Determination of the spinning reserve ancillary service margin peak and margin off-peak parameters for the 2018-19 financial year

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Determination

1. Pursuant to clause 3.13.3A of the *Wholesale Electricity Market Rules (13 October 2017)*, the Economic Regulation Authority has determined values of 25 per cent and 50 per cent, respectively for the margin peak and margin off-peak parameters to apply in the 2018–19 financial year.

2. Spinning reserve is the ancillary service that enables a rapid increase in electricity generation (or decrease in electricity consumption) when there is a sudden shortfall in generation following the loss of a large capacity generator or transmission equipment.

3. Spinning reserve is procured to avoid involuntary customer disconnections or load shedding[1] and can be provided by synchronised generation capacity, dispatchable loads, and interruptible loads.[2,3,4]

4. Synergy is currently the default provider of the spinning reserve ancillary service under the *Wholesale Electricity Market Rules (13 October 2017)* (market rules).[5] Other market participants can also provide spinning reserve through contract to System Management, if they can do so at lower cost than Synergy or if System Management cannot meet the system reserve requirements[6] with Synergy facilities.

5. The margin peak and margin off-peak parameters (margin values) are determined annually and used by the Australian Energy Market Operator (AEMO) in an administered payment process to compensate Synergy for providing spinning reserve.[7]

6. Margin values are applied to the balancing price and the volume of spinning reserve provided to determine the payment to Synergy. This is referred to as the 'availability payment' in the market rules.

7. Ideally, generators providing spinning reserve service should be compensated based on the opportunity cost of withholding their capacity for spinning reserve. The Pennsylvania-New Jersey-Maryland Interconnection (PJM)[8] market in the United

[1] Refer to clause 3.9.2 of the market rules.

[2] A synchronized generator runs at the same frequency as in an alternating current electric power network system and therefore can dispatch electricity to the system.

[3] Interruptible loads are loads that can be automatically reduced in response to frequency changes in accordance with clause 2.29.5(a) of the market rules. A dispatchable load is a load where the quantity of electricity consumed can be increased or decreased by instruction from System Management subject to clause 2.29.5 (c) of the market rules.

[4] Under clause 3.10.2 of the market rules, the quantity of spinning reserve required is the greater of 70 per cent of the total output, including self-consumption, of the generation unit synchronised to the system that has the highest total output and the maximum load ramp expected over a period of 15 minutes.

[5] The market rules define spinning reserve as capacity held for reserve from synchronised scheduled generators, dispatchable or interruptible loads to support system frequency in the event of network or generator outages.

[6] Refer to clause 3.11.1 of the market rules.

[7] The ancillary service settlement calculations are found in clause 9.9.2(f) of the market rules.

[8] PJM Interconnection operates a competitive wholesale electricity market that covers all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia in the United States. Refer to http://www.pjm.com/about-pjm/who-we-are.aspx.

States provides a working example of functional competitive energy and ancillary service markets.

8. In Western Australia, the move to an operational co-optimised energy and ancillary services market is some years away. In the meantime, the administered availability payment for providing spinning reserve should seek to emulate the outcomes of a competitive market. The administered process to calculate margin values should be as transparent as possible whilst respecting the commercially sensitive nature of the modelling inputs.

9. The ERA found that Jacobs' calculation approach includes approximations and averages that simplify the derivation of margin values and their underlying variables. Some may increase the administered spinning reserve cost while others may reduce it.

10. The ERA has identified conceptual and mathematical improvements to the calculation of margin values. In particular, the ERA proposes revisions to the estimation of availability payments to better reflect the settlement outcomes of a competitive ancillary service market. The ERA revised the calculation of margin values to minimise forecast errors for Synergy's availability payments. These conceptual and mathematical improvements are explained in Appendix 2.

11. The ERA recommends a thorough review of the inputs to the model and a more intensive verification process with those parties providing assumptions including an explanation of how the inputs will be used prior to modelling.

12. The ERA supports improving the transparency of the estimation process through the provision of additional information to market stakeholders including detailed information about the simulation method used and the calculation of margin values. The ERA also recommends that AEMO annually conducts and publishes sensitivity and back-casting analyses as a routine part of estimating the margin values (refer to paragraph 47).

13. Using Jacobs' modelling results, the ERA has recalculated margin values using a regression analysis technique. This is discussed in detail in Appendix 2, section A2.2. Rather than using Jacobs' averaging method, the application of regression analysis ensures that forecast errors in Synergy's availability payment are minimised.

14. Since its first submission to the ERA in November 2017, AEMO revised its proposal in December 2017, January 2018, and March 2018 to correct drafting and calculation errors. The ERA's determined margin values and the main underlying variables used in the estimation are presented in Table 1 along with AEMO's proposed margin values for comparison.

Table 1. Margin values and main underlying variables as estimated by AEMO and determined by the ERA for the 2018–19 financial year

Values	AEMO's proposal (November 2017)	AEMO's proposal (December 2017)	AEMO's proposal (January 2018)	AEMO's final proposal (March 2018)	ERA's determination
Reason(s) for revision		• Jacobs corrected inconsistencies in estimated figures for margin values and availability costs throughout its report.	• Jacobs corrected a modelling assumption error affecting Synergy fuel constraints and prices. • Jacobs also revised the application of balancing prices to the calculation of availability costs.	• Jacobs corrected an error in the modelling inputs where the volume of expected contracted spinning reserve was incorrect.	• The ERA used Jacobs' modelling outputs in AEMO's final proposal to recalculate margin values based on regression analysis.
Margin off-peak (%)	64	64	38	71	**50**
Margin peak (%)	49	48	28	34	**25**
Average annual spinning reserve capacity off-peak (MW)[a]	193.0	193.0	194.4	189.0	189.0
Average annual spinning reserve capacity peak (MW)[a]	224.8	224.9	228.4	224.1	224.1
System marginal price off-peak ($/MWh)	41.76	41.76	41.89	39.52	39.52
System marginal price peak ($/MWh)	55.41	55.41	55.16	54.44	54.44
Off-peak estimated availability cost ($m)	5.22	5.20	3.18	5.16	5.09[b]
Peak estimated availability cost ($m)	11.80	11.77	6.97	8.0	7.97[b]
Estimated annual availability cost ($m)	17.02	16.97	10.15	13.15	13.06[b]

[a] The average annual spinning reserve capacity refers to the spinning reserve capacity requirement, which is calculated for each trading interval and is set by the dispatch profile in Jacobs' model.

[b] The ERA used Jacobs method for the calculation of availability costs, however, it used the distribution of all underlying variables to estimate availability cost figures. Jacobs uses averages for estimating some of these underlying variables and therefore their estimation slightly varies from the ERA's.

1. Margin values determination process

15. New margin values are determined for each financial year. The market rules require AEMO to calculate and submit proposed margin values to the ERA by 30 November of the prior year.[9] The ERA must determine, by 31 March, the margin values that are to apply in the upcoming financial year.

16. In proposing the margin values, the market rules require AEMO to take account of:

    - "the margin Synergy could reasonably have been expected to earn on energy sales forgone due to the supply of Spinning Reserve Service"; and

    - "the loss in efficiency of Synergy's scheduled generators that System Management has scheduled (or caused to be scheduled) to provide Spinning Reserve Service… that could be reasonably expected due to the scheduling of those reserves".[10]

17. In making its determination, the ERA undertakes public consultation and considers the Wholesale Electricity Market (WEM) objectives,[11] and AEMO's proposal.[12]

18. AEMO engaged Jacobs to estimate margin values for the 2018–19 financial year and submitted its initial proposal for margin values on 30 November 2017. On 15 December 2017, AEMO submitted a revised proposal to correct inconsistencies in some figures across its report. AEMO provided the ERA with a confidential report, prepared by Jacobs, on the modelling assumptions used in deriving the margin values and the outcomes of a back-casting analysis[13] used to assess the accuracy of the model. AEMO's proposal and Jacobs' public report, including the results from its back-casting analysis are available on the ERA's website.[14]

19. Following receipt of AEMO's proposal, the ERA is required to release an issues paper and invite public submissions.[15] The issues paper was published on 3 January 2018.[16]

20. On 31 January 2018, AEMO submitted a revised version of its proposal to the ERA. In its revised report, AEMO remedied a material error in the estimation of the margin values. Consequently, the ERA published AEMO's revised proposal and Jacobs' public report and extended its public consultation period.

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[9] Refer to clause 3.13.3A (a) of the market rules.

[10] Refer to clause 3.13.3A (i) and 3.13.3A (ii) of the market rules.

[11] Refer to clause 1.2 of the market rules.

[12] Refer to clause 3.13.3A of the market rules.

[13] In the back-casting analysis Jacobs used actual electricity demand and generator outages in the 2016–17 financial year in its simulation of the WEM. It compared the outcomes of this model against the actual outcomes in the market for the same period. Jacobs made adjustments in the model to better align modelling outcomes with historical market outcomes.

[14] Refer to https://www.erawa.com.au/electricity/wholesale-electricity-market/determinations/ancillary-services/spinning-reserve-margin_peak-and-margin_off-peak

[15] Market Rule 3.13.3A (b)

[16] Refer to https://www.erawa.com.au/cproot/18585/2/2018-19%20Margin%20values%20issues%20paper.PDF

21. The ERA received three public submissions during the consultation period from Bluewaters Power, Perth Energy, and Synergy and received a late submission from AEMO. These submissions are available on the ERA's website and are summarised in Appendix 1.

22. On 1 March 2018, AEMO advised the ERA that it intended to submit a further revision to proposed margin values following identification of another material modelling error. The ERA published a notice on 2 March, advising stakeholders of this development.[17]

23. The ERA has a legislative deadline to determine margin values by 31 March 2018. Consequently, there was insufficient time to undertake a second consultation with stakeholders on AEMO's latest proposal. For transparency, AEMO's final proposal for margin values was published on the ERA's website on 16 March 2018.

24. The ERA used AEMO's final proposal to determine margin values to apply in the 2018–19 financial year (refer to Table 1).

2. Emulating a competitive market

25. The ERA supports the development of a competitive market for the procurement of ancillary services to promote competition and enhance economic efficiency. In their submissions to the issues paper, Perth Energy and Synergy supported the development of a competitive spinning reserve ancillary service market.[18]

26. In effectively competitive energy and ancillary services markets, payments to spinning reserve providers should be determined based on the foregone benefits of withholding generation capacity from the energy market. If revenues from providing energy and ancillary services are not comparable, this can bias participation in providing one service or another which may drive up system costs.

27. A market operator seeks to minimise the total cost of an electricity supply system comprising energy and ancillary services markets. This is achieved by concurrently optimising, or co-optimising energy and ancillary services markets. In a co-optimised market, generators are dispatched to minimise costs across both energy and ancillary services.

28. In the WEM, spinning reserve is scheduled by System Management primarily from Synergy's portfolio supplemented by contracts with third parties. AEMO's contracts with spinning reserve providers are usually let on the basis of a discount on the margin values.[19]

29. Participants other than Synergy can and do provide contract load following and spinning reserve services but participation is limited. Perth Energy noted in its submission that AEMO has no obligation under the market rules to commit the most competitively priced resources to provide spinning reserve and Synergy is the default provider of the service. It claimed that this, coupled with the high cost of complying

[17] Refer to the ERA's notice 'Resubmission of revised proposal for margin values', https://www.erawa.com.au/cproot/18749/2/Notice_AEMO%20to%20resubmit%20revised%20proposed%20margin%20values.pdf

[18] Refer to Synergy's submission, page 2, and Perth Energy's submission, page 1.

