Preliminary modelling of BESS gate closure options

11 November 2025

Contents

1. Overview

1.1. We have undertaken preliminary modelling of different trading strategies and gate closure arrangements to help us understand the differences in:

(a) consumer benefits from energy arbitrage, and

(b) BESS profitability.

1.2. The different strategies and gate closure options are described in detail in section 7 of the paper.

1.3. As a reminder, consumers benefit from energy arbitrage through reductions in wholesale purchase costs.

1.4. For simplicity, we have modelled a single BESS of medium size (50MW/100MWh).

1.5. We have modelled each of the following trading scenarios with both one-hour and 30-minute gate closure periods:

(a) **Full capacity with state of charge (SoC) constraints**: This means trading at full capacity, at all times, with SoC constraints. With one-hour gate closure, this represents our preferred option described in section 7. Under this scenario, bids and offers are given economic prices based on predictions of future prices. For example, offer prices would reflect the opportunity cost of discharging in that period compared to discharging in a later period.

(b) **Conservative pricing**: This means trading only at times when profits are expected, with conservative prices.[1] This represents our trading conservatively option described in the body of the paper, but assuming the BESS always trades conservatively in prices rather than quantities.

1.6. We tested the scenarios in a historical market setting over a full year (1 July 2024 to 30 June 2025).

1.7. Our results from this preliminary modelling indicate:

(a) Trading at full capacity with SoC constraints and one-hour gate closure (our preferred option) can provide significantly greater wholesale purchase cost savings, and more profits to BESS owners, compared to conservative pricing with either one-hour or 30-minute gate closure.

(b) There is little difference in consumer benefits or a BESS' profits between one-hour and 30-minute gate closure if trading at full capacity with SoC constraints.

(c) When trading conservatively with prices, 30-minute gate closure enables BESS to earn materially greater profits than one-hour gate closure as it helps prevent financial losses.

1.8. We will gain a better view of the differences between various policy options by refining our models and running new scenarios, eg, to represent a conservative in quantities strategy. Feedback from this consultation will improve our understanding of how BESSs are likely to operate in the market. This will help us to further develop our models ahead of consultation on any proposed Code amendments.

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1 SoC constraints are not applied in this scenario.

2. Description of battery model parameters

2.1. We model different BESS strategies in vSPD[2]. We have chosen these parameters to balance the need to replicate the parameters we expect to see in BESSs entering the market over the next few years, with the need for simplicity in our modelling.[3]

Battery setup

2.2. We modelled one BESS located at the BRB2201 market node. This is the same site as Meridian's Ruakākā BESS.

2.3. In the model, the battery can charge and discharge up to 50MW.

2.4. It can store up to 100MWh of electricity.

2.5. We have chosen a single BESS to simplify the optimisation model we use.

2.6. We have chosen a moderately sized BESS as we consider it is big enough to have an impact on the market without significantly changing trading strategies of other market participants. This ensures the historical trading data we use is relevant to our simulation.

Battery cost and lifespan

2.7. The battery costs $1,000,000 per MW of capacity.

2.8. It is expected to last for 8,000 charge-discharge cycles.

2.9. This gives a degradation cost of $62.50 per MWh which is applied every time the battery discharges, including self-discharge.

Efficiency and energy loss

2.10. The battery is assumed to have a 90% roundtrip efficiency. This is assumed to be symmetrical, meaning there are about 5.13% of energy losses when charging and again when discharging.

2.11. It also loses 2% of its stored energy every 30 days due to self-discharge. This works out to about 0.0014% per trading period. Again, this small loss is included in the degradation cost.

Operating limits

2.12. The battery's state of charge is kept between 12.5 MWh and 87.5 MWh. This may help extend its battery life and meet warranty conditions, and also ensures it can provide both fast instantaneous reserve (FIR) and sustained instantaneous reserve (SIR) at any time.

Simplifications in the model

2.13. This is a simplistic battery model and does not include things like:

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2 vSPD is a replica of the System Operator's market dispatch and pricing tool. It is available at https://github.com/ElectricityAuthority/vSPD

3 We have researched the possible parameters of existing and future BESS by talking to participants, and online research.

(a) power used by support system like cooling or controls

(b) effects of temperature on battery degradation

(c) aging over time even when not used

(d) changes in performance as the battery ages

(e) limits on how fast the battery can charge or discharge

(f) efficiency changes based on energy level, power, or temperature

3. Battery optimisation and simulation method

Forecasting spot prices

3.1. Both strategies require predictions of electricity prices:

(a) trading at full capacity with SoC constraints requires price predictions to determine bid and offer prices (described in detail further below).

