ELECTRICITY AUTHORITY
TE MANA HIKO

Appendix A: How we calculate competitive risk management prices

Contents

1. Purpose

1.1. This appendix discusses how we have calculated our estimates of competitive risk management prices, both for our modelling and for comparison to prices received by non-integrated retailers in the OTC market.

2. Contracts contain risk premia

2.1. Hedging allows participants to manage their overall risk profile and exposure to the underlying spot market. The ability to hedge this risk has inherent value. Such value will be reflected in the risk premia present in forward contracts. That is, the party selling the hedge receives a premium for taking on the risk for the purchaser. The Australian Energy Market Commission (AEMC) provide a good description of risk premia:

"*The risk premium required by a market participant or intermediary to offer a fixed price for some future period (a forward, swap or contract for difference) in exchange for spot market exposure. In the absence of a risk premium, at the time the transaction is entered into, the market price for the forward contract would be equal to the expected spot price over the term of the agreed contract leaving the parties to the transaction indifferent to the choice of the spot or fixed price. The generally used explanation for the difference between the expected spot price and the forward price is that the party offering a fixed price requires compensation for the risk it is assuming in accepting the spot price. The risk premium is also expected to be impacted by other factors including market liquidity. In a less liquid market the risk premium is expected to be higher.*"[1]

2.2. Electricity hedges contain multiple risk factors (such as market liquidity, as mentioned above by AEMC) that require different premia. Here we discuss different risk factors and – where possible – estimated resulting risk premia. We also discuss how these risk premia may vary over time.

3. For comparison to the prices offered in the OTC market, we start with ASX prices

ASX prices are an unbiased predictor of spot prices

3.1. Our analysis finds that between 2011 and 2023 ASX prices at Benmore appear to be unbiased, with about half of traded prices higher than the settled price and about half lower.[2] Between 2018 and 2023 traded prices were lower than the settled price two thirds of the time, but this appears to have been driven by unexpected shocks, most notably declining and less predictable output from several natural gas fields from around March 2018 and Russia's invasion of Ukraine in early 2022.

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1 https://www.aemc.gov.au/sites/default/files/content/6c3cdee8-aaa0-44c9-8597-3de9dadebb98/Seed-report.PDF

2 We use the term "settled price" to refer to the settlement price on expiration of the contract. This is the time-weighted average spot price over the term of the contract and is the (variable) price that contracts are settled against.

3.2. The traded price is the average price at which a given ASX futures contract is traded on a particular day, while the settled price is the time-weighted average spot price for the quarter related to the ASX futures contract.

3.3. In a risk neutral, competitive market the traded price should reflect the general consensus of expected prices. Assuming that expectations are equally likely to be too high or too low, the traded price should be an unbiased predictor of the spot price, at least in the long term.

3.4. Not all parties are risk neutral and may use ASX futures as a risk management tool. Retailers may be willing to pay a risk premium to avoid the risk of high prices while generators may be willing to be paid less to avoid the risk of low prices. This risk premium could therefore result in traded prices that are higher or lower than the consensus of expected prices. However, if they balance out over the longer-term, we could still find traded prices to be unbiased predictors of final spot prices over the long term. Where they do not balance out, this suggests there is asymmetric risk in the market (for the risk that the instrument covers).

3.5. Figure 1 and Figure 2 show the distribution of the difference between the daily traded price and the settled price. A negative value means that the traded price was lower than the settled price, while a positive value means the reverse. These distribution graphs exclude trades that occurred during the quarter they correspond to, i.e. this is the distribution of trades which occurred prior to the start of the quarter.[3]

3.6. Figure 1 shows the density plot at Benmore between 2011 and 2023. This plot has a bimodal distribution, with a median value of -$1.74/MWh, indicating that just over half of traded prices were lower than settled prices and almost half were higher.[4] Overall, this indicates that traded prices at Benmore are unbiased in the long term, with traded prices usually (50% of the time) within $30/MWh of the settled price.

