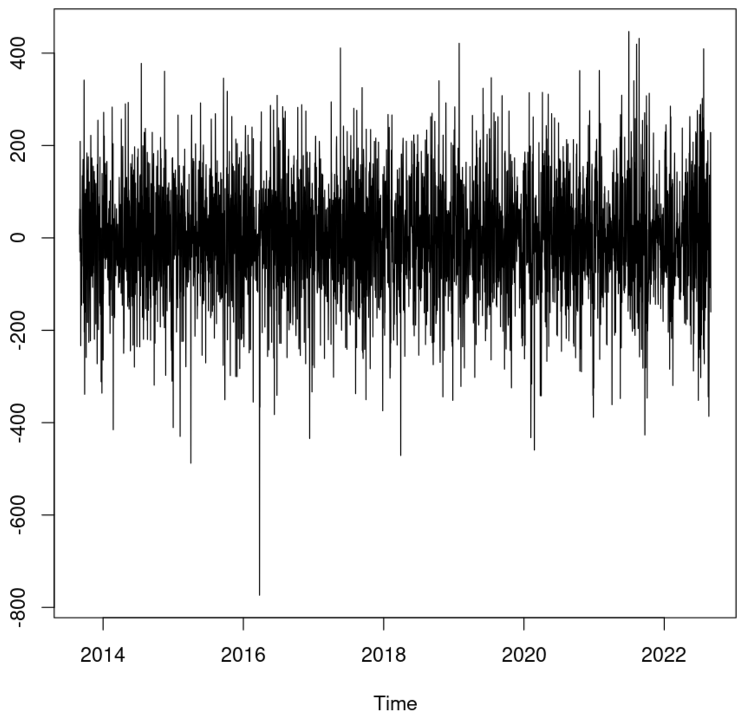


Figure 13: Residuals from the model for Upper North Island.

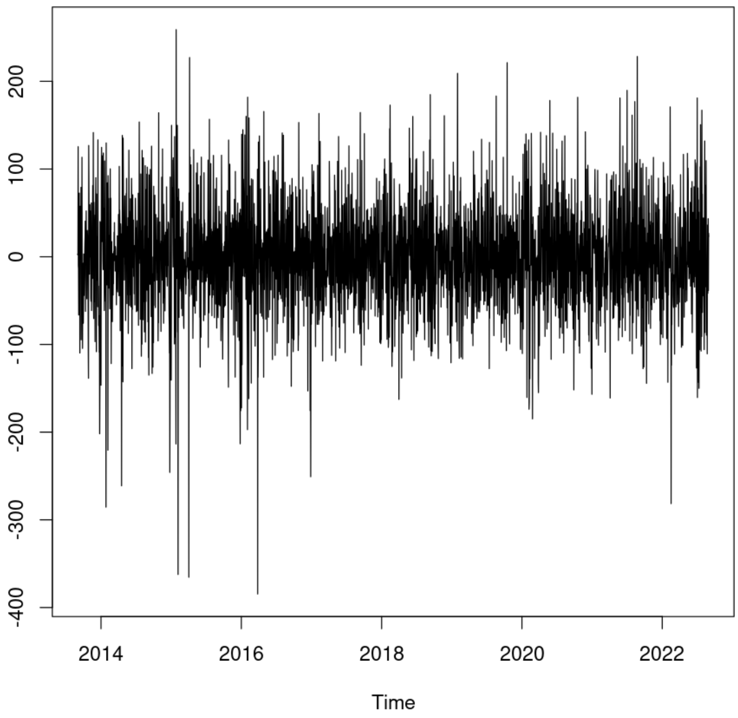


Figure 14: Residuals from the model for Lower North Island.