(b) conservative pricing requires price predictions to decide when the battery should charge or discharge.

3.2. We predict prices using historical forecast schedules available at gate closure adjusted for the impact of the BESS.

3.3. We start with forecast prices from the price-responsive schedule short (PRSS) and price-responsive schedule long (PRSL).[4] We use the most up-to-date forecasts available at gate closure.[5] This gives us about 1.5 days of forecast prices to use in the battery optimisation.

3.4. We then estimate the impact of BESS use on prices to get the price predictions we use in our various models.

Estimating price impact from battery use

3.5. In the market, BESSs will be able to estimate their impact on prices by looking at results of forecast schedules that include their bids and offers, and by assessing price sensitivities published on WITS. It is therefore important that our model accounts for the impact of BESS on prices.

3.6. We use price sensitivity tests in vSPD[6] to see how battery charging and discharging might affect prices. To do this, we:

(a) interpolate the sensitivity tests to estimate what prices would be if national demand was 50MW lower. We repeat this for the case where it is 50MW higher.

(b) calculate the gradient between -50MW and +50MW. This creates the red line in Figure 1.

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4 Selected schedules are available at: https://www.emi.ea.govt.nz/Wholesale/Datasets/ForecastPrices

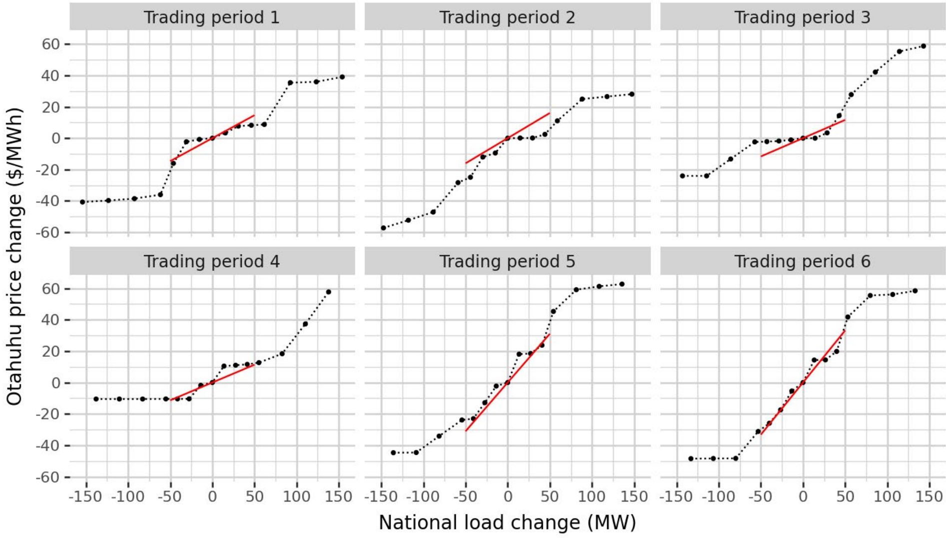
5 We determine this by looking at the run time of historical schedules

6 We used price sensitivities we had previously simulated off the last price responsive schedule runs for each trading period. These tests provided price sensitivities for various percentage changes in demand. We then applied the price changes from those tests to the most recent PRS schedules available at gate closure.

(c) adjust the result to prevent negative price values when demand drops.

3.7. This price gradient for each trading period is internalised within the BESS optimisation model and applied to all forecast prices.

Figure 1: Sensitivity runs of vSPD and BESS price gradient.



Battery optimisation

3.8. We run a profit maximisation model just before gate closure, which chooses the optimal times and quantities to charge and discharge, subject to state of charge limits.

3.9. One limitation is that the model does not account for how other market participants might change their bids or offers in response to the battery.

3.10. Another limitation is that the optimisation model doesn't consider instantaneous reserves. We excluded instantaneous reserves from the model for simplicity.

We apply SoC constraints to dispatch outcomes

3.11. Just before gate closure, we finalise the BESS's bids, offers, and reserve offers (described in detail in the next section).

3.12. We simulate dispatch and apply SoC constraints to ensure dispatch remains feasible given potential outcomes after gate closure.[7]

3.13. This should typically only be needed for the trading at full capacity strategy. This is because the conservative pricing strategy is designed to ensure SoC limits are only exceeded in reasonably unforeseeable circumstances. We applied SoC constraints for this strategy to replicate the trade revisions that would occur should such circumstances occur.