3.7. Figure 2 shows the density plot at Otahuhu between 2011 and 2023. This plot is close to a normal distribution, with a median value of -$5.99/MWh as 55% of traded prices were lower than the settled price. Similar to Benmore, the traded price was usually (50% of the time) within $30/MWh of the settled price.

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[3] We exclude trades undertaken within the quarter as these trades are not of as much interest to us – that is, we wish to see how well prices of trades in advance of the quarter compare to the settled price.

[4] This bimodal distribution is probably related to the direction of power flow and hence price differential between the islands. This is mainly driven by hydrological inflows and is relatively unpredictable more than a few months ahead.

Figure 1: Density plot of difference between traded and settled price at Benmore, 2011-2023

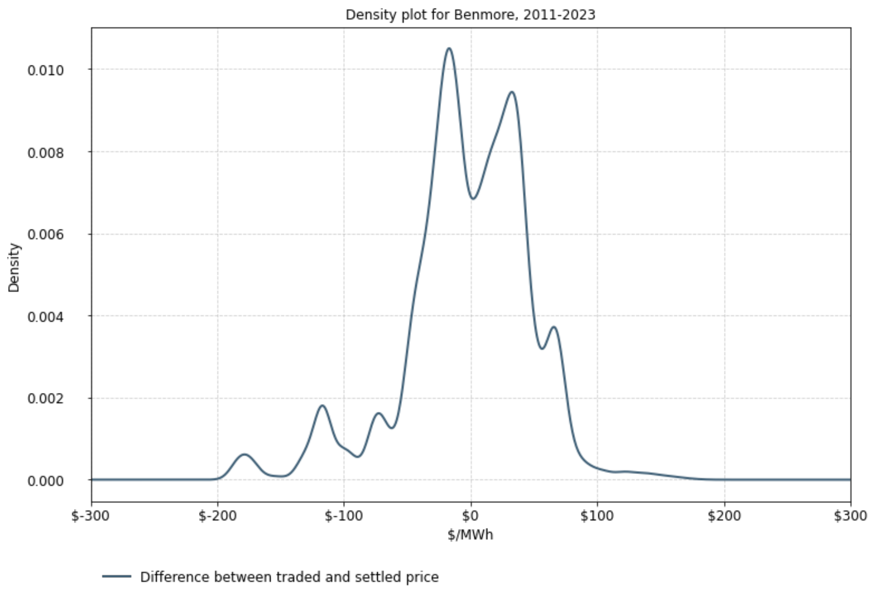
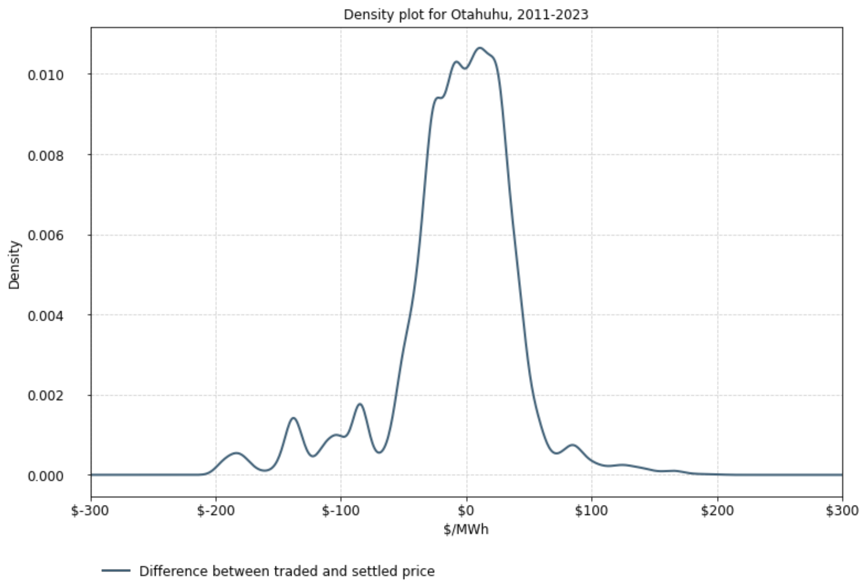