[19] This contract structure is not prescribed in the market rules.

with technical requirements for the provision of spinning reserve, discourages participation.

30. Bluewaters Power argued the margin values estimation process should provide a price signal for market participants who are considering contracting to supply spinning reserve.[20] However, a change in the contracted quantity of spinning reserve alters forecast spinning reserve costs. Bluewaters Power noted that AEMO uses contracted spinning reserve volumes from previous years in its estimation of future margin values.

31. To estimate margin values, AEMO requires volumes of contracted spinning reserve. During the estimation process, AEMO does not have a reliable estimate of these volumes until contracts for the next financial year are let. If contracts assumed in the modelling are not realised, the modelling outcomes are no longer valid. System Management usually lets spinning reserve contracts after the ERA has determined margin values.

32. Bluewaters Power recommended that the outcomes of the spinning reserve procurement process with other market participants are taken into account by AEMO in estimating margin values. If this is not possible, Bluewaters Power recommended that the ERA accounts for revised contract values in its determination.

33. Bluewaters Power also noted that the procurement of spinning reserve from other market participants was discussed in the Market Advisory Committee meeting on 13 December 2017.[21] The Market Advisory Committee considered an arrangement that allows market participants to use AEMO's annual proposal for margin values as a spinning reserve price signal to revise their offers for the provision of the service.

34. The ERA cannot adjust margin values based on updated contracted spinning reserve volumes, as this would require revised simulations of the WEM, which are not possible in the current legislative timeframe. However, the ERA welcomes advice from AEMO that it is currently reviewing its schedule and process for the spinning reserve procurement to improve the accuracy of the estimation process and enhance participation from independent spinning reserve providers.[22]

35. Perth Energy stated that the development of a spinning reserve market would eliminate the need for theoretical modelling of spinning reserve availability payments, which is prone to assumption, concept, and calculation errors. The ERA generally supports market based outcomes as being economically efficient. However, given the intent of current market reforms to eventually move to a co-optimised energy and ancillary service market, a cost-benefit analysis should be conducted to assess the feasibility of developing an interim market.

36. The ERA investigated which of the principles underpinning a competitive spinning reserve market could be used to determine the current administrative spinning reserve payments in the WEM. These principles, outlined in Appendix 2, are likely to have implications for other ancillary service determinations, such as Cost_LR.[23] The ERA

[20] Refer to Bluewaters Power's response to the ERA's issues paper for 2018–19 margin values (page 5) and their response to the ERA's issues paper for 2017–18 (page 2) available on the ERA's website.

[21] Rule Change Panel (2017) Minutes – Meeting 2017-08, Rule Change Panel, Perth, pp 12-13; https://www.erawa.com.au/cproot/18732/2/MAC%20Meeting%202017-08%20Minutes.pdf

[22] Also refer to the Market Advisory Committee meeting 2017-08. AEMO stated that for the next review of margin values it is considering how the outcomes of the expression of interest process for the spinning reserve contracts could be used in the estimation of margin values.

[23] Refer to clause 3.13.3b in the market rules

encourages AEMO to consider and apply these principles where appropriate for future ancillary services proposals.

3. Analysis

37. Each month AEMO compensates Synergy for providing the spinning reserve service. Under the market rules the compensation for each interval is determined as a function of the margin values, and the market determined balancing price and spinning reserve quantities.[24] Equation 1 shows a simplified version of the formula specified in the market rules for estimating availability payments to Synergy.

$$A(t) = \frac{1}{2}\, mv.p_t.max\left[0, q_{SR,t} - q_{LFAS_{up},t} - q_{SR,c}\right] \quad (1)$$

In Equation 1, for a trading interval t,

- $A(t)$ is the availability payment ($) to Synergy;
- mv is the $margin\,peak$, if the trading interval is a peak trading interval and $margin\ off-peak$, if the trading interval is off-peak;
- p_t is the balancing price ($/MWh);
- $q_{SR,t}$ is the quantity (MW) of spinning reserve;
- $q_{LFAS_{up,t}}$ is the quantity (MW) of load following ancillary service raise; and
- $q_{SR,c,t}$ is the quantity (MW) of contracted spinning reserve ancillary service.

38. Jacobs determined the parameter margin values, mv, based on its forecast of the coming year's availability payments (referred to by Jacobs as the availability cost), balancing price, and spinning reserve, load following ancillary service, and contracted spinning reserve quantities. Jacobs estimated margin values in three steps:

    a) Simulation: Jacobs developed a model of the WEM to simulate market outcomes including balancing prices, revenue and generation costs, spinning and load rejection reserve quantities, and load following ancillary service quantities for all trading intervals in the 2018–19 financial year. The model provided estimates of the variables in Equation 1.

    b) Availability cost estimation: Jacobs estimated the availability cost term, $A(t)$, by comparing Synergy's revenue and generation costs in four market scenarios with and without provision of spinning reserve, and also with and without provision of load rejection reserve.

[24] Clause 9.9.2(f) provides the total payment to all market participants for spinning reserve service in trading interval t:

SR_Availability_Payment(t)=0.5xMargin(t)xBalancing_Price(t)x max(0, SR_Capacity(t) – LF_Up_Capacity(t) – Sum(c ϵ CAS_SR,ASP_SRQ(c,t))) + Sum(c ϵ CAS_SR,ASP_SRPayment(c,m) / TITM)).

c) Margin values estimation: Jacobs rearranged Equation 1 to estimate average margin value parameters.

Each of these steps is outlined in the following three sections 3.1, 3.2, and 3.3.

3.1. Simulation

39. Jacobs developed simulations of the WEM for scenarios with and without the provision of spinning reserve. AEMO consulted on Jacobs' modelling approach and input assumptions publicly and also directly and confidentially with major generators in early October 2017 and published an assumptions report.[25] AEMO received submissions from Alinta Energy and NewGen Power Kwinana Pty Ltd.

40. Alinta challenged the assumption there would be no new generators in the WEM for the 2018–19 financial year. It recommended updating the assumption following the capacity certification process. AEMO expressed reluctance to 'pre-empt' the outcomes of the reserve capacity certification process. Jacobs remodelled the margin values twice since the completion of the certification process but did not reflect new generators or changes to accredited capacity.[26]

41. The market rules imply an equivalence between load following raise and spinning reserve.[27] Jacobs' estimation approach emulates this for all generators participating in the load following market except Newgen Kwinana and Cockburn CCGT. AEMO excluded NewGen Kwinana's capacity citing a long expired exemption from compliance with the technical rules.[28] NewGen Power questioned AEMO's rationale for excluding NewGen Power Kwinana's load following capacity.

42. AEMO's response to NewGen Kwinana claimed NewGen Power was ineligible to reduce the spinning reserve requirement via load following because it lacks a spinning reserve contract. AEMO made no reference to the generator's technical capability to provide spinning reserve.

43. It is reasonable to exclude capacity from a generator if it is incapable of providing spinning reserve for technical reasons, even if the generator is capable of meeting the less stringent load following raise service. However, AEMO's response to NewGen imposes a contractual requirement.[29] Such a requirement appears to have no foundation in the market rules.

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[25] Refer to http://www.aemo.com.au/Stakeholder-Consultation/Consultations/2017-Margin-Peak-and-Margin-Off-Peak-Review---Assumptions

[26] AEMO also certified a new generator capacity, Carnegie Clean Energy, for the 2018–19 capacity year.

[27] Market Rule 9.9.2 (f) reduces the spinning reserve quantity for settlement by the load following raise cleared in the market.

[28] Jacobs (2017) Draft Assumptions Report – PUBLIC- Consultation, Jacobs, Melbourne, p25 available from https://www.aemo.com.au/Stakeholder-Consultation/Consultations/2017-Margin-Peak-and-Margin-Off-Peak-Review---Assumptions

Also, Western Power (2014) Western Power's list of exemptions from compliance from Technical Rules granted after 1 July 2007, Western Power, Perth p7

https://www.erawa.com.au/cproot/13100/2/20141218%20Western%20Power%20exemption%20from%20technical%20rules%20list%20-%20Dec%202014.pdf

[29] Jacobs (2017) Final Assumptions Report PUBLIC v14, Jacobs, Melbourne, p30, available from https://www.aemo.com.au/-

44. The review identified a number of modelling assumptions and parameters that would raise or lower the availability cost. The ERA recommends that AEMO explicitly and confidentially tests fuel price input assumptions with market participants. In particular, the ERA recommends that AEMO revisits the application of fuel supply curves in the market simulation model.

45. AEMO's consultation process for the assumptions report should ensure the market participants understand how the information they provide will be used. Consultation should actively verify inputs, including those that are unchanged from year to year.

46. To enhance transparency, the ERA also recommends that AEMO publishes a detailed explanation of the simulation model that has been developed, how input parameters are used, and how the model is validated. Bluewaters Power and Perth Energy noted that the procurement of spinning reserve is not sufficiently transparent. Bluewaters Power supported the continuous improvement of the estimation process.[30]

47. Jacobs conducted sensitivity analysis on its simulation model through December 2017. This exercise identified the modelling error leading to the revised margin values proposed by AEMO at the end of January 2018. Conducting sensitivity analysis should guide the scrutiny applied to input parameters and modelling assumptions and information gathered through consultation. The ERA recommends that AEMO continues to conduct and publish back-casting and sensitivity analysis annually to promote confidence in the estimation of margin values. These exercises could be used to improve model accuracy, validate model development, and facilitate the interpretation of modelling results.

3.2. Availability cost estimation

48. Jacobs used the results of the simulation model to estimate Synergy's availability payments (costs), A. Jacobs compared revenue and generation cost outputs from 10 iterations of four market scenarios, with and without provision of spinning reserve, and also with and without provision of load rejection reserve.[31]

49. Jacobs used Equation 2 to estimate Synergy's availability payments for each trading interval in the 2018–19 financial year:

$$A = C_{SR} - C_{noSR} + (Q_{noSR} - Q_{SR}).p_e \qquad (2)$$

where,

- C_{SR} is Synergy's total generation costs for its portfolio of plants, including start-up costs, in the scenario where spinning reserve is provided by Synergy and those market participants contracted to provide the service (the reserve provision scenario);

/media/Files/Stakeholder_Consultation/Consultations/WA_WEM_Consultation_Documents/2017/Margin/Final-assumptions-report--PUBLIC-v14.pdf

[30] Refer to Bluewater Power's submission, page 5.

[31] Generators' unplanned outages are random. Ten random outage iterations are modelled for each reserve and load rejection scenario producing 40 iterations overall.