3.14. Example:

(a) at midnight, the battery has 15MWh stored.

[7] The state of charge constraints are applied by adjusting the bids and offers in the vSPD input file.

(b) it has bids to charge 5MW in trading periods 1 and 2.

(c) we create an offer to discharge 10MW in trading period 3.

(d) if the earlier bids do not clear, the battery will fall outside its ideal operating range and not be able to meet its SIR requirements.

3.15. We adjust bids and offers to make sure they are feasible. Any bids or offers that would push the battery outside its ideal operating range (12.5MWh to 87.5MWh) are removed.

3.16. If the battery is close to falling outside this range due to self-discharge, we add a small, high-priced bid to prevent this.

Quantity and pricing strategies

Conservative pricing

3.17. Under the conservative pricing strategy, we determine bid and offer quantities using the profit maximisation model run at gate closure. The most profitable times and quantities are chosen based on what is achievable given state of charge limits.

3.18. We set bid prices at $6,499 per MWh and offer prices at $0 per MWh. This guarantees the battery is fully dispatched (unless a transmission outage or scarcity situation occurs).

3.19. We determine generation reserve offer quantities for FIR and SIR in each trading period as the remaining MW capacity after accounting for the quantity of energy offered. We do this because we expect that it will generally be more profitable for the BESS to be dispatched for energy rather than instantaneous reserve, noting that energy prices tend to be higher than instantaneous reserve prices.

3.20. We offer generation reserve at $0 for both FIR and SIR.

3.21. A limitation of our models is that interruptible load is not offered in either strategy. We considered it would be simpler to model and assess results without interruptible load included at this stage.

Full capacity with SoC constraints

3.22. Under the full capacity with SoC constraints strategy, we bid and offer the full charge/discharge capacity in every trading period, with SoC constraints ensuring dispatch is achievable.

3.23. To determine bid and offer prices, we split the battery into five 10MW bid blocks and five 10MW offer blocks.

3.24. For each block, we re-run the profit maximisation model and compare to the original result. This enables us to calculate the price at which the owner would be indifferent to being dispatched at the full 10MW.[8]

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8 The state of charge constraints remove infeasible quantities starting at the highest priced offer tranches and lowest priced bid tranches.

3.25. For simplicity, we offer generation reserve in full as FIR and SIR at all times, with $0 prices.[9]

4. Simulation results and insights

4.1. We tested both strategies over a full year (1 July 2024 to 30 June 2025), using both one-hour and 30-minute gate closure times.

4.2. Figure 2 shows the wholesale purchase cost savings (excluding purchases from our simulated BESS) from each scenario. These savings are the difference between wholesale purchase costs without our BESS and the wholesale purchase costs with our BESS.

4.3. To calculate the wholesale purchase costs without BESS, we:

(a) get the final energy price at each node

(b) multiply it by reconciled demand at each node to get each market node's retail cost in each trading period[10]

(c) add up the cost across all market nodes and trading periods.

4.4. For the wholesale purchase costs with BESS, we repeat this, using instead the modelled prices from vSPD with the battery included.

4.5. Wholesale purchase costs are significantly reduced in all scenarios. Some of the cost reductions are likely due to the steady, low-cost source of instantaneous reserves.[11]

4.6. We note that some differences between scenarios will be attributable to chance.

4.7. The full capacity with SoC constraints strategy leads to the largest wholesale purchase cost savings, likely because it helps to limit unforeseen price spikes. This may in part be due to this strategy including full generation reserve offers at times when it expects it would be profitable for the BESS to generate. This allows the market dispatch engine to determine the optimal combination of energy and generation reserve to dispatch at these times.

4.8. In our models, the wholesale purchase cost reductions are similar across different gate closures for both trading strategies. Slightly greater reductions occurred with the longer gate closure in the conservative pricing strategy. This may be because, at shorter gate closure, the strategy is more able to avoid trading at times when the BESS ends up losing money but reducing wholesale purchase costs. For example, the BESS could create wholesale purchase cost savings by reducing wholesale prices when discharging by more than it increases prices when charging. However, in doing so, they may at times not earn sufficient revenue to recover degradation costs.

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9 vSPD will determine the optimal dispatch of energy and generation reserve within the MW discharge limit.