Figure 2: Density plot of difference between traded and settled price at Otahuhu, 2011-2023



Higher prices since 2018 are likely due to external shocks

3.8. There has been a structural increase in spot prices and hence settled prices since late 2018. Figure 3 and Figure 4 show the density plots for contracts expiring from 2018 to 2023. These more closely resemble a normal distribution, with a median of -$22/MWh for Benmore and -$28/MWh for Otahuhu. Two-thirds of ASX futures expiring between 2018 and 2023 traded at prices below the final settlement price.

Figure 3: Density plot of difference between traded and settled price at Benmore, contracts expiring 2018-2023

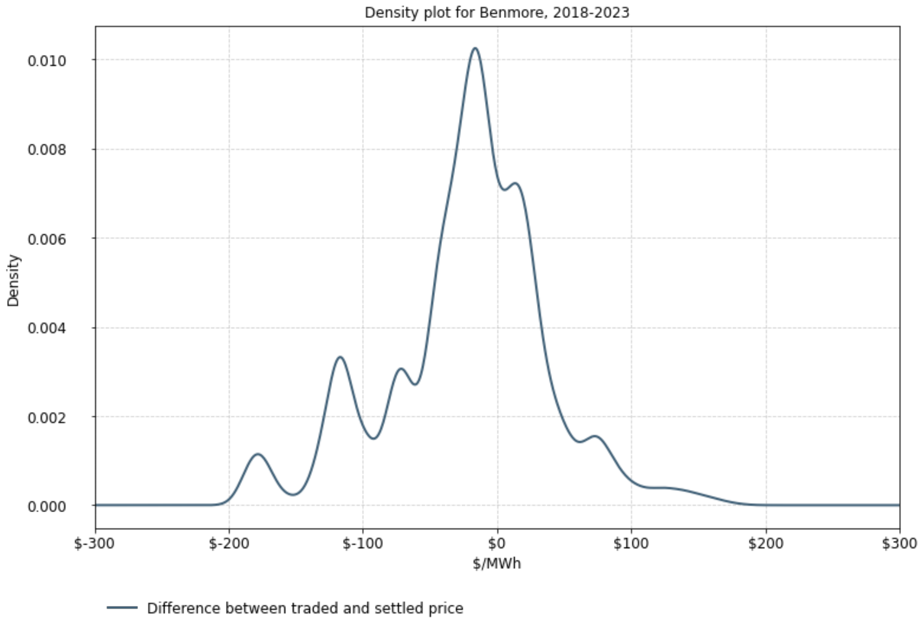
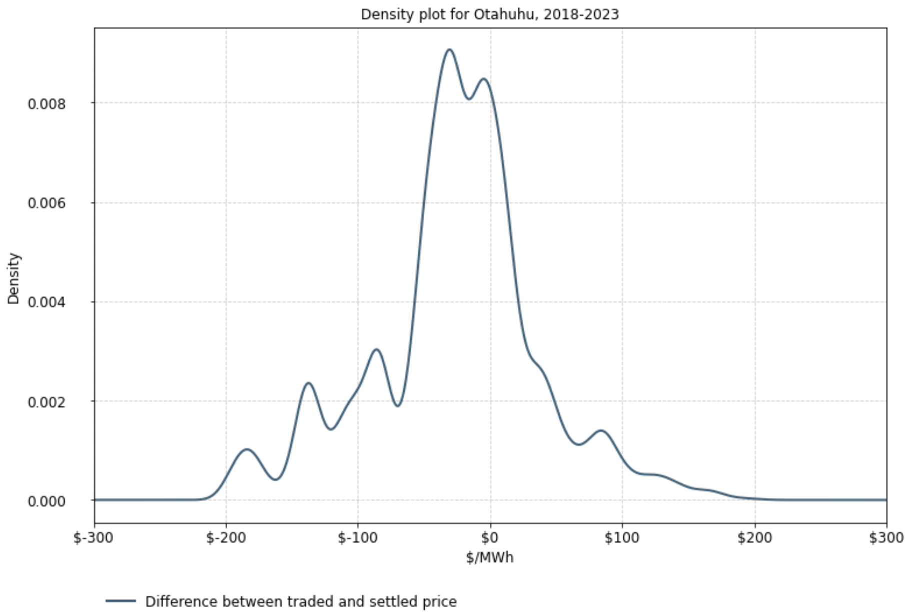