- C_{noSR} is Synergy's total generation costs for its portfolio of plants, including start-up costs, in the scenario where the market operates without a spinning reserve service (counterfactual scenario);

- Q_{SR} is Synergy's total generation volume for its portfolio of plants, in the reserve provision scenario;

- Q_{noSR} is Synergy's total generation volume for its portfolio of plants, in the counterfactual scenario;

- p_e is energy market clearing price, in the reserve provision scenario.[32]

50. The ERA's margin values issues paper revisited a question first raised by market participants in 2011, and sought market stakeholders' comments on Jacobs' approach to estimating Synergy's availability cost in Equation 2.[33] This was to ensure that Jacobs' approach is appropriate and the estimated margin values reflect the requirements of the market rules.

51. Jacobs' method for estimating the availability cost, as shown in Equation 2, accounts for output differences of Synergy generators between the scenarios with and without spinning reserve, and differences in costs incurred by Synergy generators. However, when calculating Synergy's availability cost, Jacobs' method does not account for different price outcomes in the balancing market and the gains or losses in revenue that occur as a result of potential price changes. In Equation 2, Jacobs uses the energy market clearing price from the reserve provision scenario only. Consequently, Jacobs' estimated availability cost may not fully account for the differences in the revenues that would apply if Synergy did not provide spinning reserve.

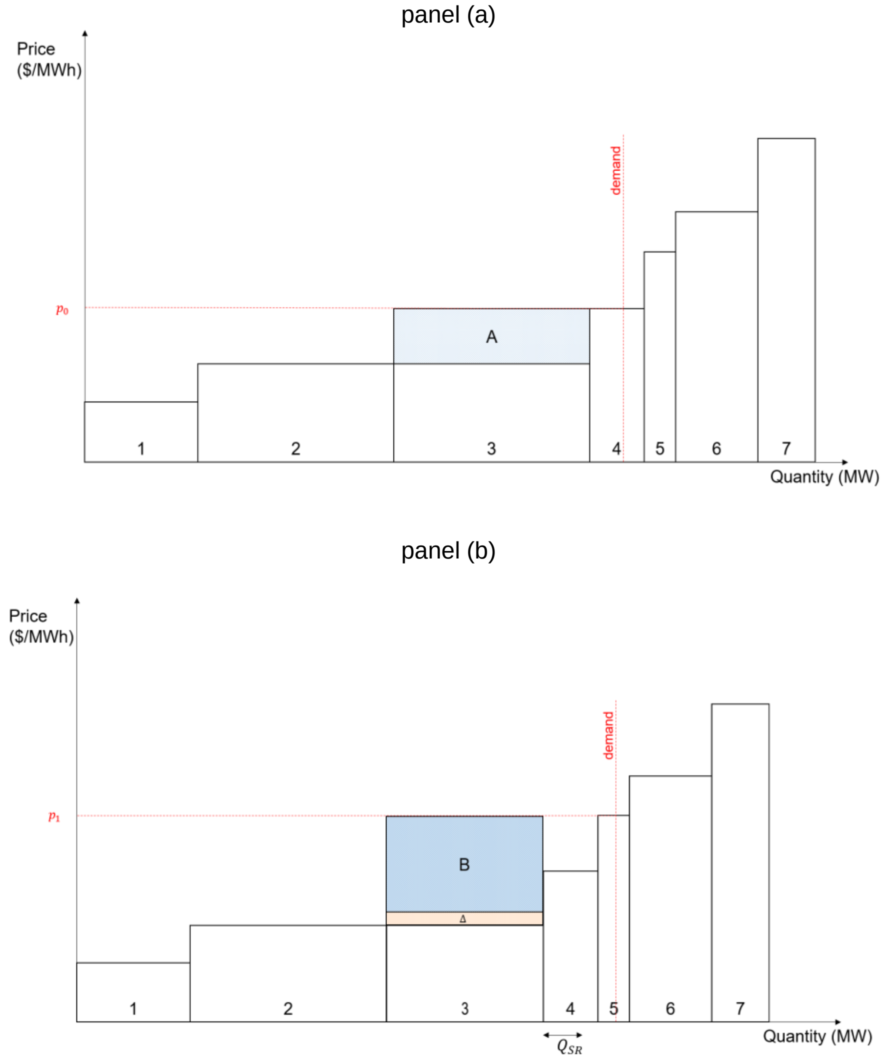
52. To explain this concept, Figure 1 illustrates an example of a trading interval in an energy market with seven generators. The height of each column represents each generator's unit supply costs (in $/MWh), while the width indicates a generator's output capacity (in MW). The area below a unit supply cost shows a generator's total supply cost.[34] The highest supply cost in the merit order sets the market clearing price where supply intersects energy demand. In this example, when no spinning reserve is provided (referred to as the counterfactual scenario in Jacobs' calculation), generator 4 is the marginal generator and the market is cleared at price, p_0. Generators 1 to 3 are infra-marginal and collect economic surplus.

[32] In its report on 30 January 2018, Jacobs revised this formula and for the market price it applied modeled system marginal price in scenario with provision of spinning reserve and load rejection reserve services.

[33] For details refer to section 5.1 of the ERA's issues paper for the determination of 2018–19 margin values.

[34] For simplicity, in this paper we assume that the duration of a trading interval is one hour. Therefore a 1 MW of capacity delivers 1 MWh of energy in the 1-hour trading interval.

Figure 1. Change in economic surplus of the plant providing spinning reserve



53. As shown in panel (a), without the provision of reserve, generator 3 earns the economic surplus area A. After providing Q_{SR} MW of reserve, generator 3's surplus is area B, as illustrated in panel (b).[35] In this example, withholding part of generator 3's capacity for reserve increases the energy market clearing price to p_1, as set by generator 5.

54. If generator 3 is owned by a market participant with a portfolio of generators, changes in the market clearing price due to the provision of spinning reserve could change the participant's surplus for its entire generation portfolio cleared in the market. This finding is particularly important for the calculation of Synergy's availability payments. Changes in the balancing market clearing price due to the provision of spinning reserve can affect Synergy's generation portfolio revenue.

[35] Due to efficiency loss, the residual capacity of generator 3 would incur a higher supply cost, as illustrated by area Δ.

55. The ERA asked the Independent Market Operator to review this issue in 2011.[36] In 2014, the Independent Market Operator reviewed the method and argued that:

- Because the network would not be operated without a reserve, the counterfactual price (set by the cost of the marginal generator) is invalid. The Independent Market Operator stated that "while the [counterfactual] scenario provides a useful estimation of Verve Energy's[37] costs, its SMP [system marginal price] results are based on unrealistic assumptions and so are unlikely to be reflective of real market prices".

- Because Verve Energy traded most of its output through bilateral contracts "changes in the SMP [system marginal price] would only be expected to have an impact over the comparatively small quantities generated above or below Verve Energy's Net Contract Position". The Independent Market Operator stated that the inclusion of price difference would apply the price difference to all of Verve Energy's modelled generation output.[38]

56. In this year's issues paper, the ERA sought market stakeholders' views on this matter. AEMO, Bluewaters Power, and Synergy's responses to the question are summarised in Appendix 1.

57. Synergy argued that the counterfactual price would be higher due to scarcity in the spinning reserve market. This is not possible as the counterfactual marginal price is derived from a simulation scenario that assumes the WEM operates without spinning reserve. Therefore, the counterfactual scenario cannot be influenced by scarcity pricing.

58. The ERA does not support the Independent Market Operator's arguments, as presented in paragraph 55, because:

- An electricity system can operate without (sufficient) spinning reserve. However, without a spinning reserve service the frequency of load-shedding events is likely to increase. Consumers could bear losses due to losses of load,[39] which may exceed the cost of providing the reserve.

- The Independent Market Operator did not explain why the estimated costs for the counterfactual scenario are useful for estimating Synergy's costs, whereas system marginal prices are not realistic and hence not useful. The counterfactual scenario is developed based on the assumption that the network would be operated without the spinning reserve service. If the simulated system marginal prices (which are set by the marginal cost of supply of the marginal

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[36] Refer to the ERA's 2011/12 determination of Margin_Peak and Margin_Off-Peak parameters, 31 March 2011, paragraph 15. https://www.erawa.com.au/cproot/9479/2/20110331%20Determination%20of%20the%20Ancillary%20Service%20Margin_Peak%20and%20Margin_Off-Peak%20Parameters.pdf

[37] Verve Energy and Synergy merged in 2014. The merged entity now trades as Synergy.

[38] Refer to the Independent Market Operator's letter for the submission of Margin Peak and Margin Off-Peak Review 2013/14, p.2 and 3, https://www.erawa.com.au/cproot/11027/2/IMO%27s%20proposal%20on%20the%202012%20Margin%20Values%20(inclusive%20of%20independent%20assessment%20by%20consultant%20SKM%20MMA)_Redacted.pdf

[39] Domestic and commercial consumers use electricity to obtain or facilitate desired end services such as lighting, heating, transport, or industrial services. Consumers value reliable supply of electricity. This value varies by the consumer type and the duration and frequency of electricity outages.

plant) are unrealistic and not useful, it follows that Synergy's costs should be similarly unrealistic.

- Balancing market prices underlie bilateral contract prices. As noted by Bluewaters Power, changes in balancing prices would be reflected in the bilateral prices.

59. The ERA has assessed the calculation of availability payments based on the principle that the administrative process to calculate availability payments should emulate the outcomes of a competitive spinning reserve market as closely as possible.

60. When compared to a scenario without the provision of spinning reserve, withholding some infra-marginal or marginal capacity to provide spinning reserve can change the balancing market clearing price in a trading interval. This price change can affect infra-marginal generators' surplus. For instance, if the provision of reserve increases the energy market clearing price in a trading interval, the best alternative for a generator considering whether or not to provide spinning reserve would be to forego the provision of reserve, use its all available and in-merit capacity in the energy market, and benefit from the price increase when other market participants provide the reserve.

61. It follows that for a generator, the opportunity cost of withholding capacity for spinning reserve is the sum of:

    - the foregone economic surplus in the energy market for the quantity of capacity withheld for spinning reserve. This foregone surplus can be estimated based on the generators' best alternative to providing spinning reserve, ie to forego the provision of reserve and dispatch all available, and in-merit, capacity in the energy market where other market participants provide the reserve service; and

    - the total cost due to the loss in efficiency of the remaining capacity of the generator providing the reserve.

    In a spinning reserve market, participants offer their reserve based on the opportunity cost of providing one additional unit of spinning reserve, i.e. the marginal cost of providing spinning reserve.

62. In a spinning reserve market, payment is the product of the spinning reserve market clearing price and the reserve quantity. The marginal provider of spinning reserve service sets the market clearing price and infra-marginal spinning reserve providers collect economic rent. This market-based settlement process could be used as the basis for calculating the availability cost in future margin value determinations. This approach is consistent with the guidelines provided in clause 3.13.3A of the market rules.[40] A detailed discussion of this approach is presented in Appendix 2, section A2.1.