10 We use reconciled data that was used bey the clearing manager at the time.

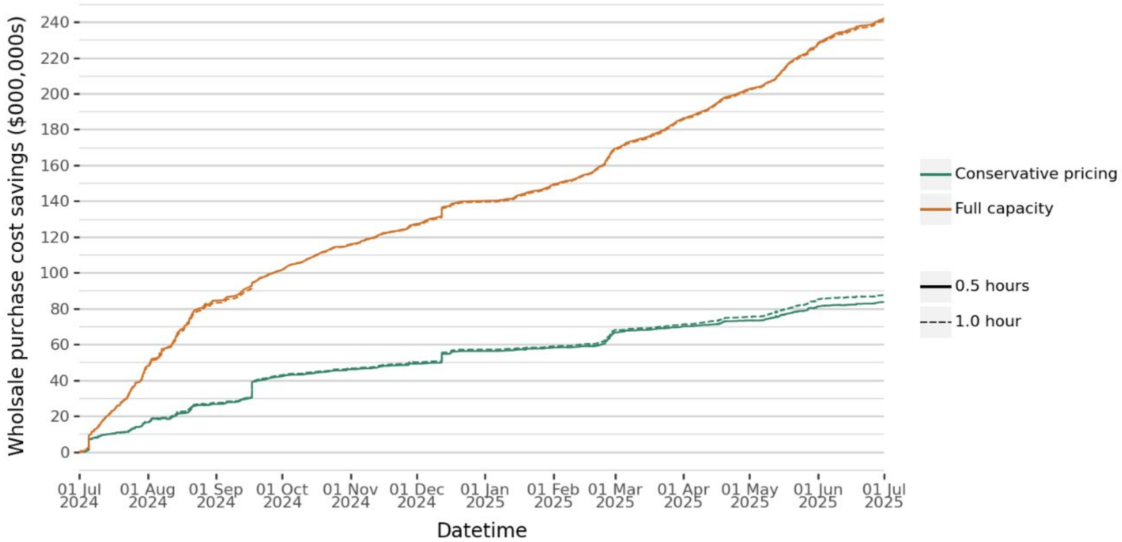
11 By providing instantaneous reserves, this frees up generation capacity from other generators that would otherwise be providing reserves, potentially leading to lower energy prices. Also, if the price of energy is being set by the risk setter (the plant setting the instantaneous reserve demand), then the cost of reserve is included directly in the energy price. Providing low-cost reserve in this scenario would therefore reduce the energy price.

4.9. This logic is consistent with what we observe in the results. Figure 2 shows the difference in wholesale purchase cost savings between 30-minute and one-hour gate closure gradually increasing form the start of April 2025 to the end of June. Figure 3 shows the conservative pricing strategy consistently making financial loses over this time, but with slightly greater losses occurring in the one-hour gate closure scenario.

4.10. We expect if financial losses were consistently occurring in real life, the trader would adapt by removing trades where expected profits were less certain. If so, more trades would likely be removed at longer horizons when price uncertainty is greater. This may lead to smaller wholesale purchase cost savings at longer gate closures.

4.11. Finally, if we modelled a strategy where the BESS traded conservatively in quantities, it would likely show significant reductions in wholesale purchase costs from reducing gate closure. This is because the total quantities traded would be more restricted the longer the gate closure period. However, as explained in the body of the paper, the reduction in wholesale purchase costs from this strategy at 30-minute gate closure would likely be much less than from our preferred option.