Figure 4: Density plot of difference between traded and settled price at Otahuhu, contracts expiring 2018-2023



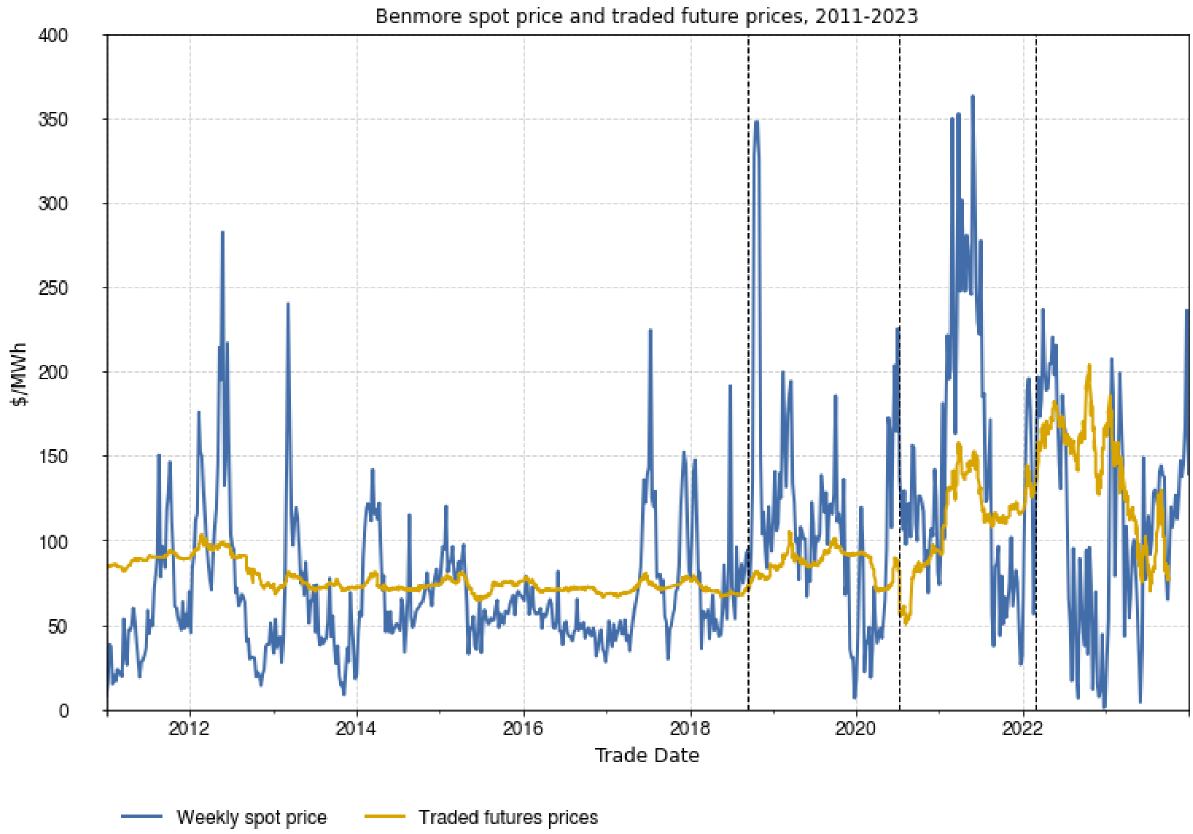
3.9. There have been several external shocks since 2018 that appear to have impacted electricity prices. Figure 5 shows the weekly average spot price and traded futures price (all quarters to the end of 2023) between 2011 and 2023, to illustrate how these shocks (indicated by dashed vertical lines) correlate with both. Firstly, there were the Pohokura gas field outages, which started in March 2018, with the spot market significantly impacted by the outage which started in September 2018. This seems to have caused an unexpected increase in prices from 2018 onwards. Our view is that increased risk of gas shortages (supply uncertainty) continues to be priced into both the spot and forward prices.