63. Based on the principle explained in paragraphs 59 to 62, Jacobs' estimation of Synergy's availability cost, as shown in Equation 2, has two broad limitations:

    a) The method incorrectly assumes that all Synergy's cost and benefit differences between the modelled scenarios (the reserve provision and the counterfactual scenarios) require compensation and therefore are included in the calculation of availability cost. Jacobs uses a co-optimisation model of the WEM, to minimise the total cost of the energy and ancillary services markets. In Jacobs modelling of the

[40] Refer to clause 3.13.3A of the market rules.

two scenarios, commitment of generators in the energy market can be different. This is to minimise the cost of the system in both energy and ancillary services markets subject to meeting the reserve requirement of the system. Actually, only those generators providing the spinning reserve service require compensation.

b) The current method does not estimate availability cost based on the marginal cost of spinning reserve by the marginal supplier. In contrast to a competitive spinning reserve market, Jacobs' approach does not allow for the collection of infra-marginal rents and therefore does not suitably emulate the outcomes of a competitive spinning reserve market.[41]

64. In its submission, Bluewaters Power identified a specific case illustrating the first limitation above, where Jacobs' estimation method does not distinguish between changes in cost and revenues of the plants providing reserve and those of the generators that replace the reserved capacity.[42] A detailed discussion of these limitations is presented in Appendix 2, section A2.1.6.

65. The market rules provide two separate payment processes for the provision of the spinning reserve and load rejection reserve services.[43] Jacobs simulated Synergy's availability cost for three separate scenarios and found that the cost of providing both services together is different from the sum of the cost of providing each service separately. Jacobs and AEMO agree that this difference, referred to as the 'interaction cost', has to be proportionally allocated to the cost of each service to meet the separate payments requirement under the market rules.

66. For calculating the interaction cost between the spinning and load rejection reserve services, Jacobs used an auxiliary variable, $availability\ cost\ (SR\ given\ LRR)$.[44] As Jacobs uses the same approach, any limitations in the calculation of availability cost are also carried into the estimation of the interaction cost.

67. The ERA recommends that AEMO considers the principle outlined in paragraphs 56 to 59 to enhance the calculation of availability cost for the spinning reserve service in its future reviews of the margin values. AEMO should also consider replicating any conceptual and mathematical improvements in proposals for the load rejection reserve service.

3.3. Margin values estimation

68. Jacobs took averages for variables on the right hand side of Equation 2 (over all trading intervals) and rearranged the formula to estimate average margin values. The ERA is concerned that using margin values determined by averaging may over or under compensate Synergy excessively. As an alternative, the ERA has used regression

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[41] In a competitive market suppliers can benefit from lower supply costs, either due to technological superiorities or efficiency improvements, as a competitive advantage. With such an advantage they can collect economic rent in the short run. A market-based payment would allow for the collection of infra-marginal rent as it would create an incentive for suppliers to lower their supply costs. This feature of the market drives down prices to consumers. In the long run, however, when all efficiency improvement opportunities are exhausted, and the market is in equilibrium, all suppliers would collect a normal economic profit.

[42] Bluewaters Power noted that with Synergy's large portfolio of generators, other Synergy generators would likely cover those Synergy units providing reserve. In such instances Synergy would not necessarily incur the revenue loss as estimated by Equation 2. Refer to Bluewaters Power's submission, page 4.

[43] Refer to clauses 3.13.3A and 3.13.3B of the market rules.

[44] Refer to page 63 of Jacobs's final report (revision 3.0, 9 March 2018).

analysis to determine margin values for the 2018–19 financial year based on Jacobs' modelling outputs. Regression analysis is preferred as uses techniques to minimise potential errors in determining margin values. This change has reduced the margin values determined for the 2018-19 financial year. Refer to Table 1.

69. A detailed discussion of the problem with averaging to find margin values is presented in Appendix 2, section A2.2.1. A detailed discussion of the regression analysis approach undertaken by the ERA is presented in Appendix 2, section A2.2.2.

4. Conclusion

70. There are challenges in the administered process used to estimate margin values. With an operational co-optimised energy and ancillary service market some years away, the ERA recommends changes to the administered process to improve the conceptual framework, process transparency and mathematical accuracy of calculated margin values used to compensate Synergy for the provision of the margin value ancillary service.

71. The ERA has identified improvements in the conceptual framework for estimating the margin values for AEMO to consider in its proposal for margin values to apply in the 2019–20 financial year.

72. AEMO should undertake and publish back-casting and sensitivity analysis results annually and review and publish its model validation and quality assurance processes to restore market participants' confidence in the process.

73. The ERA recommends that AEMO thoroughly reviews the input assumptions with market participants and their subsequent use in modelling availability cost in the resource provision and counterfactual modelling scenarios.

Appendix 1. Summary of submissions received

Issue	Comment
Synergy	
Treatment of the counterfactual scenario	Synergy reiterated the arguments raised in 2014 by the Independent Market Operator.
Shortage pricing and counterfactual balancing price	Synergy argued the counterfactual scenario is not valid insofar as balancing prices are concerned – only for volume changes. It further argued spinning reserve would lead to higher prices because “shortage pricing in the Spinning Reserve market would set the opportunity cost… of providing spinning reserve”.
Synergy’s bilateral contracts	Synergy argued retaining the current method obviates the need to consider its bilateral contracts.
Source of spinning reserve	Jacobs’ model assumes spinning reserve is provided by coal plants and that future margin values assessments will change as renewable generation penetration rate increases.
Competitive ancillary service market	Synergy supports the move to a competitive market for spinning reserve and load rejection reserve “as soon as possible”.
Perth Energy	
Estimation method	Perth Energy states spinning reserve is the least transparent form of ancillary service in the market and difficult to reliably estimate.
Estimation reliability	Perth Energy argued calculation errors highlight the need to move beyond modelled estimation methods to a market.
Third party spinning reserve	Perth Energy believes System Management’s approach to spinning reserve procurement coupled with the technical requirements limit the interest of independent power producers’ to provide spinning reserve.
Barriers to providing ancillary services	AEMO’s technical requirements and lack of obligation to dispatch most cost effective service first constitutes a barrier to participation.
Competitive ancillary services market	Perth Energy supported development of an interim spinning reserve market in parallel with balancing and load following ancillary service markets.
Bluewaters Power	
Counterfactual scenario	Bluewaters Power supported the modelling of a counterfactual scenario without spinning reserve to form the basis of the opportunity cost. Bluewaters Power does not support the contention that a scenario where independent power producers provided spinning reserve would result in the same price outcomes. It argues the market rules do not contemplate a market where independent power producers provide spinning reserve. Bluewaters Power contended that the spinning reserve process indicates a procurement sequence from no reserve, to Synergy reserve, to independent power producers’ reserve.
Synergy’s bilateral contracts	Bluewaters Power considers the bilateral contracts would ultimately reflect the balancing price outcomes. Consequently if the system marginal price was lower, the contracts would have been struck at a lower price. It considers the IMO’s arguments to be invalid.

Issue	Comment
Changes to the merit order with and without spinning reserve	Jacobs' calculation may not appropriately account for the change in quantities where Synergy plant substitute for Synergy plant providing a reserve.
Integrating margin values modelling into spinning reserve procurement process	Bluewaters Power recommends an iterative process considering the outcomes of System Management's procurement be included in the margin values modelling.
Sensitivity analysis	Sensitivity analysis should inform the independent power producers' decision on providing spinning reserve. As long as the process remains in place, it should be enhanced to improve transparency and to deliver a more economically efficient outcome.
AEMO	
Validity of the counterfactual	AEMO does not consider a scenario without spinning reserve to be valid and therefore the pricing outcomes from the scenario to be credible.
Market concern with counterfactual	AEMO considered the matter is settled because concerns with the counterfactual scenario weren't raised again by market participants.
Process and cost	AEMO acknowledges the ERA may make recommendations to amend the calculation method which will be reflected in future proposals. AEMO does not expect its costs to be affected by recommended changes to the calculation method.

Appendix 2. Proposed improvements to the calculation of availability cost and margin values

The ERA identified improvements in Jacobs' estimation of Synergy's availability cost for the spinning reserve and load rejection reserve services that could be considered by AEMO in its future reviews of the margin values. One of these improvements explores an alternative approach to estimate of availability payments. This is outlined in section A2.1.

The second improvement, applied to the determination of margin values this year, is the application of regression analysis to calculate margin values as discussed in section A2.2.

A2.1. Estimation of availability payments

The ERA assessed the calculation of spinning reserve availability cost based on the principle that the administrative process to calculate the availability payment should emulate the outcomes of a competitive spinning reserve market as closely as possible.

A2.1.1. Opportunity cost of reserve provision

As illustrated in Figure 1, withholding some infra-marginal or marginal generation capacity for providing spinning reserve can change the energy market clearing price in a trading interval. This price change can affect infra-marginal generators' surplus. A generator considering whether or not to provide spinning reserve would estimate its opportunity cost by comparing its cost and benefits after the provision of reserve to those in a scenario where the total required amount of spinning reserve is provided by other generators.[45]

If, for instance, in a trading interval the provision of spinning reserve increased the energy market price, all infra-marginal generators would benefit from the higher price. Those generators that can provide spinning reserve would consider whether to forego providing the reserve and benefit from the increase in the energy market price when other generators provide spinning reserve. For a generator the best alternative to providing spinning reserve (that option which provides the greatest value) is using its whole available, and in-merit, capacity in the energy market to benefit from the price increase and let other market participants forego energy market revenue and provide spinning reserve.

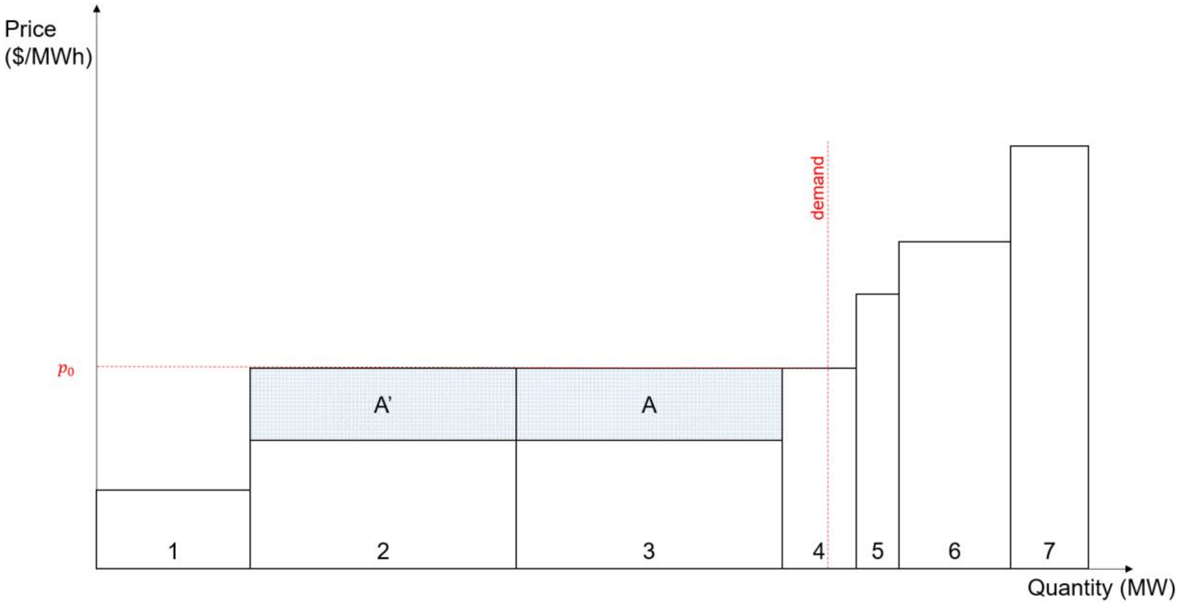
To explain the concept, Figure A1 provides an example of a trading interval in an energy market with seven generators, each with different unit supply costs. The height of each column represents each generator's unit supply costs (in $/MWh), while the width indicates a generator's output capacity (in MW). The area below a unit supply cost shows a generator's total supply cost.[46] The highest supply cost in the merit order sets the market clearing price where supply intersects energy demand. In this example, when no spinning reserve is provided, generator 4 is marginal generator and the market is cleared at price p_0. Generators 1 to 3 are infra-marginal and collect economic surplus.