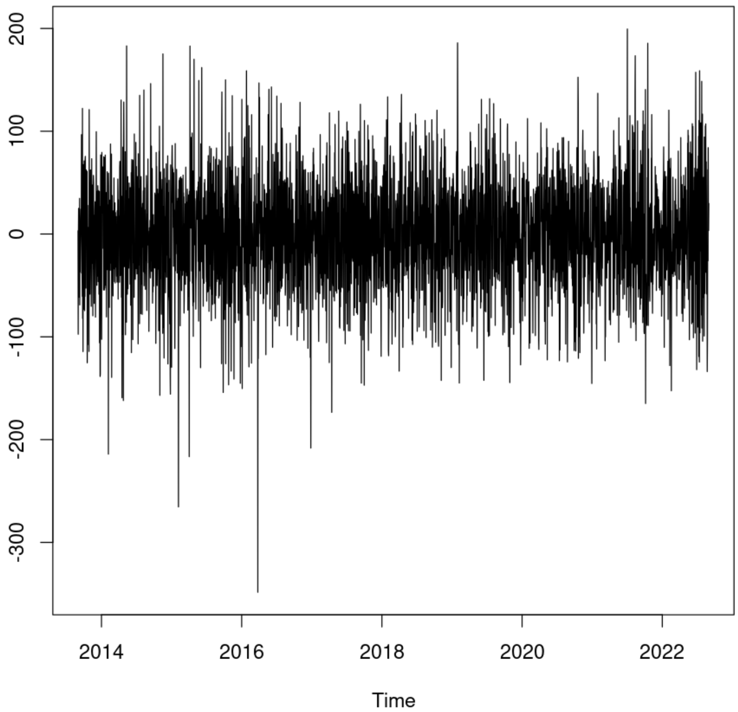


Figure 15: Residuals from the model for Upper South Island.

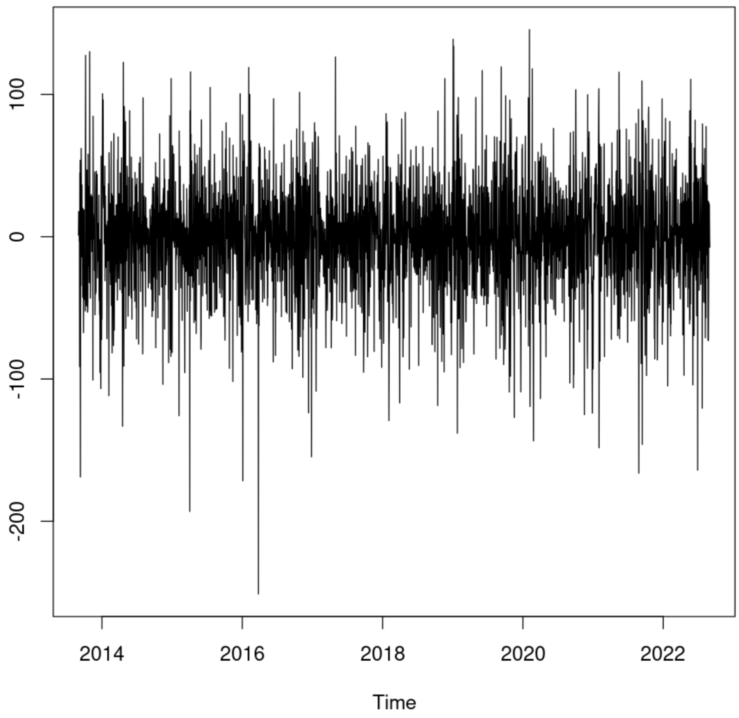
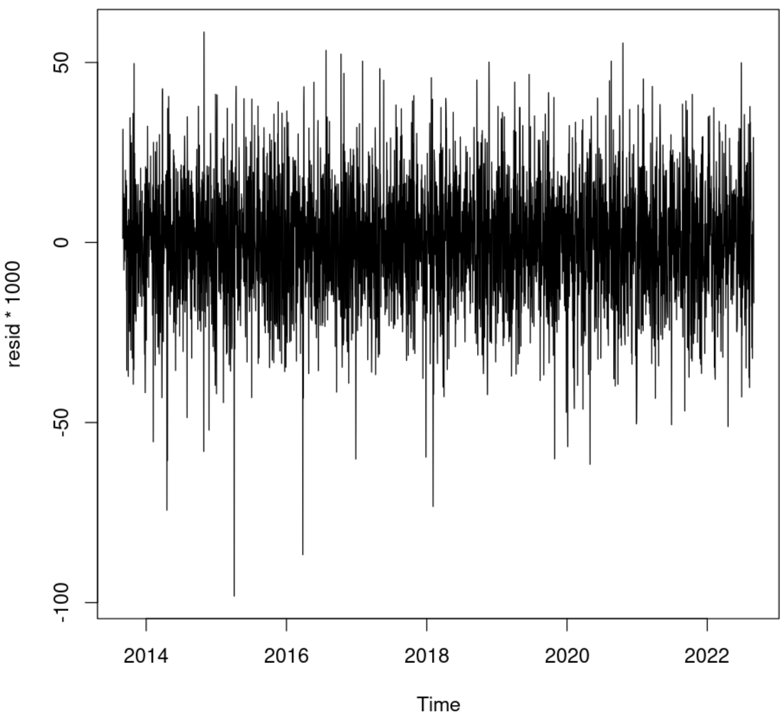


Figure 16: Residuals from the model for Lower South Island.



Glossary of abbreviations and terms

CMP	Capacity Measurement Period
ICP	Installation Control Point
LNI	Lower North Island
LSI	Lower South Island
NZGB	New Zealand Generation Balance
RCPD	Regional Coincident Peak Demand
TPM	Transmission Pricing Methodology
UNI	Upper North Island
USI	Upper South Island