3.10. Then on 9 July 2020 Rio Tinto announced it was closing the Tiwai Smelter on 31 August 2021, which correlated with a significant drop in forward prices. Prices recovered towards the end of 2020 as a new deal became likely and on 14 January 2021 Rio Tinto announced it would keep Tiwai open until the end of 2024. As a result, trades during this period—particularly in July and August 2020—were under-priced.

3.11. Finally, Russia's invasion of Ukraine on 24 February 2022, which increased international fuel prices and seemed to result in an increase in both spot and forward prices. This meant that trades before February 2022 for 2022 and 2023 quarters were more likely to have been under-priced.

3.12. This means that the under-pricing we observe in futures expiring between 2018 and 2023 can likely be explained by these external shocks rather than indicating a systemic bias.

Figure 5: Spot price and traded futures price at Benmore, 2011-2023



Spot prices are competitive

3.13. The Authority uses various tools to closely monitor spot market behaviour against the new trading conduct provisions. Based on our assessment of conduct and performance indicators and the findings in our proactive regular monitoring, the new trading conduct provisions (implemented in mid-2021) appear to be having an impact on generator behaviour.[5] We have found spot prices tend to reflect underlying conditions, indicating competitive outcomes.

3.14. As we have found that ASX prices are likely to be an unbiased predictor of spot prices in the long-run, our findings above about spot prices also indicate that ASX

5 See our weekly trading conduct reports here: https://www.ea.govt.nz/industry/monitoring/

prices are likely consistent with workable competition. We therefore use ASX prices as our basis for estimating competitive OTC contract prices, which we then compare with actual OTC contract prices.

4. We then add additional premia on top

Location premium

4.1. Since ASX products are only available at the Otahuhu and Benmore nodes, for OTC contracts traded at other nodes we need to add an estimate to account for the difference in spot prices compared to the Otahuhu and Benmore nodes. That is, the increased likelihood of prices being higher (or lower) than prices at Otahuhu or Benmore.

4.2. To do this, we calculate the average quarterly difference (from 2019 to 2023) in the spot price between the relevant contract node and either the Otahuhu node (if the contract node is in the North Island) or the Benmore node (if the contract node is in the South Island). These are shown in Table 1 for the nodes in each island that had the most requested contracts in the data received from non-integrated retailers.

4.3. The sign of the island location premia is consistent with much NI load being south of Otahuhu, while much SI load is north of Benmore.

Table 1: Location premia by quarter (ie, average difference in nodal prices)

Quarter	NI node ($/MWh)	SI node ($/MWh)
1	-6.57	11.00
2	-8.30	8.66
3	-7.39	6.92
4	-6.59	7.20

Shape premium

4.4. A shape premium is added to the contract price for peak and super-peak contracts to take into account the higher average spot prices during these periods compared to baseload prices. That is, an additional premium is added to account for the greater likelihood of higher spot prices.

4.5. We calculate the shape premium by using historical ratios of peak spot prices to baseload spot prices. Table 2 shows that these premiums have increased after 2018 (which is expected given the increase in spot price volatility). For example, super-peak contract prices for Quarter 2 can therefore be expected to be at least 1.34 times ASX baseload prices – ie, a multiplier of at least 1.34 on top of baseload ASX prices for an estimate of the shape premium in this quarter.