[45] A generator's cost and benefits could be different, if other generators would provide the spinning reserve.

[46] For simplicity, in this paper we assume that the duration of a trading interval is one hour. Therefore a 1 MW of capacity delivers 1 MWh of energy in the 1-hour trading interval.

To better illustrate changes in costs and benefits for the supplier of spinning reserve, generators 2 and 3 are assumed to have identical costs and capacities. This helps to depict how the provision of a certain amount of reserve by generator 3 affects its costs and benefits compared to the scenario where other market participants (than generator 3) provide the same amount of reserve.[47] Without the provision of reserve in the market, generators 2 and 3 collect equal amount of economic surpluses, as shown by areas A and A'.

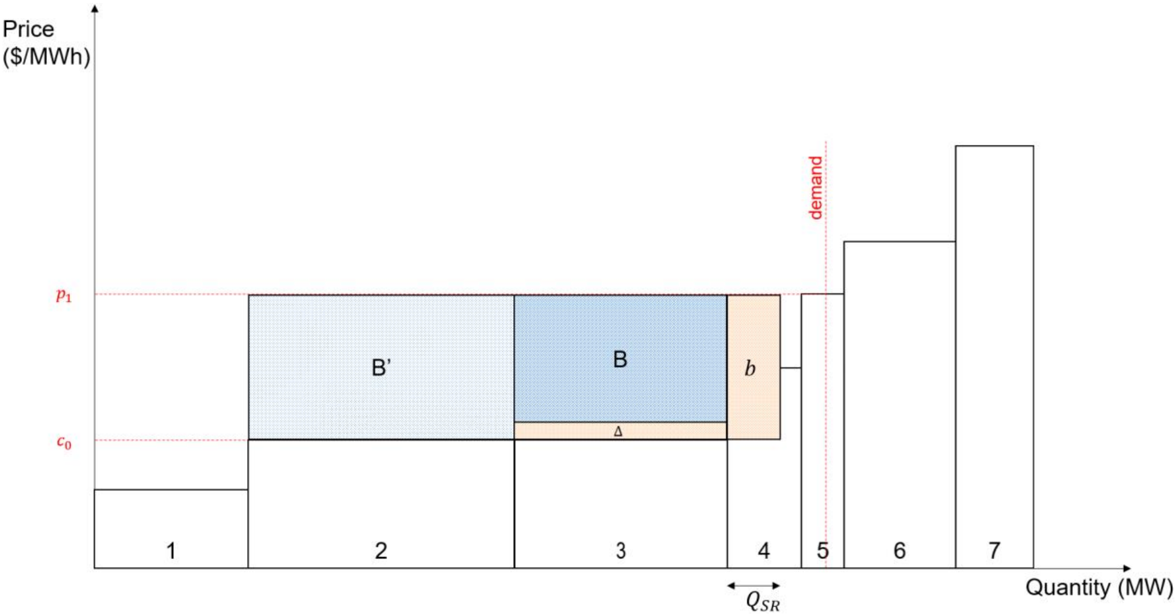
Figure A1. Energy market without the provision of reserve



As shown in Figure A2, generator 3 withholds some of its capacity to provide spinning reserve, indicated by Q_{SR} MW. As generator 3 reduces output, its efficiency decreases, causing an increase in its unit supply costs for its remaining capacity dispatched in the energy market. The total increase in the supply cost for the residual capacity of generator 3 is shown by area Δ. Generator 5 is dispatched to meet the energy demand and also becomes the marginal generator. Generator 5's supply cost sets the market clearing price at p_1.

[47] Generator 2 does not provide spinning reserve, and therefore its cost and benefits resemble those for generator 3 when other market participants provide the spinning reserve.

Figure A2. Energy market with the provision of reserve (by generator 3)



Generator 3's surplus after providing spinning reserve is shown by area B. Compared with Generator 2's surplus, ie area B', generator 3 has foregone benefits equal to areas Δ and b.

Generator 3 may also incur some operational costs for making the reserve capacity available for providing the spinning reserve service. Throughout this paper, however, it is assumed that these costs are negligible.[48]

Generator 3 could have chosen to not provide spinning reserve (similar to generator 2) and collect the additional benefits equal to area $\Delta + b$. In this example, the total (opportunity) cost of reserve provision,$TC_{Q_{SR}}$, is:

$$TC_{Q_{SR}} = (p_1 - c_0) \times Q_{SR} + \Delta \quad \text{(A1)}$$

where c_0 is generator 3's energy supply cost without the provision of reserve.

In a competitive spinning reserve market, the principle explained above underpins the estimation of reserve offers. Those generators considering whether or not to provide spinning reserve would offer reserve based on their marginal cost of reserve provision, ie the opportunity cost of providing one additional unit of reserve, which is equal to the sum of:

- the foregone economic surplus of the unit amount of capacity withheld for reserve, corresponding to area b in Figure A2;[49] and
- the increase in the cost of energy supply for the residual capacity of the plant providing one additional unit of reserve, corresponding to area Δ in Figure A2.

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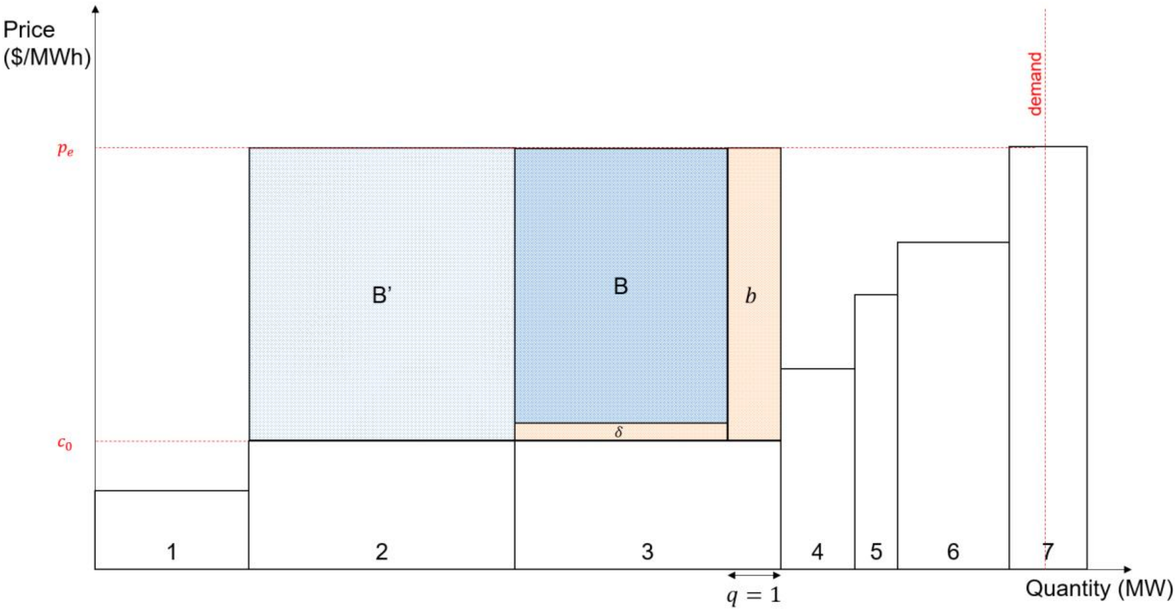
[48] Jacobs also ignores these potential additional costs of the reserve provision in its modelling of the WEM. This assumption, however, can be relaxed in applying the principle explained in this paper.

[49] For a unit amount of reserve provided, width of area b is one and its height is equal to the difference between the market clearing price after the provision of all reserve required and the supply cost before the provision of reserve.

This is shown in Figure A3, where Generator 3 estimates its opportunity cost for the provision of one unit of reserve. By providing one unit of reserve, generator 3 misses the opportunity to collect the surplus areas b and δ when compared to the scenario where other infra-marginal generators provide spinning reserve and therefore the market clears at p_e.

Figure A3. Marginal cost of reserve provision



The marginal cost of reserve is:

$$mc_{SR} = p_e - c_0 + \delta \qquad \text{(A2)}$$

where δ is the increase in the energy supply cost for the residual capacity of the plant providing one additional unit of reserve.

Mathematical derivation of Equation A2

The marginal cost of reserve provision can also be mathematically derived from Equation A1. For generator 3, marginal cost of reserve provision $mc_{SR,g3}$, is the first derivative of the total cost (as in Equation A1) with respect to the quantity of reserve provided by generator 3:

$$mc_{SR,g3} = \frac{\partial TC_{Q_{SR},g3}}{\partial Q_{SR,g3}} = p_1 - c_0 + \frac{\partial \Delta}{\partial Q_{SR,g3}}$$

where $\frac{\partial \Delta}{\partial Q_{SR,g3}} = \delta$. Note that p_1 is the energy market clearing price after the provision of all required reserve and is not dependent on the quantity of reserve provided by generator 3. The energy market would always clear at p_1 when all required reserve is provided by any set of marginal or infra-marginal generators.[1]

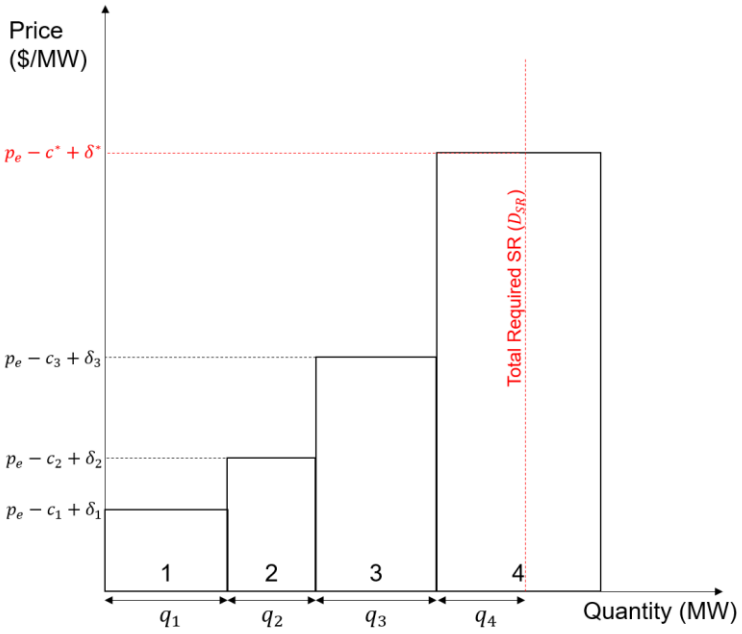
As Equation A2 shows, the marginal cost of reserve provision is independent from the market clearing price in the scenario without the provision of reserve, ie p_0 in Figure A1. The principle applied also shows that the opportunity cost of reserve provision by a generator in a portfolio of generators owned by a single market participant is independent from changes in cost and benefits for other generators in the same portfolio.