Figure 2 Cumulative wholesale purchase cost savings



Battery profitability

4.12. Figure 3 compares how much profit each strategy makes in the wholesale energy market.

4.13. As can be seen, the BESS owner’s profit is much smaller than the savings it creates for wholesale purchasers.

4.14. Both strategies earn greater profits with shorter gate closure, when more accurate price forecasts are available.

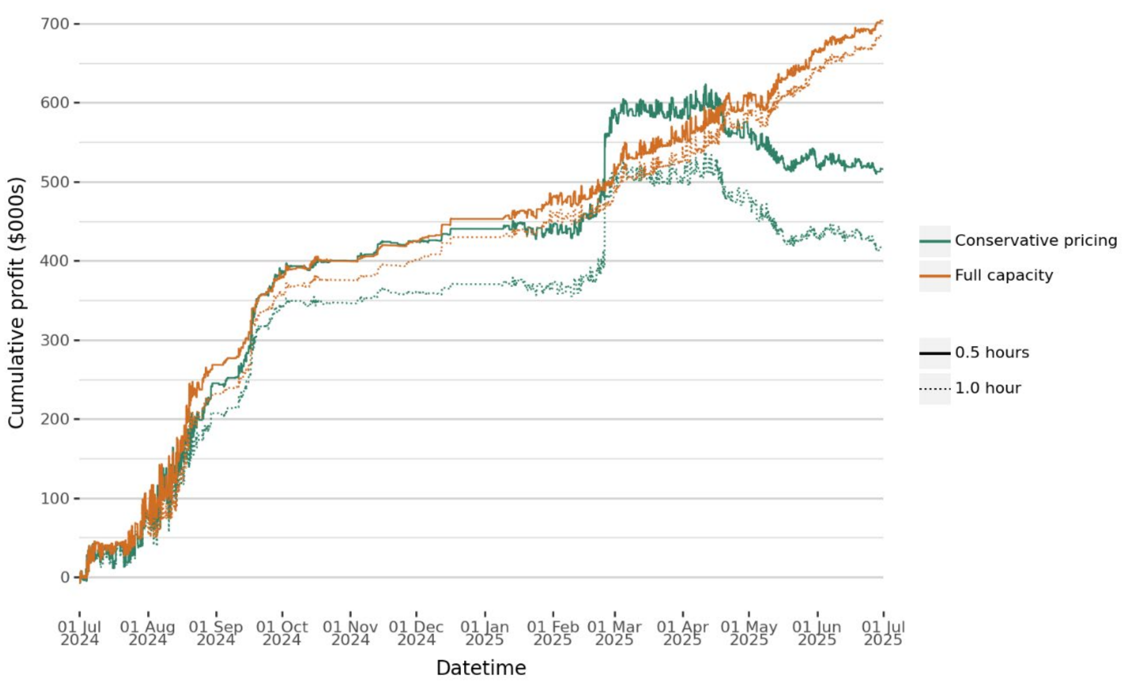
4.15. The strategy, however, makes a much bigger difference to profitability than the gate closure period.

4.16. Trading at full capacity with SoC constraints delivers greater profits compared to conservative pricing. This is what we would expect because it enables the BESS to take advantage of more opportunities and avoid financial losses.

4.17. There are many times when the conservative pricing strategy loses money. This shows there can be a big gap between expected prices and the actual market prices.

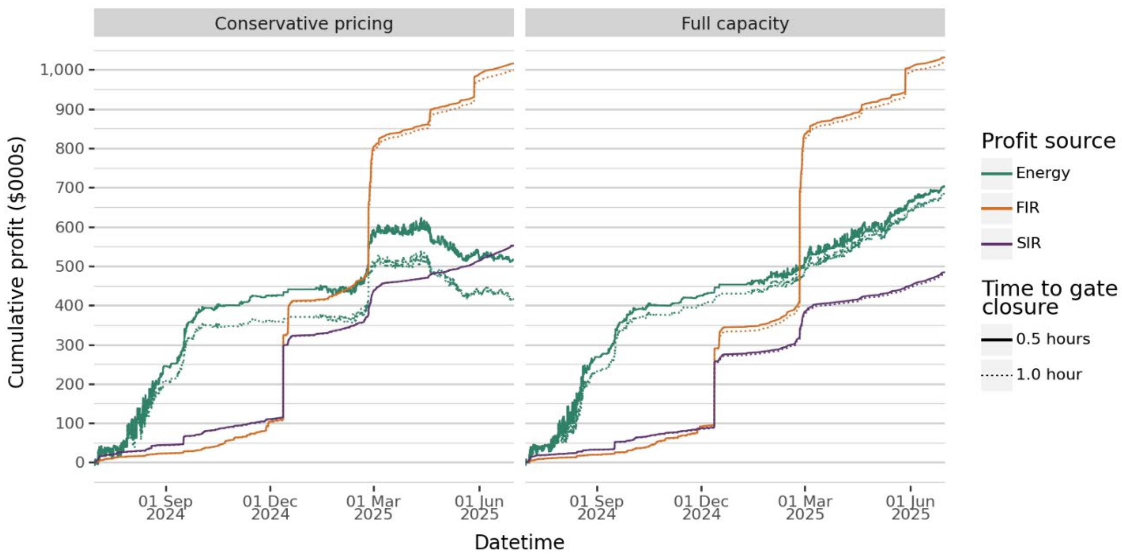
4.18. As with wholesale purchase cost savings, we note that differences in profitability between different scenarios may at times be attributable to chance.