Table 2: Estimated shape premiums

Profile		Ratio of peak to baseload prices*	Ratio of super-peak to baseload prices*
2014-2018	Q1	1.08	1.04
	Q2	1.10	1.19
	Q3	1.07	1.17
	Q4	1.06	1.06
2019-2023	Q1	1.10	1.16
	Q2	1.12	1.34
	Q3	1.12	1.29
	Q4	1.13	1.22

*Calculated as the average ratio of peak spot prices (7am to 10pm) or super-peak spot prices (7am to 9am and 5pm to 9pm) to daily average spot prices.

4.6. We also looked at the ratios of different time blocks in the FPVV prices provided by gentailers (for C&I customers). While the 4-hourly blocks do not correspond exactly with peak and super-peak time periods (and FPVV contracts are designed to align with C&I customer load profiles rather than residential profiles), they do largely line up – especially for peak (8am to 8pm, instead of 7am to 10pm). We found that the ratio of the 4-hour blocks covering 8am to 8pm was 1.11 times the overall time-weighted average price of these FPVVs (for NI contracts over business days). This falls within the range of ratios given in Table 2 for 2019-2023. Additionally, for example, for the time block covering 4pm to 8pm (again, not perfectly aligned with the evening super-peak), the average ratio was 1.24 in quarter 2. This is slightly lower than the value for quarter 2 in Table 2 below (1.34), but we consider that it is sufficiently close (given the caveats of a direct comparison to this 4-hourly block from an FPVV contract)[6] that our calculations provide a good estimate of the shape premium.

4.7. Historical shape factors may not accurately reflect the cost of these contracts in the future. An increase in intermittent generation may change expected prices at different times of the day or in different seasons. Continuing scarcity in the market to meet peak demand will also impact these shape factors. Since there is more uncertainty about how shape factors will change in a more renewable world, there is more risk associated with selling shaped contracts for the future. This means these shape premia could be even higher.

6 See chapter 5 for a discussion of why an FPVV contract price may differ from other OTC contract prices. In addition, some 4-hour blocks have higher ratios than the super-peak block in some quarters, showing that these contracts are tailored more to industrial and commercial demand patterns.

Illiquidity premium

4.8. In an illiquid market, if a participant takes on a position in that market, it cannot easily trade out of that position if it needs to. This implies that there is a premium paid to the seller of the contract to offset this risk.

4.9. Following Bevin-McCrimmon et al (2018), we ran a regression with our ex-post estimated ASX risk premium as the dependent variable.[7] Illiquidity was a significant explanatory variable in this regression analysis, with a positive relationship to the ASX premium.[8] This indicates that increasing illiquidity (or decreasing liquidity) results in a higher ASX premium.

4.10. This is consistent with Bevin-McCrimmon et al, who concluded that as liquidity increases, risk premia reduce - suggesting that market participants pay a liquidity premium when liquidity is low. They found that this is more apparent in longer term (>=2 year ahead) futures as they are the ones with the lowest average trade volumes. Our regression results generally continue to support this conclusion.

4.11. While we think there should be an additional premium added to reflect lower liquidity in the OTC market (compared to the ASX market), given the complexities involved in doing so (including estimating liquidity of the OTC market relative to the ASX market, and then translating this into an additional $/MWh figure), we have not attempted to do so here. We note however that our estimated competitive OTC prices will therefore likely be underestimated.

Spot price volatility premium

4.12. Following Bevan-McCrimmon et al, we also included a measure of spot price volatility in our regression model. We found that the coefficient of the spot price variance in the model was negative and significant (although the coefficient was quite small). This implies that on average, for baseload contracts, if spot price volatility is higher, gentailers need to insure against very low prices (more so than retailers needing to insure against very high prices). That is, gentailers are more willing to sell for lower prices with higher price volatility.

4.13. Bevin-McCrimmon et al discuss how the sign of the coefficient on spot price variance will depend on the proportion of producers relative to consumers hedging their exposure. As demand for futures contracts is spurred from both sides with "competing premia" – producers insuring against low spot prices will accept lower prices, whilst retailers insuring against high spot prices will accept higher prices. They conclude that this likely explains the lack of agreement with regards to the sign of spot price variance (ie, spot price volatility) coefficients in the empirical literature.