This can be explained with an example where in Figure A3 generators 2 and 3 are owned by a single market participant. For estimating the opportunity cost of reserve by generator 3, changes in generator 2's surplus (between no reserve and reserve provision scenarios) are irrelevant. The market generator can choose to not provide spinning reserve and collect surpluses for generators 2 and 3 (areas B', B, b and δ) when the total required reserve is provided by other generators and the market is cleared at p_e.

A2.1.2. Determination of availability payments

In a competitive spinning reserve market, the marginal cost of spinning reserve for the marginal reserve supplier would set the clearing price. This is illustrated in the stylised diagram in Figure A4, where generators 1 to 4 offer spinning reserve with price and quantities represented by the height and width of shown columns, respectively.[50]

Figure A4. Spinning reserve market offers and clearing price



Based on the required reserve D_{SR}, generator 4 is the marginal provider in the reserve market where its marginal cost of reserve $p_e - c^* + \delta^*$ sets the market clearing price. Availability payment to generators 1 to 4 is the product of the amount of reserve cleared in the market and the clearing price. For instance, for a generator g, availability payment, A_g, is:

$$A_g = q_{g,SR}(p_e - c^* + \delta^*) \quad \text{(A3)}$$

where $q_{g,SR}$ is the quantity of reserve provided by generator g.

[50] For a certain amount of reserve, those generators with higher unit energy supply cost (and lower loss in efficiency), would have a lower opportunity cost for the provision of reserve.

A2.1.3. Can availability payments be negative?

A review of Jacobs' spreadsheets found that many trading intervals had a negative availability cost. Jacobs explained that this finding means that Synergy is actually earning more revenue by providing the spinning reserve service.[51, 52] Jacobs stated the modelling results show that for many trading intervals the profit forgone component of the availability cost calculation (the second term on the right hand side of Equation A5) was negative. This is primarily an artefact of Jacobs' estimation (as in Equation A5, section A2.1.5) that examines the output of the whole portfolio rather than just individual generators providing spinning reserve.

However, Equation A3 shows that availability payments are very unlikely to be negative. Using Equation A3, a negative availability payment is only possible when the reserve market clearing price is negative:

$$p_e - c^* + \delta^* < 0$$

The term $p_e - c^*$ is always equal or greater than zero, because the spinning reserve is always provided by a marginal or an infra-marginal generator in the energy market, ie $p_e \geq c^*$. That is, to have a negative reserve market clearing price, the term δ^* should be sufficiently negative to offset the difference between p_e and c^*.[53]

A2.1.4. Estimating availability cost based on energy market simulation results

When estimating availability payments, the administrative procurement process should emulate the spinning reserve payment outcomes that might be expected in a competitive spinning reserve market. Equation A3 can be used to estimate availability payments to Synergy. Variables in the equation can be estimated through simulations of the WEM, where contracted spinning reserve suppliers and Synergy provide the required reserve (spinning reserve scenario). It is not needed to simulate a scenario without the provision of the spinning reserve service.

Assuming that Synergy is the marginal supplier of spinning reserve (for those intervals when it provides spinning reserve),[54] variables in Equation A3 can be estimated as follows:

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[51] Jacobs explained that in the model Synergy's withheld capacity was frequently replaced by higher cost Synergy gas turbines that were brought online to minimum generation levels. In such instances Synergy's total dispatch quantity was greater than that in the scenario that Synergy did not provide the spinning reserve service. Refer to page 39 of Jacobs' final report (version 3.0).

[52] Referring to Equation A5, negative energy market clearing prices could also contribute to a negative availability cost. However, in its estimation of availability payments (in Equation A5) Jacobs arbitrarily sets the minimum energy market clearing price to zero. Refer to footnote 8, page 15 in Jacobs final report (version 3.0)

[53] This can also be explained by the diagram in Figure A2. If generator 3 has an improvement in efficiency for its residual capacity in the energy market, the area Δ would be negative. If the magnitude of change in Δ is sufficient to offset the foregone benefit area b, the opportunity cost of reserve provision would be negative. If at the same trading interval generator 3 is the marginal provider of spinning reserve, availability payment to all spinning reserve providers would be negative.

[54] The market rules stipulate that System Management may enter into contracts with other market participants than Synergy for the provision of spinning reserve if it considers that Synergy facilities cannot meet the spinning reserve requirement or such contracts provide a less expensive alternative to the reserve service provided by Synergy facilities. Availability payment to other contracted spinning reserve providers is less expensive than the availability payment to Synergy. In general, it implies that currently Synergy is the marginal provider of spinning reserve. The assumption that Synergy is the marginal supplier of spinning reserve is for simplifying the calculation. This assumption, however, can be relaxed.

- Simulation results identify Synergy facilities providing spinning reserve (forming a set of generators $\boldsymbol{g}_{SR}$) and the respective quantities of reserve, $q_{g,SR}$, provided;
- The simulation also yields energy supply curves, $c_g = f(q)$, for the generators in the set $\boldsymbol{g}_{SR}$. Operator f denotes that energy supply cost c_g is derived as a function of generation output, q.
- The term $p_e - c^* + \delta^*$ can be derived via the integration formula below calculated for each reserve supplier g in the set $\boldsymbol{g}_{SR}$:

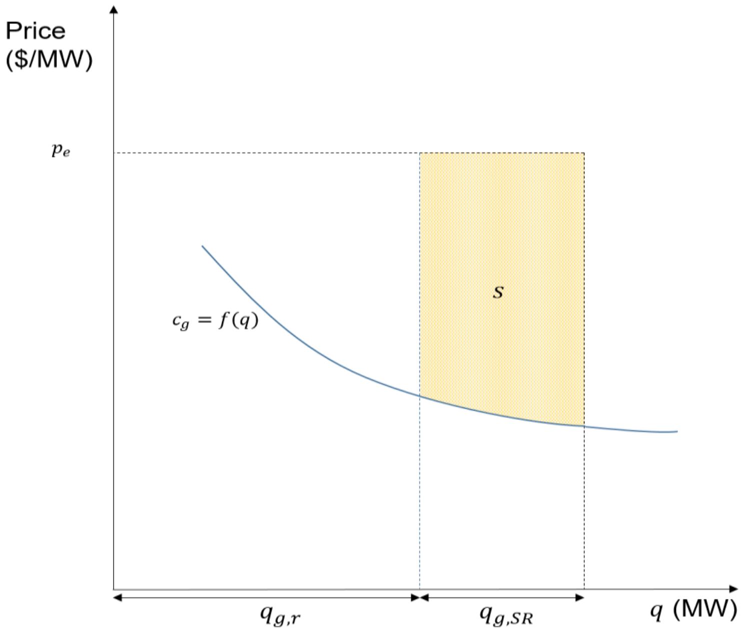
$$p_e - c + \delta = \int_{q_{g,r}}^{q_{g,r}+q_{g,SR}} (p_e - c_g) dq \qquad \text{(A4)}$$

  where $q_{g,r}$ is the (residual) capacity used to dispatch electricity in the energy market, for the plant providing $q_{g,SR}$ MW of reserve.

  $p_e - c^* + \delta^*$ is the maximum of the estimated $p_e - c + \delta$ among the plants in the set $\boldsymbol{g}_{SR}$.[55]

Figure A5 illustrates the underlying concept of the integration formula in Equation A4. For a generator g providing $q_{g,SR}$ MW of spinning reserve, the integration formula calculates the area, s, bound between the energy market clearing price, p_e, the generator's supply cost curve, c_g, the residual capacity dispatched in the energy market, $q_{g,r}$, and the total capacity the generator could dispatch without the provision of reserve, $q_{g,r} + q_{g,SR}$.

Figure A5. Calculation of the opportunity cost of reserve based on a generator's supply curve



[55] Alternatively, this integration formula can be approximated to simplify the calculation.

A2.1.5. Comparison with the PJM synchronised reserve market

The proposed approach presented above is comparable with the design of the synchronised reserve market in the PJM. Resource owners submit resource-specific offers to provide synchronised reserve, and PJM dispatch engine uses these offers together with energy offers and resource schedules to co-optimise the dispatch of energy and ancillary services.

Capable and available market participants must offer synchronised reserve with a price capped at their operating and maintenance cost of reserve provision.[56] For determining the most economic set of resources to meet the synchronized reserve requirement, the market optimisation engine calculates a resource-specific merit order price for each resource using the following formula:[57]

$$\begin{aligned} \textit{resource merit order price} = \; & \textit{resource synchronised reserve offer price} \\ & + \textit{estimated resource opportunity cost} \end{aligned}$$

The PJM market operator determines the resource opportunity cost by estimating "the area on a graph enclosed by the resource's price [supply cost] curve, the points on that curve corresponding to the resource's desired economic dispatch and the set point necessary to provide the assigned amount of synchronised reserve, and the LMP [locational marginal price]".[58] This approach in estimating opportunity cost of reserve provision matches the proposed calculation in Equation A4.

The synchronised reserve market is settled based on the clearing price in that market, which is set by the resource merit order price of the marginal reserve provider. That is, the design of the market allows for the collection of infra-marginal economic rents.

A2.1.6. Jacobs' estimation method

Jacobs uses the following formula to estimate Synergy's availability costs:

$$A = C_{SR} - C_{noSR} + (Q_{noSR} - Q_{SR}).p_e \qquad \text{(A5)}$$

where,

- C_{SR} is Synergy's total generation costs for its portfolio of plants, including start-up costs, in the reserve provision scenario;
- C_{noSR} is Synergy's total generation costs for its portfolio of plants, including start-up costs, in the counterfactual scenario;
- Q_{SR} is Synergy's total generation volume for its portfolio of plants, in reserve provision scenario;

[56] For instance, the operating and maintenance costs for operating a generator in condensing (no-load) mode for the purpose of providing synchronized reserve. These costs are likely to be negligible for infra-marginal and marginal generators that are partially dispatched and provide the spinning reserve service.

[57] This is a simplified version of the formula used in the PJM. The formula also accounts for any additional costs incurred by the reserve provider (consisting of condense start-up cost and condensation energy use cost).

[58] Refer to PJM Manual 11: Energy and Ancillary Services Market Operations, Revision: 92, 2017, pp.81-82, http://www.pjm.com/-/media/documents/manuals/m11.ashx

- Q_{noSR} is Synergy's total generation volume for its portfolio of plants, in the counterfactual scenario;
- p_e is energy market clearing price, in reserve provision scenario.[59]

In Equation A5, Synergy's availability cost is estimated based on the changes in costs and revenues for Synergy's generation portfolio. This estimation method has two broad limitations:

a) It incorrectly assumes that all differences in Synergy's revenues and costs between the reserve provision scenario and the counterfactual scenario require compensation and represent Synergy's availability cost for the reserve provision service. Jacobs develops the simulation model based on a co-optimisation of the energy and ancillary services markets. In principle, the introduction of the additional constraint, ie provision of the spinning reserve service, may change the commitment of generators in the energy market when compared to the scenario that the market is modelled without the provision of reserve. The model commits generators in the energy market to minimise the total cost of the system, ie in both the energy and ancillary services markets, subject to meeting the network reserve requirements. There may also be changes in the commitment of generators that do not provide spinning reserve. Changes in cost and benefits for these plants (or those for other generators similarly affected) do not require compensation and therefore should not be included in the calculation of spinning reserve availability cost;[60] and

b) It does not estimate the availability cost based on the marginal cost of reserve provision by the marginal supplier of reserve.