Figure 3 Cumulative wholesale energy profit for BESS



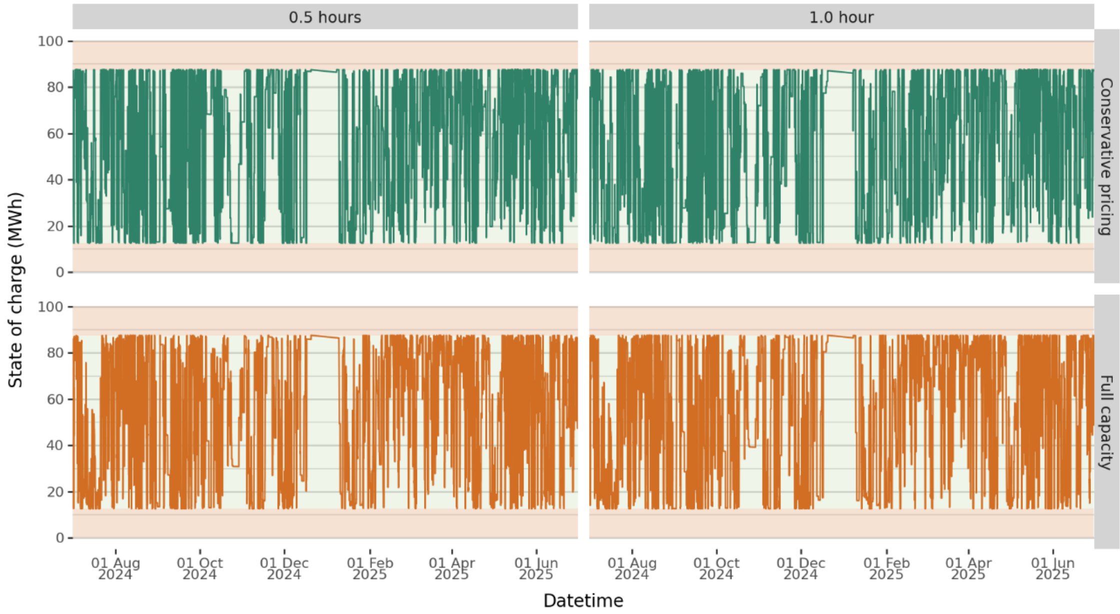
4.19. Figure 4 shows that most of the revenue comes from reserves. The amount earned from reserves is similar across both strategies and gate closure times.

Figure 4 Cumulative wholesale energy and reserve profit



4.20. Figure 5 shows that the battery was used actively throughout most of the year. However, in mid to late December and early January, usage dropped due to consistently low prices.

Figure 5 BESS state of charge



5. Potential further work

5.1. There are several different types of models and refinements to our current models that would be useful to run.

5.2. It would be useful to model further conservative trading strategies at both one-hour and 30-minute gate closure. This would more clearly demonstrate the impact of reducing gate closure if conservative trading was required under the Code. It would also more clearly demonstrate the difference between these policy options and our preferred option.

5.3. In particular, it would be useful to model a conservative in quantities strategy. It may also be useful to model a strategy that was a mixture between being conservative in prices and being conservative in quantities. This would enable charging and discharging in full when profit was expected, while being able to take advantage of limited unforeseen opportunities at other times. This might better replicate how traders would behave if conservative trading was required.

5.4. It would also be useful to have the same reserve offer strategies between the different scenarios to help us better understand the differences between energy offer strategies.

5.5. We intend to add interruptible load offers to any options we model in the future.

5.6. So far, we have used historical energy prices, adjusted for the effect of BESS energy dispatch. It may be worth rerunning vSPD with the FIR and SIR offers included, as this could lead to a better forecast of energy prices within the optimisation model.

5.7. We are also considering modelling a larger BESS. We are mindful, however, that traders would be more likely to change their bids and offers in response to larger BESS. This means our historical data may be less applicable to the situation we are modelling.

5.8. Finally, we are also considering whether to use a probability-based optimisation method, like SDDP.[12] This might improve the profitability and consumer benefits of all options.

5.9. We will consider all feedback received in submissions about our modelling as well as how BESS are likely to operate in the market. This will inform any further modelling we do should we proceed to consultation on proposed Code amendments.

12 A Julia package for SDDP is available in: https://sddp.dev/stable/