4.14. However, at super-peak times, there is less likelihood of low prices and more likelihood of very high prices. We therefore expect that retailers would have to pay an additional premium for spot price volatility at these times (on top of the shape

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7 Fergus Bevin-McCrimmon, Ivan Diaz-Rainey, Matthew McCarten, and Greg Sise, 2018, Liquidity and risk premia in electricity futures, Energy Economics 75, 503-517.

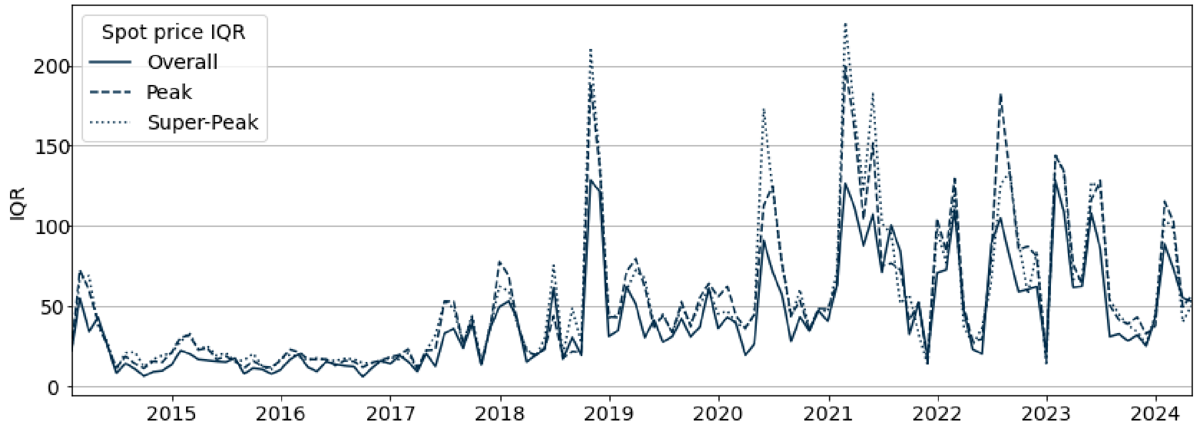
8 We used the same measure of illiquidity as in Bevin-McCrimmon et al, Amihud's Illiquidity measure calculated as the average ratio of the return on the futures contract and the volume of contracts over the prior quarter.

premium – the shape premium relates to the average level of prices, whereas here we are talking about the risk associated with volatility where there is a risk that prices go even higher than the average).

4.15. There has been increased volatility at super-peak times – even more so than at off-peak times. Figure 6 shows spot price volatility (shown using the inter-quartile range) is increasing overall, but at times more so in peak and super-peak trading periods. This suggests that this risk premium is increasing.

4.16. Again, due to the complexities involved, we have not attempted to estimate this premium, and therefore our estimate of competitive contract prices is a lower bound.

Figure 6: Spot price volatility



Scarcity premium

4.17. We also consider that an additional premium for scarcity should be added for OTC peak and super-peak contracts. While the ASX premium should include some of this risk (including expected energy scarcity, such as low hydro storage or gas supply constraints), scarcity is more likely to impact spot prices in peak periods (mainly capacity scarcity, but energy scarcity may also impact super-peak prices more than baseload prices). This means that gentailers have higher risk of being short on generation in these periods.

4.18. We decided against adding this premium to our estimated contract prices due to the complexities involved in estimating such a premium, and because some of this scarcity will be captured in the ASX premium. But it must be considered when comparing our estimated competitive contract prices to actual OTC prices that a lot of the time (especially due to current scarcity in the market) we will be underestimating contract prices.

ASX volatility premium

4.19. As discussed in chapter 5, gentailers gave us evidence that shows they sometimes – when reaching the limits of their portfolio – sell OTC contracts and under-write these by purchasing on the ASX. If gentailers expected to back a contract with an ASX trade, they would include the risk of the ASX price changing between offering the price and backing an accepted contract, as well as the cost of holding that ASX position to term.