Figure A6 provides an example of the first limitation above. Figure A6, panel (a) illustrates a market without spinning reserve, where Synergy's portfolio of generators 3 to 5 have a total cost as shown by the yellow shaded area. This area represents variable C_{noSR} in Equation A5.

Figure A6, panel (b) shows Synergy's portfolio cost after the provision of a certain amount of reserve by generator 3, as indicated by the area bound by the thick red dashed line. This area represents variable C_{SR} in Equation A5. Synergy generators 4 and 5 replace the reserved capacity.

Using Jacobs' estimation formula in Equation A5, Synergy's availability cost is the sum of the areas Δ, e_1, and e_2. In this example, the change in Synergy's generation volume is zero, and therefore availability cost is determined by the change in Synergy's portfolio cost between the counterfactual and spinning reserve scenarios.

Using the principle presented in section A2.1 and Equation A3, Synergy's availability cost is the sum of the areas b and Δ. In this example, Jacobs calculation method underestimates Synergy's availability cost. In calculating availability cost, Equation A4 should not include

[59] In its report on 30 January 2018, Jacobs revised this formula and for the market price it applied modeled system marginal price in scenario with provision of spinning reserve and load rejection reserve services.

[60] Jacobs modelling outputs show that the commitment of (Synergy or non-Synergy) generators in the balancing market can be different between the reserve provision and the counterfactual scenarios. Jacobs assumes that all changes in cost and benefits for Synergy generators, between the two scenarios, can be attributed to the provision of the spinning reserve service. If Jacobs' applied principle was correct, non-Synergy generators would also incur an availability cost for all trading intervals a generators' commitment changed.

the cost and revenues of Synergy generators 4 and 5, which do not provide spinning reserve.

Figure A6. Limitations of Jacobs' estimation of availability cost – Example 1

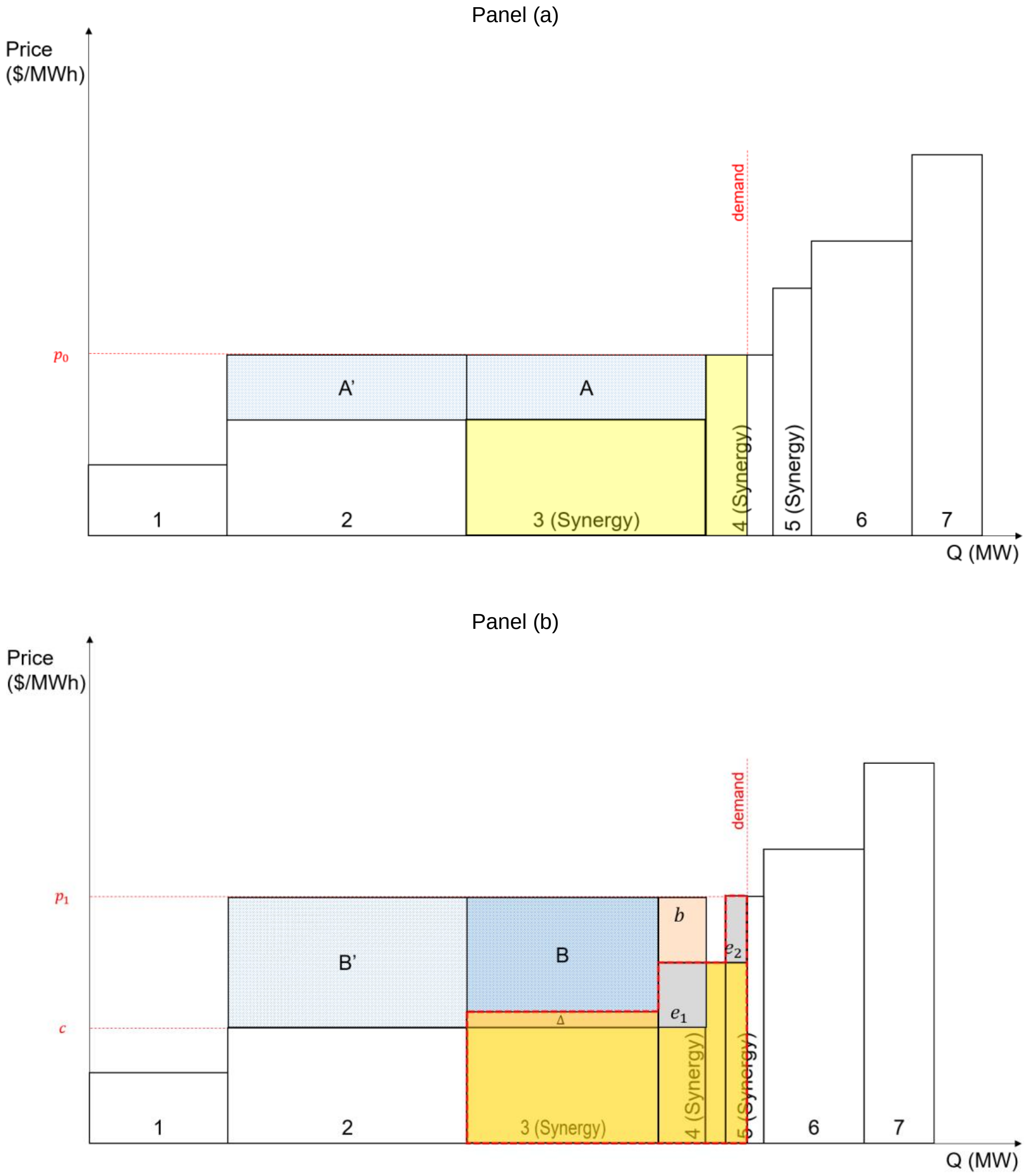


Figure A7 provides an example of the second limitation of Jacobs' estimation of availability cost. In this example, spinning reserve requirement is met by Synergy generators 1 and 3. The reserved capacity is replaced by non-Synergy generators 4 and 5. Using Equation A5, Synergy's availability cost is the sum of areas b_1, Δ_1, b_3, and Δ_3.

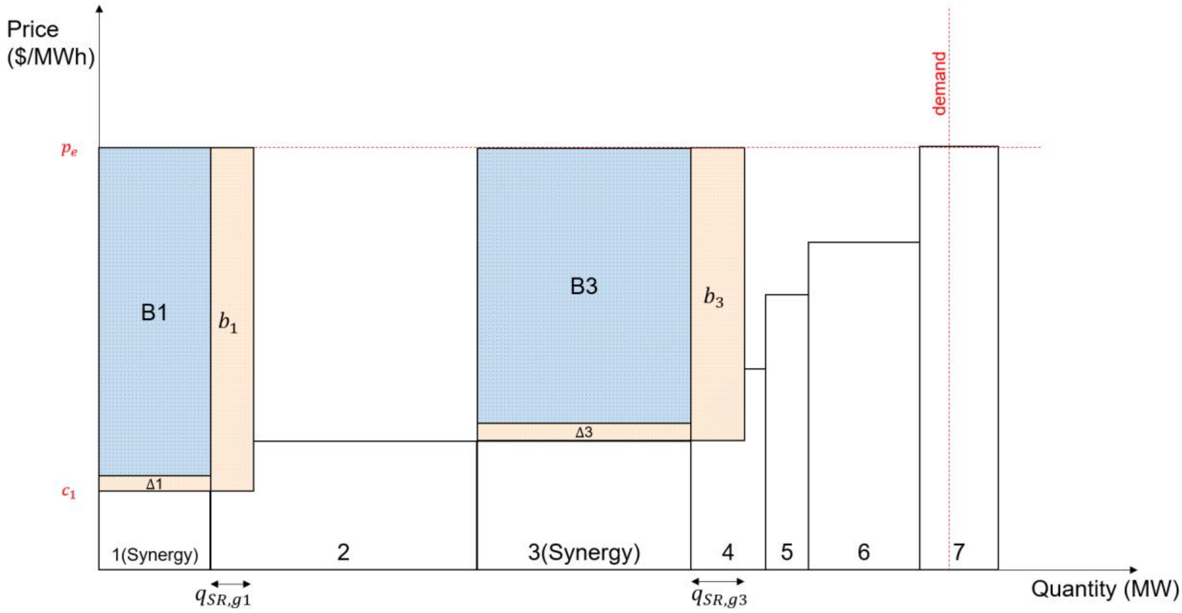
Using Equation A3 and noting that generator 1 would be the marginal provider of spinning reserve in the spinning reserve market, Synergy's availability cost is:

$$A = (q_{SR,g1} + q_{SR,g3})(p_e - c_1 + \delta_1)$$

where c_1 is generator 1's energy supply cost before the provision of reserve and δ_1 is the increase in the supply cost of the residual capacity of generator 1 in the energy market due to the provision of one additional unit of reserve.

Jacobs' approach for the estimation of availability cost does not allow for the collection of economic surplus in the spinning reserve market, so it would only allow generator 3 to receive an availability payment equal to its marginal cost of reserve provision.

Figure A7. Limitations of Jacobs' estimation of availability cost – Example 2



A2.1.7. Limitations of the proposed approach

The proposed approach for the estimation of availability cost may also have some limitations. It is developed to emulate the outcomes of a competitive market for the spinning reserve ancillary service. Although, in principle, using a competitive process to deliver the reserve service produces the most economically efficient outcome, currently the WEM procures the service administratively, where Synergy is the default provider of the service. The proposed approach also assumes that the spinning reserve and energy markets are co-optimised, whereas in the WEM energy and ancillary services are optimised separately.

To illustrate the effect of these limitations, the example given in Figure A7 is revisited. It is assumed that in addition to generators 1 and 3, generator 2 is also owned by Synergy. If after the provision of reserve, generator 7's output is below its minimum operating capacity, generator 2 should reduce its output to make room for additional output from generator 7.

In a co-optimised energy and ancillary service market, generator 2 does not require compensation for the reduction in its output, as the optimisation engine commits generators to minimise the total cost of the system. Correspondingly, the proposed approach does not consider any compensation for generator 2 and Synergy would only be compensated for the reserve provision service by generators 1 and 3.

However, in the WEM the provision of reserve and potential changes in the commitment of units is provided through Synergy generators only. In this example, a co-optimised dispatch model could commit non-Synergy generators 5 or 6 to reduce their outputs (instead of Synergy generator 2) to minimise the cost of the system, whereas under the current market rules such services are only provided by Synergy units.

In comparison with Jacobs' estimation approach, the proposed method for the calculation of Synergy's availability costs better reflects a competitive spinning reserve market payments. Jacobs uses a co-optimised simulation of the energy and ancillary services in the WEM, and therefore the model basis for the calculation of availability costs is common between both approaches. Although both approaches may not be able to fully capture the reality of current operation of the system, the proposed approach better emulates the outcomes of a competitive and co-optimised spinning reserve ancillary services market.