4.20. Table 3 shows the average daily range of prices on the ASX by quarter from 2019 to 2023.[9] These are slightly lower than the margins that gentailers added based on the examples they gave us, which were between $5/MWh and $18/MWh. Margins added by gentailers were highest when the amount of MW requested was high. The stated reason for this by gentailers was that it could take several days of trading to back a position for a large contract, and therefore there was a higher risk of price changes. We checked this by also looking at the average price range within weeks (also shown in Table 3). These ranges are higher than the average daily ranges, confirming the assertion by gentailers that selling a higher volume may come at higher risk.

4.21. We did not attempt to add this premium to our estimated competitive contract prices due to the uncertainty involved in the calculation and in keeping with not adding other premia.

Table 3: Average daily range in ASX prices ($/MWh)

Profile		Benmore average daily range	Otahuhu average daily range	Benmore average weekly range	Otahuhu average weekly range
2019-2023	Q1	3.71	4.27	7.50	7.70
	Q2	4.50	5.43	9.00	10.33
	Q3	4.17	4.93	8.44	9.53
	Q4	2.79	3.01	5.53	5.84

Range calculated as the maximum price within the day or week, less the minimum price within the day or week

5. For our modelling we start with our estimated risk neutral prices

5.1. In our modelling (see Appendix B) we have used risk neutral prices in the baseline scenario. As discussed in Appendix B, this allowed us to compare substitutes for risk management.

5.2. Based on the way we constructed these risk neutral prices, they already include a premium for shape. That is, the risk neutral price is calculated using spot prices within the trading periods of the relevant contract type – so for super-peak contracts, the risk neutral price is based on spot prices within the morning and evening peaks. We also only model prices at Benmore and Otahuhu so do not need to add a location premium.

9 We do not have the data to compare to prior years.

5.3. For our “competitive risk management prices” scenario, we then add the historical ASX premium (ex-post estimates), as set out below. The ASX premium varies by quarter.

5.4. We do not attempt to add additional premia, as discussed in section 4. Again, we therefore consider that we are underestimating contract prices.

Our estimated ex-post ASX risk premium is positive in winter and negative in summer

5.5. Our analysis found that traded prices at Benmore were lower than settled prices 71% of the time for the March quarter and 59% of the time for the December quarter, or 83% and 64% at Otahuhu respectively (see Table 4). With low demand in December and March there is a higher chance of very low prices. Generators may therefore be willing to take a lower price to reduce the risk of receiving prices below their costs. Our analysis suggests there may be a negative risk premium of between $10/MWh and $20/MWh (subtracted from expected prices) during summer months.

5.6. In comparison, the June and September quarters had traded prices which were lower than settled prices only about a third of the time, suggesting that traded prices were usually higher than expected prices. High demand in June and September increases the risk of high prices, either sustained due to low lake levels or other fuel supply uncertainty, or price spikes during high peak demand. Therefore, retailers may be willing to pay a risk premium during these quarters to reduce their exposure to very high prices. Our analysis suggests there may be a positive risk premium between $10/MWh and $25/MWh (added to expected prices) during winter months.

5.7. We acknowledge that ex-post estimates of this risk premium are imperfect – they may capture dynamics that are unrelated to the ex-ante premium, such as a lack of trades on any day, and unexpected outcomes in the market. However, ex-ante estimates require estimating future expected spot prices, which is both difficult to do and means any resulting risk premia would be dependent on the assumptions and modelling approach used to estimate expected prices.

Table 4: Difference between traded price and settled price, by quarter*

	Benmore	Otahuhu	Benmore	Otahuhu
	Price difference below $0/MWh (%)		Average price difference ($/MWh)	
Q1	71	83	-21	-20
Q2	35	31	17	9
Q3	33	39	25	16
Q4	59	64	-9	-15

*Use’s data from 2011 to 2023.