A2.2. Estimation of margin values

Jacobs rearranged the formula in clause 9.9.2 (f) of the market rules, as also presented in a simplified form in Equation 1, to estimate average margin values for peak and off-peak trading intervals. However, Jacobs' calculation, ignores the covariance between availability cost, balancing price, and adjusted quantity of spinning reserve distributions and so does not calculate average margin values correctly. Nevertheless, applying average margin values may also over or under compensate Synergy, excessively. This paper first explains the error in calculating average margin values and then proposes the application of regression analysis as an enhanced method.

A2.2.1. Estimation of average margin values

Jacobs estimates margin values by rearranging Equation 1:

$$mv = \frac{\tilde{A}(t)}{0.5\,\tilde{p}_t.max[0, \tilde{q}_{SR,t} - \tilde{q}_{LFAS_{up},t} - \tilde{q}_{SR,c}]}$$

It estimates the amounts of $\tilde{A}(t)$, $\tilde{p}_t$, $\tilde{q}_{SR,t}$, and $\tilde{q}_{LFAS_{up},t}$ from a modelling of the WEM for the 2018–19 financial year, and for 17,472 half-hourly trading intervals. The tilde signs on these variables indicate that they are random variables, with distributions derived from the modelling.

In its spreadsheets, Jacobs uses the following formula to calculate an average margin value, $\overline{mv}$, (for peak and off peak intervals separately[61]) for the financial year under study:

$$\overline{mv} = \frac{\sum_{t=1}^{17,472} A(t)}{0.5 \times \sum_{t=1}^{17,742} (p_t \times \bar{q})}$$

where $\bar{q}$ is the average of $\tilde{q}_{SR,t} - \tilde{q}_{LFAS_{up},t} - \tilde{q}_{SR,c}$ term over all modelled trading intervals adjusted by contracted spinning reserve volumes.[62,63]

[61] For simplicity, this paper only presents the concept for the calculation of margin values. The calculation concepts explained apply to both margin peak and margin off peak parameters.

[62] This is a simplification of Jacobs' approach. The estimation of the term $\bar{q}$, makes adjustments for Cockburn and Newgen Kwinana capacities. These terms are omitted from the explanation in this paper for simplicity.

[63] Although the maximum operator is omitted in Jacobs' calculation, in this case it may not affect the results, because the average of the term $q_{SR,t} - q_{LFAS_{up},t} - q_{SR,c}$ based on modelling results is always greater than zero.

Jacobs assumes that the average margin value can be calculated by dividing the average of availability payment over all trading intervals by the average of the product of balancing price and the average of the term $max[0, \tilde{q}_{SR,t} - \tilde{q}_{LFAS_{up},t} - \tilde{q}_{SR,c}]$.[64]

Jacobs' estimation of average margin values is incorrect. To explain the problem, three random variables X, Y and Z are considered. Random variable Z is the product of variables X and Y. In principle, the expected value (average of) random variable Z is:

$$\mathcal{E}[Z] = \mathcal{E}[X \times Y] = \mathcal{E}[X] \times \mathcal{E}[Y] - cov(X, Y)$$

where operator $\mathcal{E}$ denotes expected value, and $cov(X, Y)$ represents the covariance between random variables X and Y.[65]

Using the above principle and starting from Equation 1, the average of margin value is as below:

$$\overline{mv} = \mathcal{E}[A(t)] \times \mathcal{E}\left[\frac{1}{0.5\, p_t.\max\left[0, q_{SR,t} - q_{LFAS_{up},t} - q_{SR,c}\right]}\right] - cov(A(t), \frac{1}{0.5 \times p_t \times \max\left[0, q_{SR,t} - q_{LFAS_{up},t} - q_{SR,c}\right]})$$

In Jacobs' calculation the covariance term is neglected. Also in estimating the average of the product of the price and quantities, ie $p_t.\max\left[0, \left(q_{SR,t} - q_{LFAS_{up},t} - q_{SR,c}\right)\right]$, Jacobs ignores the covariance between the price and quantity distributions.[66]

If margin values are to be determined by rearranging Equation 1 and estimating an average amount, Jacobs could first estimate the margin value for each trading interval separately. This process yields distributions for margin peak and off-peak values, which could be used to estimate average margin values. However, section A2.2.2 explains that determining margin value parameters based on an average amount is not suitable for estimating availability payments.

A2.2.2. Estimation of margin values based on regression analysis

Referring to Equation 1, the market rules specify a (linear) relationship between the availability payment, balancing price, and the adjusted spinning reserve quantity variables. Equation 1 can be written as,

$$\tilde{A}\,(t) = mv.\tilde{x}_t$$

where,

$$\tilde{x}_t = 0.5\tilde{p}_t.\max[0, \tilde{q}_{SR,t} - \tilde{q}_{LFAS_{up},t} - \tilde{q}_{SR,c}]$$

Margin value mv, is the constant parameter in the formula that can be determined based on the distributions of $\tilde{A}\,(t)$ and $\tilde{x}_t$ derived from the modelling step. A linear regression

[64] Both nominator and denominator in the previous equation can be divided by the total number of intervals. Therefore, the equation is dividing the average of availability cost $A(t)$ by the average of the term $p_t \times \bar{q}$.

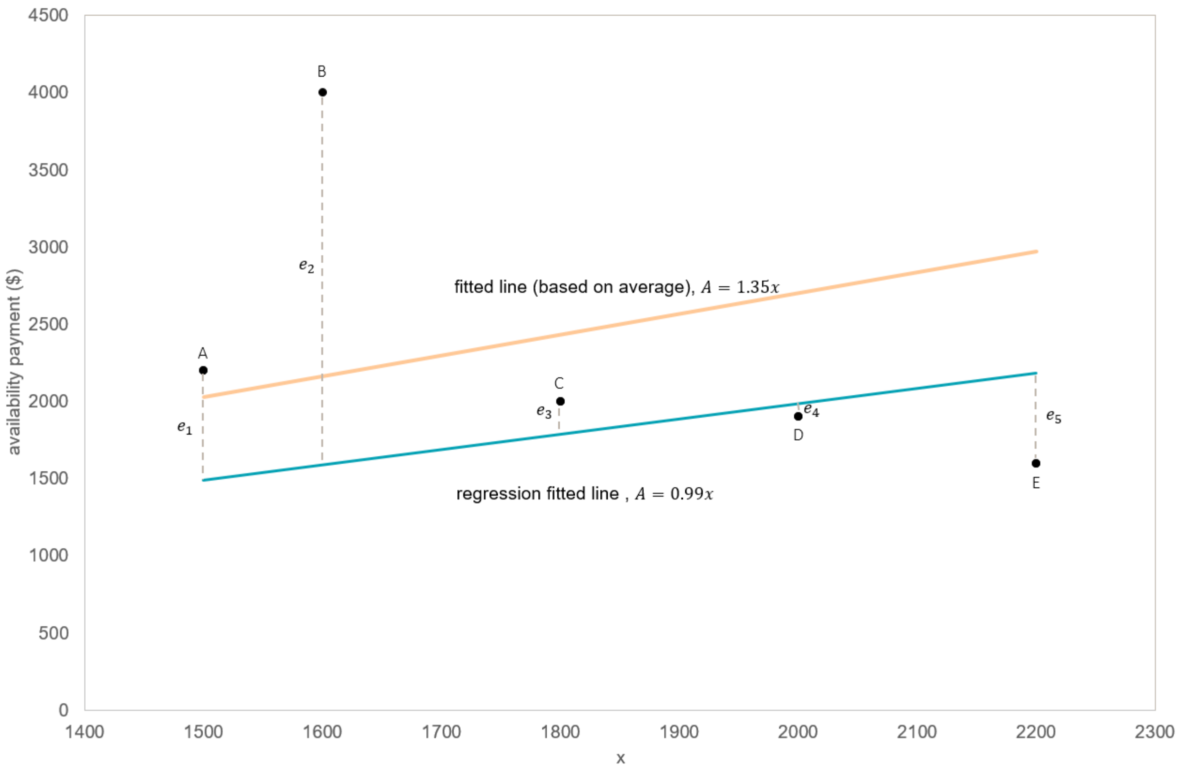
[65] If random variables X and Y are independent, the covariance between them is zero. In such case, the expected value of the product of X and Y is equal to the product of the expected value of X and Y.

[66] Note that the terms in the calculation of average margin value are highly likely to be correlated. These are outcomes of a model used to simulate the WEM and their covariance is not likely to be zero.

approach can be used to estimate the margin value parameter. The stylised graph in Figure A8 helps to explain why a regression based estimation of margin values is superior to an averaging approach.

As explained previously, results of the modelling step yield distributions for variables in Equation 1. Figure A8 provides a hypothetical sample of five estimates (points A to E) for $\tilde{A}(t)$ and variable $\tilde{x}_t$ as defined above.[67] In this example, a linear regression line with an intercept of zero is fitted to points A to E. The regression line can be used to estimate the amount of availability payment based on estimates of variable x_t. To quantitatively measure how accurately the regression line fits the sample of points A to E, regression errors e_1 to e_5 can be calculated. For instance, e_1 represents the difference between the compensation paid to Synergy (approximately $1,500) and Synergy's availability cost ($2,200, point A).

Figure A8. Estimation of margin values based on regression analysis and averaging approach



Note: Fitted lines represent estimated availability payments to Synergy. Points A to E represent Synergy's availability cost (opportunity cost of providing reserve).

Several linear lines, with different slopes (and intercept of zero), can be used to fit to the sample of four points in this example. However, the best fit can be determined based on least square error criterion. The straight line that best fits the set of data points A to D is the one for which the sum of squared errors is smallest. Margin value is the slope of the linear regression line that provides the best fit for the sample of data points A to D.

Setting margin values based on the least square criterion ensures that the sum of squared errors in estimating availability payments is minimised. That is, the estimated availability

[67] The modelling yields a sample of 17,472 estimates for variables $availability\ payment(t)$ and x_t, out of which a hypothetical sample of four points is drawn in this simplified example.

payments determined by the specified linear formula in the market rules will be generally closer to the amount of availability cost as estimated by the modelling of the market, when compared to an average margin value.[68]

Note that average margin value as estimated by Jacobs does not necessarily minimise payment errors, and therefore it does not ensure that availability payments to Synergy, as estimated by the linear formula in the market rules, are as close as possible to the forecasted availability costs . For the given sample of five points in Figure A8 the estimated margin value by the averaging approach ($mv = 135\%$) is greater than that estimated by the regression approach ($mv = 99\%$). In this example, Synergy will be overcompensated if the averaging approach is used when compared to the regression approach.[69]

[68] A non-linear regression may produce a better fit for the availability cost results. Nonetheless, the market rules prescribe a linear fit (with zero intercept) for estimating availability payments.

[69] Although, in this example the margin value determined by the averaging approach is greater than that determined by the regression method, this is not always the case. In this example, the relatively large availability cost in point B biases the average value upward. In principle, if the distribution of errors is fully symmetrical with a mean of zero, average margin value would be equal to that determined by the least square criterion.